COBRA
Annual Report 2007

Achievements, Highlights and Prospects

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts

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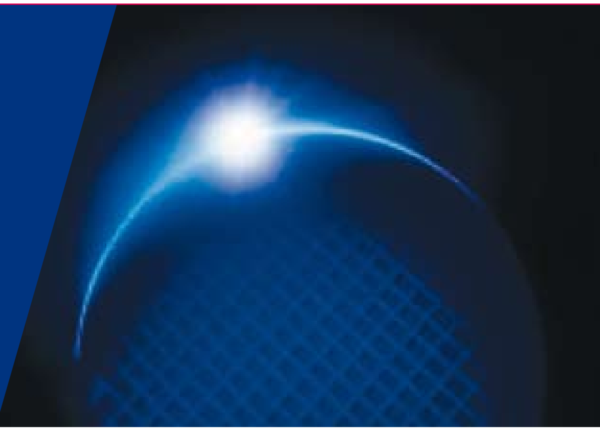
1 Preface



It is my pleasure to present the 2007 annual report of the COBRA Research Institute. The report summarizes major achievements obtained within and by the COBRA community. This involves first of all the scientific highlights, but also other important activities are described that took place in 2007.

As a matter of course, it is unavoidable that only a selection of activities has been included in this report. Those readers who are interested in more complete or detailed accounts on the research or other activities within COBRA are referred to the group sites via the COBRA website (www.cobra.tue.nl).

I would like to take this opportunity to express my thanks to all involved in COBRA for their contribution in 2007. A special word of thanks goes to my colleague, ir. Jacco Kwaaitaal, for collecting and editing the material for this annual report.

Prof.dr. Harm Dorren
Scientific Director of COBRA

September 2008

COBRA

2 Introduction

COBRA Research Institute

COBRA is the Inter-University Research Institute on Communication Technology Basic Research and Applications. Research groups from the disciplines of physics, electrical engineering and chemistry from Eindhoven University of Technology and Vrije Universiteit Amsterdam in The Netherlands have combined their efforts in the Research-Institute COBRA to achieve added value in their education and research. The activities range from basic research in physics on novel materials and devices to research on communication systems and system applications.

COBRA is worldwide recognised as a leading research institute in the field of optoelectronic devices and communication systems technology. One reason for this is the state-of-the-art infrastructure with respect to the fabrication of devices and with respect to the design and characterization of devices and systems. COBRA maintains a facility in the fields of material growth, processing, lithography and ultra-high bitrate analysis for ultrafast broadband optical communication, which belongs to the most advanced in the world. This not only makes it an attractive place to work for top scientists from all over the world, but makes COBRA also an attractive partner for industrial collaborations. Moreover, COBRA researchers find their way to leading international institutes and industries. These qualities brought COBRA to the position of preferred partner in strategic alliances with industry, academia, international projects and Networks of Excellences in the European Framework Programmes of the European Commission.

COBRA Mission

The general mission of COBRA is to *excel in acquisition, transfer and application of knowledge in communication technology and its spin-off for society in general and for industry in particular*. In this respect communication technology should be understood as collecting, saving, processing, transporting, routing and presentation of information. The central element in COBRA's policy is therefore to cover the full dynamical trajectory from nano-optics and nano-electronics up to and including the applications in communication devices and systems. Built on a vision of long-term developments COBRA actively defines and initiates top-level long-term programs, in close collaboration with industry.

COBRA in Figures for 2007	
Total annual budget	~ 15 M€
Research staff	~ 20
Postdocs	~ 20
PhD students	~ 65
Technicians	~ 10
Cleanroom for III-V technology	~ 800 m^2

Prof.dr. H.J.S. Dorren
Scientific Director

Ir. J.J.B. Kwaaitaal
Scientific Secretary

Mrs. S.P. de Leeuw
Management Assistent

Mr. T. Cremers
Financial Controller

COBRA Office

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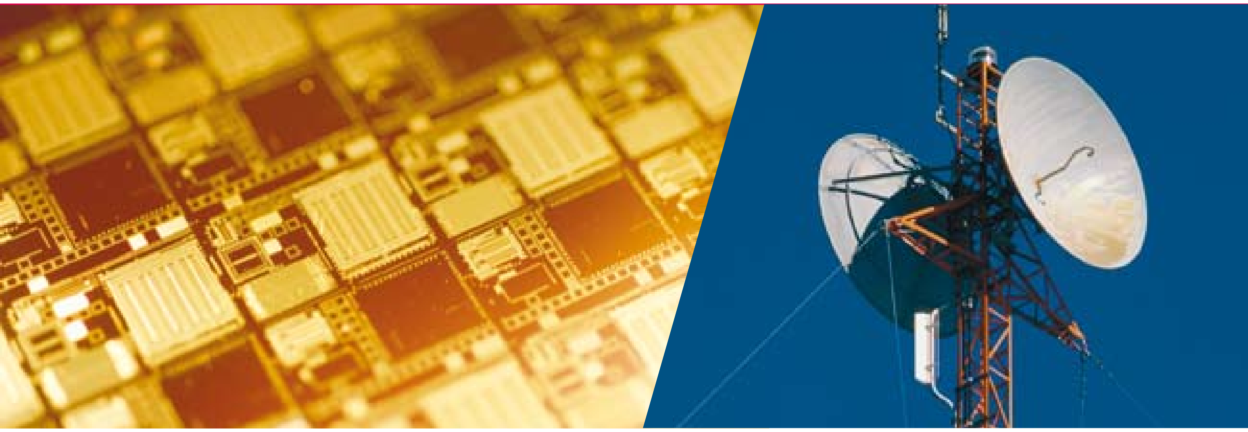
Annual Report 2007

This report describes the achievements, highlights and prospects of the COBRA Research Institute in 2007. Chapter 3 describes the research performed within COBRA. The research activities are carried out in different groups based upon their discipline within the field of communications. The chapter starts with an overview of the general highlights and proceeds with a description of the research activities and achievements per group. Chapter 4 describes the education and dissemination activities of COBRA. Chapter 5 describes important developments and prospects for COBRA.

3 Research



3.1 Highlights

In an experiment using higher order modulation and long distance transmission, a speed of 1.1 Tbit/s (10 x 111 Gbit/s, 50 GHz spaced) POLMUX-RZ-DQPSK over 2375 km using coherent equalisation has been demonstrated.

Error-free all-optical packet switching as a world's first has been achieved in a transmission experiment at 160 Gbit/s, using 54 km of field installed fiber links around the city of Eindhoven.

A successful attempt was made in the creation of the world's first metallic nano-cavity laser with a diameter of 210nm (the smallest electrically pumped laser ever reported).

Highlights in ultra-high data rate at 30 to 60Ghz wireless transmission include a VCO with a world-record Figure-of-Merit, design and evaluation of a complete 30GHz receive chain with excellent performance at the limits of the IC technology used, and a new concept for beam-forming transceivers that is expected to provide a breakthrough in cost reduction.

In the area of ultra-low-power wireless communication, two novel architectures for an FHSS transceiver were conceived, resulting in a factor 7 and 6 less power consumption compared to state-of-the-art transceivers, for respectively an asymmetric and symmetric wireless scenario.

A mixed analytical-numerical approach has been developed to design single-mode fibers with controlled and optimized properties. These properties include dispersion, dispersion slope, mode-field diameter, effective cut-off wavelength and macro-bending losses. These properties and their gradients have been incorporated in a nonlinear optimization scheme for the fault-tolerant design of optical fibers. In particular, bending losses can now be analyzed accurately from large to small radii of curvature.

We developed a powerful real-time face recognition technique, novel multiview 3D coding techniques, multi-layer 3D system architectures, automatic 2D-to-3D conversion techniques, 4D wire-frame-based models of human behavior, groundbreaking depth estimation techniques, and real-time 3D techniques for semantic analysis of e.g. sports games, traffic violations, and neonatal pathologies. Two spin-out companies (ViNotion and Iphion) were set up.

In the context of our new Center for Wireless Technology Eindhoven, we reported the world's first MIMO channel characterization techniques in the so-called angular domain, which admits a simple ray-tracing-like view of the link between transmit and receive antennas.

Prof.ir. A.M.J. Koonen

Prof.dr. H.J.S. Dorren

3.2 Activities and Achievements

3.2.1 Electro-optical Communication (ECO) – NRC Photonics Participant

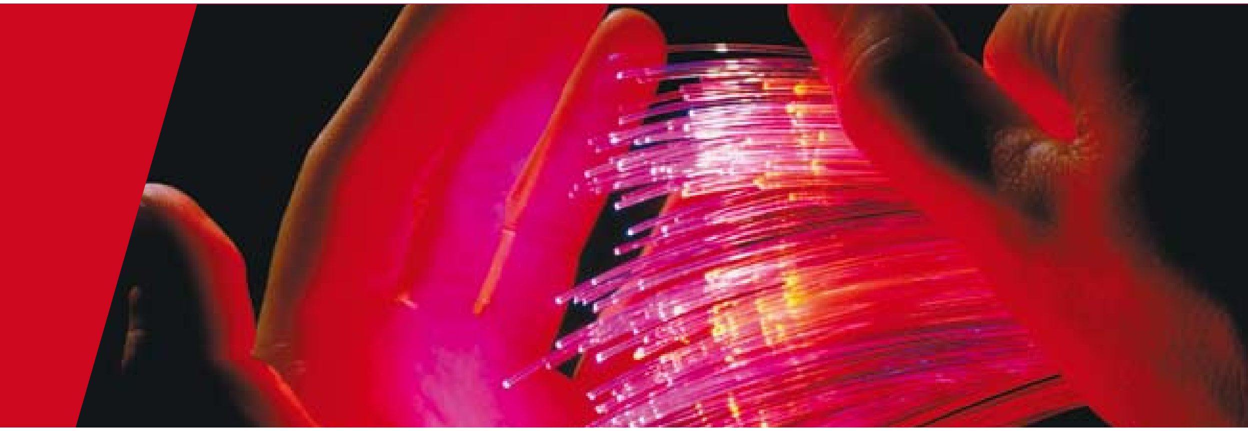
ECO's research programme fits in the theme "Connected World". It is organized around our vision of the globe-spanning "optical ether": an ultra-broadband congestion-free network wherein the users experience access to a virtually unlimited communication capacity wherever and whenever they want it. This vision needs optical communication network techniques, for realizing robust ultra-high capacity transport over long links, for all-optical routing in the nodes in order to build transparent ultra-fast connections, and for creating ultra-flexible and broadband access to the user. We cooperate with leading academic and industrial research institutes, and we fulfill key roles in international (e.g., EC's FP6 and FP7) and national programmes (e.g., Freeband, Smartmix MEMPHIS, IOP GenCom,...). ECO is a key group in the COBRA research school. In NIRICT, ECO is leading the Strategic Research Agenda Broadband Communication Systems. Furthermore, ECO is the initiator of the eiTT, the European Institute on Telecommunication Technologies, an alliance for research and education.

High-capacity links

100 Gbit/s Ethernet is a powerful new standard for data transmission in metro links. We conducted in the O-band 100 Gbit/s transmission experiments by WDM of four 25 Gbit/s channels using solely semiconductor opto-electronic devices. In cooperation with Siemens, Fraunhofer Institute HHI and AT&T, we carried out a unique C-band field experiment with 107 *Gbit/s ETDM transmission* over conventional fibre in New Jersey, USA. All-optical regeneration and robust modulation formats are key research areas in the field of long haul high capacity optical transmission. Together with Siemens Munich, we achieved error-free transmission of 3 Tbit/s (40 wavelengths x 85.6 Gbit/s) *POLMUX-RZ-DQPSK* over 1700 km standard single-mode fibre [1]. Furthermore, 1.1 Tbit/s (10 x 111 Gbit/s, 50 GHz spaced) POLMUX-RZ-DQPSK over 2375 km using *coherent equalisation* has been demonstrated. Joint decision maximum likelihood sequence estimation was explored to increase the signal robustness.

Telecommunication nodes

The research has focused on *ultrafast all-optical packet switching*, for which a fast optical wavelength converter is essential. Our approach of cascading a semiconductor optical amplifier (SOA) with a detuned optical filter sizeably improved the operation speed of *wavelength conversion*, firstly to 160 Gbit/s and later to 320 Gbit/s [2]. We succeeded using a similar approach in an Optical Time Division Demultiplexer to achieve 640/40 Gbit/s demultiplexing using a single SOA. Another key building block item is an *all-optical flip-flop*. With CIP Integration (a British Telecom spin-out company), we made an integrated and packaged



all-optical flip-flop. This flip-flop could be set and reset within 100 ps. We used this flip-flop to achieve error-free all-optical packet switching using data packets witch payload at 160 Gbit/s that propagate over 54 km of field installed fiber links around Eindhoven. Key contributions with these techniques were made to the FP6 project LASAGNE [3], and will be continued in the FP7 projects BOOM and HISTORIC.

