Sustaining the Basic Research Program of the International School of Photonics

Final Report

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The true democrat is he who with purely non-violent means defends his liberty and, therefore, his country's and ultimately that of the whole of mankind.

Terrorism and deception are weapons not of the strong but of the weak.

Mahatma Ghandi

Abstract:

The interaction between industries and institutions like universities can be seen as a basic characteristic of developed economies. In developing economies however, this characteristic is often not there. The relation between industries and universities influences the knowledge base of a country and thus its competitiveness with other countries. This competitiveness cannot be ignored in the highly interlinked world we live in.

This research focuses on the relations between the Cochin University of Science and Technology (CUSAT), specifically the faculty the International School of Photonics (ISP), and different industries in Kerala, India. This research shows that there are no industry-institution relationships in Kerala on a large and more formal scale. This holds for most parts of India. Because of this, knowledge generated at universities is not utilised in practice, while a lot of companies could use such knowledge to upgrade their production processes so that they can be more efficient in their own struggle to survive.

Based on the research model of Bongenaar and Szirmai (1999) a model for transferring technology from the university to the relevant firms has been formulated. This model was used to analyse the different stages that are needed for a successful transfer of technology.

The basic focus of this research was on the research program of the International School of Photonics and its applications within the industry of Kerala. To know more about the photonics needs of the different companies in Kerala a market study has been performed. To know more about the problems and constraints and also the projects of the International School of Photonics interviews with the staff members of ISP have been performed.

Conclusions:

Opportunities for applying research projects of ISP in the industry are rather limited. There are few companies that could use the technology on a larger scale, but only a few. This is mainly because of the kind of technology. Photonics is very capital intensive. It is a specialisation in physics and not many people know about it. This was one of the main reasons why there is no interaction with industry. Firms have no idea that the International School of Photonics exists and what kind of applications they could develop for industry. Using specific and general interest creation instruments could solve this problem.

Industrial firms are interested in investing in collaboration projects if the projects will be beneficial to them. The companies have to be persuaded by using free consultancy and key informants (change agents) as general and specific persuasion instruments.

Seminars as persuasion instruments proved not to be very efficient. The combination of folders and a good internet site should prove a better way of interesting enterprises. The folders should be distributed to specific industrial sectors and should contain relevant information about the products of ISP.

The biggest constraint for the transfer of technology is the difference in attitudes of universities and industry. The university is a government institution with no incentives to work with deadlines, strikes, bureaucracy etc. Industrial firms have deadlines to meet, think commercially and are private institutions. These two attitudes are very hard to reconcile.

Fibre optic sensors would be the most applicable technology in the research field of ISP. They are easy to make and cheap and they have many applications in different production processes. They can be used for measurement and communicational purposes. One of the big advantages of Fibre Optic Sensors and Fibre Optic Communication is that they are not susceptible to EMI (Electro Magnetic Interference).

In the field of photonics applications, competition from foreign research institutions and foreign producers is fierce. ISP is a very young department and has no means to compete with the larger foreign institutions that have been working on this field much longer. So the focus of this research was on companies that have

never heard from ISP and its products. The only way the ISP can compete is by searching for interaction with the industry that is in the vicinity. That is where their competitive advantage lies against large foreign research institutes and foreign producers. They have to find their own markets.

The entire research program of ISP cannot be sustained through commercialisation of its research projects because:

1.) There are too little companies that have photonics needs
2.) The applications of the research are not very large
3.) Part of the money generated by these projects will have to be paid to the university
4.) There is no history of industry-institution interaction and thus no experience with these kind of processes

Acknowledgements:

I would like to thank my family, friends and especially my girlfriend who have supported tremendously especially during this research. I also have tremendous gratitude for all the people from the ISP department who have helped me to understand the ways and culture of the people in India. My knowledge on this subject is however far from complete, without these people I would have been lost.

I would also like to thank all the staff members for sharing their knowledge on the subject. A vote off thanks goes to Mr Girija Vallabhan for guiding me during my field research, Mr. K.P.S Nair from Engineering for setting up all the contacts with the different companies, Mr. Sukumaran Nair from Applied Economics for helping me in the beginning of the research and Mr. Gopikrishnan for his help with the people from the Export Zone.

Special thanks goes to Thomas Lee and his family for giving me a home away from home.

Reader's guide:

Chapter 1 will give the basic background of the research together with all the methodological issues concerned in this research. Chapter 2 provides the theoretical background of the research and the justification of the research model. Chapter 3 contains the practical design of the research: the initial constraints and the operationalisation of the relevant variables. Chapter 4 gives the results from the market survey and the conducted ISP interviews. In Chapter 5 the theoretical model is reflected against the empirical findings from the research. The report ends with Chapter 6, conclusions and Chapter 7, recommendations.

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Chapter 1: Introduction

Relations between knowledge institutes, like universities, R&D institutes and firms have always been very important in sustaining the competitive capability of a nation. Universities provide firms with a flow of people with certain knowledge and skills (Nelson 1993). Firms can consult universities on certain problems. Universities perform (basic) research, which has always been recognised as a driving force behind the generation of new technologies. Also, new technologies can give rise to new scientific disciplines. In some developing countries relations between universities and firms are weak and in some cases even non-existent. In this research the factors that influence these relations will be examined. The research will try to identify possible commercial applications for the research of ISP, so that the International School of Photonics (ISP) can sustain itself financially.

§ 1.1 Background of the research

The Dutch organisation for international cooperation in higher education (Nuffic) administers the "Joint Financing Programme for Cooperation in Higher Education" (MHO) on behalf of the Directorate General International Cooperation (DGIS) of the Dutch Ministry of Foreign Affairs. The ultimate goal of the MHO programme is to contribute to the national development of countries in which MHO support is given. On 13th march 1996 the Cochin University of Science and Technology was admitted to the MHO programme. One projects was called "Strengthening the International School of Photonics", in which the Technical University Eindhoven was engaged as the counterpart for strengthening of the International School of Photonics.

In the year 2003, the financial support from the Dutch ministry of foreign affairs will come to an end. By this time, ISP will have to support itself financially. One possibility for doing this is the commercialisation of basic research projects. Two questions immediately come to mind:

(1) Which projects of ISP have the potential to be commercialised (and how can this be done)?
(2) Which companies (or other actors) have the need and the capability to assimilate the technology from ISP?

To answer these questions the following research question and problem definition have been formulated. The aim and the research question have been formulated after talking with Mr. J.C van Cranenbroek, who is the project coordinator of the initial "Strengthening of the International School of Photonics at the Cochin University of Science and Technology, India"-project.

§ 1.2 Methodological issues

§ 1.2.1 Aim and research question

Aim of the research:
To contribute to the sustainability of research done at the International School of Photonics at the Cochin University of Science and Technology, Kerala, India through commercialisation of applications.

Research question:
Which possible commercial applications could the fundamental research done at International School of Photonics have in the state of Kerala, India, and how can these applications be realised?

Sub-questions:
1. What are possible applications of existing fundamental research program?
2. What are photonics needs of manufacturing firms in Kerala/ other states in India?
3. Which existing projects have the greatest chance of commercial success?

4. What actions by the institute and conditions in the market influence chances of successful commercialisation?
5. Can theoretical analyses of technology development contribute to identifying obstacles to commercial applications of fundamental photonics research?

§ 1.2.2 Research framework

The following research framework has been formulated based on an extensive literature study. Chapter 2 of this document provides the theoretical background of the model. In Appendix A, the references of the study are given.

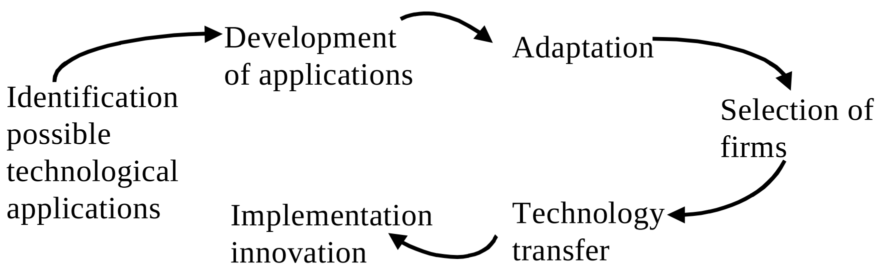

Fig. 1: The Research Framework

Though Fig. 1 suggests a linear transfer model from the university to the selected firms, the technology development process is anything but linear. The process phases are all interlinked, and one phase could come before or at the same time as another. The model must be seen as an iterative process, much like the innovation process. For the figure's simplicity, the model is represented as linear, but in fact it is iterative. The "Identification possible technological applications" and the "Selection of firms" stages can be initiated at the same time. The model will be explained in more detail in Chapter 2.

The following questions follow from the research model:

1. Which possible applications with commercialisation potential can be identified?
2. Which steps are needed to develop the technological application?
3. Which steps are needed to adapt the possible technological applications?
4. Which firms can be selected for possible technology transfer?
5. Which steps must be taken for the actual transfer of technology?
6. Which steps must be taken for actual implementation within the organisation of the innovation?

§ 1.2.3 The research approach

The research is explorative in nature, because there are no variables tested. Also, the research method practically is called "action research". Action research is a kind of "learning by doing". The researcher learns about specific group-processes or changes by actively participating in or manipulating one or more aspects of the processes mentioned (Gaillard, H. 1994). Specifically the variant of so-called "participating action research" has been followed. The goal of this kind of research is finding solutions for concrete problems or conflicts. The procedure is generally as follows. The researcher tries to learn from the target-group concerned, through empathy and friendly relationships, what their needs, feelings and problems are. Essential background information is knowledge of the history and the political and socio-economic situation of the target-group. When sufficient insight and understanding of the problems of the target-group is acquired, together is searched for possible solutions by dialogue (Gaillard, H. 1994).

§ 1.3 The Research Subject: the International School of Photonics

The International School of Photonics (ISP) at CUSAT (Cochin University of Science and Technology) was founded February 28th 1995 by a restructuring of the activities of the Laser Division of the Department of Physics. The Laser Division in this University has been carrying pioneering work by way of Research and Development in lasers and their applications as well as in Fiber Optical Technology. De-linking the laser laboratories along with the faculty members formed the nucleus of the ISP.

Now ISP provides courses at M. Tech. (Master of Technology and comparable with Ir. in Holland see Fig. 11) and M. Phil (course for teachers) levels, trains Ph. D. students in different areas of Photonics and related fields and pursues Research and Development in areas like laser induced plasmas, photothermal and photo acoustic phenomena, non-linear optics, photonics materials, laser material processing and fiber optic sensors (Also see paragraph 2.6).

The International School of Photonics consists of 5 staff members and 43 students (26 PhD, 15 M. Tech. and 2 M. Phil.). There is also a supporting staff of 5 people. The government gives funding for PhD students and this is probably the reason why there are so many PhD students.

ISP is being funded by the Dutch organization Nuffic and there is an intensive exchange program for staff and students between ISP and the Technical University of Eindhoven (TU/e) under the ISP-MHO project. In this program ISP has contacts with the Dutch COBRA institute of the Eindhoven University of Technology where two PhD students are currently trained for a Dutch PhD. These two students will return to CUSAT, after they graduated in Holland, and they will become teachers at ISP. This will contribute to the improvement of the education system at ISP.

Currently ISP has published a large number of papers but they have never patented any technology. There was only one clear example of interaction with the industry and this was in a very informal way.

§ 1.4 Social and scientific relevance of the research

The social relevance of this research is that it contributes to the sustainable development of the national innovation system of India through the sustaining of the research program of the International School of Photonics, and through the strengthening of relations between ISP and innovative firms.

The scientific relevance of this research is that it contributes to the understanding of the factors that influence the transfer of technology between the University of Science and Technology, specifically the International School of Photonics, and capable companies within the national innovation system of India.

Chapter 2: Theoretical background

§ 2.1 Innovation

In this research important is the application of basic research, in other words the translation of fundamental research to application research. Fundamental Research is transferred to the concept "Technology" through the process of invention, Technology in its turn is being transferred to the concept "Technique" through the process of innovation. The "Techniques" are being disseminated in actual applications through diffusion and implementation. This context is important to understand innovation in this research.
Before explaining a relevant model of innovation the concept "innovation" must be defined. Innovation is linked with the concept invention. Rogers (1983) defined an *invention* as: "the output and the process by which a new idea is discovered or created". An innovation is an idea or object *perceived* as new by a group of people (Rogers, E.M. 1983). Lundvall saw innovation not as single event, but as a cumulative process (Lundvall, B. 1992; p.9). He argued that because of the fact that the stages of invention, innovation and diffusion are blurred; it is difficult to separate invention and innovation in time. Both definitions complement each other, rather than that they contradict each other. So both definitions will be used in this research. Innovation as an idea or object *perceived* as new by a group of people. This is applicable when the applications of the research in the production processes of the firms are being discussed. Innovation is also a continuing, cumulative learning process of invention, innovation and diffusion. In short, innovation are new and better ways of doing things. This relates innovation to the process of ISP learning how to commercialise research programs. This is a very valuable continuing learning process. When ISP commercialises one project it gains knowledge how to commercialise future projects and what the possible problems can be.

In this research the main question is how to create from basic research done at the International School of Photonics (ISP) innovations that can be utilized to make money. In other words, the problem is how to transform an invention into an innovation. Some writers suggest that the innovation process is market driven (Kline, S.J. and Rosenberg, N. 1986) and that firms are responsible for the innovation process. This is the case in most innovation processes and this is called in some cases "technology pull". However, ISP is a relatively new science in India and therefore it is possible that the market is not able to innovate the new ideas from ISP. In this case ISP should initiate the innovation process. This can be called "technology push". Technology is here understood as "knowledge about how to do things" and deals with techniques – the choices made when applying technology in specific circumstances with respect to economic, physical and social conditions (Evenson, R. and Westphal, L.1993).

§ 2.2 The chain-linked model of Kline and Rosenberg

Kline and Rosenberg (1986) designed a very useful model of innovation called "the Chain-linked model". With this model they want to stress the importance of so-called feedback paths that take place in the innovation cycle:

> "In an ideal world of omniscient people, one would get the design of the innovation workable and optimised the first time. In the real world of inadequate information, high uncertainty, and fallible people, nothing like this happens. Shortcoming and failures are part of the learning process that creates innovation of every kind. Innovation accordingly demands feedback, and effective innovation demands rapid, accurate feedback with appropriate follow-on actions." (Kline and Rosenberg, 1986)

They defined science to be "the creation, discovery, verification, collation, reorganization, and dissemination of knowledge about physical, biological and social nature".

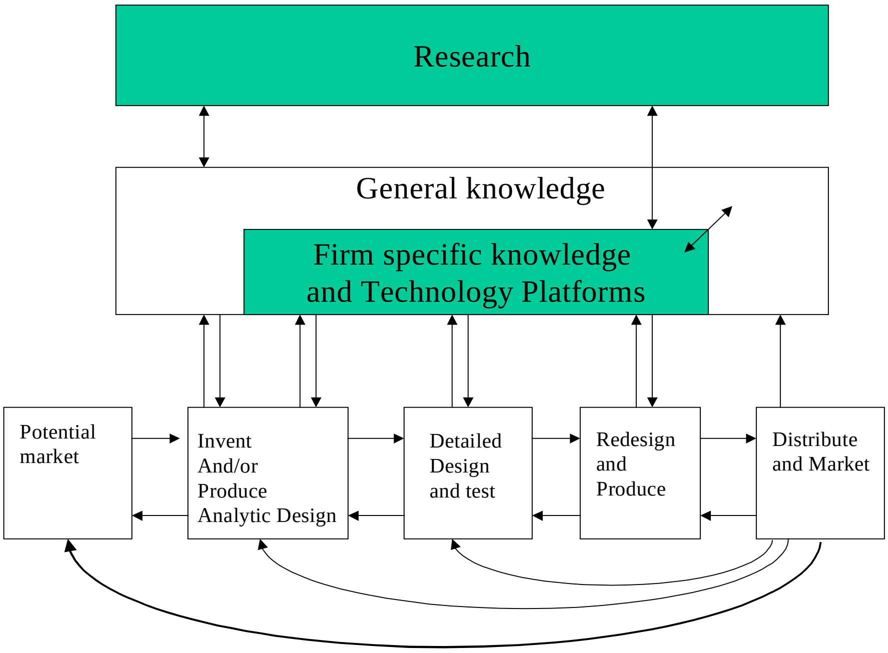

Fig. 2: Feedbacks and interactions in the process of innovation. Source: based on Kline and Rosenberg (1986: 290, Figure 3) and Myers and Rosenbloom (1996: 216, Figure 9-3)

Fig. 2 represents the chain-linked model from Kline and Rosenberg (Malecki, E.J. 1997). Here the two concepts "invention" and "innovation" are clearly separated. Invention belongs to the Research part of the model. Innovation is the process done by firms at the bottom of the figure. Here one can see the numerous feedback loops that influence the innovation process. This model is as a general innovation model very useful in this research. It provides an idea of what is important in most innovation processes and which factors influence this process. However, it is not said that this model is also applicable in a low-level income country like India. Especially with technology like Photonics, it is very probable that the market solely cannot accomplish a market-driven innovation process like in Fig. 2. In that case, ISP should have a more active role in generating a suitable market for Photonics.

The model of Kline and Rosenberg operates in a national environment. Clearly, there are more factors that influence the innovation process. More important factors are provided by the theory of the Competitive Advantage of Nations.

§ 2.3 The Competitive Advantage of Nations

Porter (1990) created a model in which he defines the determinants of competitive advantages between nations. Innovation is very important aspect for a firm if it wants to create competitive advantage.

> "Firms create competitive advantage by perceiving or discovering new and better ways to compete in an industry and bringing them to market, which is ultimately an act of innovation. *Innovation* here is defined broadly, to include both improvements in technology and better methods or ways of doing things. It can be manifested in product changes, process changes, new approaches to marketing, new forms of distribution, and new conceptions of scope. Innovators not only respond to possibilities for change, but also force it to proceed faster. Much innovation, in practice, is rather mundane and incremental rather than radical. It depends more on a cumulation of small insights and advances than on major technological breakthroughs. It often involves ideas that are not "new" but have never been vigorously pursued. It results from organisational learning as much as from formal R&D. It always involved investment in developing skills and knowledge, and usually in physical assets and marketing effort. (Porter, M.E. 1990)"

Porter links the success of a firm to its competitive advantage over other firms. He characterises two different types of competitive advantage: *lower cost* and *differentiation*. Lower cost is the ability of a firm to design, produce and market a comparable product more efficiently than its competitors. At prices at or near competitors, lower cost translates into superior return.

Differentiation is the ability to provide unique and superior value to the buyer in terms of product quality, special features, or after-sale services. Differentiation allows a firm to command a premium price, which leads to superior profitability provided costs are comparable to those of competitors.

Porter created a model called the diamond of competitive advantages of nations, where he defines determinants that are responsible for competitive advantages.

1) *Factor conditions.* The nation's position in factors of production, such as skilled labour or infrastructure, necessary to compete in a given industry.
2) *Demand conditions.* The nature of home demand for the industry's product or service.
3) *Related and supporting industries.* The presence or absence in the nation of supplier industries and related industries that are internationally competitive.
4) *Firm strategy, structure and rivalry.* The conditions in the nation governing how companies are created, organised, and managed, and the nature of domestic rivalry.

Porter says that these determinants, individually and as a system, create the context in which a nation's firms are born and compete: the availability of resources and skills necessary for competitive advantage in an industry; the information that shapes what opportunities are perceived and the directions in which resources and skills are deployed; the goals of the owners, managers, and employees that are involved in or carry out competition; and most importantly, the *pressures* on firms to invest and innovate. "Nations are likely to succeed in industries or industry segments where the national "diamond" is the most favourable. (Porter, M.E. 1990) " In this research favourable factor conditions are for example: schooled workers, capital and good infrastructure.
The following figure represents this model:

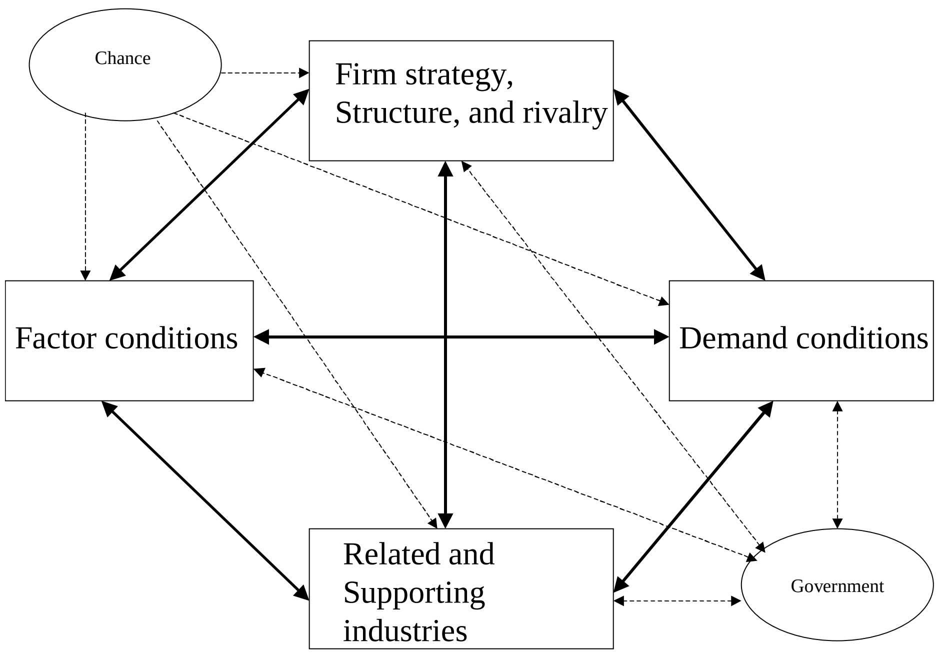

Fig. 3: The Diamond of Competitive Advantage of Nations, Porter, M.E. (1990)

§ 2.4 The national system of innovation theory

A key question in development-research is why innovation and technical change can be so influential in economic development in some countries but so much less in others. The object of studies has become “the national system of innovation” defined as the network of economic agents together with the institutions and policies that influence their innovative behaviour and performance (Clark, N. 2000).

In the concept of a national system of innovation, that has been introduced by Freeman (Edquist, C. 1997) and has been further elaborated by Lundvall (Lundvall, B. 1992), national characteristics influence the total system of innovation. The conceptual model of Fig. 2 is influenced by national culture and national ideologies. Johnson elaborates a national system of innovations as “all interrelated, institutional and structural factors in a nation, which generate, select and diffuse innovation” (Lundvall, B. 1992).

The functioning of ISP is influenced by the total working of the national system of innovation. By influencing the working of ISP a small part of the total national system of innovation is influenced.

In the following model of innovation (see Fig. 4) the chain-linked model of Rosenberg and Kline is merged with concepts from the national system of innovation theory as well as with concepts from Porter’s “theory of competitive advantage of nations”.

The model is also specified for this research, so “Research” is now called “Research ISP”, and “Firm specific knowledge” is now called “Firms and firm specific knowledge”. So the concept of “firm specific knowledge” is broadened from specific knowledge to the firm’s overall characteristics. It is knowledge that is transferred, but more characteristics come into play when transferring technology.

As Fig. 4 shows, the chain-linked model of Kline and Rosenberg operates in a national environment. From the national system of innovation theorists, like Lundvall, Nelson and Edquist, two concepts are added to the first conceptual model of Rosenberg and Kline: “R&D institutes” and “Government policy”.

With the concept of R&D institutes, a distinction is made between knowledge that is generated at a university and the knowledge that is generated at an R&D institute. At the university, knowledge is generated from performing basic research programs. The R&D institutes use the knowledge from the universities, and transform this knowledge into practical applications (in other words, innovate the inventions of universities). Sometimes (or even in most cases) the firms themselves have R&D institutes that perform the transformation process. But, in very complex situations expert R&D institutes must be advised.

Firms are concerned with so called “product innovation” whereas ISP is concerned with “process innovation”. Both concepts are used in the conceptual model. The arrow between ISP and Firms is mostly concerned with process innovation.

