Reconfigurable Spectral Phase Encoder in a Silicon Photonics Platform

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IX. ITG-Workshop, Photonische Komponenten und Mikrosysteme, Nürnberg
11 May 2011

Overview

- Introduction
- Proposed method
- Designed structure
- Discussion

Introduction

- Integrated optics: Miniaturization and integration of optical components
  - Low energy consumption
  - High data rate
  - Very low production costs
- Materials
  - III / IV semiconductors
  - Silicon

Introduction

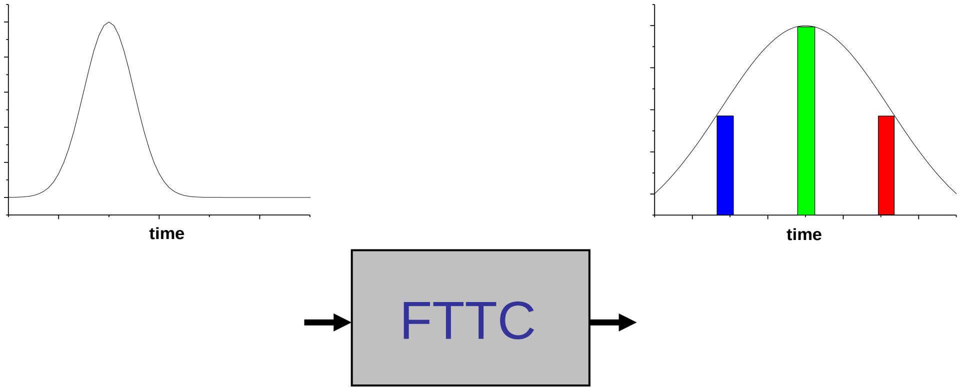
- Advanced silicon microelectronic technology
- Fabrication of silicon photonics circuits in a CMOS production line
- Merging of optics and electronics on one chip

Applications of spectral phase encoder

- Optical delays
- Dispersion production
- Pulse shaping
- Packet compression
- Jitter compensation
- ….

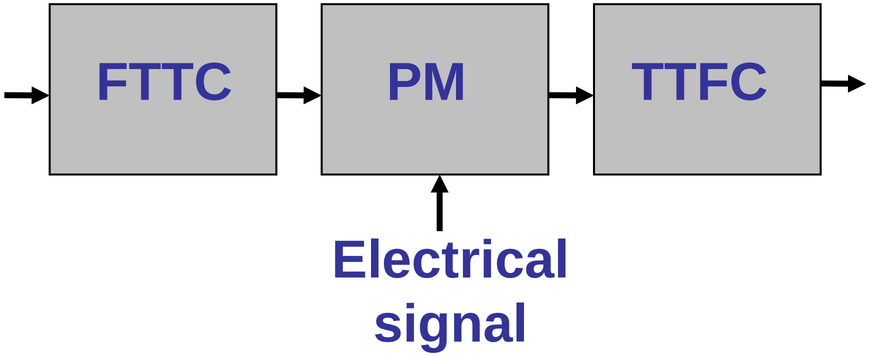
Frequency-to-time conversion (FTTC)

- In a dispersive media, different spectral components of the incoming signal travel with different speed.
- Using a media with pure second order dispersion: we can have a linear mapping between the frequency and time.