User access networks

Our research has focused on extending and diversifying the huge capacity of the core and metro network towards the end user's home and even into his home [4]. Hence we investigate a *dynamically adjustable wavelength-routed fibre-to-the-home access network* in the Freeband Broadband Photonic Access project. We realized a 1.25 Gbit/s user access system with a colourless optical network unit using a reflective SOA, and using a tunable micro-ring add/drop multiplexer for selecting the wavelength channel. For providing *high-capacity wireless connections*, with our patented Optical Frequency Multiplying (OFM) technique, we generated high-purity microwave carriers which convey comprehensive high-capacity wireless modulation signal formats to simplified remote antenna sites. Thus we reached a record capacity of 120 Mbit/s in QAM-64 format at 40 GHz over 25 km of single-mode fibre, and the same capacity at 24 GHz over 4.4 km of silica graded-index multimode fibre, both showing OFM's unique dispersion-robustness [5]. For *easy-to-install in-building networks*, next to wireless communication, we pursued research in *high-speed wired communication* deploying large-core multimode Plastic Optical Fibre (POF). In cooperation with Siemens, we achieved a record of 1.008 Gbit/s over 100m of 1 mm core step-index PMMA POF, using 80-tones with QAM-64/-256 formats. Moreover, we demonstrated an alternative QAM emulation by means of a 2-channel WDM solution, at the Broadband Europe 2007 exhibition. In *Personal Area Networks*, we showed the first proof-of-principle of *spectrally-sliced OCDMA*, for multiple access on a shared optical user access network. Our access and in-building research activities continue in leading roles in FP7 projects (ALPHA, BONE, POF-PLUS), and in the Smartmix project MEMPHIS.

Key publications

1 D. van den Borne, S.L. Jansen, E. Gottwald, P. Krummrich, G.-D. Khoe, H. de Waardt, "1.6-b/s/Hz spectrally efficient transmission over 1,700 km of SSMF using 40 x 85.6-Gbit/s POLMUX-RZ-DQPSK", IEEE J. of Lightwave Technology, Vol. 25, pp 222—232, 2007 (invited)

2 Y. Liu, E. Tangdiongga, Z. Li, H. d. Waardt, A.M.J. Koonen, G. D. Khoe, X. Shu, I. Bennion, and H. J. S. Dorren, "Error-free 320-Gb/s all-optical wavelength conversion using a single semiconductor optical amplifier", Journal of

Lightwave Technology, 25(1), 103-108, 2007 (Invited)

3 J. Herrera, O. Raz, E. Tangdiongga, Y. Liu, J. Marti, F. Ramos, G.D. Maxwell, A. Poustie, H.C. Mulvad, M.T. Hill, H. de Waardt, G.D. Khoe, A.M.J. Koonen, H.J.S. Dorren, “160 Gb/s all-optical packet switched network operation over 110 km of field installed fiber”, in proc. OFC 07 (PDP5) (pp. 1-3). Anaheim, CA, USA, 2007 (post deadline paper)

4 E. Tangdiongga, H.C. Mulvad, H. de Waardt, G.D. Khoe, A.M.J. Koonen, and H.J.S. Dorren, ”SOA-based clock recovery and demultiplexing in a lab trial of 640 Gb/s OTDM transmission over 50 km fibre link”, in proc. ECOC 07 (PDS 1.2) (pp. 1-2). Berlin, Germany, 2007 (post deadline paper).

5 M. Garcia Larrode, A.M.J. Koonen, J.J. Vegas Olmos, and E.J.M. Verdurmen, “Microwave signals generation and transmission based on optical frequency multiplication with a polarization interferometer”, Journal of Lightwave Technology, 25(6), 1372-1378, 2007

Prof.dr.ir. M.K. Smit

Dr. Y.S. Oei

3.2.2 Opto-Electronic Devices (OED) – NRC Photonics Participant

The mission of OED is:

- to make major contributions to Indium-Phosphide semiconductor based Photonic Integration Technology and its applications,
- to educate graduate and Ph.D. students for a professional career in the fields of optical communication and opto-electronics, and
- to contribute to technological innovation through cooperation with industry

OED's applied research focuses on design and demonstration of novel Photonic ICs up to a proof-of-concept level, and on extending the capabilities of the integration technology by adding novel or improved devices. Its long term research is focused on ultrasmall and ultrafast lasers as building blocks in Very Large Scale Photonic Integrated Circuits (VLSI) for digital photonic applications.

Photonic Integrated Circuit Design and Technology

Since the early nineties the complexity of Photonic ICs doubles each $2^{1}/_{2}$ year, similar to Moore's law in electronics but at a slightly slower speed, and at a much lower complexity level: OED and its spinoff company 35Photonics reported a number of world records in this development. The COBRA/OED integration philosophy is based on realization of a broad range of functionalities with a small set of building blocks which can be realized in a generic technology, just like transistors, capacitors and resistors in electronics (CMOS).

OED's recent research focuses on two activities:

1) exploring and extending the application potential of the generic technology in advanced Photonic ICs for use in a broad range of fields (like telecoms, datacoms, sensors, health, security and metrology) and
2) expanding the potential of the generic technology by adding novel building blocks. COBRA/OED leads the European Consortium on Photonic Integration Technology (JePPIX, www.jeppix.eu) that has most of Europe's key players in the fields of InP-based Photonic IC research, chip manufacturing, Photonic CAD and equipment manufacturing on board.

Highlights over the last three years have been:

- the best performing integrated mode locked ring laser reported so far that operates in the long wavelength telecommunication window
- control and visualization of complex laser dynamics and chaos in Photonic Integrated laser devices (published in Physical Review Letters)
- development of two generic building blocks for enhancing the generic technology with polarisation handling capability: a polarisation converter and a novel integrated polarisation splitter/combiner
- the world's first 1.55 µm Quantum-Dot Ring Lasers (cooperation PSN)
- and an 80 Gb/s wavelength converter (cooperation ECO)

Nanolasers for Digital Photonics

For the long term OED is focusing on ultracompact lasers for use in digital photonic applications, and their integration with silicon-based electronics. Since we published the world's smallest electrically pumped photonic flip-flop in 2004 (published in Nature) we worked on lasers that are much smaller. Recently we achieved a major breakthrough: the world's first metallic nanocavity lasers, devices that are not much larger than modern transistors (diameter < 300 nm), and with a potential to become even smaller and to operate at speeds in the THz range. Until recently it was commonly believed that lasing in such low-Q cavities was not possible. Our work was reviewed in an editorial in Nature Photonics. The first device operated at 70K with a 6 μA threshold current. We are presently close to room temperature (RT) and expect to reach RT operation in the next year. This device may cause a revolution in ultrafast signal processing.

Highlight:

- The world's first metallic nano-cavity laser (the smallest electrically pumped laser ever reported, Nature Photonics Oct 2007)

Key publications

1 Hill, M.T.; Oei, Y.S.; Smalbrugge, E.; Zhu, Y.; de Vries, T.; van Veldhoven, P.J.; van Otten, F.W.M.; Eijkemans, T.J.; Turkiewicz, J.P.; de Waardt, H.; Geluk, E.J.; Kwon, S.-H.; Lee, Y.-H.; Nötzel, R.; Smit, M.K.; Lasing in metallic-coated nanocavities, Nature Photonics, Vol 1, Nr. 10, pp 589—594, 2007

2 Yousefi, M.; Barbarin, Y.; Beri, S.; Bente, E.A.J.M.; Smit, M.K.; Nötzel, R.; Lenstra, D., "New role for nonlinear dynamics and chaos in integrated semiconductor laser technology", Phys. Rev. Lett. 98, nr. 044101, 2007, pp. 1-4

3 Heck, M.J.R.; Bente, A.J.M.; Barbarin, Y.; Lenstra, D.; Smit, M.K.; Monolithic Semiconductor Waveguide Device Concept for Picosecond Pulse Amplification, Isolation, and Spectral Shaping, IEEE Journal of Quantum Electronics, Volume 43, Issue 10, Page(s): 910 – 922, 2007

4 Augustin, L.M., van der Tol, J.J.G.M., Hanfoug, R., de Laat, W.J.M., van de Moosdijk, M.J.E., van Dijk, P.W.L., Oei, Y.S., Smit, M.K., A single etch-step fabrication-tolerant polarization splitter, Journal of Lightwave Technology, Vol 25, Issue 3, pp 740 -746, 2007

5 Docter, B., Segawa, T., Kakitsuka, T., Matsuo, S., Ishii, T., Kawaguchi, Y., Kondo, Y., Suzuki, H., Karouta, F., Smit, M.K., Short Cavity DBR Laser Using Vertical Groove Gratings for Large-Scale Photonic Integrated Circuits, IEEE Photonics Technology Letters, volume: 19, issue: 19, startpage: 1469, 2007

Prof.dr.ir. E.R. Fledderus

3.2.3 Radiocommunication (ECR)

The research program of the ECR-group focuses on the development of broadband wireless systems, more specifically on: “Antennas and Propagation (A&P)” and “Digital Radio Systems (DRS)”. The research on 60 GHz radio is done within the BSIK project “WiComm” and the IOP GenCom project “SiGi-Spot”. In these projects, the ECR-group cooperates with the ECO-, MsM-, and EM-group, TUD, UT, TNO, KPN, and Philips. The A&P research for microcellular systems is done within the project ”Space Wave modeling” with CRC Canada and also within a project called “Liquid Bandwidth” together with KPN and TNO-ICT.

Antennas and Propagation

The A&P research focuses on two scenarios: microcell (UMTS) and picocell (60 GHz radio).

Antennas and propagation research for UMTS. In the framework of the project on ”Space Wave modeling” of the urban mobile radio channel and the “Liquid Bandwidth” project, a novel measurement system that can measure the complete angle-delay spectrum of the multipath waves for a moving mobile was further enhanced and tested [1]. This angle/delay information is essential for the design and performance analysis of mobile communication systems using smart antennas or MIMO techniques. From a comparison of the measured results with 3-D ray-tracing simulations it was found that the dominant specular components are predicted in line with measurements, but that a substantial amount of energy was not predicted by the simulations. For the modeling of these missing scattering components a multi-dimensional clustering method was developed and tested [2].

Antennas and propagation research for 60 GHz radio. Within the “SiGi-Spot” project a novel low-cost planar antenna array that operates at 60 GHz has been designed and optimized. This antenna shows an excellent performance in both bandwidth and radiation efficiency. Moreover, a measurement setup has been designed and built for measuring the radiation pattern of these antennas. The measurements confirm the simulated excellent antenna properties.

In the framework of the “Wicomm” project channel characteristics in the frequency band of 60 GHz were investigated and analysed based on channel measurements and ray-tracing simulations. Statistical channel parameters were retrieved from measurements to study the multipath effect and frequency selectivity for omnidirectional and directional antenna configurations [3]. The impact of directional antennas and multiple beamformers on radio transmission was analytically formulated for multipath Rician channel environments.

Digital Radio Systems

The DRS-research focuses on two ways to achieve higher data rates: increasing spectral efficiency (MIMO) and using more bandwidth (60 GHz radio).

Multiple-input multiple-output systems (MIMO). To reduce the performance impact of front-end non-linearities in MIMO systems two approaches were proposed and examined. The first one is a transmitter-based method, which reduces the peak-to-power ratio of the MIMO OFDM signals. The second method is receiver-based and corrects for transmitter-caused non-linearities. Simulation results reveal that with the help of digital compensation methods considerable impairment levels can be sustained, without suffering substantially from performance degradation [4].
60 GHz radio systems. Research on the "WiComm" project addresses the (digital) baseband design of a low-cost and high data-rate 60 GHz transceiver which will have very limited performance as regards the RF-part. These severe impairments must be absorbed by the baseband system. A comparison of single- and multi-carrier block transmissions has been made under the effect of non-linearity of the power amplifier at the transmitter.
The "SiGi-Spot" project has started with a study towards application scenarios. The scenario work is performed to obtain a realistic set of user- and system requirements. From this work it occurs that the bit-rate target should be 2 Gbps which should be scalable to 10 Gbps in the future when technology allows (around 2010). Maximum transmission distance amounts to 10 m in a typical indoor environment [5].

Key publications

1 Bultitude, R.J.C., Schenk, T.C.W., Op de Kamp, N.A.A. & Adnani, N.; A propagation-measurement-based evaluation of channel characteristics and models pertinent to the expansion of mobile radio systems to frequencies beyond 2 GHz. IEEE Transactions on Vehicular Technology, 56(2), 382-388, 2007.

2 Kwakkernaat, M.R.J.A.E., and Herben, M.H.A.J.; Analysis of clustered multipath estimates in nonstationary radio channels, Proc. PIMRC 2007, Greece, 2007, pp.1-5.

3 Yang, H., Smulders, P.F.M., and Herben, M.H.A.J; Channel characteristics and transmission performance for various channel configurations, EURASIP Journal of Wireless Communications and Networking, 2007, pp. 1-15.

4 Schenk, T.C.W., Hofstad, R.W. van der, Fledderus, E.R. & Smulders, P.F.M.; Distribution of the ICI term in phase noise impaired OFDM systems. IEEE Transactions on Wireless Communications, 6 (4), 1488-1500, 2007.

5 Smulders, P., Yang, H., and Akkermans, I.; On the design of low-cost 60-GHz Radios for multigigabit-per-second transmission over short distances, IEEE Communications Magazine, Vol. 45, no. 12, pp. 44-51, 2007.

Prof.dr.ir. A.H.M. van Roermund

3.2.4 Mixed-signal Microelectronics (MsM)

The MsM group focuses on on-chip embedded frontend circuits that link digital baseband to antenna, with focus on wireless RF data communication. This comprises AD and DA converters, and RF circuits and systems, with the focus on five themes:

1. *Smart front ends*: extensive on-chip intelligence for cognitive circuits & systems, flexible hardware and multi-user & multi-standard; and for optimization of performance, yield, robustness, and low-power; 2.*broadband high-data rate; 3. ultra-low power; 4. design re-use; and 5. optimal analog/digital co-operation and co-existence*. We preferably implement in deep-sub micron CMOS. Recently we also explore emerging technologies (organic TFTs, MEMs, el/optic ICs).