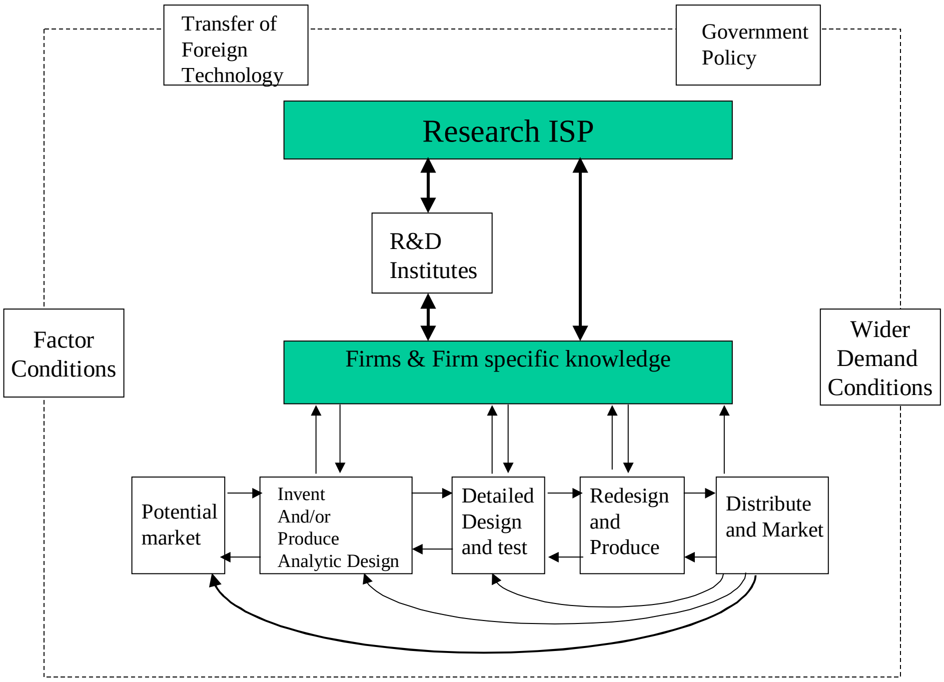

Fig. 4: Conceptual model based on Kline, S.J. and Rosenberg, N. 1986 and Porter, M.E. 1990

Government policy influences every aspect of the conceptual model of innovation. As stated in the book of Lundvall (1992): "Government has an important role to play as the only agency responsible for the overall coherence of the national system of innovation as well as for the cohesion of the social system as a whole." Porter also suggested that government policy profoundly influences the competitive advantage of a nation.

> "Government, at all levels, can improve or detract from the national advantage. This role is seen most clearly by examining how policies influence each of the determinants. Antitrust policy affects domestic rivalry. Regulation can alter home demand conditions. Investment in education can change factor conditions. Government purchases can stimulate related and supporting industries. Policies implemented without consideration of how they influence the entire system of determinants are as likely to undermine national advantage as enhance it (Porter, M.E. 1990)."

Johnson agrees with Porter on the importance of the government in the book of Lundvall (Lundvall, B. 1992). He says that the government is responsible for standards and regulations, making interaction more efficient, and is responsible for the communications infrastructure and the formal educational system. In his words: "The importance of the state basically follows from its unique power to define and supervise the institutions of property rights. Thereby it influences the total incentive system and the appropriateness of technical innovations, permitting and protecting them as rent-yielding assets."

Fig. 4 also combines the chain-linked model with concepts derived from the diamond of competitive advantage of Porter. In Fig. 4, Factor conditions and Demand conditions influence the chain-linked model. Here Factor Conditions will be defined as: "nothing more than the inputs necessary to compete in any industry, such as labour, arable land, natural resources, capital, and infrastructure (Porter, M.E. 1990)." Porter groups the factor conditions into human resources, physical resources, knowledge resources, capital resources and infrastructure. A concept that is not part of Porter's definition of Factor Conditions, but what could also be important for the national system of innovation is the "Technological Information System", which holds "patents and intellectual property", "standards and metrology" and "publications and information" (Rush *et al.* 1996). It is a more detailed specification of Porter's infrastructure.

The wider demand conditions are defined as: "the composition (or nature of buyer needs) of home demand, the size and pattern of growth of home demand, and the mechanisms by which a nation's domestic preferences are transmitted to foreign markets (Porter 1990)."

This is not the same as the concept of “potential market”, because that concept suggests a specified product that can be marketed. The concept of “Wider Demand Conditions” deals with the whole demand structure of a nation, not just one specific market for one product. The Kerala economy is currently in a crisis (See Appendix H) so the wider demand conditions are very different from a developed country. There are a lot of constraints in India that influence day-to-day life and therefore also influence this research and its out comings.

Finally, the concept of “Transfer of Foreign Technology” was added. This concept was not directly identified as important from the initial literature study, but during the research it was found that this concept was very important. First of all, ISP gets her knowledge partially through a collaboration project with the Dutch COBRA institute. Secondly, a lot of competition comes from foreign institutes in the USA, Japan and Europe. Very often, these institutes have been working in the field of photonics much longer than ISP has, and therefore are no match for ISP. However, the competitive advantage of ISP lies in its location. ISP should establish a link between the companies in the neighbourhood of the university (in Kerala), because these companies have never thought of using photonics and are therefore virtually untouched by foreign competition. ISP can offer applications that are tailor-made and require a lot of communication, which is easier for ISP than for the foreign companies, because they are close by. There are a lot of companies that operate outside Kerala that probably can use photonics, but than ISP has to compete with the foreign institutes, which is very hard since they have only been established since 1995.

The innovation model of Fig. 4 will be used in this research as a general background model of factors that also influence the transfer of technology and the general innovation process. However, this research is only concerned with the arrow between “Research ISP” and “Firms and firm specific knowledge”. Or in other words, the transfer of technology from a research institute to specific firms (or even other actors that are capable of assimilating the technology and have use for Photonics technology).

§ 2.5 The transfer of technology[1]

§ 2.5.1 The Bongenaar and Szirmai model

Bongenaar and Szirmai (1999) suggested a model for the transfer of knowledge from a Tanzanian R&D Institute to specific firms. They identified several important stages in the “Technology Development Process”.

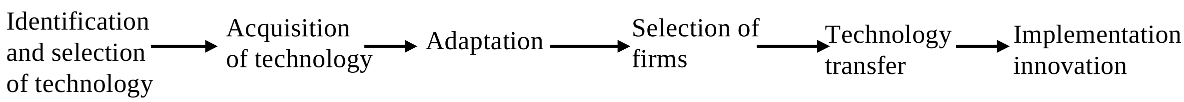

Fig. 5: The Technology Development Process of Bongenaar, B. and Szirmai, A. (1999)

These phases are represented in the conceptual model from Fig. 4 as the arrow between “R&D institutes” and “Firms and firm specific knowledge”. However, this research is concerned with the arrow from “Research ISP” and “Firms and firm specific knowledge”. Therefore, the first two stages of the Bongenaar and Szirmai model are of no use in this research. The model has to be adapted.

For this research the following stages are identified as important stages in the diffusion process of the invention:

[1] Technology was earlier defined as “knowledge about how to do things” and deals with techniques – the choices made when applying technology in specific circumstances with respect to economic, physical and social conditions (Evenson, R. and Westphal, L. 1993)

1. *The adaptation stage.* The purpose of adapting a technology is to develop a system that will function optimally in the domestic industry. Quality and quantity of the technical and non-technical participation in the project determine the outcome of this process.
2. *The selection of firms for the technology transfer stage.* This phase involves interesting firms in the new technology, persuading them to accept it and selecting the firms with the greatest potential for successful implementation. Confronting characteristics of the technology with characteristics of the firm assesses a firm's potential.
3. *The technology transfer stage.* The actual transfer of the technology not only involves the sale of equipment and information, but also the transfer of the knowledge needed for operating and maintaining the technology. The transfer of knowledge is difficult and must be given priority attention during the transfer process.
4. *The implementation of the technology within the selected firms.* The technology, normally involving a production process, must be made operational at the firm's premises. Especially during the first period of operation, the entrepreneurs should be supported in the process of making the technical and organisational changes required

In this research the transfer of technology from a university, which conducts *basic* research, to a specific firm is investigated. The university should direct their research to the needs of the market (firms). In a study performed by Rush *et al.* (1996) several successful Research Technology Institutes (RTIs) from all over the world were examined for their activities within the national system of innovation.

They were analysed on the following activities: Basic Research, Applied Research, Experimental Development, Design and Applications Engineering, Technical Services, Standards and Certification and Diffusion. All RTIs were involved in the diffusion of technology. It is important for the strategy of the institution that the technology research that is undertaken is relevant for the industry involved (Rush *et al* 1996, p. 3). So the first stage should be "the identification of possible technological applications" from their basic research. The second stage should be "the actual development of the application". Now, the rest of the Bongenaar & Szirmai model for technology transfer is used.

The following model is the final research model:

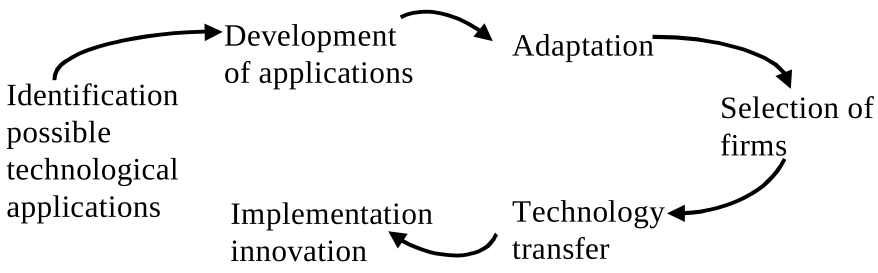

Fig. 6: The Final Research Model based on Bongenaar, B. and Szirmai, A. (1999)

These stages suggest a linear transfer model from the Technology Institute to the selected firms. The development process however is everything but linear. As Kline and Rosenberg indicated (1986) the innovation process is a "subsequent improvement process", it is an iterative process. These stages are represented linear to make the model easier to understand, but the stages actually are all interlinked. The stages could easily be placed in another order.

§ 2.5.2 Description of conceptual definitions

Possible technological applications:

From the basic research projects done at ISP, possible applications for markets must be identified. The applications must be directed at the actors that can assimilate the technology. The applications have to be "appropriate".

From Bongenaar and Szirmai (1999) "*appropriateness* refers to the evaluation of effects of technologies within the wider societal context, both in the short run and the long run.
The chosen technology should be appropriate in terms of local market conditions, local resources, labour supply and quality of workforce, environmental and geographic conditions, cultural features and national objectives and policies (Van Egmond-de Wilde de Ligny, E.L.C. 2000)".:

Appropriateness should also mean that the technology is relevant for the industry that must adopt it (Rush *et al*, 1996). It would be useful for the university to ask questions about the next development stages in this stage of the development process, for example

1. How difficult is it to develop the technology?
2. How difficult is it to adapt the technology to a selected industry?
3. How difficult is it to select an industry for this technology?
4. How difficult is it to transfer the technology to a selected firm?
5. How difficult is it to implement the technology in a selected firm?

If these questions reveal that the technology is very difficult to develop, adapt, select, transfer and implement, than it would be wiser not to pursue the development any further for commercial reasons. These questions can also reveal which stages are the most problematic, and therefore need more attention than other stages.

Development of the possible applications:

In this stage the institute actually develops the applications or assists other institutions in developing the application. It is wise for them to develop the applications with an eye to the future as pointed out in the identification phase. In fact, in all of the stages the university should pay attention to the difficulty of one stage reflected to the other, and against the expected revenues that they receive in the future for the technology. Logically, if the expected revenues are lower than the costs of developing the technology than the development stage should be terminated. This requires organisational capability from the side of the university. Commercial development requires a market oriented development organisation. This could be difficult, because of the nature of the institute. However, it is necessary if commercialisation is to succeed. The main issue in this research is to build the *technological capability* of the International School of Photonics in such a way that they will be able to sustain themselves in the future though commercialisation. So important is that there is a market for their technology, and that they are capable of responding adequately to this market.

Adaptation:

Adaptation means that the applications are adapted so that they are more appropriate for local conditions. The original definition of the adaptation stage was based on the idea that the technology was transferred from a country, other than the developing economy in which the application should work. In the case of this research, the technology is generated at ISP. However, the adaptation phase is still an important phase in the research framework, because the developed application has to function in an environment other than the one at the university. In the case of complex technology like photonics, it is very conceivable that the developed application has to be adapted to the "technological capability" and the needs of the firms that want to assimilate the technology. So the adaptation phase is defined as a refined development phase. Three other concepts influence the adaptation of the technology:

1. The characteristics of the technology: appropriateness of the developed application
2. The technological capabilities of the ISP
3. The characteristics (capabilities, needs etc.) of the target environment

This can be seen in the following figure:

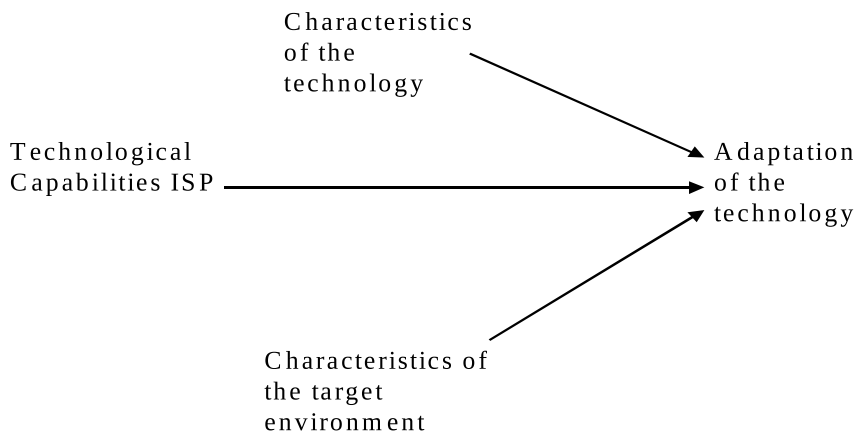

Fig. 7: Adaptation of technology, based on Bongenaar, B, and Szirmai, A. 1999

Selection of firms:

This is the phase were the firms that are capable of assimilating the technologies are selected. The firms will have to have the need for the technology.

The following figure based on the model of Bongenaar and Szirmai (1999) postulates the different factors involved with the selection of firms.

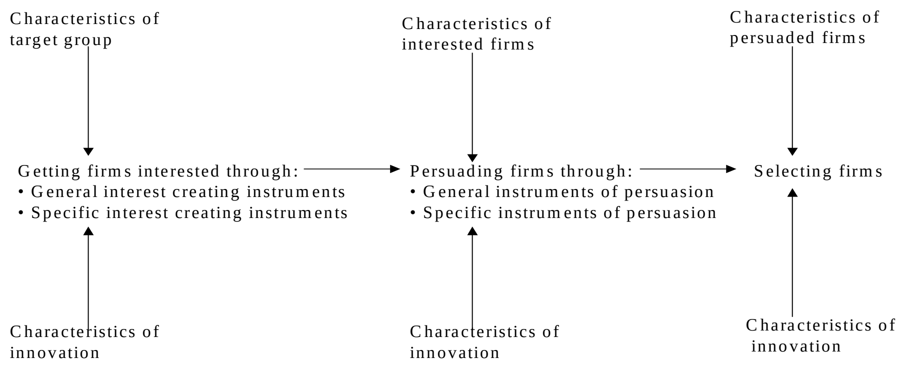

Fig. 8: The selection of firms, based on Bongenaar, B. and Szirmai, A. 1999

In this figure, the characteristics of the innovation and the target group again influence the process of selection. The first stage involves getting the interest of the firms through the use of specific interest creation instruments, like communication methods, networking and using so called change agents (See Bongenaar, B. and Szirmai, A.1999). This is basically PR-work. Next, the firms are persuaded to engage in the transferring process. An active role by the university is required. The specific instruments of persuasion are: giving free consultancy, giving the technology ownership to the company, financial stimuli, private guidance, tailor made (re)design, result insurance, pilot plant implementation and approaching so-called gatekeepers (See also Bongenaar, B. and Szirmai,A. 1999). At the most right of the figure, the actual selection of firms to which the technology will be transferred takes place. The *specific* instruments for creating interest and persuasion are located towards a specific firm or target group.

Technology transfer phase:

In this phase, the actual technology transfer takes place. The transfer of hardware consists of a simple transaction of machinery and goods. Written information (Infoware) needs time to be understood, but in itself it is easy to transfer. Due to the often tacit and encoded nature of technological knowledge, special attention has to be paid to the transfer of knowledge via training, instruction, learning and education. The transfer of human knowledge (Humanware) involves longer learning periods, and is essential to the functioning of the technology. The difference between existing knowledge capabilities and the knowledge requirements of the technology, determines the required time and effort for the transfer process (Bongenaar, B. and Szirmai, A. 1999). Again the technological capabilities of both the university and the selected firms are of influence to the transfer of knowledge. Also, the organisation of the knowledge transfer influences the rate of knowledge transfer.

Implementation of innovation:

The implementation phase is the phase in which the firms implement the technology into the organisation and use it in their innovation process. During this phase the university could support the firms in overcoming problems. The technology has to be diffused to managers, engineers and production workers within the organisation. In this phase tacit knowledge necessary to make a technology function in a given environment has to have a chance to develop (Bongenaar, B. and Szirmai, A. 1999).

Technological Capabilities:

In all of the stages, and specifically in the adaptation-stage, Technological Capability is a very important concept. There are two scopes important in the concept of Technological Capability. Technological Capability on the Macro-level (country-level) and Technological Capability on firm level. In the foregoing part of this report the Technological Capability on country level has been covered by the Systems of Innovation theory. Several stages in the theoretical model use Technological Capability of the firm (to adapt and implement the technology) and the capability of ISP to develop, select the firms, select the technology etc. Technological Capability is the total stock of national resources (Macro-level) that can be committed to the production system, giving the necessary inputs for efficient and effective production. The stock of national resources is composed of the stock of technologies, human resources, natural resources, the organisation and institutions that are part of the sectoral infrastructure (Egmond-de Wilde de Ligny, E.L.C. v. 2000). This stock of resources should supply the country with the means, skills, and know-how to select, master and adapt the technologies needed and most appropriate to the social system of the country concerned. This stock should also enable the country to develop and generate its own technologies (self-reliant technology generation). Due to lack of technological capabilities, a country may fail to use the scarce resources efficiently, resulting in higher costs to enterprises and to the national economy.

Firms however should also have the “technological capability” assimilate the technology (see also, Romijn, H.A. 1996) “Simply providing equipment and operating instructions, patents, designs or blueprints do not ensure that the technology will be effectively utilized. The assimilation of technology has to be accompanied by local learning, in other words, technological capabilities have to be created. The more complex the technology, the more skills and effort are required to acquire them. Yet, ate any level of complexity, an effort needs to be made (United Nations, 2000)”.

As well as the firms, the International School of Photonics should have the technological capabilities to select the suitable firms and transfer the knowledge. Even more, ISP should be able to control the entire diffusion process from beginning to end. This means that ISP must have the organisational capacity to accompany the innovation process in case of “technology push”. Also, ISP should first and foremost have the capability to create commercially marketable products and/or services.

§ 2.6. The ISP Photonics Technology

Photonics is the technology, which uses photons to achieve various engineering objectives. Photonics have been used in optical communications, sensors, instrumentation, and computing. As Gupta puts it in his book (Gupta, M.C. 1997): "The area of Photonics reflects the synergy between optics and electronics and also shows the tie between optical materials, devices and systems. The subject of photonics plays a key role in many segments of industry such as optical communication, information storage, electronic display, signal processing, electronic imaging, etc."

Semiconductor materials play a major role in the photonics area as they are used for light generation, for detection, modulation, and fabrication of monolithic optoelectronic devices.

§ 2.6.1. Different fields in Photonics Technology

There are a lot of different fields in photonics technology but in this research only three fields are very important. The first field is called Spectroscopy, the second field is called Interferometry and the third field is concerned with Microscopy.

Spectroscopy is concerned with recognising gasses, pollutions, precision measurements and metallurgic measurements by analysing the wavelength (Energy) within a spectrum. By recognising the wavelengths of a spectrum and analysing differences in these wavelengths various measurements can be performed.

Interferometry uses two light beams to measure various displacements. The following figure provides a schematic overview of an interferometric meter.

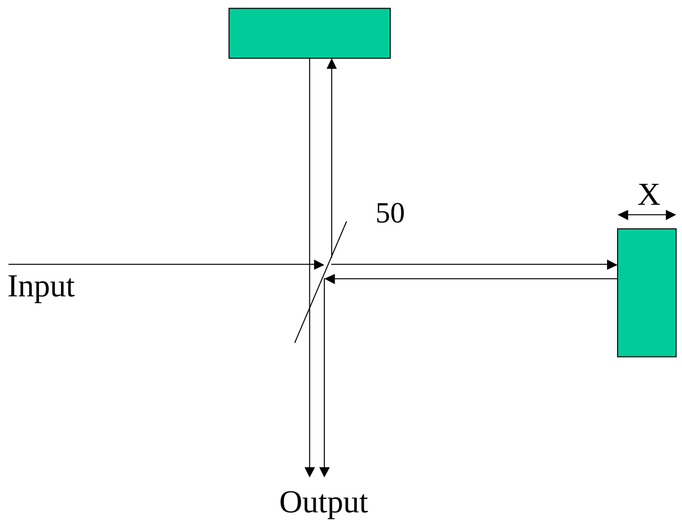

Fig. 9: Interferometric meter

Here the left mirror changes in displacement (X) and because of this the wavelength of the right laser beam will change respectively with the wavelength of the left causing an increase or a decrease in the intensity of the output of the meter. The wavelength of the output laser is approximately 500 nm, so this meter can measure with an accuracy of 5 nm. The principle of interferometry is also used in laser gyrometers, for measuring velocity of a liquid and for measuring the frequency of the light.

The third field in photonics was microscopy. *Microscopy* uses a laser beam for very accurate engineering purposes. A big advantage of the laser beam is that it can be focused. Because of this, lasers are used in applications such as writing IC's (ASML).

§ 2.6.2. What is a Photon?

By the definition of Max Plank, light consists of particles that are called photons. Some prefer to regard photons as localised packages of energy (Yeh, C. 1994). A photon has zero rest mass and caries electromagnetic energy and momentum. It travels at the speed of light in vacuum, but is retarded in matter. Photons have a dual particle/wavelike property. The emission and absorption of photons occur in quanta of energy.

Photon Energy

The energy of a photon can be expressed as $E = hv$, where h is Plank's constant and v is the frequency of the harmonic oscillator to which the photon belongs. As $h = 6.63 \times 10^{-34}$ J-s and is a constant, energy can be added or subtracted in steps only; that is, energy is quantized. The wavelike nature of a photon is revealed in the frequency v, which can be related to the wavelength by the equation $v\lambda = c$, the velocity of light *in vacuo* as in classical theory. The unit of energy is Joules. Its practical unit is electron-volts (eV). But a convenient unit is reciprocal wavelength (cm^{-1}).

Interaction of Photons with Atoms (Important in Laser applications)

A bundle of photons in motion constitute a beam of light. The electric field of the light wave can interact with the valence electron(s) of the atom in matter. The force exerted on the atom causes the atom's electrons to vibrate or accelerate. Conversely, vibrating electric charges emit light. The interaction process is governed by rules of quantum mechanics, which allow only specific levels of energy to participate in the exchange. Two processes may be observed in this interaction, absorption and emission. The latter can again be divided into spontaneous and stimulated emission.

Absorption. The photon may impart energy to the matter or atom if its energy matches the difference between two energy levels. The atom thus gains energy and the photon is said to be absorbed. The atom is thereby raised to a higher energy level. Conversely, the interaction between photon and matter may result in the transition of the atom to a lower energy level, resulting in the emission of a photon of energy equal to the difference in energy between levels. In all these transitions, the law for conservation of energy holds true.

Spontaneous emission. If the atom is initially in the upper energy level, it may drop spontaneously to a lower level and release its energy as a photon. As the transition is independent of the number of photons that may already be in the mode, it is called spontaneous emission. It is a random phenomenon. The probability of spontaneous emissions is proportional to the transition cross section, which is a function of the frequency.

