@NIT

The Nortel Institute for Telecommunications (NIT) is an interdisciplinary, inter-faculty, research institute based in The Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto. NIT provides global university-based leadership in the field of emerging communications technology and focuses on the key areas of research and development, education and training, strategic analysis, and information exchange. The Institute was formed in 1997 through contributions from Nortel Networks, the University of Toronto, the Canada Foundation for Innovation, and the Government of Ontario.

Nortel Institute for Telecommunications at the University of Toronto

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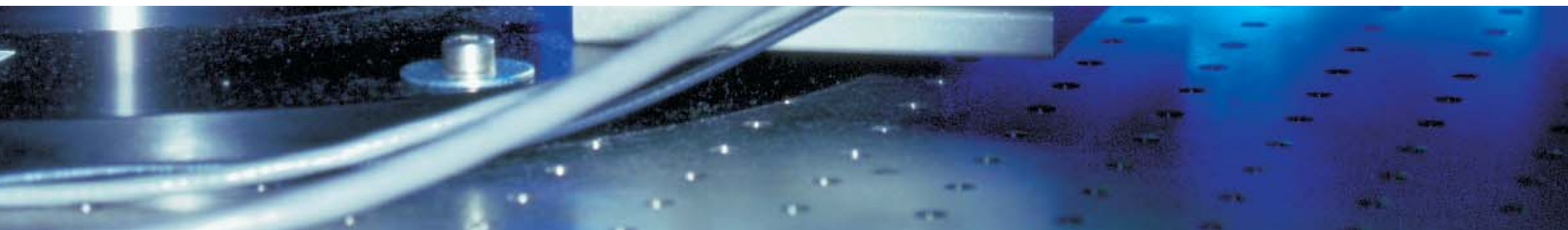


PROFESSOR J. STEWART AITCHISON

Professor J. Stewart Aitchison was appointed Director of the Nortel Institute for Telecommunications (NIT) in 2004. He is Professor and Chair of the Photonics group in The Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto. Professor Aitchison is also the All-Optical Networks Emerging Technology/Device Prototyping thrust leader at NIT.

A Nortel Institute Associate from 2001-2003, Professor Aitchison's research focuses on the related areas of nonlinear optics and optical integration, with the aim of developing novel optical switching, routing, and wavelength conversion components which will enhance the functionality of integrated optical circuits. He is the author or co-author of over 250 refereed journal and conference papers. Professor Aitchison is a Fellow of the Institute of Physics (London), a Fellow of the Optical Society of America, and a senior member of IEEE -LEOS.

Professor Aitchison received a B.Sc., with first-class honours, and a Ph.D. from the Physics Department, Heriot-Watt University, in 1984 and 1987, respectively. From 1988 to 1990, he was a Postdoctoral Member of Technical Staff at Bellcore, Red Bank, New Jersey. He joined the Department of Electronics and Electrical Engineering, University of Glasgow, in 1990 and was promoted to a personal chair as Professor of Photonics in 1999. In 2001, he became the holder of the Nortel Institute Chair in Emerging Technology.

New Director brings renewed leadership and vision to NIT

DIRECTOR'S update

I would like to welcome you to the latest issue of *@NIT* and the first issue since I took over as Director.

Over the last year, the Nortel Institute research board has been involved in the development of a strategic business plan. Our aim is to continue to operate the open research facilities, support interdisciplinary research projects, and provide opportunities for staff and student exchanges. In addition, the Institute is evolving to encompass a wider range of emerging communications technology research.

We have benefited from the recent award of a Canada Foundation for Innovation / Ontario Innovation Trust - Ministry of Economic Development and Trade funded project to work on the "Nanofabrication of Metamaterials". This new funding will allow us to establish a state-of-the-art electron beam lithography system and enhance the infrastructure available in the cleanroom, as well as that in the EM test and measurement laboratories. These additional facilities open up many new and exciting opportunities for researchers. We are also working to make some of the facilities currently located in the microfabrication facility in the Pratt building available to researchers. In addition, we are actively investigating other sources of funding for the Institute which will enable us to continue to maintain and operate the open research labs for the benefit of all researchers.

The Nortel Institute Open Research Facility continues to be used by a growing number of researchers, both from the University of Toronto and from across Canada. In 2004 the facilities were used by a total of 295 undergraduate, graduate, postdoctoral researchers and faculty members.

The Institute continues to support major research thrusts in Advanced Wireless Mobility, Organic and Polymer Optoelectronics, Emerging Technologies, Novel Microwave Technologies and Network Architecture.

"These additional facilities open up many new and exciting opportunities for researchers"

In this issue we are profiling some of the growing number of research projects that are benefiting from the Open Research Facility; you will be able to read about projects which investigate discrete devices, subsystems, and systems. Another key goal of the Institute was to establish and promote new research themes which are related to telecommunications. In this issue we are pleased to highlight a research project between the Faculty of Nursing and Nortel Networks which aims to deliver wireless patient records to the bedside.

Researchers associated with the Institute continue to receive international recognition. Many of the research projects have resulted in invited or plenary presentations at international meetings. I would like to take this opportunity to congratulate the students and faculty who have received such recognition.

The Nortel Institute has also undergone significant administrative staffing changes in recent months, I would like to take this opportunity to welcome two new members of staff to Institute. Rosanne Natale became the new Program Manager in 2004. Prior to joining the Nortel Institute, Rosanne spent five years as the Executive Director of the Science Outreach program, a self-funded unit within the Faculty of Applied Science and Engineering which implements a variety of engineering enrichment programs and reaches over 20,000 youth per year. Rosanne holds a B.Sc. in Chemistry from the University of Toronto and brings experience in the areas of fundraising, budgeting, and project management. Rosanne is a member of the Association of Fundraising Professionals, and sits on the Board of Directors of several community-based organizations.

Crystal Hillis Lumley has been appointed as our new Administrative Assistant. Crystal recently graduated from the University of Toronto at Mississauga (UTM) with her Honours Bachelor of Science. While attending UTM she also worked part-time for the City of Toronto in the West District Parks & Recreation Payroll and Staff Support Department.

Finally, I would like to take this opportunity to thank Professor Peter Smith for his time and commitment as the previous director of the NIT. Professor Smith has been a key factor in the success of the Nortel Institute.

I hope you enjoy this copy of our newsletter and we would welcome any feedback or comments.

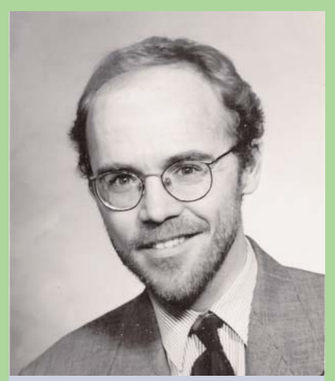
J. STEWART AITCHISON

Laboratory and Optical Experiment, Z-scan and DFWM nonlinear experiments, OPOL, courtesy of the Ultrafast Photonics Lab at the University of Toronto

NORTEL INSTITUTE
Research Chairs

The Nortel Institute Chair in Network Architecture and Services vacated by thrust leader Professor Alberto Leon-Garcia has been filled by Professor Jorg Liebeherr of the University of Virginia. Professor Liebeherr's research interests include service guarantees, peer-to-peer networks, multiple access, and traffic engineering. These areas concern issues such as dissemination of data from multiple receivers, protocols in local area networks to access a shared broadcast channel, and control algorithms to balance the resource load in a network. Professor Liebeherr will assume his position at The Edward S. Rogers Sr. Department of Electrical and Computer Engineering on July 1, 2005.

The Chair in Emerging Technology continues to be held by Professor J. Stewart Aitchison of The Edward S. Rogers Sr. Department of Electrical and Computer Engineering.



Professor Jorg Liebeherr

Other Chairs associated with the Nortel Institute for Telecommunications include the Junior Chair in Software Engineering, currently held by Professor Baochun Li, and the Chair in Communications Networks, held by Professor Shahrokh Valaeee. Both professors belong to The Edward S. Rogers Sr. Department of Electrical and Computer Engineering.