Analog-to-digital (AD) & Digital-to-Analog (AD) converters

We exploited the advantages of analog and digital by finding optimal combinations, in most cases in a smart and flexible way [1].

AD converters: We developed the first generalized model for the power dissipation of Sigma-Delta Modulator (SDM) conditioning-conversion channels, introduced and elaborated a new concept for SDM conversion with an improved interference insensitivity and power/performance balance, and realized an 89dB DR ADC with 1MHz bandwidth and <2mW dissipation. We introduced a new limit-cycle theory for SDMs and for quantization noise, enabling with this unique approach improved designs, demonstrated by a realized state-of-the-art flexible 121-modes SDM [2]. For Nyquist ADCs, we focused on accuracy, flexibility, reconfigurability and smartness. With our new "C+C" concept we realized 2-bits improvement over conventional high-accuracy ADCs [3].

DA converters: we concentrated on high-speed, converters and on programmability and self-calibration. A very-high-speed (<2GS/s) DAC was realized for broadband data transmission. Two new self-calibration methods for mismatch and timing errors were derived. A 12bit self-calibrated DAC, and a flexible DAC based on 4 parallel sub-DACs, including a new calibration technique were implemented. As a further extension a test chip of a flexible 16bit DAC, based on 16 parallel 12bit sub-DACs was realized in CMOS 45nm. We introduced the first analytical description for thermometer/binary DA-INL as a function of spreads in the current sources, as a combination of 'Brownian Bridge' processes.

RF circuits & systems

Three main research directions are followed. 'Smart' techniques are extensively used to achieve flexibility and performance improvements.

Ultra-high data rate at 30 to 60GHz: we aim for a completely integrated, smart (and therefore flexible and high-performance) transceiver. We focused on the individual building blocks as well as transceiver architectures. All building blocks (LNA, PA, VCOs,

mixers, dividers) have been realized and have been or are being evaluated. Highlights include a VCO with a world-record Figure-of-Merit, design and evaluation of a complete 30GHz receive chain with excellent performance at the limits of the IC technology used, and a new concept for beam-forming transceivers that is expected to provide a breakthrough in cost reduction.

Below 5 GHz: The focus was on robustness and flexibility. On the transmit side, we concentrated on the power amplifier and adaptive matching towards the antenna [5]. On the receive side, we focused on reconfigurable RF building blocks, algorithms for calibrating imperfections of the RF circuits, and MIMO receivers. Highlights include, among others, a high efficiency 2-stage GaAs PHEMT class E power amplifier and a new 3G limit-cycle power amplifier concept.

Ultra-low-power: Two novel architectures for an FHSS transceiver were conceived and implemented [4]. The first transmitter-only architecture fully exploits the specific characteristics of an asymmetric wireless scenario, resulting in a crystal-less transmitter, which consumes 7 times less than the state-of-the-art FHSS transmitter and has a reduced form-factor. The second architecture, for a symmetric wireless ad-hoc networks, uses a crystal but the transceiver power efficiency is boosted reducing the synthesizer power consumption by a factor 6 compared to the state-of-the-art hopping synthesizers. These two architectures can cover the application area of both WSN and WPAN.

Key publications

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2 Ouzounov, S.F., Hegt, J.A. & Roermund, A.H.M. van (2007). Sub-harmonic Limit-cycle Sigma-delta Modulation, Applied to AD Conversion - Analog Circuit Design. Houten: Spinger – The Netherlands (Book).

3 Quinn, Patrick J., Roermund, Arthur H.M. van., Switched-Capacitor Techniques for High-Accuracy Filter and ADC Design. Springer, book. Series: Analog Circuits and Signal Processing, 2007, XVIII, 244 p., ISBN: 978-1-4020-6257-5

4 Lopelli, E., Tang, J.D. van der & Roermund, A.H.M. van (2007). A 1mA Ultra-low Power FHSS TX Front-end Utilizing Direct- modulation with Digital Pre-distortion. IEEE Journal of Solid-State Circuits, Volume 42, Issue 10, Oct. 2007, Page(s): 2212-2223.

5 Bezooijen, A., Straten, F. van, Mahmoudi, R., Roermund, A.H.M. van (2007). Power Amplifier Protection by Adaptive Output Power Control. IEEE Journal of Solid-State Circuits, 42(9), 1834-1841.

Prof.dr. A.G. Tijhuis

3.2.5 Electromagnetics (EM)

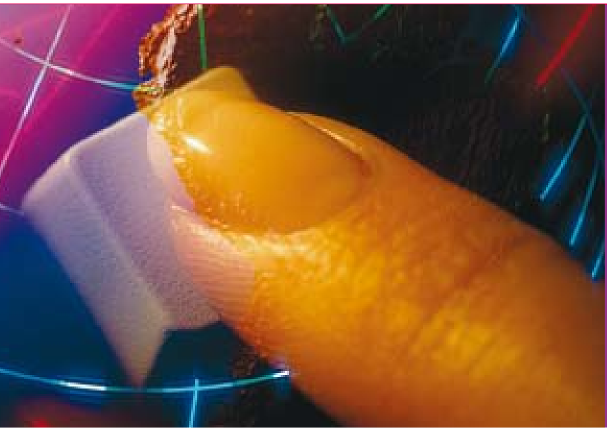
In the Electromagnetics chair, the behaviour of electromagnetic fields in a wide range of applications from various disciplines of electrical engineering is investigated. Our research program aims at synergy between fundamental and applied research.

Efficient Modelling of Electromagnetic Fields

The goal of the fundamental research in Electromagnetics is to make the transition from *Engineering Electromagnetics* towards *Electromagnetic Engineering*. The aim is to solve the synthesis problem, where a parameterized configuration is matched to engineering specifications. In a straightforward implementation, one or more parameter sweeps are carried out. Alternatively, the design criteria can be combined into a cost or fitness function, which is then minimized by nonlinear optimization. Our research has focused on the final stage of this design process, where an initial estimate is available. In that stage, full-wave modeling must be combined with line-search optimization, which amounts to successive sweeps with respect to a line-search parameter. Two new concepts have been developed by our team to reduce the duration of a single field computation "from hours to minutes", so that it may be repeated tens of times in the optimization.

- The *marching-on-in-anything* approach allows us to carry out field computations with a varying physical parameter at the cost of a few steps in a single, iterative field computation. These parameters include frequency, source and object position, size and constitution of a scattering object, and the line-search parameter mentioned above. As a demonstrator, we used a contrast-source integral-equation approach to model the excitation of a human head by a plane wave at varying direction of incidence. The computation time per angle was reduced by approximately a factor of 25, which is typical for our approach. Further, mode-based preconditioning was developed to accelerate the convergence of iterative 3D field computations based on a finite-difference version of Maxwell's equations. The resulting algorithm was applied successfully to wave-guiding and electromagnetic bandgap (EBG) configurations.

- *Diakoptics* allows us to separate the total 2D or 3D domain in which the electromagnetic field needs to be determined into sub domains, in which appropriate techniques may be chosen to compute the possible field behavior. Boundary conditions are then used to connect the sub domains. The advantage of this approach is that only the sub domain in which the parameters are actually varied needs to be re-evaluated. Two possible tracks were followed. For special shapes of the interface, a local modal decomposition of the field is commonly used. We used this concept to model the behavior



of an antenna element for the next generation of phased-array radar systems. LEGO (linear embedding based on Green's operators), which uses equivalence principle, was developed in our team for interfaces of arbitrary shape [2]. For 2D structures, the Schelkunoff and Love formulations were compared and applied to finite and infinitely periodic EBG structures. Proof of concept was established for a small number of cells in 3D computations.

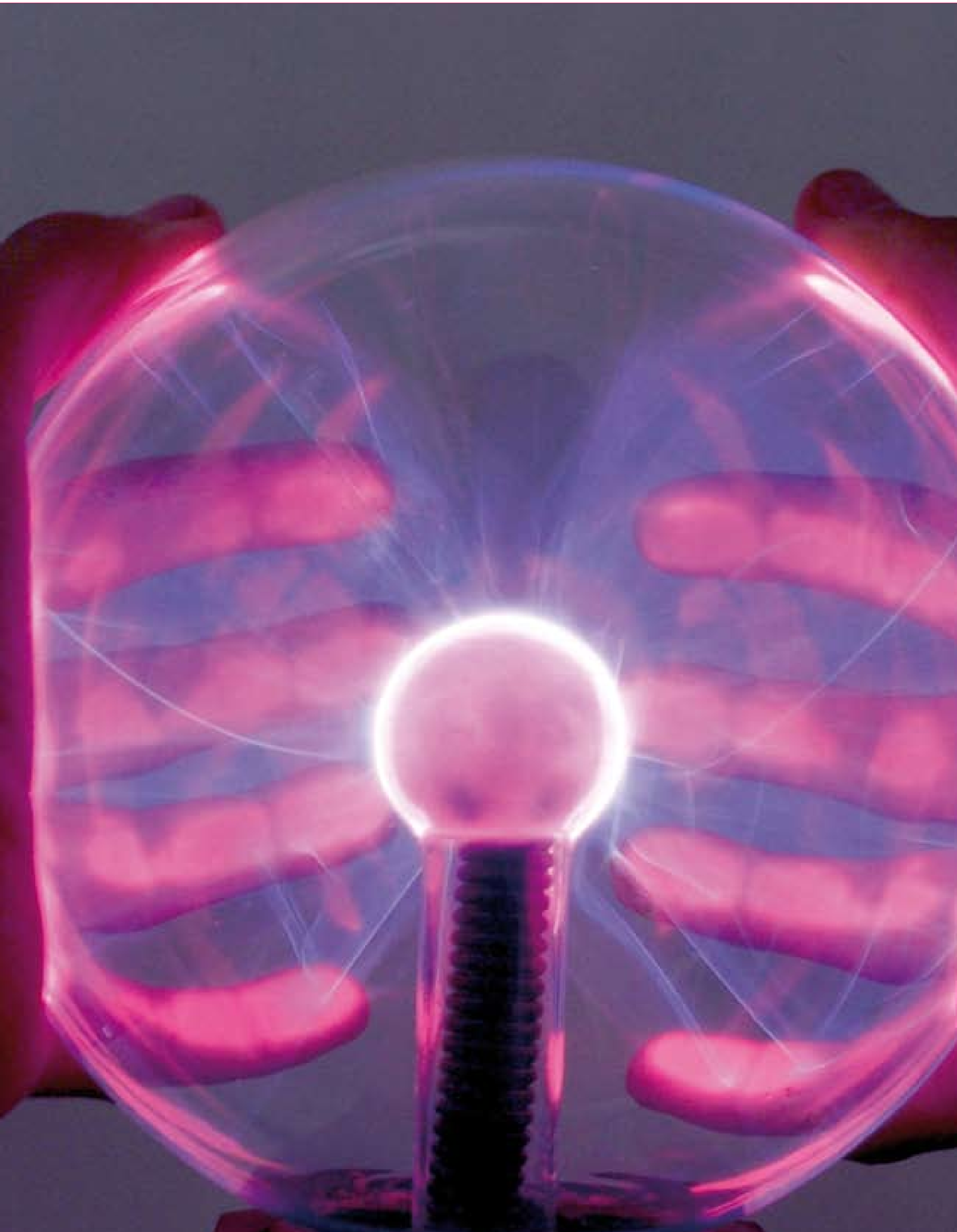
The next challenge is the *optimization* as such. An infinite array of rectangular patch antennas on top of a dielectric layer and a conducting ground plane, excited by vertical electric dipoles was chosen as the initial test geometry. We optimized the pattern and the polarization of the scattered field. It was confirmed that the choice of the cost function has a considerable influence on the convergence of nonlinear optimization schemes.

Applications of Electromagnetic Field Modelling

The second pillar of our research program is the application of electromagnetic modeling tools to a variety of applications from Electrical Engineering. We apply existing schemes such as the method of moments, the finite-difference and the finite-element methods, and we tune our own algorithms to specific applications. A strong cross-fertilization exists with the fundamental research described above. We mention three highlights.

- In collaboration with our partners, several techniques were developed for the analysis and design of antenna arrays. Applications are in antenna arrays for radar and astronomy, where the Netherlands has a unique position. In collaboration with Thales, a general modeling strategy for frequency-selective surfaces has been implemented and accelerated [1]. Collaboration with CASA and Thales has resulted in an eigenfunction approach to analyze large, finite arrays [3]. With TNO Defence, Security and Safety, the multimode equivalent network approach was extended to include waveguide feeds. This led to the successful defense of three Ph.D. theses between December 2004 and October 2005. Since then, the eigenfunction approach has been extended to slots in coaxial cables for transmission in indoor communications, in an exchange project with the Politecnico de Torino.

- A mixed analytical-numerical approach has been developed to design single-mode fibers with controlled and optimized properties. These properties include dispersion, dispersion slope, mode-field diameter, effective cut-off wavelength and macro-bending losses. These properties and their gradients have been incorporated in a nonlinear optimization scheme for the fault-tolerant design of optical fibers. In particular, bending losses can now be analyzed accurately from large to small radii of curvature [5]. Mode-



group diversity multiplexing for multi-mode fibers has successfully been simulated, including the effect of mode-selective spatial filtering.

