Karlsruhe Institute of Technology

HELMHOLTZ ASSOCIATION

High speed optical data transmission for detector applications

Piotr Skwierawski

Matter and Technologies Annual Meeting

INSTITUTE FOR DATA PROCESSING AND ELECTRONICS (IPE)

Outline

- Introduction
- Wavelength Division Multiplexing
- Silicon Organic Hybrid Modulators
- Optical Packaging
- Summary

Introduction

Advantages of Optical Communication

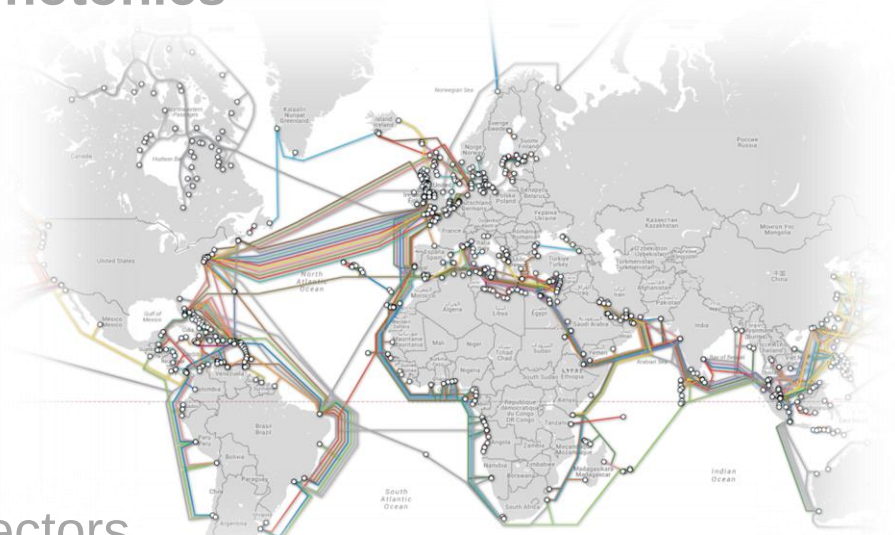
- Transmission bandwidth (250 …190) THz = 60 THz
- Immunity to electromagnetic interference
- Low fiber loss (0.2 dB/km @ 1550 nm)

Additional advantages of Silicon Photonics

- Dense packaging
- Cost effective silicon
- CMOS compatible

The Vision

- High-speed interconnects for fast readout in large-scale particle detectors



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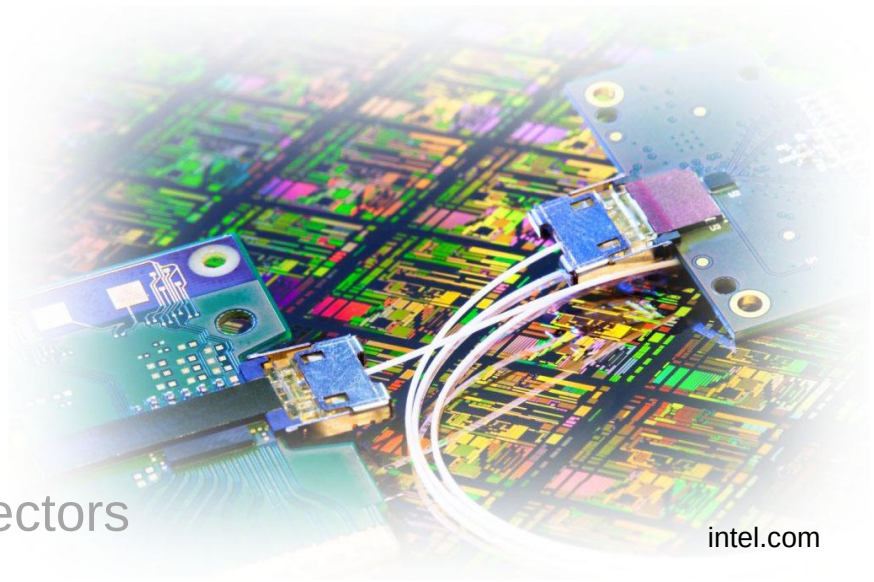

