Programmable on-chip photonic signal processor based on a microdisk resonator array

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MWP2018, Oct. 22-25, 2018
Toulouse, France

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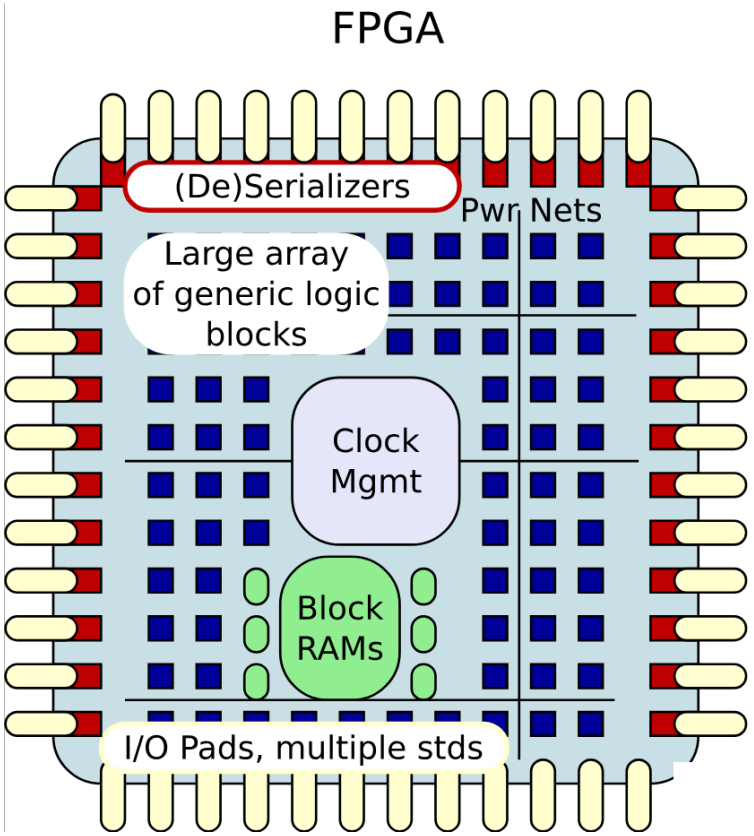
Introduction



A **field-programmable gate array** (**FPGA**) is an electronic integrated circuit designed to be configured by a customer after being manufactured.

Introduction

Can we have a photonic FPGA?

Introduction - Programmable photonic signal processors

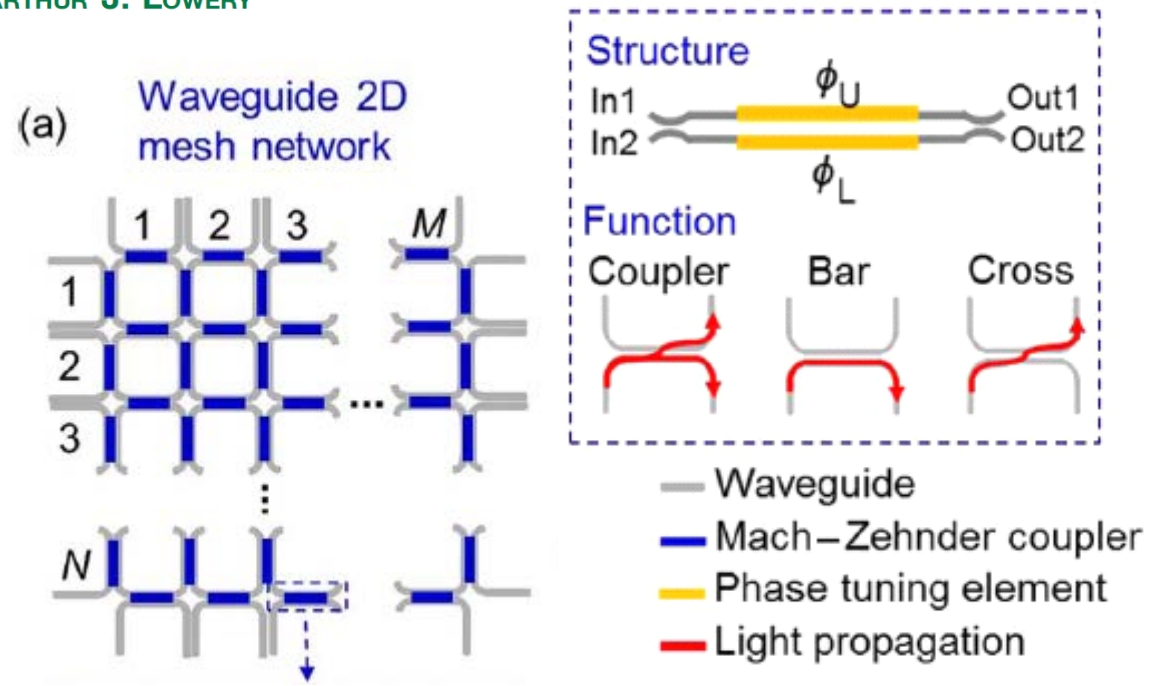
Research Article Vol. 2, No. 10 / October 2015 / Optica 854

optica

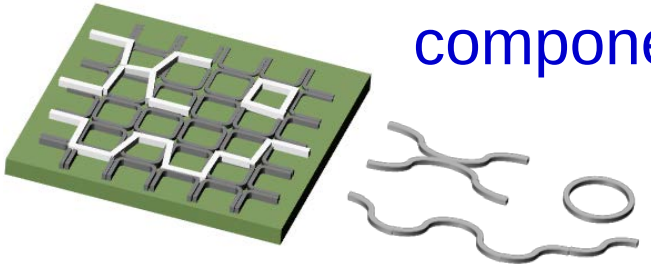
Programmable photonic signal processor chip for radiofrequency applications

Leimeng Zhuang,[1,*] Chris G. H. Roeloffzen,[2] Marcel Hoekman,[3] Klaus-J. Boller,[4] and Arthur J. Lowery[1,5]

