

Invest in Sweden

# Photonics Sweden



*Get enlightened*



## Sweden

### Why Sweden?

- Sweden is a front runner in a large number of ICT sectors, ranging from microelectronics to photonics and wireless systems
- World's most knowledge-based economy
- Continuous public efforts and investments
- Sweden heads innovation performance in the EU
- Integrated chain from academic discovery to global launch
- Competitive business costs
- Stable macro-economics and favorable business climate

### Focus on Sweden to gain the lead in photonics

- State-of-the-art fiber optical network test-bed for true broadband field tests
- Cost-effective broadband access technology for fiber optical networks
- Advanced simulation techniques for efficient use of fiber optical network equipment
- Design and optimization of advanced fiber optical amplifiers
- All fiber optical network components, i.e. polarization control with no moving parts
- Collaboration with Swedish companies and universities in optical communications technologies

## Get enlightened in Sweden

*Optical technologies illuminate the world. Light becomes the principal medium for voice and data communication. CDs and DVDs replace magnetic recording methods for large volumes of data. Modern medical advances are inconceivable without optical technologies. Photonics (also known as optoelectronics) is a fast-growing area of technology using light as a means of communicating information.*

**Fast expanding sector** Photonics has particular application in telecommunications where it can provide high-speed switching mechanisms capable of handling enormous traffic volumes within data networks. It also offers a number of applications in sensors, e.g. monitoring movements in structures. The technology has given rise to many new companies developing specialist applications ranging from laser technologies to software for managing optical solutions. It is not only one of the fastest expanding sectors at present, it is also having a truly remarkable impact, perhaps only rivaled by that of biotechnology. Few limits are in sight, creating an exciting and driving potential for groundbreaking research, novel applications and new enterprises. In almost every major area of photonics one can foresee the potential to change the world. This almost unique adaptability is the best guarantee that the future of photonics will be even brighter as new frontiers materialize.

**Photonics Sweden cluster** During the last three decades in Sweden, internationally renowned photonics research activities have grown into academic centers of excellence, fostered innovative entrepreneurs and created important manufacturing facilities in all areas of photonics.

The Photonics Sweden cluster is a non-profit consortium of Swedish companies, university research groups, institutes and support organizations, formed following the impetus of activities in Sweden. The objectives are to bring together people and organizations to facilitate processes of research, technology transfer and the generation of business opportunities.

**R&D collaboration between business and academia** Photonics Sweden's goal is to encourage the interaction of industry, academia and research organizations in order to foster the development and application of new technologies. The cluster aims to present a high profile for the business sector, propagating its achievements and acting as a center of expertise to attract and assist inward investment. By promoting the technology in education and interacting with academia it encourages the training of specific skills to fulfill industry requirements.

Photonics Sweden offers academic research and education at top Swedish universities as well as applied R&D at the Acreo Photonics Center. The cluster is located around these universities and their huge pool of systems know-how. Besides generating new Masters and Ph.D. graduates specializing in photonics, international investors are also offered advantageous terms and conditions.

# Leading position in photonics

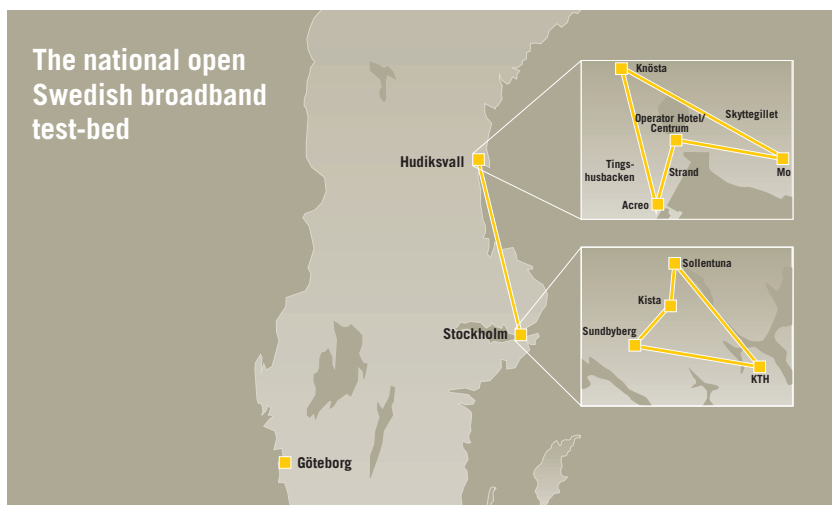
Sweden maintains a leading position in photonics with broad engagement in fundamental research as well as a lively photonics industry. The Swedish commitment to optics and photonics dates back to the 1940s. The first laser diodes were processed already in the mid-seventies when also Sweden's deep engagement in fiber optics commenced.