Stimulated emission. If an atom is in the upper energy level and the mode already contains a photon, the atom may be stimulated to emit another photon that duplicates itself in frequency, the direction of propagation and polarization.

These processes are used in various laser applications. Lasers of all kinds are used as light sources and semiconductor detectors.

There are several kinds of lasers:

- Solid-state lasers: Solid-state lasers have many applications besides telecommunication systems. These lasers are intended to satisfy the demand of higher-power output, and they operate over a widely different frequency range that semiconductor lasers cannot easily fulfil.
- Other Laser sources: Gaseous lasers, dye lasers, excimer lasers. Free-electron lasers, and X-ray lasers are all sources with high-power capability and together they span a wide frequency range.

§ 2.6.3. The ISP Projects

The International School of Photonics has several different areas of research; the most important ones for this research are listed below:

Laser produced plasmas
In this field, a subject of matter is irradiated with a high-energy laser pulse. This generates intense luminous plasma rapidly expanding from the irradiated spot. Spectroscopic studies on such plasma emission can yield a rich fund of information on the composition, evolution and dynamics of the plasma and the interactions taking place within the plasma. At ISP Laser Induced Plasma has been a subject of research using various target materials like: metals, insulators, semiconductors, polymers and high temperature superconductors. These studies give the people at ISP more insight in the phenomena associated with Laser Induced Plasma.

Photothermal deflection studies
The investigation on the interaction of optical radiation with matter provides means for the thermal and optical characterisation of materials. The absorption of optical radiation is followed either by radiative or non-radiative de-excitation processes. The latter process results in the generation of heat. The conversion of optical energy to heat energy via non-radiative de-excitation is called photothermal effect. There are various photothermal effects like rise in temperature of the sample on irradiation, generation of acoustic waves, change in refractive index etc.

Photothermal Deflection Technique (PDT) is one of the above mentioned photothermal effects. The technique is based essentially on the changes in the refractive index of the medium produced by the absorption of optical radiation (also called the pump beam). It is detected by sending a second, low power laser beam (probe) through the sample or through the adjacent coupling medium so that the probe beam will be experience a change in optical path length causing it to deflect from the original direction. This phenomenon is also called the mirage effect.

The change in path length is measured as a function of the refractive index gradient (RIG) in PTD technique. In this case, the probe laser passing through the inhomogeneous medium with RIG gets deflected from the original path. A position sensitive detector (PSD), which is kept along its path, measures the amount of deflection. The amount of deflection is a function of the magnitude of the RIG, which in turn depends on various thermal and optical properties of the sample. PDT is a non-contact and highly sensitive technique for the optical and thermal characterisation of materials of different forms.

Studies on photoacoustic phenomena
The Photo Acoustic effect is basically the phenomenon of generation of acoustic waves when a sample is irradiated with pulsed or modulated light beams. This effect has certain unique characteristics, which makes it a versatile tool for probing the optical and thermal properties of samples in gaseous, liquid or solid states. The Photo Acoustic effect can be picked up with the use of a very sensitive microphone.

Optical Fibres
Photonic detection is the reverse process of photonic generation. It is used not merely to detect the presence of radiation, but to measure its intensity quantitatively as well. If the light source carries information, that is, a modulated signal, detection could include the process of demodulation. A fibre optic can be used in the optical communications. Here it is considerably better to use an optic fibre to transfer data instead of using a coax cable. The coax cable can transmit about 1 GHZ of data whereas the optic fibre system can transmit 10 THz. This field is the largest application of optical fibres, but ISP does not pursue this field. The research of ISP focuses on the design and development of optical fibre *sensors*. By removing a piece of the cladding the fibre can be used as a sensor. The uncladded region of the fiber that functions as the sensor element can be coated with metalloid phythalocyanines or certain specific dye which shows selective adsorption corresponding to different gases. Laser light transmitted through fiber can in its turn be detected using a fiber power meter. Change in the refractive index/adsorption surrounding the sensor element due to a change in the sample brings about a change in the intensity of the light guided through the fiber.
At ISP, a compact portable Fibre Optic Sensor has been developed for the level monitoring of glucose. This sensor has obvious medical applications. For more info on Fibre Optic Sensors see Appendix I.

Chapter 3: Practical design of the research

This chapter contains the constraints, which initially were identified in the beginning of the research, for transferring the technology from the International School of Photonics to the industry. Also, the operationalisation of the relevant variables in the research is given in this chapter.

§ 3.1 The initial constraints

From informal conversations with staff members of ISP several constraints to the successful transfer of technology were identified in the initial stage of the research:

1.) *Different attitudes between the university and the firms*: because of the fact that the university is a government institution and the firms are private institutions, there is a difference in attitude. The university doesn't have a time barrier, which stimulates the process of technology creation. Firms on the other hand have to provide products and services by a certain date. So whenever a firm has a technical problem, the university can solve it but it will take too much time. The concept of "Characteristics of the target environment" and the Technological Capability of ISP are important concepts for reducing the gap between the attitudes of the university and the firms (See Fig. 7. and Fig. 8).
2.) *With this there is also competition on the area from abroad.* The International School of Photonics, as well as Universities as a whole, cannot compete with foreign institutes that have a long history of research in a subject of research. This makes that firms will always choose for the faster and more researched solution of a foreign institution instead of choosing for the more time-taking solution of the university in India. This concept is embedded in the conceptual model of Fig. 4 in the concept of "Transfer of Technology".
3.) *Furthermore, companies do not frequently invest in improving their production process.* The reason for this is probably the lack of financial surplus to invest (See Factor Conditions in Fig. 4). When you are just making ends meet, and you are making profit, then the incentive to invest in better production capabilities is very low. This problem is very hard to change, and it is inhibitive of the developing nature of the country.
4.) *In Kerala, there are no R&D institutes present that serve as private institutions between the university and firms.* Firms have their own R&D departments, because they don't want to be dependent on any other institution. Independence is the way to survive for a company, because institutions rise and close at a very fast rate. The R&D departments within the firms should be involved in the transfer and implementation phases of the technology transfer process. The linkages between R&D institutes and the firms that are represented in Fig. 4 are in this case very short but also very tight. The question is however, in how far these departments can be compared to R&D *Institutes*.
5.) *A photonics industry in Kerala is currently not present.* But photonics is used in a variety of electrical applications. The innovations however that use photonics technology are small-scale. Even outside of Kerala it is difficult to create large-scale innovations, because even though there are companies that use photonics technology, these companies can also get their knowledge from the foreign institutions. Competition on the area of photonics is almost impossible for the International School of Photonics, because they are only beginners in the field. So the most probable innovation to come from their research is in the local industry that uses "basic" photonics technology applications and not in the highly competitive photonics industry outside Kerala.
6.) *There is also a lack of knowledge on how to proceed in the technology transfer process.* In most cases, knowledge about commercialisation processes is very limited and this results in the inability to create a research policy that is adequate and provides insight into the important aspects of research applications, so that the gap between the firms' needs and the possible applications of the research is not getting smaller. An adequate research policy should steer the research in a direction in that the gap between applications of the research and the needs of firms is as small as possible, so that transferring knowledge occurs naturally and easily. This research is the first step in solving this problem. The theory that was presented in this report should provide enough information about the technology development processes.

In a later stage of the research other constraints were identified:

7.) The professors haven't got much time to engage in collaboration projects because of their teaching and research responsibilities. The administration office in CUSAT should provide more means for engaging in these outdoor-activities. In overall India there is not much of a culture where Industry-Institution Interaction takes place, whereas in the Developed Countries, these linkages are common practice. Not only from ISP should this interaction take place, but from the university as a whole. The policy of CUSAT has to be changed as well as the policy of ISP.
8.) Engaging in collaboration projects is not part of the goals of ISP. The industry interaction is given but low priority. Maybe this will change when they need the industry to support them financially.

§ 3.2 Operationalisation of the relevant variables

In this research a research framework for the development and transfer of technology was formulated. In this research two stages from the model are being investigated: The "Identification of Possible Technological Applications" and the "Selection of Firms" stages. These stages form the beginning of the process and the other stages cannot begin when these two stages are not completed. Both stages have been researched with the help of a questionnaire. The first stage has been investigated by performing interviews with the staff members of ISP and the second stage has been investigated by a market survey. This survey was not only done to gain knowledge about the needs of the firms but at the same time to get the firms interested in the photonics technology and ISP. At least the companies that have been visited have been confronted with ISP and its products. This was the first step for possible future relationships between the industry and the university. In all the stages in the research model the characteristics of the technology, the characteristics of the target group, characteristics of the institute and environmental constraints are investigated. The concept of "photonics needs" relates to the technical aspects of the model and the "Firm's Willingness" concept relates to the non-technical aspects of the research model.
Photonics needs has been defined as: the degree of applicability of Photonics Technology, specifically (knowledge about) lasers, sensors, semiconductors, lenses, in a production process or the willingness to produce products from the International School of Photonics. This need for photonics technology has been expressed in a score.

Firm's willingness is the willingness of a firm to invest in and implement the photonics technology. If the firm is willing to invest and they have a need for a specific application of the research of ISP or a specific product from ISP it is believed that there will be a very high chance that the transfer of technology will be successful.

§ 3.2.1 Photonics needs

The needs of an organisation (company) for photonics depend on a number of variables. Not in the least it depends on the kind of product that the company produces. If the company makes photonics products, like lasers or fibre optic sensors, than the company is most likely interested in the research program of ISP. It is in these cases that the process for transferring technology is initiated by the company. This is how ISP has been looking at the companies in the neighbourhood in the past. Are they making a photonics product? No, then they are not likely able to use our products. The concept of Photonics Needs is represented in the research model in Fig. 7 and Fig. 8 by the concept of "Characteristic of the Innovation". The Characteristics of the innovation influences the use of the innovation within the selected firms.

The fact is that "photonics" is a technology that is used in a number of various applications. If one only looks at the photonics product making firms in Kerala, than you are probably finished very quickly. More interesting is the question if companies in the vicinity, that have never heard of photonics or even thought about it for that matter, can use knowledge from ISP. Even more important is the fact that the companies that are producing the photonics products like lasers and fibre optic sensors are also connected with other institutes that have the know-how on photonics. This means that ISP has to compete with these institutes. ISP is unable to compete with these, for the most part specialised and foreign, institutes, because first of all, they have only started since 1995. This means that they have only 7 years of experience, whereas other institutes might be specialising in this field for over 20 years. Secondly, ISP has only five staff members and approximately 26 PhD students. So the capacity for competing is very low. Thirdly, they lack the finances and the facilities for producing in large quantities. So the only way that they can apply their knowledge in practical applications in companies is with so-called “tailor-made” applications.

Their strength lies in their location. Companies that have never heard of ISP, and have never thought of using photonics technology can have problems that can easily be solved by knowledge of ISP. It is in these cases that ISP can diffuse its knowledge. It is in these cases that ISP has an advantage over the larger foreign institutes. They should be able to link with firms in the vicinity and providing them with specially designed and adapted applications for their use. In this research two kinds of applications for photonics technology (lasers, fibre optic sensors, semiconductors, lenses) have been defined. One application is using the lasers, fibre optic sensors, semiconductors and lenses in the production process. The second application lies with monitoring and controlling of the production process. Lasers can be used in two ways, to cut and produce a product (however this is very specialised and expensive), but also for measuring an object. This is used in the controlling of the production process. In this research a difference had to be made between using a laser as a production tool and using a laser as a measurement tool. The difference was made for fibre optic sensors, semiconductors and lenses as well. It has to be acknowledged however, that this separation was not always clear to the respondent and therefore a bias in the data is present. Sometimes it was possible to verify the answers from the questionnaire with observational data, but this was not the case with all the companies. They simply would not give permission to see their production plant.

Furthermore, the needs of a company could also lie in wanting to produce the actual products from ISP or wanting to use its services (laboratory, library etc). In the following table the total operationalisation is given for the photonics needs. The measuring instrument reveals the way that the variable has been measured. P. stands for Part of the questionnaire, Q. stands for the Question, MS stands for the questionnaire used in the Market Study (given in Appendix E), II stands for the questionnaire used in the ISP Interviews (given in Appendix C), O. stands for observation and DR stands for Desk Research. The table gives insight in the way that the concept of “Photonics Needs” is defined and measured.

Tab. 1: The Operationalisation of "Photonics Needs"

Concept	*Dimension*	*Variable*	*Measuring Instrument*[1]
The degree of applicability of Photonics Technology, specifically (knowledge about) lasers, sensors, semiconductors, optical solutions (lenses), in a production process	The use of photonics applications in the actual manufacturing process	• Kind of product that is manufactured • Kind of production process (chemical, constructive, service, assembly, other) • Capital intensity of the production process • How many people work on the manufacturing process • How many work by hand, without machines or jigs and fixtures • How many machines are used in the manufacturing process • Number of them that (can) use laser technology • Number of them that (can) use fibre optic sensors • Number of them that (can) use semiconductors • Number of them that (can) use optical solutions (lenses)	• P. 2 Q. 11,12 (MS) • P. 3.2 Q. 2, 3 (MS) • P. 3.2 Q. 1, 2 (MS) • P. 3.2 Q. 4 (MS) • P. 3.2 Q. 5 (MS) • P. 3.2 Q. 6, 7, 8, 9, 10, 11 (MS) • P. 3.2 Q. 13, 14, 15, 16 (MS & O) • P. 3.2 Q. 17, 18, 19, 20 (MS & O) • P. 3.2 Q. 21, 22, 23, 24 (MS & O) • P. 3.2 Q. 25, 26, 27, 28 (MS & O)
	The use of Photonics Technology in the Monitoring and controlling of the manufacturing process	• Automatic monitoring an controlling or by hand • Kind of system (in case of automatic) • Purpose of system • Other systems, like safety systems? • Number of lasers (that can be) used in the system • Number of fibre optic sensors (that can be) used in the system • Number of semiconductors (that can be) used in the system • Number of lenses (that can be) used in the system • Use of hand measuring instruments to control the process • Number of lasers (that can be) used in the instrument • Number of fibre optic sensors (that can be) used in the instrument • Number of semiconductors (that can be) used in the instrument • Number of lenses (that can be) used in the instrument	• P. 3.3 Q. 3 (MS) • P. 3.3 Q. 9 (MS) • P. 3.3 Q. 9 (MS) • P. 3.3 Q. 26, 27 (MS) • P. 3.3 Q. 10, 11, 12, 13 (MS & O) • P. 3.3 Q. 14, 15, 16, 17 (MS &O) • P. 3.3 Q. 18, 19, 20, 21 (MS &O) • P. 3.3 Q. 22, 23, 24, 25 (MS &O) • P. 3.3 Q. 4 (MS) • P. 3.3 Q. 5, 6, 7, 8 (MS & O) • P. 3.3 Q. 5, 6, 7, 8 (MS &O) • P. 3.3 Q. 5, 6, 7, 8 (MS & O) • P. 3.3 O. 5, 6, 7, 8 (MS & O)
	Willingness to produce photonics products	• Characteristics products from ISP • Characteristics company	• P. 3.1 (MS) • P. 3.1 (MS)

[1.] MS = Market Study; O = Observation; P. = Part; Q. = Question; II. = ISP Interviews; DR. = Desk Research

§ 3.2.2 Firms willingness to invest in and implement the photonics technology

The fact that ISP is able to create a technology that is applicable within the production and monitoring process of a firm is not enough to ensure that the transfer of technology will be a success or even takes place. Another concept is very important: the willingness of a firm to invest in and implement the photonics technology. Most of the dimensions within this complex concept are of a social/cultural nature rather then a technical nature. In this research, 5 dimensions are defined that influence the willingness of a firm to invest in photonics technology.

1.) *Characteristics of the innovation (see Fig. 7 and Fig. 8 of the research model)*: this dimension depends largely on the production process of a firm and the way that ISP can contribute to the better functioning of the production process. The application will cost the firm money so the innovation has to have certain characteristics that prove the investment to be financially feasible. A firm is a private institution in most cases and has to make profit in order to survive. If an innovation will improve their production process in a way that money is saved through an improved production process, than the innovation will likely be adopted by the firm.

2.) Characteristics of the firm (see Fig. 8of the research model): the willingness of the firm also largely depends on the characteristics of the firm. For example if the firm is having a money surplus and is able to invest in upgrading their production process. When the firm isn't making a profit, the firm is not likely to take an interest.

3.) *Technological capability of the International School of Photonics (see Fig. 7 of the research model)*: a firm will have to trust on the skills of the International School of Photonics. They will have to have the capability, not only to create the product, but also to manage the whole transfer of technology. Also they should get the back up from the university to proceed in these projects. The university policy now does not include industry-institution interaction.

4.) *Active attitude of ISP towards the firms (see Fig. 8 of the research model):* firms are the ones that have the money. So they are not likely to come to ISP on their own behalf. It is also not likely that they have ever heard from ISP or its products. ISP should have a very active attitude to transfer their knowledge. It all depends on ISP's ability to interest and persuade the firms in collaboration projects or products from ISP. The willingness of ISP to transfer their technology, the emphasis they put on transferring their technology is very important. When ISP doesn't see the need for transferring, then the process is very likely to fail. Firms will not be persuaded to invest and implement the technology.

5.) *Environmental constraints (see the conceptual model presented in Fig. 4)*: other factors that influence the willingness of a firm to invest in photonics and thus the transfer of technology process are government influence, competition, factor conditions, wider demand conditions, infrastructure (see also chapter 2, specifically paragraph 2.4 and onwards).

Tab. 2 gives the operationalisation of the "willingness of the firms to invest and implement photonics". Here also the measuring instrument has been given as in Table 1.

The questionnaires that were used to gather the data from ISP and the companies were made with the help of tables 1 and 2. The questionnaires are given in appendices C and E respectively.
The questionnaire that was used to get the data from the companies was pre-tested with 9 different companies. The questionnaire that was used to get the data from ISP was not pre-tested, because of the low amount of respondents (5 staff members). Both the questionnaires have been made in consultancy with Mr. Szirmai from the faculty of Technology Management from the Eindhoven University of Technology. In the case of the questionnaire for the companies, Mr. K.P.S Nair, a reader from Engineering College at CUSAT and specialised in engineering and management, Mr. M.K. Sukumaran Nair, professor at the Applied Economics faculty from CUSAT and Mr. Gopikrishnan, a former student from ISP and currently working in the industry (Nanowave Technologies Ltd.) have all contributed to the improvement of the questionnaire.

Tab. 2: Operationalisation of the "Firms Willingness"

Concept	*Dimension*	*Variable*	*Measuring Instrument*[1]
Firms willingness to invest in and implement the photonics technology	Characteristics of the innovative photonics technology	• Technologically advancement of the optical solutions • Price of the optical solutions • Simplicity of the optical solutions • Competitiveness of the optical solutions with other (foreign) technology • Current projects • Past projects • Benefits of these projects • Adaptability • Appropriateness	• P. 2 Q. 13 to 20 (II) • P. 2 Q. 21 to 28 (II) • P. 2 Q. 29 to 36 (II) • P. 2 Q. 10, 11, 12 (II) • P. 1 Q. 10 to 15 (II & DR) • P. 1 Q. 16 to 21 (II & DR) • DR • DR • DR

	Characteristics of the firms	• Branch of the company
		• Small scale, medium scale, large scale industry
		• Network of the firm
		  o When founded?
		  o How many suppliers?
		  o How many customers?
		  o Kind of customers?
		• Financial surplus available to invest
		• Number of people that are contracted at firm
		• Number of them that had schooling
		• Degree of the schooling
		• Presence of a R&D department
		• Number of people that work at the R&D department
		• Number of people that had a certain degree of schooling in he R&D department
		• Purpose of the R&D department
		• Where does the manufacturing equipment come from (India or outside, own firm or other)
		• General infrastructure of the firm
		• Organisation of the firm
		• Attitude of the firm towards photonics technology
		• Attitude of the firm towards ISP (CUSAT)
			• P. 2 Q. 4 to 9 (MS)
			• P. 2 Q. 10 (MS)
			• P. 2 Q. 2 (MS)
			• P. 2 Q. 15 P. 3.2 Q. 12 (MS)
			• P. 2 Q. 14 (MS)
			• P. 2 Q. 13 (MS)
			• P. 4 Q. 5 (MS & DR)
			• P. 2 Q. 17, 18, 19, 20, 21 (MS)
			• P. 2 Q. 22 to 27 (MS)
			• P. 2 Q. 22 to 27 (MS)
			• P. 2 Q. 28 (MS)
			• P. 2 Q. 30, 31, 32 (MS)
			• P. 2 Q. 33 (MS)
			• P. 2 Q. 29 (MS)
			• P. 3.2 Q. 12 (MS)
			• O.
			• O.
			• P. 3.1 Q. 2, 3, 4, 5 (MS)
			• P. 4 Q. 1, 2, 3, 4, 5, 6, 7 (MS)

	Technological Capability ISP	• Financial surplus of ISP • Number of people working at ISP • Number of people capable for the transfer of knowledge process • Infrastructure of ISP • Organisation of ISP • Goal ISP (how they observe the future) • Time professors • Policy CUSAT industry interaction	• P. 2 Q. 42 (II) • P. 1 Q. 25 to 32 P. 2 Q. 1 (II) • P. 2 Q. 2 (II) • O. • O. • P. 2 Q. 3 (II) • O. • P. 3 Q. 15 (II)
	Active attitude of ISP toward firms	• General interest creating instruments used • Specific interest creating instruments used • General instruments of persuasion used • Specific instruments of persuasion used • Cooperation with other departments • Number of people willing to transfer	• P. 4 Q. 1 to 11 (II) • P. 4 Q. 1 to 11 (II) • P. 4 Q. 15, 16, 17, 18 (II) • P. 4 Q. 15, 16, 17, 18 (II) • P. 3 Q. 9, 10, 11, 12, (II) • P. 2 Q. 4, 5 P. 3 Q. 15 (II)
	Environmental constraints	• Government influence • Competition with other institutions (foreign or local) • Factor Conditions • Wider Demand structure • Infrastructure country	• P. 3 Q. 3, 13, 14, 15 (II) • P. 2 Q. 10, 11, 12 (II) • DR • DR • O.

[1.] MS = Market Study; O = Observation; P. = Part; Q. = Question; II. = ISP Interviews; DR.= Desk Research

§ 3.2.2 Practical problems during the research

During the research some adjustments to the initial research approach had to be made because of some practical problems. Initially it was the idea that data from the firms would be collected by means of a survey. However, this idea was rejected after talks with different professors and scholars. Apparently if a company receives a questionnaire it is not likely that they would send it back, so every questionnaire had to be collected from the companies.

Also, a research framework was unavailable. There was no list of companies that could be used for selecting the companies randomly. So, the results of this research are not to be generalised with the overall population of companies in Kerala. This fact was no problem however, because the goal of the research was not to get general data on all the companies in Kerala, but to get to know the companies that are able to adopt the technology from ISP. Because the nature of this technology is very specialised, small-scale industries that do not use any machinery in their production process have not been included in this research. According to two key informants (Dr. M.K. Sukumaran Nair, applied economics and Mr. K.P.S. Nair, Engineering college), the companies that are listed in Appendix B are most of the major medium-large scale companies within Kerala that can use photonics technology.

Because of the attack on the parliament in Delhi on 11 December 2001, restrictions were made against foreigners. When a foreigner wants to visit a government company, he has to have a clearance with the general manager most of the time and this can only be received after requesting by form a letter from the director of ISP (or in some cases a letter from the Vice-Chancellor of CUSAT) directed to the manager. So, needless to say that this was a time-consuming business. Initially it was the idea also to visit companies outside of Kerala. But because of the difficulty of getting permission and the time that was available for performing the research this idea was eventually abandoned. However, as was stated earlier, the strength of ISP lies in its location. Companies that are outside Kerala that were known to the key informants were using Photonics technology, which is probably provided by institutes that have the know-how. This means competition for ISP. So interviewing different companies outside Kerala would probably have not given much more possibilities for interaction anyway.