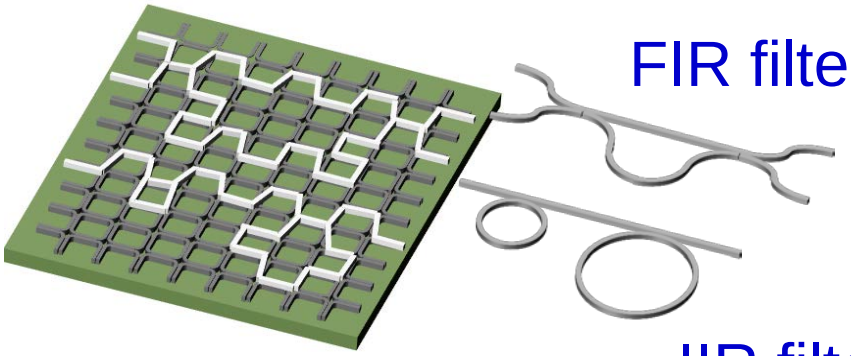
Rectangular cell



Basic circuit components

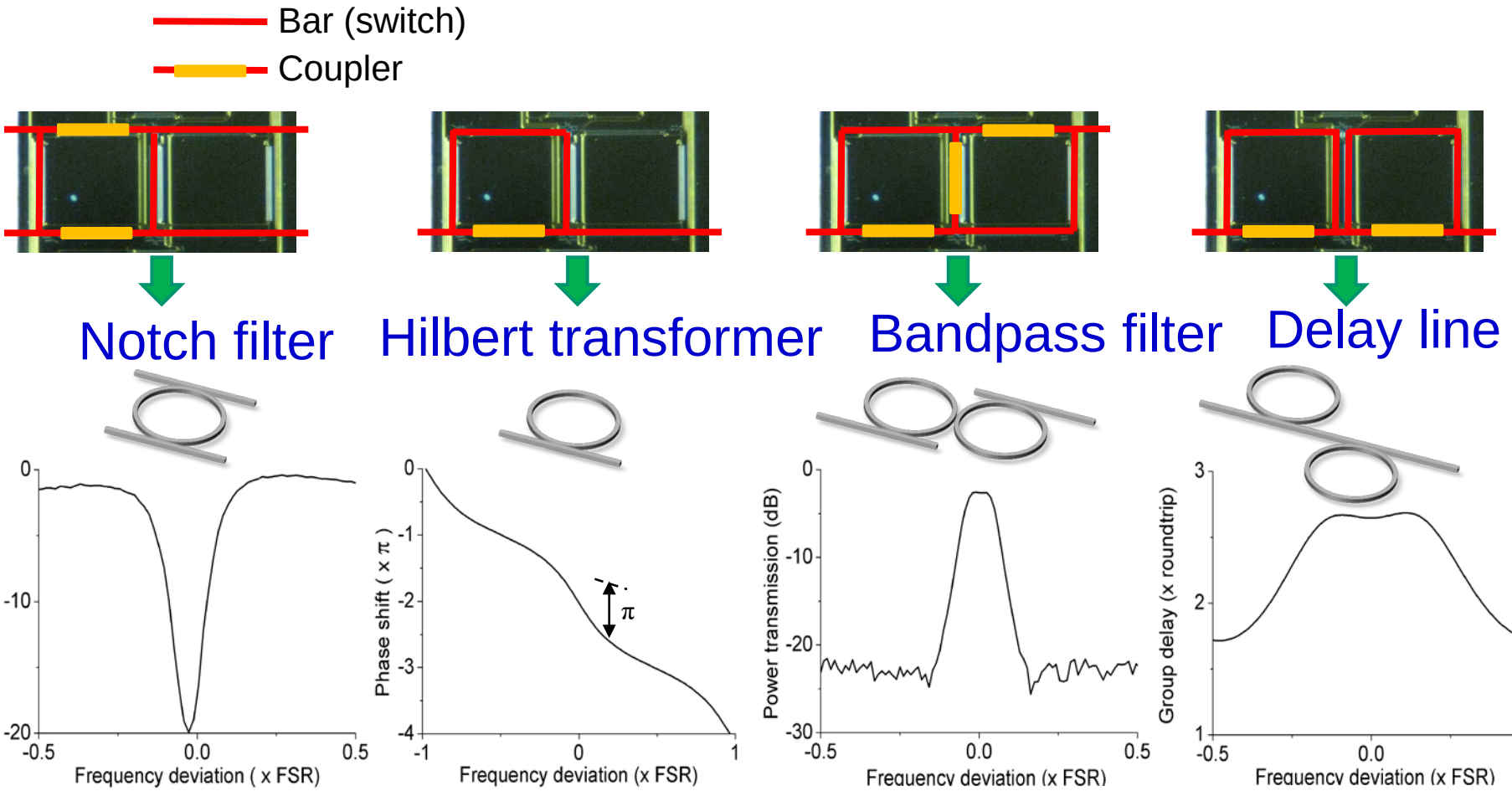


FIR filter



IIR filter

Proof-of-concept demonstration



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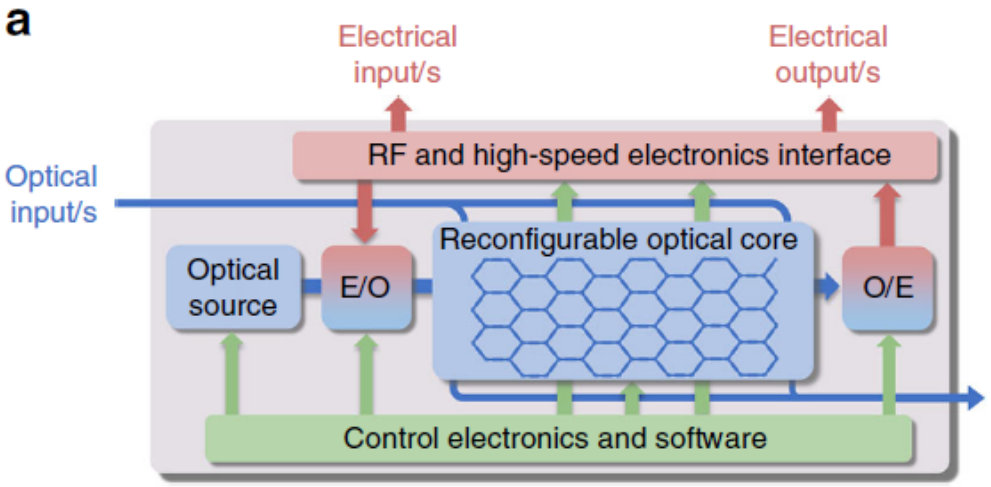
ARTICLE

DOI: 10.1038/s41467-017-00714-1 OPEN

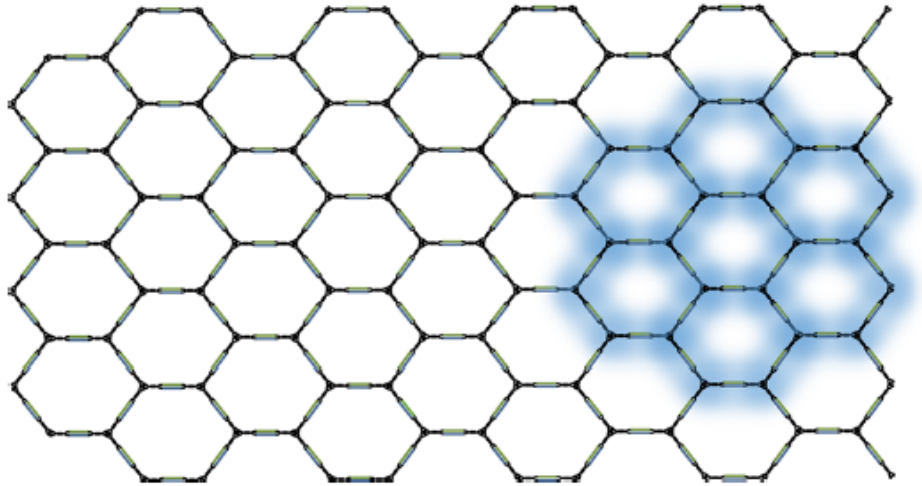
Multipurpose silicon photonics signal processor core

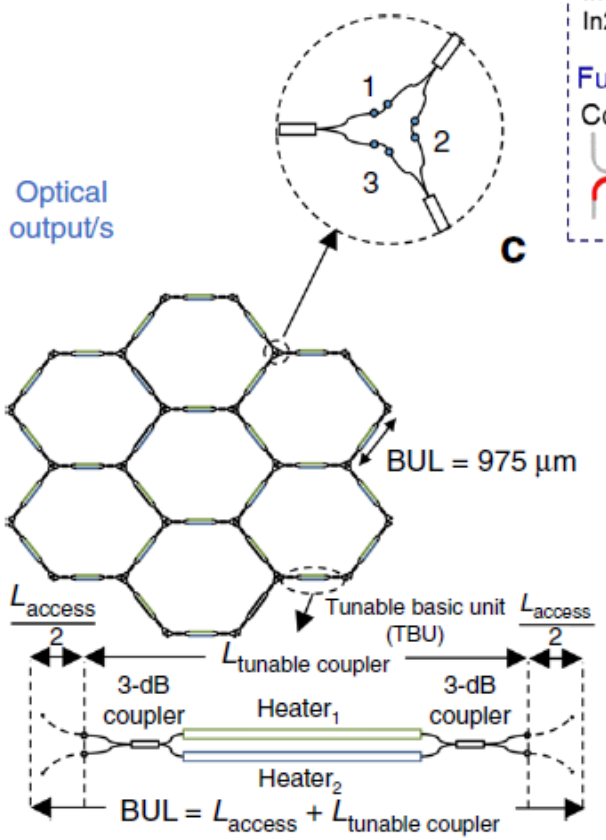
Daniel Pérez[1], Ivana Gasulla[1], Lee Crudgington[2], David J. Thomson[2], Ali Z. Khokhar[2], Ke Li[2], Wei Cao[2], Goran Z. Mashanovich[2,3] & José Capmany[1]

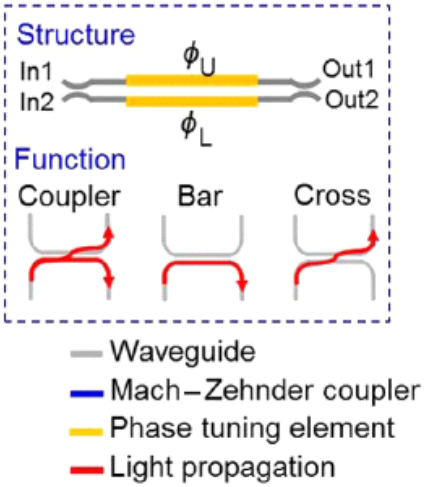
Introduction - Programmable photonic signal processors



