UNIVERSITY OF Southampton

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

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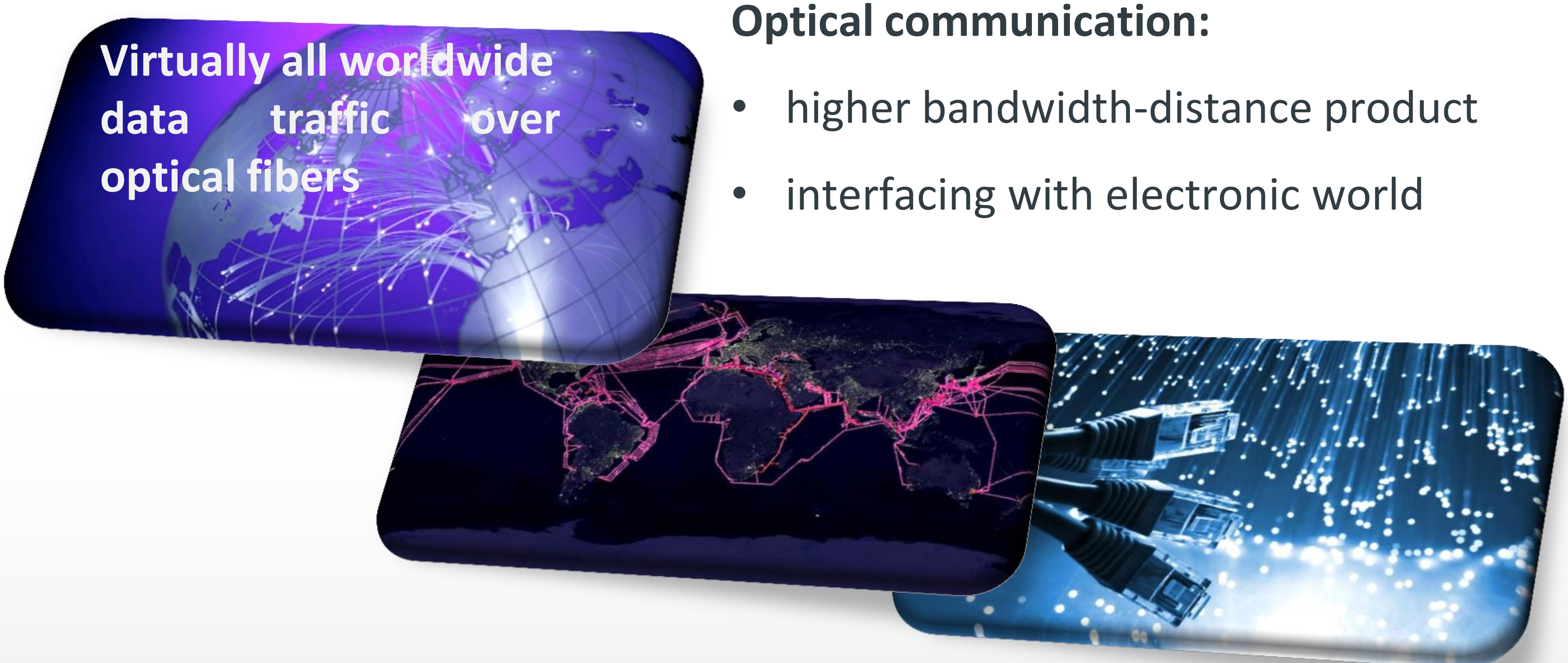
Part I:

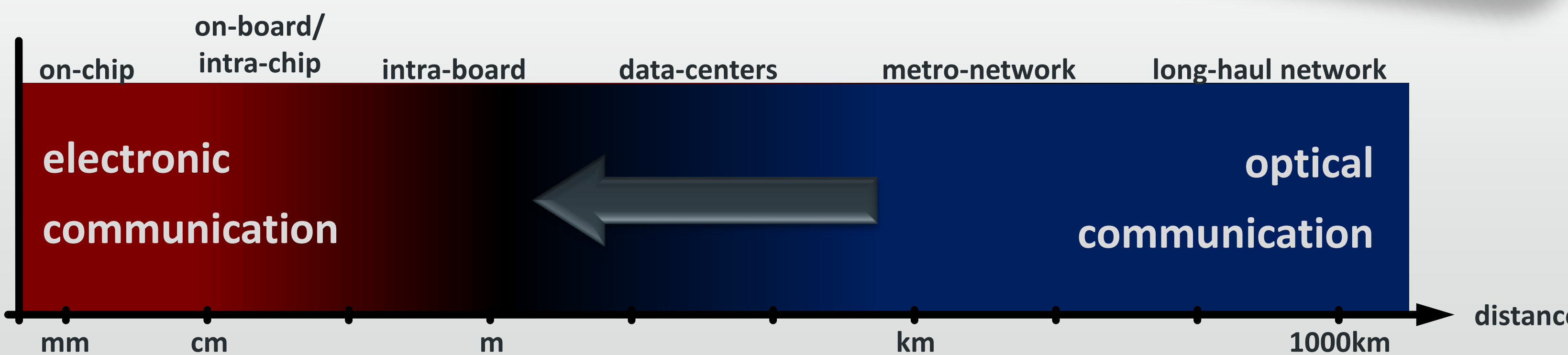
Why do we need to map the flow of light in a photonic chip?