Managers and general managers of the different companies mostly answered the Questionnaires that were given to them. Sometimes engineers were given the questionnaires, because they knew the most about the technical aspects of the production processes.

Chapter 4: Results

This chapter states the results that were conceived from the market study and the interviews conducted at the International School of Photonics. These results should enable us in answering the different research questions that were given in Chapter 1 of this report.

§ 4.1 The Market Study

§ 4.1.1 The visited firms

The market study was conducted with the list of companies stated in Appendix B. Only the companies within Kerala were visited due to lack of time within the research. Also, because of the attack on the Indian parliament in Delhi on 11 December 2001, it became harder for foreigners to visit firms, especially firms that have any linkages with the central government. This is why 7 of the 31 companies listed in appendix B were not implied to give permission for visiting the firm at all. Some of the companies only wanted to fill up the questionnaire, without a visit to the production plant. 3 companies were not visited at all due to lack of time. These companies were not supposed to have a large need for photonics. They were on the low-priority scale.

The following companies have been visited.

Tab. 3: Visited Companies

Number	*Company*	*Observation*	*Questionnaire*
1	Nest Power Electronics Pvt. Ltd (Nest Group)	No	Yes
2	Sun Fibre Optics (P) Ltd. (Nest Group)	No	Yes
3	Nest R&D Centre (Nest Group)	No	Yes
4	Swiftlink Pvt. Ltd. (Nest Group)	No	Yes
5	Nest Cyber Campus (Nest Group)	No	Yes
6	Nest Group	No	Yes
7	Nortpak Fibre Optics (P) Ltd. (Nest Group)	No	Yes
8	SABA Powerdex Pvt. Ltd. (Nest Group)	No	Yes
9	Apollo Tyres Ltd.	Yes	Yes
10	Indian Aluminium Company Ltd., Extrusion Division	Yes	Yes
11	Indian Aluminium Company Ltd., Smelter Division	No	Yes
12	Holmarc Slides and Controls (p) Ltd	Yes	Yes
13	Hindustan Latex Ltd.	Yes	Yes
14	Carborandam United Ltd	Yes	Yes
15	Futura Medical Products (P) Ltd.	Yes	Yes
16	TATA Tetlay	Yes	Yes
17	Hindustan Insecticides Ltd	No	Yes
18	Binani Zinc. Ltd.	Yes	Yes
19	KMML	No	Yes
20	OEN Ltd.	Yes	Yes
21	Hindustan Machine Tools Ltd.	Yes	Yes

The first nine companies all belong to a group called "Nest". This group collaborates with companies in the USA who produce, amongst other products, fibre optic sensors. They are located in a "Special Export Zone", where they are not bothered by power cuts and where they get subsidised by the government of Kerala (for more information see Appendix G). Here different intermediate inputs are imported from the USA and are assembled and returned for selling. Only assembly is done here, because of the low price of labour. They also have an R&D centre and they have a lot of knowledge about photonics. The pre-test for the questionnaire was done in these companies.

Because of their location 9 companies could be used in the pre-test, therefore getting as much feedback as possible.
The data that was gathered by the questionnaire in the first time was still used in the further analysis, wherever that was possible. It became clear after the first 9 companies that observation was necessary to complement the data collected from the questionnaire. Sometimes the companies would not give permission to visit the plant and therefore no observation was performed. Table 3 also shows which companies were observed.
The following firms did not give back the questionnaire or were not visited at all:

Tab. 4: Companies that were not visited or didn't return the questionnaire

Number	*Company*	*Given Questionnaire*	*Returned Questionnaire*
1	Connectors Ltd. (OEN)	No	No
2	Crysand	Yes	No
3	FACT	Yes	No
4	Hindustan Lever Ltd	Yes	No
5	Hindustan News Print Ltd	No	No
6	Hindustan Organic Chemicals	Yes	No
7	Kerala Argromachinery Corporation	Yes	No
8	Kochi Refineries Ltd	Yes	No
9	Malayala Manorama	No	No
10	Milma	No	No
11	Naval Physical Oceanographic Laboratory	Yes	No
12	TATA TETLAY, Munar	No	No
13	TELK	Yes	No

So there were 8 companies that were given a questionnaire and that didn't return it. This means that with the extra 22 returned questionnaires a total of 30 questionnaires were distributed of which 22 returned (after picking up). The 8 companies were all companies that did not give permission to come and said they would sent the questionnaire back themselves. Obviously, the decision in the beginning of this research to visit the companies in person rather than perform a survey by post was a good one. The non-response would probably be very high. Now, the non-response in the market study is 27 % (8 questionnaires out of 30).

§ 4.1.2 Results from the market study

The data collected from the questionnaires has been analysed using descriptive statistics. The questionnaire concerns technical as well as non-technical data. For comparing different companies on technical aspects a score was given to each company based on the answers to the questionnaire. The score is a number between 0-10. 0 means no photonics application at all and 10 means a lot of photonics technology is used or can be used (for more information see paragraph 4.1.2.2).

§ 4.1.2.1 Non-Technical data

Characteristics of the companies (see also Fig 8. of the research model):
The respondents were also asked if the company had any relationship with a university or other R&D institutes to assess the situation and to get more insight in the constraints that were obstructing the transferring of technology process (Part 4, Question 1, 2, 3 Market Study).

Tab. 5: Relationship with an R&D institute/university? (P. 4 Q 1, 2, 3 MS)

	Number	*Percentage [%]*
Yes	8	36.36
No	13	59.09
Don't know	1	4.55
Total respondents	22	100

As can be seen in Tab. 5, 59 % of the questioned companies have no relationship with any institute like CUSAT or an R&D institute. The reasons given for the fact that there are no relationships are diverse. Most of the firms said that either they hadn't seen the need for initiating such a relationship or that the university did not initiate such a relationship. Another reason might be the fact that the companies have never heard of the International School of Photonics and its research projects. ISP is but a small faculty of a comparatively small university. It is for this reason that PR-work is very important for getting firms interested in the products of ISP (See the so-called interest creation instruments in Chapter 2.5.2, Selection of Firms). In most cases, the company has its own R&D facility. In some of these cases the company has all the knowledge it needs within this facility.

Tab. 6: Does the company have an R&D department? (P. 2 Q. 28 MS)

R&D Dept. Available?	*Number*	*Percentage [%]*
Yes	16	72.73
No	6	27.27
Total respondents	22	100

Tab. 7: The primary function of the R&D department (P. 2 Q. 29 MS)

Function R&D	*Number*	*Percentage [%]*
New product and process development	13	59.09
Research and development	1	4.55
Trouble-shooting, technical support	2	9.09
Blank	4	18.18
Not Applicable	2	9.09
Total respondents	22	100

Tab. 6 and Tab. 7 show that from the 22 respondents 72.73 % says that there is an R&D department present in the company and that most of these departments have, as a primary function within the company, "new product and process development". However, from the observations done at the companies, it became clear that most of these R&D departments don't have the technical capacity for adapting the photonics technology. Adapting fibre optic sensors for example needs advanced equipment for cutting and splicing (joining of two fibres) the sensors. This cannot be done by hand and this equipment is pretty expensive.

Tab. 8: The education level within the R&D department (P. 2 Q. 33 MS)

	SSLC	*Pre-degree*	*ITI*	*B.Sc.*	*Diploma*	*B. Tech.*	*M.Sc.*	*M. Tech*	*Doctorate*	*Other, namely*
Nest Power Electronics Pvt. Ltd (Nest Group)	all	all	0	0	10	20	0	2	0	0
Sun Fibre Optics (P) Ltd. (Nest Group)	0	0	5	0	5	48	0	1	1	0
Nest R&D Centre (Nest Group)		1	3		7	30		20	1	
Swiftlink Pvt. Ltd. (Nest Group)										
Nest Cyber Campus (Nest Group)	0	0	0	5	0	5	0	0	0	0
Nest Group										
Nortpak Fibre Optics (P) Ltd. (Nest Group)										
SABA Powerdex Pvt. Ltd. (Nest Group)										
Apollo Tyres Ltd.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Indian Aluminium Company Ltd., Extrusion Division										
Indian Aluminium Company Ltd., Smelter Division	0	0	2	2	5	4	1	1	0	0
Holmarc Slides and Controls (p) Ltd	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

	SSLC	Pre-degree	ITI	B.Sc.	Diploma	B. Tech.	M.Sc.	M. Tech	Doctorate	Other, namely
Hindustan Latex Ltd.				3	2		2			
Carborandam United Ltd				1		2				
Futura Medical Products (P) Ltd.										
TATA Tetlay										
Hindustan Insecticides Ltd	2			5			3		2	
Binani Zinc. Ltd.	4			4		3	6	1	2	
KMML							4			
OEN Ltd.			10		2	4				
Hindustan Machine Tools Ltd.	4	0	8	0	10	10	0	8	0	

Tab. 8 shows the distribution of level of education of the workers of the different R&D departments of the different companies. It gives an indication of the education of the workers to which the technology should be transferred. A number of companies did not fill in this question (blank lines in the table).

Tab. 9: The highest level of education at the R&D departments

Highest level education R&D department	*Number*	*Percentage [%]*
SSLC	0	0
Pre-degree	0	0
ITI	0	0
B.Sc.	0	0
Diploma	0	0
B. Tech.	3	13.64
M.Sc.	3	13.64
M. Tech.	3	13.64
PhD.	4	18.18
Other, namely	0	0
Blank/N.A.	9	40.91
Total respondents	22	100

The table above shows that there are companies that have people with a high level of education working within the R&D department. Unfortunately, 40.91% of all the respondents either did not fill in the question or the question was not applicable to them. The data gathered from this question is not very reliable because of the high non-response to this question. The question was difficult to answer and therefore the answers should be taken as an indication and nothing more. However, it shows that the knowledge level at the companies is not per definition too low, as was commented by some of the professors at ISP in the early stages of this research (also see Tab. 8). The companies can be educated to use photonics applications.

In another question, the respondents were asked to characterise their production process:

Tab. 10: Characterisation of the production process (1) (P. 2 Q. 3 MS)

Production Process	*Number*	*Percentage [%]*
Product making	16	80
Service providing	2	10
Both	2	10
Total respondents	20[1]	100

80 % of the companies are product-making companies. The companies were not selected on their production process in the beginning of the research, because the researcher did not have any knowledge on the companies other than their names. However, the companies have been selected by key-persons at the university. This would give a bias for generalisation. Generalisation is not possible with this data anyhow, because the absence of a research framework and the low number of respondents. Service lending

companies are not likely to have any need for photonics technology. But 80 percent of the companies are product-making companies, so this is not a problem.

Tab. 11: Characterisation of the production process (2) (P. 3.2 Q. 1 MS)

Production process	*Number*	*Percentage [%]*
Labour intensive	10	45.45
Capital intensive	11	50.00
Both	1	4.55
Total respondents	22	100

Tab. 12: Characterisation of the production process (3) (P. 3.2 Q. 3 MS)

Production Process	*Number*	*Percentage [%]*
Chemical	6	27.27
Construction	0	0
Assembly	8	36.36
Extrusion	1	4.55
Chemical and assembly	1	4.55
Design and assembly	1	4.55
Mechanical and assembly	1	4.55
Packaging	1	4.55
Manufacture and assembly	1	4.55
Fusion	1	4.55
N.A.	1	4.55
Total respondents	22	100

12 out of 22 companies are involved in some kind of assembly process. This is 54.55% of the total number of respondents. 31.82% of the respondents however, have some kind of chemical process. Photonics applications have few applications in assembly processes, especially if they are labour intensive assembly processes, but in chemical production processes photonics technologies are very much so applicable.

With fibre optic sensors one could measure all kinds of fluids, gases and displacements. There is one device that the International School of Photonics has made that is called the glucose-meter. It uses a laser to measure glucose in a given material, such as urine, by measuring the refractive index of the material. In another project fibre optic sensors were designed for measuring ammonia and other gases. These kinds of applications are very usable in a chemical production process.

The financial status of the companies could not be assessed from the data from the questionnaire. Only two companies would give an indication of the amount of money that they were willing to invest in collaboration projects. Most of the companies indicated that the investment was based on the specific project. This should than be discussed with the personnel from ISP in a later stage, when concrete projects have been established. From the environment that the companies work in it is clear however that the amount of money that they are able to spend is not very high. India still is a developing economy and the economy of Kerala is currently in a recession (see appendix H). The highest amount that was given was 1 Lac Rs (100000 Rs = about 2300 Euro). This money is not enough to sustain the total research program of ISP, but it can be used for maintenance and so-called infrastructural funds. However, the projects all have to be assessed in a commercial way by the staff of ISP. In other words, the revenues of the project should not be lower than the actual costs of the project. A so-called feasibility study should provide the proper assessment for this.

[1] There are only 20 companies and there are 22 respondents, because in some of the companies the questionnaires given to more than 1 respondent. This factor has been taken into account with the data analysis.

Willingness of the companies (also see Table 2):
A question was asked whether the company would be willing to invest in collaboration projects with the International School of Photonics. The following table shows that 41% of the respondents are willing to invest in collaboration projects:

Tab. 13: Willingness to invest in collaboration projects (P. 4 Q. 4 MS)

	Number	*Percentage [%]*
Yes	9	40.91
No	8	36.36
Maybe	1	4.55
Blank	4	18.18
Total respondents	22	100

It was expected that most of the companies would never have heard of ISP and photonics applications. This could be a reason why there was no initiation for contact from the side of the companies. The following tables show that most of the companies has never heard of the International School of Photonics or photonics applications.

Tab. 14: Has the respondent ever heard from ISP? (P. 3.1 Q. 1 MS)

	Number	*Percentage [%]*
Yes	10	45.45
No	12	54.55
Total respondents	22	100

Tab. 15: Is the respondent aware of photonics applications? (P. 3.1 Q. 2 MS)

	Number	*Percentage [%]*
Yes	7	31.82
No	15	68.18
Total respondents	22	100

When the respondent was asked if the applications could enhance the company's production process, most of them answered affirmatively. This is remarkable, because 68 % of the respondents did not even know the applications of photonics. But at the least this shows that the companies are positively stemmed towards photonics applications.

Tab. 16: Can Photonics enhance the production process of the company? (P. 3.1 Q. 3, 4, 5 MS)

	Number	*Percentage [%]*
Yes	14	63.64
No	1	4.55
Don't know	7	31.82
Total respondents	22	100

Furthermore, the respondent was asked if the company would be interested in producing products from ISP. Because of the high figure of respondents that said yes, a bias is expected in this question. It could be that the respondent thought that the question was "Are you interested in products from ISP?". In any case, most of the companies are interested in (producing) products from ISP.

Tab. 17: Is interested in producing products from ISP? (P. 3.1 Q. 6, 7 MS)

	Number	*Percentage [%]*
Yes	15	68.18
No	3	13.64
Don't know	1	4.55
Not applicable	2	9.09
Blank	1	4.55
Total respondents	22	100

Also, several companies are interested in getting free consultancy. ISP should contact the firms that asked for free consultancy that have the biggest potential for collaboration projects. A list of the companies is given in Appendix F. In the list a priority is also given to the companies that wanted consultancy. High priority should be contacted within 6 months after the end of this project, as soon as possible. Middle priority should be contacted within a year after the end of this project. Low priority can be contacted in the long run.

Tab. 18: Does the respondent want free consultancy? (P. 4 Q. 7 MS)

	Number	*Percentage [%]*
Yes	13	59.09
No	4	18.18
Blank	5	22.73
Total respondents	22	100

§ 4.1.2.2 Technical Data

A tool was needed to assess the technical "need" for photonics within the different companies. The question was how to compare the different companies on their different needs. A score was given to them on a scale from 0 to 10. 0 means that the company has no need for photonics application and 10 means a perfect score. Points were given based on the answers in the questionnaire. If the company used lasers, fibre optic sensors, semiconductors or lenses within their production process, it was assumed that there would be more need for an application. If there were no machines using lasers, fibre optic sensors, semiconductors or lenses, the question was asked if it would be possible to use lasers, fibre optic sensors, semiconductors or lenses. If these questions were answered affirmative then a point would be given. It could also be possible that the applications would be used in the monitoring and controlling of the production process. Then the point system was the same. Whenever lasers, fibre optic sensors, semiconductors or lenses were used a point was given and if they were not used but the respondent thought that they could be used also a point was given. When the company was interested not in applications but in the producing products from ISP, points were also given. And when the production process was capital intensive a point was given as well. It is believed that a capital-intensive production process has more need for photonics than a labour-intensive production process.

All these points were given to every company and recalculated to a point between 0 and 10. This tool is a very rough tool and should be used as such. The point is just to give an idea about which company has a lot of application and therefore should prove a good counterpart in a collaboration projects. These points were used in appendix F to give a priority to the companies, which should be contacted first.

Tab. 19 gives the different scores that the different companies got. For every category (lasers, fibre optic sensors, semiconductors, lenses and rest) also a specific score is given. – Means no applications at all and ++++ means a perfect score. ISP has expertise in Lasers and in Fibre Optic Sensors (F.O.S.) and thus when a company uses photonics technology by using semiconductor technology the knowledge from ISP is not very relevant. This is why the "ISP Score" is given. This is the score that is actually relevant for ISP. The category "Rest" in this table contains the question if the company would like to produce products from ISP, whether the company uses light-based measurement equipments and whether the production process is capital intensive or labour intensive. If the company has a high score and this results from high points in the laser and fibre optic sensors category, the company is a good match for ISP.

Tab. 19: The Photonics needs of the different companies (Based on Part 3.2 and Part 3.3 of MS)

No.	Company name	General Score	ISP Score	Lasers	F.o.s.	Semic.	Lenses	Rest
1	Nest Power Electronics Pvt. Ltd.	3.41	3	–	+	–	–	++
2	Sun Fibre Optics (P) Ltd.	5.45	4,1	+	+	+	+	+
3	Nest R&D Centre	*6.36*	*5*	–	–	–	–	+
4	Swiftlink Pvt. Ltd.	*10*	*6,4*	–	–	–	–	+
5	Nest Cyber Campus	0.00	0	–	–	–	–	–
6	Nest Group	2.73	2	–	–	+	–	+++
7	Nortpak Fibre Optics (P) Ltd.	2.5	2,3	–	–	–	–	+++
8	SABA Powerdex Pvt. Ltd.	*8.64*	*5,5*	+	+	+	–	+
9	Apollo Tyres Ltd.	*6.82*	*3,2*	–	–	+	+	++
10	Indian Aluminium Company, Extrusion division	2.95	0,9	–	–	+	+	+
11	Indian Aluminium Company Ltd.	3.64	1,8	+	–	++	–	+
12	Indian Aluminium Company Ltd.	2.95	1,8	–	–	+	–	+++
13	Holmarc	0.91	0,9	–	–	–	–	++++
14	Hindustan Latex Ltd.	2.73	1,8	+	–	+	–	+
15	Carborandam United Ltd.	1.82	0	–	–	++	++	–
16	Futura Medical Products (P) Ltd.	5	2,7	–	–	+	+	+
17	TATA Tetlay	4.55	4,6	+	+	–	+	+++
18	Hindustan Insecticides Ltd.	2.73	1,8	–	–	+	–	+++
19	Binani Zinc. Ltd.	*6.36*	*4,6*	+	–	–	–	+
20	KMML	*7.27*	*5*	–	–	–	–	+
21	OEN	5.23	3,6	–	–	–	–	+
22	HMT	4.09	3	–	+	+	–	++
	Average	6.01	5	–	–	+	–	++

The following companies would thus be interesting for ISP collaboration:

1. Nest R&D Centre
2. Swiftlink Pvt. Ltd.
3. SABA Powerdex Pvt. Ltd.
4. Appollo Tyres Ltd.
5. Binani Zinc. Ltd.
6. KMML

A small description of the companies that were named above is provided in appendix G. *These companies are also selected based on the expectations of the researcher.* It is clear from Tab. 19 that the applications in the companies are very small in most of the companies.

The following table shows how many companies have what kind of score.

Tab. 20: Number of companies that have a certain score

ISP Score	Number of companies
0-1	4
1-2	5
2-3	4
3-4	2
4-5	5
5-6	1
6-7	1
7-8	0
8-9	0
9-10	0
Total	22

From Tab. 20 it is clear that most of the companies (20) can only use the applications of ISP in a very small way. This is not very surprising considering the kind of technology that photonics is. It is very capital intensive and it will require a lot of knowledge and skill for using such a technology. The adaptation of the technology from the ISP environment to the actual working environment of the application is therefore a very large one. It will take a lot of effort to adapt the research of ISP to the environment of the company. But there are companies that can use the technology in a large way. The low number of companies that could use the technology only constraints the sustainability of the research program through commercialisation even more. This is yet another reason that the entire research program of ISP cannot be sustained through commercialisation processes.

§ 4.2 The ISP Interviews

§ 4.2.1 Practical issues

The five staff members of ISP were interviewed by means of a structured questionnaire to get information about the constraints concerning the technology transfer processes, the technical capability of ISP and other relevant variables. The operationalisation done in § 3.2 in this document was used in the formulation of the questionnaire. The questionnaire has been made in consultation with Mr. Szirmai from the faculty of Technology Management, from the Eindhoven University of Technology. The questionnaire as used has been given in appendix C of this report. There was no non-response in this case. The questionnaire was first filled up by the respondent and than a follow-up interview was done to clarify the answers that were given.

§ 4.2.2 Results

Because there were so little respondents (5) is this case descriptive statistics were used to get structured results.

The projects that were commercialised at ISP:
From the interviews it became clear that only one of the projects was commercialised in a company. This was done in a very informal way at Holmarc.

Holmarc is a company that makes opto-mechanical devices for research in optics and in photonics. The Managing Director Mr. Jolly Cyriac founded this company in 1993. They have produced a so-called “education kit” for optics, lasers and fibre optic sensors, with the help of the professors from ISP. The education kit consists of a base plate on top of which optical fibres can be mounted as well as lasers so that various experiments can be executed for educational purposes. Holmarc sells its products to other industries and final consumers and they have about 200 customers. Holmarc has about 30 people employed off which 22 is technical staff, 2 are administrative staff and 2 are managing staff. Most of the employees are ITI degree (16) or Diploma (4) degree holders. The highest level of education in Holmarc is M. Tech. (1 employee). They do not have an R&D department available. Holmarc does not use photonics within their production process but they are willing to produce products from ISP, as they did with the education kit.

Interesting is that although Holmarc scores very low on the photonics needs scale (0.91, see Tab. 19) commercialisation has been achieved. So the scores that were given to the companies are mere guidelines for the technical part of the process. A lot of other variables influence the commercialisation process and in that way all the companies can be potential "customers". It is just that the ones with a higher score on the scale are probably easier to persuade to invest in collaboration projects.

Technological Capability of ISP (see Fig. 7 and Tab. 2):

All the staff members think that photonics can be applicable in industries in Kerala as well as outside Kerala (P. 2 Q. 6, 7, 8, 9 II). 3 out of 5 staff members think that the competition in the photonics field is very high (P. 2 Q. 10 II), but 4 out 5 staff members think that ISP can compete in certain areas like fabrication of photo acoustic cells and fibre optic sensors (P. 2 Q. 11, 12 II).

Tab. 21: Is ISP capable to create technologically advanced products? (P. 2 Q. 13 to 20 II)

Capable of creating technologically advanced products in the field of:	*Answer*	*Respondents*
Lasers?	Yes	3
	No	2
	Total	5
Fibre optic sensors?	Yes	3
	No	2
	Total	5
Semiconductors?	Yes	0
	No	5
	Total	5
Lenses?	Yes	1
	No	4
	Total	5

As Tab. 21 shows, 3 out of 5 staff members think that they can create technologically advanced products in the fields of lasers and fibre optic sensors. In the field of semiconductors and lenses they cannot, because they are not working on these fields at the moment.

Tab. 22: Is ISP capable to create price competitive products? (P. 2 Q. 21 to 28 II)

Capable of creating price competitive products in the field of:	*Answer*	*Respondents*
Lasers?	Yes	2
	No	3
	Total	5
Fibre optic sensors?	Yes	1
	No	4
	Total	5
Semiconductors?	Yes	1
	No	4
	Total	5
Lenses?	Yes	1
	No	4
	Total	5

Tab. 22 shows that the staff members are not at all convinced that ISP is able to create price competitive products at all. Not on a global scale anyway.

