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Scuola Superiore
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Network-on-Chip Using Silicon Photonics Waveguide Arrays

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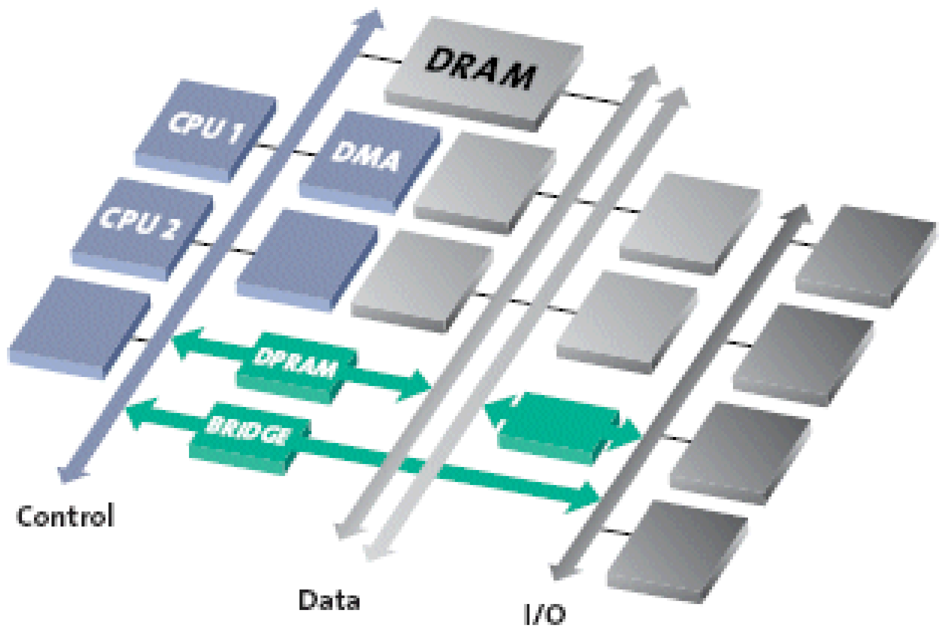
Datacom and Computercom Applications

- Optical network-on-Chip (NoC)
  - networks interconnecting cores, memories, and/or systems
  - applications: multi/many-core computing systems, embedded systems, SoC
  - main requirements and challenges: chip integration, energy efficiency, low-latency, packaging scalability



