L3:Laboratory of micro/nano photonics

The Laboratory of Micro/Nano Photonics is recognized at national level, and funded between 2001 and 2004, as a **Centre of Excellence in Micro and Nano - Photonics.**

• **Mission**: Research and development activities in the field of micro/nano-photonics and optical MEMS focused on the development of micro/ nano structures based on new materials and processes and photonic integrated circuits based on heterogeneous integration technology; development of materials, technologies and components for optical MEMS.

• Main areas of expertise

- Modeling, simulation, design of micro and nano photonic structures and optoelectronic devices;
- new materials for micro/nano opto-electro-mechanical systems integration (e.g. compound semiconductors, functional polymer, hybrid organic-inorganic nano-compozites and glasses), and related fabrication processes (including mixed technologies);
- passive and active micro-nano-photonic structures,
- hybrid or monolithic integrated photonic circuits and MOEMS (including heterogeneous platforms) for optical communications, interconnects and optical signal processing;
- MOEMS for bio-medical and environment applications;
- optical and structural investigation of semiconductors, dielectrics and polymers nanocomposites thin layers

• European Projects

FP6: ◆Waferbonding and Active Passive Integration Technology (WAPITI), STREP, Priority 2 (IST), Thematic area: optical, opto-electronic, photonic functional components.

◆Advanced Handling and Assembly in Microtechnology - ASSEMIC (2004-2008), Marie Curie Research Training Network;

◆Multi-Material Micro Manufacture: Technologies and Applications4M, NoE - priority 3, NMP;

FP7: ◆Flexible Patterning of Complex Micro Structures using Adaptive Embossing Technology - IP priority NMP

◆European Centre of Excellence in Microwave, Millimeter Wave and Optical Devices - CSA-programme capacities

• **Team** has multidisciplinary expertise and is composed of 6 senior researchers (5 with PhD in optoelectronics, materials for optoelectronics, microsystems, physics, chemistry), 2 PhD students (with background both in physics and photonics), 1 romanian early stage researcher and an early stage researcher from Moldavia (trained in the frame of ASSEMIC network).

Team from left to right:
1st row: Cristian Kusko; Florin Comanescu; Dana Cristea; Catalin Cimpulungeanu;
2nd row: Roxana Rebigan; Munizer Purica; Elena Budianu; Paula Obreja; Mihai Kusko;

• **Specific facilities**: **Modelling and simulation**: Finite-Difference Time-Domain (FDTD) simulation and design software Opti FDTD 6.0, waweguide optics design software- OptiBPM 8.1, software for design and modelling of active devices based on semiconductor heterostructures (Opti-HS); integrated and fiber optical gratings design software (OptiGrating); software for active device simulation (transport, thermal and optical properties) -LaserMod.

Characterization: spectrophotometers for UV-VIS-NIR and IR spectral range; spectroscopic ellipsometer for materials characterization; experimental set-up for optoelectric characterization in UV-VIS-IR spectral range of optoelectronic and photonic components, circuits.

New: High Resolution Raman Spectrometers LabRAM HR - High resolution confocal Raman microscope, offers unique spectral resolution and sensitivity on a bench-top microscope system.

Applications: microscopy and analysis into semiconductors, nano-materials , polymers.

Laboratory Head — Dr. Dana Cristea (dana.cristea@imt.ro)

Dr. Dana Cristea obtained the MSc in Electronics (1982) and PhD in Optoelectronics and Materials for Electronics from "Politehnica" University, Bucharest, Romania. From 1982 until 1994 she was a research scientist in the Department of Optoelectronics and Sensors from the Research & Development Institute for Electronic Components, Bucharest, Romania. Since 1994 she has been a senior researcher in the National Institute for R&D in Microtechnologies (IMT- Bucharest), Romania, head of Laboratory of Micro/Nanophotonics since 1997 and head of Department for Multidisciplinary Research since 2002; since 1990 she is Associate Professor at "Politehnica" University, Bucharest, Faculty of Electronics. Her main research activities are in the fields of optoelectronics and photonic integrated circuits, optical MEMS for communications, chemo and bio-sensors with optical read-out.

