

A close-up photograph of a microelectronics circuit board, showing intricate patterns of copper traces and a central integrated circuit. A bright red laser beam is directed at the board, creating a sharp focal point on the central component. The background is a soft, out-of-focus blue and cyan, suggesting a laboratory or industrial setting.

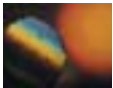
Research

in focus



Department of Microelectronics and Information Technology
- part of the IT University in Kista

Research in Focus



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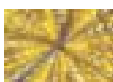
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Building Bridges

Microelectronics and information technology developments occur at an amazing pace, and ever-greater demands are being placed on people and organizations at the forefront.

- ♦ ***There is a need for deeper understanding of materials, devices and technical systems, at the same time as the complexity is increasing exponentially.***
- ♦ ***There is a need for broader knowledge and understanding so that breakthroughs can be made and new disciplines opened up.***
- ♦ ***There is a need for integration of different skills and subject areas, in order to cross barriers and to do things previously considered impossible.***

At KTH, Royal Institute of Technology, we want to take this challenge and have therefore established the Department of Microelectronics and Information Technology – IMIT – by merging the former Departments of Electronics and Telecommunications, and parts of the Department of Physics. Within this new grouping more than 45 professors are leading a broad spectrum of research fields – from fundamental physics, through materials physics and optics, electronic and photonic devices, electronic and computer systems to connectivity systems for both telecommunications and computers. In other words, the aim is to cover most of what is – in the widest sense – the rapidly increasing field of information technology and beyond. IMIT represents research from “Materials to Internet”, building bridges between fundamental science and applied engineering

IMIT is thus well equipped to meet new challenges and to solve new problems – fundamental as well as applied. The best ideas and creative solutions arise at the boundaries of different cultures and disciplines. We already have a productive co-operation with other universities, with industry and with research centers and are steadily looking for new opportunities especially within cross-disciplinary research fields.

On the next few pages, we present samples of our skills and resources applicable to research. However, please note that in addition to research, one of our most valuable resources is education. Spanning from basic undergraduate level to the forefront in new technologies we provide a great variety of courses.

We hope to arouse your curiosity and to join you in future collaborative projects.

***Mikael Östling
Head of Department***



KTH Kungl Tekniska Högskolan

KTH, The Royal Institute of Technology, was founded in 1827 and is the largest of the six universities of technology in Sweden today. KTH main campus is located in central Stockholm, and KTH has also campuses located in Kista, Haninge and Södertälje. The KTH Kista Campus, with the Electrum and Forum buildings, is Sweden's largest research resource within information and communication technology.

Largest in Sweden

KTH provides one third of Sweden's capacity for engineering studies and technical research at post-secondary level, and training of engineers. KTH has, in total, approximately 18 000 undergraduate students, 1 400 active postgraduate students and in all 3 200 employees, including almost 200 professors.

The education and research carried out cover a wide field – from natural sciences to all branches of technology, including Architecture, Engineering and Business Management, Infrastructure and Planning, and Environmental Technology.

Education

KTH has a number of M.Sc. programmes, and one in Architecture, in all 4.5 years of studies, as well as B.Sc. programmes of 3 years duration. There are also further education courses, primarily for architects and engineers. KTH provides courses within its normal operations, financed by government, and special courses on demand. This interaction with society is an integrated part of KTH's operations.

Research

KTH's research has increasingly come to focus on activities motivated or initiated by the needs of industry or society. At the same time, basic long-term research, which will form the basis of future development, is carefully maintained. KTH is regularly conducting joint research and development projects with major industries. To promote long term research and close collaboration with industry, KTH hosts more than ten Centres of Excellence, focusing on specialities ranging from IT Design to Bioprocess Engineering. KTH hosts and participates in a number of national and international – mainly EU – research programmes.

Collaboration

KTH has well established educational and research collaboration with universities and colleges all over the world, primarily in Europe, USA, Australia and South East Asia. Levels of academic exchange are also increasing with Eastern Europe, primarily with the Baltic States.

KTH also has an organisation to facilitate commercialisation based on research carried out at KTH. This includes advisory services, and a possibility to offer business infrastructure to small and growing enterprises. There are several examples of successful companies, which have passed through the commercialisation process at KTH.

Visit www.kth.se.



IT University

The IT University in Kista is the common name for all academic activities in Kista /Stockholm. The organisation is "virtual", in the sense that it includes departments and centres from three universities – KTH, Stockholm University and Karolinska Institutet (Sweden's only university for medicine) – acting together under the name IT University.

In the centre of Swedish IT industry

The IT University is located in Kista, the centre for Swedish IT industry. More than 700 companies are located in Kista. Most of them work in high tech fields such as telecom, electronics and software, with Ericsson as the dominating one. Kista is ranked as one of the world's most attractive regions for industrial establishment in the IT area. One key reason is the easy access to the university with its students and research results.

Education

The IT University provides B.Sc., M.Sc. and graduate education as well as short courses within the fields of Microelectronics, Circuit Design, Communication Systems and Information Systems, spanning the broad field between basic physics, and computer science. For the year of 2001 the IT University has, in total, about 3 500 students, of which 140 are Ph.D. students. The number of students is planned to increase to a total of at least 8 000 students in year 2008. The education is in many respects pioneering, including novel pedagogic ideas and IT support with laptop computers, wireless networks and interactive rooms for the students.

Research

The research at the IT University covers, in a broad sense, the infrastructure of the IT society. It includes IT systems and applications, communication systems, software and hardware solutions, device technology, and fundamental physics. Many graduate students are closely collaborating with the local companies. One important goal for the education, beside the scientific results, is the demand from the society for individuals with a deep competence in the front line of technology development.

Organisation

The IT University is organised in three departments for education and research:

- Department of Microelectronics and Information Technology
- Department of System and Computer Science
- Department of Applied Information Technology

There are also a number of research centres, dedicated for industrially relevant research.

Visit www.it.kth.se.

Department of

Microelectronics and Information Technology

The Department of Microelectronics and Information Technology (IMIT) is the largest department within the IT University, with more than 260 employees, among those are 45 professors, 85 researchers and 160 Ph.D. students.