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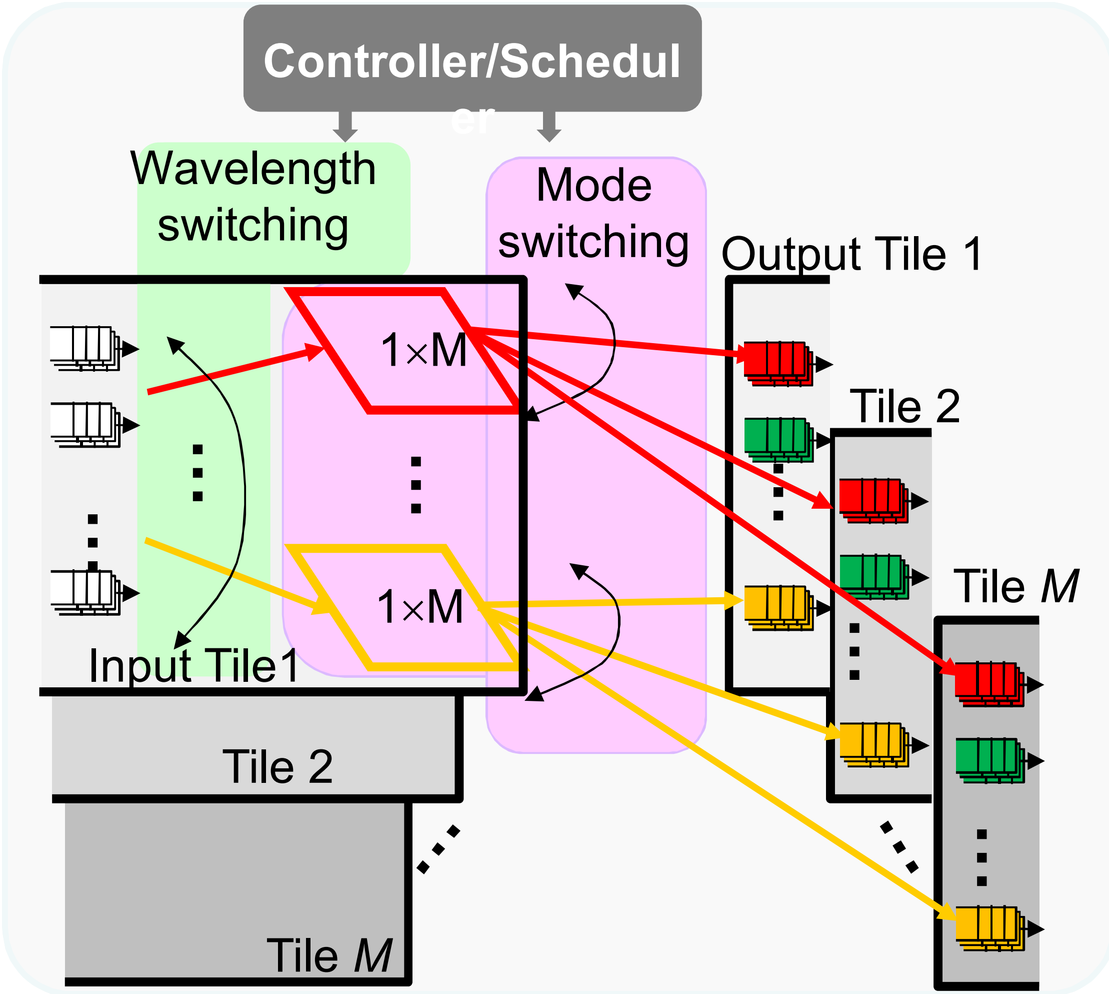
State of the Art

- Photonic integrated NoCs realized mainly based on optical space switching
  - switching elements: ring resonators, Mach-Zehnder interferometers, or semiconductor optical amplifier gates
    - ☹ Rather limited flexibility and scalability:

      if ports ↗, switching elements ↗↗ ➔footprint ↗, power consumption ↗
- Novel domain for multiplexing and switching: mode
- Mode multiplexing and demultiplexing demonstrated in Si PICs:
  - possibility of handling the individual modes with good performance