Hexagonal cell

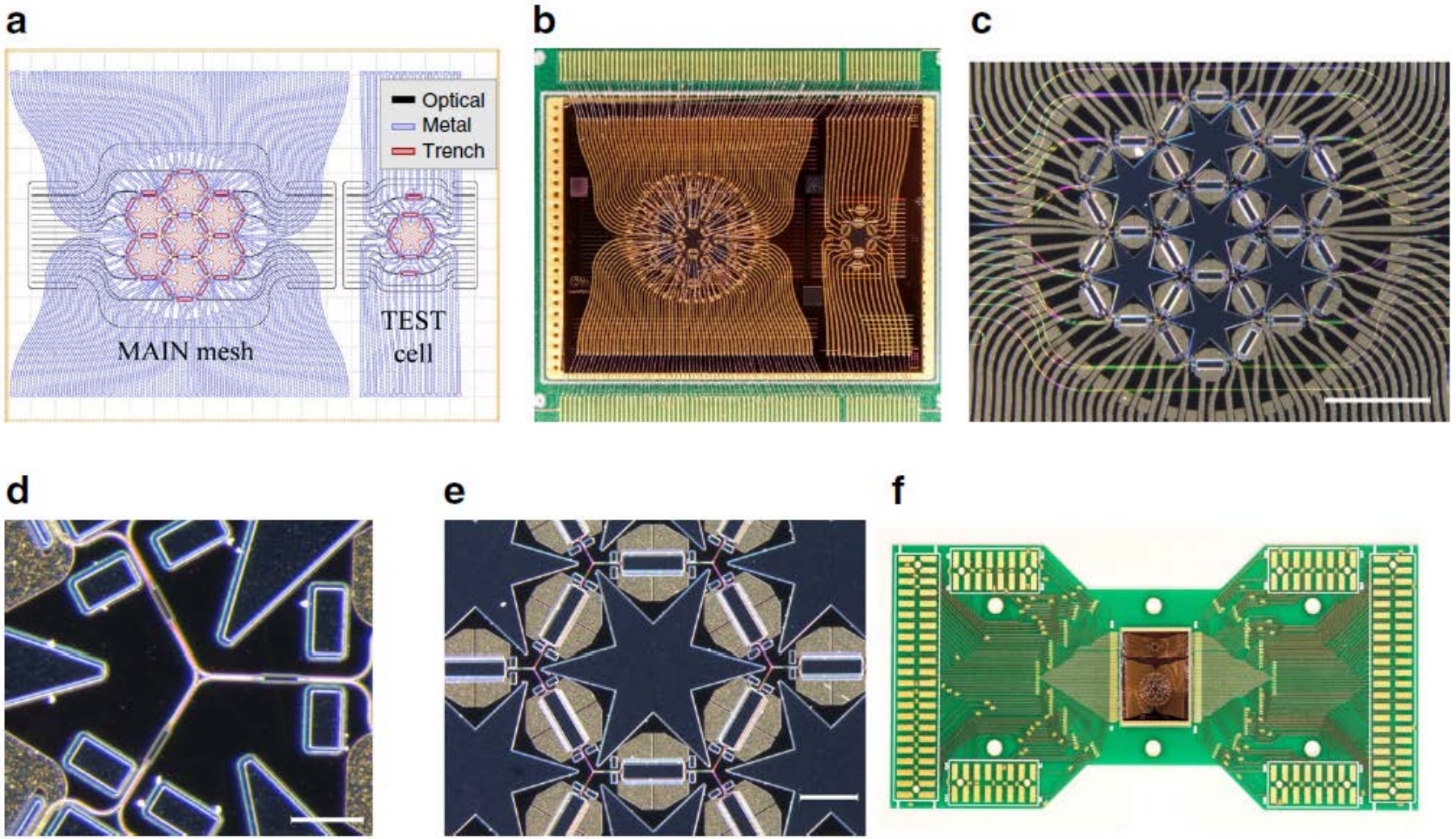




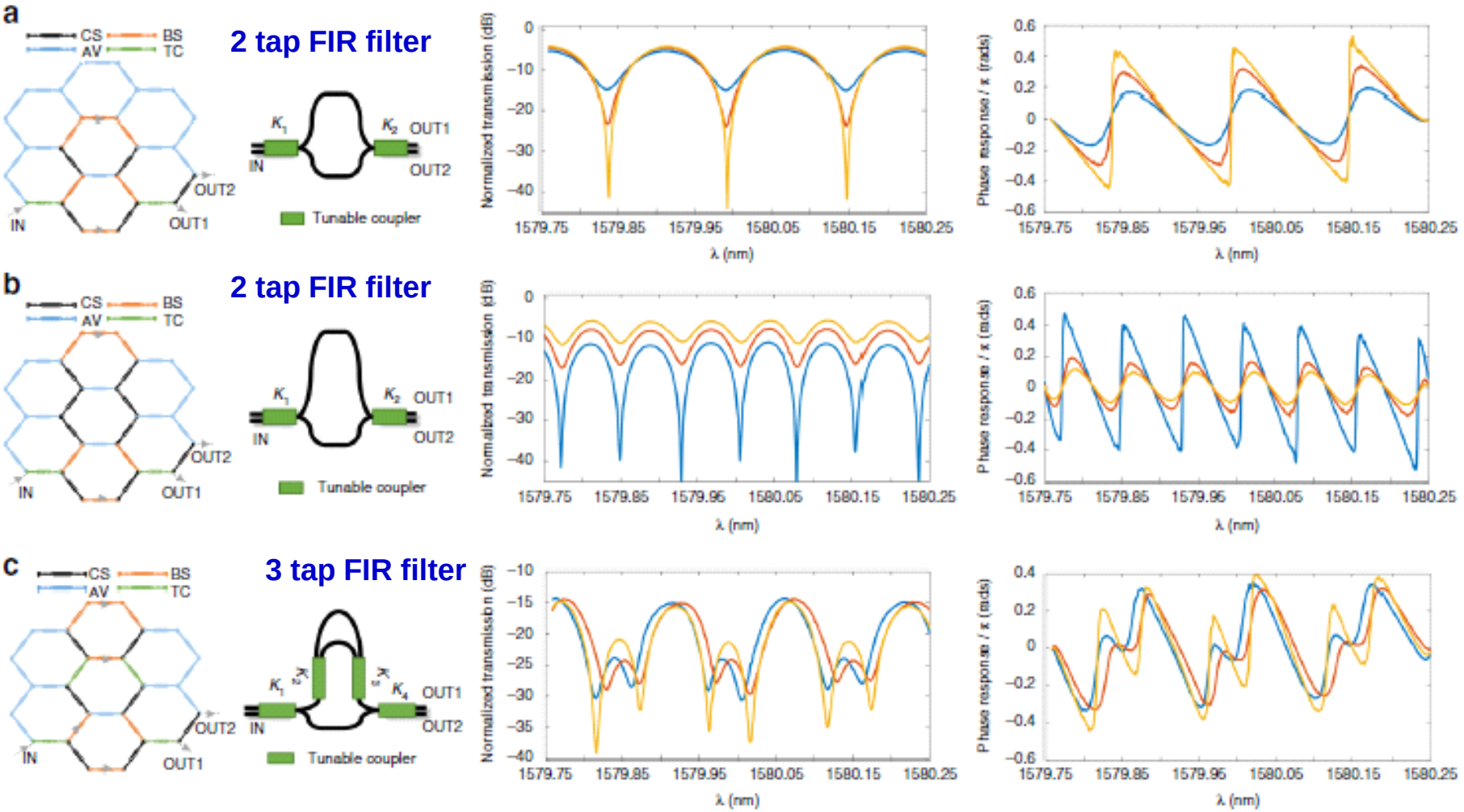


D. Pérez, I. Gasulla, L. Crudgington, D. Thomson, A. Khokhar, K. Li, W. Cao, G. Mashanovich and J. Capmany, Nature Commun., 8, 636 (2017).

Introduction - Programmable photonic signal processors



Introduction - Programmable photonic signal processors



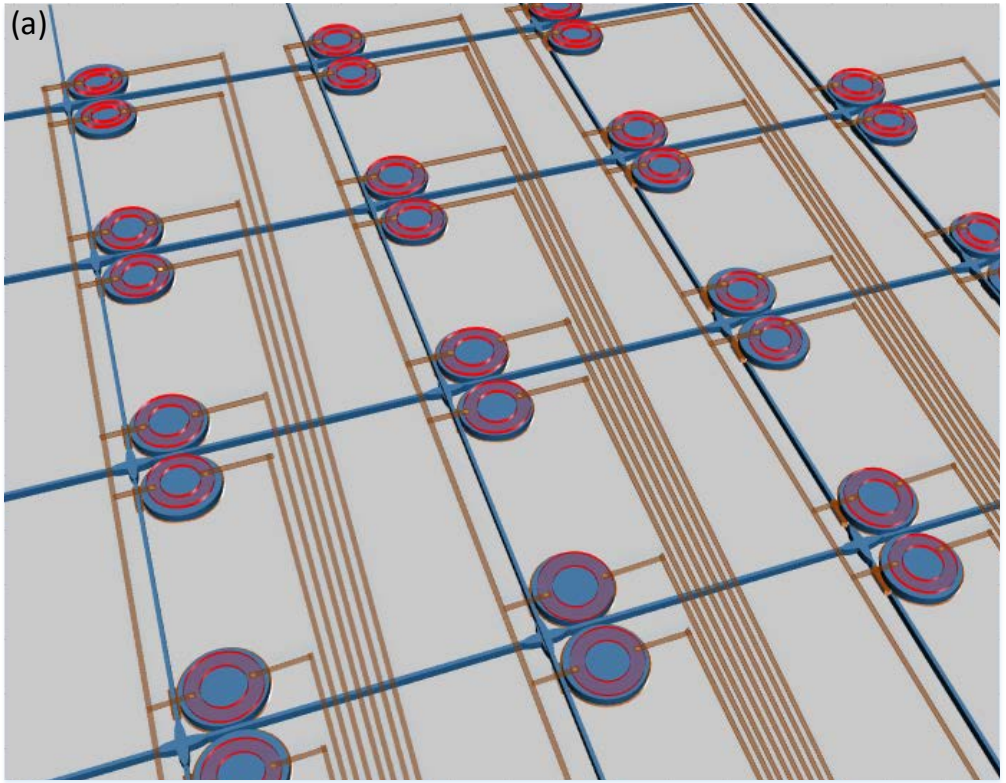
Introduction

The architectures reported in the two previous papers

- has large size and high power consumption – small-scale integration
- less flexibility in reconfigurability

Solution: to change the rectangular or hexagonal cells to microdisk cells.