- Inspired by the demand from the EMC community, collaboration was started with CWI Amsterdam, TNO Defence, Security and Safety and ONERA to study the influence of stochastic effects on electromagnetic fields. The traditional EMC setup of a straight wire over a conducting ground plane was chosen as our first test configuration. The stochastic effects are introduced by allowing random oscillations in the location of the wire. We compared the results of repeatedly applying a specially developed, highly efficient numerical code derived from earlier work [4], followed by a statistical analysis with those of developing a special formulation, followed by a few numerical computations. Experimental validation is in progress. The results will also be used to include fault tolerance in our research on Electromagnetic Engineering.

Key publications

1 Paulides, M.M., Vossen, S.H.J.A., Zwamborn, A.P.M. & Rhoon van, G.C. (2007). A head and neck hyperthermia applicator: theoretical antenna design. International Journal on Hyperthermia, 23, 59-67.

2 Hon, B.P. de & Arnold, J.M. (2007). Discrete Green's function diakoptics for stable FDTD interaction between multiply-connected domains. In R.D. Graglia (Ed.), 2007 International Conference on Electromagnetics in Advanced Applications (pp. 1-4). Torino, Italy: Politecnico di Torino.

3 Bekers, D.J., Eijndhoven, S.J.L. van & Tijhuis, A.G. (2007). Frequency and Element Independent Behavior of Array Eigencurrents and its Application in Finite-Array Analysis. In 2007 URSI EMTS Commission B - Electromagnetic Theory Symposium (pp. 1-3). Ottawa, Canada: URSI.

4 Van Beurden, M.C. and Tijhuis, A.G., Analysis and regularization of the thin-wire integral equation with reduced kernel, IEEE Trans. Antennas Propagat., vol. 55, no.1, 2007, pp. 120-129.

5 Smink, R.W., de Hon, B.P., and Tijhuis, A.G., "Bending loss in optical fibers – a full-wave approach", J.Opt. Soc. Am. B, vol.24, no. 10, 2007, pp. 2610-2618.

Prof.dr.ir. J.W.M. Bergmans

3.2.6 Signal Processing Systems (SPS)

The group advances signal-processing technology through a mixture of analytic and systems-oriented work. To this end a 'curiosity-driven' sub-program on signal transforms and filter banks is combined with three systems-oriented sub-programs that deal with media signal processing, signal processing for communications, and medical signal processing. These contexts are selected because they are challenging and relevant. Moreover, in-depth contextual know-how is available via strategic partnerships and cross-appointments.

Signal transforms and filter banks

This research deals with advanced time-frequency signal transforms and efficient real-time implementation of these transforms via filter banks. The main focus is on fractional transforms and on the phase-space descriptions:

- A generic way for the fractionalization of cyclic transforms has been presented.
- A general class of modes that have a Gaussian-type generating function, has been presented. The class includes all Hermite-Gaussian type modes that were reported previously, and brings them into one uniform framework.
- The well-known linear canonical transformation has been reformulated such that the usual mathematical singularity is now absent. Together with the so-called Iwasawa decomposition, this has led to a generic realization of arbitrary first-order optical systems, based on cylindrical lenses and (predefined) sections of free space.
- A classification of the linear canonical transformation has been derived, based on simple and realizable first-order optical kernels [1]. As a result, the system's eigenfunctions can now be found with great ease.

Media signal processing

This research deals with the processing of media information such as audio, video, and computer data. It aims at algorithms and approaches that combine state-of-the-art performance with a high computational efficiency. We developed a unified theory for blind separation of multiple sources based on arbitrary-order signal cumulants and nonstationarities. Our novel parametric approach for acoustic dereverberation sets new performance standards. Our video work has increasingly dealt with real-time 3D systems. We developed a powerful real-time face recognition technique, novel multiview 3D coding techniques, multi-layer 3D system architectures, automatic 2D-to-3D conversion techniques, 4D wire-frame-based models of human behavior, groundbreaking depth estimation techniques, and real-time 3D techniques for semantic analysis of e.g. sports games, traffic violations, and neonatal pathologies [2]. Two spin-out companies (ViNotion and Iphion) were set up.

Signal processing for communications

This research studies fundamental communication limits, and develops efficient yet simple

modulation, network coding, adaptation, equalization, timing recovery, and detection techniques. Systems-oriented work demonstrates these techniques in optical storage and wireless and optical transmission. Commercial impact is evidenced by many patents.

For optical storage we developed backwards compatible techniques for future 4th generation systems, e.g. for near-minimum-bit-error rate adaptation [3], 2-dimensional intersymbol interference cancellation, and characterization of mixtures of modulation noise and additive noise. We also developed bit-detection techniques that optimally handle these mixtures and that use parity-check codes for significant performance improvements. In the context of our new Center for Wireless Technology Eindhoven, we reported the world's first MIMO channel characterization techniques in the so-called angular domain, which admits a simple ray-tracing-like view of the link between transmit and receive antennas. With Philips Research we developed innovative agile transmission strategies that exploit the basic channel state information that is available in modern communication standards.

Medical signal processing

This research deals with medical monitoring and decision-support techniques. It aims at improving diagnostic capabilities, at reducing risk to the patient, and at lowering complexity and cost. Scientifically it focuses on simple dynamic models of physiology, on efficient parameter-estimation for these models, on robust spatiotemporal signal processing in highly nonstationary settings. Cross-appointments ensure a close collaboration with strategic partners.

Our award-winning cardiovascular quantification techniques were clinically validated and refined [4], and were extended to new pathologies (e.g. prostate cancer) and to the MRI imaging modality. Our work on fetal monitoring, with the Maxima Medical Center, has led to a new standard for suppression of the maternal electrocardioagram, to an award-winning non-invasive technique for assessment of intra-uterine pressure that may replace invasive techniques, to the word's first contactless registration of the fetal electrocardiogram via capacitive electrodes (with Philips Research), and to a prototype system for clinical validation of these techniques. Our work on neurometry has led to a breakthrough in correction of eye-movement artifacts, by using a camera as a basis for correction, bringing the ideal of single-trial analysis a significant step closer [5].

Key publications

1 M.J. Bastiaans and T. Alieva, 'Classification of lossless first-order optical systems and the linear canonical transformation', J. Opt. Soc. Am. A 24, 2007, pp. 1053-1062.

2 Han, Jungong & With, P.H.N. de, ‘3-D camera modeling and its applications in sports broadcast video analysis’, Proc. of International Workshop on Multimedia Content Analysis and Mining, 2007, pp. 434-443.

3 J. Riani, S.J.M.L. Van Beneden, J.W.M. Bergmans, and A.H.J. Immink, ‘Near minimum bit-error-rate equalizer adaptation for PRML Systems’, IEEE Trans. Commun., 55, 2007, pp. 2316-2327.

4 M. Mischi, A.H.M. Jansen, and H.H.M. Korsten, ‘Identification of cardiovascular dilution systems by contrast ultrasounc’, Ultrasound in Med. & Biol. 33, 2007, pp. 439-451.

5 J.J.M. Kierkels, J. Riani, J.W.M. Bergmans, and G.J.M. van Boxtel, ‘Using an eye tracker for accurate eye movement artifact correction’, IEEE Trans. Biomed. Eng. 54, 2007, pp. 1256-1267.

Dr. T.D. Visser

3.2.7 Quantum Electronics Theory (QE)

Research on quantum electronics theory focuses on interactions between light and matter, with particular application to light generation and wave guiding principles, semiconductor lasers and other optoelectronic devices. Fundamental studies of wave propagation, light diffraction and wave guiding in relevant structures are performed.

Surface plasmons and enhanced transmission
It is shown how surface plasmons that travel between the slits in Young's interference experiment can change the state of spatial coherence of the field that is radiated by the two apertures. Surprisingly, the coherence can both be increased and decreased, depending on the slit separation distance. This results in a modulation of the visibility of the interference fringes. Since many properties of a light field - such as its spectrum, polarization, and directionality - may change on propagation and are dependent on the spatial coherence of the source, our results suggest that the use of surface plasmons provides a new way to alter or even tailor the statistical properties of a light field [1].

Furthermore, we report on a method to generate a stationary interference pattern from two independent optical sources, each illuminating a single slit in Young's interference experiment. The pattern arises as a result of the action of surface plasmons traveling between subwavelength slits milled in a metal film. The visibility of the interference pattern can be manipulated by tuning the wavelength of one of the optical sources [2].

Key publications

1 Choon How Gan, Greg Gbur, and Taco D. Visser, Surface Plasmons Modulate the Spatial Coherence of Light in Young's Interference Experiment, Physical Review Letters, January 26, 2007 (doi: PhysRevLett.98.043908).

2 N. Kuzmin, G.W. 't Hooft, E.R. Eliel, G. Gbur, H.F. Schouten, and T.D. Visser, Enhancement of spatial coherence by surface plasmons, Optics Letters, Vol. 32, No. 5, March 1, 2007, pp. 445-447.

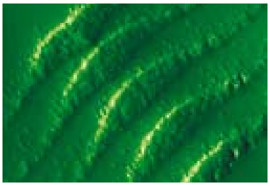
Prof.dr. P.M. Koenraad

Dr. R. Nötzel

3.2.8 Photonics and Semiconductor Nanophysics (PSN)
– NRC Photonics Participant

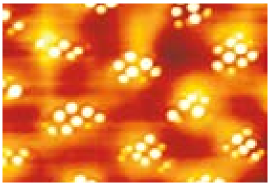
The Photonics and Semiconductor Nanophysics Group is focused on the epitaxial growth, the scanning probe analysis and the optics of artificial low-dimensional semiconductor nanostructures, with a present emphasis on quantum dots and photonic bandgap crystals. The research activities of the group, which are strongly interrelated are listed below.

Scanning Probe Analysis of semiconductor nanostructures:
Imaging of semiconductor quantum dots and magnetic impurities. The figure shows a Scanning Tunneling Microscopy picture of stacked quantum dots on an area of 55x55 nm.



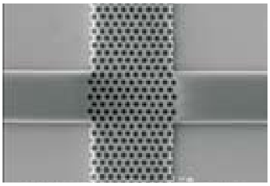
Scanning Tunneling Microscopy Image (55x55 nm)

Epitaxial growth:
Lateral ordering of III/V quantum dots. The figure shows a lattice of ordered InAs quantum dot molecules on GaAs (311)B formed by self-organized anisotropic strain engineering.

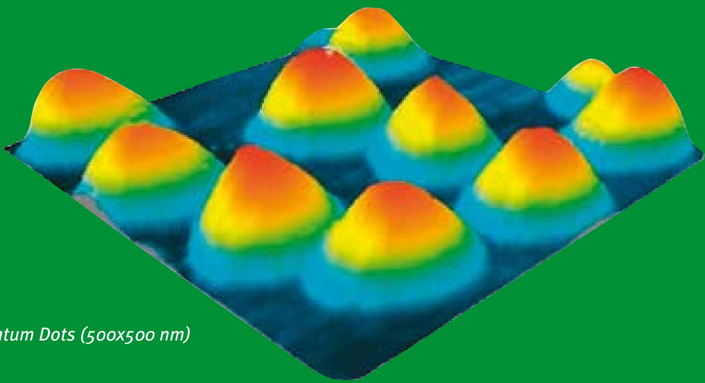


Ordered Quantum Dots

Nanophotonics:
InP based (tunable) photonic bandgap crystals. The figure shows a top view of a photonic bandgap crystal which has been etched into an InP waveguide.

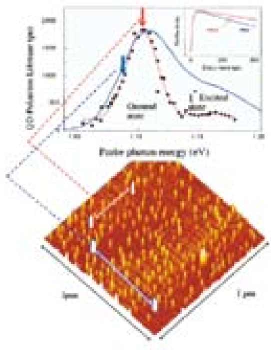


Photonic Bandgap Crystal



Quantum Dots (500x500 nm)

Ultrafast Optics of III/V semiconductor nanostructures:
Electromagnetic coupling of quantum dots and all-optical switching. The figure shows a long-range polariton coupling between quantum dots.



Polariton coupling of Quantum Dots

The Photonics and Semiconductor Nanophysics group collaborates with the Opto-Electronic Devices group of Prof M.K. Smit and the Electro-Optical communication system group of Prof A.M.J. Koonen at the Department of Electrical Engineering on photonic crystals, femtosecond all-optical switching and photonic integration of components based on III/V semiconductors.

The group is a member of the European Network of Excellence SANDiE which focuses on the exploration and application of self-assembled nanostructures, the STREP network ASPRINT on Advanced nanoprobing, the European Network of Excellence ePIXnet on photonic integration, the STREP network PICMOS on photonic layers on a Si-CMOS, the “Towards Ultrafast Communication” consortium within the Dutch Freeband programme and finally participates in the national ICES/bsik programs NanoImpuls and NanoNed.

Prof.dr.ir. R.A.J. Janssen

3.2.9 Molecular Materials and Nanosystems (M2N)

The objective of the research is to investigate and develop functional molecules, macromolecules, materials, and nanostructures with special electrical or optical properties that may find future application in advanced technological applications such as transistors, light-emitting diodes, photovoltaic cells, and data storage. The interest for these functional molecular materials and nanosystems is motivated by the scientific challenge they pose to physics and chemistry in which miniaturization of devices to the molecular level and the role and use of nanoscopic dimensions are intriguing. A wide range of subjects and techniques are used to accomplish these goals.