SCHOLARSHIPS:
Enhancing the Student Experience

The establishment of the Nortel Institute for Telecommunications (NIT) resulted in a permanent endowed scholarship in support of undergraduate students at the University of Toronto. Contributions from Nortel Networks, the Government of Ontario, and the University of Toronto will ensure that one award per year with a projected value of approximately $5000 is given to an outstanding student in accordance with the University's policy on student awards. Engineering Science student Kun Wang received the 2004 Nortel Institute Undergraduate Scholarship on December 6, 2004.

A similar scholarship was created for graduate students in the Masters of Engineering in Telecommunications (MET) program. Valued at approximately $13,000, scholarships were awarded to MET students ManLi Mary Zhao and Guofeng Tyrone Qi in 2004.

NIT has also supported a scholarship program in the Department of Physics that provides scholarships to undergraduate and graduate students interested in optical sciences.

ABOVE: From left to right: Prof. J. Stewart Aitchison (Director, NIT), Kun Wang (NIT Scholarship Winner 2004), Cathy Malcolm (Strategic External Research – Nortel Networks), and Sean Ingram (Admissions & Awards)

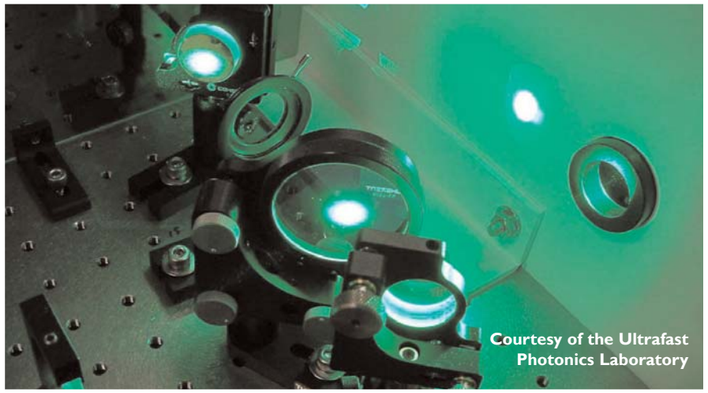
NIT RESEARCHERS'
Honours and Awards

PROFESSOR J. STEWART AITCHISON was elected a fellow of the Optical Society of America in 2005 for his contributions to "Optical Spatial Solitons and Nonlinear Integrated Optics".

PROFESSOR GEORGE V. ELEFTHERIADES, Advanced Wireless/Mobility thrust leader at the Nortel Institute for Telecommunications (NIT), is one of six recipients of a 2004 Natural Sciences and Engineering Research Council of Canada (NSERC) Steacie Fellowship for his research on "left-handed" metamaterials. Steacie Fellowships are awarded to enhance the career development of outstanding and highly promising scientists and engineers who are faculty members of Canadian universities, and who have demonstrated a significant capacity for original research though still in the early stages of their careers.

Professor Eleftheriades' paper, co-authored with A.K. Iyer and P.C. Kremer, entitled "Planar negative refractive index media using periodically L-C loaded transmission lines" was designated by the Institute of Scientific Information as a "Hot Paper" meaning that it was one of the most cited papers in the field of Engineering for January-March 2004.

Professor Eleftheriades' research was highlighted in the December 19, 2003 edition of *Science*, which featured "left-handed" metamaterials as one of the top 10 breakthroughs of the year in 2003.



Courtesy of the Ultrafast Photonics Laboratory

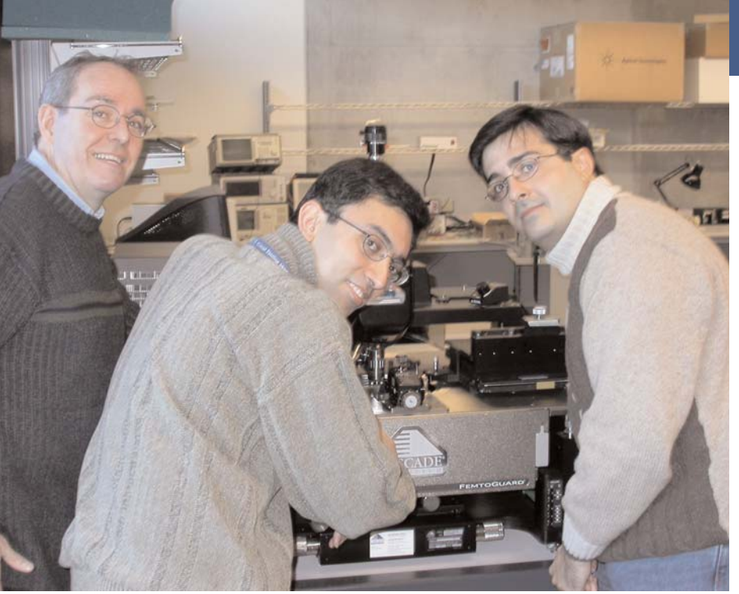
DR. LUKASZ BRZOZOWSKI, who completed his Ph.D. using NIT facilities in October 2003 under the supervision of Professor Edward (Ted) H. Sargent, won the 2004 Governor General's Gold Medal for his doctoral work. Dr. Brzozowski devised the theory, and carried out the pioneering experiments, to define a new area at the confluence of nanotechnology and photonics. The devices, which Dr. Brzozowski built and patented, resulted in 14 journal publications and enable information borne over light to be controlled, manipulated, and corrected. Dr. Brzozowski's research has helped to bring the control and robustness of the domain of electronic computing into the world of light.

PROFESSOR TED SARGENT, NIT thrust leader for Organic and Polymer Photonic Materials and Devices, is taking his sabbatical as Visiting Professor, Massachusetts Institute of Technology during the 2004-2005 academic year. His work will include MIT-Toronto collaborative research.

Professor Sargent was also named one of "Canada's Top 40 Under 40" for 2003-2004. This national program, founded and managed by The Caldwell Partners, honours Canadians who have reached a significant level of success before the age of 40.

Professor Sargent was recognized by the highly respected *Technology Review* magazine as one of the top 100 innovators under the age of 35 in October 2003. *Technology Review* recognizes researchers engaging in cutting-edge research in their fields, with focus on areas such as computing, biotech and medicine, the Internet, and nanotechnology.

Congratulations to these NIT researchers for their outstanding achievements!



From left to right:
Professor Ken Martin (supervisor),

Mohammad Hajirostam (Ph.D. candidate),

Afshin Haftbaradaran (Ph.D. candidate)

CMOS

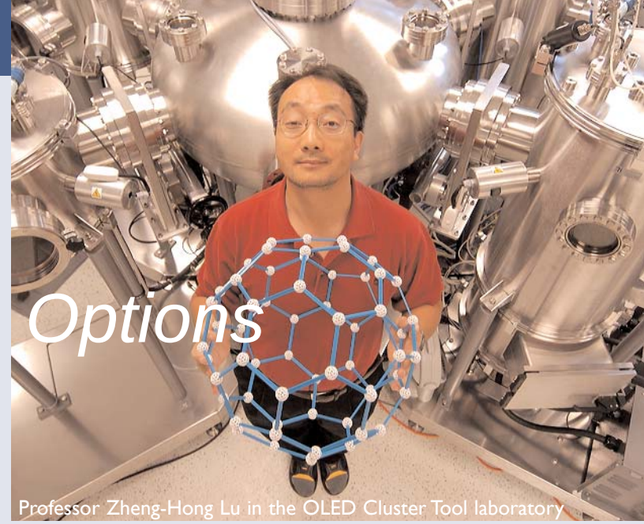
on-chip broadband tuner design for CATV and cable modem

Ph.D. candidate Mohammad Hajirostam and Professor Ken Martin of The Edward S. Rogers Sr. Department of Electrical and Computer Engineering are using the Nortel Institute for Telecommunications (NIT) Open Research Facility to design and implement a complementary metal oxide semiconductor (CMOS) on-chip tuner for cable TV (CATV) and cable modems. TV and cable modem receivers are large power-consuming blocks. Even the most recent double-conversion tuner requires two off-chip surface acoustic wave (SAW) filters for signal selection and image rejection. To prevent using these high-Q, high-frequency off-chip components, a double-conversion low-intermediate-frequency (low-IF) architecture has been adopted to implement the tuner. In this architecture, an analog-digital image-rejection technique improves the image-rejection performance of the receiver. An area and power-efficient infinite-impulse-response (IIR) filter is also used for signal selection. This filter combines, pulse-shaping, signal selection, and decimation in one block. As a result, there is no need to use any off-chip filter in the receiver, and a completely on-chip implementation becomes possible.