Today, fundamental as well as applied research is performed mainly at three universities: the Royal Institute of Technology in Stockholm; the Chalmers University of Technology in Göteborg, the second largest city in Sweden, and the Mid Sweden University in Sundsvall, in central Sweden.

The independent research institute, Acreo AB, forms a bridge between basic academic research and the industry's needs for applying the latest technologies in new profitable products. Swedish academic R&D in photonics today engages some 150 highly qualified scientists.

**Government support** Many of Sweden's photonic efforts today are directed towards fiber optical communications. The government is committed to maintaining and developing the nation's position as a world leader in information and communications technologies (ICT). To this end, more than USD 1,300 million has been allocated to install full broadband capacity throughout the entire country. Substantial grants have also been allocated for R&D encompassing both fundamental research for next generation high-capacity fiber optical infrastructure as well as for developing cost-effective solutions for today's networks.

Academic institutions and Acreo form important breeding grounds for many start-up companies in photonics. Recent years have seen the formation of many exciting new enterprises mainly in the field of fiber optical communication. Swedish photonic companies range from large global organizations, such as Ericsson, to small or medium-sized companies with a few highly specialized products, for example monitoring and sensor systems. Sweden's commitment to photonics is also reflected in the fact that it hosts the European Conference on Optical Communication (ECOC) 2004.



## Leading information economy

2003, ranking

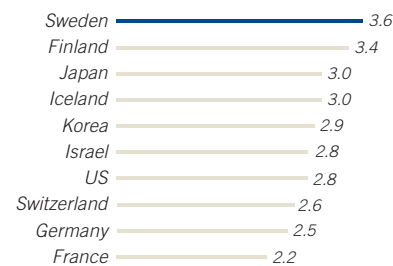
1. Sweden
2. Denmark
3. Netherlands
4. Norway
5. Finland
6. New Zealand
7. Switzerland
8. US
9. Austria
10. Canada

Note: Sweden was top rated for the fourth consecutive year. Ranking takes into account the country's ability to access and absorb information and information technology. In the index, statistics from 55 countries are being compared, including PC and internet usage, telecommunications infrastructure, education levels etc.

Source: IDC/World Times Information Society Index, 2003

## High R&D expenditure

2001, percent of GDP



Note: Sweden spends more on R&D in relation to GDP than any other country. One-third of expenditure is publicly funded.

Source: IMD, 2003

## Number of patents in force

2000, per 100,000 inhabitants

1. Luxembourg	6,722
2. Switzerland	1,214
3. Sweden	1,098
4. Belgium	834
5. Japan	820

Note: Sweden is a notable global innovator, ranking high in patents per capita.