A disk-based large scale photonic FPGA



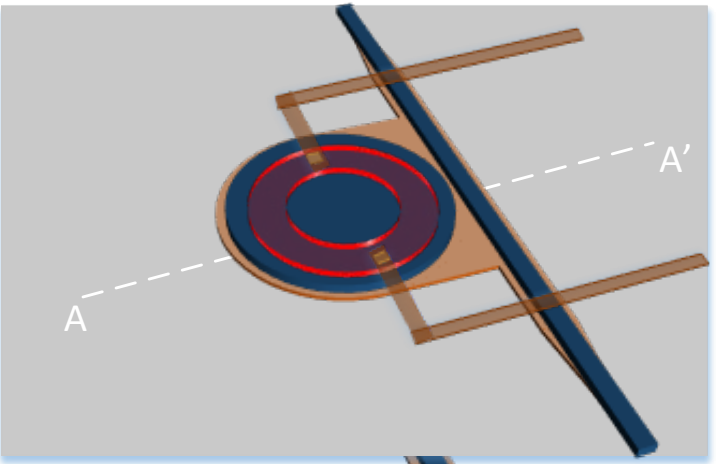
Wire waveguide

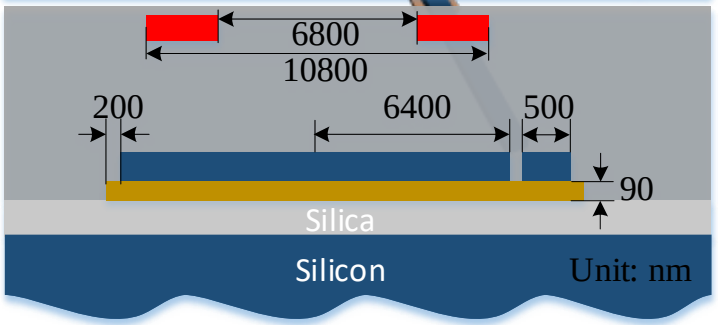
Waveguide crossing

Micro-disk resonator

Metallic line

Metallic micro-heater





Rib waveguide

Slab waveguide

Thermal resistor

Via

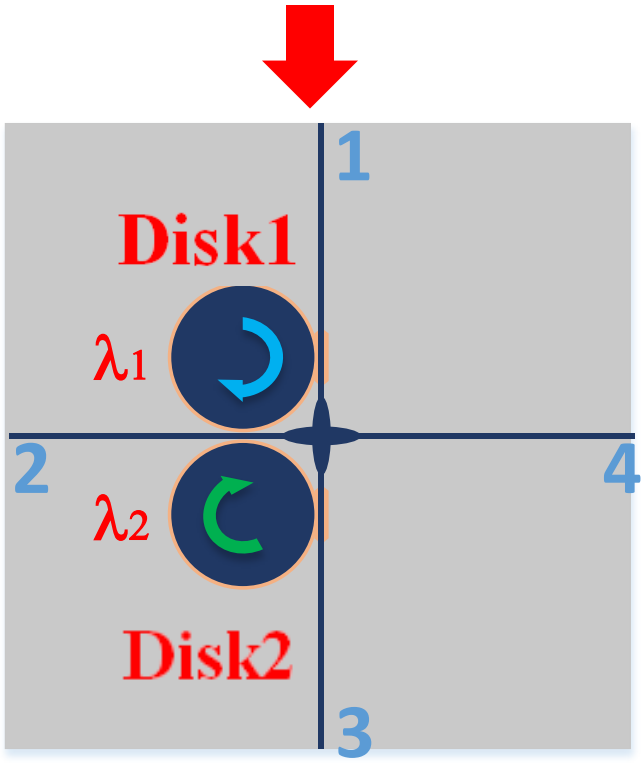
Electrode

8 x 8 disk mesh network

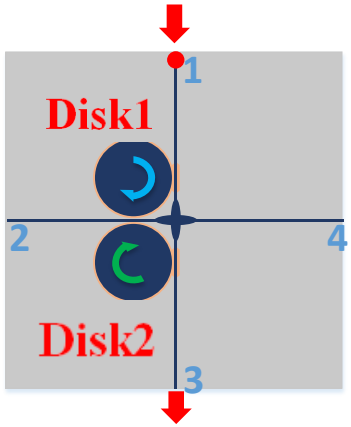
Much smaller size

Operation – signal routing

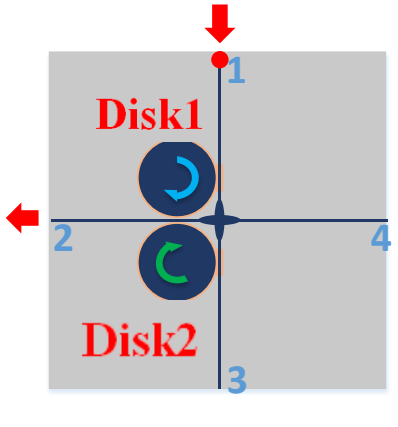
Input optical signal λ_o



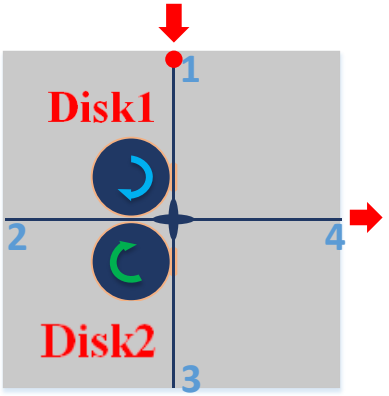
$\lambda_o \neq \lambda_1 \neq \lambda_2$