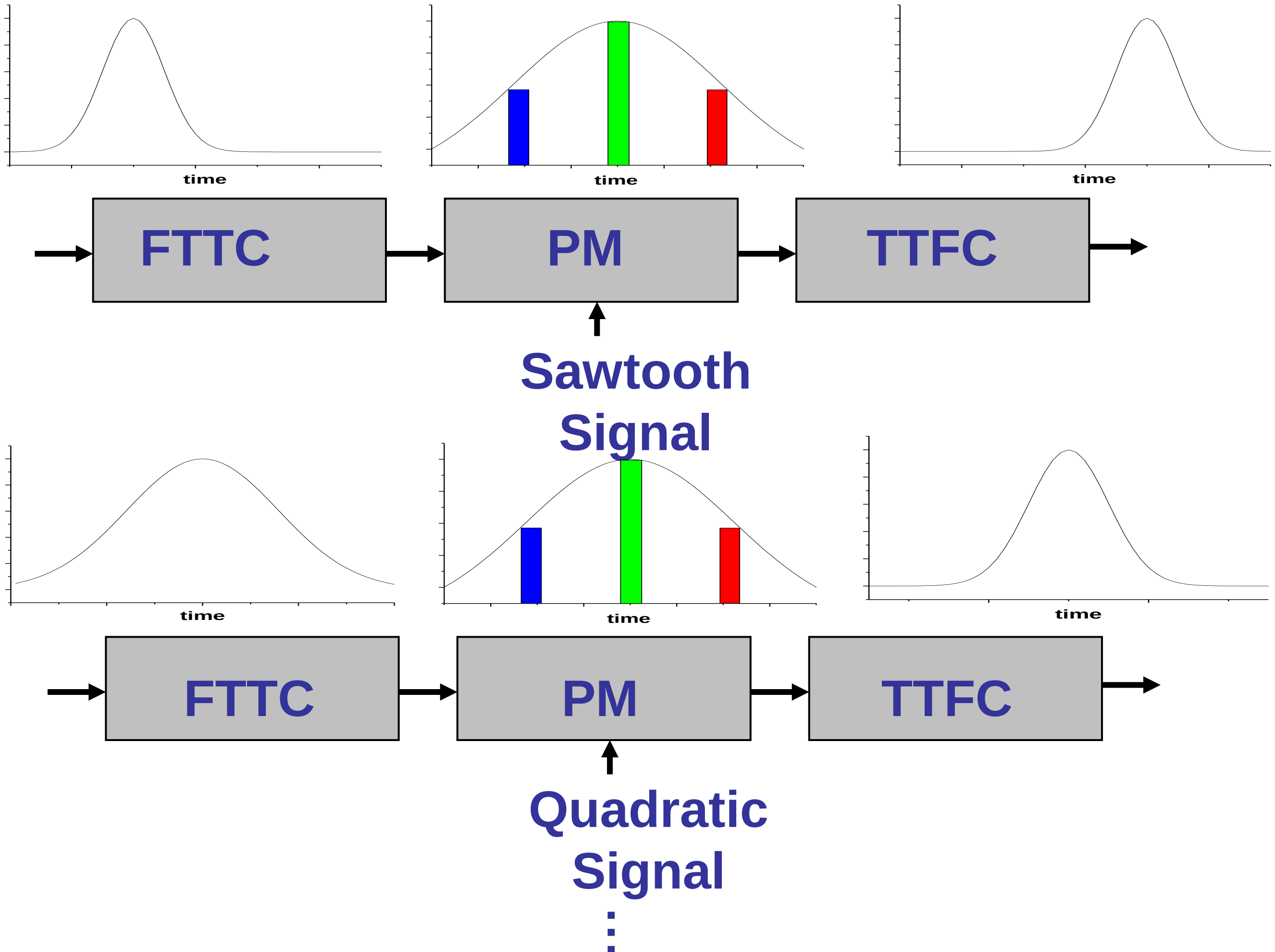


Schematic diagram of the structure

- The different spectral components of the incoming signal (which have been mapped into different delays) can be manipulated simply by a phase modulator (PM).
- Another dispersive media with dispersion equal to the dispersion of the FTTC but with inverted sign is used for time-to-frequency conversion (TTFC)



Schematic diagram of the structure



Generated dispersion

- The produced group delay (T_g), accumulated dispersion (AD) and accumulated dispersion slope (AS) can be expressed as:

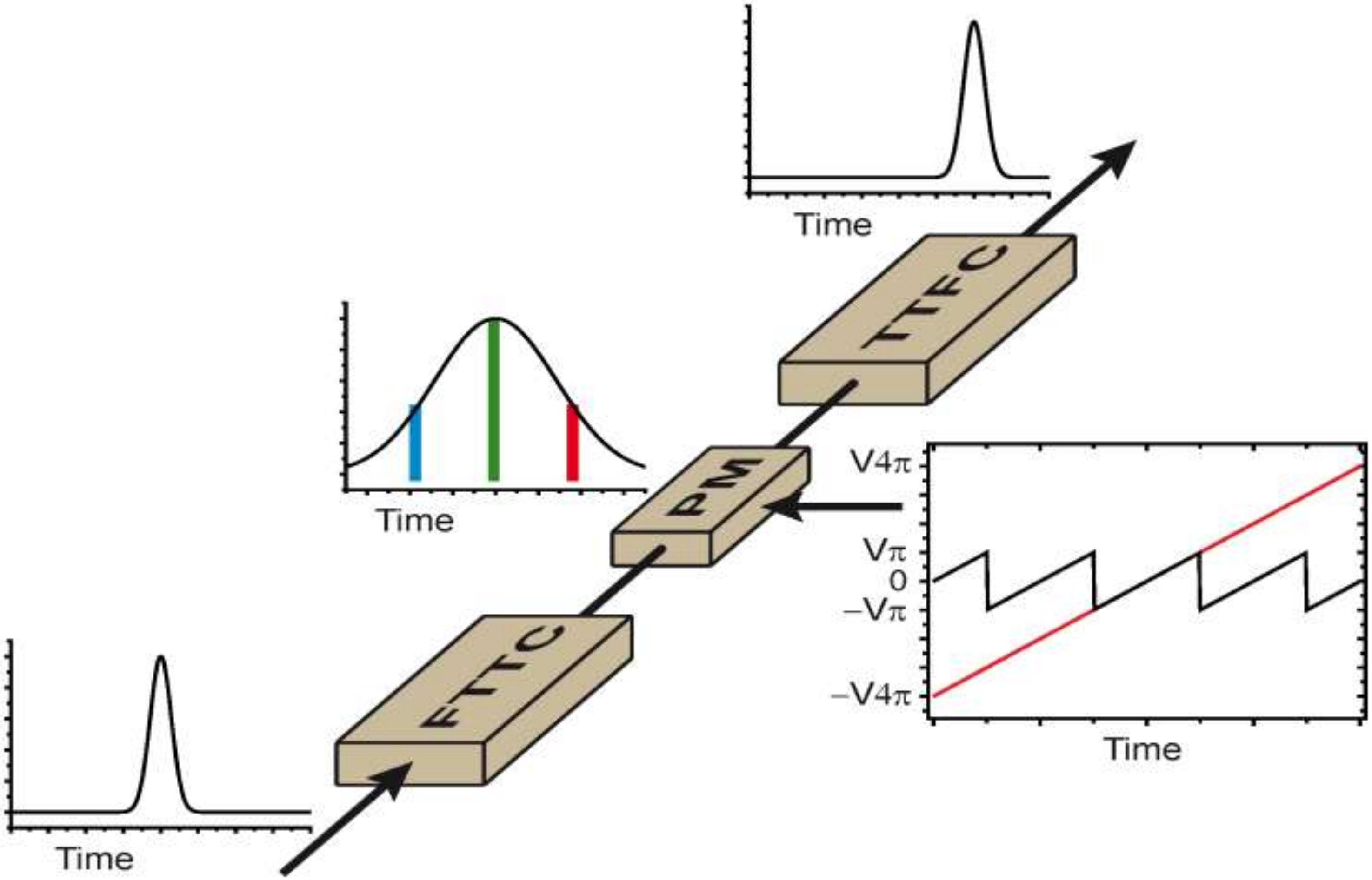
$$T_g = \frac{\partial\varphi}{\partial\omega} = \frac{\partial\varphi}{\partial t}\frac{\partial t}{\partial\lambda}\frac{\partial\lambda}{\partial\omega} = \frac{\partial\varphi}{\partial t} D \frac{\lambda_0^2}{2\pi c}$$

$$AD = \frac{\partial T_g}{\partial\lambda} = \frac{\partial^2\varphi}{\partial t^2} D^2 \frac{\lambda_0^2}{2\pi c}$$