Optical vs electronic data communication



Optical communication:

- higher bandwidth-distance product
- interfacing with electronic world



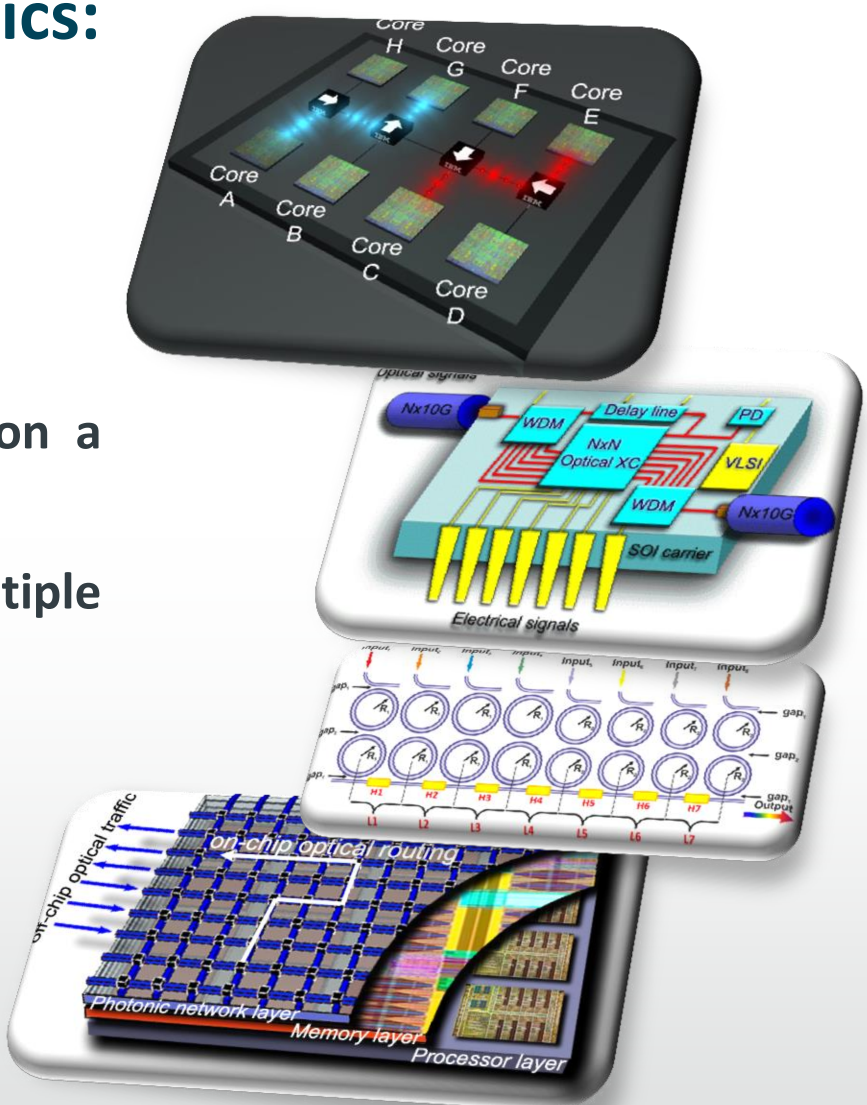
Consequences for integrated optics:

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!

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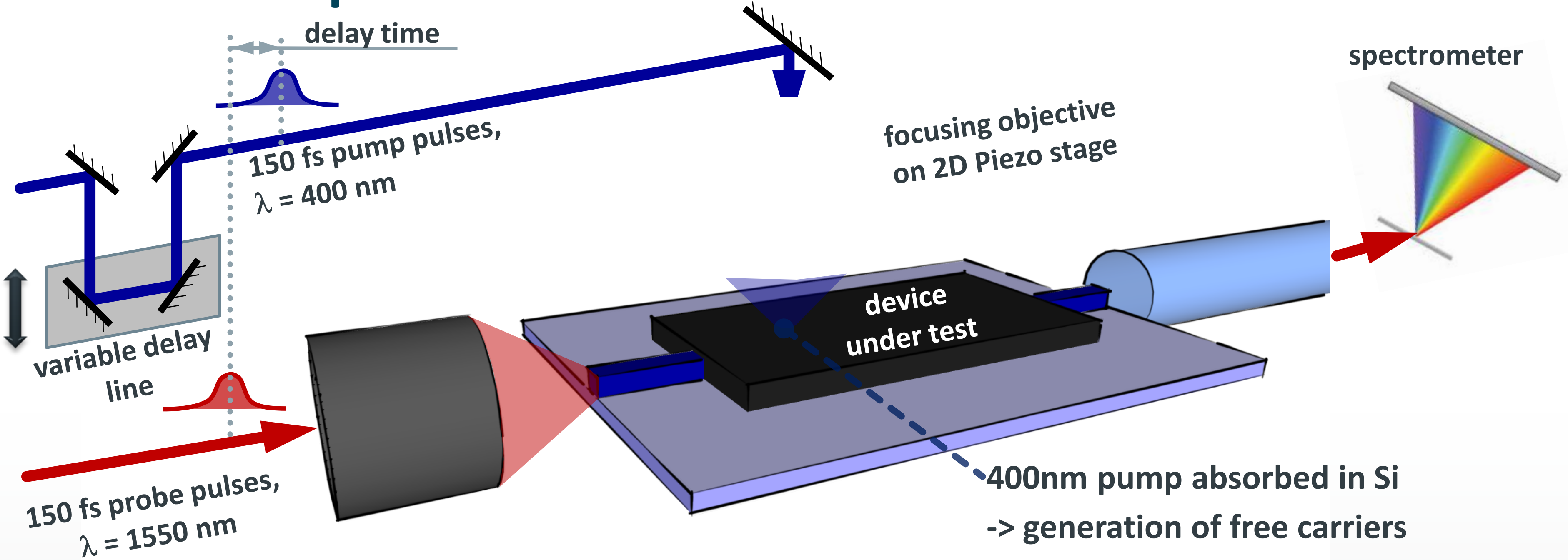
Part II:

How do we
map the flow of light
in a photonic chip?

