Acreo Fiber Optic Center

Annual Report 2008

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VINNOVA

IN PARTNERSHIP WITH THE Knowledge Foundation

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Summary

The following annual report highlights results at Acreo Fiber Optic Center in 2008. The report span the Center's applied research and innovation on fiber optic technologies, our technology development of fiber optic systems and applications, and our communications activities.

2007-2008 in numbers

- 43 scientific papers in journals and conference proceedings
- 6 student theses (MSc and PhD)
- 1 book and 1 book chapter
- 2 patent applications, more under preparation

- 20 industrial partners
- 11'000 contributed hours from industrial partners
- 4 academic groups participating
- Around 70 researchers and engineers involved in the activities each year.

Introduction

Fiber optics - an enabling technology with many applications

The optical fiber is best known for its ability to carry information at high speed over long distances. In 2008, twenty years after the first transatlantic fiber optic cable, practically all long distance telecommunications are carried by optical fiber, and the number of fiber installations to the home or premises is continuously increasing.

Less often thought of are a multitude of other applications where optical fiber technologies are exploited in a variety of ways. Fiber optics has a number of unique features, such as the capacity to carry high optical powers in flexible light guides for welding stations, the ability to transfer images in endoscopes, the beam quality and compactness of fiber lasers, distributed sensing along pipelines, and low weight and high transmission bandwidth in avionics.

Conveniently, many of the underlying fiber optic technologies are common to different systems and solutions. In fact, this is one of the cornerstones of Acreo Fiber Optic Center. In the Center, industrial partners from different application areas have a common interest in the development of generic fiber optic technologies so that these can then be adapted to their own particular need.

Optical fiber technologies will continue to enable new and better solutions in a range of industries. The investment into a generic fiber optic platform will help the Swedish industry to exploit the possibilities. We firmly believe that the importance of fiber optics, besides telecom, will be widely evident over the next few decades.

About Acreo Fiber Optic Center

Acreo Fiber Optic Center (www.acreo.se/fiberopticcenter) is a center for research, development and innovation in fiber optics. It was created when a number of partners signed an agreement to collaborate with the purpose of creating new and improved fiber optic solutions. The Center has received an *Institute Excellence Center* award from Vinnova, SSF and KK-foundation, as well as complementary funding from Region Gävleborg and Nutek (within EUs strategic regional funding program). The activities started in January 2007.

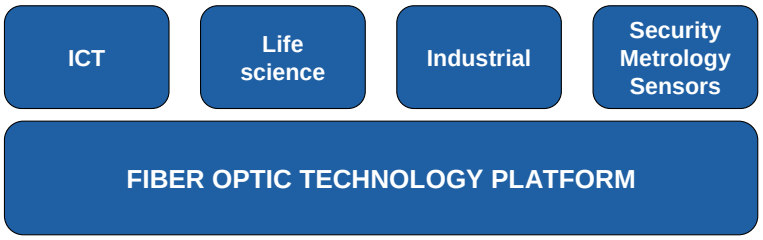
Presently, 20 industrial partners in the Center represent different industrial sectors, including tele-communications, medical technologies, defense, manufacture and instrumentation. The four academic partner groups are located at KTH, Mid Sweden University and Karolinska Institute. Acreo is the coordinating partner.

About Acreo

Acreo AB (www.acreo.se) is Sweden's largest research institute in optics, microelectronics and communications technologies. Acreo supports Swedish industry with innovations, competence, resources and R&D expertise within the focus areas of the institute. The overall aim is to generate growth in Sweden. Acreo AB is a part of Swedish ICT.

Technology platform → Applications

The technical activities in the Center are structured in two major programs targeting a Technology Platform (Research Program) and Applications (Applied program). The structure is based on the fact that fiber optics is an enabling technology that can be exploited in a wide range of application areas.

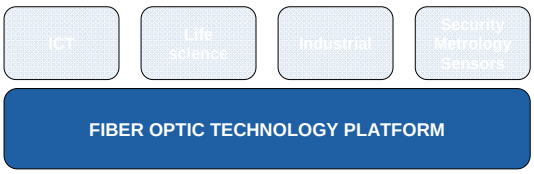


- **Technology platform**
  Research and innovation on specialty fibers, fiber Bragg gratings, fiber components and sensing techniques. The platform sets a solid scientific base for the Center. The projects are exploratory and there is a close collaboration with university staff and students.

- **Applications**
  Industrial solutions are developed using different fiber optic techniques. These projects are of a more applied character, and aim at the development of new and improved products for the participating partners.

The two programs are closely interlinked. Already in this second year, we see technologies that are developed in the research program being exploited in the applied projects. For example, IPR for nanosecond switching is being studied for use in fiber laser cavities. Another example is a technique for depositing inorganic coatings on fibers, a technique that is now being verified for products.

Technology platform – Research program



Here, the Center carries out research on novel glass materials, specialty fibers, fiber Bragg gratings, fiber components and sensing techniques.

The platform sets a solid scientific base for the Center, and ensures the development of new technologies and innovations. The projects are exploratory and carried out in close collaboration with university staff and students.

A high degree of innovation is essential for the research to benefit the partner consortium. We also get specifications and constraints in dialogue with the industrial partners, so that the investigations are carried out with the knowledge that the academically interesting results become interesting also from an industrial perspective.

The work can be said to focus on new and better fibers and fiber components, and their original use in new fields.

The technology platform projects are:

- Specialty fibers
  - Harsh environment fibers
  - Photodarkening
  - Fiber drawing processes
- Functional Fibers
  - Electrically controlled fiber
  - Micro fluidics
  - Minimally invasive technologies
- Fiber Bragg gratings
- Fiber optic sensors

Specialty fibers

Acreo Fiberlab in Hudiksvall

The term *specialty fiber* is used for almost any type of optical fiber except for the highest volume telecommunications transmission fibers. A specialty fiber is either a value-added standard fiber (e.g. by providing a coating that protects it from harsh environments) or a fiber with special intrinsic properties (e.g. with special dopants, refractive index profile, geometrical structure, strength etc).

For example, when optical communication is deployed in oil and gas production systems, in mines or on cargo ships, the requirements on shock, vibrations, temperature ranges, tensile stress, and ambient protection is typically higher than in normal communications installations. Here, a specially coated fiber is required.

In other cases, the quest for compactness requires fibers with low optical loss on bending and small fiber diameters. Yet other applications need special glass compositions, fiber geometries or guiding properties to provide sensing functions. The solution for all these applications is a specialty fiber.

Acreo Fiberlab is a state-of-the-art resource for developing and producing specialty fibers. The facility is one of the leading labs world-wide, and the resource allows Acreo Fiber Optic Center to adapt fibers for use in new fields (e.g. process industry) or in novel products (e.g. special sensing configurations).

Harsh environment fiber

Carbon coated fibers with their characteristic dark grey color.

When using fiber optic solutions in challenging environments, the fibers needs to be extra protected. For example, down-hole oil recovery applications commonly display temperatures above 150 °C and hydrogen rich atmospheres, and the fibers need a hermetic, high temperature coating. A few established fiber types are used for these applications, but they have their draw-backs. For example, the hermeticity of carbon fails at temperatures above 200 °C.

The long term target of this project is to develop materials and coating techniques for fibers, to enable the implementation of fiber solutions in harsher environments than are possible today. The first target has been to develop a technology for hermetic fibers for moderate temperatures (up to 170 °C), using carbon as the hermetic coating.

A process for depositing carbon coating on fibers is not unique, and several other fiber manufacturers have this capability. Instead, the vision of this project is that the CVD platform can be extended to other materials, once we have established the carbon process.