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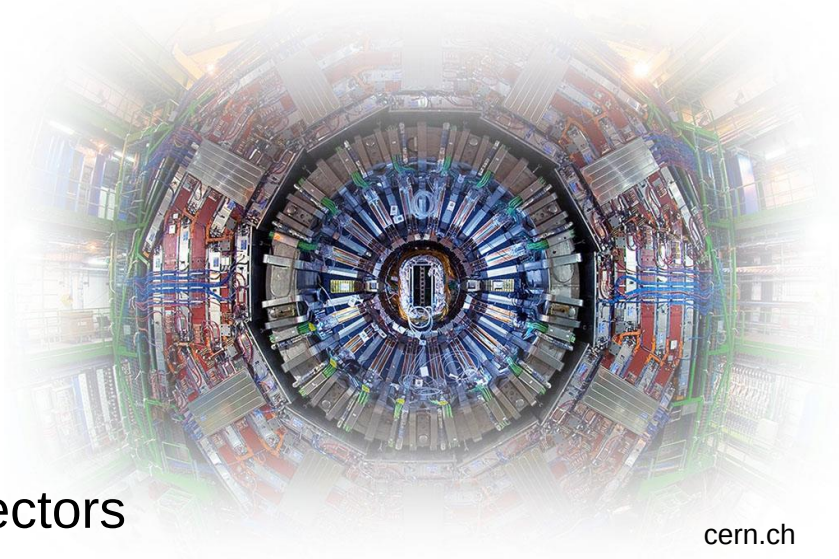