New Materials

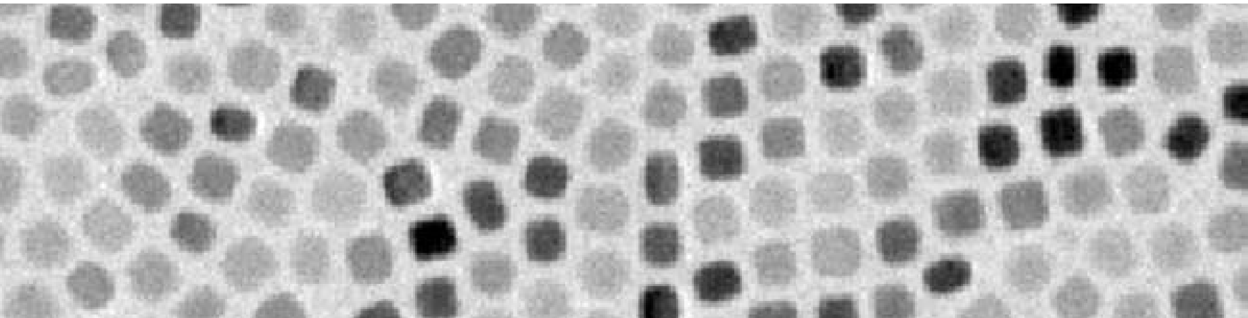
Synthetic organic, inorganic, and polymer chemistry are used to prepare new molecules and materials that have been designed to fulfill new functionalities. Presently attention is focused on low-band gap polymers, n-type conducting polymers, conjugated block copolymers and inorganic and metal nanoparticles.

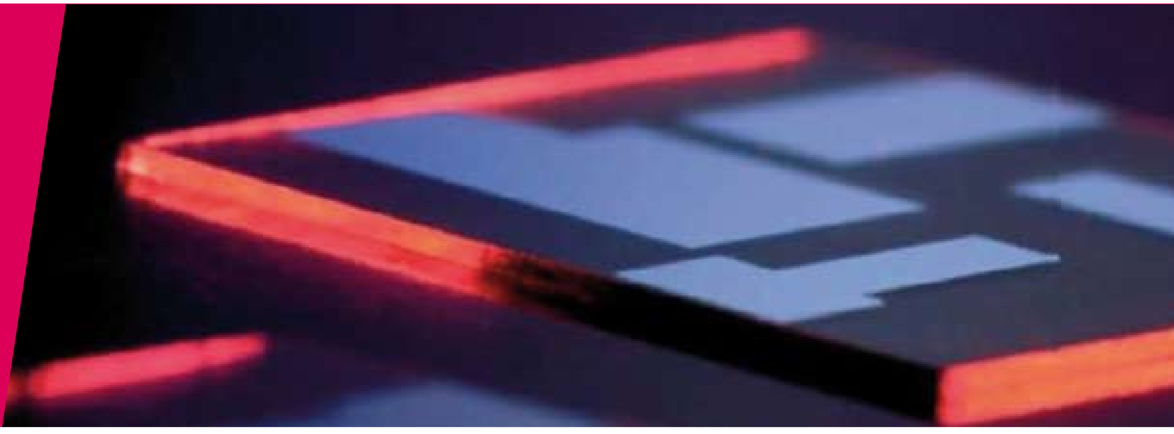
Nano-Scale Characterization

Inelastic tunneling spectroscopy is used to observe vibration spectra of single molecules. These experimental studies are complemented with advanced theoretical calculations. Atomic force microscopy and scanning Kelvin probe microscopy are used to study the morphology of conjugated polymers layers in actual working devices.

Optical Spectroscopy

Optical spectroscopy on time scales from 100 fs to 10 ms are being performed to visualize the primary photoexcitations in molecular materials and molecules and to investigate the kinetics of energy and electrons transfer and recombination reactions. Furthermore we study phosphorescence of triplet states in conjugated molecules and use high-resolution energy electron-loss spectroscopy to study vibrational and electronic transitions of oriented molecules at crystalline surfaces. Time-resolved spectroscopy on working photovoltaic devices is being used to monitor charge generation under operating conditions.





Opto-Electronic Devices

The preparation and characterization of opto-electronic devices such as light-emitting diodes and solar cells, and more recently also IR detectors, transistors, and memory devices is an important part of our work. It completes the line molecule-macromolecule-material-machine and enables to test new designs and ideas for macroscopic functionality. In this respect we focus on aspects of the role of interfaces by studying contacts with ion-beam techniques and the morphology of the active layer. We investigate the transport and injection mechanisms of charges by current voltage characteristics and impedance spectroscopy.

Key publications

J. Gilot, M. M. Wienk, and R. A. J. Janssen, Double and triple junction polymer solar cells processed from solution, Appl. Phys. Lett. 90, 143512 (2007)

2 P. T. K. Chin, C. de Mello Donegá, S. S. van Bavel, S. C. J. Meskers, N. A. J. M. Sommerdijk, and R. A. J. Janssen, Highly luminescent CdTe/CdSe colloidal heteronanocrystals with temperature dependent emission color, J. Am. Chem. Soc. 129, 14880 (2007)

3 A. Mantovani Nardes, M. Kemerink, R. A. J. Janssen, J. A. M. Bastiaansen, N. M. M. Kiggen, B. M. W. Langeveld, A. J. J. M. van Breemen, and M. M. de Kok, Microscopic understanding of the anisotropic conductivity of PEDOT:PSS thin films. Adv. Mater. 19, 1196 (2007)

4 D. Wasserberg, S. C. J. Meskers, and R. A. J. Janssen, Phosphorescent resonant energy transfer between iridium complexes.J. Phys. Chem. A. 111, 1381 (2007)

5 F. Verbakel, S. C.J. Meskers, and R. A. J. Janssen, Electronic memory effects in diodes of zinc oxide- nanoparticles in a matrix of polystyrene or poly(3-hexylthiophene), J. Appl. Phys, 102, 083701 (2007)

Prof.dr. B. Koopmans

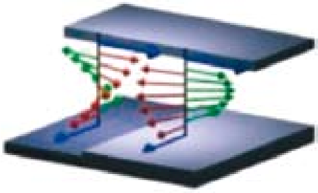
3.2.10 Physics of Nanostructures Group (FNA)

The mission of the group is the exploration and exploitation of novel physical phenomena at the nanometer scale by engineering the (magnetic) properties and structure of nanosystems.

The program is inspired by the challenges of nanoscience and nanotechnology. At present, the main emphasis is on processes and systems that are relevant for the future development of (magnetic) data storage and spinelectronics. While this approach is strongly curiosity driven, aiming at a high scientific impact, particular those issues are selected with a high technological relevance.

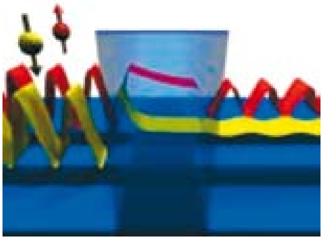
Nanomagnetism

Deposition and engineering of layered and nano-structured systems. In-situ and ex-situ characterization of structural and magnetic properties. Implementation and development of novel SPM methods for analysis and manipulation at nanometer to atomic scale [1,2].



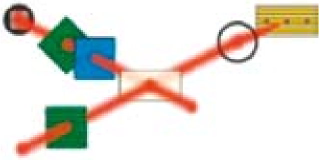
Spintronics

Tailoring spin-polarized transport in ferromagnetic and hybrid nanostructures. Specific emphasis on magnetic tunnel-junctions, spin-injection / manipulation in(to) semiconductors, and molecular spintronics [3,4].



Ultrafast spin dynamics

Investigation of ultimate limits of spin dynamics in ferromagnetic nanostructures. Development of novel concepts for high-data rate recording. Development of near-field femtosecond magneto-optical microscopy [5].



Key publications

1 J. B. Koopmans, “Spin dynamics: The ultimate view”, Nature Mat. 6, 715 (2007)

2 F. Dalla Longa, J.T. Kohlhepp, W.J.M. de Jonge and B. Koopmans, “Influence of photon angular momentum on ultrafast demagnetization in Nickel”, Phys. Rev. B 75, 224431-1 (2007)

3 H.J.M. Swagten, P.V. Paluskar, R. Lavrijsen, J.T. Kohlhepp, and B. Koopmans, “Tunneling spin polarization and annealing of Co72Fe20B8”, J. Magn. Magn. Mater. 310, 2012 (2007)

4 H.J.M. Swagten, “Spin tunneling in magnetic junctions (Chapter Book)”, in Handbook of Magnetic Materials, volume 17, pp. 1-122, Elsevier (2007)

5 J.J.H.M. Schoonus, A.T. Filip, H.J.M. Swagten, B. Koopmans, “Enhanced electrical spin injection and detection in biased lateral ferromagnet-semiconductor structures”, J. Phys. Cond. Mat. 19, 276201 (2007)

4 Education and Dissemination

4.1 Dissertations

Geldenhuys, R.:
Contention resolution in optical packet-switched cross-connects.
Promotor/copromotor: prof.ir. G.D. Khoe, prof.ir. A.M.J. Koonen & dr. H.J.S. Dorren. Technische Universiteit Eindhoven, 5 March 2007, pp. 1-127.

Li, Z.:
Ultrafast all-optical signal processing using semiconductor optical amplifiers.
Promotor/copromotor: prof.ir. G.D. Khoe, prof.dr. D. Lenstra & dr. H.J.S. Dorren. Technische Universiteit Eindhoven, 12 June 2007, pp. 1-136.

Barbarin, Y.:
1.55 um integrated modelocked semiconductor lasers.
Promotor/copromotor: prof.dr.ir. M.K. Smit, prof.dr. D. Lenstra & dr. E.A.J.M. Bente. Technische Universiteit Eindhoven, 2 April 2007, pp. 1-180.

Vidojkovic, V.:
Multi Band RF Front Ends with Adaptive Image Rejection.
Promotor/copromotor: prof.dr.ir. A.H.M. van Roermund & dr.ir. J.D. van der Tang. Technische Universiteit Eindhoven, 9 January 2007, pp. 1-215.

Dijk, N. van:
New Concepts for EMC Standards Applicable to Multimedia Products.
Promotor/copromotor: prof.dr. A.G. Tijhuis, prof.dr.ir. F.B.J. Leferink & dr.ir. P.A. Beeckman. Technische Universiteit Eindhoven, 27 June 2007, pp. 1-137.

Water, A.M. van de:
LEGO, Linear Embedding via Green's Operators.
Promotor/copromotor: prof.dr. A.G. Tijhuis, dr.ir. B.P. de Hon & dr.ir. P.J.I. de Maagt. Technische Universiteit Eindhoven, 31 October 2007, pp. 1-312.

Biswas, A.:
Advances in Perceptual Stereo Audio Coding Using Linear Prediction Techniques. Promotor/copromotor: prof.dr. R.J. Sluijter, prof.dr. A.G. Kohlrausch & dr.ir. A.C. den Brinker. Technische Universiteit Eindhoven, 15 May 2007, pp.1-180.

Zhou, D.:
Lateral positioning and wavelength control of InP based quantum wires and dots. Promotor/copromotor: prof.dr. P.M. Koenraad, prof.dr. K.H. Ploog & dr. R. Nötzel. Technische Universiteit Eindhoven, 10 April 2007, pp. 1-101.

Popa, C.:
Density functional theory studies of scanning for adsorption and reactivity on rhodium surfaces.
Promotor/copromotor: prof.dr. R.A. van Santen, dr.ir. C.F.J. Flipse & dr. A.P.J. Jansen. Technische Universiteit Eindhoven, 25 June 2007, pp. 1-152.

4.2 Master of Science in Broadband Telecommunication Technologies

The COBRA groups have jointly developed a Master's degree program in Broadband Telecommunication Technologies (BTT). The BTT Master's degree program is broadly based, including compulsory courses in electromagnetism, physics, mathematics, digital network technology and performance analysis. Wireless and optical communication systems and networks and RF electronic and photonic devices also form part of the program. A student can choose elective courses from a list of more than thirty subjects. These include photonic ICs, network operation, computational electromagnetics, adaptive signal processing, ultra-fast optical switching and coding theory. The program also contains courses on professional development and two internships. The studies are completed by a research project.

The special Master's degree program Broadband Telecommunication Technologies lasts two years. Each year consists of 60 ECTS (European Credit Transfer System). These credit points are subdivided as follows:

first year	
Physics and mathematical courses	10%
Broadband Telecommunication Technology courses	40%
Internship	15%
Development activities	15%
Electives	20%

second year	
Electives	10%
Internship	25%
Final research project	65%

The BTT Master's degree program is organized by the departments of Electrical Engineering, Mathematics and Computer Science, Applied Physics, Chemical Engineering, and Technology Management. A total of fourteen research groups are involved in this Master's program.

4.3 Capita Selecta on Quantum Dots

Subject: Capita Selecta on Quantum Dots

Date: Monday December 3, 2007; 9:00 – 17:00h.
Topics: *Fabrication of Quantum Dots*, R. Nötzel
Atomic-scale analysis of quantum dots, P.M. Koenraad
Quantum dot lasers and amplifiers, E.A.J.M. Bente
Quantum dot single photon generation, A. Fiore
Abstract: This Tutorial series will introduce you into the exciting field of self-assembled semiconductor quantum dots. A semiconductor quantum dot is the ultimate quantum confined structure. The lateral dimensions of quantum dots are of the order of several 10 nm and need to be controlled with atomic scale precision – a true challenge for today's nanotechnology. Its unique electronic properties rely on the quantum confinement of electrons in all three dimensions leading to atomic-like behaviour. This opens up a new area for basic physics studies as well as applications in novel opto-electronic devices.