UPMS – setup in the ORC FastLab



400nm pump absorbed in Si

-> generation of free carriers

- reduction of refractive index by 0.4
- induced absorption

localized perturbation in the photonic circuit

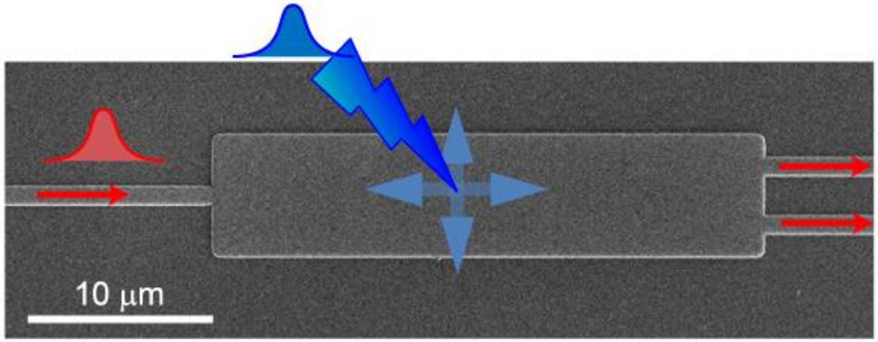
- **addressing individual elements by pumping a small spot from top**
- **access to the time response of elements**
- **full spectrum for each measured point**

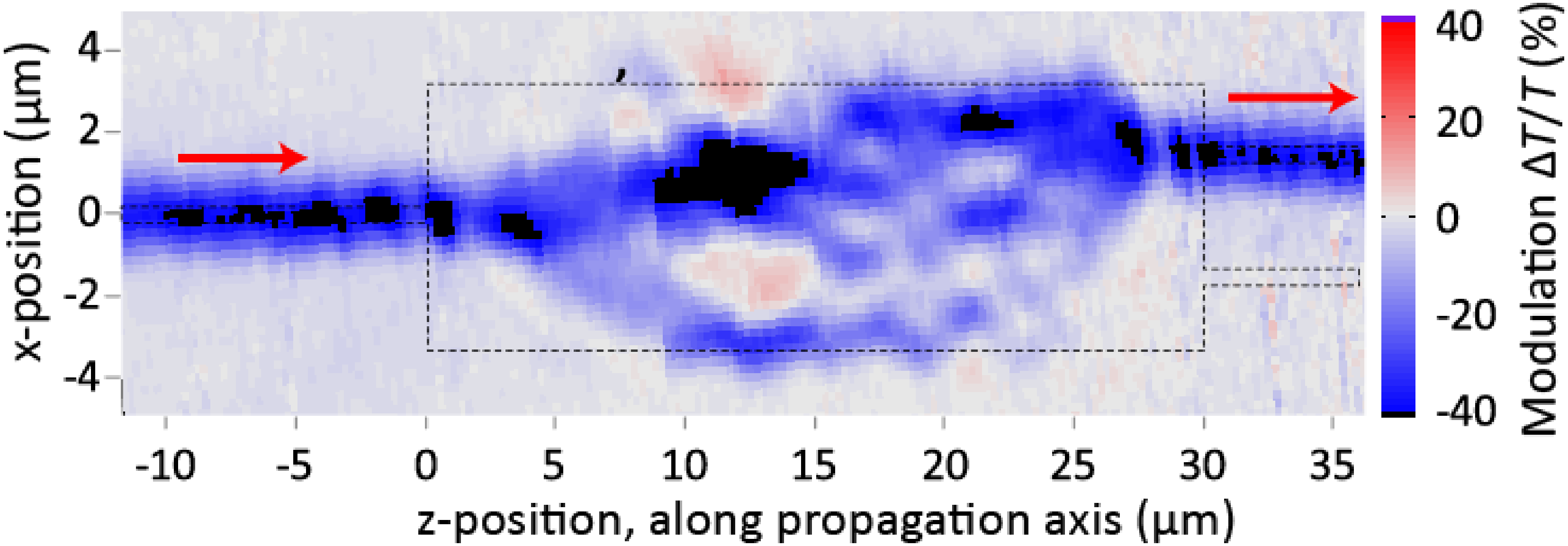
In a nutshell, UPMS finds how much light of which wavelength is at a given time at the investigated position