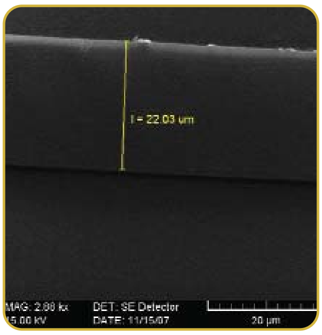
She is author of more than 80 publications in international scientific journals and conference proceedings. She is also a reviewer in Romanian and international scientific journals and evaluator of European projects (FP6, FP7). She is project manager for national and European projects.

MIXED TECHNOLOGIES FOR MICROPHOTONICS

• SOL-GEL NANOCOMPOSITES FOR MICROPHOTONICS

The sol-gel method is a flexible and convenient way to prepare oxide films on several types of substrates, and for this reasons it was extensively investigated for optical waveguides fabrication. The multilayer SiO_2-TiO_2 and SiO_2-TiO_2-Al_2O_3 waveguides undoped and doped with Er_3^+ were prepared by sol-gel method. The films were deposited on Si/SiO_2 substrate by spin coating methods, followed by annealing at 900^{o}C.

Optical waveguides were obtained by patterning Er-doped sol-gel layers deposited on oxidized silicon wafers (oxide thickness over 3 μm). Two techniques were used for patterning: wet etching in buffered oxide etch (BOE) solution (40% NH_4F: 49% HF = 6:1) with an etching rate 120 nm/min at 22^{o}C and reactive ion etching in CF4 (max. etching rate: 80nm/min – at 250 W). Reactive ion etching (RIE) offers a better control of the etching process and lower over-etching. SiO_2-TiO_2-Al2O_3 based layers can be patterned only by RIE.

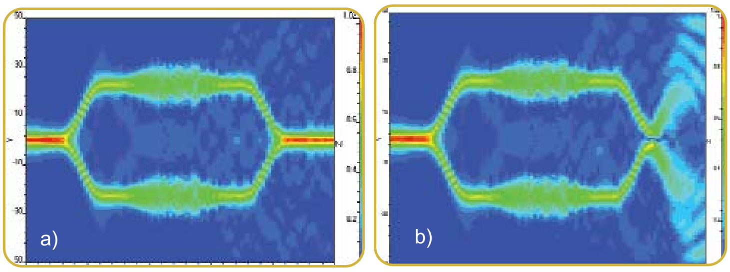


Optical waveguide (Er doped SiO_2-TiO_2-) patterned using wet etching

Co-operation with Institute of Physical Chemistry "I.G.Murgulescu" of Romanian Academy

• DESIGN OF A THERMOOPTICAL MODULATOR BASED ON SOI WAVEGUIDES

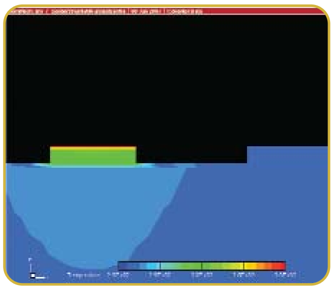
There is an increasing interest in the area of relatively low-speed, low cost modulators and switches for local area networks (LANs). Silicon is an appropriate material for modulation based on thermo optic effect due to its high value of the thermo optic coefficient. The silicon waveguides can be used for devices working at wavelengths centered around 1.55 µm, since the silicon is transparent in this wavelength domain.



Propagation in a Mach-Zehnder interferometer if there is a temperature difference between the arms: a) ΔT = 0 K; b) ΔT = 4 K

Achievements: it was designed a Mach-Zehnder modulator based on silicon on insulator (SOI) waveguides. It was used optical analysis for designing a single mode, polarization insensitive Mach-Zehnder interferometer and for solving the coupling issues regarding transition from the rib waveguide to the rectangular section waveguide used in the active zone. Also, it was used the thermal analysis for determining the required applied voltage for switching from ON to OFF state. The obtained value is 2.6 V.
The software packages employed were OptiBPM 8.0 software based on BPM (Beam Propagation Method) provided by Optiwave for the optical analysis and Coventorware 2006 software provided by Coventor Inc. for the thermal analysis

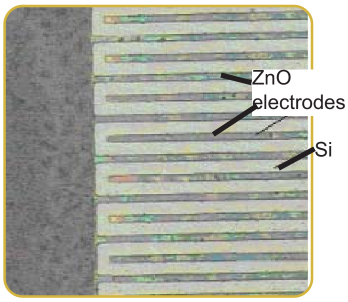
The results obtained will be used for fabrication of a thermo optical modulator.