4.4 Colloquia

Subject: High Capacity Optical Interconnects

Date: Friday January 12, 2007
Speaker: *Dr. Madeleine Glick*, Intel Research
Abstract: Optical interconnects are being considered for short link data networks as a solution enabling higher aggregate bit rates and lower power consumption. For short link length interconnects, as used in chip to chip interconnects, internal system backplanes and inter-system interconnects such as blade server backplanes, storage area networks and processing clusters, requirements are quite different to those for long distance telecommunications systems. Low power consumption, latency, and size become important criteria in addition to ultra high bandwidth. In order to achieve the projected ultra high capacity and low latency needs, we are considering optical switching fabrics. The optical switch, however, brings significant changes to the interconnect architecture in terms of how routing decisions are made and how contention resolution is managed. I discuss these issues and present our results for a multiwavelength optically switched interconnect.
Biography: Madeleine Glick received the PhD degree from Columbia University, for research on optical properties of GaAs based quantum wells. She continued research in this subject as a postdoc at the Physics Dept. EPFL, Switzerland. From 1992-96, she was Research Associate with CERN, on the Lightwave Links Project. She joined GEC Marconi, Caswell 1997 to 2001, to work on high-speed photodetectors. In 2002, she joined Intel Research. Her research interests are high capacity, multiwavelength optical interconnects for data networks and digital signal processing for optical systems. Madeleine is a Fellow of the Institute of Physics and a member of the Optics and Photonics News Editorial Advisory Committee of the Optical Society of America.

Subject: OSMOSIS research project

Date: Friday February 23, 2007
Speaker: *Dr. Cyriel Minkenberg*, IBM Zurich Research Laboratory
Abstract: In the OSMOSIS research project, IBM and Corning are jointly developing an interconnection network for high-performance computing (HPC) applications featuring an optical data path with electronic control. The data path is based on a broadcast-and-select architecture using fast semiconductor optical amplifiers to achieve cell-by-cell switching. The central controller computes an optimal switch configuration in every cell time to minimize latency and maximize throughput.
Dr. Cyriel Minkenberg will describe the objectives of the project, the key requirements deriving from the intended HPC application (latency, throughput, reliability and efficient multicast support), the architectural innovations needed to meet these challenges, and the current state of the implementation of the demonstration system, which is designed to support 64 links running at 40 Gb/s each.
Biography: Cyriel Minkenberg is a research staff member at the IBM Zurich Research Laboratory, where he is responsible for the architecture and performance evaluation of the Osmosis crossbar scheduler. His research interests include switch architectures, flow and congestion control, networking protocols, performance modeling, and simulation. Minkenberg has a PhD in electrical engineering from Eindhoven University of Technology, the Netherlands.

Subject: Novel semiconductor-based lasers for telecom and non-telecom applications

Date: Monday March 19, 2007
Speaker: *Shinji Matsuo and Hiroyuki Suzuki*, NTT Photonics Laboratories
Abstract: We introduce our recent efforts to fabricate novel semiconductor-based lasers for telecom and non-telecom applications.For telecom applications, we have developed two-types of novel tunable lasers with fast tuning speed. Digitally tunable laser using the ladder-type filter has been developed for backbone and metro networks in future photonic network systems. Tunable laser using micro-ring resonators has been developed for large scale photonic integration circuits in packet switching systems.
For non-telecom applications, we utilized wavelength conversion techniques such as sum-frequency, difference-frequency and second-harmonic generation in high-efficiency PPLN waveguides to obtain lasers with novel colors in the visible and mid-infrared regions for use in life science and gas sensing applications.

Subject: Photonic Crystal Devices

Date: Monday April 2, 2007
Speaker: *John O' Brien*
Abstract: Two-dimensional photonic crystal devices take advantage of our ability to pattern the dielectric, through nanofabrication techniques, on a scale that is shorter than the optical wavelength at which the device operates. Patterning on this length scale allows us, in principle, to engineer the electromagnetic properties of photonic devices in microscopic detail. It is a serious challenge, however, to understand how to utilize this freedom to improve device performance, and this photonic crystal device technology is still relatively immature. Nevertheless, a great deal of progress in photonic crystal device development has been made in the past few years. In this presentation I will discuss photonic crystal lasers with particular emphasis on devices capable of room temperature CW operation and devices with quantum dot active regions. The CW lasers have 3 dB bandwidths of just under 10 GHz with approximately 30 dB of side mode suppression. The photonic crystal lasers with quantum dot active regions have absorbed powers at threshold of under 10 microwatts. The presentation will describe the optical loss mechanisms in photonic crystal resonant cavities and I will also discuss efforts to model the electromagnetic properties of these devices in the near and far field using both finite-difference time-domain and finite element methods and compare these predictions to the experimental data.
The presentation will also address device issues associated with passive photonic crystal components such as optical loss, waveguide dispersion, and the design of waveguide junctions. Demonstrations of Mach-Zehnder interferometers and directional couplers will be presented and again results from experiments will be compared to numerical predictions.

Subject: Ordered Quantum Wires and Dots for Nanophotonics Applications

Date: Tuesday April 10, 2007
Speaker: *Dr. Eli Kapon*, Institute of Micro and Optoelectronics in the Physics Department of the Swiss Federal Institute of Technology in Lausanne (EPFL)
Abstract: Site- and emission wavelength control of semiconductor quantum wires (QWRs) and quantum dot (QDs) grown by metallorganic vapor phase epitaxy on patterned substrates is described.
This approach combines top-down lithography and bottom-up self-ordering processes to achieve uniform arrays of QWRs and QDs without compromising their interface and optical properties. These structures are used to study ten effects of 2D and 3D quantum confinement of excitons and exciton complexes, preparation of nonclassical photon states, QD molecules and QD superlattices, and integration of QWRs and QDs with photonic crystal cavities.

Biography: Eli Kapon received his B.Sc., M.Sc. and Ph.D. in physics from Tel Aviv University, Israel in 1974, 1978 and 1982, respectively. His Ph.D. work involved studies of lead-salt distributed Bragg reflector diode lasers operating in the mid-infrared wavelength range. He then spent two years at the California Institute of Technology, Pasadena, as a Chaim Weizmann Research Fellow, where he worked mainly on phase-locked arrays of semiconductor lasers. From 1984 till 1993 he was with Bellcore, New Jersey, first as member of technical staff, and from 1989 as a District Manager. At Bellcore, he worked first on integrated optics in III-V compound semiconductors, as well as on lateral patterning of quantum well structures by epitaxial growth on nonplanar substrates. His research interests shifted later towards low-dimensional semiconductor nanostructures, particularly quantum wires and quantum dots, their fabrication and optical properties. This work led to the first demonstration of quantum wire lasers in 1988. He managed the Quantum Structures District and the Integrated Optoelectronics District at Bellcore from 1989 till 1992 and from 1992 till 1993, respectively. In 1993 he was appointed Professor of Physics of Nanostructures at the Institute of Micro and Optoelectronics in the Physics Department of the Swiss Federal Institute of Technology in Lausanne (EPFL), where he heads the Laboratory of Nanostructures. His current research interests include self-organization of nanostructures, optical properties and electron transport in low-dimensional quantum structures, quantum wire and quantum dot lasers, and vertical cavity surface emitting lasers. Prof. Kapon is a Fellow of the Optical Society of America, the Institute of Electrical and Electronic Engineers, and the American Physical Society.

Subject: Monolithic integration of optical isolators with edge-emitting semiconductor laser diodes

Date: Monday 23 April, 2007
Speaker: *Hiromasa Shimizu*, Dr. Eng., Associate Professor, Department of Electrical and Electronic Engineering, Tokyo University of Agriculture & Technology
Abstract: We have proposed, simulated, fabricated and experimentally demonstrated monolithically integrable semiconductor active waveguide optical isolators based on the nonreciprocal loss at an wavelength range of 1530-1560nm. The semiconductor active waveguide optical isolators are composed of semiconductor optical amplifier (SOA) waveguides and ferromagnetic metals.
In TE mode semiconductor active waveguide optical isolators composed of InGaAsP SOA waveguides and Fe thin films, we demonstrated 14.7dB/mm optical isolation at the wavelength of 1550nm and 10dB/mm isolation over entire wavelength range of 1530-1560nm.
In TM mode semiconductor active waveguide optical isolators, we used epitaxially grown MnAs thin films as top ferromagnetic electrodes, and demonstrated stable electrode performance and 8.8dB/mm optical isolation.
Based on these demonstrations, we can realize monolithic integration of optical isolators with edge-emitting semiconductor laser diodes.

Biography: Hiromasa Shimizu received the B.S., M. S., and Ph. D., degrees in electronic engineering, from the University of Tokyo, Tokyo, Japan, in 1997, 1999, and 2002, respectively.
Dr. Shimizu joined the Research Center for Advanced Science and Technology, the University of Tokyo, as a Research Associate of Professor Yoshiaki NAKANO's laboratory in 2002. From January of 2007, he moved to Tokyo University of Agriculture and Technology, Tokyo, Japan, as an Associate Professor, and started to organize an individual research laboratory. Presently, he is doing research on integratab le waveguide active optical isolators, electroabsorption multiple quantum well optical modulators, and spintronics.
Dr. Shimizu received the 9th Young Scientist Award for the Presentation of an Excellent Paper at the JSAP fall meeting in 2000, the 2001 Young Scientist Award from MSJ, the Ribbon Award at 2004 Fall meeting of Material Research Society, and 2005 Japanese Journal of Applied Physics Award for the most promising young scientist. He has published 28 papers in international journals and more than 40 papers in international conference papers.

Subject: Photonic Integrated Devices for Transparent Optical Networking

Date: Monday April 23, 2007
Speaker: *Professor Yoshiaki Nakano*, Research Center for Advanced Science and Technology, The University of Tokyo
Abstract: In this talk, Japanese national project activities for developing photonic integrated devices, such as fast matrix switches, 40Gbps wavelength converters, compact and fully-athermal AWGs, Er-doped waveguide amplifier arrays, fast-tunable laser diodes, and all-optical flip-flops, will be introduced, together with their applications in optical-label transparent burst and packet switching demonstration.
Biography: Yoshiaki Nakano is a Professor at the Research Center for Advanced Science and Technology, the University of Tokyo. He is also with the Department of Electronic Engineering, Graduate School of Engineering, the University of Tokyo. He received the B. E., M. S., and Ph. D. degrees in electronic engineering, all from the University of Tokyo, Japan, in 1982, 1984, and 1987, respectively. In 1984, he spent a year at the University of California, Berkeley, as an exchange student.
In 1987, he joined the Department of Electronic Engineering, the University of Tokyo, became an Associate Professor in 1992, a Professor in 2000, and the Department Head in 2001. He moved to the Research Center for Advanced Science and Technology, the University of Tokyo, in 2002 where he is currently a Professor in the Department of Information Systems. His research interests have been physics and fabrication technologies of semiconductor distributed feedback lasers, semiconductor optical modulators/switches, and monolithically-integrated photonic circuits. In 1992, he was a visiting Associate Professor at the University of California, Santa Barbara.
Dr. Nakano is an elected member of the Board of Governors of IEEE LEOS, a member of the Board of Directors of the Japan Society of Applied Physics (JSAP), Fellow of the Institute of Electronics, Information, and Communication Engineers (IEICE), a former member of the Board of Directors of the Japan Institute of Electronics Packaging (JIEP), and the Chief Editor of Japanese Journal of Applied Physics (JJAP). He is also a member of IEEE EDS and OSA. He is currently the project leader of Japanese National Project on "Photonic Networking Technology" organaized by the Ministry of Economy, Trading, and Industry, the project leader of SORST Program on "Non-reciprocal Semiconductor Digital Photonic Integrated Circuits and their Applications to Photonic Networking" sponsored by Japan Sciency and Technology Corporation, and the chairman of the Optical Interconnect Standardization Committee of Japan Electronics Packaging and Circuits Association (JPCA). He is the recipient of the 1987 Shinohara Memorial Prize from the IEICE, the 1991 Optics Paper Award from the JSAP, and the 1997 Marubun Science Prize. He authored and coauthored over 100 refereed journal publications and over 200 international conference papers, and holds 40 patents.