Proposed NoC Architecture

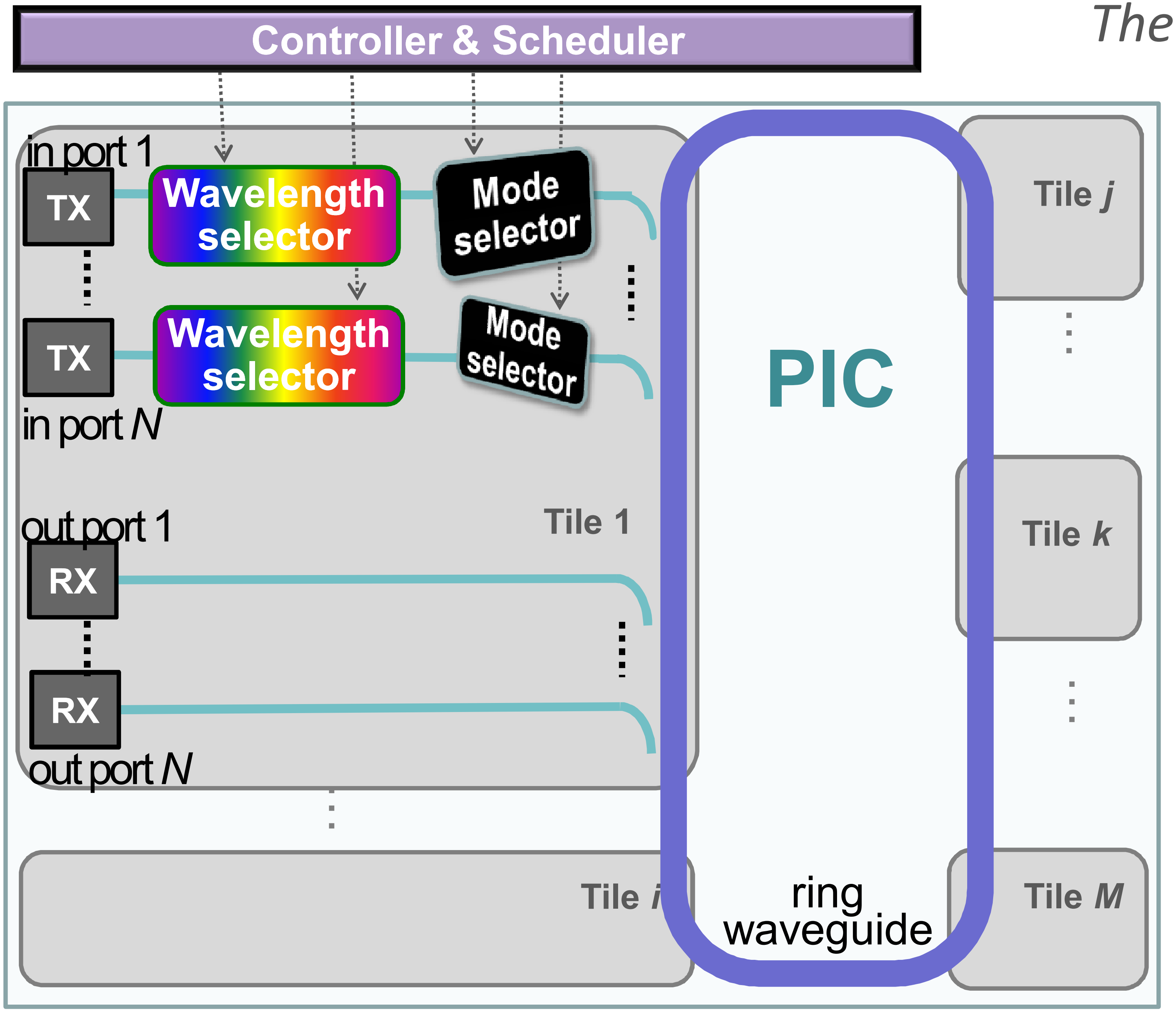
- For scalability, two switching domains:
  - mode domain
  - wavelength domain
    - ✓ enhance the NoC flexibility, scalability, parallelism and throughput
- *M* tiles with *N* input/output ports each
- In the $MN \times MN$ architecture, destination tiles and ports are uniquely identified by wavelengths and modes



- **Mode switching** is used to select the output tile
- **Wavelength switching** is used to select the output port

Mode-Wavelength Architecture

The Design



P. Velha, I. Cerutti, O. Liboiron-Ladouceur, N. Andriolli, "A Silicon Photonics Network-on-Chip Architecture based on Mode and Wavelength Switching," Proceedings of Group IV Photonics (GFP), Vancouver, Canada, agosto 2015

