Putting Silicon Photonics to Work in Canada

Jianzeng Xu

&

Dan Deptuck
About CMC Microsystems

- Headquartered in Kingston, Ontario,
- A private not-for-profit corporation since 1984 involving academia, industry and government
- 19 other national and/or international members
- 27 industry members
- 45 universities, 1 college, 1 CEGEP
- National Design Network Clients:
  - More than 800 faculty members, 2000 post-graduate students and, indirectly, their collaborators including about 400 companies.
History—Milestones

• **1984 -1995** Microelectronics Only to Academics

• **1995 – 2005** Mostly Microelectronics Only to Academics
  – Some MEMS, Microfluidics
  – Some Photonics/Optoelectronics

• **2005 – 2015** Microsystems mostly to Academics, but increasing services to Industry; established *DMT Microsystems* in 2007
  – Microelectronics
  – MEMS
  – Photonics/Optoelectronics
  – Microfluidics
  – Embedded Software / FPGA / Microcontrollers
  – Software Quality tools / Architectural tools
Canada’s National Design Network

CMC is managing two NDN microsystems projects:
- Creating Economic Value for Canada (NSERC)
- Embedded Systems Canada (CFI and Provinces)
National Design Network

- More than 800 faculty members
- 2000 post-graduate students
- And their collaborators, including about 400 companies

- Leading-edge tools, technologies and solutions
- Opportunities for networking, partnership and collaboration
- A means to translate research into commercial success including *DMT Microsystems*
Operations... Design, Prototype, Test

CAD Tools

Prototyping Technologies

Test

Embedded software

Drivers, RTOS, API & Dev. Kit
Library of “plug-in” functional modules—commercial and/or university-developed

Training

User groups, reference designs, documentation, etc.

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FACT Network
(showing university-based Labs)

- NanoQuébec
- CMC FACT Services
- CMC Client
- 3CRN2
- GCM + LASEM
- CIRFE
- Nanofab
- CLS
- ECTI
- Innovation Park Lab
- Brockhouse

Managed by CMC
## Research Outcomes Enabled in 2011

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<table>
<thead>
<tr>
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<tr>
<td>Journal or Other Publications</td>
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<tr>
<td>National Awards</td>
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<td>International Awards</td>
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<tr>
<td>Graduate Student Courses</td>
<td>355</td>
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<tr>
<td>Undergraduate Student Courses</td>
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### Outcomes Enabled by CMC - Commercialization Merit

<table>
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<tr>
<th>Commercialization Outcomes Enabled in 2011</th>
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<tr>
<td>Startup Companies</td>
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<tr>
<td>Patents (applied for/or issued)</td>
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<tr>
<td>Licenses</td>
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<td>Disclosures</td>
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<td>Interactions with Canadian Industry</td>
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<tr>
<td>Value of Canadian Interactions</td>
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<td>Interactions with Foreign Industry</td>
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<tr>
<td>Value of Foreign Interactions</td>
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</table>
Client Research Attributes 2011

National Design Network

Technology Application

- Auto 9%
- ICT &/or Entertain. 29%
- Defence (incl. Security) 13%
- Aerospace 11%
- Natural Res. (incl. Energy) 8%
- Agriculture 3%
- Environment 5%
- Biomed &/or Pharma 22%

n = 776

Design-Oriented Interests

- Molecular 12%
- Digital 12%
- RF 9%
- System 14%
- Analog 9%
- Quantum 4%
- Nano 8%
- Microfluidics 5%
- MEMS 10%
- Embedded Software 7%
- Mixed signal 10%

n = 776

Disciplines/Departments

- Elec. & Comp./Elec. Eng. 63%
- Mech. Eng. 8%
- Computer Science 8%
- Other Eng. 4%
- Eng. Physics 7%
- Chemistry 3%
- Other 4%
- ‘Other’ includes: Biochemistry & Life Sciences
- ‘Other Eng.’ includes: Chemical Engineering & Engineering Science

n = 842

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About DMT Microsystems

- A private for-profit corporation, wholly-owned subsidiary of CMC Microsystems a private not-for-profit corporation

- Headquarters: Kingston, Canada

- Sources technical and supply chain expertise from CMC Microsystems

- Delivers MNT products and services for industrial R&D
The Industrial R&D Services Channel for CMC

Design, Prototype, Package, Test — Development Engineering Assistance —

- Design kit development
- Design rule check
- Online training information services
- Multi-Project Wafer Runs
- MicroNano fabrication laboratory services
- Technology selection consultation
- Packaging and Assembly Services
- Low- to medium-volume for standard or custom implementations
- Test services & test equipment rentals
- Arrangements for use of test and measurement laboratory instrumentation (universities)
- Arrangements for use of MicroNano fabrication facilities

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Photonics Products and Services Overview: Prototyping

• In progress
  – InP- and GaAs-based prototyping services provided in partnership with the Canadian Photonics Fabrication Center (CPFC)
  – InP and GaAs epitaxy (CPFC, NRC-IMS, Landmark, others)
  – InP prototyping through U. Sherbrooke
  – Silicon-based passive waveguide photonics through IMEC
  – Optofluidics technology through LioniX
  – PolyMUMPS and SOIMUMPS through MEMScAP
  – NanoSOI process through INO & ANT