Subject: Status of High Speed Plastic Optical Fiber for Broadband Society

Date: Thursday April 26, 2007
Speaker: *Yasuhiro Koike*, Keiko University
Abstract: The concept of FTTH (Fiber to the Home) has become more and more popular in Japan and Korea, and the network speed requirement for end users has crossed the 100 Mbps mark. Furthermore, with the DVI system commercially available, the data rate between high-definition displays and tuners is already at 2.5Gbps. Under these circumstances, to move towards broadband society, we Keio University has proposed the concept of "Fiber to the Display", where the optical fiber is directly connected to large and high-quality flat-panel display, keeping gigabit data rate even at homes.
The biggest challenge in IT will be how to install gigabit optical fibers to local area networks at homes, offices, and buildings. However, the silica optical fibers used in the backbone of the networks have diameter less than one tenth of a hair. Therefore, installation of the silica optical fibers has not been realized, as it requires enormous amounts of cost due to the many connections, junctions, and handling of fibers. As the optical fiber which satisfies above issues, we are pursuing the research and development of high-speed plastic optical fiber (POF) that is Graded-Index POF (GI-POF). The GI-POF has a large core that enables easy handlings and connections as the existing metal cables, but can achieve the high-speed data transmission comparable to that of silica optical fibers. The POF is so flexible that it can easily be installed even in existing buildings, which brings about various options to the construction planning.
Gigabit and 10Gigabit Ethernet standards specify the use of multimode fiber and an inexpensive VCSEL

as a light source. However, the dispersion of the multimode fibers is the serious problem particularly in the 10Gigabit transmission systems. For the premises network applications, we have proposed a low-loss perfluorinated polymer based GI-POF (PF-GI-POF). The attenuation of the current PF-GI-POF is 10dB/km in 0.8–1.3μm wavelength range. In addition, material dispersion of the PF-GI-POF is lower than that of silica.
In our laboratory, the GI-POF has been prepared by the interfacial-gel polymerization process where the GI preform rod is firstly prepared and is heat-drawn into the GI-POF. Therefore, considering the mass production, this process is not necessarily an efficient process. Recently, we proposed the dopant-diffusion co-extrusion process which enables to fabricate GI-POFs continuously using small-size dopants. Moreover, the core-cladding thickness ratio can easily be controlled by changing the rotational speed of the screw installed in the extrusion machine, and GI-POFs with the same graded-index distribution condition can easily be prepared consecutively; this can reduce the cost of preparing GI-POFs.
The typical copper cable network adopted in conventional buildings is the dispersed network system, where main- and sub- servers and switches are dispersed on each floor and those are connected by copper cables. On the other hand, using high-speed GI-POFs mentioned above, we have proposed a quite novel "centralized network", where only one main server and GI-POFs are directly distributed to any outlets and terminal, without any floor switches or sub-servers in between. Therefore the security of network is very high and the maintenance fee is one fifth of the case of conventional dispersed network. Such a world-first gigabit hospital system with the centralized network using GI-POF was realized in a cardiac hospital with 320 beds, which is located in Tokyo last year. The total length of GI-POF used in this hospital is 230 km, which is likened to much longer branched veins compared to main veins of human body.
We have been further developing high-resolution and large-sized flat panel displays that can be hung on the walls for future "Giga House" of the "Fiber to the Display". For example, when elderly people get sick late at night, it will be a great relief if they can consult doctors online with such real-time clear motion picture in large-sized display without tapping the keyboard. The gigabit technology which we propose will bring us back to "Face-to-Face Communication".

Subject: Slow light in semiconductor waveguides

Date: Tuesday June 12, 2007
Speaker: *Prof. Jesper Mørk*, Research Center COM
Abstract: Recent experimental and theoretical work on slow and fast light in semiconductor waveguide structures is presented. By exploiting the effect of coherent population oscillations in an integrated structure combining amplifier and absorber elements, control of the microwave phase at gigahertz frequencies is demonstrated. Possible applications are, e.g., within phased array antennas and microwave filters. The possibility of realizing slow light based on electromagnetically induced transparency in quantum dot structures is also discussed.
Biography: Jesper Mørk received the M.Sc., Ph.D., and Dr. Techn. degrees from theTechnical University of Denmark (DTU), Lyngby, in 1986, 1988, and 2003, respectively. Since 2002, he has been a Professor in semiconductor devices for optical communication systems and is the Deputy Head of the Nanophotonics area at Research Center COM. He is associate editor of IEEE J. Quantum Elctronics and member of the Danish Research Councils. His current research interests are in the area of device physics, in particular ultrafast devices for optical signal processing, noise in nonlinear devices, and quantum photonics.

Subject: Some applications of optical processing in communications systems and networks

Date: Tuesday June 13, 2007
Speaker: *Prof. Didier Erasme,* Ecole Nationale Supérieure des Télécommunications (Télécom Paris)
Abstract: Optical communication systems and networks are living permanent evolutions over the years following constant development of new applications and new services. The role of has long been restricted to carrying high bit rate information over long distances. Now, many new optical applications are designed in order to take over operations that were traditionally dedicated to electronics for speed, cost or flexibility reasons.
The seminar will present two applications of optical signal processing studied in the ENST. The first one is a clock recovery system that uses 3-wave-mixing in a periodically poled lithium niobate device or 4-Wave-mixing in a Semiconductor optical amplifier to perform phase comparison. The second one adresses packet switching systems and will display some all-optical elements required for such architecture.
Biography: Prof. Didier Erasme was born in Paris (France) in 1960. In 1983, he received a "diplôme d'Ingénieur" in physical engineering from the Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble (INPG). In 1987, he completed a Ph.D. on $LiNbO_3$ high-frequency integrated-optic modulators in the Electrical and Electronic Engineering Dept of University College London (UCL) (UK). He joined the Ecole Nationale Supérieure des Télécommunications (Télécom Paris) in 1990 as an assistant professor in optoelectronic. In 1995, he spent a 6-months sabbatical in Professor Meint Smit's group in Delft University (Netherlands). He is a full Professor since 1998.
His current research interests are in the area of new optical functions for telecommunication optical systems and networks. Particularly, he has developed a strong interest in semiconductor laser amplifiers and other non-linear optical devices for applications in all-optical signal processing. He is author and co-author of more than 60 publications and communications in international journals and conferences. He is a member of the European

programme BREAD dedicated to the road-mapping of European Broadband-for-all activities in Europe and participates to the European Network of Excellence ePhoton/One.

Subject: Photonic Sensor Solutions for 21st Century

Date: Wednesday July 18, 2007
Speaker: *Prof. Dr. Nabeel Riza*, Visiting Professor TU Delft, Netherlands and Professor of Optics and Electrical Engineering Photonic Information Processing Systems Laboratory (http://pips.creol.ucf.edu), College of Optics & Photonics/CREOL-University of Central Florida, Orlando, USA
Abstract: Today, the global community is facing massive challenges in the energy sector. This lecture will show how a new class of photonic sensors can be intelligently engineered to solve pressing problems in extreme environment coal-fired power plants where temperatures and pressures are expected to reach 1600 degree-C and 100 atmospheres, respectively.
Biography: Prof. Dr. Nabeel Riza holds a doctorate from the California Institute of Technology. In Jan. 2002, he became the first person from the South Asia region to be awarded the prestigious International Commission for Optics (ICO) Prize and the 2001 Ernst Abbe Medal from the Carl Zeiss Foundation, Germany. Dr. Riza other awards include the 2007 Fellow Award of the IEEE, 1998 Fellow Award of the Optical Society of America (OSA) and the 1998 Fellow Award of the International Society for Optical Engineering (SPIE). After completing his Ph.D in 1989, Dr. Riza joined the General Electric Corporate Research and Development Center, where he initiated and led the GE Optically Controlled Radar Project. In 1995, he joined the College of Optics/CREOL at the University of Central Florida where he is Full Professor and Head of the Photonic Information Processing Systems Laboratory.

Subject: Solid-state cavity QED, and optical cooling of micro-mechanical systems

Date: Friday August 17, 2007
Speaker: *Dirk Bouwmeester*, Department of Physics, Center for Spintronics and Quantum Computation, University of California, Santa Barbara, USA & Huygens Laboratory, Leiden University, Leiden, NL.
Abstract: To interface photons with solid-state devices, we investigated the coupling of optically active quantum dots with optical micro- and nano-cavities. Initial experimental progress have led to the unexpected observation of ultra low threshold lasing of a photonic crystal defect mode cavity embedded with only 1 to 3 InAs self-assembled quantum dots as gain medium. Photon correlation measurements confirmed the transition from a thermal light source to a coherent light source. We also report on micro-pillar cavities with integrated oxidation apertures and electronic gates that provide an 80MHz single photon source with controllable polarization.
A second set of experiments will be addressed that has as long-term aim the transfer of a superposition of a photon propagating in two directions into a superposition of two center-of-mass motions of a tiny mirror that is placed in one path of the photon. A crucial part of the proposed experiment is an optical cavity with one end mirror as small as 20 μm in diameter attached to a high Q mechanical cantilever. Such a system has been achieved with an optical quality factor of 2,100 and a mechanical quality factor of 100,000. This provides an excellent interferometric measurement of the thermal motion of the micro-mechanical system. The thermal motion of the center-of-mass mode can be counter acted using a feedback circuit to modulate an additional optical force. Experimental results will be shown that demonstrate the optical cooling from room temperature to 135 mK.
Biography: Dirk Bouwmeester obtained his undergraduate (1991) and Ph.D. (1995) degrees in Physics from the University of Leiden in the Netherlands.
During his PhD research in the group of Prof. Woerdman and Prof. Nienhuis, he studied optical systems that simulate quantum dynamics such as quantum tunneling, geometric phases and amplitudes, and quantum random walks. In 1995-1996 he worked as a postdoctoral research together with Prof. R. Penrose on special solutions of Maxwell's equation. In 1997-1998 he worked as a postdoctoral researcher in the group of Prof. Zeilinger in Innsbruck.
In that period he worked on the first experimental demonstration of quantum teleportation and three-photon entanglement. From 1999 to 2002 he established a new quantum optics laboratory at the Center for Quantum Computation in Oxford. In that period he demonstrated quantum cloning and stimulated emission of entangled photons. From 2002 on is working at the University of California in Santa Barbara and has extended his research interest to include solid-state cavity QED, cooling of micromechanical systems, and biophysics. Since June 2007 he also obtained a part-time professorship at the University of Leiden in the Netherlands.

Subject: Circuits and materials research activities for use in OTDM network systems starting from 160 Gb/s

Date: Friday September 7, 2007
Speaker: *Yoshiyasu Ueno*, Associate Professor, Department of Electronic Engineering, Univ. of Electro-Communications, Tokyo, Japan
Abstract: This talk will cover the OTDM circuits-level and materials-level research activities that the speaker has been involved in, since late 90's, as follows:
(1) previous demonstrations of SMZ demux, DISC wavelength conversion, and SMZ 3R regeneration with 80-Gb/s or 160-Gb/s signals around year 2000, within their nation-wide, 9-year-long FESTA project (NEDO/METI, 1996-2004),
(2) on-going efforts to experimentally model and design the output waveforms with or without taking into account the faster carrier-heating-related response components, and

(3) SOA's nonlinear-performance characterizations in terms of their all-optical quantum efficiencies, maximum bitrates after acceleration, and electric dc power consumptions. Depending upon, he will also briefly mention about (4) their application-oriented activities, ie., disc-loop-type mode-locked pulse generation, or, SMZ-flip-flop memory project using integrated photonic-crystal waveguides combined with 1.3-um quantum dots.
Biography: Yoshiyasu Ueno received his master's degree in physics (Raman spectroscopy near polariton resonances) and PhD degree in applied physics (AlGaInP-MQW laser diodes) from Univ. of Tokyo in 1987 and 1998, respectively. In 1987-1994, he was engaged in R&D of MOVPE-grown, 680-nm AlGaInP, high-power laser diodes from industrial viewpoints, keeping in touch with e.g. Philips Eindhoven, IBM Zurich, and ETH Zurich in the years. These high-power lasers were commercialized and are now daily mass-produced in NEC, for use in the DVD recorders. In 1995-1996, he studied his original superlattice-related nonlinear-optics switch topic with Prof. G.I. Stegeman in CREOL, Univ. Central Florida (staying there with his wife and their two little sons about 15 months).
From 1996 through to the present, he has been studying the ultrafast, semiconductor-based, all-optical logic gates, trying to realize a historical transition from E-TDM to O-TDM network technology, as a member of the research project FESTA (sponsored by NEDO/METI, 1996-2004) and some other nation-wide projects. Some of his achievements with his many strong co-authors were, the proposal of SMZ-DISC-type circuit scheme (1998), successful wavelength conversion (168 Gb/s, 2000), optical 3R regeneration (84 Gb/s, 2001), the proposal of DISC-loop-type pulse-generator scheme (2000), its mode-locked 2-ps, 40-GHz, clock-pulse generation (2006), and fundamental modeling works for the SMZ-DISC (e.g., JOSAB 2002) and 3R schemes.
He has been a member of OSA, IEEE LEOS, and JSAP. Regarding his affiliations, he used to be working for NEC research centers in Kawasaki and Tsukuba, from 1987 through 2002. Since 2002, he has been working for the Univ. of Electro-Communications. Present numbers of his postdocs and graduate students are, respectively, one and seven (FY2007).

Subject: High-Power, Wide Tuning Range External Cavity Lasers with integrated Functional Section

Date: Friday September 25, 2007
Speaker: *Dr. Mads Loenstrup Nielsen and Dr. Shinya Sudo*, from NEC System Devices Research Laboratories, Japan
Abstract: The presentation reviews our recent activities on the development of high performance full-band wavelength tunable lasers. Our approach utilizes an external cavity configuration, which makes use of a liquid crystal (LC) tunable mirror. We also describe a gap mirror technology for integrating a functional section onto a laser gain chip. A semiconductor optical amplifier, implementing several functions, is integrated on the gain chip used in an external cavity laser, and demonstrated as a high-performance variable attenuator, booster amplifier, and data modulator at 2.5 Gb/s. Control of the mirror properties through the gap geometry is demonstrated, and further optimization is realized by a gap-filling technique, which increases the output power to above 100 mW across the C-band.
To address both C and L bands, a wide-band gain chip with a coupled quantum well active region has been developed, and we present the recent progress. Finally, we will present results on our InP-based Mach-Zehnder modulator activities.
Biographies: Shinya Sudo was born in Saitama, Japan in 1970. He received the B.E. degree in electrical engineering from University of Tokyo in 1993 and M.E. and Ph.D. degrees in electronic engineering from University of Tokyo in 1995 and 1998, respectively. In 1998, he joined NEC Corporation, where he has been engaged in the research and development of epitaxial growth and semiconductor optical devices. Dr. Sudo is a member of the Japan society of Applied Physics.
Mads L. Nielsen was born in Skanderborg, Denmark in 1975. He received the M.Sc.E. and Ph. D. degrees in electrical engineering from the Technical University of Denmark in 2000 and 2004, respectively, for work on semiconductor-based all-optical signal processing. After one year in a position as assistant professor at Research Center COM, Denmark, he joined NEC System Devices Research Laboratories at Otsu, Japan in 2005, where he is currently engaged in research and development of widely tunable lasers and high-speed modulators.