Transversal section temperature distribution in the structure.

• THIN TRANSPARENT CONDUCTING LAYERS WITH OPTICAL AND ELECTRICAL PROPERTIES SUITABLE FOR MICRO/NANOPHOTONIC APPLICATIONS.

Transparent conducting oxides (TCO) thin layers, due to their optical and electrical properties, can be used as transparent electrodes in micro/nano photonics and optoelectronics devices applications. The advantage of TCO thin layers consist in: the improvement of the photoresponse by eliminating the shadowing of active area by opaque metallic electrodes; compatibility with silicon and AIIIBV compounds technology; the posibility to obtain multilayered structures with selective spectral response and low costs for materials and deposition processes.

Achievements: Thin transparent conducting layers of ITO, ZnO used as transparent electrodes for high response MSM photodetector; undoped CdS and doped with Mn, Se, Sb; multiple pairs of TiO_2/SiO_2 thin layers for optical filter integrated with photodetector structure.



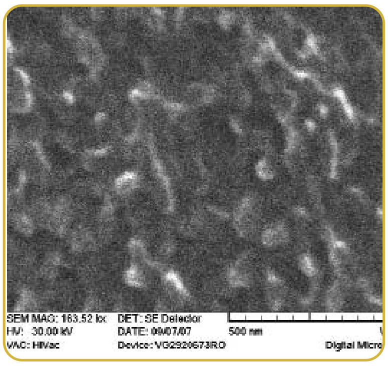
ZnO transparent electrodes on silicon to obtain MSM photodetector.

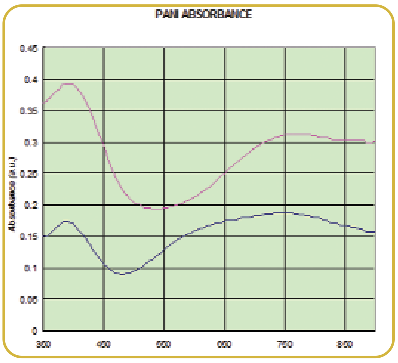
FOTONTECH, CEEX Project 2006-2008, Co-ordinator: IMT-Bucharest,
Project mamager: Dr.Dana Cristea (dana.cristea@imt.ro)

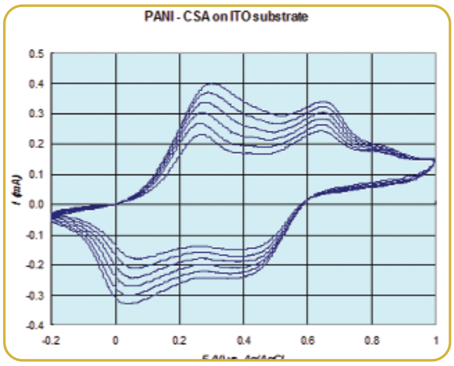
POLYANILINE FILMS FOR SENSOR APPLICATIONS

Polyaniline films (PANI) were prepared chemically by oxidative polymerisation on glass substrates, starting from aniline + ammonium persulfate. The electrodeposition of PANI films has been investigated by cyclic voltammetry with a scan rate 20 mV/s. PANI was electrochemically synthesised by anodic polymerization from an acidic solution of the monomer on ITO/glass substrates at 0.8-1 V (vs.Ag/AgCl).

Conducting polymers, especially polyaniline can be used in bio-chemical sensor applications, as well as in organic light emitting diodes, electromechanical actuators, anticorrosion coatings, electromagnetic screens, microwave absorbing material, antireflection coating, electrochromic mirrors and ultracapacitors.

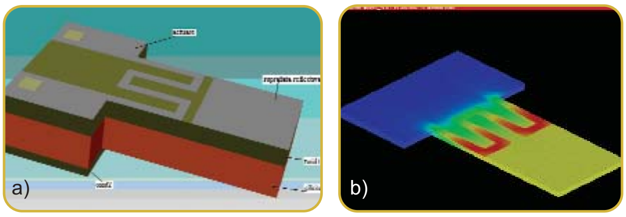




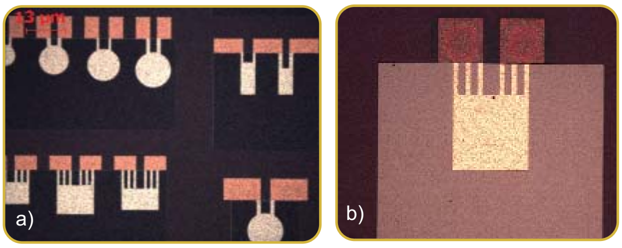


co-operation with Politehnica University in CEEX Project 2006-2008

MOVABLE MICROMIRRORS ON SILICON-ON-INSULATOR



a) micromirror structure ; b) temperature distribution versus;