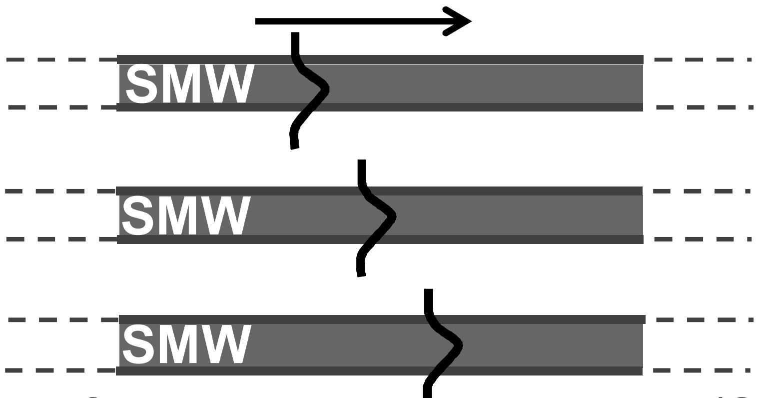
Innovative approach

Supermodes instead of Modes

- Missing component: mode selector
  - dynamic and flexible selection and de/multiplexing of the modes

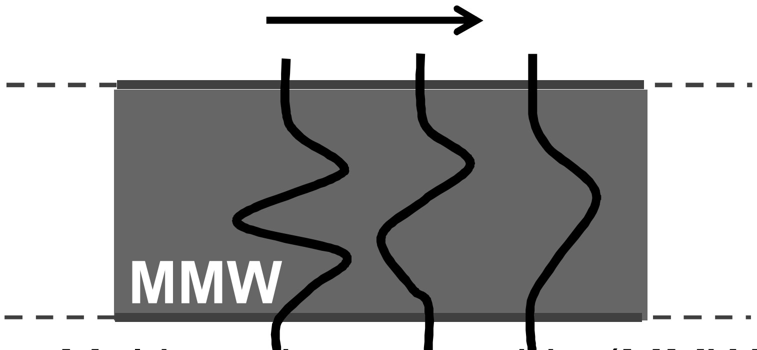
- Proposed approach: use of supermodes
  - different from the set of modes propagating in standard multi-mode waveguides
  - advantages:
    - larger design flexibility
    - easier integration of electrical controls (e.g., each waveguide can be individually tuned)
    - footprint hardly larger than the size of a standard multi-mode waveguide

Comparison of Multiplexing Techniques



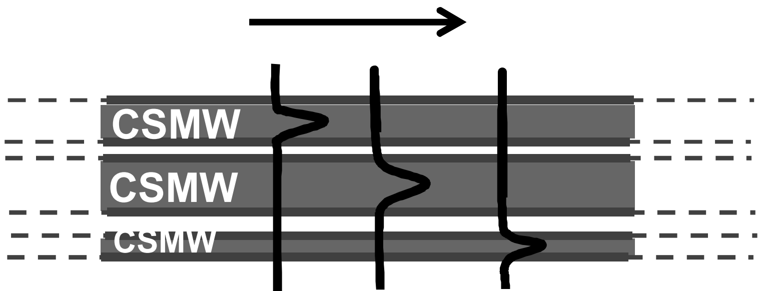
Array of single-mode waveguides (SMW)

Conventional multiplexing technique:
space division multiplexing



Multi-mode waveguide (MMW)