IMIT was formed in 2001 by merging the departments of Electronics and Teleinformatics with parts of the Physics department, the Semiconductor Laboratory and KTH Online. Within this constellation a broad competence within IT related research and development is contained, from basic physics and materials physics over electronic devices, optics and opto-electronics to electronic circuits, computer- and communication systems. The department is internationally leading within its fields, and is deeply involved in the development of Kista to a world-leading region for information science and technology. A more thorough presentation of the research activities at IMIT will be given on the following pages.

The education given by IMIT is connected to the M.Sc. programme in Information Technology at the IT University. There is an international program on System-on-chip design, Internet Technology and Wireless Communication, and in addition an entirely new M.Sc. programme in Microelectronics is being developed. IMIT contributes as well with separate courses within other M.Sc. programmes at KTH, and could readily provide courses within the competence area to other customers.

IMIT is organised in five laboratories and one section for research and education:

- Laboratory of Materials and Semiconductor Physics
- Laboratory of Solid State Devices
- Laboratory of Optics, Photonics and Quantum Electronics
- Laboratory of Electronics and Computer Systems
- Laboratory of Communication Networks
- Tslab – Telecommunication via Internetworking



There are also two centers for industrially related research, co-financed with industry and research institutes.

- KTH Semiconductor Laboratory
- Swedish Center for Internet Technology

The department is also one of the active partners in Wireless@KTH – the KTH Center for Wireless Systems – and in the Kista Photonic Research Center.

The department belongs to KTH – Kungl Tekniska Högskolan (Royal Institute of Technology) and is a part of the IT University venture in Kista / Stockholm.

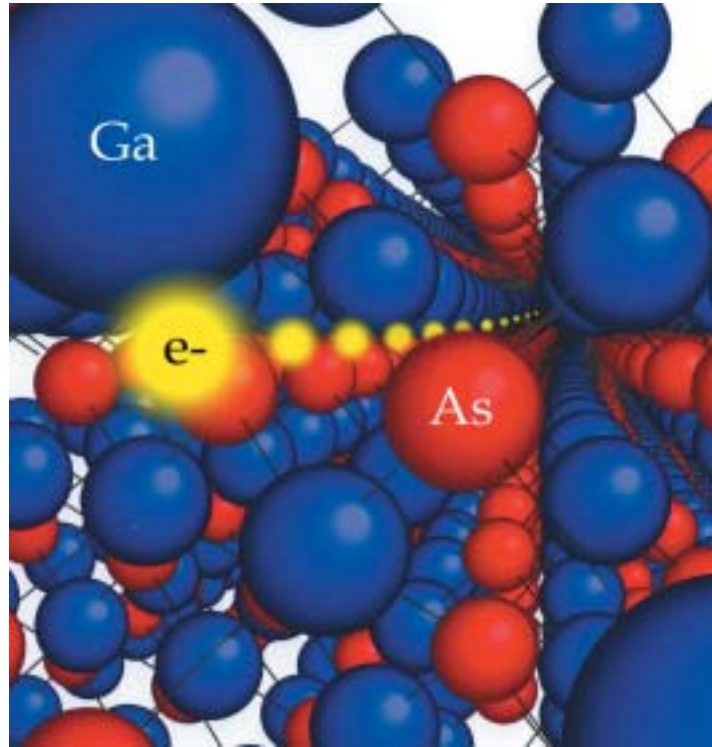
Materials and Semiconduct

5 Professors 25 Research Scientists 30 Ph.D. Students

In everyday life, we are surrounded by devices and equipment whose functions depend on crystals – the smallest constituents of the modern IT society. The key to the properties of a crystal is in the nature of the atoms within it, together with the structure of the crystal, which can be depicted as the arrangement of the atoms in a regular pattern – a lattice.

Most electronic circuits are fabricated from almost perfect single crystals of the element silicon. Certain applications, which require optical functions or operations at high frequencies, demand crystals made of more complex materials such as indium phosphide or gallium arsenide. Other applications are based on silicon carbide where high currents and high voltages are required.

The trend is towards functions requiring ever-higher levels of performance, being built directly into the semiconductor crystal itself. Quantum wells are becoming three-dimensional quantum boxes and close packing is becoming tighter, at the same time as the potential to combine different materials and components on the same chip is increasing. In short, developments are moving towards increasingly complex crystals and structures.



Materials Physics

A key to describing the properties of any material lies in the structure of the material itself. This starts with the structure of the crystal, which in turn can be explained if the properties of the state of the electrons in the lattice are known.

Quantum mechanics calculations concerning the state of electrons are thus the basis from which to gain a deeper understanding of the properties of solid materials, for example. We have done these calculations for certain elements – for example, iron and tungsten – and for important compounds, such as titanium carbide.

From the state of the electrons we can calculate bonding energy, elastic properties and heat capacity.

Our work includes both fundamental and applied research. Energy relationships of importance to metallurgical calculations are an example of our applied research. We conduct research into materials, alloys and composites of *all* types.

Semiconductor Materials

Fine control of the growth of crystals is a prerequisite for modern microelectronic and optoelectronic technology. Today, semiconductor crystals can be tailored for special components or applications. We can – atomic layer by atomic layer – control the composition and electrical conductivity of each layer of the

material and thereby alter at will the properties of the crystal. This is an important process in the manufacturing, for example, of semiconductor lasers for fibre-optics or CD-players.

Our research is mainly focused on epitaxy, i.e. growing crystals: the design, fabrication and analysis of materials and structures for advanced photonic and electronic devices. We have long experience of “bandgap engineering” which is necessary to take advantage of quantum mechanical effects in artificial crystal structures. The principal technology we use is gas phase epitaxy for gallium arsenide and indium phosphide – Metal-Organic Vapour Phase Epitaxy (MOVPE), however, we have also developed a unique manufacturing method for selective epitaxial growth of indium phosphide– Hydride-VPE.

Other fields where we are highly active include dry etching, surface emitting lasers (VCSELs) and materials analysis. One of the new techniques we have developed is “Scanning Capacitance Microscopy” (SCM) to study electrical properties at nanometer length scales.