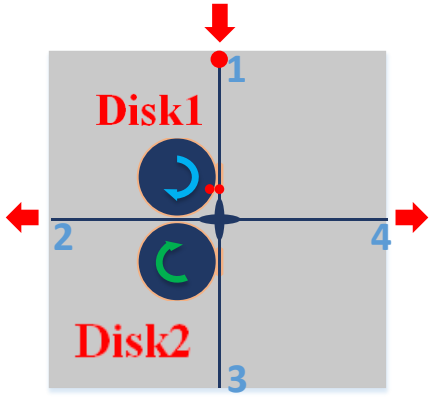
$\lambda_o = \lambda_1 \neq \lambda_2$



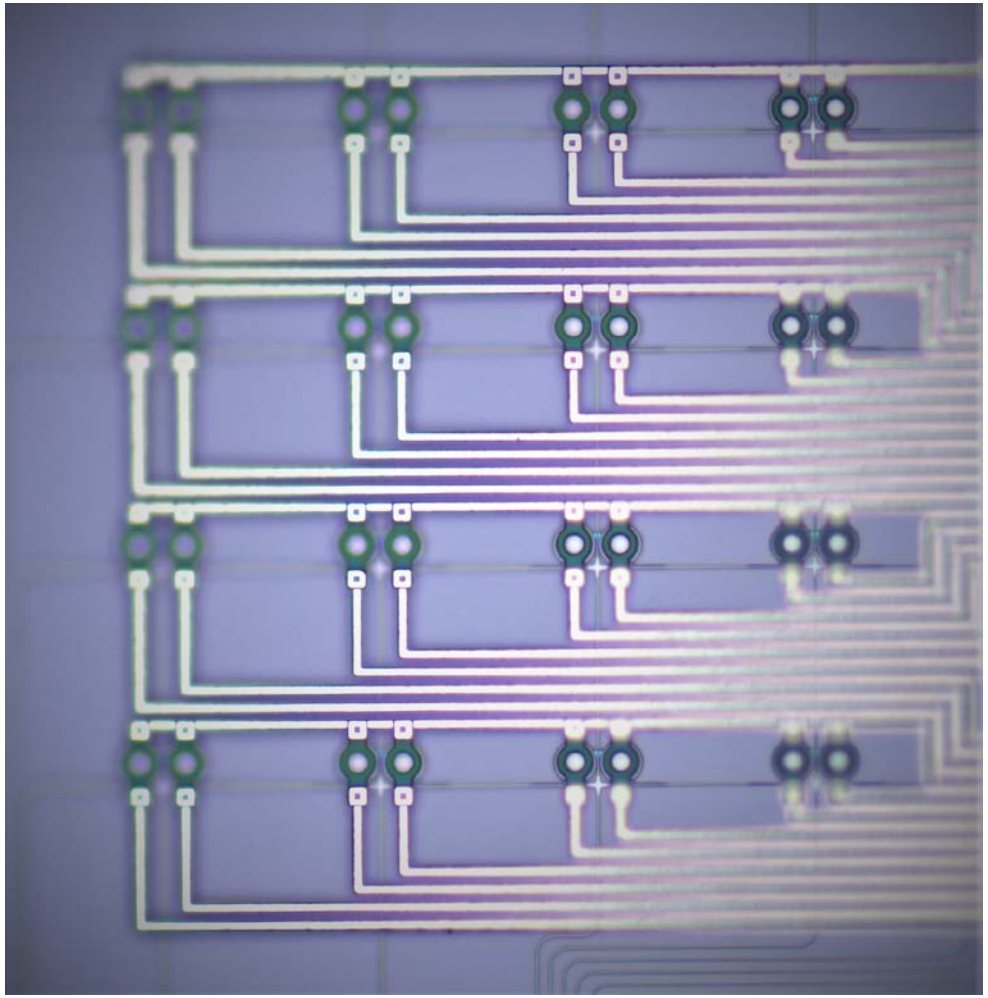
$\lambda_o = \lambda_2 \neq \lambda_1$

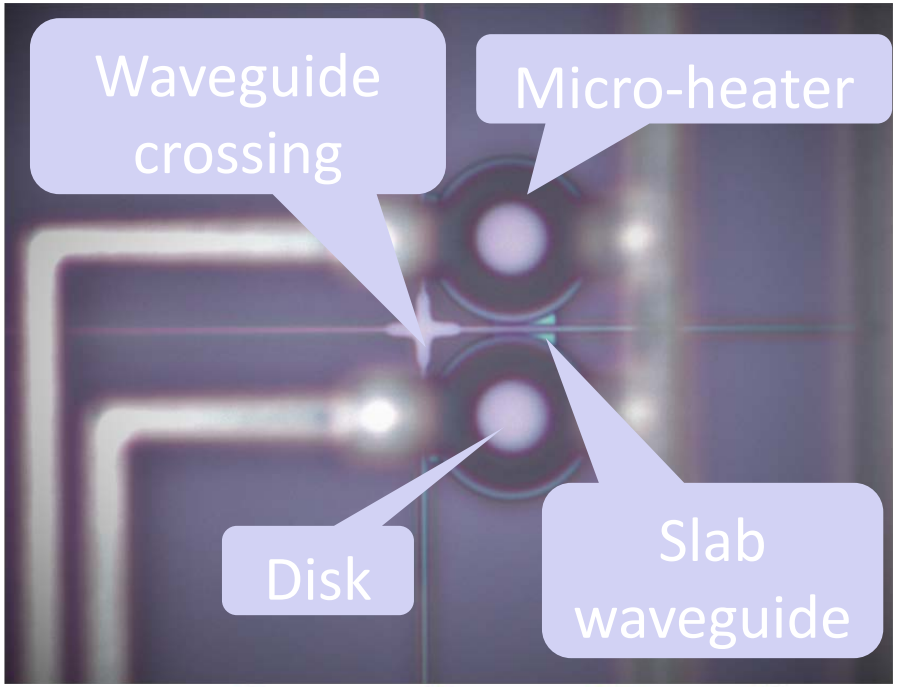


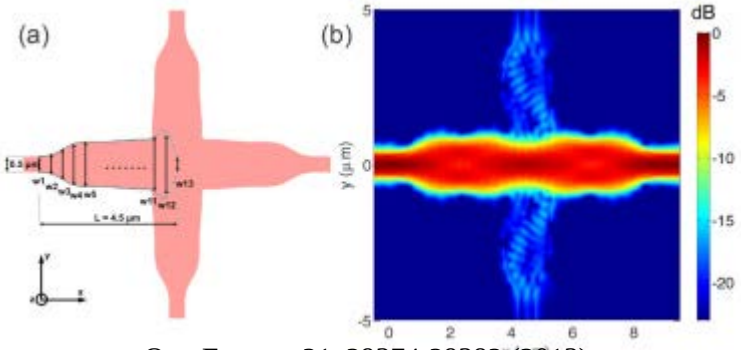
$\lambda_o = \lambda_1 = \lambda_2$



Fabricated device



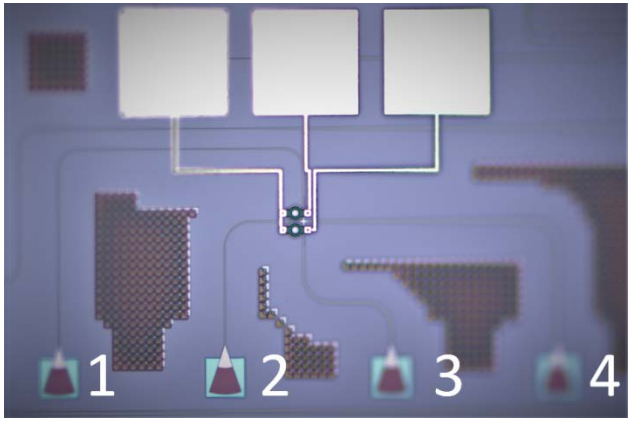


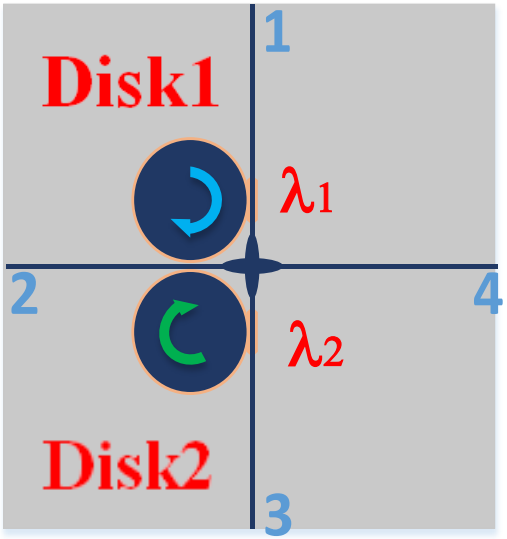


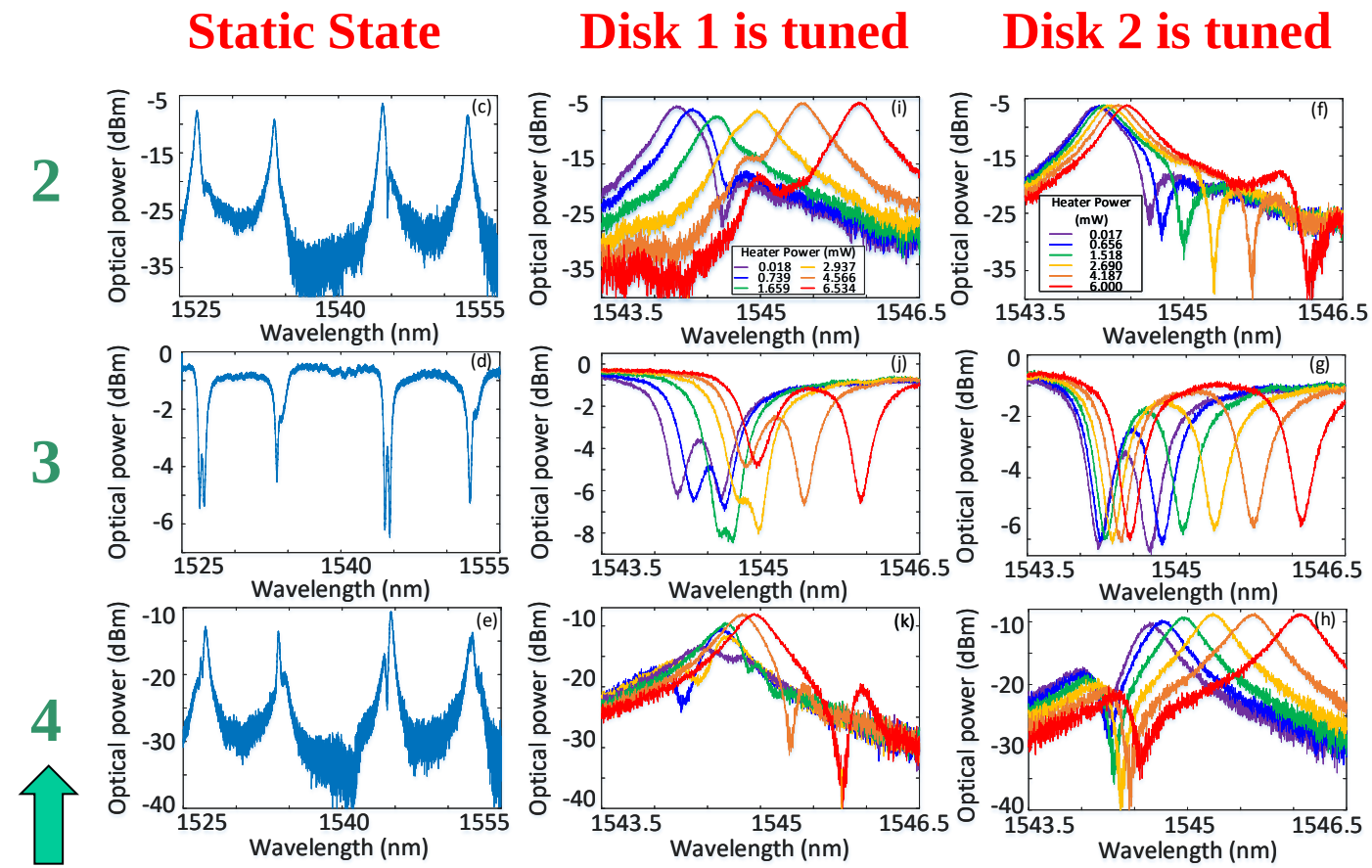
8 x 8 disk mesh network

Opt. Express 21, 29374-29382 (2013)