Spatial mapping – multimode interference device

MMI

6.5µm x 29.5µm
wire waveguides (1000nm x 220nm)
λ = 1556.5 nm

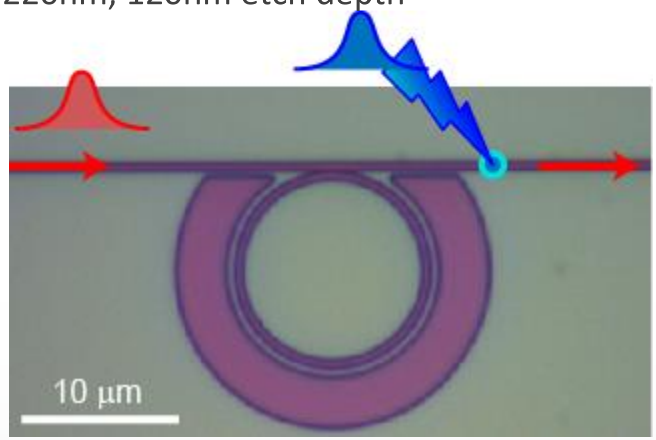


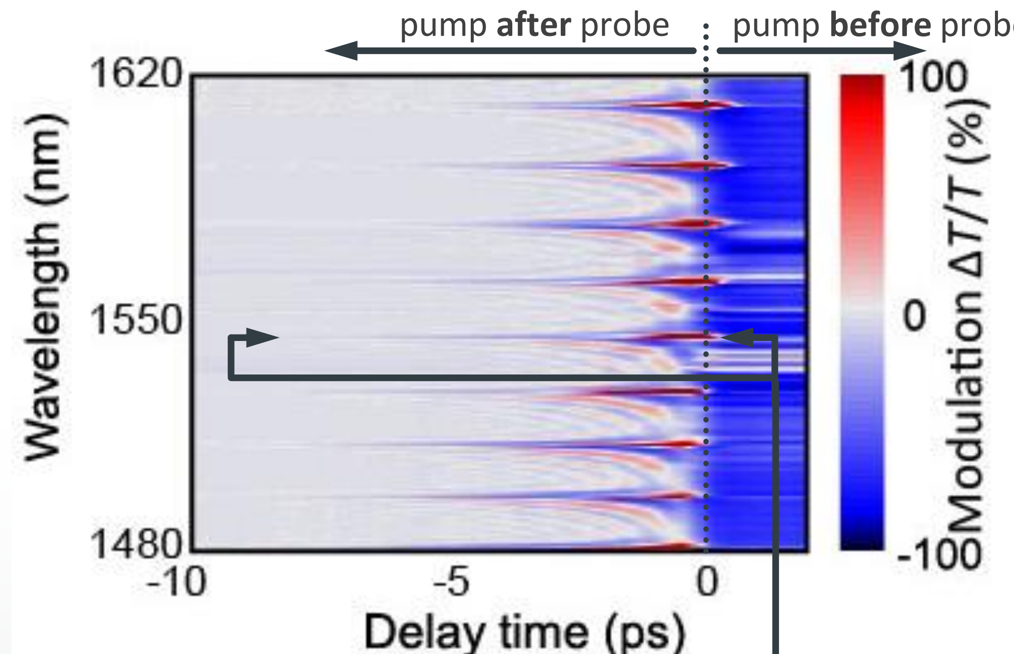


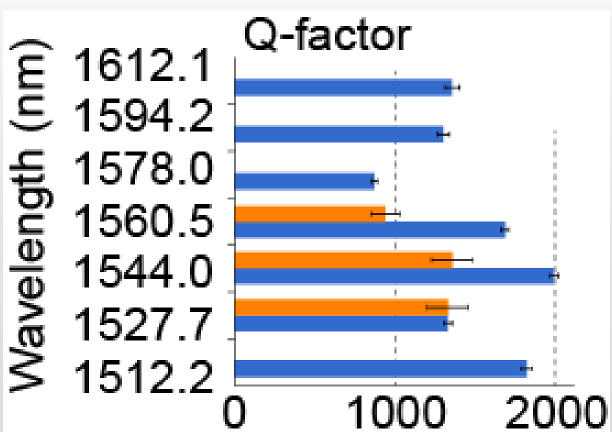
Time-domain measurements: ring resonator