cern.ch

The Vision

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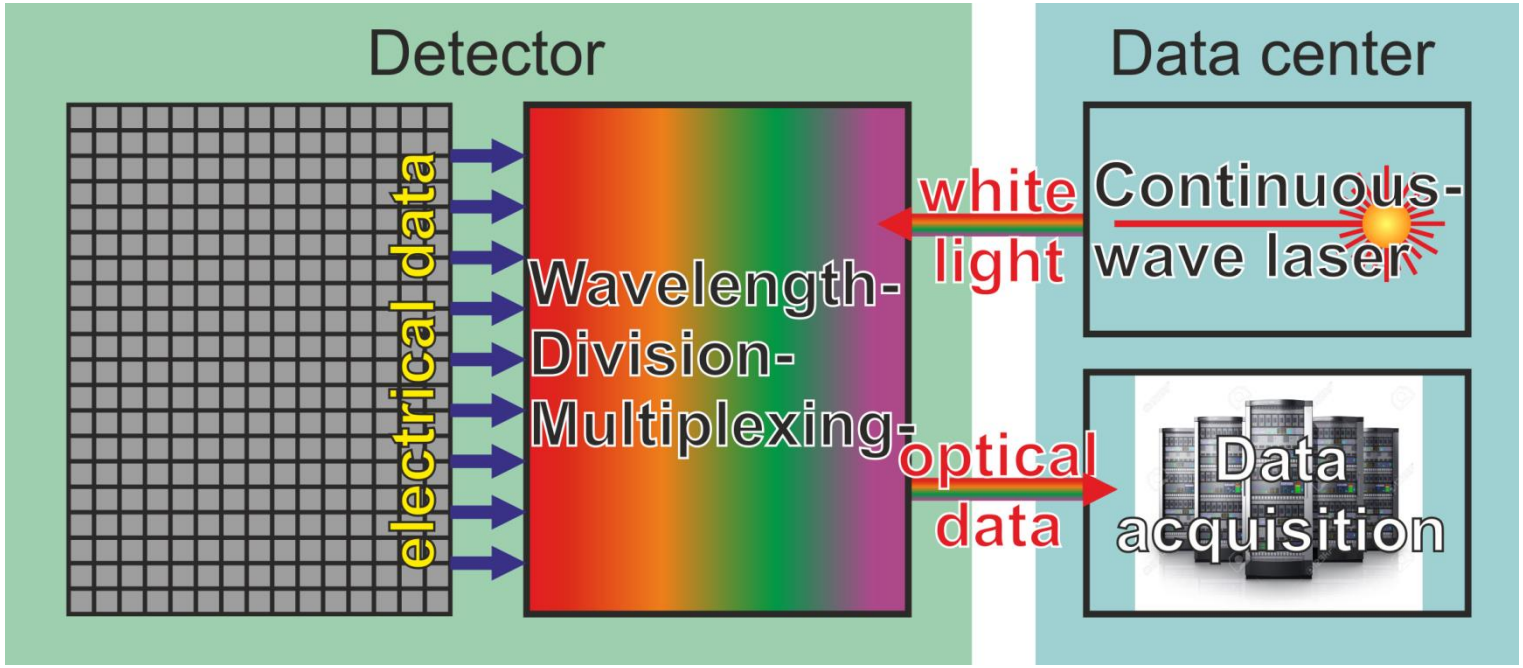
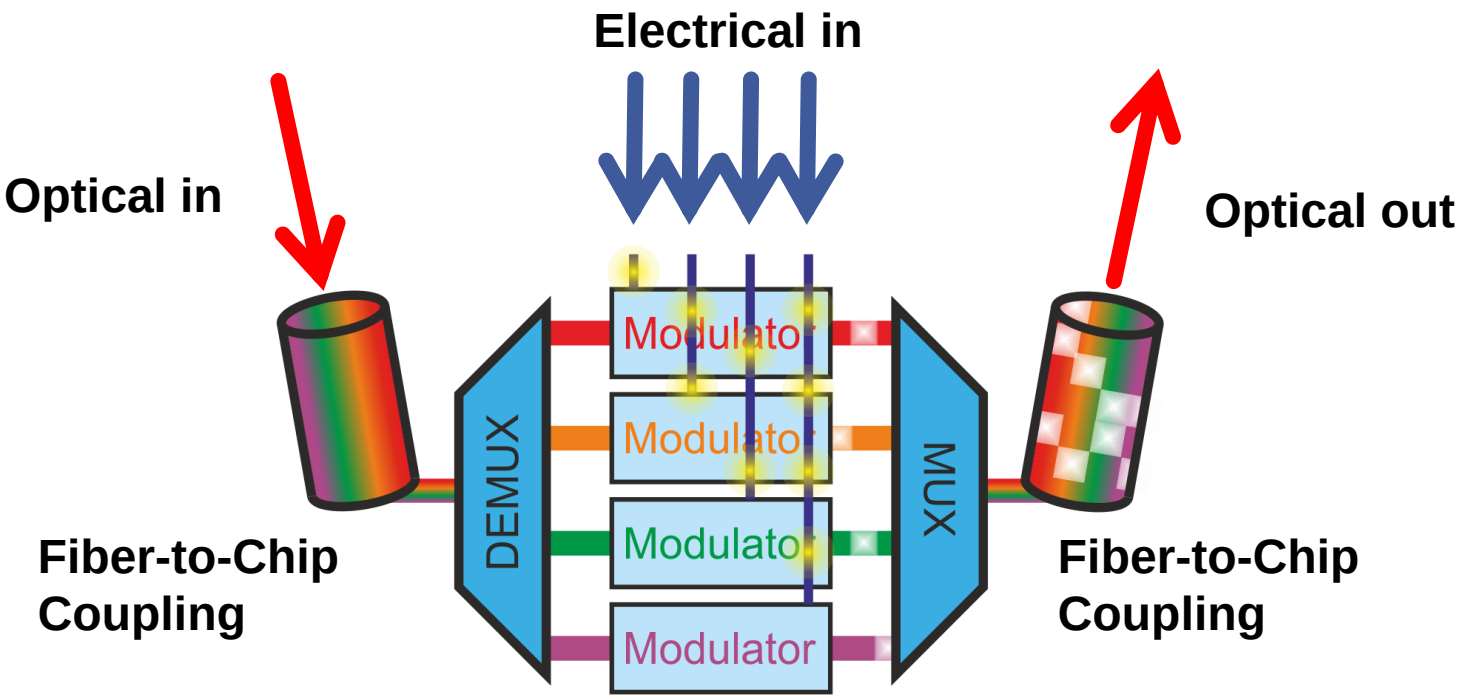
Optical Data Transmission System