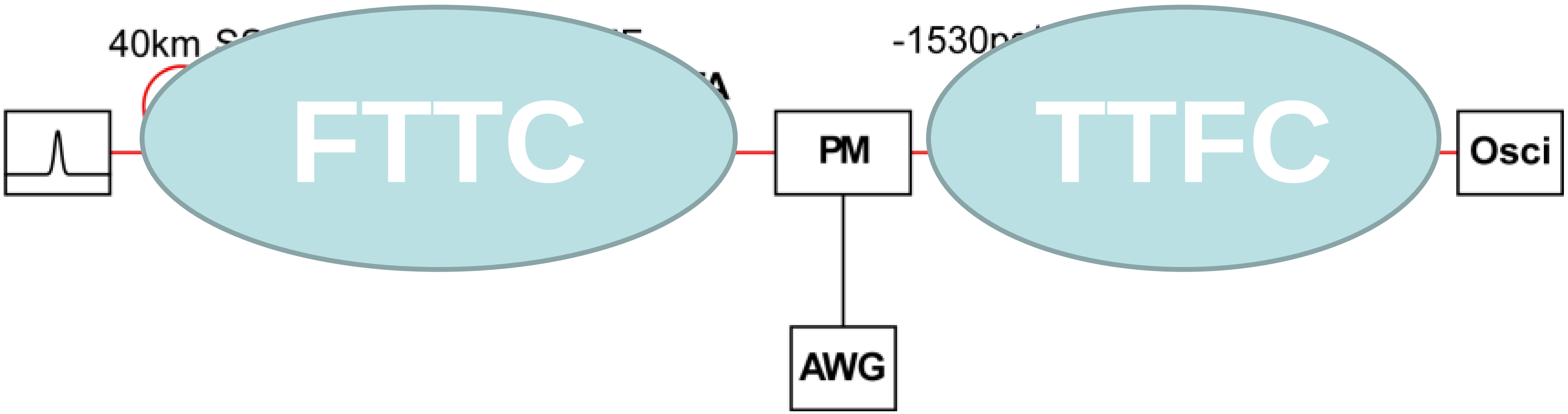
$$AS = \frac{\partial(AD)}{\partial\lambda} = \frac{\partial^3\varphi}{\partial t^3} D^3 \frac{\lambda_0^2}{2\pi c}$$

- D is the accumulated dispersion of FTTC
- φ is the phase change in the PM
- n-th order dispersion can be produced by the n-th order derivative of the phase change, i.e. $\partial^n\varphi/\partial t^n$

Experimental setup (delay)