Our long-term research projects cover areas such as the manufacture of novel, more efficient materials for semiconductor lasers, fabrication processes for photonic crystals and gallium nitride technology for new application areas.

or Physics



Solid State Electronics

Our research focuses on silicon, silicon-germanium and silicon carbide semiconductors. The research programme is process and materials oriented but also includes devices and device physics. We conduct both fundamental and applied research. We study how defects and impurity atoms influence the material and electronic properties of semiconductors, and how this affects their use in modern devices. We try to “look inside” operating devices to study current flows, electrons and holes concentrations, or to measure local temperatures.

Silicon carbide (SiC) is a “new” semiconductor material with unique properties. It has a high bandgap and very high “critical field strength”. It can be used in devices at very high temperatures and at very high voltages. It has therefore attracted considerable interest in the electric power industry. We are studying defects and impurities and seeing how they diffuse in the material. We are developing computer simulation tools to calculate the performance of devices, and a high voltage diode to investigate the

voltage tolerance of materials. We have also developed a new optical technique to “see” charge-carriers “inside” operating silicon carbide devices.

The study of defects and diffusion in semiconductors – particularly in connection with ion implantation – has a long tradition in this laboratory. In particular the characterisation of transient diffusion has aroused much interest lately. The phenomenon imposes severe limitations for achieving ultra-shallow pn-junctions – a difficult problem in modern VLSI technology.

A new and very exciting project is in the field of nano-structures in silicon. Working on this very small scale, quantum physics comes into play and silicon acquires new characteristics – one may talk about silicon nanocrystals or quantum dots. As a result silicon becomes optically active; this could be used for light-emitting devices such as in displays. We are also using electron beam lithography to fabricate nano-structures, which can subsequently be made even smaller by means of oxidation or electrochemical etching. The goal is silicon handcrafting at a nanometre level!

At the micrometre level, three-dimensional structures can be built by means of deep etching of silicon (Deep Reactive Ion Etching), which we have used to make a high sensitivity imaging X-ray detector (for dental applications). A further development here is electro-chemical etching where pillars and pores can be produced with very large aspect (depth-to-width) ratios.

Resources

An important resource for our research is the KTH Semiconductor Laboratory, where crystals and components are made for various purposes. We can provide everything from time on machines to conducting special processes and measurements. (See extended description on page 15.)

We have a comprehensive analysis facility, which includes techniques for materials analysis, such as SIMS (secondary ion mass spectrometry), RBS (Rutherford back-scattering spectrometry) and X-ray diffractometry, together with equipment for electrical characterisation of semiconductors, including DLTS (deep level transient spectroscopy), C-V and I-V measurements.

We also have reflectometers, hydrogen reaction chambers, magneto-optic equipment, magneto-resistance equipment, low temperature growth systems, etc. We can also measure the characteristics of optical devices such as lasers and light-emitting diodes.

Collaborative Partners

Some of our academic collaborators are:

Uppsala University, Sweden
Linköping University, Sweden
Chalmers University of Technology, Gothenburg, Sweden
Århus University, Denmark
Oslo University, Norway
University of Iceland
Vilnius University, Lithuania
Clarendon Laboratory, Oxford, England
Free University, Amsterdam, Netherlands
University of Würzburg, Germany
University of Trento, Italy
SUNY, Albany, USA
NIST, Gaithersburg, USA
University of Santa Barbara, USA
Australian National University, Canberra

We also collaborate with foreign and Swedish industry, on specific commissions as well as on collaborative research work. Partners include:

ACREO, Kista, Sweden
Ericsson Microelectronics, Kista, Sweden
ADC-Altitud, Järfälla, Sweden
Zarlink Semiconductors, Järfälla, Sweden
ABB Corporate Research, Västerås, Sweden
FOI, Linköping, Sweden
Philips Eindhoven, Netherlands
Agilent Technologies, USA

Glossary

Epitaxy Growing crystals – thin single crystal films of different materials in separate layers.

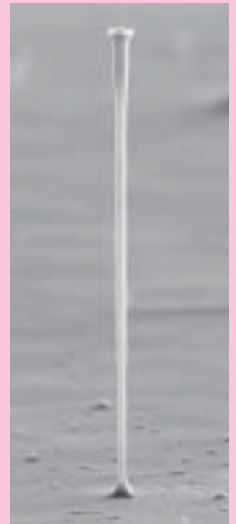
Bandgap Engineering In conjunction with epitaxy, generating artificial potential differences (because of different bandgaps in different materials); these can control electrons and light in an efficient manner. In this way, layers can be made so thin that quantum mechanics effects can be used to increase performance.

Vertical Cavity Devices Optical devices where light is emitted vertically from a semiconductor chip (in contrast to edge emitting devices where the light comes out through the narrow edge). Vertical cavity devices have many advantages, but are more difficult to make.

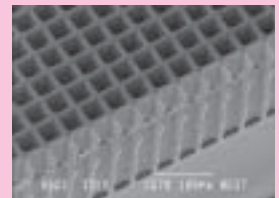
VLSI (Very Large Scale Integration) Silicon chips with very closely packed transistors.

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120 μm high pillar etched in silicon by electrochemical etching



Pores etched in silicon by DRIE (deep reactive ion etching)



Solid State Devices

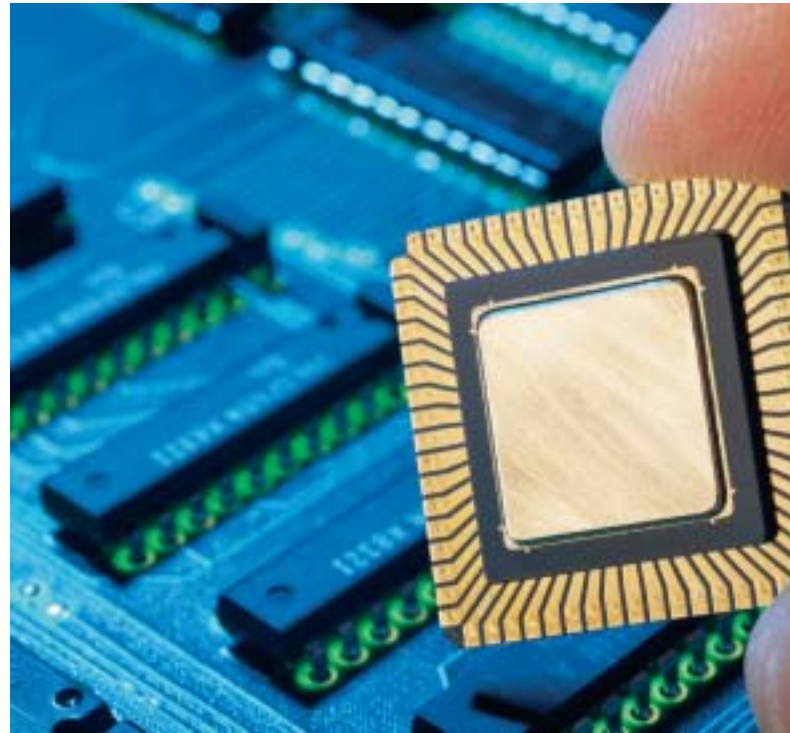
4 Professors 15 Research Scientists 30 Ph.D. Students