Measurements

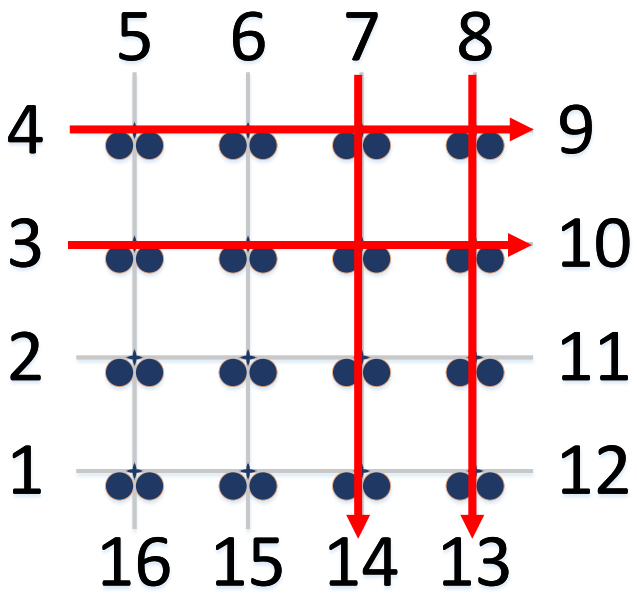


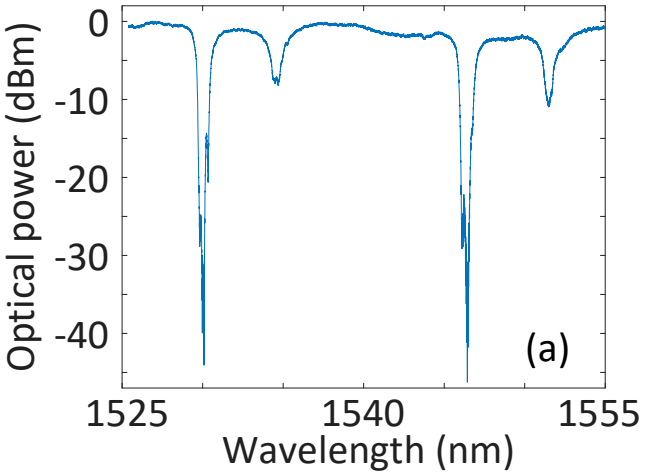


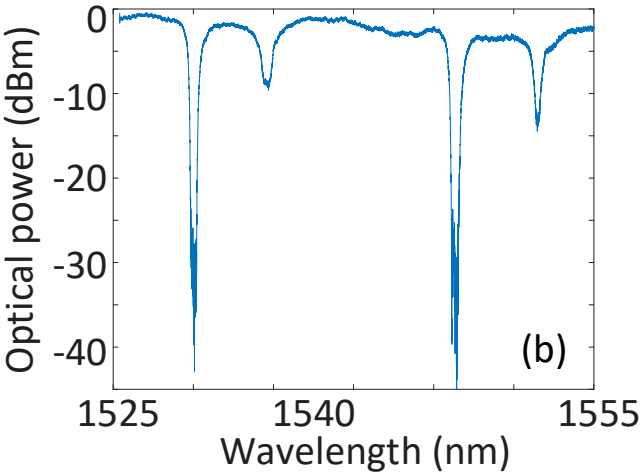


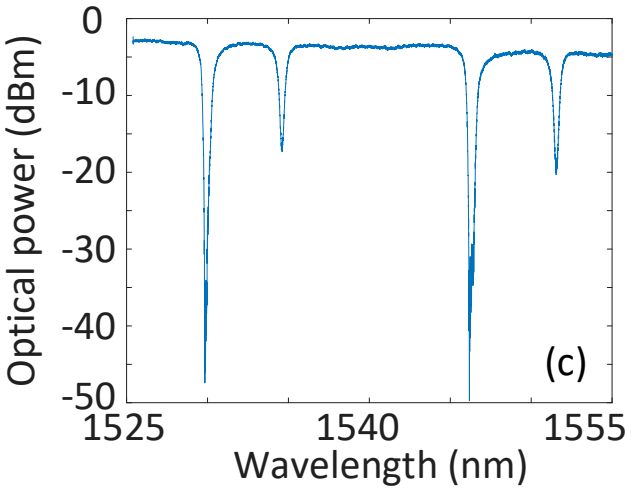
Measured by Luna OVA

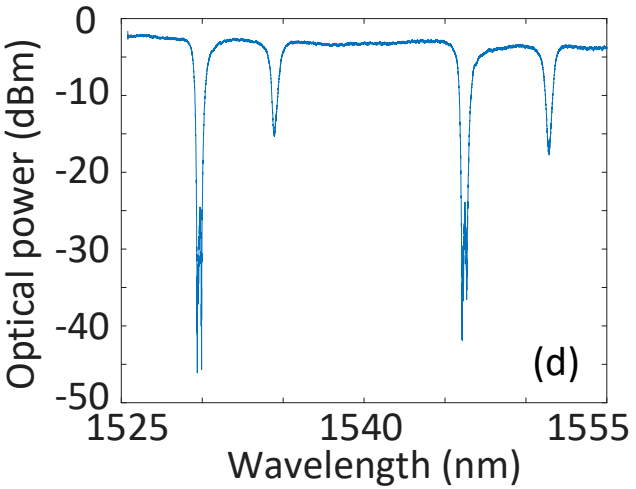
Measurements



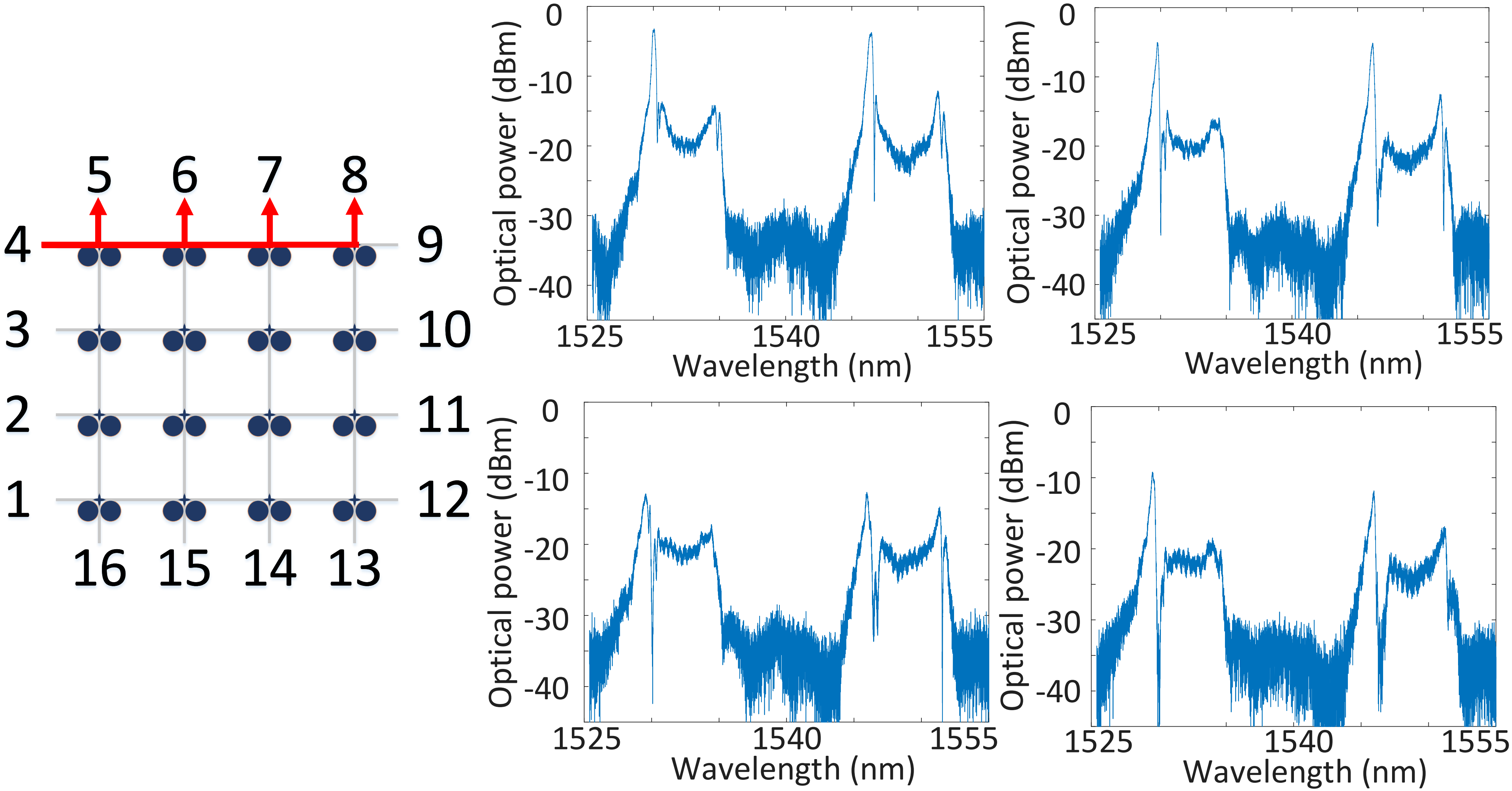






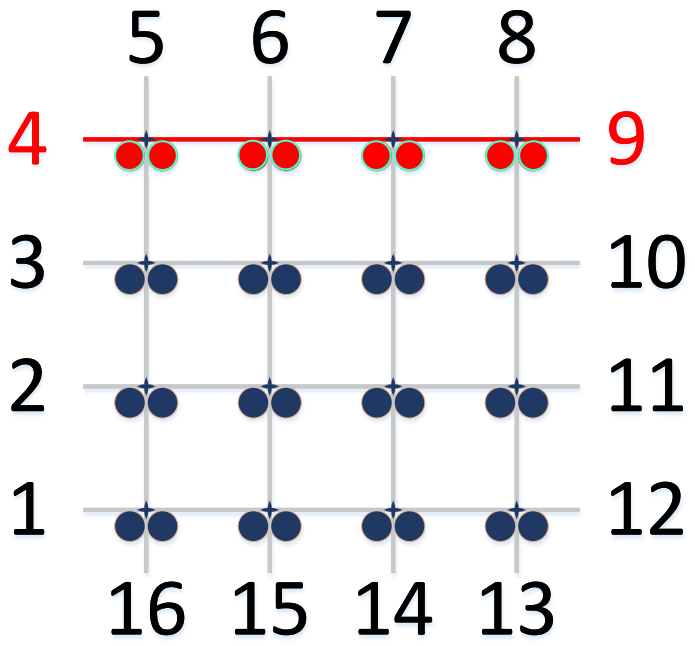


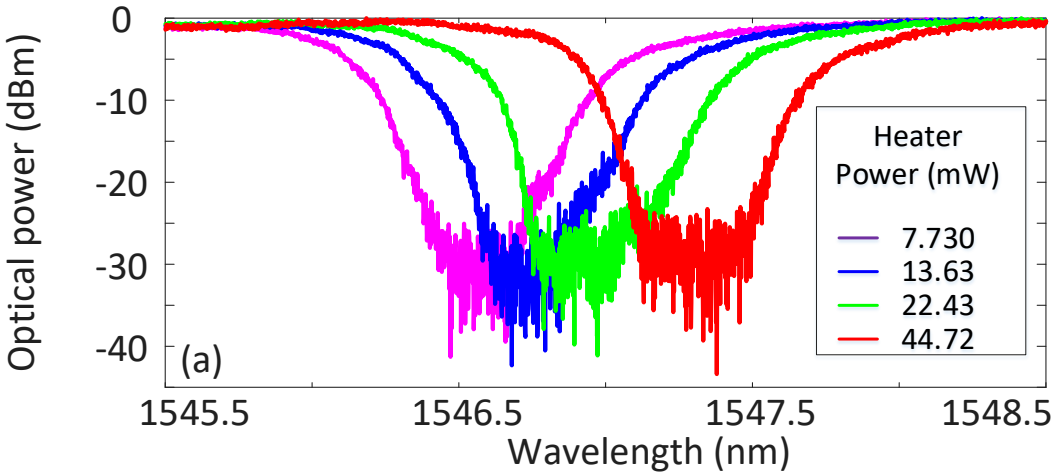