Optical image of the obtained micromirrors on silicon substrate: a) with different geometry b) micromirror with three arms and SiO_2/Cr/Au membrans

Optical MEMS (MOEMS) are widely used in various applications such as optical tomography, optical switches, laser adjustable cavities, and many other applications.
As a specific type of MOEMS, movable micromirrors are widely used in different types of applications such as miniature optical scanning devices, optical spectroscopy, adaptive optical systems, cross connects and switches in optical microsystems, communication and sensors applications. These devices can be excited by different means, such as electromagnetic actuation, electrostatic actuation, piezoelectric actuation and thermal actuation .

Achievements: modeling/simulation and design of movable micromirrors on silicon and SOI substrates, thermally actuated based on bimorph layer or a resistance integrated on silicon substrates. The displacement along z axe was investigated using Coventorware software taking into account material properties and structure geometry.

The micromirrors with different geometry were obtained on silicon substrate using RIE etching and wet etching processes

MINASIST + project (2006-2008) contact person dr. Munizer Purica (munizer.purica@imt.ro)

NUMERICAL INVESTIGATION OF LEFT – HANDED METAMATERIALS

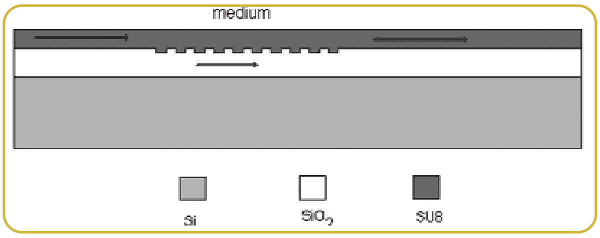
Metamaterilas are novel periodic systems, patterned at micro and nanoscale, for which the effective electromagnetic proprieties like electric permittivity and magnetic permeability can be artificially engineered. A very interesting class of metamaterials are the left - handed metamaterials (LHM) which present simultaneously a negative permittivity and permeability, and implicitly, a negative refraction index. Beside the interesting electromagnetic and optical phenomena occuring in LHMs, threre is a plethora of novel application in imaging (perfect lens), invisibility, waveguiding, etc. We use a combination of theoretical methods and numerical algorithms to investigate and design various LHM at microwave, infrared and optical frequencies.

CEEX Project (2006 – 2008) Optical properties of nanostructured materials.
Coordinator: IMT Bucharest, Project manager: Cristian Kusko (cristian.kusko@imt.ro)

DESIGN OF A REFRACTOMETRIC CHEMO-OPTICAL SENSOR BASED ON LONG PERIOD WAVEGUIDE GRATING

A long period waveguide grating device for sensing the change of the refractive index of the medium was designed and modeled with the OptiGrating software. This sensor works by coupling the radiation propagating in the fundamental mode to the leaky, substrate modes with the influence of the long period gratings.

MINASIST + project (2006-2008)
Contact person dr. Dana Cristea (dana.cristea@imt.ro)

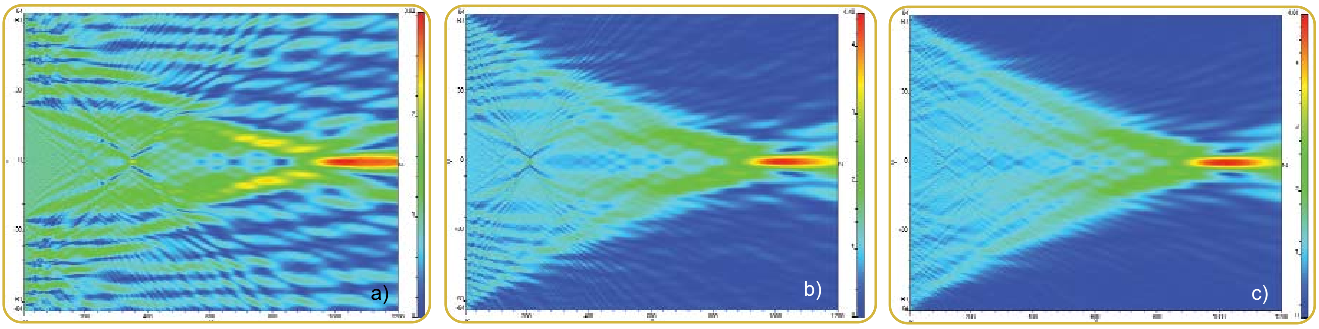


Scheme of the proposed LPWG sensor.