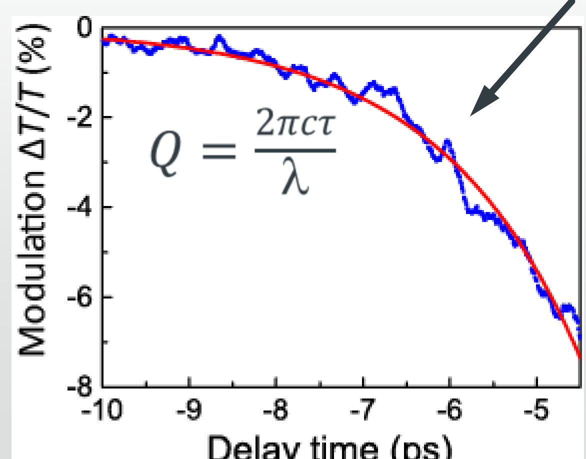
ring resonator

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





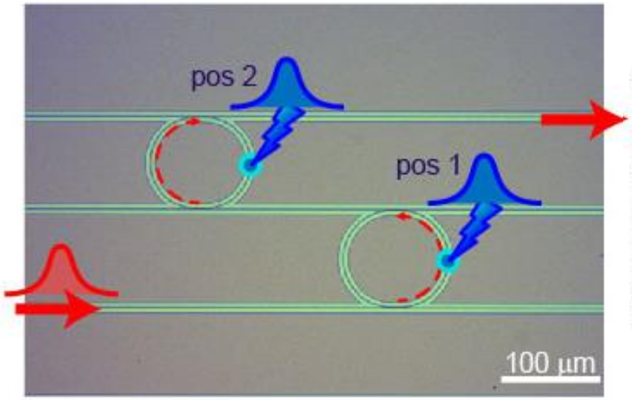


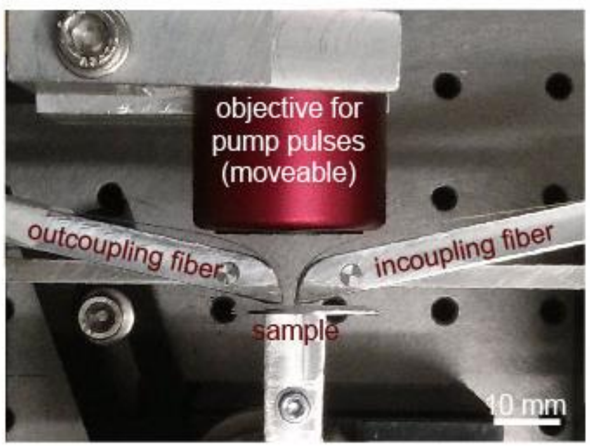


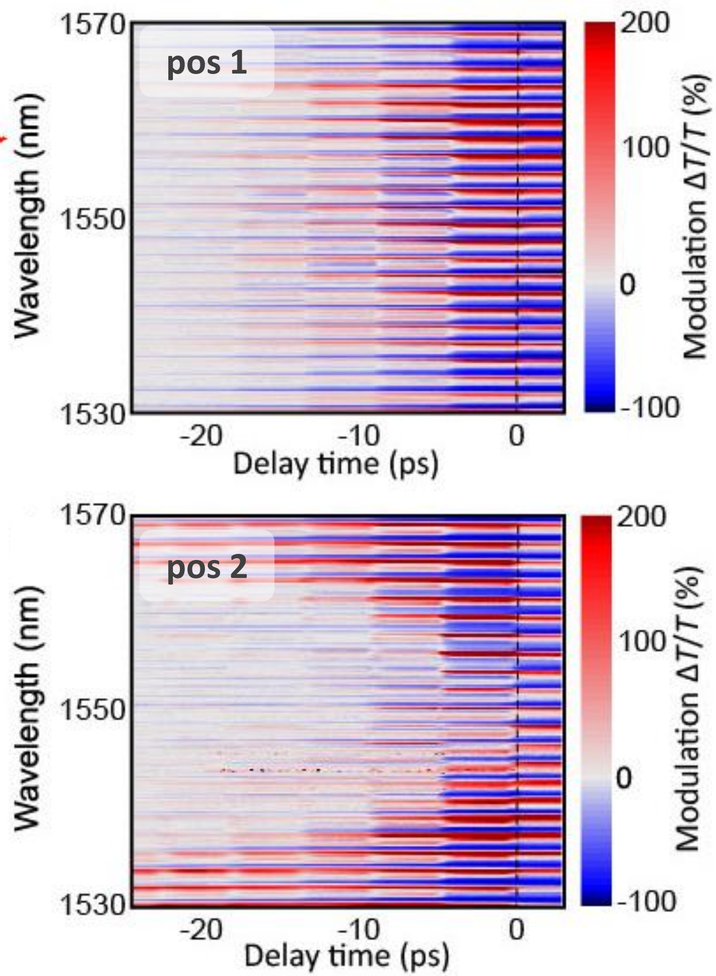
Time-domain measurements: Vernier resonators

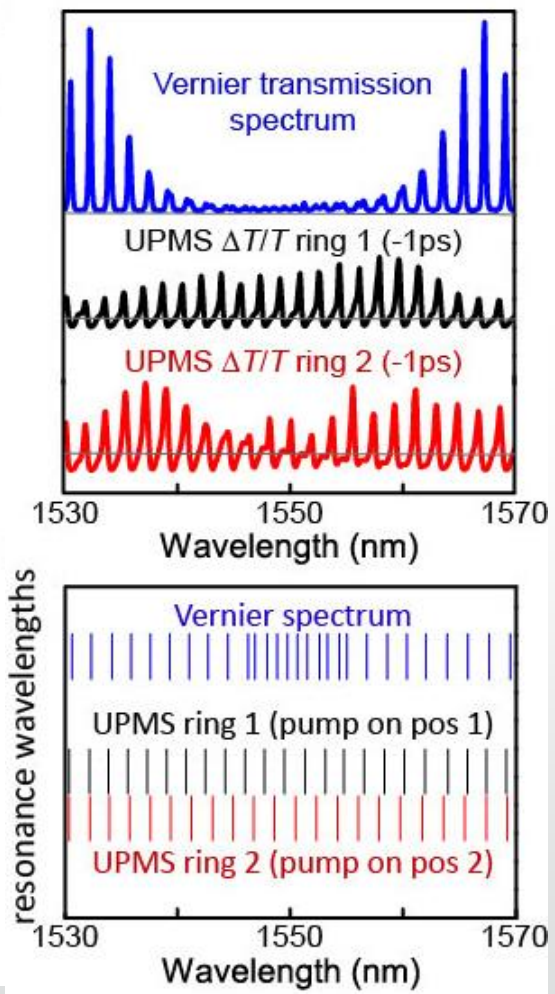
racetrack resonators

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 Δn_{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

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David Thomson
Frederic Gardes
Youfang Hu

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Do you want to know more?