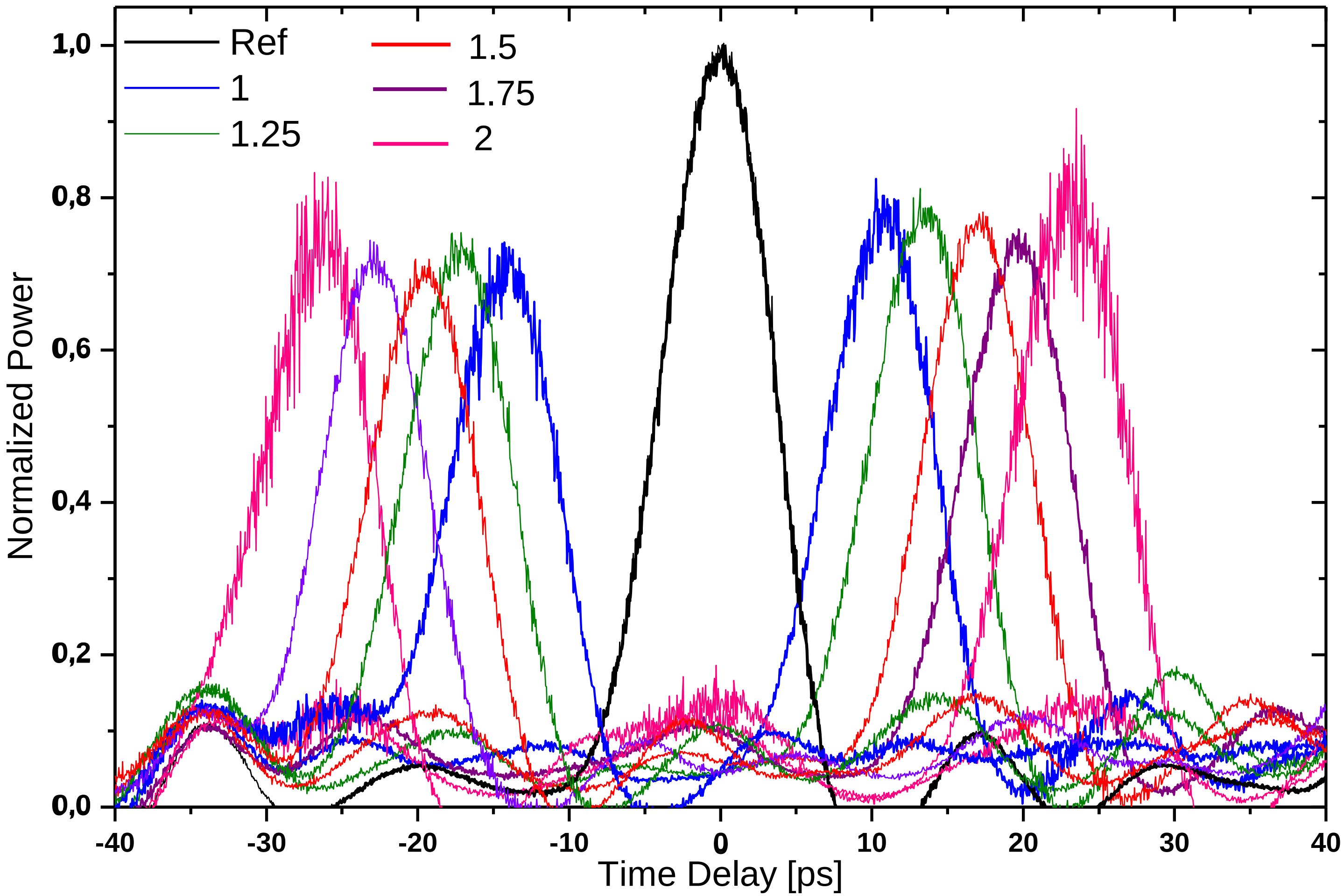


Experimental Setup

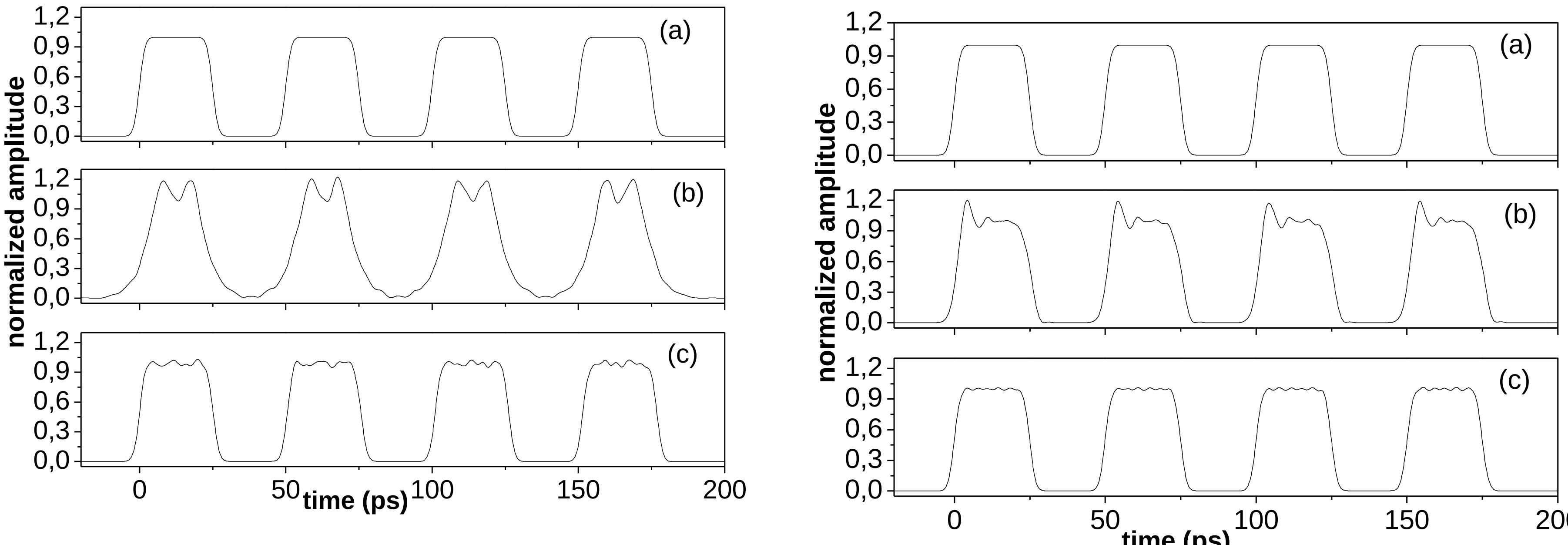


- 2.5 ps input pulse
- 4.5 ps output pulses
- up to 20 pulse widths tuning range

Experimental results (delay)

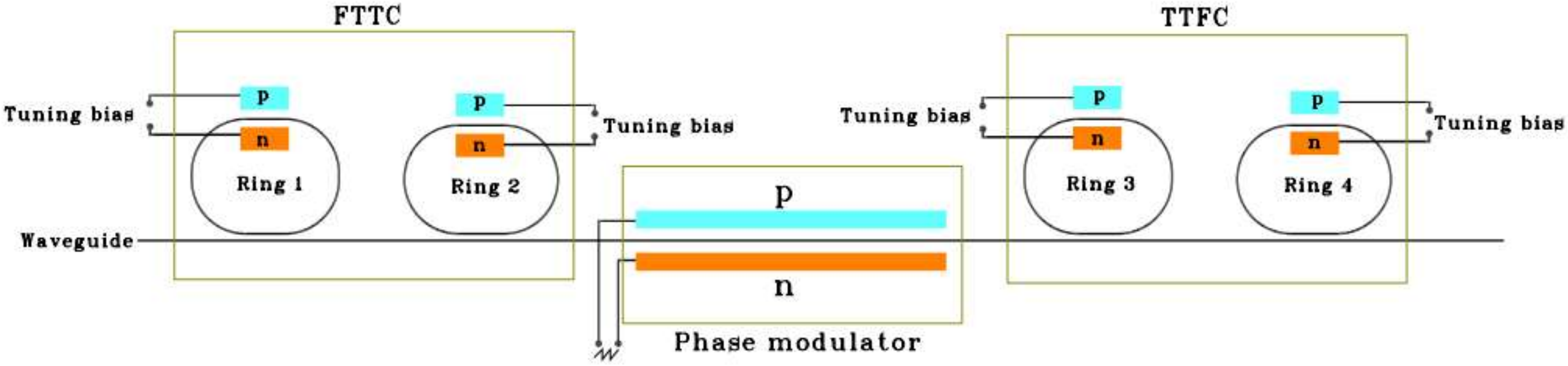


Simulation results (second and third order dispersion production)



- A media with a pure second order dispersion of 1.6 ns/nm for FTTC