Source: IMD, 2003

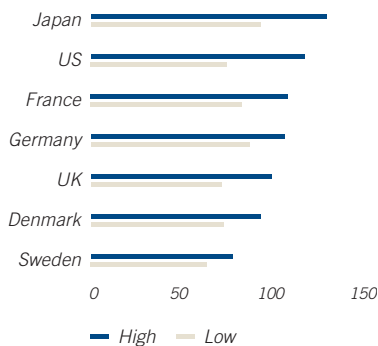
## Sweden – center of excellence in photonics research

### Core competencies in photonics

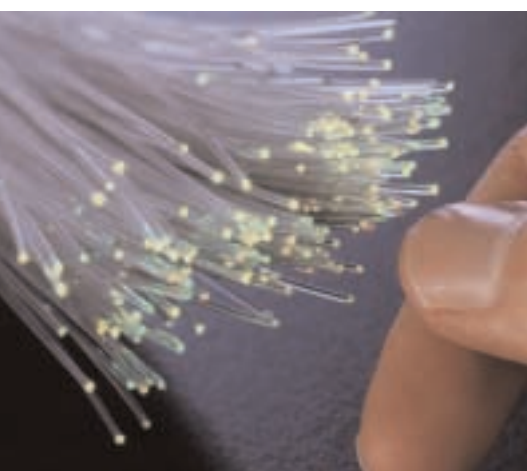
- Epitaxial growth and process technology
- High-speed photonic devices
- Diode-pumped solid-state lasers
- Semiconductor lasers
- Ultra-fast optics
- Multiple quantum-well spatial light modulators
- Photonics crystals
- Silica-on-silicon wave guides
- Hybrid integration
- Optical assembly and packaging
- Fiber Bragg gratings
- Specialty fibers
- Optical networking
- Quantum optics

### Competitive engineering costs

USD (including social charges)



Source: Mercer Sweden and ISA, 2003



A comprehensive scientific environment and comparatively large resources are crucial for advancing international developments in this key area. Academic entities, such as the Royal Institute of Technology, the Chalmers University of Technology, the Mid Sweden University and the Acreo industrial research institute all perform world-class photonics research and development. Attached to these research institutes are a number of highly qualified laboratory facilities.

**Royal Institute of Technology (KTH)** Photonics research at KTH covers a broad range of areas and offers vertical integration to combine expertise in photonic networks and transmission with device research and research in basic enabling mechanisms. This approach is highly justified in a new field like photonics, where the development is rapid but maturity is much lower than in, for instance, electronics.

In terms of applications, the emphasis is on telecommunications, where the relevant research issues today concern solving the partly interrelated problems of low functionality, large physical size and high cost. However, in-house technology also encompasses other emergent application areas, notably biophotonics, which corresponds well with Sweden's strong biotech position.

Dominant research areas include ultrafast technology and systems, quantum information technology and systems, optical transmission, integrated photonics devices as well as material science and technology in III V's and silica/silicon systems. Global breakthroughs have occurred in several of these areas.

Research at KTH has formed the basis for several start-up companies, and has provided strong support for existing businesses, in telecom and other segments.

[www.kth.se](http://www.kth.se)

**Chalmers University of Technology** Research and education at the Photonics Laboratory in Chalmers' Microelectronics department are being conducted in the areas of fiber optical communication, optoelectronics, and optics.

Chalmers' fiber optical communications activities cover transmission impairments at high data rates, all-optical data manipulation, optical signals monitoring and system aspects of microwave photonics. Transmissions are evaluated in the presence of polarization-mode dispersion, and these efforts have provided greater insight into this fiber property. Through using fibers with enhanced non-linearity, in conjunction with high power optical amplifiers, a widely tunable wavelength converter has been presented, together with ultrafast (> 500 GHz) all-optical sampling. The sampling system has also been further improved to include eye-analysis, which results in an estimated bit-error rate.

Research in the area of optoelectronics focuses on Vertical Cavity Surface Emitting Lasers (VCSELs) and related technologies. Achievements include the development of strongly index-guided coherent VCSEL arrays, VCSELs and VCSEL-based multimode links for the transmission of microwave signals, high speed VCSELs for applications in free space optical interconnects, and the establishment of a vertical external cavity surface emitting laser (VECSEL) technology. In addition, accelerated efforts have been made within high-performance gain materials for long wavelength emission on GaAs substrates. Targeting 1,300 nm emission from InAs quantum dots (QDs), a compre-

hensive study has been performed on the effects of pre-layers and cap-layers on the structural and optical properties of MBE-grown InAs QDs.