R. Bruck et al.,
“Device-level characterization of the flow of light in integrated photonic circuits using ultrafast photomodulation spectroscopy”,
Nature Photonics (2014), accepted

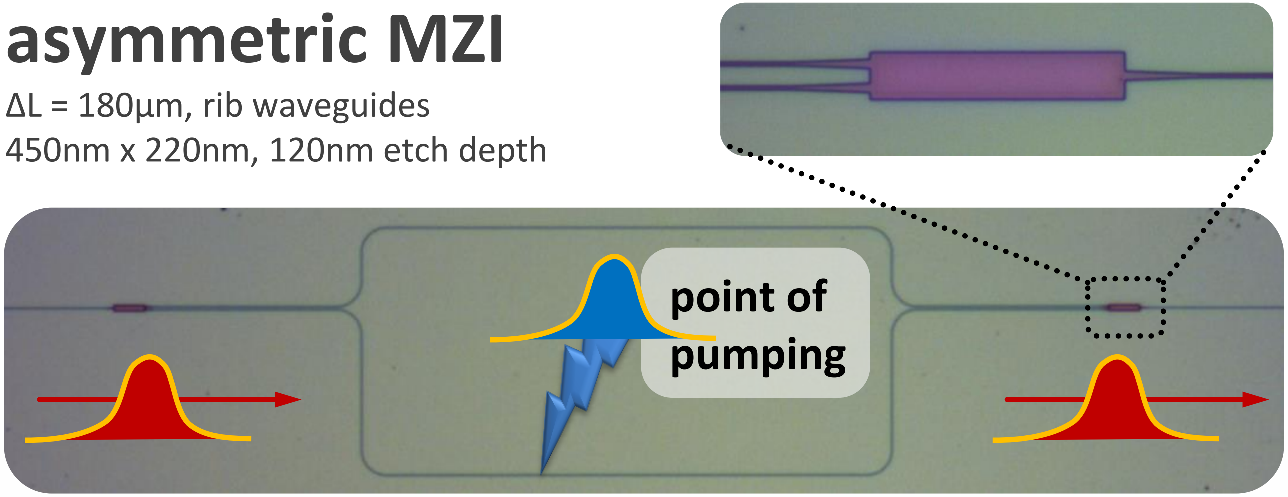
or

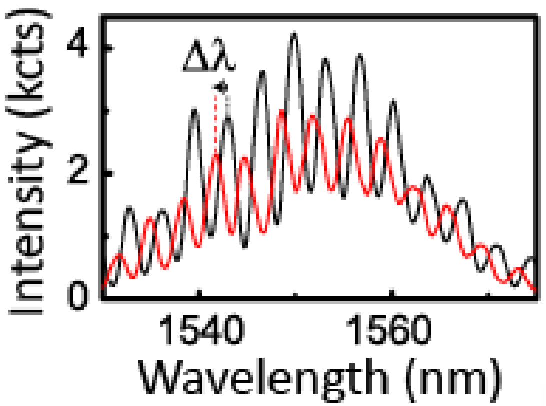
http://arxiv.org/abs/1406.1931

