Mapping the flow of light in a photonic chip using Ultrafast Photomodulation Spectroscopy (UPMS)

Roman Bruck & Otto Muskens
in collaboration with groups of Graham Reed & Vittorio Passaro
r.bruck@soton.ac.uk

19 09 2014
Part I:

Why do we need to map the flow of light in a photonic chip?
Optical vs electronic data communication

Optical communication:
- higher bandwidth-distance product
- interfacing with electronic world

Virtually all worldwide data traffic over optical fibers

- on-chip
- on-board/intra-chip
- intra-board
- data-centers
- metro-network
- long-haul network

electronic communication

optical communication
Consequences for integrated optics:

all-optical signal processing

on-chip optical data communication

the photonic chip

- integration of more functions on a single chip

- complex designs with multiple subsequent elements

Silicon on insulator (SOI) as most promising platform:

- compatible with electronics world

- mature technology platform & mass production

New characterization tools for complex chips are needed!
Part II:

How do we map the flow of light in a photonic chip?
UPMS – setup in the ORC FastLab

- addressing individual elements by pumping a small spot from top
- access to the time response of elements
- full spectrum for each measured point

In a nutshell, UPMS finds how much light of which wavelength is at a given time at the investigated position

Delay time

150 fs pump pulses, \( \lambda = 400 \text{ nm} \)

150 fs probe pulses, \( \lambda = 1550 \text{ nm} \)

- 400 nm pump absorbed in Si
  - \( \rightarrow \) generation of free carriers
    - reduction of refractive index by 0.4
    - induced absorption

Localized perturbation in the photonic circuit
Spatial mapping – multimode interference device

**MMI**

6.5µm x 29.5µm
wire waveguides (1000nm x 220nm)
\( \lambda = 1556.5 \text{ nm} \)
Time-domain measurements: ring resonator

d=12µm, rib waveguides
450nm x 220nm, 120nm etch depth

\[ Q = \frac{2\pi c \tau}{\lambda} \]
Time-domain measurements: Vernier resonators

racetrack resonators  d=94µm & 104µm, rib waveguides 450nm x 400nm, 180nm etch depth
Summary

Mapping the flow of light by Ultrafast Photomodulation Spectroscopy UPMS:

- spatial domain: sub-µm spatial resolution
- time domain: ultrafast time resolution
- frequency domain: spectrally resolved result
- large effect on silicon $\Delta n_{Si} = -0.4 + 0.06i$

Characterization of any SOI waveguide device

- transparent claddings
- end face & grating coupling
- particularly for complex designs, where transmission function of single elements is obscured
- no test structures needed
Acknowledgements

Otto Muskens & group

Contributions from:
Graham Reed
Goran Mashanovich
Ben Mills
Benedetto Troia
Vittorio Passaro
David Thomson
Frederic Gardes
Youfang Hu

Roman Bruck
r.bruck@soton.ac.uk

Funding organizations
Do you want to know more?


or

Effect of the pump pulses on silicon asymmetric MZI

\[ \Delta L = 180 \mu m, \text{ rib waveguides} \]

450nm x 220nm, 120nm etch depth
Time-domain measurements: group index

straight waveguide
wire waveguides, 470nm x 220nm
UPMS – upgrade of FastLab setup

- Upgrade for grating couplers
- New Piezo stage, 29mm travel in 3D (mid of October)