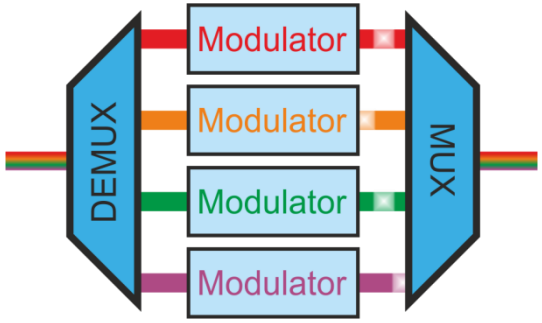
- Monolithically integrated wavelength-division-multiplexing system
- Lasers located off-detector
- Massive reduction of optical fibers through optical terabit communication

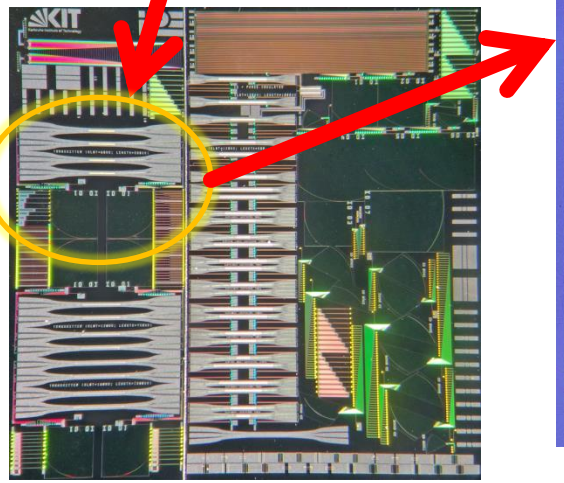
Wavelength Division Multiplexing (WDM)