Measurements

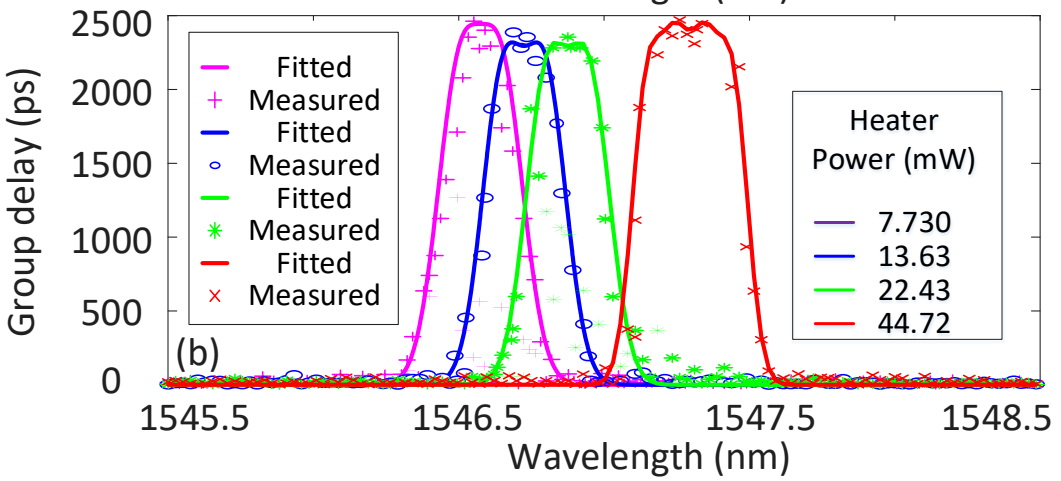


Delay-line demonstration

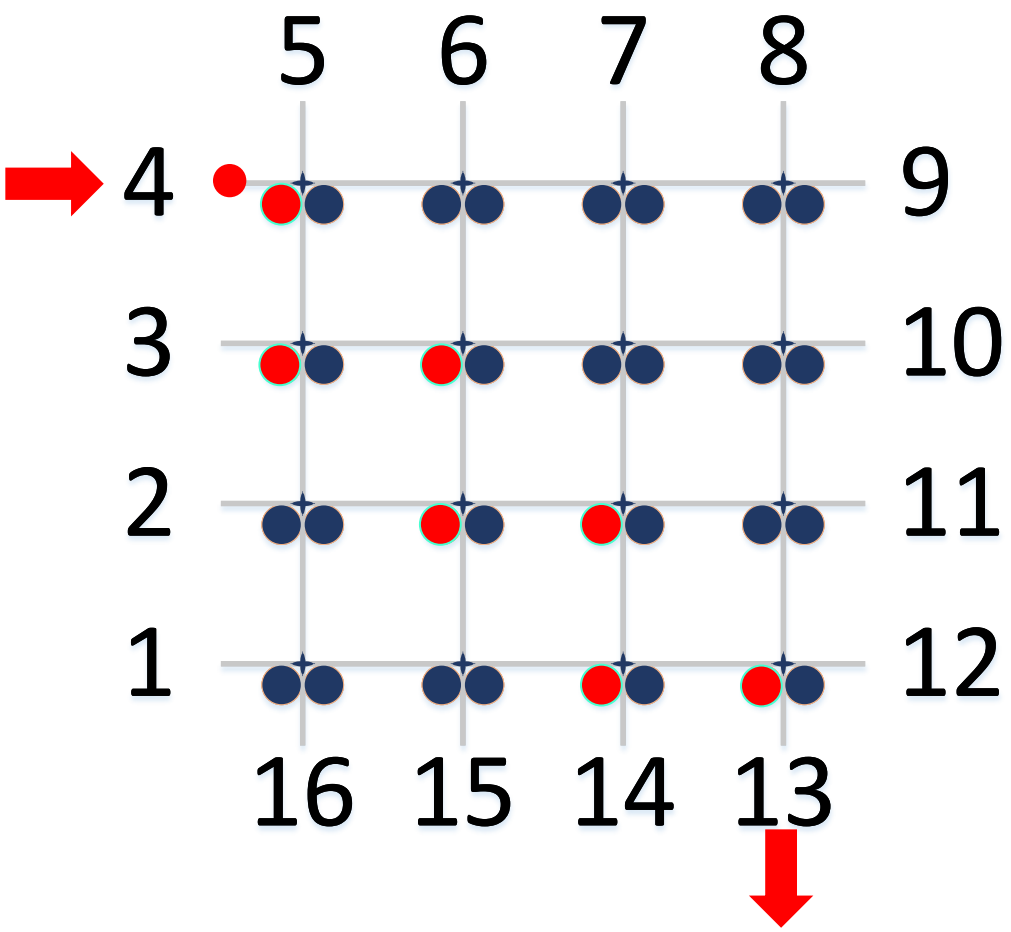
An on-chip tunable optical delay line based on 8 cascaded MDRs in all-pass filter configuration

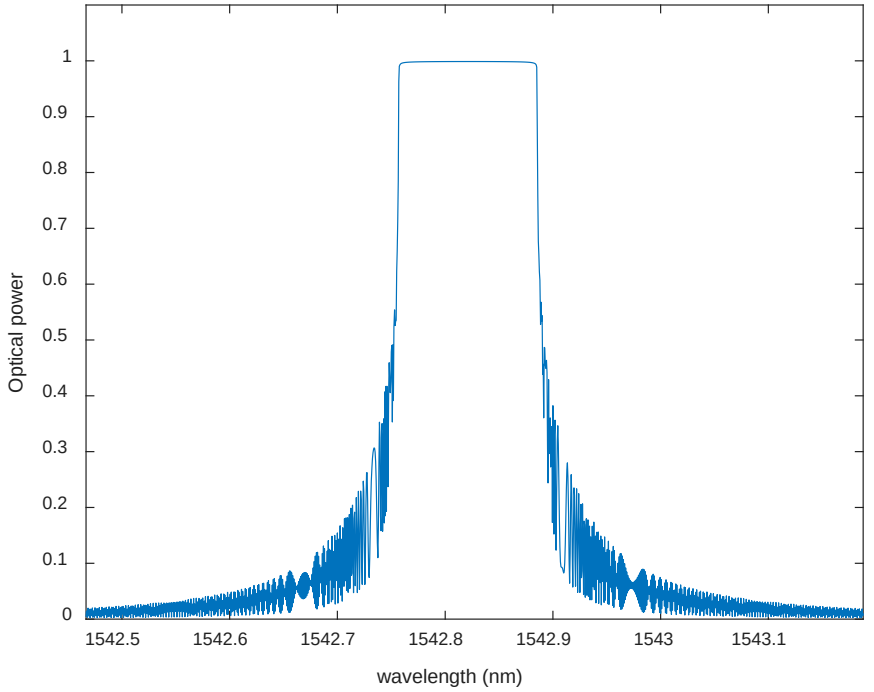


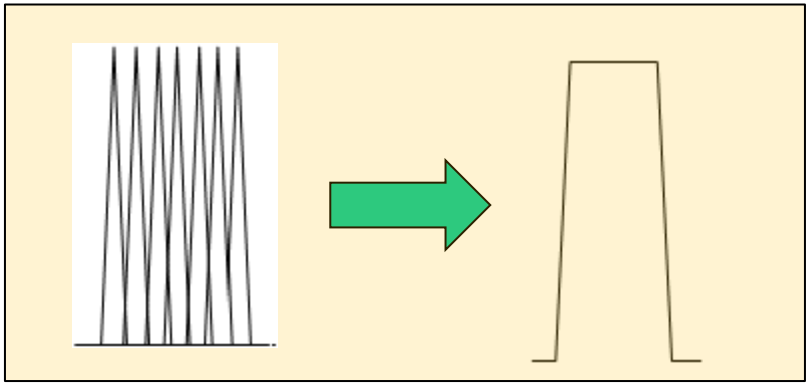




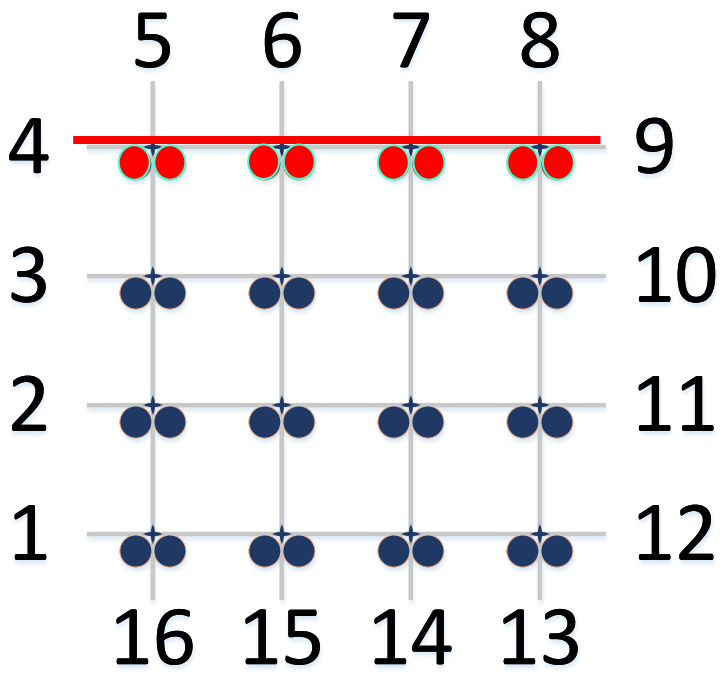
Discussion: as a flat-top bandpass optical filter