MICRO-OPTICAL DEVICES FOR OPTICAL PROCESSING

DESIGN OF THE DIFFRACTIVE OPTICAL ELEMENTS

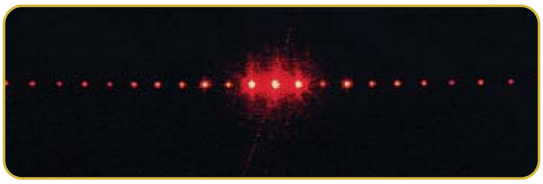
Diffractive Optical Elements (DOEs) are used in many areas like optical communication, optical interconnection, sensors, beam shaping, etc. The team from our laboratory designs DOEs using analytical expressions in the case of the Fresnel lens or diffraction grating and the dedicated software 3Lith provided by Raith. Gmbh for DOEs with complex function. The designed DOEs are based on discrete levels configuration (2, 4 and 8 levels).

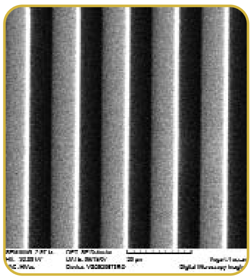


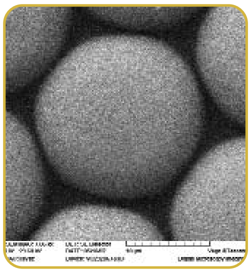
Simulation with OptiBPM software of radiation propagation trough Fresnel Lens with a) 2 levels; b) 4 levels; c) 8 levels.

FABRICATION MICRO-OPTICAL COMPONENT

Results: polimer-based microoptical elements obtain using replication techniques


Application: diffractive optical elements


PDMS grating


PMMA diffractive optical element Microlens array in epoxy resin

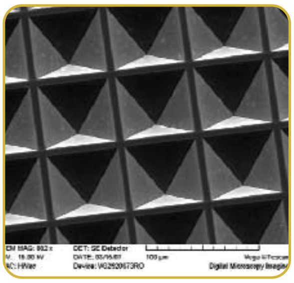
CEEX Project (2006 – 2008) Micro-optical devices for optical processing. Coordinator: IMT Bucharest , Project manager: Dana Cristea (dana.cristea@imt.ro)

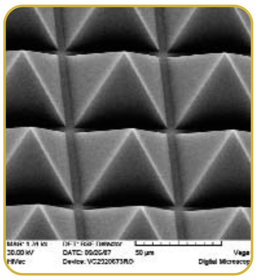
REPLICATION TECHNIQUES FOR MICRO-OPTICS

Replica molding is one the most simple soft-lithography techniques that can be used to generate micro and nanostructures in polymers with a resolution of a few nm. This technique is based on direct 3D replication in a polymeric material of molds easily obtained by standard processes.

Achievements: replicas for various patterns (dots, lines, prism and lens) were obtained in polymethylmethacrylate (PMMA), epoxy resin and polydimethylsiloxane (PDMS) in different conditions for polymer coating and curing.

PN II Project (2007-2010), Development of soft lithography techniques for micro and nano-photonics. Coordinator: IMT Bucharest, Project manager: Paula Obreja (paula.obreja@imt.ro)


Masters obtained in SiO_2/Si by anisotropic etching

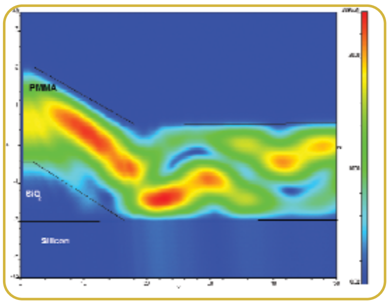

Replica in PMMA and epoxy resin

INTEGRATED BIOPHOTONICS POLYMER CHIP

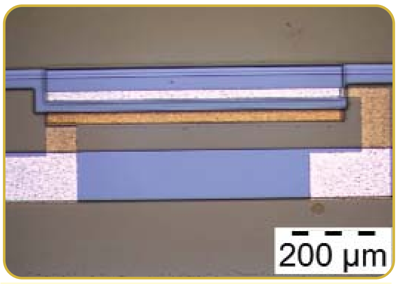
PMMA waveguides fabricated by deep-UV induced refractive index modification were integrated with a silicon photodiode. The optical copling between waveguide and the photodiode is achieved by leaky-waves.