Subject: University, Industry & Government Collaborations for Optics & Photonics Innovation

Date: Monday October 22, 2007
Speaker: *Kimio Tatsuno*, PhD, Hitachi Ltd., CRL., / OITDA & Tokyo Metropolitan University
Abstract: In the technology front of optical industry in Japan, optical recording, semiconductor stepper, fiber communication, digital camera and OCT are contributing to the improvement of people's higher quality of life and to the industrial economical growth. We review and report our analytical results in these fields from the aspects of the University, Industry and Government collaborations including international comparison to enhance the progress of sustainable global photonic innovation eco-systems.
Biography: In 1973, he joined Hitachi CRL (Central Research Laboratory) Kokubunji, Tokyo, after receiving his master degree of applied physics from the university of Osaka. He started his research on the "Holographic memory" and involved in the development of optics for the diode laser applications as "Optical disk", "Diode laser interferometer" and "Laser beam printer". From 1986 to 1987, he stayed at Philips Research Lab., Eindhoven as an exchange researcher for the development of optics for "Phase coupled array lasers". Being back to CRL of Hitachi Ltd., he continued his research on the wavelength conversion of diode pumped solid state SHG Lasers

and from 1995, he lead the project for the development of diode laser transceiver modules for optical fiber communications.
In 2003, he joined NISTEP (National Institute of Science and Technology Policy) in the Ministry of Education, Science and Technology Japan and involved in the research and politics proposals from the aspects of industry, university and government collaborations for the innovation eco-systems. And in 2007, he joined OITDA (Optoelectronic Industry & Technology Development Association) on leave from Hitachi Ltd., for the planning and promotion of the national photonic project. He is a part time professor at the Tokyo Metropolitan University and a member of JSAP, OSJ, IEICE, OSA, IEEE/LEOS and serving for them as a committee member.

Subject: Si Photonics: Emission and Detection of Light on Si Platform

Date: Monday October 22, 2007
Speaker: *Yasuhiko Ishikawa*, Department of Materials Engineering, Graduate School of Engineering The University of Tokyo
Abstract: Si-based photonics has attracted interests for economical optical communication systems as well as high-speed inter/intra-chip optical interconnects. Using Si-CMOS fabrication technology, passive devices such as Si waveguides and filters have been realized. Next challenge should be the realization of active components: light emitters, modulators and photodetectors. We will talk about our recent progress on near-infrared Ge photodetectors on Si, where the absorption edge is expanded from 1550 nm (C-band) to 1620 nm (L-band) due to the narrowing of direct band gap of Ge induced by a tensile strain. As for the light emission, an enhanced photoluminescence from Si microring resonators will be presented.
Biography: He received his B.Eng., M.Eng. and Ph.D. degrees from Hokkaido University, Sapporo, Japan, in 1993, 1995, and 1998, respectively. He was engaged in research on MBE/MOCVD growth and scanning probe microscopy characterizations of III-V compound semiconductors. From 1998 to 2005, he worked at Research Institute of Electronics, Shizuoka University, Hamamatsu, Japan, in the research field of Si-on-insulator material science, Si/SiO2 resonant tunneling devices and Si single-electron devices. In 2001-2002, he was a Visiting Scientist in the Material Processing Center/Microphotoics Center, Massachusetts Institute of Technology, Boston, USA. He was engaged in research on Ge photodiodes on Si for near-infrared detectors on Si platform. Since 2006, he has been a Lecturer/Assistant Professor in the Department of Materials Engineering, The University of Tokyo. He is currently engaged in research on Si-based photonic devices, optoelectronic integrated circuits on Si and their applications to communication and bio-sensing systems. He is a member of the Japan Society of Applied Physics and the Materials Research Society.

Subject: Nanowires and nanolasers: how small can a laser be?

Date: Thursday October 25, 2007
Speaker: *Professor Cun-Zheng Ning*, IEEE/LEOS Distinguished Lecturer, Center for Nanophotonics-Arizona Institute of NanoElectronics, Center of Solid State Electronics Research (CSSER) and Department of Electrical Engineering, Arizona State University, Tempe, AZ 85287
Abstract: The pursuit of nanotechnology in general and miniaturization of electronic devices in particular have seriously challenged the optoelectronics community to develop ever smaller lasers and optoelectronic devices compatible with the trend in microelectronics. Vertical-cavity surface emitting lasers measured a few microns were once the smallest lasers. The situation is now rapidly changing over the last 5 years with the demonstration of lasing capability of a single semiconductor nanowire of ~100 nanometers in diameter. The ultimate challenge to the community is: can one make a laser that is smaller than the wavelength in all 3 dimensions, or what is the ultimate size limit of a laser?
To answer this and related questions, my lecture will start with an overview of impressive recent progress in growth, fabrication, and characterization of semiconductor nanowires and demonstration of lasing activities in various wavelengths. These lasers represent one of the smallest lasers of any kind at present. We will show how this new type of miniaturized lasers differs from the conventional semiconductor lasers. To further reduce the dimension of nanowire lasers, a recent proposal of using metal coating of semiconductor wires will be evaluated by numerical simulation. We will show that a proper design of a metal coated semiconductor nanowire can achieve lasing threshold despite significant metal loss. Finally some recent novel ideas involving surface plasmonic excitations at metal-semiconductor interface will be discussed where much smaller lasers could be potentially made, with size independent of wavelengths.

Subject: Negative Refraction at Visible Frequencies: Towards a (nearly) Perfect Lens

Date: Wednesday November 14, 2007
Speaker: *Jennifer Dionne*, PhD candidate in the Applied Physics Department at the California Institute of Technology.
Abstract: Negative index materials (NIMs) are characterized by an electric permittivity and a magnetic permeability that are simultaneously negative, resulting in a negative index of refraction. Unlike all naturally occurring materials, NIMs are characterized by a group velocity oriented opposite to the phase velocity. If NIMs could be artificially engineered, a variety of exotic and enabling effects would be observed, including negative refraction at the interface between positive and negative index media, a reversed Doppler effect, and Cerenekov radiation that is emitted opposite to the

direction of source velocity. Additionally, NIMs would amplify evanescent electromagnetic Fourier components, creating the possibility for a "perfect lens" that could resolve arbitrarily-small feature sizes. Recent studies have demonstrated NIMs at acoustic, microwave, and near-infrared frequencies using metamaterials composed of subwavelength resonant elements. However, negative refraction at visible frequencies has remained elusive.
In my talk, I will present direct experimental evidence of negative refraction in the blue-green region of the visible. Negative indices are achieved by exploiting the unique properties of surface plasmons, which are characterized by antiparallel group and phase velocities over a tunable frequency range. Negative indices as high as -5 are obtained for wavelengths between 470nm and 530nm in gold / silicon nitride / silver structures, and both negative refraction and focusing can be observed. Our results indicate the accessibility of broad-band negative refraction over a wide range of visible wavelengths, facilitating design of a new materials class with extraordinary optical properties and applications.
Biography: Jennifer Dionne is a PhD candidate in the Applied Physics Department at the California Institute of Technology. Working with Professor Harry Atwater, her research has focused on nanophotonic systems, emphasizing the design and analysis of plasmonic materials for subwavelength microscopy and active electrooptic devices. She received a MS degree in Applied Physics from Caltech in 2005 and BS degrees in Physics and Systems Science & Mathematics from Washington University in St. Louis in 2003. She is a National Science Foundation Graduate Research Fellow and the recipient of the National Defense Science and Engineering Graduate Fellowship.

Subject: Application-aware networking: why and how

Date: Thursday December 20, 2007
Speaker: *Dr Antonio Liotta*, Reader, Department of Computing and Electronic Systems, University of Essex, Colchester, CO4 3SQ, UK. E-mail: aliotta@essex.ac.uk
Abstract: Today, users take always-on connectivity for granted even if they are on-the-move. They expect full, secured access to their personalized environment, services, and data. Not only users but also networks move, interconnect, and interoperate within a highly dynamic and heterogeneous context. Ubiquitous connectivity has become a concrete possibility, thanks to a varied choice of wireless and cellular networks. At the same time, optical technologies allow transfer rates comparable to those of a computer bus.
These unprecedented network capabilities have enabled distributed applications that can rely upon tight coupling and low latency among user terminals. However, in practice those very same applications are network-hungry and clash, rather than amicably coexist, with the network itself. This is for instance the case with eScience applications, storage Grids, content distribution networks, and peer-to-peer streaming and file sharing applications.
In this talk we revisit the requirements that the most common applications pose onto hybrid networks, illustrating and putting in perspective the problems that arise when network-agnostic applications run on top of application-unaware networks. These issues are highlighted through a number of practical case studies carried out at Essex in the context of EU project Phosphorus and of a number of other industrial projects funded by Vodafone and British Telecom.
Our analysis identifies the shortcomings of current network architectures and service management frameworks, with particular attention to those introduced by 3GPP (the 3rd generation partnership project) and the IMS (the IP Multimedia Subsystem), which are supported by most telecommunication standards bodies.
We conclude with an outlook on the topic of application-aware networking, indicating promising research threads towards truly pervasive networks and services.
Biography: Dr Antonio Liotta is a Reader at the Department of Computing and Electronic Systems, University of Essex, UK. He has over 80 publications in the areas of telecommunication services, distributed computing, and advanced networking. Dr Liotta is a Fellow of the U.K. Higher Education Academy and serves a number of senior advisory boards including: the Peer Review College of EPSRC (the U.K. Engineering and Physical Sciences Research Council); the scientific advisory panel of the IWT (the Belgian Research Council); the Board of Editors of the Journal of Network and System Management (Springer); and the advisory board of editors of the International Journal of Network Management (Wiley). He is an active member of the networking research community. He is a Co-Chair of ComP2P'08, has co-organised 3 international conferences, serving the Technical Programme Committee of 68 conferences. At the University of Essex he leads the Pervasive Services team, known for its pioneering work on operator-mediated peer-to-peer systems.

4.5 Publications

A complete list of COBRA publications for 2007 can be found through the COBRA website and at the following link location:
http://w3.ele.tue.nl/en/COBRA/publications/.

5 Prospects

5.1 Three Technology Research Schools (3TOS)

The Inter-University Research Institute for 'Communication Technology: Basic Research and Applications' (COBRA) of the Eindhoven University of Technology, the Delft Institute for Microelectronics and Submicron Technology (DIMES) of Delft University of Technology and the MESA+ Institute for Nanotechnology of the Twente University share educational and research interests. Together, these three technological research schools cover about 90% of their research field in the Netherlands. Being in that position, the three top research institutes collaborate on education and research, specifically aiming at following goals:

- Generation and maintaining a joint educational program, bundling the whole spectrum of the education that is offered to PhD students by the three institutes, amongst others, organizing of summer schools for 3TOS PhD students.
- Jointly strengthening of the technological aspects of the PhD education.
- Aiming at cooperation with other institutes within Europe in the area of research, infrastructure and PhD education.
- Joint generation of new research projects using the combined strengths of the three institutes.
- Jointly generate funds for new hardware/ infrastructure that makes it easier to acquire the most prestigious projects to optimize/improve the public infrastructure.
- Seek and prefer each others partnership in large project proposals.

5.2 Digital Photonics

The current generation of optical chips is based on analogue signal processing, although most signals are digitally coded. Characteristic for analogue signal processing is that the required components are relatively large (hundreds of millimeters) and the signal quality reduces in every step by introducing noise and other disturbing signals. For this reason, the signal needs to be regenerated after going through a number of process steps. We therefore expect that the complexity of analogue optical chips will remain limited to a few hundreds of components per chip. For chips with more complexity, a development similar to the one in micro-electronics is required to switch to digital signal processing. In this case only two signal levels are used and the signal is inherently regenerated after every step.

COBRA aims at the generation of the scientific and technological breakthroughs that are required to open the research field of digital photonics. Digital photonics will play an essential role in future generations communication nodes. These communication nodes should be able to route Internet packets at ever higher speeds and capacity, while consuming at substantially low power levels. Electronics can not handle this task in the future because of limitations in speed and because the circuits are heating up due to increasing power consumption. Our Internet society will be paralyzed when the communication nodes can not be adequately upgraded.

Digital photonics will play an essential role for these future upgrades. In order to open the era of digital photonics a number of scientific and technological breakthroughs have to be realized. Details of these breakthroughs are in the fields of fundamental semiconductor physics, opto-electronic devices and systems. They should lead to the generation of Very Large Scale Integrated (VLSI) photonics integrated circuits and their applications in communication systems. COBRA is in a strong position to be leading in this field since its researchers invented several ultra compact optical elements that have the potential to act as key building blocks for VSLI-Photonics.

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