Chalmers' research in the area of optics is directed towards the manufacture of diffracting micro reliefs and on novel applications of diffracting devices.

[www.chalmers.se](http://www.chalmers.se)

**Mid Sweden University (MHS)** Photonics research at MHS is mainly focused on the optical properties of rare-earth metal ions in semiconductors and glasses. Rare earths are key ingredients in many photonic devices enabling some of today's most important modern applications, for instance amplifiers for fiber optical communication, medium- and high-power fiber and solid-state lasers for cutting, welding and medical purposes, and ultra-stable lasers for calibration and measurement. It is therefore noteworthy that optimal rare-earth chemical clusters, that play a crucial role in these applications, are essentially unknown entities today. Research efforts at MHS aims to fill this knowledge gap. To this end, MHS works jointly with Swedish and international research groups covering solid-state theory, material chemistry and optical fiber and semiconductor technology. The university also cooperates closely with industry.

In all rare-earth clusters the individual rare-earth ions are subject to influences from crystal fields originating from various chemical environments. This leads to different optical properties. Certain environments around a rare-earth ion are very efficient for optical amplification. Others can, for example, invoke detrimental loss mechanisms such as destructive up-conversion or energy transfer, accidental degeneracy that can lead to ESA (excited state absorption), bad radiative or non-radiative transitions, ASE (amplified spontaneous emission) and others. Are these bad effects interior natural constants or can we influence them in a controlled, predictable way in order to improve performance of our components and systems? MHS researchers are developing advanced physical models for examining how chemical environments influence these rare-earth ions and how interaction with electromagnetic radiation is subsequently affected. The ultimate goal is to determine optimal environments for specific rare-earth ion applications. [www.mh.se](http://www.mh.se)

**Acreo – bridging academia and industry** Acreo was formed in 1999 through the merger of Sweden's respected Institute of Optical Research (IOF) and the Industrial Microelectronic Center (IMC), both with roots in the early fifties. Acreo has established itself as a key player on the forefront of innovation as well as a competent partner in international R&D. Acreo is jointly owned by an industrial association and the Swedish government and employs about 200 highly qualified scientists, engineers and support personnel. Acreo's headquarters are located in the vibrant technology area of Kista just outside the capital Stockholm with branches in four other cities.

Acreo bridges academic research and industry. A close collaboration with leading universities and extensive internal research allows Acreo to serve its customers with contract R&D providing innovative solutions for tomorrow's products. The uniquely broad competence spectrum encompasses technology areas, such as Integrated Circuit Design, Microelectronic Process Technologies, Packaging Technologies, Robust Electronics, Sensor Technologies and Photonics and Optical Components and Systems. [www.acreo.se](http://www.acreo.se)

## Centers of excellence

### Mid Sweden University

#### Photonics staff

2 professors • 3 PhD • 2 graduate students

#### Research areas

- Rare Earth doped silica and silicon

#### Contact

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### Acreo Photonics Center

#### Photonics staff

30 scientists • 15 PhD

#### Research areas

- Optical Transmission and Networking
- Broadband communications test-bed
- Optical specialty fibers
- Fiber Optic components
- Fiber Bragg gratings
- Microwave photonics

#### Contact

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Sundsvall

Hudiksvall

Kista  
Stockholm

Göteborg

### Royal Institute of Technology

#### Photonics staff

7 professors • 18 PhD • 28 graduate students

#### Research areas

- Ultra high speed light modulators
- Photonic crystals
- Integrated photonic devices
- Rare Earth doped devices
- Laser technology
- Biophotonics
- Quantum optics

#### Contact

Lars Thylén: [lthylen@imit.kth.se](mailto:lthylen@imit.kth.se)