When this project started, it involved in depth studies of processes and kinetics of chemical vapor deposition (CVD). Over the course of the project, the research on CVD processes has given way for process development and verification of the same coating technology.

In 2008, we have developed a process for hermetic carbon coatings on fiber, as well as techniques to combine the carbon coating with polyimide. The hermeticity of the fibers was verified by exposing fibers with and without carbon coatings for up to 14 days at 1 atm H_2, 170 °C. The induced losses for the carbon coated samples were barely detectable (less than 0.2dB/km), compared to the high losses induced in conventionally coated reference samples (~10dB/km). The results were verified for both singlemode and multimode fibers. Tests of mechanical strength and fatigue after aging were also carried out, with excellent results.

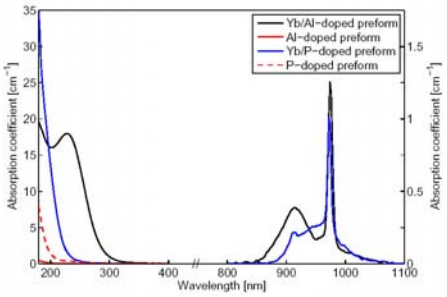
In parallel, research on alternative materials has continued. It is the ambition that the CVD technology will be extended to other inorganic functional coatings, to provide even better protection, or to provide the fiber with novel coatings.

The activities in the project involve materials and fiber drawing expertise at Acreo, materials expertise from Pekka Soininen and others at Beneq, and applications expertise from Dr. Saeed Rehman at Fiberlogix. Dr. Lars Norin is driving the research with technical support from Mats Eriksson, Helena Ericsson-Qvist, and Håkan Olsson at Acreo Fiberlab.

Photodarkening

When operating fiber lasers at high powers, there is typically a gradual decrease in laser efficiency. The degradation reduces the lifetime of the lasers, and has been a significant limitation for the introduction of fiber lasers into the high power market.

The effect has been termed 'photodarkening'. Its origin and possible countermeasures has been a debate in the glass material and optical fiber community for some time. The problem is particularly relevant for pulsed lasers operating at high inversion.



The key to understanding photodarkening lies in the ultraviolet absorption characteristics.

In a PhD work carried out at Acreo and concluded in 2008, Magnus Engholm explained some of the physical mechanisms responsible for photodarkening. In short, the key lies in understanding the absorption characteristics in the ultraviolet part of the spectrum and the possibility of mixed valence states for the lasing ion. For ytterbium-doped materials, the excitation of a charge-transfer absorption band in the ultraviolet leads to the formation of free charges in the matrix. These charges, in turn, are responsible for an increased optical loss. The position of the charge-transfer band is different for different silica hosts, e.g. for alumino- or phosphosilicate glasses. By using a host with an absorption edge shifted further into the ultraviolet, it was demonstrated that photodarkening can be decreased to very low levels.

The theoretical understanding of the origin of photodarkening now opens for improved materials for high power lasers. Indeed, recent results from Acreo describe the codoping with cerium to mitigate photodarkening, a result that has received much attention in the high power fiber laser community. We believe that the results will help to firmly establish fiber lasers for use in the high power regimes.

The project has had the participation from PhD student Magnus Engholm and experts at Crystal Fibre in Denmark, besides the supervision by Dr Lars Norin and the MCVD expertise of Niclas Sjödin at Acreo.

Fiber drawing processes

In 2008, we have developed processes for e.g. reducing the fiber twist to a few degrees per meter. With a minimized twist, the polarization effects are more predictable in components made from the specialty fiber. The twist is also important in e.g. image transfer fiber, where the image should not be distorted or rotated when transmitted.

Control of the fiber drawing process.

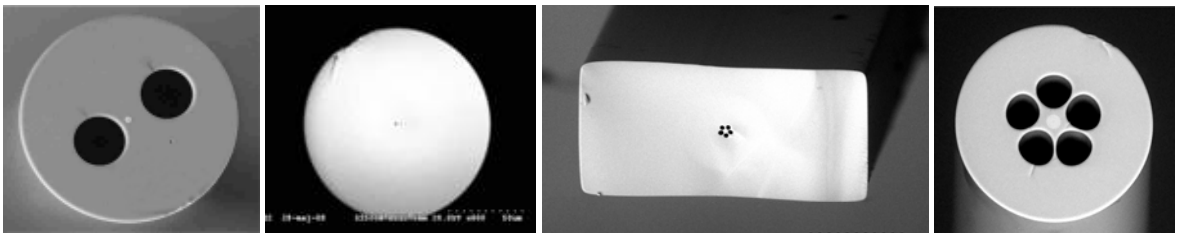
We have also started the development of all-fiber high power components, combining expertise in glass processing, fiber drawing, coating techniques, components development, high power lasers and photo induced effects in glass.

The R&D on fiber drawing techniques is driven by Dr Per Helander, together with the fiber drawing experts at Acreo Fiberlab.

Functional fibers

Acreo has developed unique technologies and processes for designing and manufacturing microstructured fibers. These are fibers with non-standard geometries. A typical structure has one or several holes, 10-40µm in diameter, in the cross-section of the fiber. Other fibers have one or more flat surfaces, square holes, micron-sized structures or several cores. Fiber sizes can range from 50µm to a few millimeters in diameter. Another proprietary technology is the filling of fibers with metal electrodes.

The development of components and technologies based on these microstructured fibers is the focus of the project Functional Fibers.



Acreo designs and manufactures some of the world's best microstructured fibers.

Electrical control of fibers

Although silica optical fibers are the best type of waveguide known to man, in contrast to III-V semiconductors, it is difficult to perform in fibers functions such as modulation and switching. Thus, fiber lasers are not as easily controlled as semiconductor lasers. Fibers are used in optical switching demonstrations, but generally not controlled using electrical pulses, as $LiNbO_3$ crystals are. In order to gate light in a fiber, one needs to couple out the light and use external means, such as Pockel's cells, mechanical choppers or pigtailed components. This is clearly a missing functionality.

Electrooptic phase modulator using a poled fiber.

Electrically controlled fibers are one focus of our research activities. Potential applications of these fibers range from high speed spectroscopic studies (e.g., for laser breakdown analysis of metal debris) to pulsed fiber laser marking, and from studies of brain activity in mice to switching and polarization control of light in optical telecom systems.

In order to allow for electrical switching, fibers are fabricated with holes and provided with internal metal electrodes. Two complementary techniques are used to this end, one based on the application of current pulses to the internal electrodes, causing the creation of a shock wave in the devices. The other technique is based on poling the fibers with high voltage at modest temperature (<300 °C), after which our fibers become electrooptic, i.e., the refractive index can be adjusted with the application of an electric field.

Based on the shock-wave principle, we have developed devices within the framework of the Center (IP applied for) where the transmission of a fiber can be gated within nanoseconds. The polarization of light in the fiber can be rotated with the application of a nanosecond current pulse and rotated back again with a subsequent electrical pulse. This allowed us to select single pulses out of a sequence of mode-locked pulses in an all-fiber and all-spliced arrangement.

When placed inside a fiber laser cavity, this fiber light gate can be used to rapidly switch the laser from an OFF-state to an ON-state. Q-switching is of interest because all energy pumped during a long off-period can be extracted in a short nanosecond pulse, for laser marking without excessively heating the sample. At present, the technology is being further verified in a project outside the scope of Acreo Fiber Optic Center. Further, the interest raised with the start-up company Swedelase led to

their affiliation to our Center and the establishment of a development project of a fiber laser incorporating our device. These activities are further mentioned later in this annual report.