The team has used the NIT Open Research Facility to test the RF front-end of the receiver. As one of the most important parts of the receiver, a mixer was fabricated in a CMOSP18 technology. The main goals were to measure the gain, noise, and linearity of the mixer, and investigate the noise-linearity trade-offs. All the equipment required for the measurement was available in the NIT Open Research Facility, including power supplies, bias-Ts, power splitters and combiners, coaxial cables, and related connectors used to set up the testing fixture.

Signal generators and spectrum analyzers were used to measure the gain and linearity of the mixer, while a noise source along with a noise figure meter were used to measure the noise performance of the mixer. These measurements helped the team to gain a better understanding of the noise and linearity performance of a typical mixer, especially in higher frequencies. The results will assist in designing the additional blocks of the receiver. For more information on this project, contact Mohammad Hajirostam at mohammad@eecg.toronto.edu. ■

NEW technology provides *FLEXIBLE* Options



Professor Zheng-Hong Lu in the OLED Cluster Tool laboratory

Nortel Institute for Telecommunications (NIT) researchers have produced the first flexible organic light-emitting devices (FOLEDs) in Canada. This major research breakthrough was led by Professor Zheng-Hong Lu, Department of Materials Science and Engineering, Faculty of Applied Science and Engineering, and his research team. FOLEDs are organic light-emitting diodes (OLEDs) fabricated on flexible substrates, whereas traditional flat panel displays, such as LCDs, are fabricated on glass substrates. To truly understand this discovery, picture yourself reading an electronic newspaper or communicating with your family by unrolling a large-screen display. When you are finished, you will roll it back up to the size of a pen and place it safely in your pocket. This is the just one remarkable implication of the FOLED innovation.

These flexible materials have significant performance advantages over traditional glass substrates. FOLEDs clearly offer revolutionary features such as flexibility, low weight, and lower production costs. They can be made on a wide variety of substrates from transparent plastic films to reflective metal foils, providing the ability to conform, bend, or roll a display into any shape. The use of thin plastic substrates also significantly reduces the weight of flat panel display such as those in cell-phones, portable computers, and large-area televisions. Furthermore, they are more robust in terms of transportation and installation compared to their glass-based counterparts.

The key to making efficient and robust OLEDs is the engineering of interfaces between organic molecules and inorganic metal electrodes. Organic light-emitting diodes are current-driven devices, and any electrical resistance at interfaces will produce heat under current flow. Most organic molecules are very fragile, and thus failure at the interfaces dominates the OLED performance and lifetime. Producing resistance-free, metal-molecule interfaces, known as Ohmic contact, is the foundation of any molecular device. Professor Lu's group has discovered a unique combination which renders the metal-molecule interface Ohmic, and has taken the OLED's performance to the next level. For example, they discovered that with proprietary interface structures the OLEDs can be driven to their extreme (10A/cm2) to yield super bright light (over 70,000 cd/m2) using ordinary light-emitting molecules.

Today superluminescent OLEDs (SOLEDs) can be produced for applications such as flat-panel displays, organic-silicon heterojunction chips for telecommunication, solid-state illumination, specialty biomedical lighting, architectural lighting, entertainment and decorative lighting, vehicles, mobile appliances, and LCD backlighting. The commercialization of this new discovery is well underway, through partnership with the University of Toronto Innovations Foundation and Norel Optronics, a recently formed University of Toronto spin-off company.

For more information, contact Professor Zheng-Hong Lu at zhenghong.lu@utoronto.ca. ■

DISTINGUISHED LECTURE SERIES

The Nortel Institute welcomes leading researchers to the University of Toronto as part of the NIT Distinguished Lecture Series. Recent and upcoming Distinguished Lectures hosted by the Nortel Institute include:

Recent Advances in Fibre-Optic Parametric Amplifiers
Govind Agrawal, Professor, The Institute of Optics, University of Rochester

The Perfect Lens: Resolution Beyond the Limits of Wavelength
Sir John B. Pendry, FRS, Professor, Imperial College London

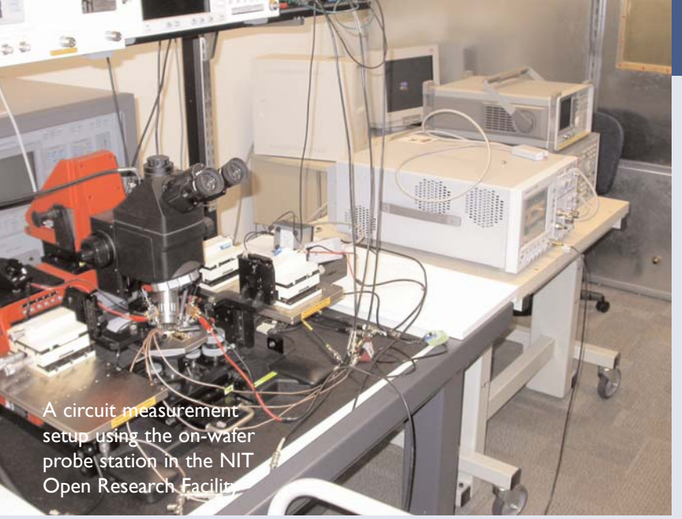
Transmitters for Wireless Communication
Dave Rutledge, Professor, Caltech, Pasadena, California

Nonlinear Optical Spectroscopy
Eric W. Van Stryland, Professor of Optics and Director, School of Optics/CREOL
University of Central Florida, Orlando, Florida

For detailed information about the content of these lectures, visit the NIT website at www.nit.utoronto.ca.

NIT OPEN RESEARCH FACILITY OPEN HOUSE

The 2004 NIT Open Research Facility (ORF) Open House was held on September 14, 2004 with over seventy-five researchers in attendance. This event provided researchers from within the University of Toronto and the University Health Network an opportunity to visit the facilities, tour the labs, and receive an overview about the current and future status of the NIT Open Research Facility from NIT Director, Professor J. Stewart Aitchison. Research posters were also presented by ORF users. The Open House is an annual event; if you are interested in attending the open house in 2005, please contact the Nortel Institute at nortel.institute@utoronto.ca.



A circuit measurement setup using the on-wafer probe station in the NIT Open Research Facility

"…equalizers capable of compensating for the frequency-dependent losses…"

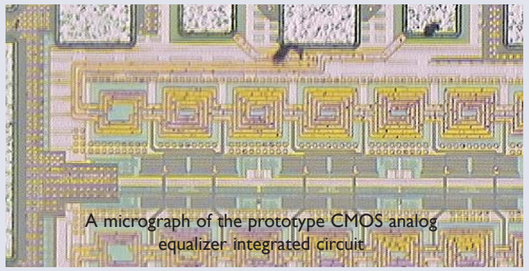
new chip aims at improving transmission speed

▶ HIGH-SPEED

Integrated Transceivers

Research to extend the rate, range, and robustness of multi-Gb/s optical and electrical communication is underway at the Nortel Institute for Telecommunications (NIT) Open Research Facility (ORF) RF & Microwave Testing Lab. Professor Tony Chan Carusone of The Edward S. Rogers Sr. Department of Electrical and Computer Engineering and his Integrated Systems group are currently using the ORF to characterize integrated circuit transceivers fabricated in silicon technologies. The high frequencies, and extremely broad bandwidth (0-50GHz) required for these applications, makes testing a key challenge in this field. Wafer probing is generally used to eliminate the need for device packaging, and network analyzers measure the devices' frequency response.