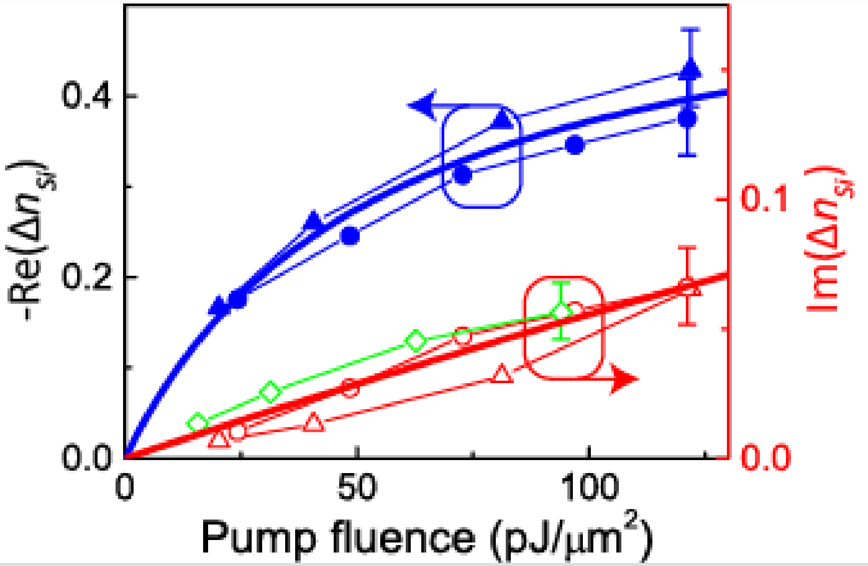
Effect of the pump pulses on silicon

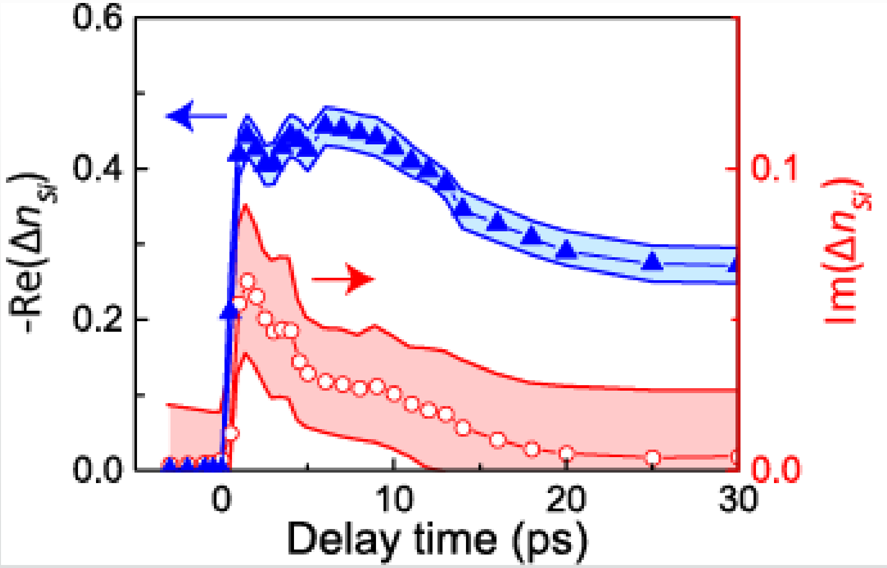
asymmetric MZI

ΔL = 180μm, rib waveguides
450nm x 220nm, 120nm etch depth





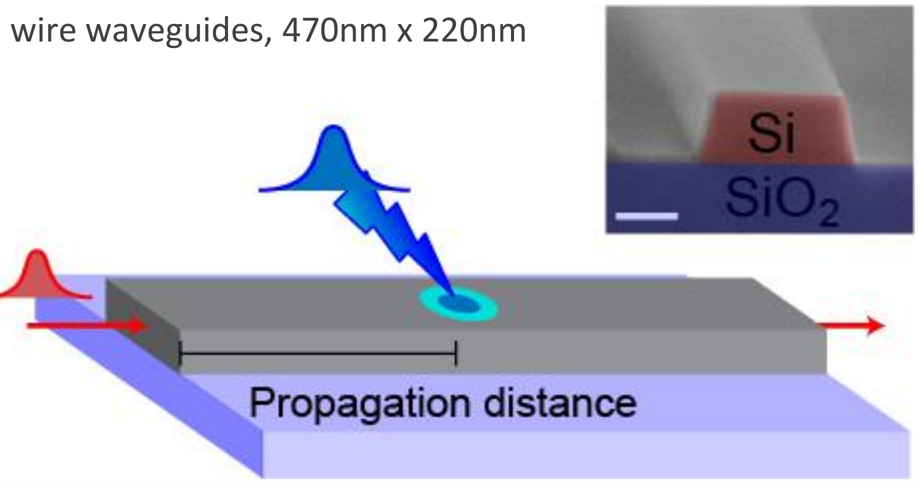


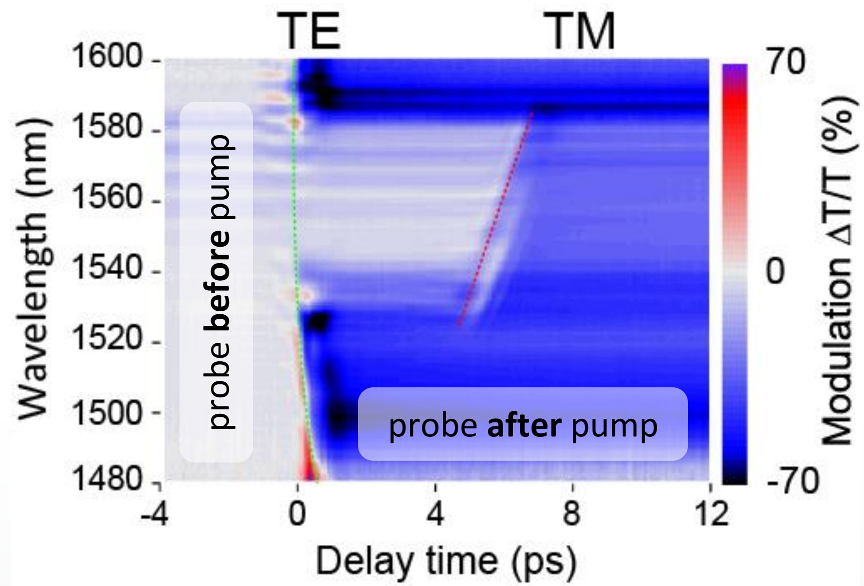