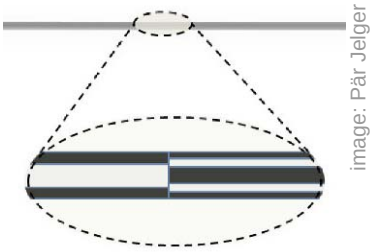
Not only do our devices have performance parameters that have not been achieved anywhere else, but they have been developed into rugged prototypes, in packages that allow for their shipment and use in other laboratories and research environments. The picture above illustrates a phase modulator incorporating a poled fiber.

Our group is internationally leading in the technology of electrically controlled fiber, and our technique starts being reproduced in the various countries, including the UK, Australia and Brazil in research groups with which we maintain strong collaboration links. These take concrete expression in the form of visits by scientists from those countries, shipment of our components to them for tests and common research, participation in applications for external research projects funded by entities abroad (e.g., Australia) or internationally, invitations for participation as examiners in PhD dissertations, invitation to write or edit a book, etc.

From the end of 2008, the activity of electrically controlled fibers has the engagement of one full time PhD student (Mikael Malmström) and one part time PhD student (Pär Jelger), supervised or co-supervised by Walter Margulis. This work is being carried out in association with the Laser Physics group of the Department of Applied Physics of the Royal Institute of Technology, with the engagement of Prof. Fredrik Laurell and Docent Valdas Paskiskievics. At Acreo, a few senior scientists work on these activities, from close to 100% of the time (Oleksandr Tarasenko) to some 20% (Ralf Koch).

Micro fluidics

An additional way of exploiting optical fibers is in the form of micro fluidic devices, where light co-exists with liquids or gases in various geometries. The ability of fabricating light-guiding fibers with internal holes or simply capillaries that are filled with fluids is essential here, and our Center dominates this technology. Various application areas can be addressed.



Flow separation and detection technique in electrophoresis experiment.

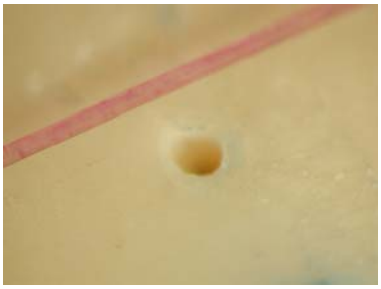
In biology and medicine development, proteins and tagged cells can flow in a buffer in the holes and be excited or interrogated by light. This is then used for identification of protein sequences. Capillary electrophoresis for DNA sequencing is an area of our interest

By filling the capillary and fiber holes with various highly nonlinear liquids, or solutions containing quantum dot materials, a new dimension is gained in nonlinear fiber optics. Without ever leaving the spliced fiber construction, light can move from glass to liquid and to nanoparticles, and even be affected by electric fields applied by means of internal electrodes. This work is now being developed with KTH and in parcery with a research group in Brazil, and has envisaged applications in electric field sensing, dispersion compensation, laser physics and nonlinear optics.

A third application area that is possible but that so far not been implemented by us is the use of the holes for the collection of gases for sensing and monitoring. The technique could be useful for sampling in e.g. chemically aggressive or sensitive environments such as the exhaust of processing plants in the steel industry or in the exhaled air from hospital patients.

The work in micro fluidics was carried out in 2008 in collaboration with KTH by Prof. Fredrik Laurell, Dr. Mårten Stjernström and PhD student Pär Jelger, and Prof. Gunnar Björk and student Aziza Sudirman, whose research activities are described below. Our main exploitation avenues are so far scientific publications, graduate theses and IPR. Industrial contacts in this area are still incipient.

Minimally invasive technologies



Bone ablated by laser. The pink line is an optical fiber.

Following discussions with colleagues performing bone-marrow transplantations in leukemia patients, we identified the possibility of using light in a fiber to open small holes in bones to allow for blood transfusion, using fiber side-holes for the collection of fluid. We believe that this technique could be less damaging than the ones used at present, and make possible other surgery, such as opening peep-holes for brain tumor biopsy. Likewise, the removal of hard material in stones with guided laser light, and the collection of fluids trapped in inclusions with fibers are of great interest to geologists, since the contamination risk is reduced by the minimal handling. Both applications require the combination of high power optical delivery with the collection of liquid samples by micro fluidics. A third aspect identified was the advantage of guiding the ablation and collection processes by means of reflectometry.

We set out an ambitious project aiming at demonstrating the combination of laser ablation and liquid sample collection through fiber holes, both guided by optical reflectometry in a single optical fiber. This is obviously a long term project, with several phases of development and improvements both in vitro and with animal model before implementation for clinical use.

The project started in October 2008 after a long delay. A master's student, Aziza Sudirman, made considerable progress during this period and has been able to combine reflectometry and micro fluidics in a series of convincing demonstrations. Thin samples are also being laser ablated at present. It is hoped that the project will continue with a PhD scholarship at the rapid rate of achievements of this initial phase also in the next months.

The project has the participation of Prof. Gunnar Björk at KTH and Prof. Moustapha Hassan at Karolinska Institute in Huddinge, besides supervision by Walter Margulis at Acreo and the work of Aziza Sudirman. The research group of Nils Holm at the Geology Department of Stockholm University is also involved in the research.

Fiber Bragg gratings

Fiber Bragg gratings (FBGs) are spatially periodic perturbations created by exposing the fiber from the side to a UV laser beam. Acreo has an advanced facility for fabricating such components, and has raised an international reputation in the field over the last 15 years. The field has evolved from basic research in the early 1990's to a mature technology employed in telecommunications and fiber sensors.

High speed fiber Bragg grating switching

The main focus of our activities in FBGs in our research program this year centered on the combination of gratings with electrical control using fibers with internal electrodes. We have demonstrated the possibility to steer the gratings in nanoseconds. High-speed wavelength switching is thus possible, with applications in fiber lasers, spectroscopy and radar.

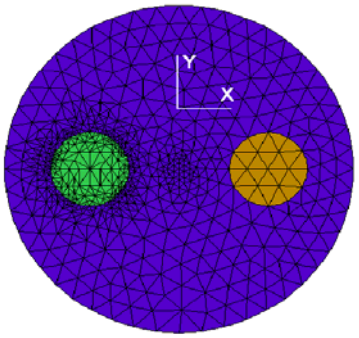


image: Zhangwei Yu

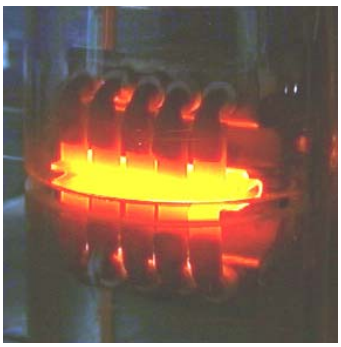
Finite elements mesh for analyzing the response of FBGs to shock-wave pulses.

This work was carried out at Acreo as the second half of a PhD thesis by Zhangwei Yu, under the supervision of senior scientists Pierre-Yves Fonjallaz and Walter Margulis, and at KTH by Prof. Lars Thylén. The work raised wide international interest and Zhangwei was invited to transform her thesis into a book, already published.

More recently, a diploma work student (Patrik Rugeland) started investigating the use of such electrically tuned fiber Bragg gratings for rapid sweep of radar frequencies. This work is carried out in collaboration with Saab Avitronics, and briefly described later in this report.