Professor Chan Carusone's group has demonstrated equalizers capable of compensating for the frequency-dependent losses in optical and electronic links up to 40GHz. These equalizers have applications in optical fibre and chip-to-chip communication over printed circuit boards. Using a combination of novel circuits and architectures, they are the first equalizers to be demonstrated at these frequencies fabricated using inexpensive complementary metal oxide semiconductor (CMOS) technology. The results of this work will be presented at the June 2005 Symposium on VLSI Circuits in Kyoto, Japan. For more information about this research, contact Professor Chan Carusone at tcc@eecg.utoronto.ca. ■



A micrograph of the prototype CMOS analog equalizer integrated circuit

NIT: Breaking Down the Barriers to Interdisciplinary Research

Central to the mission of the Nortel Institute is the promotion and conduct of intensely collaborative research. NIT research concentrates on areas chosen for their strategic value to the Canadian economy, their interrelatedness and common equipment requirements, the world-class expertise in these areas within the Institute and the University, and their potential for growth and future economic impact. Recently NIT helped foster a collaborative research project between Professor Diane Doran of the Faculty of Nursing and Nortel Networks.

OUTCOMES in the Palm of Your Hand

In an increasingly competitive health care environment, it is essential that health care professionals and hospitals be able to document the outcomes of care, to improve quality and patient safety based on relevant data, and to communicate their extensive recording of information in a standardized way.

Nortel Networks is collaborating with Communications and Information Technology Ontario to advance this ability by supporting a recently-initiated project, "Outcomes In the Palm of Your Hand." Additional funding for the project has been provided by the Ontario Ministry of Health and Long-Term Care, and has been complemented by in-kind support from participating organizations. Funding from the Canadian Health Services Research Foundation is enabling the inclusion of agencies that provide nursing services in clients' homes.

The project will evaluate the usability of personal digital assistants (PDAs) by nurses to collect, utilize, and communicate health information, and the feasibility of using PDAs to increase nurses' access to and utilization of best-practice information electronically. In the past the patient data have been collected, in tedious fashion, using pen and paper. This project will enable nurses to record information electronically, directly at the point of care, eliminating the need to recopy or to provide remote entry of their data. In addition to the data recording component, to help guide their care nurses will be able, at the bedside, to electronically access valuable care-related information such as core practice elements from the Nursing Best Practice Guidelines prepared by the Registered Nurses Association of Ontario.

In the initial stages of the project, nurses at two Toronto hospitals and at two community agencies contributed ideas and recommendations for the design of a Prototype System, based on their preferences for resources they would like to have in their hands, right at the point of care, and information that they would like to be able to enter electronically at the bedside. The Prototype System will be tested in a laboratory setting, using standardized patient scenarios with 'stand-ins' instead of real patients, to address issues related to the usability of the PDAs and the quality of data collected. This will be followed by field testing the Prototype System with patients in clinical settings.

The study is co-led by Dr. Diane Doran, Interim Dean of the Faculty of Nursing, and Dr. John Mylopoulos, Bell University Laboratories Chair in Information Systems, Department of Computer Science, University of Toronto. This is a landmark study that could impressively impact health care throughout Ontario and beyond. It has the potential to transform nursing practice extensively in exciting, progressive, and tangible ways. For additional information, please contact Jennifer Carryer, Research Project Manager by e-mail at doran.research@utoronto.ca. ■

MAJOR CFI AWARD TO NIT RESEARCHERS

NIT thrust leaders, J. Stewart Aitchison and George Eleftheriades, along with Professors Peter Herman, Mohammad Mojahedi (The Edward S. Rogers Sr. Department of Electrical and Computer Engineering), and Henry VanDriel (Department of Physics), have been awarded a $4.6 million grant from the Canada Foundation for Innovation (CFI) for their research on the "Nanofabrication of Metamaterials". Matching funds of $4.6 million from the Ontario Innovation Trust/Ministry of Economic Development and Trade, along with $2.5 million in contributions from industrial collaborators, result in an overall project budget of $11.6 million.

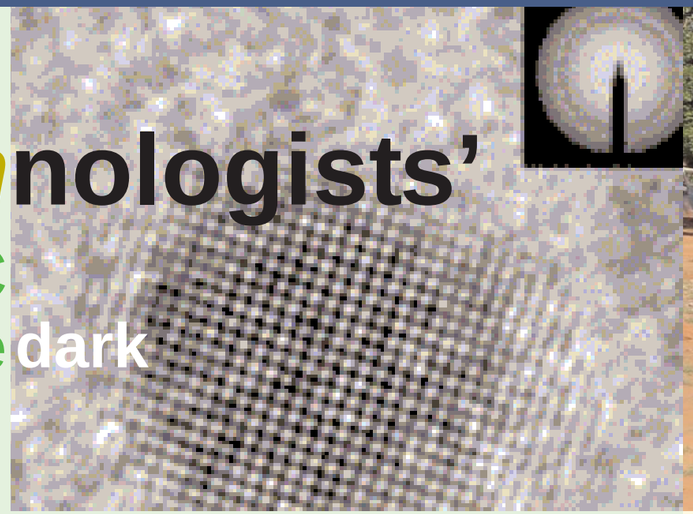
The engineering of highly structured composite materials into electronic, microwave, or optical circuits promises new electromagnetic responses that are counterintuitive, or unknown to exist in ordinary materials. These metamaterials can revolutionize the present state of technology, promising many developments, including:

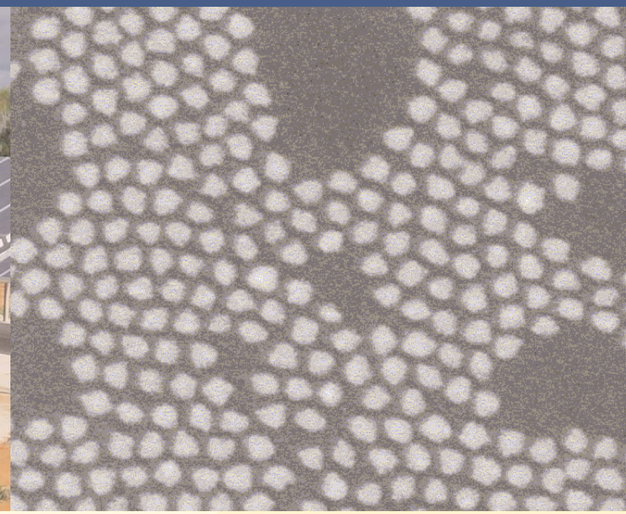
- media with negative indexes of refraction that reverse the refractive properties of conventional materials
- "super-lenses" that focus light to dimensions smaller than a wavelength
- optoelectronic devices with abnormal velocities
- optical materials with uncharacteristically strong magnetic responses to control and manipulate light

The infrastructure obtained with these funds will provide the team with the nanofabrication tools necessary for innovative research, ensuring Canadian global leadership in this new research field. The equipment will make possible first observations of basic phenomena, and is especially significant in targeting the unexplored frontiers of the microwave, infrared, and visible frequency regions. The tools also make possible the nanoprecision controls that will underpin a strong technical development program to exploit novel metamaterial properties in devices and systems. This practical demonstration will significantly enhance the competitiveness of Canada's high-tech industry through new partnerships.

The Canada Foundation for Innovation is an independent corporation created by the Government of Canada to fund research infrastructure. The CFI's mandate is to strengthen the capacity of Canadian universities, colleges, research hospitals, and non-profit research institutions to carry out world-class research and technology development that benefits Canadians.