### Chalmers University of Technology

#### Photonics staff

7 professors • 8 PhD • 16 graduate students

#### Research areas

- Ultra high speed fiber optical communication
- Polarisation Mode Dispersion, PMD
- Lasers
- Gain structures and materials
- Integrated diffractive optical elements

#### Contact

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## A selection of photonics companies in Sweden

**Accilon Photonics** [www.accilon.com](http://www.accilon.com)

Optical monitoring technologies and products

**Albax Systems** [www.laserbulb.com](http://www.laserbulb.com)

Free space communications

**Artema Medical** [www.artema.se](http://www.artema.se)

Infrared medical gas analyzers

**BT Ignite Network**

[www.btglobalservices.com/nordics](http://www.btglobalservices.com/nordics)

Network operator

**Cernolux** [www.cernolux.com](http://www.cernolux.com)

Low loss tunable Optical Add/Drop Multiplexer

**Cobolt** [www.cobolt.se](http://www.cobolt.se)

Diode-pumped SSL in blue and other visible colors

**Comlase** [www.comlase.com](http://www.comlase.com)

High power, high reliability laser diodes

**Ericsson Network Technologies**

[www.ericsson.com/networktechnologies](http://www.ericsson.com/networktechnologies)

Fiber optical systems

**FLIR Systems**

[www.flirthermography.com](http://www.flirthermography.com)

Infrared imaging

**Future Instrument Fiber Optics**

[www.futureinstrument.se](http://www.futureinstrument.se)

Optical fiber splicing

**i3 micro** [www.i3micro.com](http://www.i3micro.com)

IP products such as residential gateways, set-top boxes and streaming servers

**Imego** [www.imego.com](http://www.imego.com)

Customized micro-sensors

**IR Vision** [www.ir-vision.com](http://www.ir-vision.com)

Wireless optical data communication

**IVP – Integrated Vision Products**

[www.ivp.se](http://www.ivp.se)

3-D Machine Vision

**Kreatel** [www.kreatel.com](http://www.kreatel.com)

IP set-top boxes for interactive TV services

**LIMAB** [www.limab.se](http://www.limab.se)

Laser gauges, measurement systems and sensors

**Linus** [www.linusdisplay.com](http://www.linusdisplay.com)

3-D displays

**Lumentis** [www.lumentis.com](http://www.lumentis.com)

“One in all” solution for CWDM, DWDM and SDH/SONET applications

**Micronic Laser Systems**

[www.micronic.se](http://www.micronic.se)

High-end laser pattern generators for photo-mask production

**Net Insight** [www.netinsight.se](http://www.netinsight.se)

Data, voice and video (“Triple-Play”) optical networking equipment

## Diversified and creative providers of photonics infrastructure

Sweden has a historically strong position in photonics. Relative to the size of the country the industrial activities must be considered extensive. Recent explosive commercial development in photonics is fuelled by the sharp increase in current and anticipated demand for greater bandwidth and network capacity in the telecom industry. The unique suburb of Stockholm-Kista, which blends high-tech start-ups, first-class applied research, spin-off mechanisms and general innovative infrastructure, has already bred a generation of successful new enterprises in photonics. Furthermore, Kista has an attractive track record for research and cooperation with industry. This, in turn, has spurred efforts and investments in cheap mass production and enabled further photonics development toward integration, increased functionality and lower cost. This progress also offers major advantages for companies in sectors outside telecommunications.

### Acree Photonics Center

Acree is engaged in many important photonic disciplines: Fiber optical networking and broadband technologies, specialty fibers, low cost photonic interconnect and packaging, semiconductor lasers, Fiber Bragg gratings and fiber sensor technology. Access to advanced laboratories is essential for an efficient R&D process and the Center has a number of unique laboratory resources available for supporting its customers:

- A full-scale test-bed for up to 40 Gbit/s field tests of optical networking technologies and applications
- An optical networking lab for up to 40 Gbit/s transmission tests
- A fully equipped state-of-the-art laboratory for development and manufacturing of specialty optical fibers
- Advanced facilities for designing, prototyping and testing Fiber Bragg gratings
- A 2,100 m<sup>2</sup> clean room with several process lines for processing various semiconductor materials

The Center has the resources and competencies necessary to assist its clients in the complete chain from initial modeling and design, via processing and manufacturing, to tests and verifications. Its internal R&D explores the latest technologies offering potential for exciting new products. These results are available to the industrial community.