High temperature gratings

Another area that our research program approached is the fabrication of high temperature gratings, first developed at Acreo a few years ago. The gratings that are originally created by UV exposure become, after processing at high temperature, a spatially periodic distribution of chemical elements (fluorine or oxygen) in the glass core. This leads to a periodic refractive index modulation and reflection of light at the particular wavelength that matches the periodicity. These grating are potentially stable to >1000 °C. Applications envisaged in the near future involve the oil industry and well as studies of combustion engines at high temperatures. Acreo receives regular demands for gratings of this type. There are still issues that are both of research interest and of practical importance, such as a long term finite wavelength shift of the Bragg peak of fibers kept at temperatures close to or above 1000 °C.

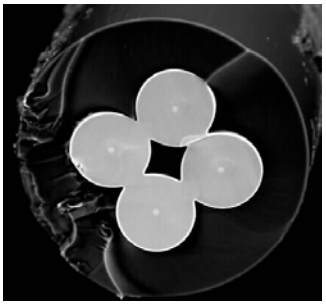


The gratings are processed at high temperatures after UV exposure.

A master's student worked on the subject (Hanna Lundbäck from KTH, supervised by Carola Sterner at Acreo) and further investigated some important aspects of the technology.

Fiber optic sensors

Siamese fibers for sensing



Siamese fibers.

Acreo has recently developed a way of fabricating multiple fibers in a Siamese arrangement. As illustrated in the picture above, where four fibers are drawn as one, the individual fibers are still clearly identified, but connected in a single glass entity. Two and four Siamese fibers have been manufactured. Multiple fibers can be used for the creation of fiber monolithic interferometers, where the various arms of the interferometer are rigidly connected and have strictly the same length. Input and output coupling can be performed to individual fibers and to sources and detectors with low loss.

One reason for this development was the interest by various international research groups in fiber Bragg gratings in multicore fibers. The close proximity of the cores ensures similar temperature effects in all cores, while bending leads to the wavelength of the FBGs shifting differently depending on the direction of the fiber bend. Our Siamese components allow the same sensitivity to bend, while facilitating low-loss coupling. Collaborations are being established with research groups working towards the oil industry for pressure and displacement sensing.

Besides the glass work and fiber drawing expertise at Fiberlab that have made these fibers possible, the development of processes for splicing (Erik Zetterlund) and writing fiber Bragg gratings (Dr Carola Sterner) in these fibers have been essential for making components that can now be studied for sensor applications.

Low cost coupling loss sensor

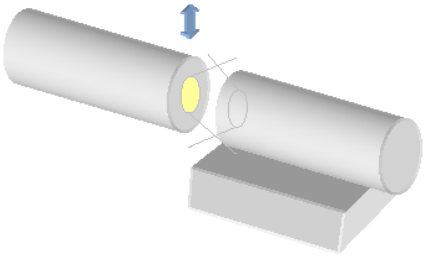


image: Johan Jason

Schematic configuration of the fiber optic temperature sensor. The movable fiber is mounted on a flexing bimetal plate.

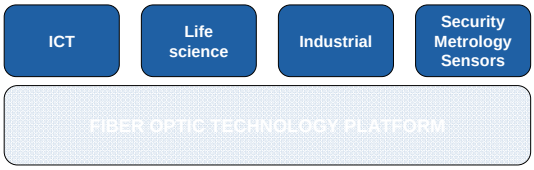
The project aimed at developing a low-cost, high sensitivity, intensity modulated sensor that could be easily interrogated and networked using either an optical time domain reflectometry (OTDR) system or simple light emitting diode and photo detector-based equipment.

A sensor configuration was designed, based on the coupling loss between two fibers (see illustration). The sensor can be used for displacement and vibration measurements. Mounting the moving fiber on a flexing bimetal plate turned the configuration into a temperature sensor. A number of these sensors were installed to monitor the cooking process of wood chips in pulp production (at Iggesund Paperboard AB).

This licentiate project was concluded in 2008, when Johan Jason at Fiberson defended his thesis. Johan has been supervised by Prof. Hans-Erik Nilsson at Mid Sweden University, and by Dr Bertil Arvidsson, Ericsson Network Technologies AB. Johan now continues his PhD thesis work with other OTDR-related technologies.

Applications – Applied program

These activities aim at the development of new and improved products for the participating partners.



The fiber optic technology platform (research program, described on pages 6-13nefit all these applied projects. Indeed, several of the results from the research program are already being studied for specific applications, e.g. the shock-wave switching technique for fiber lasers.

The fact that these projects are carried out within the Center has been beneficial in several ways. In particular, a dialogue between partners and projects on specific technical issues have provided better solutions. For example, one partner of the center acquired components from another partner for high power beam delivery into fibers through Acreo's mediation.

It is a long term ambition that two or more industrial partners co-invest in specific applied projects. By co-investing, the partners will not only share costs and risks, they will also better benefit from each others competence and resources. To encourage this model, the Center partly sponsors projects that involve several partners, if these projects are not too product specific.

Most of these applied projects are partly or fully confidential, and the description in the report is brief. Some projects are omitted from the report. For more information, please contact Acreo or the partners involved.

We choose to divide the fiber optic application space into four different segments:

- Information and Communication
- Life Sciences
- Industrial Production / Manufacturing
- Security, Metrology and Sensors

For each of these segments, we summarize some of relevant achievements in the year 2008.

Information and Communication

The low-loss optical fiber and the optical amplifier were two key enablers for the growth of optical telecommunications. The development continues of new and better fibers, components and subsystems using fiber optics.

photo: Inmec N.T.

Modules for access networks.

The intelligence of the subsystems is increasing, driven by the shift from static networks to the agile or reconfigurable network. A second trend is toward low-cost techniques, driven by the expansion of fiber access networks (FTTx). Examples are new fibers for fast, efficient and low cost fiber wiring, as well as modules and equipment for cost-effective handling and installation.

Cost-effective fiber access installation techniques

Inmec Network Technologies develops fiber optic splice enclosures and other modules for fast and cost-effective installations of fiber access networks. The development of the modules have involved e.g. environmental protection tests according to the IP-68 standards, with third party tests carried out at Acreo.

Tunable add/drop modules using specialty fiber

Proximion Fiber Systems has developed an add/drop module based on fiber Bragg grating technologies and a specially designed micro structured fiber. The component is based on an earlier invention at Proximion. A specialty fiber was designed and developed together with Acreo Fiberlab.

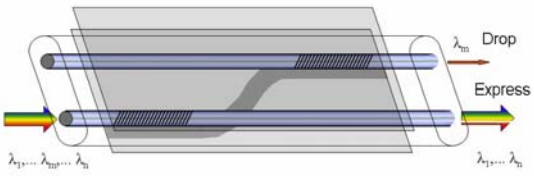


image: Proximion

Schematic view of the add/drop device..

Processes for splicing and in/out-coupling of light, as well as other post-processing techniques required for the components, have been developed. First demonstrations of a functioning add/drop module was accomplished in 2008.

Life Sciences

Today, the main use of fiber optics in medicine involves illumination, image transfer (endoscopy) and flexible laser delivery. However, with an accelerating cost for healthcare for an aging population, there is a strong demand for more efficient and less costly procedures for diagnostics and treatment. Minimally invasive procedures can involve less pain, faster patient recovery, less scarring and tissue injury, and higher accuracy. Operation time can be longer, but hospitalization time is normally shorter, significantly lowering the overall costs.

image: Samba Sensors

Ultra-miniature pressure sensors..

There is an intense development of minimally invasive technologies, and we believe that fiber optics will be playing a vital role in the future in the life science area.