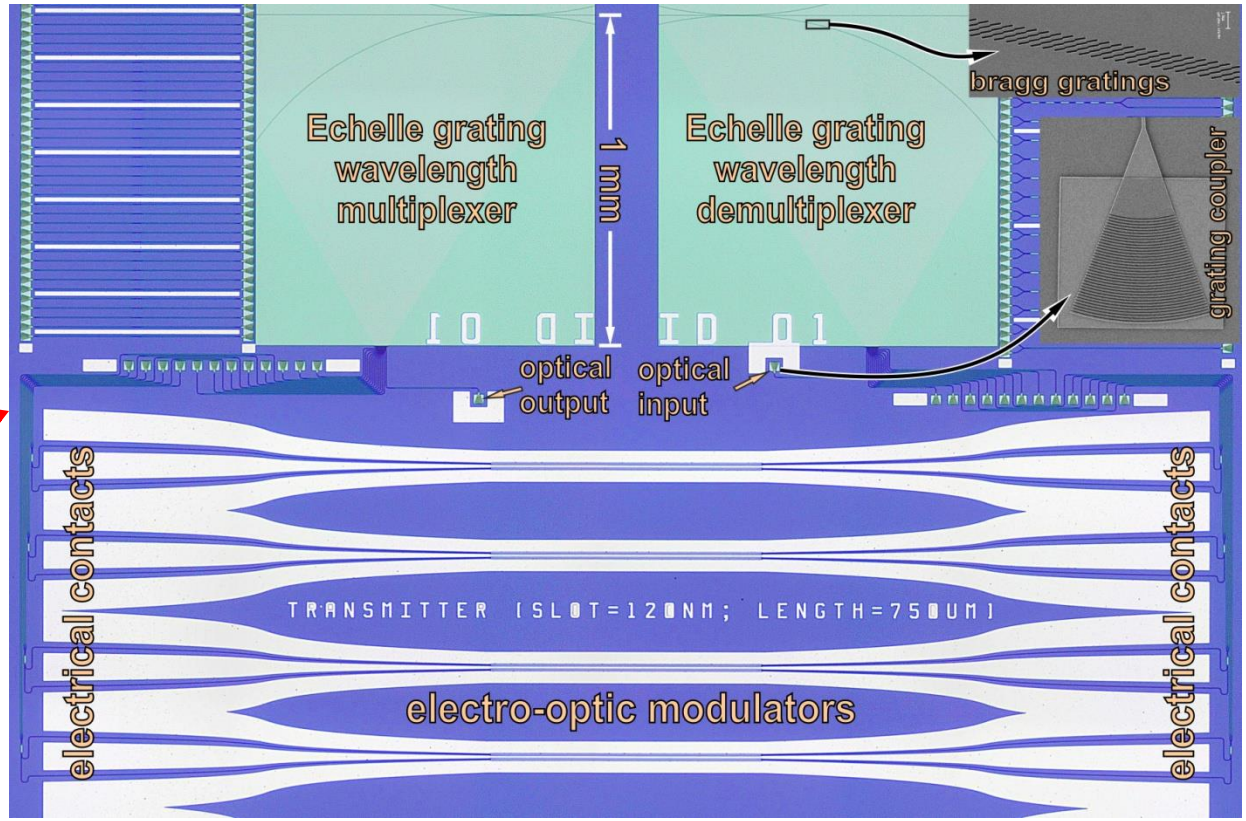


- Optical carriers of different wavelengths
- Each carrier modulated by independent data stream
- All channels multiplexed on one single fiber