*nanotech*nologists' NEW PLASTIC can see in the dark





BY SONNET L'ABBÉ

Infrared-sensitive material could lead to better use of solar spectrum

Imagine a home with "smart" walls responsive to the environment in the room, a digital camera sensitive enough to work in the dark, or clothing with the capacity to turn the sun's power into electrical energy. Researchers at University of Toronto have invented an infrared-sensitive material that could shortly turn these possibilities into realities.

In a paper published on the *Nature Materials* website in February 2005, NIT thrust leader Professor Ted Sargent, Nortel Networks - Canada Research Chair in Emerging Technologies at U of T's Edward S. Rogers Sr. Department of Electrical and Computer Engineering, and his team report on their achievement in tailoring matter to harvest the sun's invisible rays. "We made particles from semiconductor crystals which were exactly two, three or four nanometres in size. The nanoparticles were so small they remained dispersed in everyday solvents just like the particles in paint," explains Sargent. Then, they tuned the tiny nanocrystals to catch light at very long wavelengths. The result - a sprayable infrared detector.

Existing technology has given us solution-processible, light-sensitive materials that have made large, low-cost solar cells, displays, and sensors possible, but these materials have so far only worked in the visible light spectrum, says Sargent. "These same functions are needed in the infrared for many imaging applications in the medical field and for fiber optic communications," he said.

The discovery may also help in the quest for renewable energy sources. Flexible, roller-processed solar cells have the potential to harness the sun's power, but efficiency, flexibility and cost are going to determine how that potential becomes practice, says Josh Wolfe, Managing Partner and nanotechnology venture capital investor at Lux Capital in Manhattan. Wolfe, who was not part of the research team, says the findings in the paper are significant: "These flexible photovoltaics could harness half of the sun's spectrum not previously accessed."

Professor Peter Peumans of Stanford University, who has reviewed the U of T team's research, also acknowledges the groundbreaking nature of the work. "Our calculations show that, with further improvements in efficiency, combining infrared and visible photovoltaics could allow up to 30 per cent of the sun's radiant energy to be harnessed, compared to six per cent in today's best plastic solar cells."

U of T electrical and computer engineering graduate student Steve MacDonald carried out many of the experiments that produced the world's first solution-processed photovoltaic in the infrared. "The key was finding the right molecules to wrap around our nanoparticles," he explains. "Too long and the particles couldn't deliver their electrical energy to our circuit; too short, and they clumped up, losing their nanoscale properties. It turned out that one nanometer - eight carbon atoms strung together in a chain - was 'just right'."

Other members of the U of T research team are Gerasimos Konstantatos, Shiguo Zhang, Paul W. Cyr, Ethan J.D. Klem, and Larissa Lavina of The Edward S. Rogers Sr. Department of Electrical and Computer Engineering; Cyr is also with the Department of Chemistry. The research was supported in part by the Government of Ontario through Materials and Manufacturing Ontario, a division of the Ontario Centres of Excellence; the Natural Sciences and Engineering Research Council of Canada through its Collaborative Research and Development Program; Nortel Networks; the Canada Foundation for Innovation; the Ontario Innovation Trust; the Canada Research Chairs Programme; and the Ontario Graduate Scholarship. For more information about this research, contact Professor Ted Sargent at ted.sargent@utoronto.ca. ■

Top left: A nanometer-resolved microscope image of a nanoparticle, or quantum dots, similar to that used to make the infrared detectors. The particle is six nanometers - billionths of a meter - in diameter. Individual columns of bonded lead and sulfur atoms are resolved in the image. Such nanoparticles were suspended in a solvent and dried like paint to make a large-area device. Image courtesy of M. A. Hines & G. D. Scholes, Advanced Materials (2003) 15, 1845.

Middle: Coniston solar panels (Image: Northern Territory - Government of Australia).

Top right: PbS quantum dots self-organized on a carbon grid. G. Konstantatos, S. McDonald, L. Levina, E. H. Sargent, unpublished 2004

Below: Optical parametric amplifier (TOPAS), pumped by a TI-Sapphire regenerative and multi-pass chirped pulse amplifier (TITAN), OPOL Laboratory

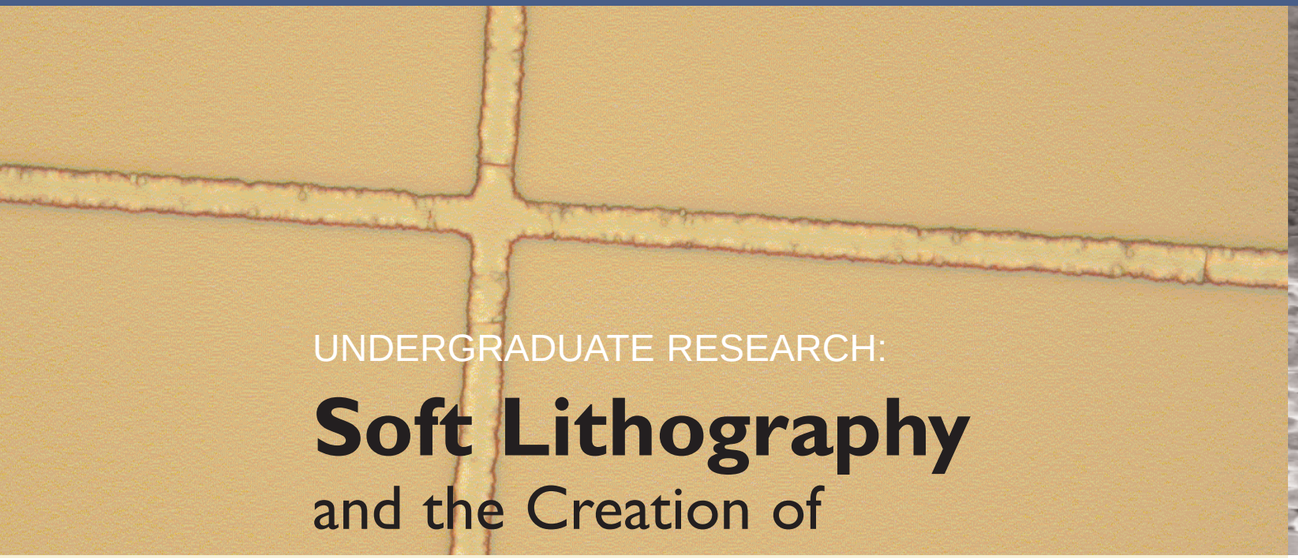
ONTARIO RESEARCH AND DEVELOPMENT CHALLENGE FUND-OPOL PROJECT

The Government of Ontario through the Ontario Research and Development Challenge Fund (ORDCF) has provided in excess of $10 million in funding for the Nortel Institute for Telecommunications (NIT) and the related *Research in Organic and Polymer Optoelectronics: Materials and Devices for a New Paradigm in Telecommunications and Information Technology (OPOL)* project.

Key researchers involved in this interdepartmental, inter-university project include Professor Zheng-Hong Lu, Department of Materials Science and Engineering, University of Toronto; Professor Ian Manners, Department of Chemistry, University of Toronto; Professors Ted Sargent and Peter Smith, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, University of Toronto; and Professor Wayne Wang, Department of Chemistry, Carleton University. These researchers explored a new and emerging class of materials and devices based on thin films composed of small organic molecules and conjugated polymers. These materials have the flexibility and robustness of plastics, but can be used to process information in electronic form to generate light, sense heat and pressure, and act on information. The project has been highly successful, fulfilling all the mandated tasks and associated milestones for innovative research in this area.

Funding for the $3.126 million OPOL project came to an end in December 2004, and the University of Toronto laser characterization laboratory that was established as a result of this project has proven to be a major asset to NIT research programs - and to the University in general. It has been in constant use since its establishment and has provided the key equipment resources for a substantial number of thesis research projects. The facilities have been used by large numbers of graduate and undergraduate students, post-doctoral fellows, and professors.