## Opportunities to join the Acree Photonics Center

**The Swedish Acree fiber optical test-bed** Acree offers an open test-bed for fiber optical communication facilitating broadband connectivity between real end-users in two metropolitan areas in Sweden. With full-scale field tests at the cost of laboratory tests. It facilitates realistic testing, with actual end-user feedback of important aspects of fiber optical networking, such as network management and control, network architecture, protocols and dynamic wavelength switching. Interoperability testing between different systems, subsystems and components, is another important activity.

**SW package for vendor-specific WDM system modeling** When developing a vendor-specific SW-package for accurate modeling of WDM transmission systems, Acreo starts with commercially available simulation tools, and then adds component characterization, integration of experimental results and system verifications to the final SW package. This approach facilitates efficient and expedient design processes for cost-efficient networks while also increasing customer benefit when supplied with the transmission system.

**Diode-Pumped Solid-State Lasers (DPSSL)** Acreo has developed and patented a new design concept with proven versatility for miniature lasers. The concept is based on a silicon micro bench with wet-etched V grooves and is applicable to many kinds of DPSSL. Another focus is on DPSSL in the visible spectral range. The emphasis has been on quasi-three-level lasers and frequency conversion into the blue spectral range. New, powerful and compact DPSSL enable smaller equipment size, lower power consumption and lower life-cycle cost.

**Cheaper optical sub-assembly** To meet stringent cost-demands in transport, metro and access markets Acreo has developed and patented the Nova platform, a hybridization technology, for Optical Sub-Assembly. The platform utilizes a combination of established as well as novel techniques: passive alignment on silicon carriers with sub-micrometer single-mode precision through the use of flip-chip mounting, micro-machining in silicon, and polymer optical waveguides in BCB, benzocyclobutene.

**Fiber-based components for polarization control** Acreo has developed and patented an all-fiber component for tunable polarization control, based on a microstructured fiber. The component promises low losses, simple integration, robustness and low cost and uses a specialty fiber with an internal axial electrode. Upon Ohmic heating the electrode will expand and strain the fiber core asymmetrically thus changing the polarization state of the signal in the fiber.

**Optical fiber strain-sensor system** Acreo has developed an extremely fast fiber-based, distributed, strain-sensing system. The system is capable of monitoring operational load, as well as detecting damage, in mechanical structures, vehicles and machines. The system is based on Fiber Bragg gratings and allows sampling rates of up to 500 kHz from more than 50 measurement points. The system can be modified for sampling rates of more than 10 MHz.

**Advanced optoelectronic modulator arrays for optical communication and signal processing** Acreo is developing a range of advanced surface-normal semiconductor light modulators for optical communication and signal processing applications. These modulators are advanced optoelectronic components whose structures are similar to vertical-cavity surface emitting lasers (VCSELs). Very fast modulation speeds (40 GHz), wide apertures and low-cost manufacturing are some important features of these modulator arrays that already have been manufactured in sizes up to 128 x 128 pixels.