Optical multiplexing using modes

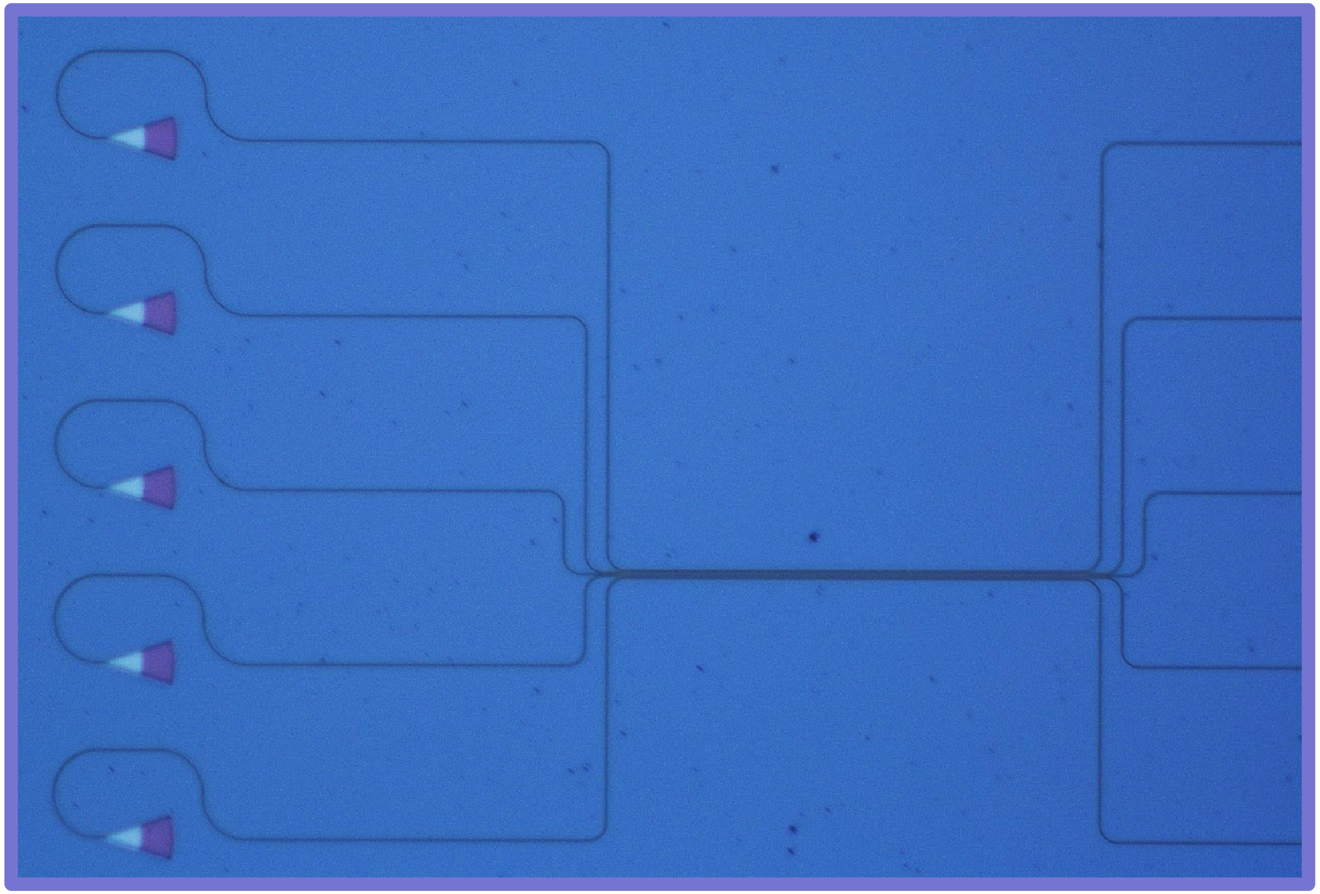


Array of *coupled* single-mode waveguides

Novel optical techniques:
supermodes

Aperiodic array of waveguides

- Si-based fabrication
- Fabricated through SiEPIC program in an E-beam run at the Univ. of Washington on 220nm SOI with single-etch process