Fiber optic sensing of oxygen

Artema Medical and Acreo have collaborated in the development of techniques for analysis of anesthetic gases. In addition, we have invented and carried out a proof-of-concept work on a novel fiber optic detection technique for oxygen, based on laser spectroscopy, waveguiding principles and cost-effective assembly.

Researchers and engineers from Artema and Acreo have worked together in the Acreo laboratories in the projects.

Improved miniaturized pressure sensing

Samba Sensors offer ultra-miniature pressure transducers and control systems, primarily for applications in the life sciences. The sensors are based on Fabry-Perot sensors mounted on optical fibers. Acreo Fiberlab has developed a new fiber based on the design from Samba, and this fiber is now under tests at the company.

Disposable sensors

Sensible Solutions offer disposable moisture detection systems based on low-cost electronic printing techniques for sensors and radio transmitters. For some applications, the systems need to provide a better accuracy. A study of alternative methods have been initiated, where fiber optic techniques are one alternative. Starting early 2009, a PhD student within Acreo Fiber Optic Center will be studying low cost measurement techniques, supervised by senior staff at Mid Sweden University and Sensible Solutions. Acreo will provide co-supervision and support on fiber optic handling, optical measurement principles and more.

Industrial Production / Manufacturing

Laser-based materials processing

The high power laser area in Acreo Fiber Optic Center involves several partners, all of whom have been involved to a smaller or larger extent in the activities during 2008. Although the partners have different technical focus and business interests, it is useful to note that there is one common denominator, namely *high laser powers*.

Swedelase Photonics is developing improved fiber laser designs, and plan to include fiber components for switching and pulse control. A development project is carried out within the Center, where a researcher at Swedelase is working in the Acreo labs, with Acreo researchers.

The fiber optic Q-switch allows for nanosecond switching of lasers.

Saab Bofors Dynamics is studying laser based ignition systems where fiber optic power delivery is one critical issue. They are driving a three year development project within the Center, studying e.g. power delivery issues. Optoskand has unique competence for high power solutions and has provided test samples specially adapted to the requirements from Saab Bofors Dynamics.

Fiberson is, together with Acreo, developing cabling solutions for high power laser delivery.

The combination of the competence, resources and requirements from these four industrial partners, together with the competence at Acreo and KTH/Laserphysics is an excellent platform for making a real impact in the high power laser and fiber laser area.

High precision machining

System 3R offers clamping chucks, pallets and automation equipment. Seco Tools offers metal cutting products, including cemented carbide inserts and insert carriers for turning, milling and holemaking.

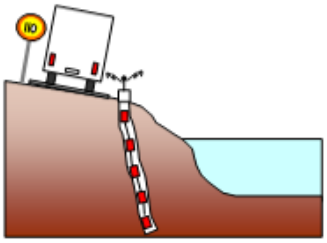
Both of these companies have identified a potential added business if they could offer a technology for real-time high precision positioning measurements in manufacturing. A joint project has been carried out within the Center, and a measurement system based on fiber optic interferometry has been developed. Some of the unique technologies in the project involve the building practices (mounting of the fiber) and algorithms for data processing. The mounting principle is a background technology from System 3R, and has been further developed in the project.

High precision positioning measurements on clamping chucks.

System 3R has designed and manufactured the prototype clamping chuck on which the sensor demonstrator was mounted by Acreo. System 3R has also carried out tests in manufacturing environment. At a working distance around 50µm, the system shows an accuracy of 10 nanometer in an almost real-time (sub-second) read-out.

Security, Metrology and Sensors

The early development of fiber optic sensors was centered on the US Navy's need for high sensitivity acoustic sensors to detect the ultra quiet Soviet submarines in the 1970s. The fiber optic gyroscope was developed around the same time. The development around the Fabry-Perot cavities was intense in the late 80s. The current wave of development of fiber optic sensors is centered around the use of fiber Bragg gratings (FBGs), and distributed sensing based on Brillouin and Raman scattering in optical fibers.



The fiber optic inclinometer.

With some notable exceptions, there has been a limited market penetration of fiber sensors. There are several barriers that is yet to be overcome; a disturbing lack of standardization; the manufacturing infrastructure is immature; lack of multiparameter sensing systems; complex deployment and repair; etc.

Despite the above, sensing and metrology are areas where fiber optics can and will make a significant difference, exploiting some of its unique features combined with the fact that many of the needed components (e.g. light sources) are falling in price.

Reliable and cost effective environmental monitoring

Bergsäker is developing a reliable, accurate and cost-effective system for monitoring environmental effects during and after construction projects. The fiber optic sensor, designed and developed at Acreo, offers an accuracy of approximately 0.001 degrees and a resolution of 0.0003 degrees, well within the target specifications, and more than an order of magnitude better than the earlier non-fiber components. The development project is managed by Bergsäker and carried out within the Center framework.

Fiber optic radar applications / microwave photonics

Fiber optic techniques can be used to detect and process radar signals. The fiber techniques can potentially improve e.g. speed, linear dynamics, signal to noise ratio, weight and size compared to purely microwave-based systems. Indeed, there are also several potential limitations, and the area is fairly immature.

Saab Avitronics and Acreo have formulated a master's thesis project studying rapid photonic detection of microwave signals in the frequency range ~2-18 GHz. The student, Patrik Rugeland, is employed at Saab Avitronics, and performs his thesis work in the Acreo laboratories, supervised by Walter Margulis at Acreo.

Center organization

Staff and resources

Acreo Fiber Optic Center exploit the expertise of staff at Acreo and other Center partners. The Acreo staff includes fifteen experienced scientists and technicians. A number of masters and PhD students are affiliated with the Center. Two senior scientists at Acreo also have positions at partner universities.

Around 70 people have participated in the Center projects in 2008, including the participation by industrial partners and university students and staff.

Laboratory resources

Acreo Fiberlab (www.acreo.se/fiberlab) is a state-of-the-art laboratory for designing, developing and producing specialty fibers and preforms. With a very flexible facility, that was designed internally and built for maximum performance, the laboratory can quickly respond to requirements for novel fibers or preforms. The facility houses international research collaborations, process development projects, and OEM production.

Acreo's Fiber Bragg grating facility is specially built to be able to realize new grating designs for research and development. The system can produce gratings for wavelengths from the visible region up to 1700 nm, including the commercial telecom bands 1310 and 1550 nm. Acreo can realize fiber Bragg gratings for room temperature applications and for high temperatures.

A well equipped Applications laboratory and extensive measurements and characterization resources are indispensable for the development of new fiber optic components and solutions

International R&D Advisors

- Prof. Raman Kashyap, Dept. Engineering Physics and Electrical Engineering, Ecole Polytechnique de Montreal, Canada.
- Prof. Valerio Pruneri, the Institute of Photonic Sciences, Catalan Institution for Research and Advanced Studies, ICREA, Barcelona, Spain.
- Prof. Roy Taylor, Physics Department, Imperial College, London, England.

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Center board

Helene Andersson Svahn

Professor Helene Andersson Svahn is heading the Nanobiotechnology department at the Royal Institute of Technology in Sweden. Dr. Andersson Svahn received her Ph. D. in Electrical Engineering at the Royal Institute of Technology in 2001 and holds a M. Sc. in Molecular Biotechnology from Uppsala University.

In 2002-2005 Dr Andersson Svahn was Marketing Director at Silex Microsystems which develops and manufactures microchips for Telecom and Life Science Industry. In 2005-2008 she was professor in Applied BIOMEMS at MESA+ Research Institute in Holland. Currently she is CEO of the startup company Picovitro AB (part time).