The OPOL project has delivered significant research results. Most recently, the associated researchers have developed functional organic composite materials for information processing, transmission, and display including C60 buckyball molecules linked to form a polymer network. They have also developed a process for integrated device structures for telecommunication based on highly simplified, scalable thin-film processing. The highly successful OPOL project resulted in 16 patents, 225 publications in refereed journals, and a variety of international collaborations.



UNDERGRADUATE RESEARCH:

Soft Lithography and the Creation of Integrated Waveguide Devices

Integrated sensor chips have potential applications in environmental sensing, drug discovery, and medical diagnosis

Fourth-Year Engineering Science student Ronnie Linklater is currently working under the supervision of Professor Stewart Aitchison, attempting to produce an integrated lab-on-a-chip type device with direct optical fibre attachments. The devices are constructed from a soft polymer, poly(dimethylsiloxane) (PDMS), that has imbedded microfluidic channels which cross optical waveguides.

In order to create these devices, Mr. Linklater is using the NIT cleanroom to investigate a soft lithography process, which allows for quick replication of pre-made molds. Molds are formed by photolithography of a thin photoresist spun on glass. Liquid pre-polymer is then cast over the mold and polymerized at high temperature. Following curing the PDMS replica is then peeled from the mold and bonded to a second layer of PDMS, thereby enclosing the channels and waveguides. Early characterization of these waveguides indicates a loss of approximately 2-4dB/cm. Such integrated sensor chips have potential applications in environmental sensing, drug discovery, and medical diagnosis. For more information about this research, contact Professor J. Stewart Aitchison at stewart.aitchison@utoronto.ca. ■

ABOVE:
Mold made of SU-8 (5) on glass

FIG 1: linear air-cavities embedded inside the opal after selective removal of the photoresist

FIG 2: lines of photoresist buried by a second deposition of additonal 520 nm spheres

FIG 3: SEM image of an array of 5um lines of photoresitst on the surface of a 510nm silica opal at 10k magnification

FIG 4: 5 mm wide line of photoresist on the surface of a 520 nm silica opal

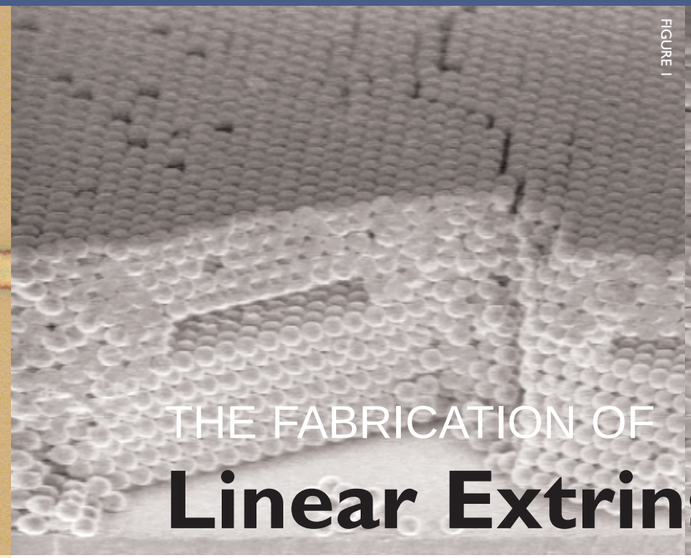


FIGURE 1

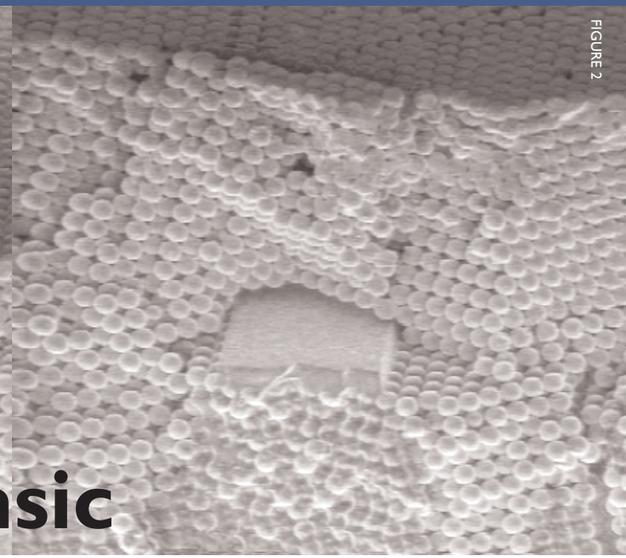


FIGURE 2

THE FABRICATION OF

Linear Extrinsic Defects in Opals

The NIT is helping to support inter-disciplinary research involving the Department of Chemistry, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering and the Department of Materials Science and Engineering, which examines colloidal crystals or opals. These crystals offer a straight-forward and inexpensive route to the fabrication of 3-D photonic bandgap materials. However, many potential applications of these photonic crystals require the creation of a well defined defect state. A simple method to fabricate linear extrinsic defects in opals combining photolithography and colloidal self-assembly has been developed by Ph.D. candidate Envangellos Vekris. A temporary pattern of photoresist is printed onto the surface of a silica opal by contact photolithography. A second layer of opal is then deposited to completely encapsulate the pattern with spheres. Lastly, the photoresist pattern is removed by exposure to an oxygen plasma to create an array of buried linear cavities embedded inside the opal. The resulting film is thermally robust and can be infiltrated with a material of high-refractive index (e.g. Si) to create an inverse opal having a full photonic band gap and containing embedded linear defects.

For more information about this research, contact Van at evekris@chem.utoronto.ca or Professor Geoff Ozin at gozin@chem.utoronto.ca. ■

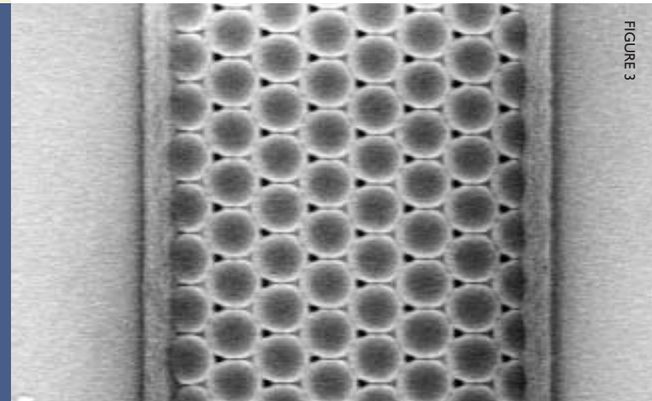


FIGURE 3

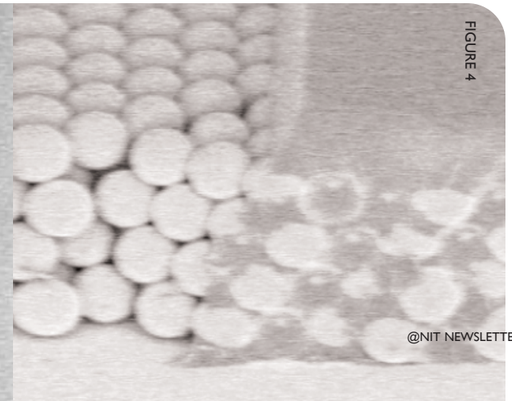


FIGURE 4

Open Research Facility
CONTACTS

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RF & Microwave, Antenna Test, and Micromachine Etching Labs:
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nortel institute

The Nortel Institute for Telecommunications (NIT) Open Research Facility (ORF) is a multi-disciplinary, hands-on research environment offering valuable research opportunities and educational experiences. The 1,100-square-metre facility houses state-of-the-art equipment in 10 laboratories, and contains Network Architecture, RF & Microwave, Antenna Test, Device Prototyping and Fabrication, and Characterization labs.