One goal of research is to extend fundamental scientific knowledge and to develop applications for new materials and new experimental techniques, which in turn can be applied to new devices. Examples of fundamental techniques which can be put to use include crystal growth and advanced analysis technology. Using these techniques, new materials and structures can be made and investigated. Furthermore we can study their physical characteristics.

In practice, in order to make use of the results of materials research, there is a need for solid skills in device technology. This includes device physics and the modelling and manufacture of devices. The subject combines knowledge from, and integration of, the fields of materials physics and electronic circuits.

A topical application is the device technology required for wireless communications, such as mobile telephony, base stations and Bluetooth. The market demands ever smaller and faster transistors. This is mainly a matter of removing the causes of current bottlenecks and finding better solutions for e.g. A/D converters, low power circuits for mobile telephones, and fast and reliable circuits for base stations.

The combination of semiconductor research in device technology and fundamental research in the physics of condensed matter is providing the capability to develop the electronic devices for the future.



Condensed Matter Physics

We have the technology for growing crystals and access to advanced experimental instrumentation. This is used for determining the characteristics of materials and for studying their electrical and magnetic properties.

We grow crystals in various forms – e.g. as films or multiple layers – with the capability to store information in the form of electric pulses or magnetic fields. We are studying weak magnetic fields, infrared radiation and stress, together with the properties of the material in reacting to electric and magnetic fields and in conducting electrical, magnetic or optical signals.

In order to make optimum use of high temperature superconductors in electronic applications, it is, of course, necessary to understand their behaviour in magnetic fields. We are studying vortex dynamics and the critical current density of superconductors.

We are conducting research into quasi-crystals and oxide materials – e.g. superconductors, ferro-electrics, colossal

magneto resistance, thin ferrite films, electronic transfer characteristics and metal/insulator transitions.

We also possess skills in single crystal manufacture, thin film manufacture, X-ray diffraction analysis, magnetic measurement, dielectric measurement, electron transference and microwave spectrometry.

Device Technology

Our work covers device physics and the modelling and manufacture of devices. We are primarily studying silicon and silicon-germanium transistors, although we also study new materials such as silicon carbide (SiC), as well as integrated passive components such as capacitors, resistors and inductances required to build analog circuits.

One important research area is high frequency silicon. CMOS is the dominant technology for the manufacture of



circuits and microprocessors, but it has not yet been able to establish itself in the field of analog applications at high frequencies. In research, our challenge is to develop CMOS for use at radio frequencies – RF-CMOS.

In order that the wireless Internet may be successfully developed, it is necessary for CMOS technology to be established in the 5-10 GHz band. Mobile terminals, microwave links and fibre-optic communications will require circuits operating in the frequency band of 60-70 GHz. There will also be a demand for radical new circuit architecture to cope with the demands of RF-CMOS.

Bipolar high frequency silicon is another important area of our work. It deals with the development of bipolar integrated circuits, which combine analog, RF and digital

technologies – BiCMOS technology. These combination chips are required for future developments in the mobile application area. The current low transfer rates in mobile telephony will increase from around 10 kb/s today through 1 Mb/s, up to 10 Mb/s in the future. This will place heavy demands on constituent devices.

Silicon carbide (SiC) is a new and promising semiconductor material. We are conducting research into high frequency and high voltage applications for SiC. The material has properties that make it suitable for very high voltages, power and temperature, and also for high frequencies. We are developing fundamental sub-processes for the manufacture of devices such as etching, metallisation and dielectric deposition, so that we can subsequently combine them into processes for making transistors.



Silicon wafer with devices made in our semiconductor laboratory.

Resources

We have a full range of equipment, not only for the production of new materials and thin films, but also for the study of light over a wide frequency range, the analysis of electrical, magnetic and optical characteristics in the bands from microwaves to infra-red and ultra-violet light, and in temperatures from 4.2K (liquid helium) to 1400°C.

This equipment includes broadband radio spectrometers, magneto-optic spectrometers, ferro-electric and piezo-electric measurement instruments, super conducting magnets and magnetometers. We have access to all device-processing equipment needed in The KTH Semiconductor Laboratory. (See extended description on page 15.)

Our laboratory for the characterisation of devices can handle up to 300 mm wafers, in a light tight, RF-shielded test station. Electrical measurements can be conducted at temperatures between 10 and 300°C, with currents from 20fA to 1A and voltages from 1 mV to 300 V. Comprehensive s-parameter analysis can be conducted between 45 MHz and 26.5 GHz. Additionally, we can conduct capacitance measurements between 20 Hz and 1 MHz, together with 1/f noise measurements. Physics based simulations of both devices and manufacturing processes can be carried out using software from Avanti, Silvaco and ISE.