The main goal of ISP is not to be price competitive but to give good education and manpower training. Their research projects can only be applicable with people that do not really know about photonics because the people that do know can easily go to more advanced and cheaper players in the world market.

Tab. 23: Is ISP capable to create easy to use products? (P. 2 Q. 29 to 36 II)

Capable of creating easy to use products in the field of:	*Answer*	*Respondents*
Lasers?	Yes	4
	No	1
	Total	5
Fibre optic sensors?	Yes	5
	No	0
	Total	5
Semiconductors?	Yes	1
	No	4
	Total	5
Lenses?	Yes	1
	No	4
	Total	5

Tab. 23 shows that the staff members of ISP believe that they can make easy to use products in the fields of lasers and fibre optics sensors. There has been a prototype created of a glucose meter that uses a laser to measure the glucose level in urine and other liquids. This is a good example of a very marketable product. It has been said that this product has not been marketed because ISP did not see the need to do so. In the field of semiconductors and lenses they cannot.

All of the staff members think that the project with the greatest commercial potential is a project with Fibre Optic Sensors (P. 2 Q 37 II). This would be concurred by the data from Tab. 21, Tab. 22 and Tab. 23. There have been 3 projects undertaken, of which the last, under AICTE (All India Council for Technical Education), is still running. Mr. P. Radhakrishnan is the Principal Investigator of the current AICTE project. The aim of this project is to design and develop a range of intensity modulated and interferometric type sensors, which will be employed for monitoring pollutant gases and contaminants in groundwater. More on the principles of this sensor will be explained in appendix I.

Active attitude of ISP towards firms (See Fig. 8 and Tab. 2):

4 out of the five staff members that were interviewed find it useful that their projects would be commercialised. Although the commercialisation cannot sustain the whole ISP research program and the applications within the industry is very minimal, every project helps to raise funds (P. 2 Q. 4 II).

All the staff members think that ISP should seek contact with the companies and 4 out 5 staff members think that ISP should invest in collaboration projects with the industry (P. 2 Q. 38, 39, 40, 41 II). The fact is however that there is no budget for these investments within ISP or within the university (P. 2 Q. 42 II). The government also doesn't stimulate the university to seek contact with industries (P. 3 Q. 13 II). Basically this is the core of the problem. There is no history of transferring technology from universities to industries. The university is a government institution and the industries are private institutions with deadlines, budgets, turnovers etc. There is a big gap in the attitude of the university, where time doesn't really matters and where strikes are often and common, and the attitudes of the industry where time is money an deadlines have to be made. There are some informal cases in India where there is an interaction present, but in most cases there is nothing of the sort. Attitude building is a long-time and very hard process, which involves education and stimulation of all the parties involved and cannot be achieved within the small period of time in which this research was performed. Therefore, this falls out of the scope of this research as far as solving the problem. Identifying however is as important as solving a problem and that was the main focus of this project.

The Environmental Constraints, Explanations for the lack of Industry-Institution Interaction:

The staff members of ISP for suggested several explanations for the lack of Industry-Institution Interaction:

1. *There is a lack of photonics based industry in Kerala.* It is true that there is not much advanced industry in the state of Kerala. The data that was collected in the market study confirms that photonics applications are small within most of the companies in Kerala. There are however companies that use the technology. The reason for this should not be sought in the lack of industry in Kerala in the opinion of the researcher, but more in the basic properties of the technology. Photonics is not a technology that is used on a very wide scale or it is used on a very broad scale depending on how one defines photonics technology. LEDs and Lasers are frequently used in almost every piece of electrical equipment. Some professors at the faculty defined photonics in a way that it was used in almost everything. These machines are however electrical in nature and the electrical components used in them are most of the time not very new. It is the nature of the research that is done at ISP that it is not used in widely. “Propagations of light within a certain material” hasn’t got that many applications and it needs a lot of adaptation until it can be used in an industrial application.
2. *Lack of exposure of ISP products to industry outside Kerala.* This is probably true. The companies outside Kerala would not know ISP and its products. This can also be said for the companies within Kerala as was proven in from the market study. Investing in PR-work can solve this fact and within the MHO project there has been made a budget for this already. ISP has made some folders but they haven’t been very recent and these folders are mainly spread among academics. They should give specific folders to specific parts of the industry. There should also be an easy to reach Internet site, which is updated regularly and has information that would interest the industry. There was a site under construction during the time of this research. ISP organises every once a year a seminar on photonics and provides workshops. This should be the main attraction for the industry according to some of the staff members, however, the industry is not approached and only academics show up. Most of the companies do not have time to send somebody away for a whole week to attend to a seminar and they are not interested in the presentation given. This general interest creation instrument isn’t very appropriate for getting the industry interested. Possibly, a good Internet site and folders that people can request through the Internet would be more effective. This was demonstrated during one of the visits in the market study, where an engineer got to know about a machine that they could use on the Internet and where he had gotten some folders on. The company was now on the verge of purchasing that machine. The university and ISP also uses media whenever there is a seminar and such, but this would probably provide only minor exposure and people tend to forget the news very quickly. So the Internet site in combination with folders is the best option. A key person from ISP should also visit the companies as has been done with the market study in this research. This because there is no history of industry-institution interaction and the university should take the first step but they don not really know how. This has been done now, and there should be a follow-up where the staff from ISP takes initiative and goes to the companies that have requested free consultation. This is the list of companies that is provided on appendix F.
3. *Lack of Industry-Institution Interaction in India per se.* This problem has been addressed in the foregoing part of this report. This is the core of the problem and is not easily solved. It is something that is embedded within the culture of India. Maybe, 50 years from now, things are different for the Netherlands themselves didn’t have much industry-institution interaction 50 years ago.
4. *Lack of proper equipment at ISP.* ISP is a small faculty at a small university and is not capable of producing en masse fibre optics or lasers. So price competitiveness is very hard for them. They have got proper labs that the industry could use for calibration of their machines. Also, for the creation of large numbers or even the installation and practical side of a collaboration project, third parties can also be involved as intermediaries. Holmarc and Nanowave Technologies can be assisting companies for the practical side of the project, while ISP gives consultancy and acts as supervisor of the project.
5. *The research projects of ISP are not industry orientated.* This is probably true but it has its deep-rooted reasons within the fact that there is no real history and therefore attitude for industry-institution interaction. But their projects could be changed and new projects can be undertaken with more eye to the problems of the industry. Most of the applications of photonics in the industry are in

the monitoring and controlling of their production processes. Fibre optic sensors would, in these applications, be the most suitable of possible technical solutions. They can be used to measure temperature, pressure, and chemicals like ammonia, displacements, in short everything that has a spectrum. One possible research project in the future would be using fibre optics sensors to detect ammonia in Binani Zinc Ltd and with Hindustan Latex. They use ammonia and that could be a hazardous chemical for the employees. A system wit fibre optics sensors could provide more safety for the employees. A fact is also that application of research is in some cases far more difficult than the basic research that is currently done at ISP. Problems like environmental distortions and mechanical and electrical installation are to be addressed and have been proven to be very tricky in projects that were done in Europe in the past. Also when the research has more industrial and practical focus than that will also help the students of ISP to understand why they need to know the basics and in what ways their knowledge could be applicable.

6. *The Industry is not interested in ISP and its products*. This is in fact untrue, but given as a reason by the staff members. The data that was collected in the market study shows that the industry is in fact very much interested in ISP and its products, if and when these products are economically feasible. The products have to have some revenues otherwise the industry is not interested. This is the attitude of the industry. The advantages of the products of ISP lie in the fact that by using fibre optic sensors or lasers to control the production process in the production process can be made more efficient and more accurate. Thus improving the process the quality of the products is improved or the number of products that can be made is higher and so getting more revenue in the company. It is therefore not very easy to say what the revenue should be when applying some kind of photonics technology. This depends on the current production process and when it was up-dated. Most of the companies in Kerala were founded in the 60s and the 70s and they haven't upgraded their production process until it was absolutely necessary. Most of the companies lack outlook for the future and are reluctant to improve their production process when they are making money. But it is still believed by three out of five staff members that some companies can be persuaded to invest in collaboration projects with ISP when they see that it can be beneficial for them. All the staff members think that free consultancy and the use of key-figures within the company would be the most efficient way of doing this. One other example is OEN where they make connectors. They would like to fabricate a new connector, which uses some kind of photoelectric technology. They do not know how to proceed on this however. ISP could give some consultancy in this matter on how they can manufacture this connector and what would be needed for it.
7. *Lack of knowledge about the industry at ISP.* This is only partially true. There is a lot of knowledge with the staff members on what kind of industry there is in Kerala. Only they do not see the application happening with companies that have no relation whatsoever with photonics. The professors are only interested in companies that are photonics based. They should change this attitude and be open-minded about projects that can be done with companies like Binani Zinc Ltd, OEN, Hindustan Latex as well. Appendices B and F provide the names and addresses of most of the important companies within Kerala.
8. *Not enough people for undertaking projects.* The staff members are under somewhat harsh working pressure as it is. One staff member will retire in a few months and most of the professors have side duties besides the teaching jobs. One job is the job of technician that has been done by Mr Girija Vallabhan, the retiring staff member. There has been a vacancy for this job for five years and every time, because of the bureaucracy in the university, this vacancy is still open. There is money within the MHO project allocated to train this person in the Technical University Eindhoven but still there is nothing moving within the university mill. A technician would also be beneficial in a collaboration project with the industry. Otherwise, a third party would have to be involved for the installation and practical parts of the project. This third party could be a third company like Holmarc or the just starting Nanowave Technologies from Mr. Gopikrishnan.
9. *ISP is too young.* It is a fact that ISP is only started in 1996 and therefore has a long way to go. ISP is doing very well within the constrictions that are put upon them by the university and the society. The relation between ISP and the industry will have to grow and that will take time. Also, time is needed to adjust the research program and the attitude of the university.

The following table shows the constraints that the staff members identified for the technology transfer process (P. 3. Q. 15 II).

Tab. 24: The constraints that obstruct the technology development process. (P. 3 Q. 15 II)

Constraint	*Not at all*	*Marginally*	*Substantially*	*Severely*	*Total*
The ending of the MHO funding	2	2	0	1	5
The ending of the relationship with COBRA	2	2	0	1	5
Bureaucracy within the university	0	4	0	1	5
Bureaucracy outside the university	1	2	2	0	5
Lack of knowledge about commercialisation processes	1	1	3	0	5
Lack of experience with commercialisation processes	0	1	2	2	5
Lack of interest in commercialisation	1	1	2	1	5
Differing attitudes within university and firms	0	0	2	3	5
Competition with institutions from Europe, USA, Japan, etc.	1	1	1	2	5
Competition with institutions in India	2	3	0	0	5
No funds for investments at the university	0	1	2	2	5
No funds for investments at the companies	0	2	2	1	5
No demand for applicable research projects from ISP at the firms	1	1	2	1	5
No willingness to transfer the knowledge from the side of ISP	5	0	0	0	5
No willingness from the side of the firms to adopt the technology	1	1	3	0	5
No policy for industry institution interaction	1	1	2	1	5
Other namely, unwillingness on part of industry for modernisation	0	0	1	0	1
Other namely, lack of manpower in ISP for industrial research	0	0	1	0	1

Tab. 24 shows that the differing attitudes in the university and the firms are a very large constraint for the process of technology transfer. Here also the competition with foreign institutes is not seen as a big constraint, but in reality it is in fact there. Also lack of knowledge about commercialisation processes is important. That problem should be at least partially solved by the literature that is stated in this report.

Tab. 25: The constraints for continuation of the International School of Photonics. (P. 4 Q. 19 II)

Constraint continuation ISP	*Not at all*	*Marginally*	*Substantially*	*Severely*	*Total*
The ending of the MHO funding	1	2	1	1	5
The ending of the relationship with COBRA	1	3	0	1	5
No commercialisation of any projects	2	2	0	1	5
Bureaucracy within the university	0	4	1	0	5
Bureaucracy outside the university	0	5	0	0	5
Competition with institutions from Europe, USA, Japan, etc.	3	1	0	1	5
Competition with institutions in India	2	3	0	0	5
No funds for investments at the university	0	3	0	2	5
No funds for investments at the companies	1	0	2	1	4
The leaving of staff members	2	2	1	0	5
No available students	3	1	0	0	4
Other namely, government policies towards research	0	0	1	0	1

In Tab. 25 the constraints for continuation of ISP are assessed. The ending of the MHO funding and the ending of the relationship with COBRA are not seen as big constraints for the continuation of ISP. Also no commercialisation of any projects is seen as a very big constraint for the continuity of ISP. Bureaucracy within the university and no funds at the university are seen as bigger constraints, but the continuation of ISP does not seem to be a grave concern at the moment.

Chapter 5: Reflection of the empirical findings against the theoretical model

In this research, the following research model has been used:

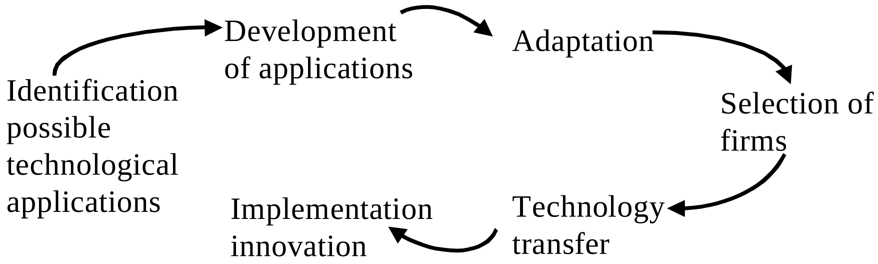

Fig. 10: Theoretical Framework

This model has been created from researching relevant literature. The question is however, in how far this model can be used in practice in India. In this chapter the different stages of the model will be assessed against the empirical findings in this research.

§ 5.1 Identification of possible technological applications

This stage, together with the "Selection of Relevant firms"-stage, has been very important in this research. These two stages have been the backbone of this research. The other stages in this model can only be followed when the "identification" stage and the "selection of firms" stage have been completed. One cannot develop an application until an actual application has been identified and ISP cannot transfer technology to a firm unless they have identified and selected the relevant firm.

In paragraph 2.5.2, the identification stage in the theoretical model has been explained. In this stage a very important concept has been the *appropriateness* of the technology towards the environment that the technology has to work in. It must be concluded after the experience in India that the research projects from the International School of Photonics are not very appropriate to be used in an under developed environment such as in India. This is one of the reasons that it was found that there are only six companies that can use the technology. This follows from the data presented in Table 18. Most of the companies can only use the technology of ISP in a very small way. This is logical because of the lack of appropriateness of the technology. In the state Kerala, agriculture is still very dominant. There are only a handful of large companies that can adapt the technology that ISP wants to transfer. Most of these companies have been visited in this research and have been assessed for their "Photonics Needs".

However, regardless whether the technology is appropriate or not, the project that included the development of Fibre Optic Sensors was seen as a project with possible technological applications. Fibre Optic Sensors can be used in a lot of different applications and are very cheap to manufacture. Also, there is a lot of knowledge on the subject within ISP. In the last week of the research the staff of ISP got a possible research and collaboration project on Fibre Optic Sensors within small-scale company in Ernakulam. This company was not visited in the research, because only large and medium scale companies would have the financial capability to adapt the research of ISP. Photonics is a rather expensive technology. This new project at ISP confirms that Fibre Optic Sensors are very well applicable within a practical environment.

§ 5.2 Development of applications

In this stage the technological capability of the International School of Photonics is very important. From the interviews that were conducted at ISP and the observations that were done it must concluded that the technological capability of ISP to develop practical applications and disseminate them is low.

A very important factor in this is that there are only 5 staff members at ISP and 26 PhD students. ISP is not a very large faculty and on top of this: commercialisation of their research projects is not the main goal of ISP. It is a government institution that has to educate students. So any projects that the professors do have to be done besides their normal teaching duties. Because lack of funding and the total bureaucracy within the university the staff and the students also have to cope with mundane problems that obstruct their normal duties. The infrastructure is rather poor and the bureaucracy is very high. This all does not improve the technological capability of ISP.

It takes time to develop the applications and the necessary social and factual infrastructure. A very important spillover in this research is the fact that people at ISP have been confronted with commercialisation and that they have *thought* about this. This research has changed their views on interaction with the industry. In the future they may or may not choose to interact with the industry but now they decide this rationally. In the past, it simply was not done as a fact in a very systematic and formal way. It was not part of the culture. It still is very hard and not done largely, but know the people at ISP at least know that it can be beneficial and they know *how* to commercialise their projects. The theory that has been provided in chapter 2 in this report can be used as a guideline for commercialisation. The model that is discussed here is very relevant in any context that involves technology transfer from universities to industries, whether it is in a developed or a developing country. In the latter, the model can be used to guide the people through the process. It makes them aware of the different stages and thus they can make rational decisions towards a successful transfer of technology.

But also in developed countries the technology transfer can be a problem. Universities often face problems if they should do only basic academic research or if they should do applicable research. The latter often is seen as less academic and there is a continuing discussion going on whether the university should stick to performing basic research or not. It is often forgotten that transferring technology to industries is a very major driving force in keeping the national industry on a level on which it can compete with other industries in the world. It is also very important that universities in developed countries continue to transfer their technology to universities in developing countries so that the developing countries can catch up. If this does not happen than there will be a continuing discrepancy between the rich and the poor and this gap is a basic fundament of war and instability in the world. The latest example of this threat that poverty is against developed countries is the attack on the empire state building on September 11th 2001 in New York. In this light it is imperative that the struggle against world poverty continues and that the universities in developed countries continue to play their role in this.

§ 5.3 Adaptation of the Technology

As has been explained in chapter 1 in this report, the adaptation stage in the transfer of technology model depends on three basic concepts:

1. The characteristics of the technology: appropriateness of the developed application
2. The technological capabilities of the International School of Photonics
3. The characteristics (capabilities, needs, etc.) of the target environment

This has been represented in Fig. 7. The first concept has been discussed in § 5.1 of this chapter. It was concluded that the technology of ISP was not very appropriate in a developing environment. This has been concluded also from the results from the market study. In § 5.2 it was concluded that the technological capabilities of ISP are but marginally. The last concept of this stage can be reflected against the data that was gathered in the market study. Here the relevant companies were approached and interviewed with a questionnaire. From this study it became clear that the needs of the companies with respect to photonics technology is but low. This was expected up front because of the nature of the technology. But it also became clear that the industry is very interested if ISP can prove that the technology can be useful and that it has revenues for the company. All in all, from these three concepts and the data gathered in this research it must be concluded that the adaptation stage is very hard and very important. The technology that is created within ISP is basically fundamental research. These projects have to be adapted to the practical, profit seeking industry. This takes time and effort and has to be given priority in the technology transfer process. It should be investigated up front whether the project will provide the revenues to break even with the initial costs to adapt the technology. With Fibre Optic Sensors, this should be no problem, because the fibres are cheap and the knowledge is present within ISP. It should be challenging for ISP to use the fibres in a practical environment. The application is bound to have engineering challenges in practice.

§ 5.4 Selection of Firms

As said in the foregoing text in this chapter, this stage has been very important in this research. Basically, because that is was has been done with the market study. 6 different companies have been selected from a list of 22 companies on their needs on photonics technology. Also the model that was presented in Fig. 4 has been a guide throughout the research. It was found that a very large problem why the ISP did not have any relations with the industry and why the industry did not know about ISP was that there was no general and specific interest creation instrument at hand. ISP presently has solved this problem partially by installing a new web site and this research has also helped in interesting the industry. This research has basically been action research in which the researcher actively takes part in the environment that he/she is studying. There has been money reserved by Nuffic within the MHO project for doing PR work and ISP is working on improving their image within the industry. A lot can still be done in this field.

§ 5.5 Technology Transfer

Time will tell whether ISP is capable to transfer their technology to the industry. The transferring of technology has been done in one case before, in the case of the “Education kit” that was produced by Holmarc. This was done in a very informal way. ISP should be aware that strict guidance of the company is necessary in this stage and that training of the people of the company can also be very important.
This phase however was less important in this research, because there was no technology to actually transfer.

§ 5.6 Implementation of the innovation

Here it is hard to predict the outcome because of the lack of projects that have been implemented at this point, because of the lack of actually transferred technologies.

The basic conclusion that can be drawn from this chapter is that the used Research Framework is very relevant and very useful in both developed and developing countries. The theoretical model provides insight in the different relevant stages in technology transfer from the university to industry. The most important stages in this research were the “Selection of relevant firms” stage and the “identification of possible technological applications” stage.

Chapter 6: Conclusions

§ 6.1 Introduction

In the beginning of this report four sub-questions were formulated in order to answer the research question postulated in the first chapter of this document. The sub-questions were the following:
Sub-questions:

1. What are possible applications of existing fundamental research program?
2. What are photonics needs of manufacturing firms in Kerala/ other states in India?
3. Which existing projects have the greatest chance of commercial success?
4. What actions by the institute and conditions in the market influence chances of successful commercialisation?
5. Can theoretical analyses of technology development contribute to identifying obstacles to commercial applications of fundamental photonics research?

With the data that was collected in this research and that was formulated in this document all these questions can be answered.

§ 6.2 What are possible applications of the existing fundamental research program?

Possible applications of the existing fundamental research program needed in the beginning some clarifications on what photonics applications (or photonics needs) were. During the operationalisation of the relevant variables this became a problem. In chapter 3 of this document, photonics needs of the different firms were defined “the degree of applicability of Photonics Technology, specifically (knowledge about) lasers, sensors, semiconductors, lenses, in a production process or the willingness to produce products from the International School of Photonics”. From the interviews that were conducted at ISP however, it became clear that most of the expertise of the International School of Photonics lies in Lasers and their applications and Fibre Optic Sensors and their applications.

Lasers can be used in the industry for cutting, welding, grinding, etc., within the manufacturing process of a company, but lasers can also be used for measurement of locations and displacements in the controlling and monitoring of the production processes.

Fibre Optic Sensors however can be used for measurement and communication purposes. So their application lies in the monitoring and controlling of the production processes. One of the big advantages of Fibre Optic Sensors and Fibre Optic Communication is that they are not susceptible to EMI (Electro Magnetic Interference).

The measurements and the application of these two fields of the research program that it is hard to specify. Everything with a spectrum can be measured. The only problem is the environment in which fibre optics and lasers have to work. This environment cannot be too rough or too dusty. This is why most of the companies that work with these kinds of equipments have a controlled environment for temperature, humidity and dust.

§ 6.3 What are photonics needs of manufacturing firms in Kerala?

This was analysed during the market research and the data that was provided in Chapter 4.1 of this document answers this question to some extent. The question is however a very difficult one because there are a lot of different companies with a lot of different production processes and products. To solve this problem somewhat, a score has been given, inadequate as it may be, that provides the means to compare all the different companies. But as the case of Holmarc shows, when the photonics needs score is low,

commercialisation can still be achieved. This is because of the fact the score says only something about the technical matter of the problem and nothing about the social factors that come into play.
As shown in the market survey most of the needs of the firms are low when it comes to using lasers and fibre optics sensors in the production process, either for manufacturing purposes or for controlling and monitoring purposes. There are a couple of companies that are using or can use the technology in a bigger way, but most the companies do not use and cannot use the technology and are therefore not very compatible with the research of ISP. Because of this fact, the adaptation stage from the research framework will be very important and also very difficult. The research from ISP at this point is not applicable because they focus on basic research problems. If any projects are to be commercialised, the focus of the projects should be more to applications used in companies.

The firms are willing to invest in collaboration projects and are also interested in products from ISP if it will benefit them.

Only companies in Kerala have been visited so there can be no conclusions drawn about firms outside Kerala.

§ 6.4 Which existing projects have the greatest chance of commercial success?

From the interviews that were conducted at ISP four projects were suggested that would have the largest commercial potential.