[www.acreo.se](http://www.acreo.se)

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#### **Northlight Optronics**

[www.northlightoptronics.se](http://www.northlightoptronics.se)

Optoelectronic transmitters, receivers and optical amplifiers up to 10 Gb/s

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#### **Optillion** [www.optillion.se](http://www.optillion.se)

10 Gbps Fiber Optical Ethernet transceivers

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#### **OptoNova** [www.optonova.se](http://www.optonova.se)

Customized industrial inspection systems

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#### **Optronic** [www.optronic.se](http://www.optronic.se)

Technical consulting, product development and contract manufacturing of optoelectronic systems

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#### **Packet Front** [www.packetfront.com](http://www.packetfront.com)

Solutions for operator-independent Broadband Networks

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#### **PhoXtal Communications**

[www.phoxtal.com](http://www.phoxtal.com)

High-speed optical components for intelligent transmission systems

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#### **Proximion** [www.proximion.com](http://www.proximion.com)

DWDM Filters; Fiber Test and Monitoring Equipment

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#### **Radians Innova** [www.radians.se](http://www.radians.se)

Tuneable lasers for telecommunication

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#### **Saab Dynamics** [www.saab.se/dynamics](http://www.saab.se/dynamics)

Defence systems with IR and laser technology

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#### **Samba Sensor** [www.samba.se](http://www.samba.se)

Fiber Optical pressure sensor

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#### **SECA Photonics AB**

[www.secaphotonics.com](http://www.secaphotonics.com)

Automated fiber fusion solutions

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#### **Senerica** [www.senerica.com](http://www.senerica.com)

Fiber Optical Fire detection system

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#### **SenseAir** [www.senseair.se](http://www.senseair.se)

Non-dispersive infrared gas analyzers

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#### **Si-Tek Electro Optics** [www.sitek.se](http://www.sitek.se)

Position-sensitive photo detectors

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#### **Song Networks** [www.songnetworks.se](http://www.songnetworks.se)

Network operator

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#### **Spectrogon** [www.spectrogon.com](http://www.spectrogon.com)

Optical Thin Film Coatings and Holographic Gratings

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#### **Syntune** [www.syntune.com](http://www.syntune.com)

Widely tunable monolithic InP lasers at 1.5 micrometer

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#### **Tele 2** [www.tele2.com](http://www.tele2.com)

Network operator

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#### **Telenor** [www.telenor.com](http://www.telenor.com)

Network operator

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#### **TeliaSonera** [www.teliasonera.se](http://www.teliasonera.se)

Network operator

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#### **Transmode** [www.transmode.com](http://www.transmode.com)

CWDM network solutions

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#### **Wavium** [www.wavium.com](http://www.wavium.com)

Optical cross-connects

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#### **Zarlink** [www.zarlink.com](http://www.zarlink.com)

Fiber optical receivers and transmitters

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## Contact ISA and Photonics Sweden

The professional and dedicated staff of Invest in Sweden Agency, ISA, will assist you in any matters related to identifying opportunities and establishing a business in Sweden. Discussions are treated confidentially and all services are free of charge. Contact any of ISA's worldwide offices – full details are available on the web at: [www.isa.se](http://www.isa.se) and [www.photonicssweden.com](http://www.photonicssweden.com)

### Examples of investments in Swedish R&D

- ADC** (US) Acquisition of Altitun
- Cisco Systems Inc.** (US) Acquisition of Qeyton Systems
- Huawei Technologies** (China) R&D center in wireless technologies
- Intel** (US) Wireless competence center & e-business solution center
- Motorola** (US) Development center for wireless applications and services
- Samsung Electronics** (South Korea) Advanced R&D partner
- Siemens** (Germany) R&D center in wireless technologies
- Yokogawa** (Japan) R&D center in wireless technologies
- ZTE Corporation** (China) R&D center in wireless technologies

“We chose Sweden because you have such a positive attitude toward new technology and because you have made so much progress with broadband”.

*Jürgen Walter, Vice President Marketing, ICM cordless products, Siemens*

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Invest in Sweden Agency, ISA, attracts and facilitates foreign direct investment in Sweden. Responsible to the Ministry for Foreign Affairs, ISA provides information about Swedish conditions and assists foreign companies with facts, advice and contacts when considering business establishments in Sweden. ISA cooperates through a national and international network.

  
 Invest in Sweden Agency