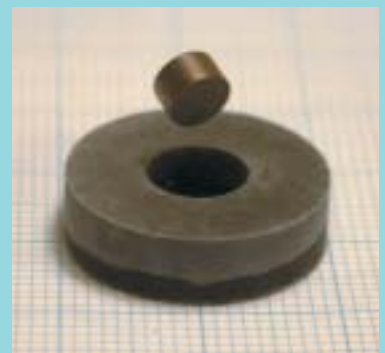
Collaborative Partners

We have a large network of contacts with universities and research centres around the world, including:

KFA Jülich, Germany
EC Ultra Low Temperature Facility, Bayreuth, Germany
Centre National de la Recherche Scientifique - CNRS Grenoble, France
Stanford University, USA
University of Florida, Gainesville, USA
Brookhaven National Laboratories, USA
University of Missouri, USA
North Carolina State University, USA
University of Virginia, USA
Kyoto University, Japan
Kumamoto University, Japan
Nagoya Institute of Technology, Japan
Osaka University, Japan

We also collaborate with industry, including:

Ericsson, Kista, Sweden
ABB Corporate Research, Västerås, Sweden
STMicroelectronics, France
Agilent Technologies, USA



Meissner Effect. A small magnetic field is pushed out of a superconductor. A magnet hovers in its own magnetic field.

Glossary

CMOS Complementary Metal Oxide Semiconductor - A technology for the manufacture of circuits and microprocessors

BiCMOS Bipolar CMOS

RF Radio Frequency

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Optics, Photonics & Quantum

5 Professors 15 Research Scientists 20 Ph.D. Students

The explosive growth of Information Technology would not be possible without fibre optics. The “electronic super highway” of the Internet is actually an optical super highway. Information in the telecommunications network is transferred as light pulses in glass fibres at amazing volumes and speeds – billions of bits per second. A particle of light is called a photon, and photonics for IT is considered to be a key enabling technology for the transmission, storage and handling of information.

Optical data transfer rates have become so high that the time taken to generate and detect short light pulses is becoming significant. It has become necessary to take account of time delays inside devices and to develop new structures with shorter rise- and fall-times

The technical development is also moving towards very low power and compact systems. How small a light pulse that can be sent while still transferring a certain amount of information is beginning to approach the limits that physics allows. At the extreme, the special laws of quantum mechanics set the limits and we are trying to understand these limits and at the same time make full use of the available physical possibilities.

Quantum physics phenomena are being described with increasingly advanced theoretical models. Current studies include physical phenomena such as non-local correlations that cannot be explained with classical physics.



Optics

In the field of optics we cover both research and applied technology within e.g. laser technology and IT. We specialise in femtosecond optics, spectroscopy of semi conducting nano-structures, electromagnetic optics, near field optics and coherent optics.

We use femtosecond lasers to investigate new semiconductor structures with very short reaction times, which can be used in rapid electro-optics. We are also developing time-resolved near field microscopy. Electromagnetic optics is concerned with the interaction of light with matter, where account has to be taken of the vector nature of the light. There are, for example, applications of micro- and nanostructures in diffractive optics and photonic materials. In coherent optics, we are studying the effects of whole or partial coherent radiation and new types of light fields.

Optics is closely associated with many other technologies and research areas – imaging, holography, optical measurement technology, fibre optics, non-linear phenomena, surface analysis, chemical analysis, quantum electronics, and the development of new lasers are all important applications of optics.

Photonics and Microwave Technology

We conduct research across a wide spectrum – from fundamental quantum physics and nanoelectronics to device technology and systems for fibre optic communications and high-speed electronics

In the field of integrated laser technology and electro-optics, we are developing and conducting research into devices for fibre optic communications – from manufacture and process technology to the evaluation and use of such devices in systems. For example, we have developed a receiver with transistors integrated with light detectors for fibre optic systems with 40 Gigabit/sec transmission rates. This implies that one single laser could transmit the contents of seven CD-ROMs in one second through an optical fibre.

In our research into light modulators for fibre optic communications we have achieved bandwidths of over 60 GHz and we are conducting further research into new concepts to attain even higher performance.

We also have projects for optics based on silicon technology. Most of today's electronics is based on silicon, and it would

Im Electronics



therefore also be of interest to make integrated optical circuits in silicon. The technology in electro-optics and integrated optics will form the basis for broadband communications through optic fibres into the home.

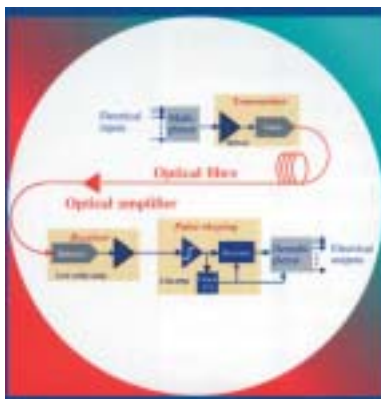
We are also working in micro-electronics where components are becoming ever smaller. We have developed special methods for making extremely small electronic components – measuring around 100 nm. The components are then so small that the electrons – wholly in accordance with quantum mechanics – begin to behave like waves. We are trying to find out what new capabilities these components, using the wave characteristics of electrons, can open up for future electronics.

Quantum Electronics and Quantum Optics

One of the great advantages of quantum physics is that it offers new opportunities for handling information rapidly and securely. We are developing “Quantum Cryptography” – a method of transmitting information with the aid of light in a way that, thanks to the laws of physics, guarantees that every attempt to eavesdrop will be detected. In this project we are building a quantum cryptographic system, which is directly compatible with conventional fibre optic systems.

We are also studying the characteristics of photonic components based on periodic dielectric structures where the refractive index varies in one or more dimensions – these are known as optical crystals, or photonic bandgap structures.

In the field of minute semiconductor lasers, we are working with mathematical models for the properties of light in surface emitting lasers.



Resources

We have equipment for high-speed laser optics and spectroscopy, including a Titanium-Sapphire laser system, which can produce femtosecond pulses. We have measurement instruments for time-resolved photoluminescence, transmission and reflection measurements that can be combined with scanning near field optical microscopy (SNOM). We have excellent experimental resources for time-resolved and spectroscopic measurements of very weak light, and we also have a cryostatic facility where we can conduct detailed electrical and optical interference measurements at very low temperatures.

We also have advanced instrumentation for the electrical measurement of high-frequency components up to 20 Gbit/second and for microwave measurements up to 60 GHz.