WDM chip integration

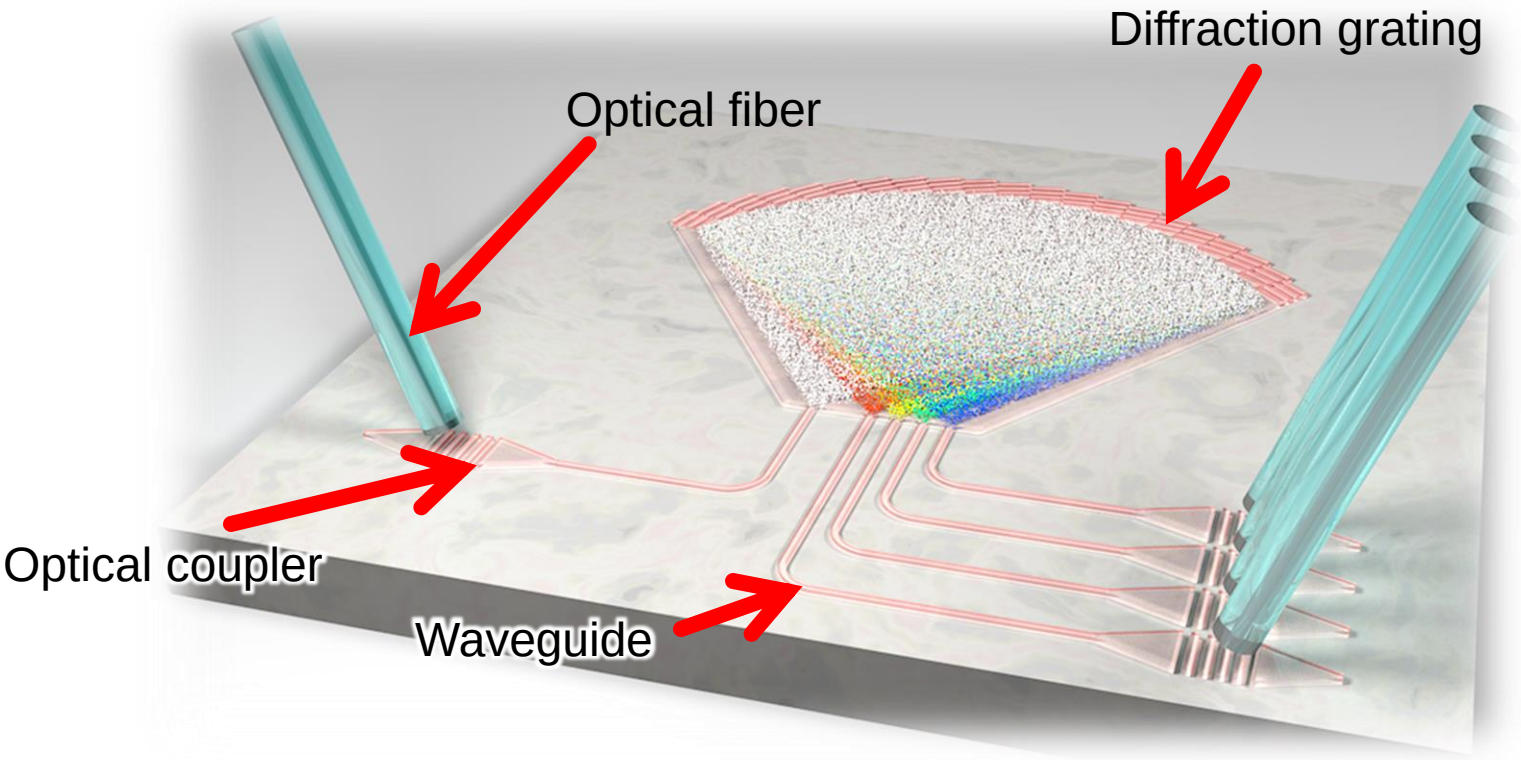






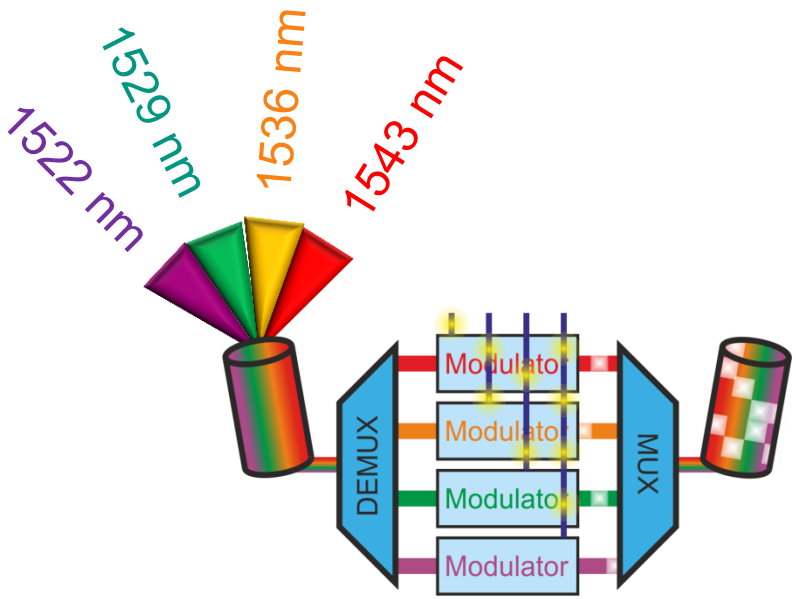
- Electro-optic modulators and (de-)multiplexers on the same chip

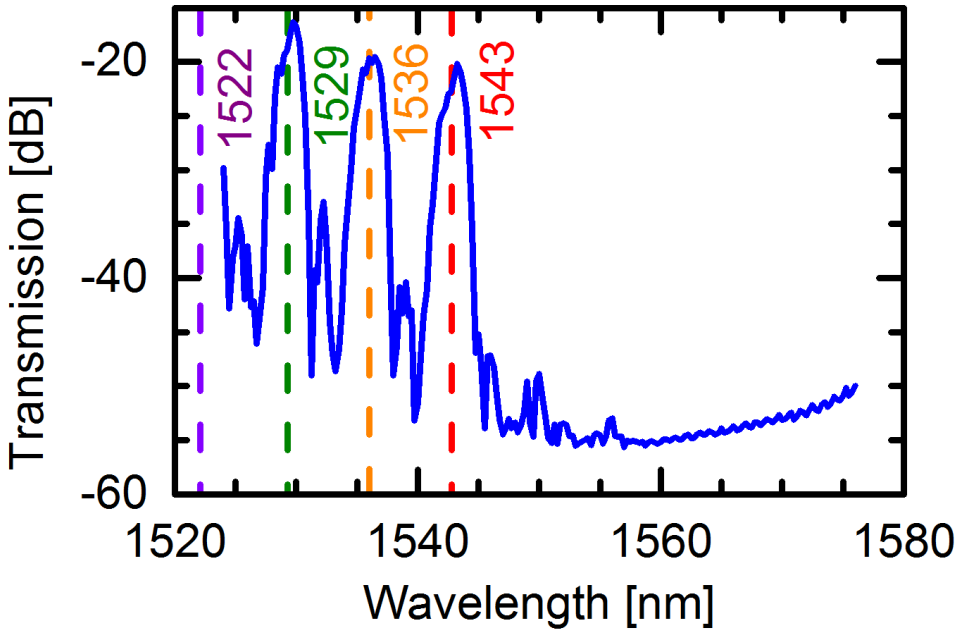
Echelle grating (de-)multiplexer



- White light is diverging into two dimensional free-space region
- Concave grating is reflecting and diffracting
- Light of different wavelengths are concentrated into output waveguides