Håkan Dahlquist

P Håkan Dahlquist M. Sc. ME graduated from KTH in 1983. After the ASEA trainee course he worked with R&D at ABB Robotics until 1995. His research fields were dynamic simulation and performance optimization. Responsibility for mechanical performance in robot development projects became later his major task. Dahlquist came to System 3R in 1995 and has held positions as design manager, quality manager and since 2007 research & quality manager.

Dahlquist is the holders of several patents in the fields of robotics, tooling systems and fiber optic metrology. He has during his career gained a broad experience in transforming ideas, inventions and research results into industrial products. How to design and produce for full quality assurance is also a part of this.

Gunnar Edwall

Gunnar Edwall, born 1945, has recently retired from a position as Senior Expert Broadband Technologies at Ericsson. He has also served 28 years as Senior Expert Fiber Optic Technologies and Broadband Technologies at Ericsson, and been a member of the management team of Ericsson (corporate) Research. In parallel with the work at Ericsson, Edwall has served 12 years as adjunct professor in Optics at Royal Institute of Technology and 4 years as acting professor in Applied Physics at Royal Institute of Technology.

Thanks to the combined experience from academic and industrial research management, Dr Edwall has served as coordinator of several collaborative research programs, member of steering and expert groups for research programs, and reviewer of proposals and programs for research funding organizations both nationally and internationally. In 1994 he was appointed chairman with responsibility to build up the Foundation for Knowledge Transfer between Academia and Industry in Stockholm by the Swedish Government.

Stefan Ekman

CEO and Founder of Proximion Fiber Systems AB. Ekman has 15 years of experience from international purchasing. At Allgon Systems he was managing strategic sourcing, outsourcing and partnerships for supply and technology. Prior to Allgon Ekman held a number of roles within industrial co-operation for CelsiusTech (a Swedish defense company), such as offset issues, program management and strategic purchasing partnerships.

Anders Larsson

Anders Larsson, born 1944, received his M.Sc. in Electrical Engineering 1973, at the Royal Institute of Technology in Stockholm. He has more than 30 years of experience in development and manufacture of optical fiber and telecom cable. Employment in this area started in 1975 at Ericsson Telecom Cable division as development engineer. Since then he has held positions as Technical

Manager, Division Manager and vice President at Ericsson Telecom Cable Division in Hudiksvall. Since year 2003 he is CEO for Fiberson AB.

Bengt-Olof Larsson

Bengt-Olof Larsson, born 1944, is entrepreneur, founder and former CEO (during the 90s) of ElektronikGruppen (EG) AB. EG is one of the leading suppliers of electronics into the Nordic market. Listed on the Swedish stock market, O-listan. EG is operating with manufacturing and sales of electronic components in ten different countries. Their main products are fiber optic and magnetic components.

After retirement 2001, Bengt-Olof is a business angel and helps startup companies with business development. He is board member of FMOF, Acreo, Metrima, BitSim and a number of startup companies.

Hans-Erik Nilsson

Hans-Erik Nilsson finished his PhD in Solid State Electronics in 1997 at the Royal Institute of Technology, Stockholm, Sweden. The same year he got a senior research position at the Mid-Sweden University focusing on modeling of advanced semiconductor devices.

In 2002 he became a full professor in electronics design and the Head of the Electronics Design Division. In 2006 he got the position as Head of Department for the Department of Information Technology and Media. His research interests include electron and photonic devices, radiation detectors, and RF electronics.

Partners

Acreo AB is Sweden's largest research institute in optics, microelectronics and communications technologies. One of its key competence areas is Fiber Photonics. Acreo has extensive resources and expertise in fiber optics and fiber optic solutions.

Acreo supports Swedish industry with innovations, competence, resources and R&D expertise within the focus areas of the institute. The overall aim is to generate growth in Sweden.

Acreo is the coordinator of Acreo Fiber Optic Center.

Artema is an OEM supplier, committed to the provision of respiratory gas measurement technology for integration into patient monitors, anesthesia delivery systems and ventilators.

The cornerstone of Artema's vision is to provide safety and comfort in anaesthesia and intensive care for patients all over the world, by supplying innovative vital components to the medical device industry.

Beneq Oy is a Finnish nanotechnology driven company having its business focused on supplying industrial equipment and technology for functional coating applications. The key market areas are in the areas of glass coatings, photovoltaics and thin films for industrial applications.

Beneq's business concept leans on strong IPR and process know-how especially in nHALO® and nAERO™ technologies and in ALD (Atomic Layer Deposition) technology. Beneq has adopted highly networked business model where manufacturing and customer specified engineering is carried out by the supplier network.

Beneq was established a few years ago as a spin off from Nextrom Oy, a leading manufacturer of equipment for fiber optic and optical cable industries. Against this background Beneq has know how in optical fiber manufacturing and it is natural for Beneq to study opportunities to develop coating applications in this field.

All types of construction projects have an impact on the surrounding environment. This can involve everything from increased construction traffic to vibrations from explosions or noise disruption. In the worst case scenario, the environmental impact of construction can cause damage, for example to buildings as a result of subsidence or in the environment through pollution to the groundwater. This is the area in which Bergsäker works.

Bergsäker develops its own products for remote controlled environmental monitoring in order that construction projects can be carried out safely without unwanted environmental consequences.

Bäcken Industrifysik is a small international engineering company. We specialize in helping our clients to prepare new products for production including production engineering and facility design. Usually, this gives a very practical inroad into business development and sales activities. Obviously, this profile of ours has led to cooperation with many small companies and a lot of contacts with universities and science parks.

By coincidence we came into contact with AFOC when working with a major client business development project. Later, such a contact was developed in a second project. In these cases AFOC is adding knowledge and credibility to the two business ideas.

ERICSSON

Within Ericsson AB, Cables & Interconnect work with the following on optical fibre related to research aspects:

- hydrogen & radiation influence on fibres
- techniques for processing specially doped preforms for fibre manufacturing
- evaluating different fibre types by measuring refractive index profiles
- use latest instrument technology for evaluating attenuation and other transmission properties
- standardization of fibre types and measuring techniques

We are focused on telecom applications including the access network. New fibre types with different properties are being introduced into the market. It is important to use objectivity when evaluating them.

Reliability is top priority and knowledge of fibre robustness against exposure to hydrogen/ water and radiation is of great importance.

FIBER Logix

FiberLogix Ltd in England designs, manufactures and markets specialty fiber and all-fiber passive devices. Their expertise in end user requirements for harsh environment fiber solutions has been of value in Acreo Fiber Optic Center's development of specialty fibers for that area.

Fiberlogix Ltd filed for liquidation in November 2008.

Fiberson

Fiberson AB started in year 2003. The company business idea and activities is based on knowhow, in fiber optic technology. The company has its main activity in development, manufacture and sale of a linear heat detection system.

The company also participates in product development of special fiber for telecom or industrial applications. Main activity in this area is secondary coating of high power optical fiber and secondary coating on fiber for mechanically harsh environment.

Fiberson AB is also working as a consultant in education and investigations related to fiber optic technology and fiber optic access networks.

FOI

FOI is one of Europe's leading research institutes in the fields of defence and security.

FOI's sensor research covers sensors for use both above water and underwater, as well as studying the special environment in which they operate. Important scientific disciplines include optronics, lasers, radar, acoustics and sensor signal processing. In particular, the possibilities offered by networks of sensors operating together are being studied.

INMEC Network Technologies AB

Inmec Network Technologies AB, a company founded 2006 with the goal to develop a low cost product portfolio of canalization joints for buried "floating fibre" in the access network. The development has been done in cooperation with Ericsson, 3M, CUL, Fiberson and Acreo.