Collaborative Partners

We collaborate closely with a number of international organisations. Much of our research is conducted in co-operation with other research centres in Sweden and abroad. Some of our academic partners are:

Karolinska Institutet, Stockholm, Sweden
Chalmers University of Technology, Göteborg, Sweden
Linköpings Institute of Technology, Sweden
Norges teknisk-naturvitenskapelige universitet, Trondheim, Norway
Technical University of Denmark
Åbo Akademi, Finland
Tampere University, Finland
Helsinki University of Technology, Finland
Semiconductor Physics Institute, Vilnius, Lithuania
University of Utrecht, Netherlands
Freie Universität, Berlin, Germany
Technische Universität Berlin, Germany
University of Geneva, Switzerland
Ioffe Technical-Physical Institute, St. Petersburg, Russia
Los Alamos National Laboratory, USA
Stanford University, USA
Cornell University, USA
University of California at Santa Barbara, USA
University of Rochester, USA
California Institute of Technology, USA
Nihon University, Japan

In addition to fundamental research, we also participate in co-operative research work with various research centres, and with Swedish and foreign companies, such as:

ACREO, Kista, Sweden
Ericsson, Kista, Sweden
Optillion, Kista, Sweden
Zarlink, Järfälla, Sweden
ADC-Altitun, Järfälla, Sweden
Alcatel, France
France Telecom, France
Cisco Systems, USA
Lucent Technologies, USA
Nippon Telephone & Telegraph, Japan

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Electronics and Computer

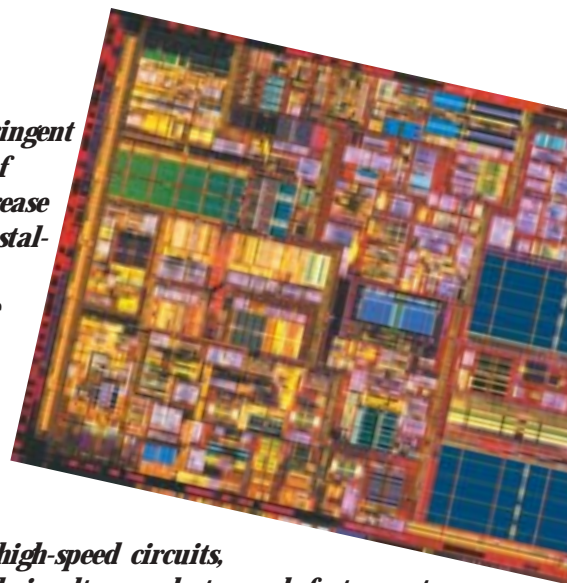
7 Professors 25 Research Scientists 40 Ph.D. Students

The current rapid developments within IT are placing increasingly stringent demands on the technology used. For example, the speed of operation of internal electronic circuits is becoming much more important. To increase these speeds, smaller and extraordinarily fast transistors have to be installed in each circuit. There are currently microprocessors, and memory banks which contain up to a billion transistors. And developments are continuing towards ever more complex systems.

Radio electronics plays a key role in the development of mobile communication systems. We will face new challenges in finding new radio architectures and smart circuit solutions to meet demands on cost, power, bandwidth, linearity etc. A range of new wireless system solutions and services will emerge as a result.

In order to produce high performance applications based on these high-speed circuits, parallel computing has been developed; here several processors are used simultaneously to work faster or to solve problems, which are too large for just one processor. This strategy can also be seen at chip level. Several manufacturers are planning multiprocessors on chips in their products, and we will also see this in embedded systems. Computer architectures can also be improved to achieve higher efficiency. And then it becomes a question of the art of designing computers with the focus on the interface between hardware and software.

In the case of network applications, besides programming and other techniques, there is a need for analysis and verification of the network. There are tools on the market, which can analyse and generate codes. However, networks also require analysis from a perspective more allied to behavioural science in order to be able to guarantee that the network and its applications function together as intended.



Electronic System Design

We are conducting research into how best to describe and design electronic circuits, which contain a billion transistors. This is a complex problem as there are no computer programs available at present, which can solve this problem satisfactorily

Current programs for the design of electronic circuits give rise to many faults. In our research we are trying to develop methods based on mathematical models, which will help to design properly functioning electronic circuits in a simple manner.

The demands on electronic circuits increase daily. How should the circuits of the future be designed to run at speeds of over 1 GHz? Large amounts of electrical energy are required in order to be able to process this volume of information in a traditional electronic circuit. This makes the circuit hot and thereby cease to function. We are investigating whether circuits can be divided into smaller blocks so that all the transistors are not switched exactly simultaneously thus avoiding peak power pulses.

Radio Electronics

Our research is focused on the design of the new radio systems in low cost technologies. Radio electronics are central to the mobile

systems. Alongside mobile systems such as 2G, GPRS and 3G, which have considerable geographic coverage, there are several smaller systems like PAN or WLAN. There are great differences in performance, degree of coverage, efficiency levels and, last but not least, price.

In all these systems, future progress will depend to a great extent on how well we succeed in solving the radio issues involved. There is a need for detailed knowledge of a number of different areas, e.g. signal processing, components, analogue electronics, mixed signal design, standards and radio technology. Furthermore, an analogue design in silicon, for example, is still not predictable in the same way as a digital one – and it is quite simply more difficult to make it work.

Computer Architecture

Our research is conducted in two fields: parallel computing and computer architecture. It is important that the software corresponds with the architecture for the best performance. In modern computer architectures, e.g. in the Intel IA-64, the hardware is exposed to the programmers, which has meant that questions associated with architecture have become more important in recent years.

As regards server architecture, parallel systems have become

Systems



the most common model. We can also see that this strategy is being chosen at chip level. Several manufacturers are planning multiprocessors on chips in their products and the trend is towards seeing this in embedded systems as well. We conduct research into both software and hardware for parallel systems.

Parallel and Distributed Systems

The construction of high performance network applications is a difficult task. It is not enough to be able to program – it is also necessary to be able to undertake the modelling, program analysis, specification and verification of networks.

We have to be able to analyse computer systems from a perspective more allied to behavioural science. For instance in the context of safety- or security-critical applications such as absence of deadlocks or malfunctions, data integrity, or confidentiality.

In order to develop these analysis methods we need deeper knowledge of semantics and program logic as well as application-oriented skills.

Our research focus lies on the principles, tools and applications of semantics-based software specification and verification. It includes program analysis techniques for specification and verification, modelling languages based on UML (Unified Modelling Language) and techniques for using experimental programming languages such as Haskell.