• Over the next year
  – Active photonic devices on silicon

• New fabrication options under exploration:
  – SOI photonics + CMOS integration
  – Photonic integration on InP

• Future/speculative
  – Plasmonic waveguides
Photonics Products and Services Overview: CAD

- CAD tools for
  - Mode solving
  - Beam propagation method (BPM) simulation
  - Design optimization
  - Physical layout and verification of optical components
    - CMC supplies design kits to customize the design environment for the fabrication process
  - New CAD tools soon to be available for
    - Finite difference time domain (FDTD) simulation
    - Active device simulation
    - Free space optics
Past training sessions conducted on CAD tool usage as needed

Future “train the trainer” courses for new CAD tools

The year-long Silicon Nanophotonics Fabrication Course, delivered in partnership with UBC, takes students through a complete design, fabrication and testing cycle using the passive SOI photonics technology from IMEC.

- Participation includes graduate students from across Canada + a Canadian government research organization + a U.S. university + two companies.

NSERC CREATE initiatives in photonics
Photonics design activity flow

- Client design
- Layout simulate
- Verify
- Many iterations
- (relatively) few iterations
- Clean design
- Foundry

CMC
IMEC SOI photonics technology

- Silicon-on-insulator, 220nm top Si film, 2000nm buried oxide (BOX)
- 193nm deep UV lithography, enabling features down to ~120 nm
- Supports design and fabrication of a range of PLCs including:
  - photonic crystals
  - waveguides (photonic crystal or ridge)
  - gratings for fiber coupling
  - multiplexers (diffraction or arrayed waveguide)
  - ring resonators
  - filters
- Target applications include optical communications, sensors, and biomedical devices

Directional coupler in a racetrack resonator
Rectangular waveguide coupled to a photonic crystal waveguide
IMEC SOI Photonics Devices

Fabricated SOI Wgs: Spiral

Fabricated SOI Wgs: Coupler

Fabricated SOI Wgs: RR [Raha]

Straight-through Power Transmission ($\sigma^2$) vs. Wavelength, ID:13
SOI Racetrack Resonator Temperature Dependence
Merged layout 2009
Integrating active devices: LETI FLEX process

- Adds the following process modules to a passive SOI waveguide technology:
  - Silicon & germanium epitaxy, in full film or in cavities
  - Implantation & annealing of boron and phosphorus
  - Metallization for large metal contacts (openings larger than 2 microns)
  - Resistive heaters
FP7 ESSenTIAL

The Silicon Photonics Platform ePIXfab now brings silicon photonics within reach of European small and medium sized enterprises. Based on a consortium of major research institutes with silicon photonics expertise, ESSenTIAL will reach out to European industry and will support them to evaluate silicon photonics in the context of concrete applications and markets. To ensure low-cost early access and scalability to manufacturing, the maturity of silicon photonic IC technology will be enhanced by-

- setting up a library of generic devices
- a level of process and device benchmarking and a well maintained design flow
- offering for the first time, devices in a standard package to allow easy testing
- training on the photonic-IC and packaging services, including hands-on design training
- maturity, standardization and sustainability driven by a steadily growing userbase, from Europe and elsewhere.

The project is co-funded by the European Union under the Seventh Framework Program
IME Silicon Photonics Process
Luxtera LuxG Process

- Monolithically integrated 130 nm SOI process combining standard electronic devices with integrated optoelectronic components
- Fully integrated design kit in standard EDA environment including physical verification and simulation
- Characterized and validated models for all devices across process and environmental corners
Photonic Device Packaging

- Supported features:
  - Metal housing with AlN chip submount
  - Single/array fibre pigtailling
  - Wire bond or flip chip assembly with multiple electrical pins (DC & RF)
  - Trace impedance management
  - Thermoelectric cooler and thermistor

Courtesy: Tyndall National Institute
Microsystem Integration Platform Standard Implementation

A benchtop instrument intended for multi-technology validation of the functionality of a micro-device in a system context.

- Enables proof-of-concept experiments at a laboratory-based system level
- Bridges the gap between algorithmic/architectural exploration, stimulus, and measurement of sensors and actuators.
- Addresses specific research needs through a modular, customizable, and programmable system
- Existing variants address MEMS, micromirror, microfluidic, and RF-MEMS applications
The Photonic MIP project will generate a MIP variant optimized for prototyping of optics-based systems

- Optical source and detection modules
- Fibre-based interface to an optical “hardware in the loop”
- Configurability through suite of modules offering imaging, spectral measurement, filtering, tunability, as driven by application-specific requirements

Currently under development through collaboration with Embedded Systems Canada researchers
Photonics Technology Strategy 2012-2016

• Photonics as a systems-enabling technology: focus on integration
  – More photonic functionality on the same chip (silicon photonics, InP integration)
  – Integration of photonics and microelectronics
    • Monolithic approaches (SOI+CMOS, InP)
    • Hybrid approaches—packaging & assembly
  – Integration of photonics with microfluidics & MEMS

• Support some custom device fabrication

• Support some activity in new materials
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