The propagation loss of the waveguides was 0.16 dB/cm at 650 nm. The fiber to chip coupling loss was 1.2-2.7 dB/facet depending on the dicing quality.

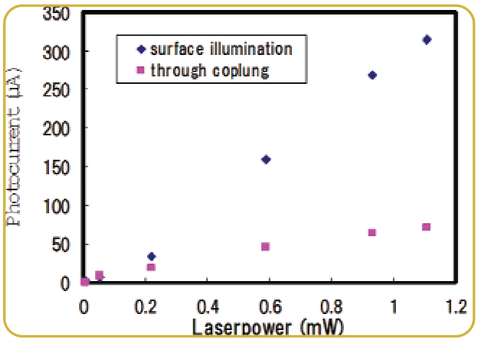
The measurements indicated that 47% of the guided optical power can be coupled in the photodiode within a coupligh length of 200 µm.



Field distribution in the waveguide-photodiode coupling region (simulation with OptiFDTD software; PMMA-waveguide – 2500 nm thick, wavelength – 800 nm



Optical micrograph of the PMMA waveguide integrated with the silicon photodiode



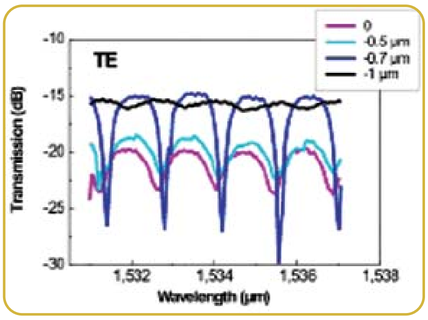
Photocurrent versus laser power in case of top ilumination and in case of copuling with the PMMA waveguide

Joint research project in the frame of the FP6 Network of Excellece MULTI-MATERIAL MICRO MANUFACTURE: Technologies and Applications (4M)
Co-operation with Institute for Microstructure Technology (IMT), Forschungszentrum Karlsruhe (FZK), Germany

WAFERBONDING AND ACTIVE PASSIVE INTEGRATION TECHNOLOGY AND IMPLEMENTATION

Acronym: (**WAPITI**) Instrument: STREP FP 6, Priority 2, IST
Coordinator - Fraunhofer Institute for Telecommunications, Heinrich Hertz-Institut, Berlin, Germany; Dr. **Helmut Heidrich** (Helmut.Heidrich@hhi.fraunhofer.de).
Partners: National Kapodestrian Univ. of Athens (GREECE); Cambridge Univ., Engineering Depart.(UNITED KINGDOM); EV Group, E. Thallner GmbH, Scharding (AUSTRIA); Max Planck Institute of Microstructure Physics, Halle (GERMANY);National Institute for R&D in Microtechnologies, Bucharest (ROMANIA)

The **main objectives** of the **WAPITI** project:



Experimental spectra obtained at HHI for structures designed by IMT

- Establish a novel and feasible method of fabrication for vertically coupled micro ring resonators by wafer bonding technology.
- Development of passive and active micro ring resonators devices based on this technology

IMT role: IMT team has modeled simulated and designed both passive and active micro ring resonators devices using photonic simulation packages OptiFDTD and OptiBPM.

IMT team studies aimed obtaining single-mode operating micro ring resonators and adjustment of the fabrication parameters in order to achieve the desired working characteristics of the devices. HHI has fabricated micro ring resonators designed by IMT that presented good working characteristics.

Main scientific papers:

1. **M. Kusko**, et al, *Numerical analysis of microring resonator obtained by wafer-bonding technology*, Proc. SPIE 5956, 59561E (2005) .
2. **M. Kusko,** et al, *Design of single-mode vertically coupled microring resonators*, Journal of Optics A: Pure and Applied Optics, (accepted)