Distributed Computer Systems

The distributed computer systems group (DCS) is focused on software tools and methods for supporting the development of distributed systems and applications; especially on systems for networked and mobile computing.

As part of our research activities, we try out our tools, methods and software in realistic applications, either as research prototypes (demos), or in cooperation with external partners – mainly industry.

We concentrate our efforts on the following sub-areas:

Design and implementation of network-enabled programming languages and systems; in particular the Mozart programming system.

New algorithms, middleware, libraries and techniques to support distribution and software-based high availability in large scale distributed systems; for example our EU project on peer-to-peer computing

The design and use of intelligent agent technology for studying and simulating emergent behavior in large-scale systems; for example our work on social simulation of the web in the EU project I-Cities.

Resources

We are able to conduct evaluations of performance and to propose solutions within our area of expertise. We can also provide support for practical modelling, specification and verification tasks. We also offer courses in the following subjects:

- Low power design
- Interconnect-centric design
- Fault tolerant design
- HW/SW Codesign
- System Modelling
- ASIC Design

Collaborative Partners

We have an active collaboration programme with universities and industry, both nationally and internationally. Among our collaborative partners are:

- Uppsala University, Sweden
- Linköpings Institute of Technology, Sweden
- Chalmers University of Technology, Göteborg, Sweden
- Lund Institute of Technology, Sweden
- Turku Technical University, Finland
- Oulu University, Finland
- Tallin Technical University, Estonia
- Universität Braunschweig, Germany
- Universitat Politècnica de Catalunya, Barcelona, Spain
- Ohio State University, USA
- University of California, Berkeley, USA

Our contacts in industry include:

- Telefonaktiebolaget LM Ericsson, Stockholm Sweden
- Ericsson Radio, Kista Sweden
- Ericsson Infokom, Kista Sweden
- ACREO, Linköping Sweden
- Spirea, Sweden
- Axis Communications, Lund Sweden
- IMEC, Belgium
- Pallas GmbH, Brühl, Germany

We also co-operate closely with the Swedish Institute of Computer Science (SICS), Kista, Sweden.

Glossary

IP-block Intellectual Property a separately designed device which is integrated with specific designs on the same chip.

ASIC Application Specific Integrated Circuit integrated circuits of specific design.

LAN Local Area Network

PAN Personal Area Network

WLAN Wireless LAN

CMOS Complementary Metal Oxide Semiconductor. A technology for the manufacture of circuits and microprocessors.



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Communication Networks

4 Professors 10 Research Scientists 10 Ph.D. Students

Telecommunications has become a driving force for research and technological development. A number of technologies and systems have been developed in order to fulfil various requirements. For example, systems based on optics and electronics have been developed for fibre and radio communications to satisfy the needs for high capacity and greater mobility.

Hardware and software have their proper places in all systems. But how can the potential of different technologies be exploited and combined to construct future communications networks? What is the best way to provide support to both audio-visual and data services? How should networks be dimensioned and how should they be managed? These are the questions to which we seek the answers. By combining different technologies, we will obtain a result, which is greater than the sum of its parts.

Computer communications within the telecommunications field has previously been considered of minor significance. But the subject has moved from a small niche within telecommunications to one of the most active areas – a question of survival for many organisations.

Dynamic development is taking place within the Internet and mobile telephony, and is characterised by a strong belief in the future. The Internet was not created for mobile reception or for real-time services, and our research aims to study how such an adaptation can be enabled. We are also interested in the future implications of the increasingly close integration of media, computers and telecommunications.

– mainly with regard to reliability.



Teletraffic

Our research is directed primarily towards studying architecture and performance as regards the Internet. Ongoing research covers quality of service and performance monitoring on the Internet. It concerns the design of a service architecture to provide support for audio-visual services. Our ideas are based on a combination of traffic control and error control in order to achieve suitable quality levels.

In the long term, we intend to extend our studies to look at the *whole* connectivity chain from the source of information, through networks to the reception of data for presentation. We have just started a new research area: system architectures for high performance switches (over 10 Gb/s per port). We are setting up an environment suitable for testing and making prototypes. We are also studying optical networks

Computer Communications

We are conducting research into computer communications in its broadest sense. We have placed the emphasis on wireless mobile communications between computers and between computers and peripherals. Our research aims to discover the architecture and the protocols required to



support future mobile computer and telecommunications systems.

Telecommunications

We are conducting research into telecommunications systems, in particular into communications protocols. Our research is dominated by questions about mobile telecommunications. It covers services in future mobile wireless networks and markets in the new economy. We are interested in the Internet as a whole, as well as questions of scalability, mobility and wireless access. We are also conducting research into support systems for students

The computer, media and telecommunications fields are moving closer together. We are studying what this is going to mean for organisations. The challenge is to integrate the technologies and to make them generally accessible, reliable, secure and manageable.

We are also setting up a method of viewing the changes within the computer and telecommunications fields from an economic perspective. Here we will study processes from concepts to mature products and the effects on

the production methods of companies. The new technologies will create openings for new players and new business models. We will see a completely new way of thinking about products and services.

We have unique capabilities to conduct research in this field. We will have access to actual networks at the forefront of developments, which are used by real users. Examples include the wireless network in use in the IT University at Kista and the trial of "StockholmOpen.Net" – an open communications network recently inaugurated at Kista.

There are of course strong links between the research, which we are conducting, and our two newly established centres for Internet Technology and for Wireless Communications.



Services

We provide education within our speciality areas. Extended collaboration on research is of great interest, but we will also happily discuss studies for MS theses.