The environmental requirement on the products to withstand water leakage and durability in harsh environment over long time has been defined by testing in the Acreo lab in Hudiksvall.

The second generation of complete product range of joints was commercially launched in the beginning of 2009.

OptoNova AB är ett personalägt produkt-och tjänsteföretag som levererar Visionssystem för automatisk övervakning och kvalitetskontroll till tillverkningsindustrin. T.ex. Westinghouse (automatisk avsyning av kärnbränslekutsar), Förpackningsindustrin (utrustning som in-line övervakar och styr produktionsprocesser), IKEAs produktionsbolag (Swedwood Visionsystem som kontrollerar ytor, kanter, hål mm på planmöbeldetaljer).

Vi har levererat drygt 130 inspektionssystem till 22 länder. Vi utför även konsultjänster inom optik, visionteknik, bildbehandling etc.

Företaget har expanderat snabbt (Gasellföretag 2008) och har en omsättning på 32 miljoner och 27 anställda.

Idag använder vi fiberoptik främst för olika belysningstillämpningar. Vi har även identifierat ett antal sensortillämpningar där Centerresultaten kan vara intressanta.

Optoskand is a high-tech company that competes successfully on an international market. We deliver the power from your laser source to the work-piece with minimal losses thanks to a successful technology.

The market-leading Optoskand invented technology gives us an edge compared to other manufacturers. This edge is protected by a number of patents. The patents give the products a technological advantage over our competitors' products and the ambition is to register new patents each year.

The Optoskand fiber optic product line has been created to deliver high power laser radiation safely from the laser to the work piece. At the same time the market demands more flexible solutions and the dream of having the laser beam from a wall plug becomes closer and closer. The result is that we continuously work to improve and further develop the possibilities with the fundamental technology.

Approximately 10 percent of Optoskand's turnover is each year invested in research and development. Some of these resources are used for developing existing products in order to keep up with the development of the customers' products; some are used on development of new Optoskand products.

Proximion Fiber Systems AB is a world-class provider of optical modules and sub-systems based on Fiber Bragg Grating (FBG) technology.

By combining these unique optical devices with the truly innovative skills of our team, Proximion contributes to our customers' and partners' success in a variety of markets.

Saab Bofors Dynamics AB (SBD) is a vital part of Saab's defence activities with approximately 1,100 employees.

SBD is a leader in precision engagement systems meeting the requirements of the global market. The company has complete missile system solutions and develops advanced missile systems and short-range support weapons for the Swedish Defence Forces and other national defence forces and participates in international projects.

SBD has during many years studied the possibility to use laser technique in different applications. SBD have developed different types of ignition systems for the product portfolio. A solution to ignite explosives with laser technique transported by fiber has been studied.

SBD is today in a world-leading position in the area of laser ignition system. As a result of performed technology studies a number of solutions have been identified for future investigations.

Saab Avitronics is a leading supplier of Avionics and Electronic Warfare Systems on the international market and is a business unit within Saab.

We offer a full range of Electronic Warfare assets, with focus on systems, equipment and in-service support for self-protection, ESM and Electronic Attack. Key elements are radar, UV and laser sensors as well as jammers, decoys and counter-measures dispenser systems. Complete EW systems are available for airborne, naval and ground vehicle applications.

We also have avionics sub-systems in our product portfolio: safety-critical utility and control systems, mission systems, such as reconnaissance systems and display systems, and a wide range of modular avionics, for fighters, helicopters, transport as well as commercial aircraft. Key competence areas are safety critical systems and software, modular avionics, video and graphics processing, digital map systems and sensor integration.

Electronic Warfare systems usually contain broadband analog RF components for the receivers and the transmitters and digital components for fast digital signal processing. Here microwave photonics offers interesting opportunities as an alternative or a complement for both the analog and the digital parts of the systems.

Samba Sensors AB was founded in 1992 to commercialize a fiber-optic pressure sensing technology developed at Chalmers University of Technology in Gothenburg, Sweden. The original design was developed by Prof. Olof Engström to measure pressure under the extreme conditions existing in the cylinders of combustion engines.

Since 1998, the company has continued to develop its technology, aiming at the preclinical and clinical markets. Today, design, development and marketing of ultra-miniature pressure transducers and control systems, primarily for applications in the life sciences, are the main focus.

Sensible Solutions, has since 2004 by its standards as a spin-out of research of Mid Sweden University, spent significant resources exploring techniques and sensors targeting systems and methods with potential to reach an industrial, robust and effective detection and communication of wetted or saturated incontinence diapers. Targeted sensor cost is one (2) cent $ or less.

One printed moisture sensor has been fully utilized and evaluated for this purpose, monitoring wetness events, moisture transportation and saturation in a diaper on patients. Targeted application areas for this device are geriatrics care, baby care and as technical support in treatment of kids suffering from nocturnal Enuresis.

Sensible Solutions is a company providing new products and concepts for environmental sensing and measurements based on wireless, RFID and printed sensors of paper. Environmental sensing and detection covers areas as forest wildfires, water leakages, incontinence control, humidity-, temperature- and mould detection. All systems are based on cost efficient printed sensors that utilize patented technologies. The technology is likely to be adapted to other, even more sophisticated sensing applications. Taking into account the cost efficiency of the individual sensor it may be a breakthrough in monitoring of environmental processes on a massive scale.

Seco Tools develops, manufactures and markets metal cutting products worldwide. Our product portfolio includes cemented carbide inserts and insert carriers for turning, milling and holemaking.

The necessity of geometric accuracy in metal cutting solutions generates a need for high precision measurement and positioning methods in the manufacturing. We have, therefore, participated in a project aiming at nanometer-range measurement capability utilizing fiber optics.

Swedelase is a small company specializing in pulsed laser systems with attached beam steering. Important features of the systems are compactness, safety and applicability. The main applications are marking and materials processing. A vast experience of the fundamental laser technology as well as the application areas can be found within the company.

Today, the laser systems are based on solid-state designs but Swedelase is engaged in Acreo Fiber Optic Center in an effort to widen the product range with fiber-based components.

System 3R is a world-wide supplier of clamping chucks, pallets and automation equipment. Their products are mainly used in the mould & die industry.

In recent years there has been an expansion to general machining, with lower accuracy requirements, as well as to ultra precision machining with extremely high accuracy requirements. Fiber optic interferometry could in the future be an important solution in the latter case.

System 3R is situated in Vinsta, Vällingby. It has 180 employees in Vällingby and further 150 employees in Sales companies and in a division company in Flawil, Switzerland. That company produces larger pallet systems. System 3R belongs since 2001 to the Swiss company GF AgieCharmilles.

ÖSTLING Märksystem AB is specialized in industrial marking (decorative and coding) of products and packagings. Through our complete machine program we have a unique possibility to offer efficient machine solutions for every type of material, surface and production environment.

On our program we have following machine systems and different techniques: Laser-marking, Pad-printing, Ink-jet, Electrolytic marking, Needle embossing and Scribing.

We have standard machines as well as customized turnkey solutions including effective and adaptable product automation.

Our knowledge and quality thinking is a result of more than 40 years of successful business within the sector industrial product marking and identification.