- A signal with a curvature of 0.4 GHz^2 for second order dispersion production
- A signal with a curvature of 0.06 GHz^3 for third order dispersion production

The design in silicon photonics platform



- 2 pairs of ring resonators is used to produce the desired amount of dispersion for the TTFC and FTTC

Group delay of ring resonators

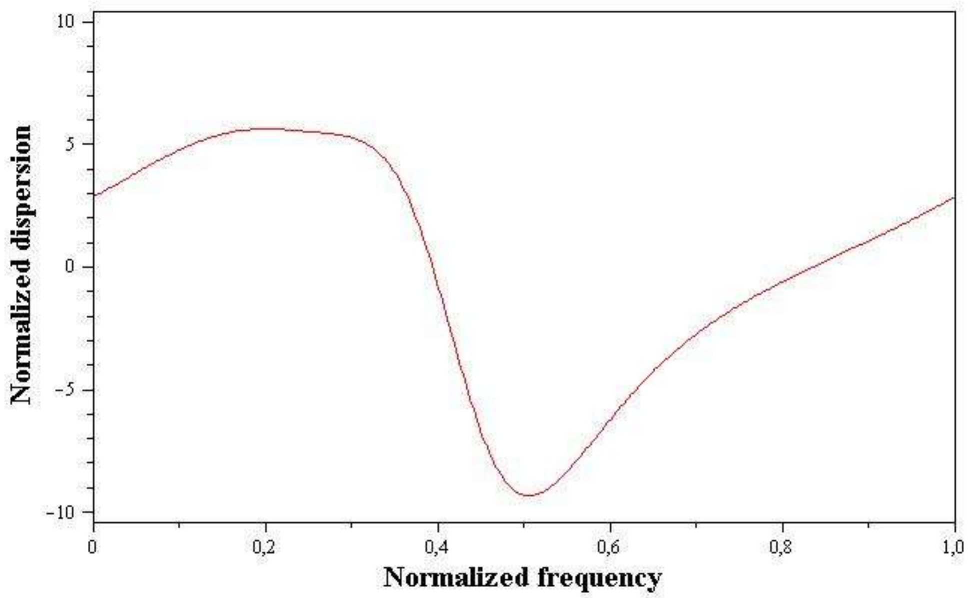
- The group delay of the cascaded ring resonators can be expressed as