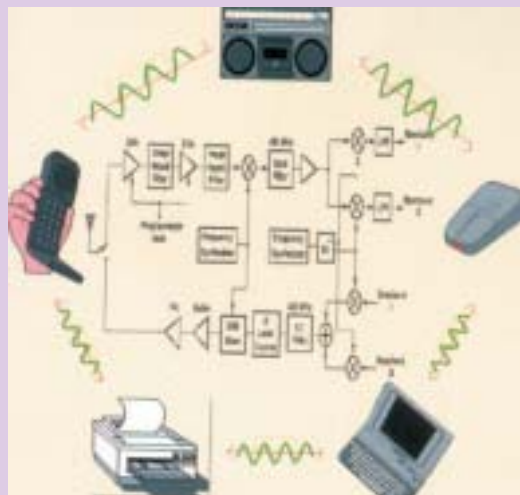
Collaborative Partners

Our network of contacts encompasses universities and research laboratories in Europe and the USA. Our academic contacts include: The Norwegian University of Science And Technology, Norway
Helsinki University of Technology, Finland
Ecole Polytechnique Fédérale de Lausanne, Switzerland
Eurecom, France
Columbia University, USA
Stanford University, USA
University of Colorado, USA

We have joint research projects with a number of companies in Sweden, such as:

Ericsson, Sweden
Nokia Network Research Center, Sweden
Telia, Sweden
Swedish Institute of Computer Science, SICS, Sweden

We co-operate with KTH's research centres for wireless systems and Internet technology. (See page 14)



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Centers

The Swedish Center for Internet Technology

The Swedish Center for Internet Technology – SCINT – acts as a catalyst for co-operation in the sphere of the Internet. The Center facilitates the co-ordination of educational initiatives and higher education concerning the Internet.

SCINT aims to conduct research and development, experimental network operations and an educational program. These activities are of the highest international quality and act as a node in the informal global network, which is driving forward the development of the Internet. The Center has a national base through co-operation with regional and local initiatives, and is well established in European and other international contexts.

SCINT attracts skilled people and builds up its own technological expertise, which is disseminated openly to all sections of society. The outcome will be unique research results, new products and services for established organisations, as well as innovations in industry.

The Swedish Center for Internet Technology opened in 2001 and offers a new Master's degree in Internet Technology.

Contact

Lars-Erik Eriksson, Director, lee@it.kth.se

Kista Photonics Research Center

Kista Photonics Research Center was formally established in January 2002 as a joint effort between the IMIT and Acreo, the Swedish Microelectronics and Optics Research Institute.

Kista Photonics Research Center has as its ambition to strengthen the prerequisite for a highly innovative Swedish photonics infrastructure and thus secure future dynamics in one of the fastest growing industrial sectors ever.

The most important rationale for the Kista Photonics Research Center is to ensure a high and timely interaction between the research competence in place in the Stockholm area within the field of photonics and companies active in the same field by performing innovative and cutting edge research. Kista Photonics Research Center sees as its role to

- be the brand name of Swedish photonics
- function as a vehicle for starting up new photonics companies
- act as a source for knowledge and excellence in photonics for existing companies
- coordinate educational efforts

Kista Photonics Research Center comprises more than 100 senior scientists, skilled technicians, and PhD students and five important laboratory facilities.

Contact

Magnus Breidne, Director, magnus.breidne@acreo.se

Wireless@KTH

Wireless@KTH is to provide education and conduct research in wireless and mobile communications. The Center is to be a meeting place for industry and the world of research, as well as a source of expertise.

Wireless communication is a strategic area for Swedish industry. The need for skilled and well-educated people in companies is very high. The multidisciplinary nature of the area therefore demands that research and development are organised differently to traditional areas.

Wireless@KTH is to be a leader and a trendsetter, and is also to provide an attractive environment to recruit leading experts from around the world. The center is to lead and co-ordinate major research projects and is to establish an attractive engineering course of international renown in the field of mobile communications.

Wireless@KTH is to collaborate actively with industry. Telia, Ericsson, Nokia and Microsoft are already partners, although in the long term we hope to be able to offer partnerships to all the companies in the Stockholm region who are active in the wireless communications area.

Wireless@KTH is situated in Kista and began operations in 2000. Organisationally, it belongs to the Institute of Signals, Sensors and Systems, but it collaborates closely with the Institute of Microelectronics and Information Technology.

The center offers a new Master's degree in wireless communication.

Contact

Claes Beckman, Director, claes.beckman@wireless.kth.se



The Semiconductor Laboratory

The Semiconductor Laboratory is KTH's resource for training and education in semiconductor processing, and for the development and manufacture of devices made from semiconductor materials. The Laboratory is able to provide complete processes for the manufacture of electronic and micro-system devices in silicon, for optoelectronics in gallium arsenide and indium phosphide, and for power devices in silicon carbide.

Its main users are the KTH departments of Microelectronics and Information Technology and of Signals, Sensors and Systems, together with ACREO, a research institute for microelectronics and optics. Established industrial firms and a growing number of spin-off companies for the development and small-scale production of semiconductor devices also use the Laboratory's facilities. In total, more than 180 people work in the Laboratory. Many more are dependent on the results of the Laboratory's processes for their work.

The Laboratory has about ten employees working on maintenance, utilities, safety, co-ordination etc.

Contact

Nils Nordell, Director, nils.nordell@imit.kth.se

Resources

The Process Laboratory has a clean room area of 1300 m² in the categories of 100, 1000 and 10000 (particles/cu. ft). In addition, there are laboratories for material analysis and for the assembly of components.

Processes for 100 and 200 mm silicon wafers :

- Stepper lithography (i-line, 0.5 μm)
- Contact lithography
- Metallisation (Sputter, evaporation)
- Dry etching (ICP, RIE)
- Si/SiGe epitaxy
- SiO_x Plasma deposition
- Furnace processes (diffusion, oxidation, deposition)
- Ion implantation
- Annealing (RTA)
- Various wet etching and cleaning processes

Processes for 100 mm GaAs, 50 mm InP and SiC:

- Stepper lithography (i-line, 0.5 μm)
- Contact lithography
- Metallisation (Sputter, steaming)
- Dry etching (ICP, RIE)
- Epitaxy:
 - MOVPE for InP/InGaAsP, GaAs/AlGaAs
 - HVPE for InP/InGaAsP
 - VPE for SiC
- SiO_x and SiN_x Plasma deposition
- Ion implantation
- Annealing (Furnace and RTA)
- Various wet etching and cleaning processes

Analysis

- X-ray diffraction
- Photoluminescence
- Hall effect measurements
- C-V- profiling
- Electron microscope (SEM)
- Optical microscope
- Ellipsometer
- Surface profilometer

The Semiconductor Laboratory also has a mechanical engineering workshop.



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Semiconductor Laboratory
Kista Photonic Research Center
Wireless@KTH (situated at Isafjordsgatan 30 B)

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KTH - Forum

Location

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