University partners

- Department of Laser Physics, KTH
- Department of Quantum Optics, KTH
- Division of Electronics Design, Mid Sweden University
- Department of Heamatology, Karolinska Institutet

Supporting partners

- Fiber Optic Valley
- Kista Photonics Research Center
- Stockholm Innovation and Growth
- SP, Technical Research Institute of Sweden

Sponsors

- Vinnova
- Swedish Foundation for Strategic Research
- The Knowledge Foundation (KK-stiftelsen)
- Hudiksvall Sparbanks Sysselsättningsstiftelse
- Region Gävleborg
- NUTEK / EU Structural Funds, Norra MellanSverige

Communications

The purpose of the communications program is to promote the use of fiber optics, to disseminate the results of the Center, and to facilitate dialogue in-between partners and with other interested.

Communications activities in 2008 include e.g. organization of Optopubs in Hudiksvall, scientific papers, conference presentations, a Center web, newsletter, classes for students at KTH and Uppsala University, supervision of high school students, being technical partner at an OTDR workshop, hosting a two-day partner event, numerous meetings with companies and other interested, and lab tours for visitors.

photo: J.Frisk, Fiber Optic Valley

Technical workshop gathers 70 participants

Dr Anne Andersson, SP and Prof Brian Culshaw, Univ of Strathclyde at the OTDR workshop held in Hudiksvall in November. The event gathered around 70 people.

Partner days 2008, 26-27 May in Hudiksvall

Center web pages: www.acreo.se/fiberopticcenter

Fiber interferometer covered in Ny Teknik, December 2008

Hudiksvalls Tidning, May 2008

Center newsletters

Yu: "Manipulating Light with Fibre Bragg Gratings"

Publications

Technical articles

Nilsson, L-E., “Fiberoptik – inte bara bredband”, Expert paper in *Elektroniktidningen*, February 2008.

Book

Yu, Z., Margulis, W., Fonjallaz, P-Y., Manipulating Light with Fibre Bragg Gratings: Nanosecond Switching using In-Fibre Electrodes and Ultra-Narrow Filtering of Millimetre-wave Signals, ISBN 978-3-63-901027-5; VDM Verlag. 2008.

Theses

1. Engholm, M., *Materials Optimization for Optical Fiber Amplifiers and Fiber Lasers*. PhD thesis. Mid Sweden University, Sundsvall, Sweden, May 2008.
2. Lundbäck, H. Complimentary studies of chemical composition gratings and their fabrication process, MSc thesis, KTH, 2008.
3. Jason, J., *Theory and Applications of Coupling Based Intensity Modulated Fibre-Optic Sensors*, Licentiate thesis, Mid Sweden University, Sundsvall, Sweden. Dec 2008.
4. Yu, Z., *Fibre Bragg Grating Components for Filtering, Switching and Lasing*. PhD thesis. Royal Institute of Technology (KTH), Stockholm, Sweden, Oct 2008.

Journal Papers

1. Engholm, M. and Norin, L., "Preventing photodarkening in ytterbium-doped high power fiber lasers; correlation to the UV-transparency of the core glass", *Optics Express*, 16, 1260–1268. 2008.
2. Engholm, M. and Norin, L., Comment on: "Photodarkening in Yb-doped aluminosilicate fibers induced by 488 nm irradiation". *Optics Letters*, 33(11), 1216-1216, 2008.
3. Jason, J., Nilsson, H-E., Arvidsson, B., and Larsson, A., "Experimental Study of an Intensity Modulated Fiber-Optic Position Sensor with a Novel Readout System", *IEEE Sensors Journal*, 8 (7), 1105-1113. 2008.
4. Jelger, P., Wang, P., Sahu, J. K., Laurell, F., Clarkson, W. A., "High-power linearly-polarized operation of a cladding-pumped Yb fibre laser using a volume Bragg grating for wavelength selection". *Optics Express*, 16, 9507. 2008.
5. Kim, J. W., Jelger, P., Sahu, J. K., Laurell, F., and Clarkson, W. A., "High-power and wavelength-tunable operation of an Er,Yb fiber laser using a volume Bragg grating", *Optics Letters*, 33, 1204. 2008.
6. Yu, Z., Tarasenko, O., Margulis, W., and Fonjallaz, P-Y. "Birefringence switching of Bragg gratings in fibers with internal electrodes", *Optics Express,* 16(11), 8229-8235. 2008.

Conference Papers

1. Engholm, M. and Norin, L., "Reduction of Photodarkening in High Power Fiber Lasers". *Photonics West*, Proc. SPIE, San Jose, USA. January 2008.
2. Engholm, M. and Norin, L., "Materials Optimization for Ytterbium-Doped High Power Fiber Lasers", *Conference on Lasers and Elecrooptics* (CLEO 2008), San Jose, May 2008.
3. Jelger, P., Stjernström, M., Margulis, W., Pasiskevicius, V., and Laurell, F., "All-Fiber Capillary Electrophoresis with Novel Axial In-Line Detection", *Conference on Lasers and Elecrooptics* (CLEO 2008), San Jose, May 2008.
4. Jelger, P., and Laurell, F., "Volume Bragg Grating Tuned Large Mode Area Fiber Laser", *ASSP - Advanced Solid-State Photonics*, Nara, Japan. January 2008.

5. Kim, J. W., Jelger, P., Wang, P., Sahu, J. K., Laurell, F., and Clarkson, W. A., "Wavelength selection in high-power cladding-pumped Er,Yb and Yb fibre lasers using volume Bragg gratings", *Conference on Lasers and Elecrooptics* (CLEO 2008), San Jose, May 2008.
6. Margulis, W., Tarasenko, O., Yu, Z, Fonjallaz, P-Y., and Knape, H., "High-speed fiber switches", *Workshop on Specialty Optical Fibers*, invited, , First international Workshop on Special Optical Fibers,WSOF08, Campinas, Brazil. August 2008.
7. Margulis, W., "Electrically controlled optical fibers", *Optikdagen 2008*, Invited. Göteborg, Sweden. November 2008.
8. Sterner, C., Koch, R., Djupsjöbacka, A., Dahlqvist, H., and Nilsson, L-E., "Macro sensor - High precision positioning system", *Optikdagen 2008*, Göteborg, November 2008.
9. Udvary, E., Berceli, T., Chacinski, M., Schatz, R., and Fonjallaz, P-Y., "Reduction of dispersion induced distortions in radio over fibre links", *38th European Microwave Conference* (EuMC), Poster 01-33, Amsterdam, Holland, October 2008.
10. Wang, P., Jelger, P., Kim, J. W., Sohu, J., Laurell, F., and Clarkson, A., "High-power linearly-polarised Yb fibre laser and tunable Er,Yb fibre laser using Volume Bragg Gratings for wavelength selection", *Europhoton Conference*, Paris, France, September 2008.
11. Yu, Z., Fonjallaz, P-Y., Margulis, W., and Tarasenko, O., "High-speed switching of a DFB grating in a twin-hole fibre", *Asia Pacific Optical Communications 2008* (APOC), Hangzhou, China. October 2008.
12. Yu, Z., Koch, R., Margulis, W., Tarasenko, O., Knape, H., and Fonjallaz, P-Y., "Nanosecond All-Fiber Polarization Switch", *Asia Optical Fiber Communication & Optoelectronic Exposition & Conference* (AOE 2008), paper SaM5, Shanghai, China. October 2008.
13. Yu, Z., Margulis, W., Fonjallaz, P-Y., and Tarasenko, O., "Physics of Electrically Switched Fiber Bragg Gratings", *Conference on Lasers and Elecrooptics* (CLEO 2008), San Jose, May 2008.
14. Yu, Z., Tarasenko, O., Knape, H., Koch, R., and Margulis, W., "Versatile all-fiber polarization switch", *Europhoton Conference*, Paris, France, September 2008.