These projects are:

1. White Cell Development under the ISRO project
2. Manufacturing of a Nitrogen Laser system under the DST project
3. Manufacturing of a Photo acoustic cell under the AICTE project
4. Manufacturing of Fibre Optic Sensors under the AICTE project

The last project was seen by all of the staff members from ISP as the project with the largest commercial potential. Fibre Optic Sensors are very cheap and easy to manufacture and a large range of applications are thinkable within the monitoring of the production processes of the visited firms. ISP has considerable knowledge on the subject. It should be easy enough to manufacture some kind of application for them. There have been prototypes manufactured that can measure ammonia. Companies like Binani Zinc Ltd. and Hindustan Latex Ltd that have ammonia exhaustions in their production process could be interested in a project like this (see also appendix I).

§ 6.5 What actions by the institute and conditions in the market influence chances of successful commercialisation?

As the market study clarified, most of the companies do not have any idea about ISP and its products. The ways in which ISP creates an image for itself is not sufficient. Using folders more specifically for the industry and using an up-dated, well reachable Internet site with interesting data would be more efficient than the seminar that is conducted once or twice a year. Not that the seminar should not be performed, but the seminar does not reach the companies sufficiently. PR-work should have more emphasis than now. Within the Dutch MHO-project there has been money allocated for this so only the execution remains.

A more commercial outlook by ISP would also be useful. The projects that are conducted now are not very practical in their applications. Another research project with more applicable outlook should be initiated, preferably with collaboration with a company like Nest R&D Centre or Swiftlink Ltd.

The fact remains however that differing attitudes between the industry and the university is a very big constraint. Government institutions like the university tend to undergo strikes on a regular basis and this is the last thing that a company wants. This problem is not likely to be solved soon and this will take a lot of time.

Also the economic climate in Kerala is deteriorating. This will result in companies not willing to invest a lot of money in collaboration projects because of their financial situation. The technology form ISP is not very appropriate in this way for a developing economy. The technology is very capital-intensive.

Also the political climate is of influence on the ways that companies are willing to communicate, as was seen after the attack on the parliament.

§ 6.6 Can theoretical analyses of technology development contribute to identifying obstacles to commercial applications of fundamental photonics research?

The theoretical analysis that was done in this report has proven very useful for identifying the obstacles to commercial applications. The theoretical analysis of the technology transfer model can be used as a guide for the future interactions with industry. The model has been carefully linked with data collected in the field research. The theoretical model provides insight in the different relevant stages in technology transfer from the university to industry in both developed and developing countries. This has been elaborated and concluded in Chapter 5 of this report.

Chapter 7: Recommendations

The following recommendations follow from the forgoing chapters. Whether or not ISP should go forward with commercialisation of the projects is left to the management of ISP. As said in the last chapter commercialisation alone cannot sustain the entire research program. But all means of generating funds should be explored. The following recommendations for successful commercialisation have been listed in order of importance.

1.) The professors should get in touch with the companies listed in appendix F and talk to them about probable collaboration projects. Give them free consultancy on how to improve their production process by using technology from ISP. Initiation by ISP is very important because there is no history of collaboration with industry. The industry is the one that have the money and ISP is selling its products so ISP should make the first step. Technically, the first step has been made and a quick follow-up is needed so that the industry still knows about the people that visited earlier. Communication is the way to gain trust and create relationships. This should all be done in six months after this project is complete, according on the time scale provided in appendix F.

2.) After communicating with the companies it should be possible to create a research project based on the needs of the industry. Practical research is needed so that the adaptation stage in the technology transfer model is as small as possible. It would also be good for the students of ISP to see practical applications of the knowledge from ISP. The creation of the projects should be done by the staff members of ISP and should be done within 6 months after completion of this project.

3.) The focus of the communication should be companies that use photonics technology as well as companies that have never heard about photonics. Competition with “foreign” institutions is very difficult for ISP and the companies that have never heard of ISP are the ones that can be persuaded in collaboration projects the easiest.

4.) For the new collaborations projects, staff members of ISP should concentrate on Fibre Optic Sensors for commercialisation. These sensors are easy and cheap to make and have a wide range of applications within the industry. Especially companies that use chemical processes in their production process can be very interested in the applications of Fibre Optic Sensors.

5.) ISP should get more attention by using general and specific interest creation instruments. Create an up-to-date and easy to reach website with data on the applications of the research projects. It may be a good idea to reserve special parts of the site for students, teachers, personnel and industrialists and academics. The Internet site should also have an e-mail address through which people can ask for folders of products. The creation of the Internet site can be finished within 2 months after this project is finished.

6.) Create folders of the products like the glucose meter and applications of Fibre Optics Sensors and spread them to specific parts of the industry. For example, take the chemical industry and give them folders on how to use Fibre Optic Sensors in environmental control. This should be done within 6 months after the completion of this project, possibly before the talks of the professors with the people from the industry so that the folders can be spread during those talks.

7.) Use key persons and free consultancy to persuade companies to invest in collaboration projects. These two instruments are believed to have the most effect and they are not expensive to execute. The key person at ISP can be any member from the staff, however Mr Nandakumaran would be the most preferable as the director of the International School of Photonics. Mr. Girija Vallabhan could also be very adept for the job, but he is retiring in a few months after completion of this project.

8.) Make clear agreements on the goals and the results of the projects with all the relevant parties.

9.) The people performing the collaboration project should keep the stages of the research model of this project in mind. The research model provides a guideline of all the stages involved in the transferring of technology. Because ISP doesn’t have any experience with transferring technology this model could prove very useful.

10.) For the practical side of the collaboration projects a third party can provide the technical expertise for manufacturing and installing. Holmarc is a good choice because they have experience with the problems involved and they have a good relationship with the professors from ISP. Also Nanowave Technologies of Mr. Gopikrishnan has potential for industry interaction. The details of this collaboration can only be assessed when a concrete project arises.

11.) A fee can also be asked from the companies in the form of new equipment. This way the department can avoid the bureaucracy from the university.

Some recommendations can also be made on the university level:

I. The vacancy of the technician should be filled immediately so that the person involved can still undergo training at the Technical University Eindhoven in the Netherlands before the ending of the MHO project in 2003. After this the money is to be returned to the Dutch ministry of foreign affairs and the money for the training will have to be paid by Cochin University of Science and Technology.

II. There should be an honest division of the fees that are generated through the collaboration projects that ISP undertakes. It used to be that 1/3 of the money goes to the department and 2/3 to the university. The department should get at least more than 50% of the generated fee, as they do all the work.

III. The university should be quick in approving the projects that ISP brings forward. All the projects have to be approved by the Registrar. This should take as little time as possible because if it takes to long, the companies will get their products from other companies that can react much quicker. It might be possible to have a special arrangement for projects that need quick review.

The success of the commercialisation of research projects largely depends on the time and effort that the professors put in the workings of the project. It is believed that the companies can be persuaded to invest in collaboration projects if these projects are beneficial to them. The funds that are generated, although they cannot sustain the entire research program, can still be very beneficial.

Abbreviations

AICTE	All India Counsel for Technical Education
BIA	Bureau for International Activities, Eindhoven University of Technology
B. Sc.	Bachelor of Science
B. Tech.	Bachelor of Technology
CEMCOP	Centre for MHO Cooperation
COBRA	Communication Technology: Basic Research and Applications, Eindhoven University of Technology
CUSAT	Cochin University of Science and Technology
DGIS	Directorate General International Cooperation
DR	Desk Research
EMI	Electro Magnetic Interference
FOS	Fibre Optic Sensors
FOT	Fibre Optic Technology
GDP	Gross Domestic Product
GNP	Gross National Product
IC	Intelligent Component
II	ISP Interview
ISP	International School of Photonics
LED	Light Emitting Diode
MHO	Mede financiering Hoger Onderwijs (Joint Financing Programme for Cooperation in Higher Education)
MS	Market Study
M. Sc.	Master of Science
M. Tech.	Master of Technology
Nuffic	Dutch Organisation for International Cooperation
O	Observation
P	Part of the Questionnaire
PDT	Photo Deflection Technique
PhD.	Doctorate
PSD	Position Sensitive Detector
Rs	Rupees
RTI	Research Technology Institute
RIG	Refractive Index Gradient
TUE	Eindhoven University of Technology

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Appendix B: The different institutes

Companies in Kerala

1. Apollo Tyres Ltd. (source: Nair)
2. Binani Zinc Ltd. (source: District Industries Centre)
3. Carborandam Universal, (source: Jolly Cyriac, Holmarc)
4. Connectors Ltd. (OEN) Electrical Apparatus for Switching or Protect Elec Circuit, *Vyttila, Kanayannur-682019* (source: District Industries Centre)
5. Crysand, Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Frankena)
6. FACT (source: Nair)
7. Futura Medicals (former Lukens Medicals), Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
8. Hindustan Insecticides Ltd., *Eloor* (source: Nair)
9. Hindustan Latex Ltd., *Trivandrum* (source: Confederation of Indian Industry)
10. Hindustan Lever Ltd. HLL (source: Nair)
11. HMT (source: Abraham Koschie, IAC)
12. Hindustan News Print Ltd., *Vellore* (source: Confederation of Indian Industry)
13. Hindustan Organic Chemicals, *Ambalamugal* (source: Nair and Confederation of Indian Industry)
14. Holmarc Slides and Controls (p) Ltd., *P.B. No 2244 Edappaly Toll, Cochin 682024, Kerala India* (source: Girijavallabhan)
15. Indian Aluminium Company Ltd., *Alupuram, south kalamassery* (source: Nair and Confederation of Indian Industry)
16. Kerala Argromachinery Coorperation, *Albani* (source: Nair)
17. KMML, *Chavara* (source: Confederation of Indian Industry)
18. Kochi Refineries Ltd., *Ambalamugal* (source: Nair and Confederation of Indian industry)
19. Malayala Manorama, *Kottayam* (source: Confederation of Indian Industry)
20. Milma (source: Nair)
21. Naval Physical Oceanographic Laboratory, *Cochin* (source: Frankena, Nair)
22. Nest Cyber campus, Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
23. NEST Group, *Kakkanad* (source: Confederation of Indian Industry)
24. Nest Power Electronics Pvt. Ltd., Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
25. Nest R&D Centre, Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
26. Nortpak Fibre Optics (p) Ltd., Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
27. OEN India Limited, specialisation: Relays also Electrical Apparatus for Switching or Protect Electrical Circuit, *Postbus 1952*, *Vyttila*, *Kanayannur-682019* (source: District Industries Centre)
28. SABA Powerdex Pvt. Ltd. (Nest group), Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
29. Sun Fibre Optics (P) Ltd. (Nest group), Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
30. Swiftlink Pvt. Ltd. (Nest group), Cochin Export Processing Zone (CEPZ), *Kakkanad* (source: Gopikrishnan)
31. TATA TETLAY, *Kochi (Willindon Island)*
32. TATA TETLAY, *Munar* (source: Nair)
33. TELK, *Angamaly* (source: Nair and Confederation of Indian Industry)

Companies outside Kerala

1. Centre for Advanced Technology, Medical and Industrial Lasers, *Indore* (source: Frankena)
2. Defence Science Centre, *New Delhi* (source: Frankena)
3. Department of Telecommunication, Telecommunication Engineering Centre, Communication and sensing is important, *Bangalore* (source: Frankena)

4. Futuristic Communication Laboratory, cable division, *Verna Electronic City, Goa-403722* (source: Frankena)
5. Indian Institute of Science (IISc), Department of Electrical Communication Engineering, *Bangalore* (communication & sensing see Frankena)
6. Indian Institutes of Technology (ITT), Physics Department, Applied Optics Laboratory, *Madras* (source: Frankena)
7. Optel, Fibres, *Bophal* (source: Frankena)
8. Opto-electronics Laboratory, *Dehra Dun* (source: Frankena)
9. PDR Videotronics (I) PVT. Ltd, *Mumbai-400025* (source: Frankena)
10. R&D Centre at Gurugav, *Goa* (source: Frankena
11. TATA/Lucent Technologies, devices for transmission electronics, *Bangalore* (source: Frankena)
12. TATA/Lucent Technologies, dr. Gopal Dass Bhavan (3rd floor), *28 Barahkamba Road, New Delhi 110001* (source: Frankena)

Appendix C: The questionnaire for ISP Interviews

Introduction

This questionnaire is designed to identify the capability of the International School of Photonics for commercialisation of its research program.

Some general remarks:

1. If there is no precoded answer, please write your answer on the questionnaire form.
2. Mark the answer (or the answers) to precoded questions in their consecutive boxes.
3. If an answer does not fit on the space of the questionnaire, please continue on the back of the paper.
4. Please make a note if a question was not clear to you.
5. If a question was not applicable, and no “Not applicable” category was printed, please mark the question with N.A. yourself
6. After answering a question, go to the question number indicated after the question. If there are no specific instructions, just go to the next question.
7. Please write your answers in capital letters.

Part 1: Background characteristics respondent

1. Identification number (Not to be filled in by the respondent):
2. Name:

…………………………………………………………………………………………………

3. Date of birth:

…………………………………………………………………………………………………

4. Current position of the respondent within the International School of Photonics (ISP):

…………………………………………………………………………………………………

5. Since what year have you been actively working within ISP?

…………………………………………………………………………………………………

6. Did you ever work for another company or organisation, before your job at ISP?

Yes (If the answer is “Yes”, go to question 7)

No (If the answer is “No”, go to question 9)

7. Which companies or organisations?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

8. How long did you work at these companies/organisations?

Company1:………………………………………………………………………………….

Company2:………………………………………………………………………………….

Company3:………………………………………………………………………………….

Company4:………………………………………………………………………………….

9. What education have you completed (mention highest degree)?

SSLC
Pre-degree
ITI
Diploma
B. Sc.
B. Tech.
M. Sc.
M. Tech.
PhD.
Other, namely…….………………………………………………………

10. Are you currently working on any research projects?

Yes (If the answer is “Yes”, go to question 11)
No (If the answer is “No”, go to question 16)

11. Please describe the projects shortly

Project 1:……………………………………………………………………………

Project 2:……………………………………………………………………………

Project 3:……………………………………………………………………………

12. What are their goals?

Project 1:……………………………………………………………………………

Project 2:……………………………………………………………………………

Project 3:……………………………………………………………………………

13.What were the reasons for embarking on these projects?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

14. Do any of these projects have research results with potential commercial applications within a firm?

Yes (If the answer is “Yes”, go to question 15)
No (If the answer is “No”, go to question 16)

15. Please describe which project(s) and what potential application below:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

16. Did you work on any projects in the past?

Yes (If the answer is “Yes”, go to question 17)

No (If the answer is “No”, go to question 22)

17. Please describe the projects shortly

Project 1:………………………………………………………………………………

Project 2:………………………………………………………………………………

Project 3:………………………………………………………………………………

Project 4:………………………………………………………………………………

18. What were their goals?

Project 1:………………………………………………………………………………

Project 2:………………………………………………………………………………

Project 3:………………………………………………………………………………

Project 4:………………………………………………………………………………

19. What were the reasons for embarking on these projects?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

20. Did any of these projects have research results with potential commercial applications within firms?

Yes (If the answer is “Yes”, go to question 21)

No (If the answer is “No”, go to question 22)

21. Please describe the project(s) and their potential applications below:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

22. Were any of your projects adopted by any firms?

Yes (If the answer is “Yes”, go to question 23)

No (If the answer is “No”, go to question 24)

23. Which projects have been adopted and by which firms?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

24. How many publications did you publicise in the different journals listed below, in the past three years:

Refereed international scientific journals (English)	
Refereed Indian scientific journals	
Professional journals	
Journals aimed at firms	
Journals aimed at a wider public	
Other journals, namely…………………………………………….	

25. Do you supervise any PhD-students?

Yes (If the answer is “Yes”, go to question 26)
No (If the answer is “No”, go to question 27)

26. How many?

…………………………………………………………………………………………………

27. Do you supervise any M.Sc. students?

Yes (If the answer is “Yes”, go to question 28)
No (If the answer is “No”, go to question 29)

28. How many?

…………………………………………………………………………………………………

29. Do you supervise any M. Tech. students?

Yes (If the answer is “Yes”, go to question 30)
No (If the answer is “No”, go to question 31)

30. How many?

…………………………………………………………………………………………………

31. Do you supervise any M. Phil. students?

Yes (If the answer is “Yes”, go to question 32)
No (If the answer is “No’, go to part 2)

32. How many?

…………………………………………………………………………………………………

Part 2: The technological capabilities of ISP

The characteristics and technological capabilities of ISP influence the possibilities for successful technology transfer. To assess in what way these influences are active, information about these characteristics/capabilities is needed.

1. How many staff members are currently working in ISP, according to your knowledge?

…………………………………………………………………………………………………

2. How many people working within the International School of Photonics have some knowledge or experience about the commercialisation of scientific research results?

……………………………………………………………………………………………

3. What are the four most important objectives of ISP?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

4. Do you feel that commercialisation is useful for the long-term viability of the institute?

Yes

No

5. Why or why not?

……………………………………………………………………………………………

……………………………………………………………………………………………

6. Do you think that there are companies in- or outside Kerala that could use the knowledge generated at ISP?

a. Inside Kerala

Yes

No

b. Outside Kerala

Yes

No

If question 6 a or b was answered with "Yes" go to question 7, otherwise go to question 9.

7. What are the names of these companies?

……………………………………………………………………………………………

……………………………………………………………………………………………

8. In what ways do you think that the companies could use the knowledge generated at ISP (after answering, go to question 10)?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

9. What are the main reasons for this, according to you?

……………………………………………………………………………………………

……………………………………………………………………………………………

10. Is there a lot of competition in the field of photonics applications?

Yes

No

11. Do you think that ISP can compete in this field on an international basis, with research institutes in Europe, the USA and Japan?

Yes

No

In some areas, namely…………………………………………………………

12. Why or why not?

……………………………………………………………………………………………

……………………………………………………………………………………………

13. In your opinion, is ISP capable of creating technologically advanced applications for the industry in the field of Fibre Optic Sensors?

Yes

No

14. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

15. In your opinion, is ISP capable of creating technologically advanced applications for the industry in the field of Laser technology?

Yes

No

16. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

17. In your opinion, is ISP capable of creating technologically advanced applications for the industry in the field of Semiconductors?

Yes

No

18. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

19. In your opinion, is ISP capable of creating technologically advanced applications for the industry in the field of Lenses?

Yes

No

20. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

21. In your opinion, is ISP capable of creating price competitive applications for the industry in the field of Fibre Optic Sensors?

Yes

No

22. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

23. In your opinion, is ISP capable of creating price competitive applications for the industry in the field of Laser technology?

Yes

No

24. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

25. In your opinion, is ISP capable of creating price competitive applications for the industry in the field of Semiconductors?

Yes

No

26. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

27. In your opinion, is ISP capable of creating price competitive applications for the industry in the field of Lenses?

Yes

No

28. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

29. In your opinion, is ISP capable of creating easy-to-use applications for the industry in the field of Fibre Optic Sensors?

Yes

No

30. Why do you think so?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

31. In your opinion, is ISP capable of creating easy-to-use applications for the industry in the field of Laser technology?

Yes

No

32. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

33. In your opinion, is ISP capable of creating easy-to-use applications for the industry in the field of Semiconductors?

Yes

No

34. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

35. In your opinion, is ISP capable of creating easy-to-use applications for the industry in the field of Lenses?

Yes

No

36. Why do you think so?

……………………………………………………………………………………………

……………………………………………………………………………………………

37. In your opinion, which projects conducted at ISP have the greatest chances for successful commercialisation (please elaborate why and how)?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

38. Do you think the institute should seek contact with companies to create a relation between companies and ISP?

Yes

No

39. Why or why not?

……………………………………………………………………………………………

40. Do you think the institute should invest in joint collaboration projects with industry?

Yes

No

41. Why or why not?

……………………………………………………………………………………………

42. Does the institute have a budget for collaboration projects? If yes, how high is this budget?

………………………………………………………………………………………………

Part 3: The environmental constraints

This part is concerned with the constraints and obstacles to successful transfer of knowledge from the institute to industry.

1. Have there been any projects from ISP adapted by any firms, according to your knowledge?

Yes (If the answer is "Yes", go to question 2)
No (If the answer is "No", go to question 3)

2. Which projects, how (explain the application), and by which firms (after answering go to question 4)?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

3. What do you think that the four most important reasons are for the fact that no firm has adapted any projects from ISP?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

4. In what way or in what ways has ISP's relation with the COBRA-institute influenced ISP?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

5. Do you think that the relationship with COBRA contributes to an improvement in the quality of scientific research at ISP?

Yes
No

6. In what way or why not?

………………………………………………………………………………………………

………………………………………………………………………………………………

7. Do you think that the relationship with COBRA contributes to the capacity of ISP to transfer technology from the institute to the industry?

Yes
No

8. In what way or why not?

…………………………………………………………………………………………

…………………………………………………………………………………………

9. Do you have any relationships with other faculties in the Cochin University of Science and Technology that can support your activities?

Yes (If the answer is "Yes", go to question 10)
No (If the answer is "No", go to question 13)

10. Which faculties?

Faculty1:………………………………………………………………………………
Faculty2:………………………………………………………………………………
Faculty3:………………………………………………………………………………

11. a) Do you think that the relationships with these faculties contribute to an improvement in the quality of scientific research at ISP?

Faculty1:
Yes
No
Faculty2:
Yes
No
Faculty3:
Yes
No

b) In what way of why not?

Faculty 1:……………………………………………………………………………...

…………………………………………………………………………………………

Faculty 2:……………………………………………………………………………...

…………………………………………………………………………………………

Faculty 3:……………………………………………………………………………...

…………………………………………………………………………………………

12. Do you think that the relationships with these faculties contribute to the capacity of ISP to transfer technology from the institute to the industry (please explain in what way)?
Faculty 1:
…………………………………………………………………………………………

…………………………………………………………………………………………
Faculty 2:
…………………………………………………………………………………………

…………………………………………………………………………………………
Faculty 3:
…………………………………………………………………………………………

…………………………………………………………………………………………
13. Does the government stimulate ISP to commercialise its research results?
Yes (If the answer was "Yes", go to question 14)
No (If the answer was "No", go to question15)
14. In what way?

…………………………………………………………………………………………

………………………………………………………………………………………

15. Which of the following items constitute constraints to a successful transfer of technology from ISP to relevant companies?

Constraint	**Not at all**	**Marginally**	**Substantially**	**Severely**
The ending of the MHO funds				
The ending of the relationship with COBRA				
Bureaucracy within the university				
Bureaucracy outside the university				
Lack of knowledge about commercialisation processes				
Lack of experience with commercialisation processes				
Lack of interest in commercialisation				
Differing attitudes between university and firms				
Competition with institutes from Europe, USA, Japan, Etc.				
Competition with institutes from India				

Constraint	Not at all	Marginally	Substantially	Severely
No funds for investment at university				
No funds for investment at the companies				
No demand for applicable research projects from ISP at firms				
No willingness to transfer knowledge from the side of ISP				
No willingness at firms to adapt knowledge from ISP				
No policy for industry institution interaction				
Other namely,				
Other namely,				
Other namely,				

Part 4: The image of ISP

1. Has the institute recently printed folders or publicity materials on the research projects of ISP to get publicity?

Yes (If the answer is "Yes", go to question 2)
No (If the answer is "No", go to question 3)

2. How and amongst whom are these folders spread (after answering go to question 4)?

…………………………………………………………………………………………………
3. Why not?

…………………………………………………………………………………………………
4. Does ISP use an Internet site to get publicity?

Yes (If the answer is "Yes", go to question 5)
No (If the answer is "No", go to question 6)

5. Is it up-dated regularly so that it contains recent data on progress of ISP?

Yes (If the answer is "Yes", go to question 7)
No (If the answer is "No", go to question 6)

6. Why not?

………………………………………………………………………………………………
7. Does ISP uses media such as television, radio or newspapers to get into the publicity?

Yes (If the answer is "Yes", go to question 8)
No (If the answer is "No", go to question 9)

8. How frequently is this being done (after answering go to question 10)?

…………………………………………………………………………………………………
9.Why not?

