InP-based Photonic Integration:

Learning from CMOS

Meint Smit  COBRA – TU Eindhoven
Roel Baets  IMEC – U Gent
Mike Wale  Oclaro
Transponder-based DWDM
Infinera’s Photonic Integrated Circuit innovation

- Size, weight, power ↓ Reliability ↑
Moore’s law for Photonic ICs

Component count

1980 1990 2000 2010

Commercial

- COBRA/35P
- Philips/COBRA
- Alcatel/Opto+
- Lucent/Bell Labs
- NTT
- Infinera
- UCSB

Photonic Integration: Learning from CMOS
What went wrong?

- Since 1990 worldwide > 1 B$ invested in development of integration technologies
- Almost all research was application driven
- Therefore almost as many technologies as applications
- For most of them: market too small for payback of investments

- (By far too) many degrees of freedom
  - many different materials and technologies
  - many different component types
  - many different wavelength ranges and applications
The (only?) way out

- Develop a **limited number** of generic wafer-scale integration technologies, that can support a **broad range** of functionalities and applications
- Move to a **generic foundry model** (as in CMOS)
  - Convergence of technologies
  - Decouple design (IP) from technology (IP)
  - Set up libraries and tools for ASPIC design
  - Organize training and design support for fabless companies
- Work on **market** development (new applications)
Generic Integration philosophy

Electronic integration
3 basic elements

Photonic integration
3 basic elements

- Waveguide
- Phase control
- Amplitude control

PWD

PHM

SOA
Photonic Integration with 3 basic building blocks

Passive Waveguide Devices
- waveguide
- curve
- MMI-coupler
- AWG-demux

Devices with Phase Modulators
- phase modulator
- amplitude modulator
- 2x2 switch
- WDM OXC

Devices with Optical Amplifiers
- optical amplifier
- λ converter, ultrafast switch
- picosecond pulse laser
- multiwavelength laser
Examples

- Optical crossconnect
- WDM-TTD switch
- Cascaded WDM laser
- Tunable multiwavelength laser
- Picosecond pulse laser
- WDM ring laser
- Multiwavelength laser
Integrated Filtered Feedback – Tunable Laser

Boudewijn Docter
Wednesday 16:00, Hall E2

NEW

Switching time: few ns
Switching current ~ 10 mA
A Generic Integration Platform

JePPIX:
Joint European Platform for InP-based Photonic Integration of Components and Circuits

Industrial partners: Oclaro, CIP, Philips, Alcatel-Thales III-V Lab, FhG-HHI, ASML, Aixtron, OPT

Photonic CAD: Phoenix, Photon Design, Filarete

Universities: COBRA –TU/e, Cambridge,

Coordination: COBRA

Step 1: Small-scale access to the COBRA process for research purposes (proof-of-concept)

Step 2: Move to an industrial foundry (EuroPIC)
non-telecom applications

- Skin analysis equipment
- Optical Coherence Tomography
- Compact Frequency-comb generators for metrology
- Readout units for fibre strain sensors

Market

Generic Technology

Custom Technology

2000 2010 2020

Optical Coherence Tomography

Skin Analysis

Photonic Integration: Learning from CMOS

ECOC'09, Wien 12/19
Complexity of InP Photonic ICs?

Nanophotonic Integration Technology

Generic Integration Technology

Component count


COBRA/35P
Philips
Opto+
Lucent
NTT
Infiner
UCSB
From analog to digital

Martin Hill et al.,

Digital photonic flip-flop
based on
coupled micro-lasers

Dimensions  < 20 x 40 \( \mu \text{m}^2 \)
Switching time  < 15 ps
Switching energy  < 6 fJ
IMOS: InP Membrane On Silicon

(a) silicon

(b) silicon

(c) IMOS

(d) silicon\n
Legend
- blue: silicon
- light blue: silicon dioxide / BCB
- red: active InGaAsP/InP
- green: passive InP

Photonic Crystal Laser

metal contacts

active region

Frederic Bordas
Tuesday 16:30, Hall E2
Metallic and Plasmonic lasers

A BREAKTHROUGH
The world’s smallest electrically injected laser (diameter 250 nm)

small active volume means low power and high speed

Martin Hill et al., Nature Photonics, October 2007
Potential

- Integration of more than 100,000 lasers on a chip
- Operating at speeds well beyond 1 THz

Superior to high-speed transistors for ultrafast signal processing
Complexity of InP Photonic ICs?

Component count


1000000

100000

10000

1000

100

10

1


Nanophotonic Integration Technology

IMOS

Generic Integration Technology

Digital

Analog

COBRA/35P

Philips

Opto+

Lucent

NTT

Infinera

UCSB
Acknowledgement: the COBRA – OED team
EU-IST, NRC Photonics, IOP, STW
ECIO
2010
CAMBRIDGE

15th European Conference on Integrated Optics
and Technical Exhibition

7 - 9 APRIL 2010

Paper submission deadline:
Monday 18 January 2010