OPEN RESEARCH FACILITY

The ORF accommodates projects from scientists in a wide range of areas, with particular focus on information technology and telecommunications research and training. Four buildings across the University of Toronto campus house the facility, which was established by various grants from the Canada Foundation for Innovation, the Ontario Innovation Trust, the Ontario Research and Development Challenge Fund, and Nortel Networks. Altogether 295 researchers including faculty members, academic and industrial collaborators, post-doctoral fellows, and students actively used the NIT Open Research Facility in 2004.

ORF labs are not dedicated or restricted to any particular research group. Professional staff maintain instruments, instruct and assist users, and run analyses as required.

Service Creation Network Architecture Lab

Composed of two main labs, this facility is designed for research on the infrastructure for Next Generation Networks (NGN) and different levels of the Open System Interconnection (OSI) model. These labs are outfitted with equipment needed to investigate novel network-based applications and services, network architecture design, management and performance, heterogeneous networking, novel network elements, and network protocols and algorithms.

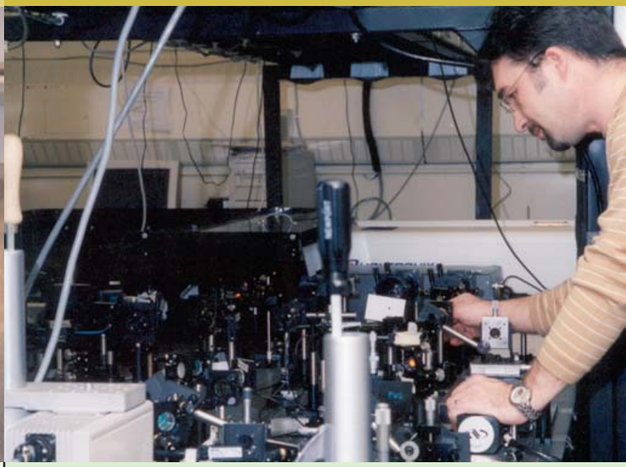
Equipment highlights:
- IP-based and TDM Systems
- Advanced Router-Tester and Traffic-Generator
- 56 IBM Blade-Servers
- Linux Server with 2.8GB Xeon Processor and 2GB RAM
- 32 Giga-Ethernet Ports
- 40 Linux Desktops
- Multimedia Rack

RF & Microwave Testing Lab

RF & Microwave Testing Lab: This state-of-the-art facility houses a complete set of RF, microwave, and millimetre-wave sources, spectrum and vector network analyzers, as well as a load-pull characterization facility. The testing lab enables coaxial as well as on-wafer probing and testing of devices and circuits.

Equipment highlights:
- Spectrum analysis up to 50GHz
- Temperature Chamber, -95°C to 15°C
- Materials impedance analysis up to 1.8GHz
- High resistance metre to measure DC characteristics of materials
- Kulicke & Soffa Wedge Bonder

Characterization Labs



The photonic characterization laboratory is based on a tunable high-power, ultra short-pulse laser system that can be used to characterize novel nonlinear optical materials and devices over a wide range of wavelengths and power levels. The labs are also equipped for characterization of the optoelectronic properties of new materials and devices. During the past year, the portfolio of available experimental techniques in the lab expanded significantly to include Variable Stripe Length (VSL) and Shifting Excitation Spot (SES) experiments for studying amplified spontaneous, emission, and waveguiding properties in nanocrystal-based thin films.

Equipment highlights:
- Semiconductor Parameter Analyzer
- Scan Spectrophotometer
- Titanium Sapphire Amplifier System
- Minilite II Pulsed Q-Switched ND:YAG Laser
- Spectroscopic Ellipsometer

nortel institute OPEN RESEARCH FACILITY

The flexible nature of the ORF, its equipment, staff, and open structure, make it ideal for prototype development and testing. The facilities are open to both academic and industrial researchers.

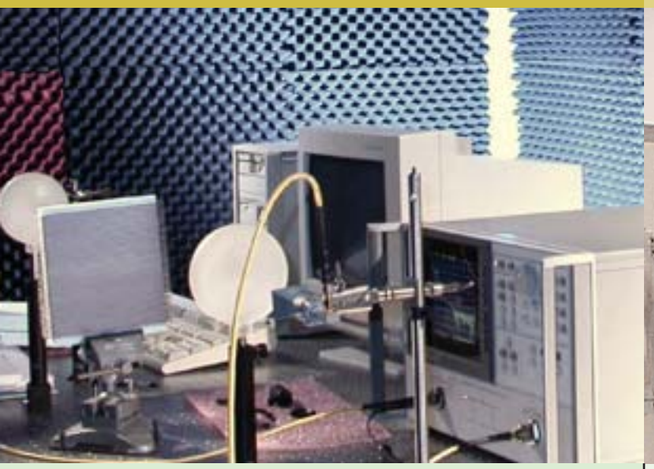
NIT encourages researchers to discuss potential research collaborations and partnerships with the appropriate NIT research thrust leader. Proposals to utilize the facility are evaluated on a case-by-case basis and reviewed to ensure high scientific standards are maintained, with priority given to academic researchers.

The facility's current funding structure partially supports the lab infrastructure, equipment, and limited staff resources.

Research projects in the facility are supported by industry and government agencies through the normal research granting mechanisms.

For more information about capabilities and accessing the Open Research Facility, please contact the appropriate lab manager.

Antenna Test Labs



These labs consist of two separate anechoic chambers fully shielded against electromagnetic interference and lined with millimetre-wave absorbers. The millimetre-wave range enables swept-frequency measurements of amplitude as well as absolute antenna gains at millimetre-wave frequencies from 50GHz to 100GHz. The associated anechoic chamber is available for analyses at lower microwave frequencies from 1GHz to 40GHz and in the millimetre-wave frequency range 34GHz to 75GHz.

Equipment highlights:
- Karl Suss Probing Station
- Focus Load-pull System up to 40GHz
- Circuit characterization open laboratory: vector network analyzers
- Vector measurement from 45MHz-94GHz in a single sweep
- Noise figure and phase noise measurement up to 26.5GHz
- Load-pull capability from 800MHz-18GHz with 2nd and 3rd harmonic tuning
- Differential TDR with 20ps risetime
- 50GHz bandwidth sampling scope
- 10Gb/s pattern generation

Device Prototyping and Fabrication

These labs allow for the design, fabrication, and testing of a range of functional integrated components.

Micromachine Etching: This lab enables the fabrication of etched microwave circuits for printed antennas, metamaterials, and microstrip circuits, as well as for micromachining of bulk silicon devices.

Equipment highlights:
- Photoresist Spinner and Dipper
- UV Exposure System
- Glass Bead Etcher
- Spray Etcher
- Micro Drill Press
- Bulk silicon micromachining capability

Cluster Tools: The Open Research Facility houses Canada's first organic light-emitting diode (OLED) cluster tools for molecular thin films and optoelectronics device prototyping. The OLED cluster tool includes a load-locked linked set of vacuum chambers for cleaning, sputter deposition, and metallization.

Equipment highlights:
- OLED Chambers
- Automated Semiconductor Measurement System

Clean Rooms: These labs provide two large areas in which to fabricate devices in silicon, compound semiconductors, ceramic, glass, and polymer. Resources include a Class 1000 photolithography/wet chemistry clean room including two fully exhausted acid wet benches and a Class 10000 clean room housing deposition and etching machines.

Equipment highlights:
- SUSS MA6 front and backside Mask Aligner
- Photoresist Patterning Machinery
- 2 ICP/RIE Etching Systems
- e-beam Evaporator
- Surface Profilometer
- Deposition and Sputtering System
- Inspection Microscope

FUTURE PLANS *for the* Open Research Facility

New funding from the Canada Foundation for Innovation and the Ontario Innovation Trust/ Ministry of Economic Development and Trade will provide infrastructure support enabling the further enhancement of the Open Research Facility. An additional Plasma Enhanced Chemical Vapour Deposition (PECVD) system will be installed in the NIT clean room. This machine will allow for the production of silica and silicon nitride layers with waveguide quality.