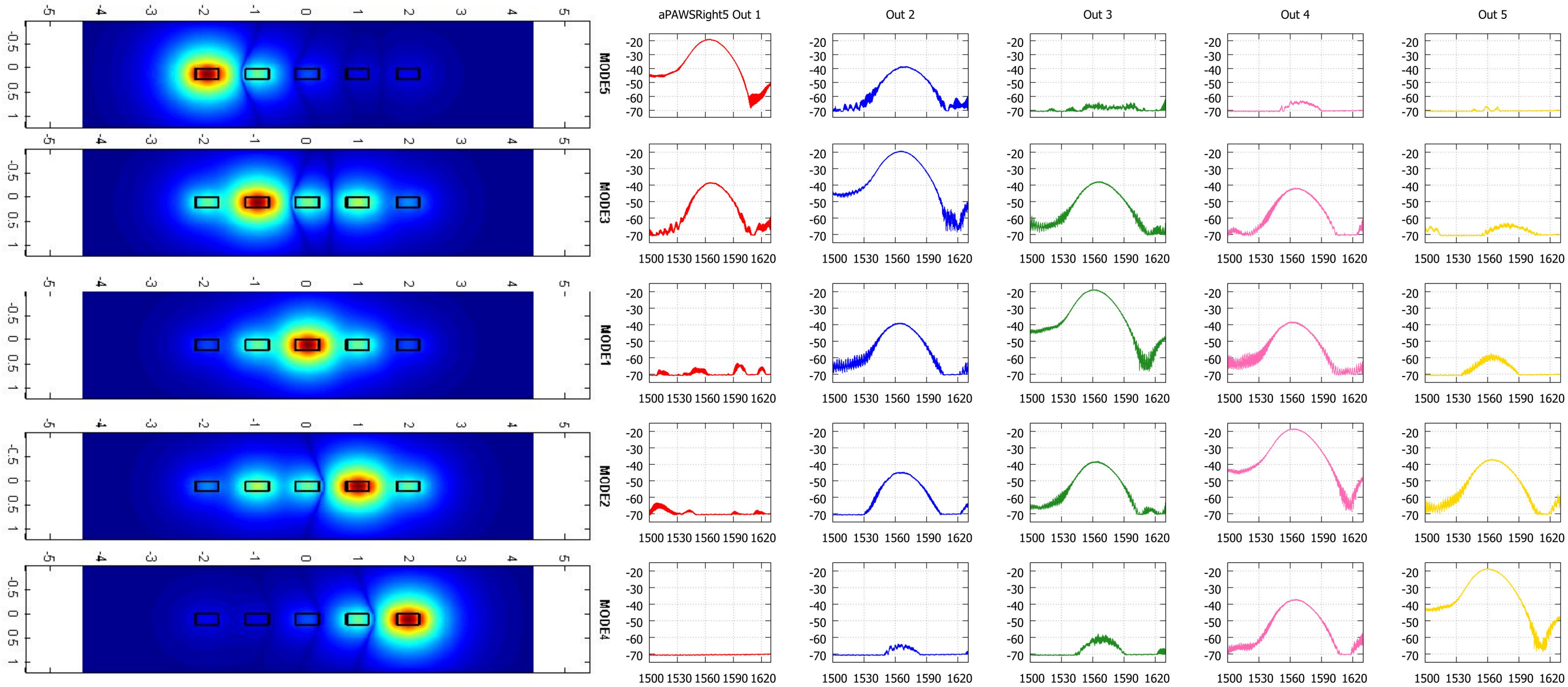


Super-Modes

Generated by Parallel, Coupled Waveguides

simulations

spectra measurements



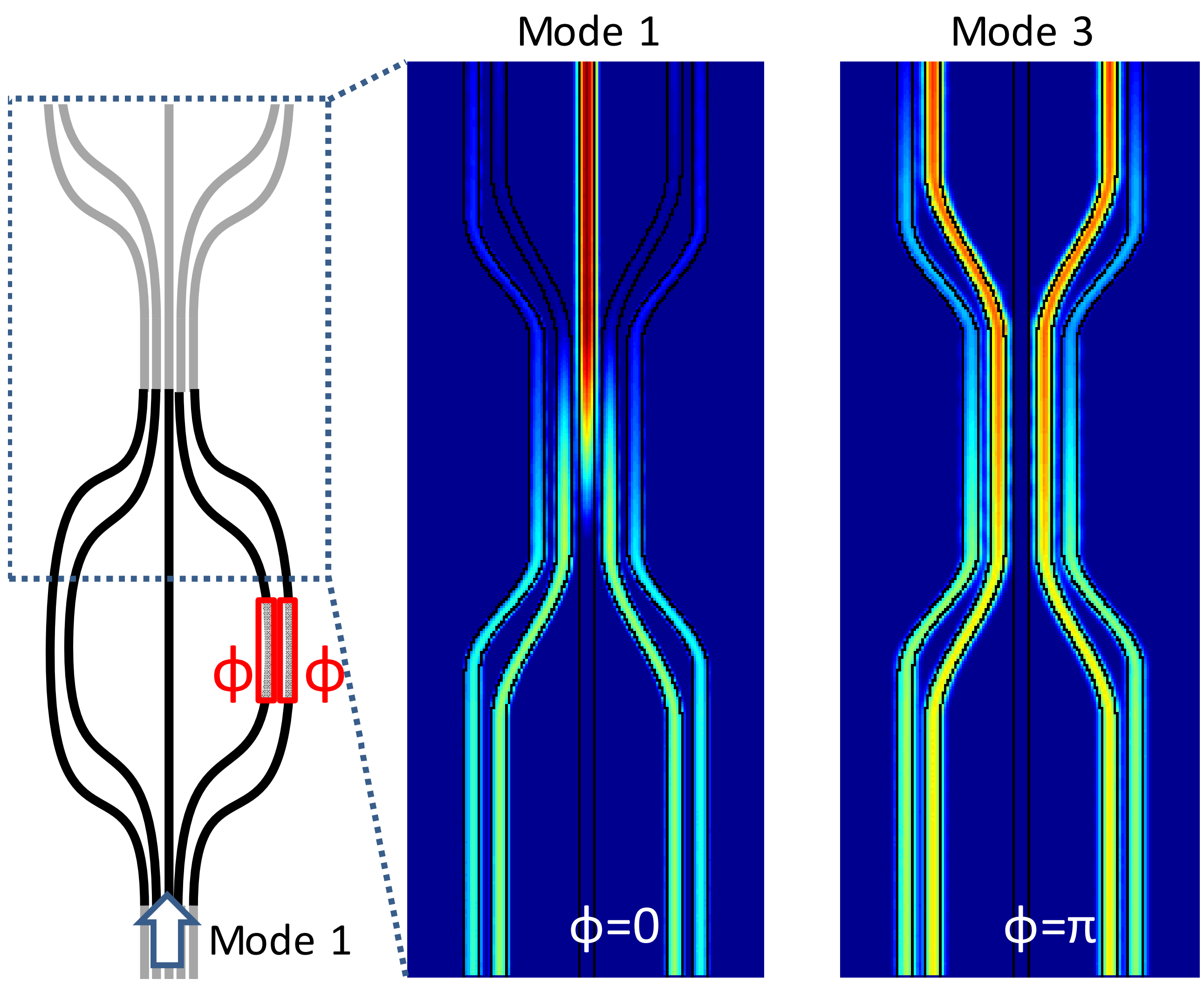
Results obtained on an array of five coupled Si waveguides with a width a [430, 440, 450, 440, 430] nm and a gap of [540, 530, 530, 540] nm

Mode Selector

Arrays of Coupled Single-mode Waveguides

Mach-Zehnder configuration with phase shifters capable of inducing a generic shift on each arm [5], to enable the generation of the desired supermode

Results obtained on an array of five coupled Si waveguides with a width a [430, 440, 450, 440, 430] nm and a gap of [550, 500, 500, 550] nm



(a) (b) (c)

Conclusions

- Mode-wavelength architecture has the potential of high scalability, low footprint, low power consumption

- Supermodes are a new domain to explore for switching and multiplexing
  - high scalability, low crosstalk, limited footprint
  - easy generation of supermodes
  - mode switching feasible with phase shifter

- Further investigation is required for developing supermode theory and components

Thank you!

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