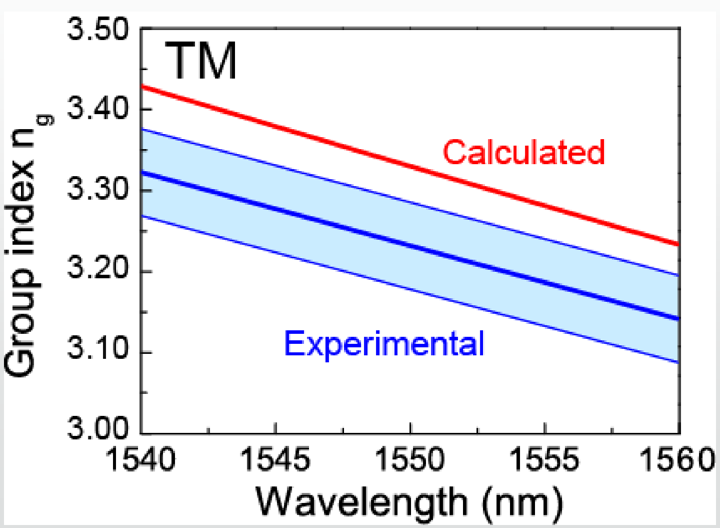
Time-domain measurements: group index

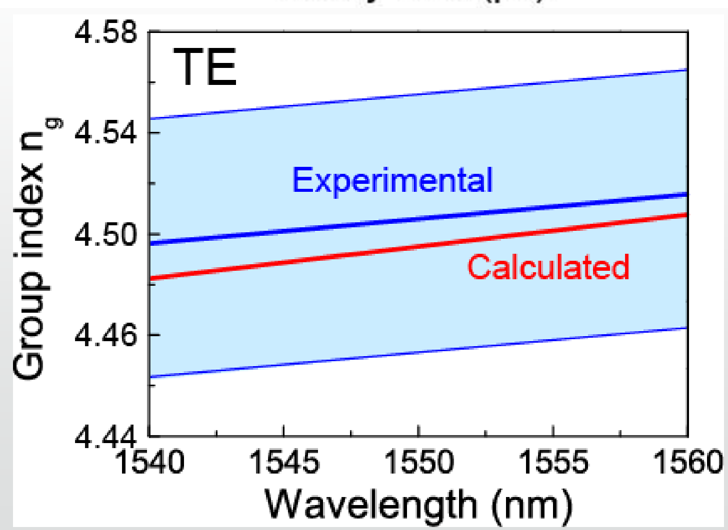
straight waveguide

wire waveguides, 470nm x 220nm

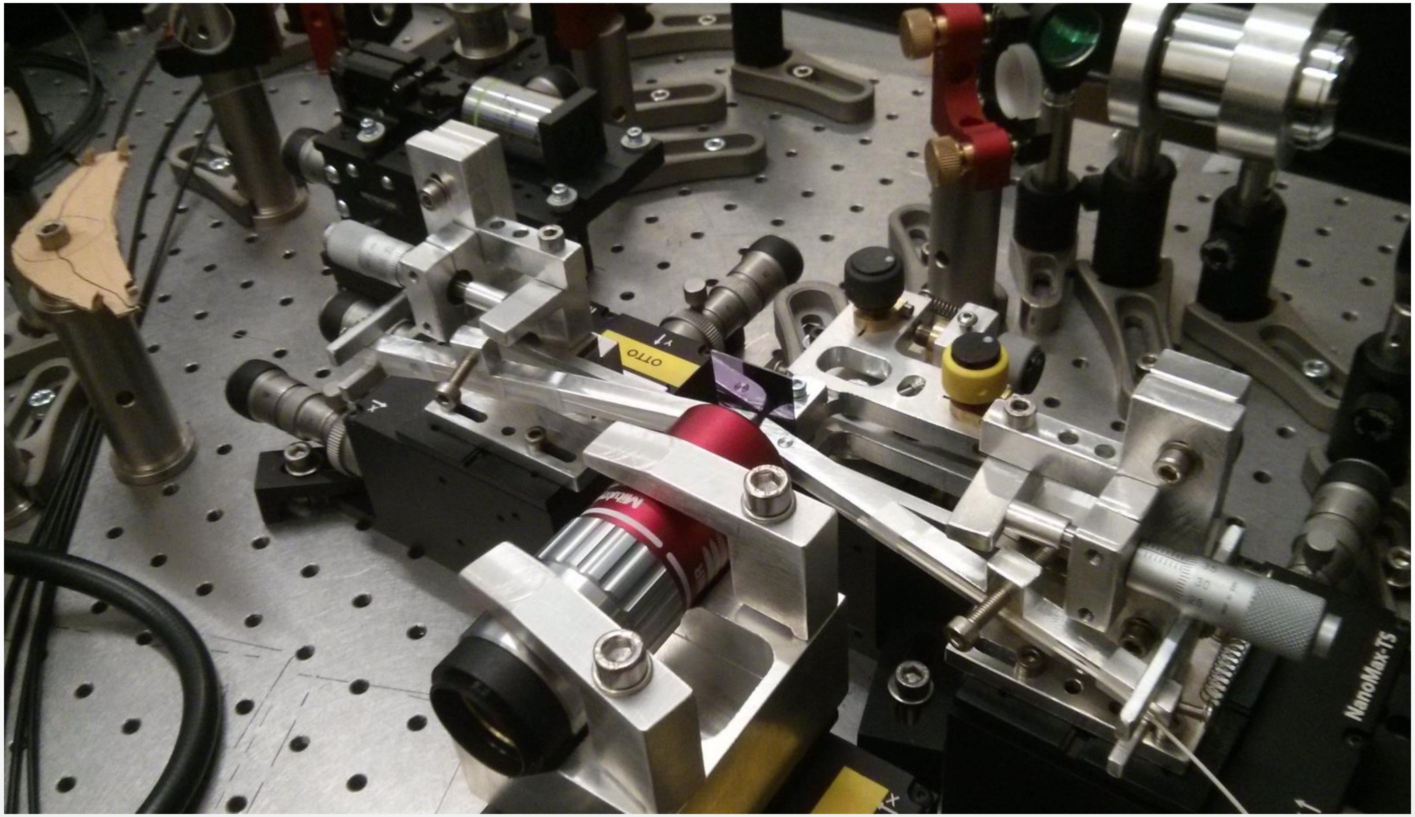








UPMS – upgrade of FastLab setup



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