An e-beam lithography facility will also be established. This facility will enable the writing of features down to 12 nm and offers the optimized combination of writing speed, feature size, stitching error, and field size. The system is expected to be in place in approximately 18 months. The establishment of an e-beam facility together the existing clean room infrastructure will result in a state-of-the-art fabrication facility which will benefit researchers from a broad range of fields.

In the Characterization Lab, the installation of a Difference Frequency Generation (DFG) unit in conjunction with the Optical Parametric Amplifier (TOPAS) will be completed as of Summer 2005. This tool will facilitate a suite of experiments in the mid-IR wavelength range.

e-beam lithography system

Additional processes and equipment that will become available within the next 24 months include Low Pressure Chemical Vapour Deposition (LPCVD), Reactive Ion Etching, Oxidation and Diffusion furnaces, and a Rapid Thermal Annealer. For more information, contact Professor J. Stewart Aitchison at stewart.aitchison@utoronto.ca.

Information Exchange & Strategic Analysis

The Nortel Institute for Telecommunications (NIT) hosted several information exchange and strategic analysis events over the past year. Detailed information about these events can be found at www.nit.utoronto.ca.

University of Tokyo-University of Toronto Exchange: Canadian and Japanese experts from academia and industry met at the University of Toronto to discuss the theme of "Emerging Complex Materials Systems for Telecommunication and Nanotechnology." This workshop fostered discussion and further collaboration among graduate students and research groups from the two universities in the rapidly evolving field of emerging materials and systems. The workshop involved several units from across the Faculty of Applied Science and Engineering, including the hosting Department of Materials Science and Engineering, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, the Nortel Institute for Telecommunications, the Energenius Centre for Advanced Nanotechnology, the Centre for Advanced Coating Technologies in the Department of Mechanical and Industrial Engineering, and the Toronto Microanalysis Centre.

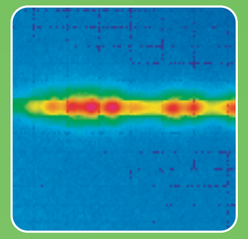
Soliton Physics Workshop: The Soliton Physics Workshop, held on March 26-28, 2004, involved leading scientists working on fundamental aspects of nonlinear optics as well as the physics behind the enabling technologies required for the realization of future telecommunication systems. Taking advantage of the Nonlinear Guided Waves Meeting in Toronto, participants were able to meet in a more focused two-day workshop, discussing topics such as spatial solitons, discrete solitons, cavity solitons, BECs solitons, spatio-temporal effects and light bullets, optics in metamaterials, nonlinear optics in ring resonators, solitons in magneto optic materials, and nonlinear optics in PBGs and Holey fibres. NIT welcomed 70 participants from around the world for this event.

Voice Over IP Industry Analysis-Hosted by Professors Alberto Leon-Garcia and Tony Yuen:
One of the objectives of the Nortel Institute is to provide timely analyses of the telecommunications industry. A key component of the Master of Engineering in Telecommunications Program is the hands-on projects conducted by the students. Each year one of the projects involves an industry analysis on some timely technology or market. In 2004, graduate student Katherine Lam conducted an analysis on the Voice Over IP industry. The deployment of Voice over IP (VoIP) has set a critical milestone in the continuing transformation of the telecommunication industry. The transport of voice using packets over broadband connections has legitimized this enabling technology in the residential market. The notion that existing and emerging voice (and video) services can be cost effectively migrated to an end-to-end IP network has created a sense of urgency for all incumbent service providers and equipment vendors to take immediate actions to protect (and expand in some instances) their businesses. As VoIP technology has matured, it has evolved into a viable option for residential customers. A number of pure play service providers such as Vonage began to aggressively market residential consumer VoIP services in the U.S. All the news and hype surrounding consumer VoIP have caught the attention of the entire industry, which motivated this detailed study on carrier VoIP in the consumer market. Ms. Lam presented her work on September 23, 2004 and her major findings are available at www.met.utoronto.ca/met/pdffiles/VoIP_Presentation.ppt.

CIPI Summer Workshop:
The Nortel Institute for Telecommunications (NIT), in conjunction with the Canadian Institute for Photonics Innovation Student Network (CIPI-S), is currently planning a photonic integrated device fabrication summer school to be held May 31-June 3, 2005 at the NIT clean room facilities.

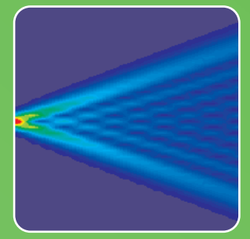
Numerous university and industry research projects currently involve integrated photonics, as it is a basic building block for technologies in fields such as biophotonics, telecommunications, and sensing. The Canada-wide CIPI-S network has thus chosen to hold one of its major 2005 scientific workshops on integrated photonics fabrication, and to utilize NIT's state-of-the-art fabrication facilities for the event. The four-day summer school will expose students to the main elements of fabrication and design using the III-V material system. Students will gain hands-on learning experience in fabricating integrated devices in a clean room setting. Each participant will have the opportunity to make a chip of waveguide devices.

Professor J. Stewart Aitchison, NIT Director, and Aaron Zilkie, University of Toronto Ph.D. candidate and CIPI-S scientific activities director, lead the organizing committee for this event. The workshop will also feature NIT lab manager Dr. Henry Lee as clean room instructor and Professor Amr Helmy of The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, as lecturer. Participation in the summer school is limited and requires membership in CIPI-S (http://student.cipi.ulaval.ca/). For more information about this event, please contact Aaron Zilkie at aaron.zilkie@utoronto.ca.



Spatial soliton in a semiconductor waveguide array

MET Scholarship Winner Man-Li Mary Zhao receiving her award



Simulation of discrete diffraction in a periodic array of waveguides

MET Director Professor Alberto Leon-Garcia

Education&TRAINING

Master of Engineering in Telecommunications Program	Executive Development Program	Certificate in Networking

The Master of Engineering in Telecommunications (MET) program within The Edward S. Rogers Sr. Department of Electrical and Computer Engineering is a unique interdisciplinary graduate program that covers all relevant aspects of telecommunications practice. From business and regulatory issues to engineering and advanced networking technology, the program is designed to prepare qualified students for leadership roles in the telecommunications industry. Students receive intense exposure to industry issues by combining classroom learning with hands-on experience through a significant project with industry. Further involvement with industry is fostered through the innovative architect-in-residence and executive-in-residence programs. NIT Novel Network Architectures and Management thrust leader Professor Alberto Leon-Garcia is the Director of the MET program, which has produced 85 graduates since its inception in 1998.

The MET Executive Development Program (EDP) gives industry professionals an overview of current telecom industry structure and dynamics, taking into consideration the regulatory and competitive landscape. The EDP builds on the strengths of the University and its industry partners through lectures that focus on critical issues surrounding the industry delivered by leading academics, industry experts, and top executives. Now in its fifth year, the EDP continues to provide its participants with a unique opportunity to interact with other leaders in the field. Previous participants include representatives from Alcatel Networks, Allstream, AT&T, BDC, Bell Canada, Celestica, CGI, CIBC, Crescendo Ventures, Ericsson Canada, Lucent, Motorola Canada, MTS Communications, Nortel Networks, Rogers Cable, Rogers Wireless, Sprint Canada, and TELUS. The week-long program takes place annually in May and is held at the University of Toronto.

The Certificate in Networking (CIN) program provides individuals working in the areas of networking and information technology with an opportunity to update their skills and competencies. The convergence of the telecom and Internet-based industries is creating new business and career opportunities. This program is intended for individuals interested in acquiring the most current knowledge related to the emergence of new communication technologies and services.

For more information about any of these programs, visit the MET website www.met.utoronto.ca or contact Linda Espeut, Operations Manager, Master of Engineering in Telecommunications at linda.espeut@utoronto.ca.

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Novel Network Architectures and Management
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Organic and Polymer Photonic Materials and Devices
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