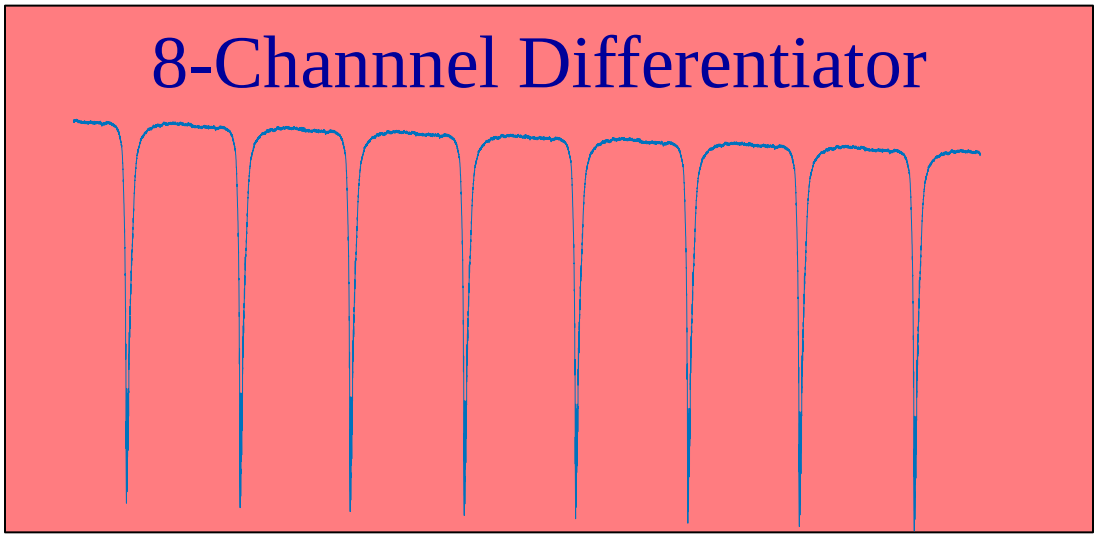


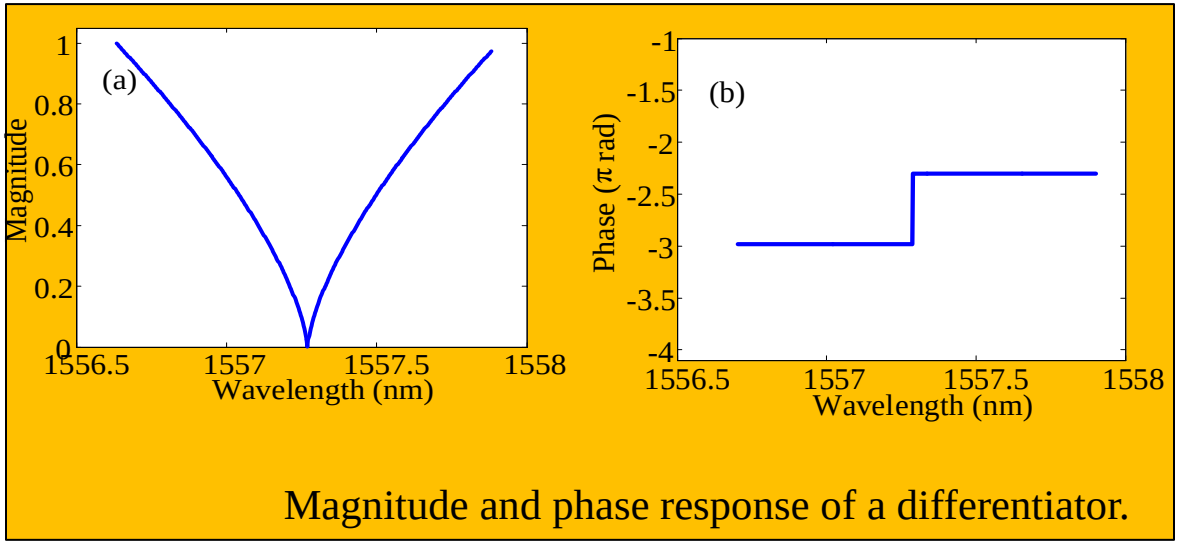
Discussion: as a multichannel differentiator - WDM systems



$$y(t) = \frac{dx(t)}{dt}$$

$$H(j\omega) = j(\omega - \omega_0) = \begin{cases} e^{j\frac{\pi}{2}}|\omega - \omega_0| & \omega > \omega_0 \\ e^{-j\frac{\pi}{2}}|\omega - \omega_0| & \omega < \omega_0 \end{cases}$$

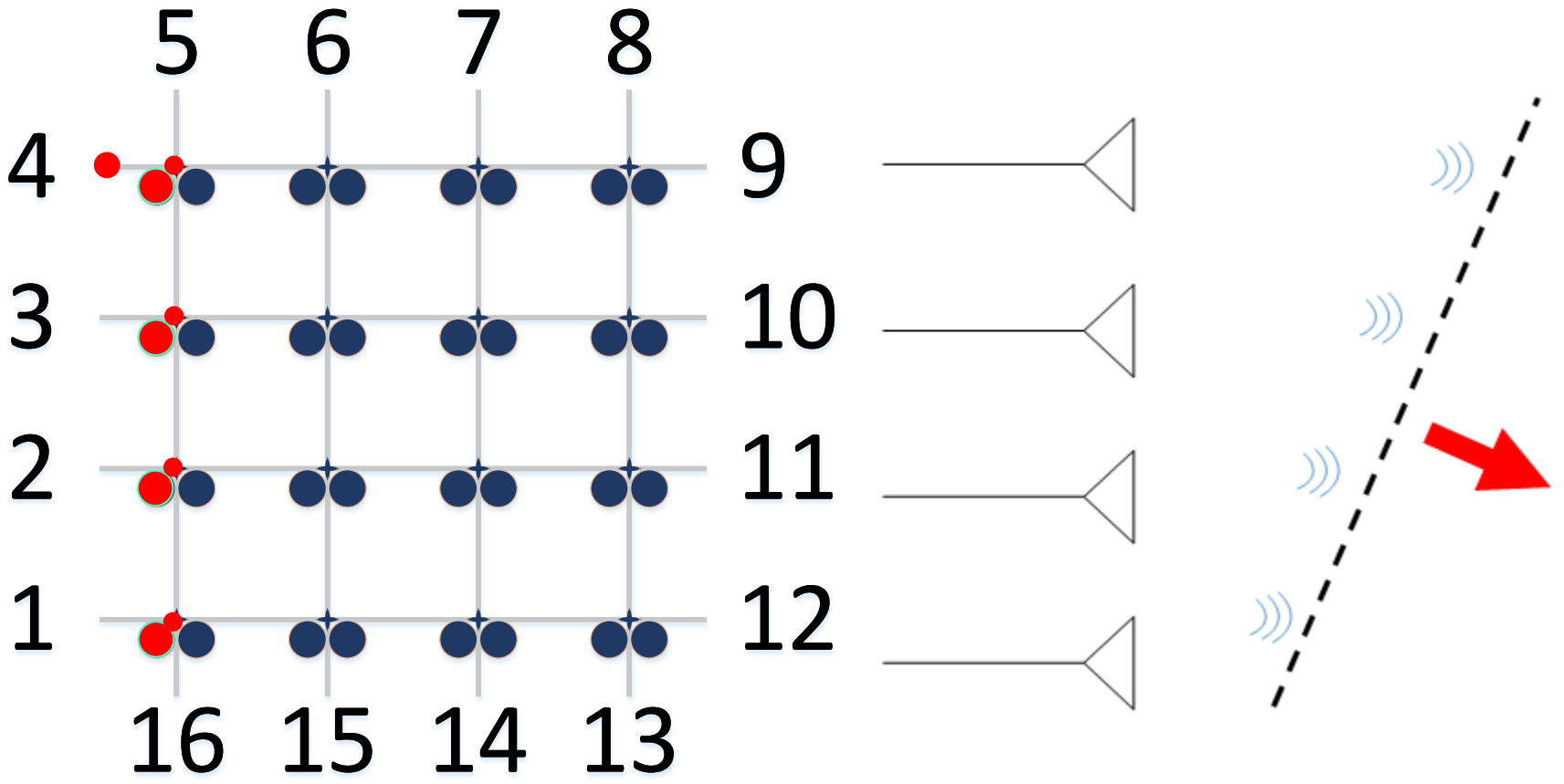




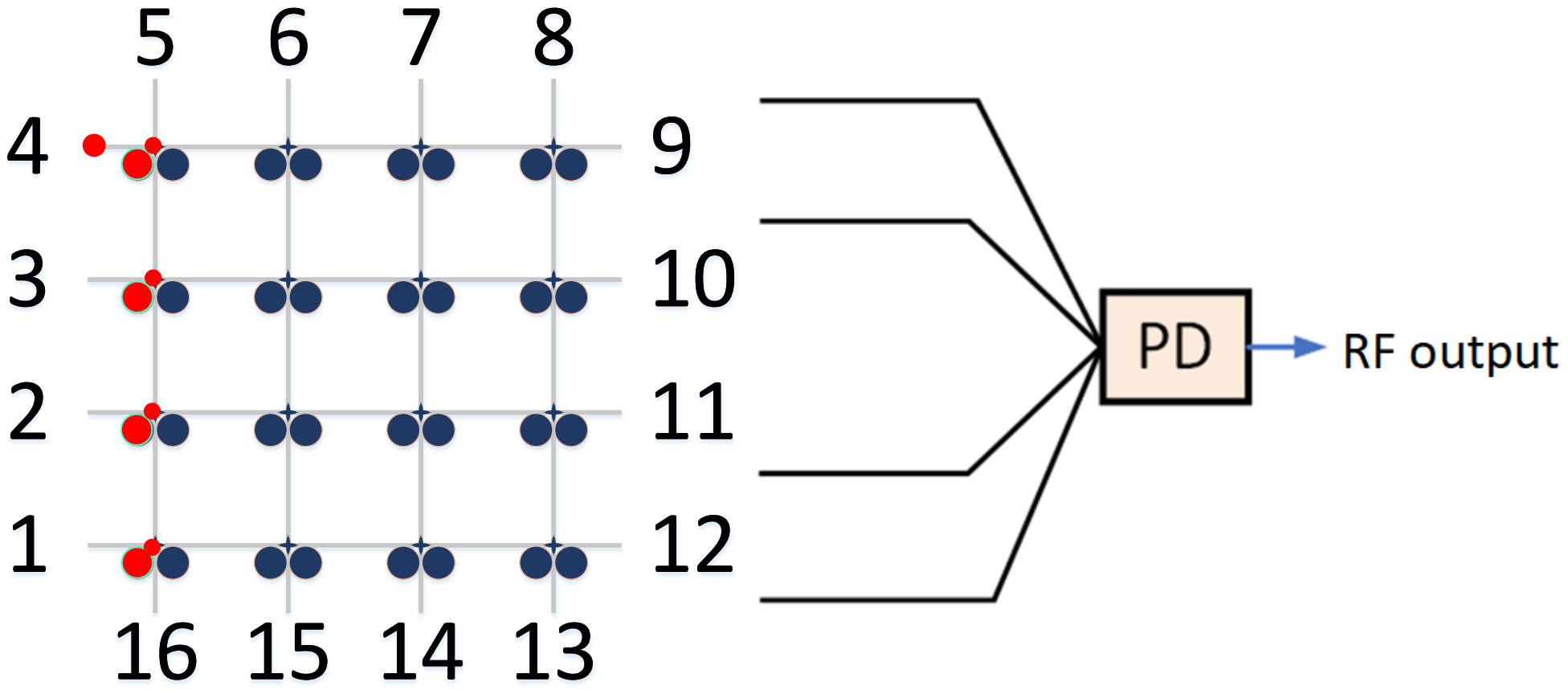
Magnitude and phase response of a differentiator.

M. Li, D. Janner, J. P. Yao, and V. Pruneri, *Opt. Express*, vol. 17, no. 22, pp. 19798-19807, Oct. 2009.

Discussion: as an optical beamforming network



Discussion: as a delay line FIR filter



Conclusion

- **A programmable photonic signal processor based on a silicon photonic microdisk array can be flexibly reconfigured and have a smaller size – suitable for large scale integration.**

- **The processor can be reconfigured to achieve diverse signal processing functions including time delay, temporal differentiation, true time delay beamforming, and microwave delay line filtering – an optical FPGA.**

CMC Microsystems

NSERC Si-EPIC program

Thank you and welcome to MWP2019 in Ottawa