$$T\sum_{n=1}^{2}\exp(-j\varphi_n)\frac{k_n}{2-k_n-2\sqrt{1-k_n}\cos(\omega T-\varphi_n)}$$

- k_n is the power coupling ratio to the n-th resonator
- T is the delay for one round trip in the ring
- φ_n is the phase shift in the n-th resonator.

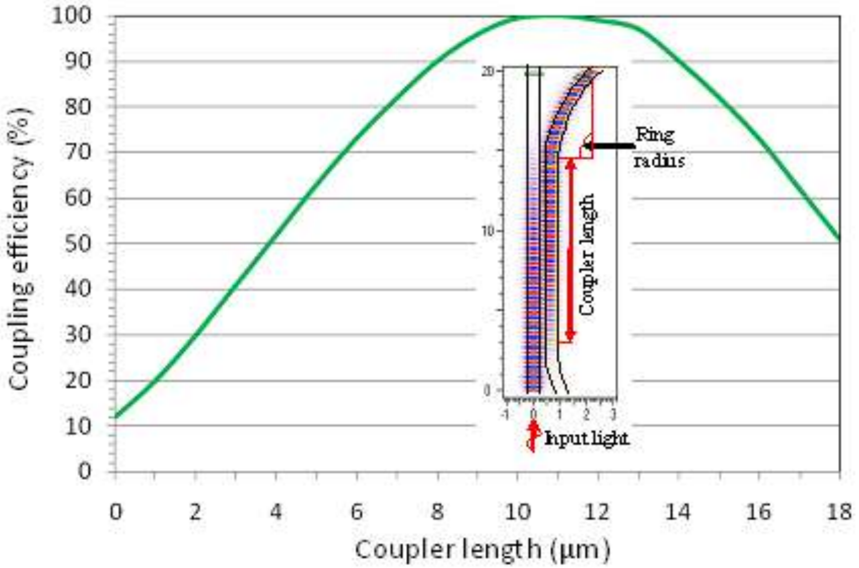
Dispersion of ring resonators

- The normalized dispersion ($-D\lambda^2/cT^2$) for the k_1 = 88%, k_2 = 96%, $\varphi_1 = \pi/2$ and $\varphi_2 = 84\pi/100$ can be obtained as follows:



The coupling efficiency depending on the length of the waveguide coupler

- The bending radius is 12.5 μm to provide low bending losses.
- For the required coupling efficiencies of k_1=88 % and k_2=96 % the simulated coupler lengths are 7.8 μm and 9.3 μm, respectively.



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Limitations of the structure

- Produced delay (considering a saw-tooth signal with the slope of 10GHz): 37 ps/mm^2 (per each resonator)
- Produced second order dispersion (considering a quadratic signal with the curvature of $0.1GHz^2$): 0.17 $ps/nm/\ mm^4$ (per each resonator)
- Produced third order dispersion (considering a third order signal with the curvature of $0.01GHz^3$): $7.8x10^{-3}$?? $ps/nm^3/\ mm^6$ (per each resonator)

Acknowledgement

- C. A. Bunge, A. Wiatrek, and S. Preußler from Hft Leipzig and H. J. Eichler from TU-Berlin.

Bundesministerium für Bildung und Forschung

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