…………………………………………………………………………………………………

10. Are there any other ways that ISP uses to get into the publicity?

……………………………………………………………………………………………

……………………………………………………………………………………………

11. How often are these ways pursued?

……………………………………………………………………………………………

12. Do you think that relevant firms (firms who are able to adapt the knowledge of ISP) know about the International School of Photonics and its current research programs?

Yes (If the answer is “Yes”, go to question 13)
No (If the answer is “No”, go to question 14)

13. What kind of image do you think these relevant firms have of ISP?

……………………………………………………………………………………………

……………………………………………………………………………………………

14. What do you think the reasons are for this?

……………………………………………………………………………………………

……………………………………………………………………………………………

15. Do you think that firms could be persuaded to invest in collaboration projects with ISP?

Yes (If the answer is “Yes”, go to question 16)
No (If the answer is “No”, go to question 18)
Don’t know (If the answer is “Don’t know”, go to question 16)

16. What persuasion instruments should be used?

Free consultancy
Technology ownership
Financial stimuli
Private guidance
Tailor made (re)design
Result insurance
Pilot plant implementation
Contact with key figures in the organisations
Other, please specify……………………………………………

17. What persuasion instruments you feel would be most effective (after answering go to question 19)?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

18. Why not?

……………………………………………………………………………………………

……………………………………………………………………………………………

19. What constraints threaten the continuity of the research done at ISP?

Constraint	**Not at all**	**Marginally**	**Substantially**	**Severely**
The ending of the MHO funding				
The ending of the relationship with COBRA				
No commercialisation of any projects				
Bureaucracy within the university				
Bureaucracy outside the university				
Competition with institutes from Europe, USA, Japan, Etc.				
Competition with institutes from India				
No funds for investment at university				
No funds for investment at the companies				
The leaving of staff members				
No available students				
Other namely,				

20. Do you think that ISP can benefit from the data collected in this questionnaire?

Yes
No

21. In what way or why not?

…………………………………………………………………………………………………

This is the end of the questionnaire
Thank you very much for your time. Your help is highly appreciated.

Appendix D: The introduction for the Companies

What is Photonics?

Photonics is the technology, which uses photons to achieve various engineering objectives. Photonics have been used in optical communication, sensors, instrumentation and optical computing hardware.

"The area of Photonics reflects the synergy between optics and electronics and also shows the tie between optical materials, devices and systems. The subject of Photonics plays a key role in many segments of industry, such as optical communication, information storage, electronic display, signal processing, electronic imaging, etc. (Gupta, M.C. 1997)"

What is a photon?

By the definition of Max Planck, light consists of particles that are called photons. Some prefer to regard photons as localized packages of energy. A photon has zero rest mass and caries electromagnetic energy and momentum. It travels at the speed of light in vacuum, but is retarded in matter. Photons have a dual particle/wavelike property. They travel like a wave and interfere and diffract like matter. The emission and absorption of photons occur in quanta of energy. This energy can be used in the various engineering purposes.

What is the International School of Photonics?

The International School of Photonics (ISP) at CUSAT (Cochin University of Technology and Science) was founded February 28th 1995 by a restructuring of the activities of the Laser Division of the Department of Physics. The Laser Division in this University has been carrying pioneering work by way of Research and Development in lasers and their applications as well as in Fiber Optical Technology. De-linking the laser laboratories along with the faculty members formed the nucleus of the ISP.
Now ISP provides courses at M. Tech. and M. Phil levels, trains Ph. D. students in thrust areas of Photonics and related fields and pursues Research and Development in front-line areas like laser induces plasmas, photothermal and photo acoustic phenomena, non-linear optics, photonics materials, laser material processing and fiber optic sensors.

ISP is being funded by the Dutch organization Nuffic and there is an intensive exchange program for staff and students between ISP and the Technical University of Eindhoven (TU/e) under the ISP-MHO project.

What is the purpose of this visit?

The purpose of this visit is to strengthen the relationship between organisations like yours and the Cochin University of Science and Technology, specifically the International School of Photonics (ISP). To do this we need to know something about the needs of your organisation with respect to the Photonics area. Knowing this we can adapt our research projects to your needs and so establish a link between the International School of Photonics and your organisation.

What is in it for you?

When the photonics needs of your company have been established, the research done at ISP can provide solutions of your problems that are cheaper, closer to your firm, easier to handle and technologically superior compared to other firms and or institutions. The knowledge of ISP on the area of photonics is extensive and it can prove very useful to you if you would consider it's potential.

Projects undertaken by ISP since 1995:

Since 1995, ISP has done several projects to gain a broad knowledge base on the photonics field. Now, they are ready to apply their knowledge in numerous practical solutions in the optical communication industry, in information storage, electronic displays, signal processing, electrical imaging, etc. ISP has undertaken the following projects since 1995:

- Investigations in Laser Spectroscopy (completed)
- Establishing a Centre for Photonic Materials and Devices (completed)
- Investigations in underwater laser beam propagation and detection (completed)
- Laser induced thermo optic spectroscopic studies using phase shift detection (completed)
- Design and development of fiber optic sensors (completed)
- Laser induced damage studies of polymer thin films (completed)
- Development of solid state dye laser materials and their characterization (completed)
- Strengthening of ISP under ISP-MHO project (ongoing)
- Studies on laser induced colliding plasma using various diagnostic tools (ongoing)

What are examples of photonics applications in a firm?

As indicated in the forgoing elaboration, photonics are used in many segments of the industry, such as optical communication, information storage, electronic display, signal processing, electronic imaging, etc. One example of photonics used in a chemical industry is when light-based measuring equipment is used for measuring the concentrate of a sample so that the chemical process can be monitored closely.
Another example where photonics technology is used is in a manufacturing industry that uses so-called pick-and-place machines to move a certain object within the process of manufacturing. In these machines lasers can be used for accurate proximity-detectors to locate the object that has to be moved. The most promising area of research that can be used in industrial applications is the Fiber Optic Sensors, where fibers are used to measure distances, displacements, straight lines, disruptions, in short, everything that has a spectrum.

Appendix E: The questionnaire for the Market Study

Introduction

This questionnaire is designed to identify applications of photonics technology within your organisation. The first part and the second part of this questionnaire is about general characteristics of you and your organisation, the third part is concerned with the photonics applications within your organisation and in the fourth, and final part, some general questions regarding the technology transfer process are asked.

Some general remarks:

8. If the answer is not in the list, please give a short description of your answer.
9. Mark the answer (or the answers) in their consecutive boxes.
10. If an answer does not fit on the space of the questionnaire, please continue on the back of the paper.
11. Please make a note if the question was not clear to you.
12. If a question was not applicable, and no “Not applicable” answer was given, please mark the question with N.A. yourself
13. After the question is answered, go to the question that is noted after the question. If there is nothing after the question, just go to the next following question.
14. Please write your answers in capital letters.

The data that will be received by this questionnaire will only be used for educational purposes.

Part 1: Background characteristics respondent

1. Identification number (Not to be filled in by the respondent):

2. Name:

………………………………………………………………………………………………

3. Current designation of the respondent within the company:

………………………………………………………………………………………………

4. Name of the department in which you are currently working:

………………………………………………………………………………………………

5. Since what year have you been actively working within the company?

………………………………………………………………………………………………

6. What education have you completed (mention highest degree)?

SSLC
Pre-degree
ITI
Diploma
B. Sc.
B. Tech.
M. Sc.
M. Tech.
PhD.
Other, namely…….…………………………………………………………

Part 2: General characteristics of your company

The general characteristics of the organisation influence the technology transfer phase. To assess in what way these influences are active, information about these characteristics is needed.

1. Name of your company:

……………………………………………………………………………………………

2. In what year was your company founded?

……………………………………………………………………………………………

3. Does your company manufacture products or does it provide services?

Product making
Service providing

4. In what type of Division is your company active?

Agriculture, hunting and forestry (If the answer is "Agriculture, hunting and forestry, go to question 5)
Fishing (If the answer is "Fishing", go to question 10)
Mining and quarrying (If the answer is "Mining and quarrying", go to question 6)
Manufacturing (If the answer is "Manufacturing", go to question 7)
Electricity, gas and water supply (If the answer is "Electricity, gas and water supply", go to question 8)
Construction (If the answer is "Construction", go to question 10)
Transport, storage and communication (If the answer is "Transport, storage and communication, go to question 9)
Public administration and defence; compulsory social security (If the answer is "Public administration and defence", go to question 10)
Education (If the answer is "Education", go to question 10)
Other, namely……..……………………………………(Go to question10)

5. In what sub sector of the agriculture, hunting and forestry is your company active? (After answering, go to question 10)

Agriculture, hunting and related service activities
Forestry, logging and related service activities
Combination of the above, please specify………...………………………..

6. In what sub sector of the mining and quarrying division is your company active? (After answering, go to question 10)

Mining of coal and lignite; extraction of peat
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
Mining of uranium and thorium ores
Other mining and quarrying
Combination of the above, please specify………...………………………..

7. In what kind of sub sector of the manufacturing division is your company active? (After answering, go to question 10)

Manufacture of food products and beverages
Manufacture of textiles
Manufacture of paper and paper products
Publishing, printing and reproduction of recorded media
Manufacture of coke, refined petroleum products and nuclear fuel
Manufacture of chemicals and chemical products

Manufacture of rubber and plastic products
Manufacture of other non-metallic mineral products
Manufacture of basic metals
Manufacture of fabricated metal products, except machinery and equipment
Manufacture of machinery and equipment
Manufacture of office, accounting and computing machinery
Manufacture of electrical machinery and apparatus
Manufacture of radio, television and communication equipment
Manufacture of medical, precision and optical instruments, watches and clocks
Combination of the above, please specify………...………………………..
Other; please specify……………………………………………………..

8. In what sub sector of electricity, gas and water division is you company active? (After answering, go to question 10)

Electricity, gas, steam and hot water supply
Collection, purification and distribution of water
Combination of the above, please specify………...………………………..

9. In what sub sector of the transport and storage division is your company active? (After answering, go to question 10)

Land transport; transport via pipelines
Water transport
Air transport
Supporting and auxiliary transport activities; activities of travel agencies
Post and telecommunications
Combination of the above, please specify………...………………………..

10. How would you describe your company: as a small-scale, a medium-scale or a large-scale industry?

Small-scale industry (0-200.000 US dollars/month)
Medium-scale industry (200.000-400000 US dollars/month)
Large-scale industry (400.000 or more US dollars/month)

11. What are the four most important products (product groups) produced by your company? (Give a short description below)

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

12. What quantities (in numbers per year) are produced of the four main products?
Product 1:...……………………………………………………………………………
Product 2:……………………………………………………………………………...
Product 3:……………………………………………………………………………...
Product 4:……………………………………………………………………………...

13. To what kind of customers do you provide your products?
- Final consumers
- Other industries
- Government institutions

14. What is the total number of customers that your company has per year?

…………………………………………………………………………………………………

15. What is the number of different suppliers that you have?
- 0-10
- 10-20
- 20-30
- 30-40
- 40 or more; please specify…………………………………………………

17. How many people are employed in total in your company?
- 0-100
- 100-200
- 200-300
- 300-400
- 400-500
- 500 or more; please specify………………………………………………

18. How many people are employed in your establishment (unit)?

…………………………………………………………………………………………………

19. Number of technical staff in your establishment:

…………………………………………………………………………………………………

20. Number of administrative staff in your establishment:

…………………………………………………………………………………………………

21 What is the number of managing staff in your establishment?

…………………………………………………………………………………………………

22. What is the number of people in your total workforce that has, as highest degree in education:

	Number
No schooling at all	
Completed primary education (SSLC)	
Completed secondary education (Pre-degree)	
Post secondary vocational education (ITI, Diploma)	
Bachelors degree	
Masters degree	
Doctorate (PhD.)	

23. Number of engineering graduates in your establishment:

a. B. Tech…………………………………………………………………………...
b. M. Tech…………………………………………………………………………..
c. PhD………………………………………………………………………………

24. Number of diploma holders in your establishment:

…………………………………………………………………………………………………

25. Number of ITI certificate holders in your establishment:

…………………………………………………………………………………………………

26. Number of science graduates in your establishment:

a. B. Sc……………………………………………………………………………...
b. M. Sc……………………………………………………………………………..
c. M Sc. And M. Tech………………………………………………………………
d. PhD………………………………………………………………………………

27. What is the highest degree of education at your organisation?

SSLC
Pre-degree
ITI
Diploma
B. Sc.
B. Tech.
M. Sc.
M. Tech.
PhD.
Other, namely…….…………………………………………………………

28. Do you have an R&D department?

Yes (If the answer is “yes”, go to question 29)
No (If the answer is “no”, go to part 3)

29. What is the primary function of the R&D department?

…………………………………………………………………………………………………

………………………………………………………………………………………………

30. Is R&D performed only by people working at the R&D department or also by other employees?

By people from the R&D department (If the answer is “Only by people from the R&D department”, go to question 32)
By other employees as well (If answer “By other employees as well”, go to question 31)

31. Estimate by how many employees:

…………………………………………………………………………………………………

32. How many people work at the R&D department?

0-10
10-20
20-30
30-40
40 or more; please specify…………………………………………………

33. How many people working at the R&D department have:

	Number
SSLC	
Pre-degree	
ITI	
B. Sc.	
Diploma	
B. Tech.	
M. Sc.	
M. Tech.	
Doctorate	
Other, namely:	

Part 3: Photonics applications in your organisation

In this part the photonics applications within your company are assessed. Two general fields of application are distinguished: the production process of your organisation and the monitoring and controlling of this production process. The questions in this part concern these two areas. First we begin with the general awareness of photonics' applications.

Part 3.1: General awareness of photonics and its potential applications

1. Did you ever hear of the International School of Photonics before this interview?

Yes, from……………………………………………………………………..
No

2. Are you aware of the applications of the research of the International School of Photonics?

Yes
No

3. Do you think that photonics technology can enhance your production process?

Yes (If the answer is "Yes", go to question 4)
No (If the answer is "No", go to question 5)
Don't know (If the answer is "Don't know", go to question 6)

4. In what way do you think photonics technology can enhance your production process? (After answering please go to question 6)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

5. Please explain why not?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

6. Are you interested in producing products from the International School of Photonics?

Yes
No

7. Please explain why or why not:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Part 3.2: The production process (only fill in the rest of part 3 when question 3 of part 2 was answered with "Product making", otherwise go to part 4)

1. Would you characterise the production process at your organisation as capital intensive or as labour intensive?

Capital intensive
Labour intensive

2. Please explain your production process briefly below:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

3. How would you categorise your production process?

As a chemical process
As a construction process
As an assembly process
As a combination of the above, namely…………………………………….
Other, please specify……………………………………………………..

4. How many people work as operators/assemblers/process technicians within the manufacturing process?

…………………………………………………………………………………………………

5. How many of these people work by hand, without any equipment?

…………………………………………………………………………………………………

6. Do you have any machines working within the production process?

Yes (If the answer is "Yes", go to question 7)
No (If the answer is "No", go to question 9)

7. How many machines in total?

…………………………………………………………………………………………………

8. Describe the use of the machines within the process:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

9. Do you have any Jigs & Fixtures within the production process?

Yes (If the answer is “Yes”, go to question 10)

No (If the answer is “No”, go to part 3.3)

10. How many Jigs & Fixtures in total?

…………………………………………………………………………………………………

11. Describe the use of the jigs & fixtures within the process:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

12. Where do these equipments (machines, jigs & fixtures) come from?

Imported from abroad, namely from………………………………………..

Other companies in India, namely………………………………………….

Manufactured by yourselves

13. How many of these equipments use lasers?

0 (If answer is “0”, go to question 14)

0-10 (If answer is “0-10”, go to question 16)

10-20 (If answer is”10-20”, go to question 16)

20-30 (If answer is “20-20”, go to question 16)

30 or more (If answer is “30 or more”, go to question 16)

Don’t know (If the answer is “Don’t know”, go to question 17)

14. Do you think that laser technology can be used in these equipments?

Yes

No

Don’t know (If the answer is “Don’t know”, go to question 17)

15. Please explain why or why not: (After explaining, go to question 17)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Please explain the application:

…………………………………………………………………………………………………

17. How many of the production equipments use fibre optic sensors?

0 (If the answer is “0”, go to question 18)

0-10 (If the answer is “0-10”, go to question 20)

10-20 (If the answer is “10-20”, go to question 20)

20-30 (If the answer is “20-30”, go to question 20)

30 or more (If the answer is “30 or more”, go to question 20)

Don’t know (If the answer is “Don’t know”, go to question 21)

18. Do you think that fibre optic sensor technology can be used in these equipments?

Yes

No

Don’t know (If the answer is “Don’t know”, go to question 21)

19. Please explain why or why not: (After explaining, go to question 21)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

20. Please explain the application:

…………………………………………………………………………………………………

21. How many of the production equipments use semiconductors?

0 (If the answer is “0”, go to question 22)

0-10 (If the answer is “0-10”, go to question 24)

10-20 (If the answer is “10-20”, go to question 24)

20-30 (If the answer is “20-30”, go to question 24)

30 or more (If the answer is “30 or more”, go to question 24)

Don’t know (If the answer is “Don’t know”, go to question 25)

22. Do you think that semiconductors be used in these equipments?

Yes

No

Don’t know (If the answer is “Don’t know”, go to question 25)

23. Please explain why or why not: (After explaining, go to question 25)

…………………………………………………………………………………………………

……..…………………………………………………………………………………………

24. Please explain the application:

…………………………………………………………………………………………………

25. How many of the production equipments use lenses (or other optical solutions, please specify)?

0 (If the answer is “0”, go to question 26)

0-10 (If the answer is “0-10”, go to question 28)

10-20 (If the answer is “10-20”, go to question 28)

20-30 (If the answer is “20-30”, go to question 28)

30 or more (If the answer is “30 or more”, go to question 28)

Don’t know (If the answer is “Don’t know”, go to question 29)

26. Do you think that lenses can be used in these equipments?

Yes

No

Don’t know (If the answer is “Don’t know”, go to question 29)

27. Please explain why or why not: (After explaining, go to question 29)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

28. Please explain the application:

……………………………………………………………………………………………

29. Can you think of any other optical applications that are used within the equipments of your production process?

……………………………………………………………………………………………

……………………………………………………………………………………………

Part 3.3: Monitoring and controlling the production process

1. Do you use a special environment control within your productions process?
Yes (If the answer is “Yes”, go to question 2)
No (If the answer is “No”, go to question 3)

2. What are the specifications of this environment?

With respect to:	
Temperature	[°C]
Humidity	[%]
Dust	[Particles/m^3]

3. How is your production process controlled, by hand or automatically?
By hand (If the answer is “By hand”, go to question 4)
Automatically (If the answer is “Automatically”, Go to question 9)
By hand and automatically (If the answer is “By hand and automatically”, answer every question in this part, regardless of the direction to go to part 4. In stead of going to part 4, you should go to question 9)

4. Do you use any measuring instruments to monitor your production process?
Yes (If the answer is “Yes”, go to question 5)
No (If the answer is “No”, go to part 4)
Don’t know (If the answer is “Don’t know”, go to part 4)

5. Do any of these instruments use light-based (optical) measurements?
Yes (If the answer is “Yes”, go to question 6)
No (If the answer is “No”, go to question 7)
Don’t know (If the answer is “Don’t know”, go to question 7)

6. Please explain the application below. (After explaining, go to part 4)

……………………………………………………………………………………………

……………………………………………………………………………………………

7. Do you think that photonics technology can be used in these instruments?
Yes
No
Don’t know (If the answer is “Don’t know”, go to part 4)

8. Please explain why or why not? (After explaining, go to part 4)

……………………………………………………………………………………………

……………………………………………………………………………………………

9. Describe the automatic monitoring system below (what is measured, how is it measured, etc.):

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

10. Does the automatic monitoring system use any lasers?

Yes (If the answer is “Yes”, go to question 11)
No (If the answer is “No”. go to question 12)
Don’t know (If the answer is “Don’t know”, go to question 12)

11. Please explain the working of the application below. (After explaining, go to question 14)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

12. Do you think that lasers can be used in the system?

Yes
No
Don’t know (If the answer is “Don’t know”, go to question 14)

13. Please explain why or why not?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

14. Does the monitoring system use any fibre optic sensors?

Yes (If the answer is “Yes”, go to question 15)
No (If the answer is “No”, go to question 16)
Don’t know (If the answer is “Don’t know”, go to question 16)

15. Please explain the working of the application below. (After explaining, go to question 18)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Do you think that fibre optic sensors can be used in the system?

Yes
No
Don’t know (If the answer is “Don’t know”, go to question 18)

17. Please explain why or why not?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

18. Does the monitoring system use any semiconductors?

Yes (If the answer is "Yes", go to question 19)
No (If the answer is "No", go to question 20)
Don't know (If the answer is "Don't know", go to question 20)

19. Please explain the working of the application below. (After explaining, go to question 22)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

20. Do you think that semiconductors can be used in the system?

Yes
No
Don't know (If the answer is "Don't know", go to question 22)

21. Please explain why or why not?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

22. Does the monitoring system use lenses?

Yes (If the answer is "Yes", go to question 23)
No (If the answer is "No", go to question 24)
Don't know (If the answer is "Don't know", go to question 24)

23. Please explain the working of the application below. (After explaining, go to question 26)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

24. Do you think that lenses can be used in the system?

Yes
No
Don't know (If the answer is "Don't know", go to question 26)

25. Please explain why or why not?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

26. Does the monitoring system use any other optical solutions, other than the applications mentioned above? Please explain:

…………………………………………………………………………………………………

…………………………………………………………………………………………………

27. Are there any other systems in your organisation that use (or can use) photonics technology that you know of?

Yes (If the answer is "Yes", go to question 28)
No (If the answer is "No", go to part 4)

28. Please explain the application(s) below:

…………………………………………………………………………………………

…………………………………………………………………………………………

Part 4: The transfer of technology

This part is concerned with the transfer of technology from the International School of Photonics and its constraints.

1. Are there any relationships between your organisation and public Scientific/R&D institutes such as the Cochin University of Science and Technology?

Yes, with………………………………………………………………… (If the answer is "Yes", go to question 2)

No (If the answer is "No", got to question 3)

2. What is your opinion about these relationships?

Good	Fair	Neutral	Rather negative	Negative

3. What do you think the reasons are for the assessment given in questions 1 and 2?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

4. Are you willing to invest in collaboration projects with the International School of Photonics?

Yes (If the answer is "Yes", go to question 5)

No (If the answer is "No", go to question 6)

5.What is the maximal amount of money you are willing to invest?

…………………………………………………………………………………………

6. Please explain why not:

…………………………………………………………………………………………

…………………………………………………………………………………………

7. Would you like to have technical consultancy without any financial liability?

Yes

No

8. Do you know the names and locations of any other organisations that might be interested in using photonics technology?

…………………………………………………………………………………………

…………………………………………………………………………………………

This is the end of the questionnaire

Thank you very much for your time. On your request the conclusions and the data from this research will be sent to you. Your help is highly appreciated.

Appendix F: Companies that wanted consultancy

Number	Company	Wants free consultancy	Priority[1]
1	Nest Power Electronics Pvt. Ltd (Nest Group)	No	
2	Sun Fiber Optics (P) Ltd. (Nest Group)	Yes	Middle
3	Nest R&D Centre (Nest Group)	Yes	High
4	Swiftlink Pvt. Ltd. (Nest Group)	Yes	High
5	Nest Cyber Campus (Nest Group)	Blank	
6	Nest Group	Blank	
7	Nortpak Fibre Optics (P) Ltd. (Nest Group)	Yes	Low
8	SABA Powerdex Pvt. Ltd. (Nest Group)	Yes	High
9	Apollo Tyres Ltd.	Yes	Middle
10	Indian Aluminium Company Ltd., Extrusion Division	Yes	Low
11	Indian Aluminium Company Ltd., Smelter Division	Yes	Low
12	Holmarc Slides and Controls (p) Ltd	Blank	
13	Hindustan Latex Ltd.	No	
14	Carborandam United Ltd	No	
15	Futura Medical Products (P) Ltd.	Blank	
16	TATA Tetlay	Maybe	Low
17	Hindustan Insecticides Ltd	Yes	Low
18	Binani Zinc. Ltd.	Yes	High
19	KMML	Yes	High
20	OEN Ltd.	Yes	Middle
21	Hindustan Machine Tools Ltd.	Yes	Middle

Tab. 26: The companies that wanted consultancy

[1]The priority was based on the grade that was obtained in the photonics needs test and was based on the expectations of the researcher. Low is a score below 5, middle is a score between 5 and 7, and high priority was given to companies with grades higher than 7 or companies with a grade close to 7 and with high expectations of the researcher.

List of contact persons:

The following people were the contact persons at the different visited companies. They can be the change agents in the follow-up period of this research.

Company	Name	Designation	Address	Phone number	Fax	E-mail
Apollo Tyres Ltd.	R.P Sasikumar	Manager Engineering	P.O. Kalamassery, Kerala 683104	556504 (direct) to 266	532961	apolloky@sancharnet.in
Binani Zinc Ltd (division of Binani Industries Ltd)	Dr. T. N. Sureshkumar	Dy. Manager (R&D)	Binanipuram-683502, Kerala, India	540274, 540175, 540276	532134	Binzinc.cochin@sme.sprintrpg.ems.vsnl.net.in
Binani Zinc Ltd (division of Binani Industries Ltd)	P.N. Abdul Sahab	Gen. Manager (instrumentation)	Binanipuram-683502, Kerala, India	540175, 540274, 276, 277, 278, 541287, 541277 (Direct)	532134	binzinc@vsnl.com (sahab)

Tab. 27: List of Contact Persons (1/4)

Company	Name	Designation	Address	Phone number	Fax	E-mail
Carborundum Universal Ltd.	George Oommen	Manager-Manufacturing	Electro Minerals Division, P.B. No. 1, Kalamassery Development Plot P.O., Ernakulam Dist, Kerala, Pin-683109, India	540525, 541058	532019	georgeo@eda.cumi.co.in
Carborundum Universal Ltd.	Prathap Kumar	Executive-technical	Electro Minerals Division, P.B. No. 1, Kalamassery Development Plot P.O., Ernakulam Dist, Kerala, Pin-683109, India	540799, 541706, 541058	532019	prathap@eda.cumi.co.in
Carborundum Universal Ltd.	P. Achuthankutty	Executive	Electro Minerals Division, P.B. No. 1, Kalamassery Development Plot P.O., Ernakulam Dist, Kerala, Pin-683109, India	540525, 541058, 541706, 540309	532019	kuttya@eda.cumi.co.in
Cochin Special Economic Zone (CSEZ)	Paul Antony I.A.S.	Development Commissioner	Government of India, Ministry of Commerce & Industry, Kakkanad, Cochin 682030, India	422571, 422551	422530	dc@csez.com Website: www.csez.com
FUTURA Medical Products (P) Ltd.	Titus Daniel	Unit Chief	Plot No. 7, CSEZ, Kakkanad, Kochi 682030	423605, 421246, 421947 (Direct) 9847043605 (Mobile)	421947	lukens@md2.vsnl.net.in lukens@md3.vsnl.net.in
Hindustan Insecticides Ltd.	B. Unnikrishnan	Engineering Manager	Udyogamandal 683501, Cochin, Kerala, India	545121 to 23	545464	hiludi@md3.vsnl.net.in
Hindustan Latex Ltd.	P.M.C. Nair BE	Dy Manager Safety	P.B. No. 2, Peroorkada P.O., Thiruvananthapuram, 695005, Kerala, India	437270	435013	
HMT Ltd.	Suresh Balasunder BE, Mtech	Joint General Manager	HMT Colony, P.O. 683503, Ernakulam Dist., Kerala, India	540731	532166	suresh_b@vsnl.com hmtk@eth.net
HMT Ltd.	Tom Zacharia Mtech	Deputy Chief Manager	HMT Colony, P.O. 683503, Ernakulam Dist., Kerala, India	540731	532166	hmtk@eth.net tomzacharia@yahoo.com
Holmarc Slides & Controls (P) Ltd.	Jolly Cyriac	Managing Director	P.B. No. 2244, Edappally Toll Cochin 682024, Kerala, India	540075, 540882	540882	holmarc@vsnl.com
KMML	E.J. Anto	Deputy General Manager	Sankaramangalam, Chavara 691583, Kollam, Kerala, India	686722 (12 lines)	680101	kmml@md3.vsnl.net.in

Tab. 28: List of Contact Persons (2/4)

Company	Name	Designation	Address	Phone number	Fax	E-mail
Nanowave Technologies (P) Ltd.	Gopikrishnan S.	Director	Cochin E-land Complex, Cultes Road, Perumbadappu, Cochin 682006, India	423790, 9846191616 (Mobile)	235390	info@nanowavetec.com Website: www.nanowavetec.com
Nest Group	A.M. Iqbal	General Manager Corporate	Corporate Office, Plot No. 2, CSEZ, Kakkanad, Kochi 682030, India	422868, 422092	423297	ami@nestcorp.net
Nest Cyber Campus	G. Hariendran Nair Mtech, MBA	Dy. General Manager (Education)	Corporate office, Plot No. 2, CSEZ, Kakkanad, Kochi 682030, India	422868, 422587	423297	ghnair@nestcorp.net
Nest Power Electronics Pvt. Ltd.	P. K. Radhakrishnan	General Manager	Plot No. 43 A, Cochin Special Economic Zone, Kakkanad, Cochin, 682030, India	91-484-423949, 421993, 422037, 423237	424808	pkrkris@nestcorp.net
Nest R&D Centre	K.R. Suresh Nair, PhD.	Director	Plot No. 43 CSEZ, Kakkanad, Cochin 682030, India	427611, 427622, 427633, 9847045895 (Mobile)	427644	suresh@nestcorp.net
Nortpak Fibre Optics Pvt. Ltd.	Sen S.	Dy. Manager	Plot No. 2, CSEZ, Kakkanad, Cochin 682030	422092, 422868, 426287 (Direct)		sens@nestcrop.net
OEN India Ltd.	Cherian Varghese	Manager HRD	Electrogiri, P.B. No. 1, Mulanthuruthy 682314, via Cochin	711321 to 711328	711891	oenindia@vsnl.com
OEN India Ltd.	Victor Mathew	G-EDP&Process Eng	Electrogiri, P.B. No. 1, Mulanthuruthy 682314, via Cochin	711321 to 711328	711891	oenindia@md3.vsnl.net.in
OEN India Ltd.	Mohandas Mukundan	Chief General Manager, engineering resources	Electrogiri, P.B. No. 1, Mulanthuruthy 682314, via Cochin	711321 to 711328	711891	oenindia@vsnl.com
OEN India Ltd	Antony Alexander	Manager R&D	Electrogiri, P.B. No. 1, Mulanthuruthy 682314, via Cochin	711321 to 711328	711891	sales@oenindia.com Website: www.oenindia.com
Indian Aluminium Company Ltd., Alapuram Smelter	Abraham Koshie	Chief Manager Production and R&D	P.B. No. 30, Kalamassery 683104, Kerala, India	532441-48	532468	A.Koshie@indal.co.in
Indian Aluminium Company Ltd., Alapuram Smelter	V. Ramanathan	Asst. Manager R&D	P.B. No. 30, Kalamassery 683104, Kerala, India	532441-48	532468	Ramanathan.V@indal.co.in

Tab. 29: List of Contact Persons (3/4)

Company	***Name***	***Designation***	***Address***	***Phone number***	***Fax***	***E-mail***
Indian Aluminium Company Ltd., Alapuram Smelter	P.C. Bhasuran	Manager Electrical	P.B. No. 30, Kalamassery 683104, Kerala, India	532441-48	532468	Bhasuran.PC@indal.co.in
Indian Aluminium Company Ltd., Extrusion Business (IEBA)	V.T. Maneesh	Metallurgist	P.B. No. 21, Kalamassery 683104, Kerala, India	542499	541887	Maneesh.VT@indal.co.in
SABA Powerdex Pvt. Ltd.	Agit Kumar C.A.	Project Manager	Plot No. 40, CSEZ, Kakkanad, Kochi 682030	425969, 427121	427119	agit@nestcorp.net
Sun Fibre Optics Pvt. Ltd.	Jessy T.	Program Leader	Plot No. 37, CSEZ, Kakkanad, Cochin 682030, India	422590, 423087	422016	jessy@nestcorp.net
Sun Fibre Optics Pvt. Ltd.	Thomas John	Chief Executive Officer	Plot No. 37, CSEZ, Kakkanad, Cochin 682030, India	422590, 423087	422016	tjohn@sfoindia.com
Swiftlink	Abraham Thomas Mundamattom	General Manager	Plot No. 43, CSEZ, Kakkanad, Cochin 682030, Kerala, India	423638, 422037, 423237, 423465 (direct), 9847040321 (Mobile)	423297, 424735	abrgomas@nestcorp.net

Tab. 30: List of Contact Persons (4/4)

Appendix G: Data on the different companies with high photonics needs score

Special Incentives Cochin Export Processing Zone, Kakkanad:

The Nest group has the location in Kakkanad in the "Export Zone". In this Zone, power cuts are not so frequently as in normal Indian life and the companies there get a subsidy from the government as well. There is no export into India from this side, but every product is shipped back to the USA after assembling. Special incentives in the export zone are:

1.) 50 % subsidy and 40 % loan towards cost of feasibility studies
2.) Investment subsidy at 15 % subject to a maximum of Rs 15 lakhs.
3.) Exemptions from power cuts, stamp duty and registration charges of instruments relating to lease, conveyance etc.
4.) Promoter contribution in respect of SC/ST entrepreneurs need be only 10 %
5.) Interest of term loans to SC/ST will be subsidised to the extent of 20 %
6.) Direct participation in share capital by State Financial Institution will be accepted in case where SC/ST entrepreneurs are unable to mobilise shares their own from the general public
7.) Exemption from the payment of property tax.
8.) Special schemes and machinery to ensure industrial peace in CEPZ.

Nest R&D Centre:

It was founded in the year 2000 but it was part of the Nest group since 1995. The company is a service lending company; all of the R&D from the Nest group is done there. Collaboration could lead to application within all the companies of the Nest group. Their main customers are other industries and government institutions and they have about 25 of them. In the total Nest group in Kakkanad about 3000 people are employed but the R&D Centre counts about 70 people. Of these people 50 are technical staff, 8 are administrative staff and 8 are managing staff. 20 people have a master's degree and 30 people have a bachelor's degree. There is 1 employee with a PhD in photonics. The main goal of the R&D department is to develop products in the field of electronics, photonics, RF (Radio Frequency) and Mechanical engineering. Other employees also do R&D as well, other than the people working in the Nest R&D centre. The number of people varies within the different companies within the Nest group. They also use a lot of photonics technology themselves for example to align fibres and polishing etc.

Swiftlink Pvt. Ltd.

Is also part of the Nest group and was founded in 1995. It is a product making company and they manufacture fibre optic passive devices. They are a medium scale company that means a turnover of between 200000 and 400000 US dollars per month. Their products are fibre optic couplers, fibre optic attenuators, fibre optic patch cords and fibre optic terminators. This company sells its products to one company in the USA where the products are marketed and soled. There are about 200 people employed in this company with 25 people working as technical staff, 15 people working as administrative staff and 5 people working as managing staff. 12 people are engineering graduates (B. Tech., M. Tech, PhD.), 20 people are diploma holders, 150 people are ITI certificate holders and 15 people are science graduates (B. Sc., M. Sc., M.Sc. and M. Tech an PhD.). M. Tech. is the highest level of education within this company. The corporate Nest group R&D Centre provides this company with services. Their production process is capital intensive and they use photonics technology within their production process.

SABA Powerdex Pvt. Ltd.

This company was reorganised into the current form in 1999 and has been a part of the Nest group since 1991. It is a product making company and they manufacture Lithium batteries. They belong to the small-scale companies and they manufactured 2 million batteries in 2001. They sell their products to other industries, probably in the USA. There are 85 people working in this company of which 65 work as technical staff, 15 as administrative staff and 5 as managing staff. 8 employees are engineering graduates, 3 employees are Diploma holders, 50 employees are ITI certificate holders and 2 employees have a science degree. The highest level of education is this company is M. Tech. They use photonics technology within their production process.

Apollo Tyres Ltd.

This is a company that was founded in 1961 and which manufactures Automotive Tyres. The company is located all over in India, namely in Bangalore and Madras. It is a large-scale industry. They manufacture four specific products in Kallammassery namely: truck tyres (350000 per year), farm tyres (36000 per year), passenger car tyres (70000 Per year) and light commercial vehicle tyres (30000 per year).
They supply final consumers, other industries and government institutions. There are about 1100 people working within the company and the highest level of education is M. Tech, MBA and C.A. There is no R&D department present but they have a corporate R&D facility.

Binani Zinc Ltd.

The company was founded in 1962 they manufacture basic metals. The main products are Zinc Ingots (30000 Mt per year), Cadmium Metal (65 Mt per year) and Sulphuric Acid (51000 Mt per year). They provide their products to other industries. There are 442 people employed in this company. 378 people work as technical staff, 64 people work as administrative staff and 113 people work as managing staff. 29 people have a B. Tech degree in engineering, 2 people have a M. Tech degree in engineering, 25 people are Diploma holders, 20 people are ITI certificate holders, 10 people have a B. Sc. degree in science, 7 people have a M. Sc. degree, 9 people have a M. Sc. and a M. Tech degree and 2 people have a PhD. There is an R&D department present, which has as primary objectives: Trouble shooting, waste utilisation, by-product recovery, raw material characterisation, process control and quality control. 20 people work in the R&D department of which 4 people have as highest degree in education SSLC, 4 B. Sc., 3 B. Tech., 6 M. Sc., 1 M. Tech and 2 PhD. The production process is capital intensive. Their production process as follows: Concentrated ore, namely zinc concentrate, is roasted to produce ZnO, which is dissolved in dilute sulphuric acid too produce a $ZnSO_4$ solution. The solution that was produced is purified and electrolysed to produce Zinc Metal. This process is basically a chemical process and they could use fibre optic sensors to control this process. Also they were interested in the time of this research in expanding their pick and place machine with a laser to control its position more accurately.

KMML (Kerala Minerals and Metals Ltd.)

When this company was founded was unclear but it has to be before 1979, because the respondent has worked in this company since. They are a large-scale industry and they manufacture titanium-dioxide pigment (rutile), which is used in paint, plastics, rubber, paper, ink etc., Titanium Tetra Chloride, which is used to make titanium sponge (metal), titanium chemicals and titanium dioxide, synthetic rutile, Rutile, which is used in welding rods and Zircon, which is used to make refractory foundries, sand and ceramics. Of the Titanium-dioxide pigment, 25000 Mt is produced per year. Of the Titanium Tetra Chloride, 60000 Mt is produced per year. Of the synthetic rutile, 2000 Mt is produced per year. How much is produced of the others products did not became clear from the questionnaire. They provide their products to about 100 other industries. There are 2500 employees within this company. 200 of them work as technical staff, another 200 work as administrative staff and 50 employees work as managing staff. 50 people have a B. Tech degree in engineering, 10 people have an M. Tech degree in engineering, 200 people are Diploma holders, 100 people are ITI certificate holders, 100 people have a B. Sc. degree, 15 people have a M. Sc. degree and 20 people have an M. Sc. and M. Tech degree. There are no PhD. holders in this company. There is an R&D department present, which has as primary objectives: new product development, process/quality improvement and waste management. There are 4 people working with a M. Sc. degree in this department. Their production process is the following: beach sand is mined and separated to produce ilmenite, zircon and rutile. Ilmenite is upgraded chemically to produce synthetic rutile. Synthetic rutile is chlorinated to produce TICL4. TICL4 is oxidised to produce T102 pigment. Pigment is surface treated to produce the final pigment. KMML earned the highest profit in the state of Kerala, which was Rs 96.66 crore (Government of Kerala, 2000).

Appendix H: The environment

India's national economy:

During 1999-2000 all India GDP growth in real terms is placed at 6.4%, which means a decline from the growth rate of 6.8% during 1998-1999. The national growth rate is projected to decline even further in 200-2001 to 6% (Government of Kerala, 2000). This report from the government of Kerala also indicated a decline in the Gross Domestic Savings Rate from 24.7% in 1997-1998 to 22.3% in 1998-1999, a decline in investment rate as the Gross Capital Formation (GCF) declined from 23.4% in 1997-1998 to 21.8% in 1998-1999 and a decline in Foreign Direct Investment from US $ 2000 million in 1998-1999 to US $ 1581 million in 1999-2000 (Government of Kerala, 2000). This means that the Indian economy is witnessing a recession. This no doubt has repercussions for the state of Kerala as well as for the rest of India.

Kerala:

Kerala has always been one of the richer parts of South-India and it still continues to be so. It has a literacy rate of more than 90% and education is regarded more highly than in other parts of India. The fact that Kerala has been a communistic state until May 2001 has made it that people are probably better of here than in Tamil Nadu for example. Bureaucracy and corruption are still order of the day but the unions in Kerala are very powerful and this gives the people the strength to object to miss-management from the state government. During this research there was a strike of all government employees that lasted for 35 days. There has to be an enormous amount of money lost because of the frequent strikes.

Because of the fall of prices of principal agricultural commodities such as coconut, rubber, pepper, cardamom, tea coffee and so on, the economy of Kerala has been passing through some extremely difficult conditions. The industry in Kerala is still largely agricultural. The decline in the revenues in this sector also constraints the income of the entire state. The State Income (SDP) at current prices is in 1999-2000 estimated at Rs 62,557 crore[1] as compared to Rs 53,553 crore in 1998-1999. The per capita income at current prices is estimated at Rs 19,461 in 1999-2000 as against Rs 16,811 in 1998-1999. Unemployment continues to be a major problem of the State. The number of job seekers on the live registers of the employment exchange continues to be quite large, the latest figure being 41.86 lakhs[1] in 2000 (Government of Kerala, 2000). An important dimension of the unemployment situation is that about 75% of the job seekers are having educational qualification of SSLC or above and 55.27 % of the job seekers are women.

Item	*1970-71*	*1980-81*	*1985-86*	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*	*1994-95*	*1995-96*	*1996-97*	*1997-98*	*1998-99*	*1999-00*
State income at current prices (Rs Crore)	1255	3823	6503	10668	12173	15102	17175	23217	28375	34470	39656	46178	53553	62557
Per capita income at current prices (Rs Crore)	594	1508	2398	3718	4200	5140	5768	7727	9327	11190	12716	14642	16811	19461

Tab. 31: Economical indicators of the state Kerala (Government of Kerala, 2000)

Industry in Kerala:

The economic policies of indiscriminate liberalisation pursued by the Central Government of India have created a situation where Indian industry in general, and small scale sector in particular are seriously threatened (government of Kerala, 2000).

[1.] 1 crore = 10,000,000 Rs and 1 Lakh = 100,000 Rs

The government of Kerala has been pursuing Public Sector reforms in the state. The following issues are being addressed:

1.) Moving away from continued dependence on Government protection.
2.) Building up an overall culture of productivity and efficiency in the organisations.
3.) Managing competition from both domestic and foreign environment.
4.) Controlling and cutting down cost at every level.
5.) Adoption of appropriate manpower policy in the PSUs (Public Sector Units).
6.) *Introducing modern production system and technology.*
7.) Improving working conditions, ensuring quality and productivity standards.
8.) Managing change as a collective effort by involvement of management, trade unions and Government.

The sixth reform in this policy suits very well with all the problems addressed in this research. Modern production systems, like the ones in developed countries, have very strong linkages between universities and industries. The knowledge base of these countries increases through interaction and the production units can produce more efficiently and productively through innovative technology. “New and better ways of doing things” secure the competitive advantage of the entire nation. In short, in every modern production system linkages between institutions like universities and R&D institutes and the industry are of the utmost importance.

The performance of medium and large-scale industries during the year 1999-2000 was encouraging according to the Economic Review 2000 of the Government of Kerala (2000). The highest profit was earned by KMML (Kerala Metals an Minerals Ltd.) and was Rs 96.66 crore.

The number of man-days lost in 1998-1999 on account of strikes and lockouts was higher than in 1997-1998, 10.88 lakh. This number was lower than the number in 1996-1997 (14.33 lakh).

The number of working factories in 12 districts increased compared to the previous year, while it decreased slightly in Kottayam district and remained at the previous year’s level in Wayanad. Ernakulam district has the highest number of factories, namely 2,858, followed by Thrissur (2556), Palghat (2004) and Kollam (1817). (Government of Kerala, 2000)

Schooling system in Kerala:

Figure 11 represents the schooling system in Kerala in general. There are some further additions possible, like the ITI certificates and the Diploma certificates. This figure represents the schooling system in a technical university like CUSAT. There are also MBA courses in CUSAT and they follow the same kind of scheme as the technical streams. SSLC is the basic schooling that everybody gets. This is mandatory. After SSLC people go for Pre-degree after which they choose for either the science stream or the engineering stream. The B. Tech degree is comparable with the American B. Sc. degree and the M. Tech. level is comparable with the American M. Sc. degree. There are also private schools and there are schools for doctors and lawyers etc, which are not part of the figure 11. In this research, an understanding about the technical school was only needed to assess the technical capability of a firm. Lawyers and doctors do not tend to have a very wide understanding of engineering.

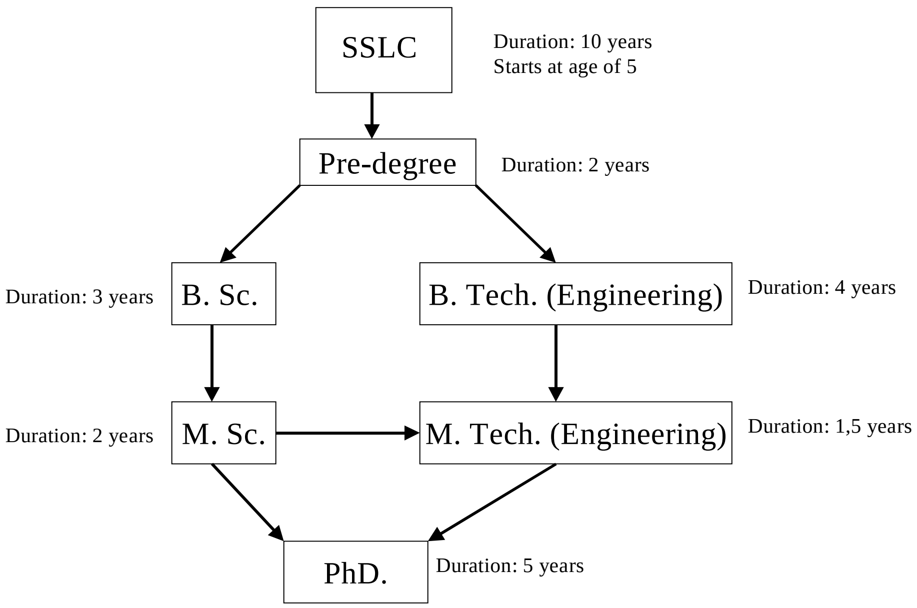

Fig. 11: The Technical Education System in Kerala

Appendix I: Design and Development of Fibre Optic Sensors

Proposed work plan:

Monitoring of gases will be carried out using the "evanescent wave technique". In evanescent wave absorption spectroscopy, the penetration of evanescent wave (EW) of a total internal reflected light into an absorption medium decreases the net amount of light guided through the fibre to its termination. A system working on the basis of the EW technique employs a multimode fiber with its cladding removed from a certain region. The uncladded region of the fiber that functions as the sensor element will be coated with metallo phythalocyanines or certain specific dye which shows selective adsorption corresponding to different gases. Laser light transmitted through fiber is detected using a fiber power meter. The pollutants flowing over this sensor element gets adsorbed and brings about a change in the peak absorption wavelength. This leads to a variation of the intensity of laser light guided through the fiber, which is a function of the nature and concentration of the pollutant gas. In fiber optic sensors to determine the concentration of contaminants in ground water, the sensor element will be enclosed in a cell containing the contaminated water. Change in the refractive index/adsorption surrounding the sensor element due to the contaminants brings about a change in the intensity of the light guided through the fiber.