WDM-performance on chip

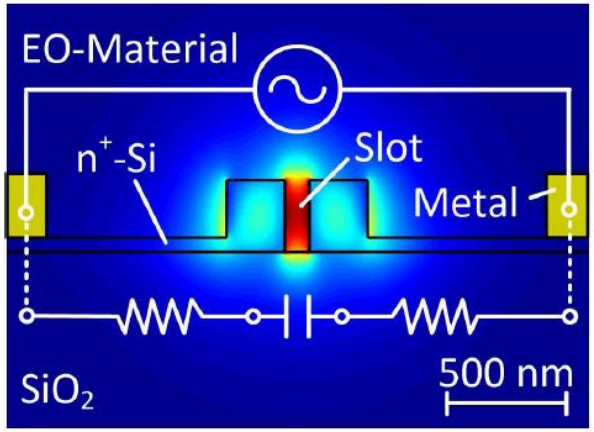




- First WDM system is working
- 4 channels (3 channels visible, the forth is beyond measurement range)
- Less than -25 dB suppression ratio

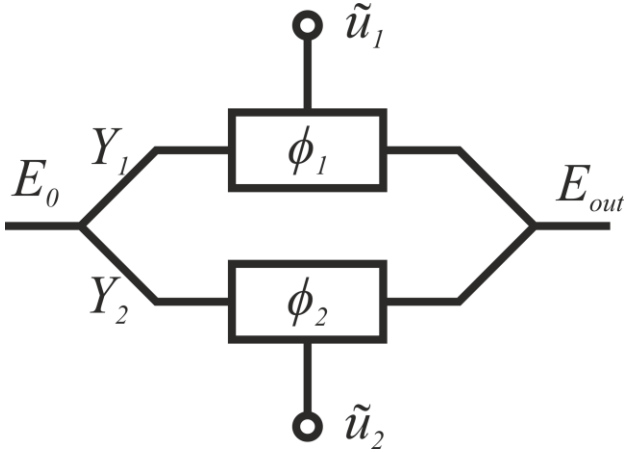
Silicon-Organic-Hybrid (SOH) Modulator

Cross section



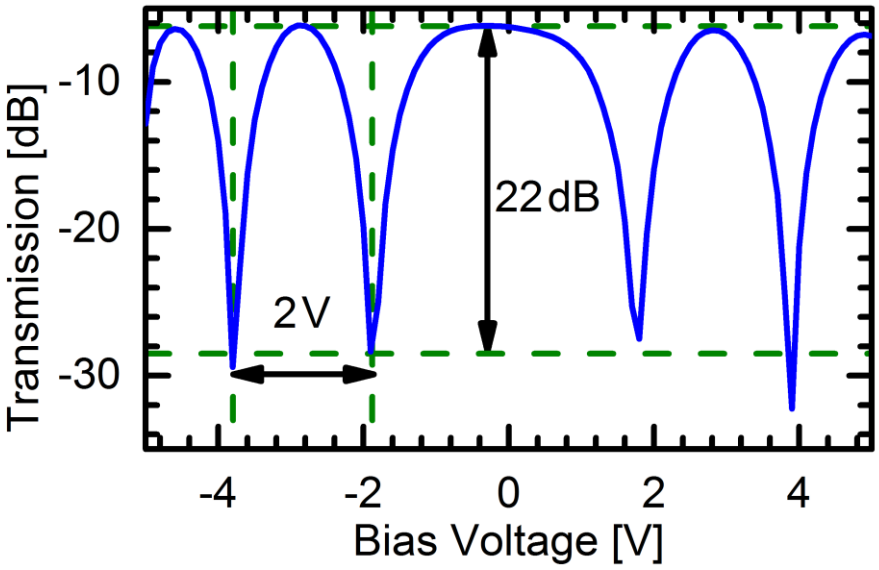
R. Palmer et al., *IEEE Photon. Technol. Lett.* **25,** 1226 (2013)

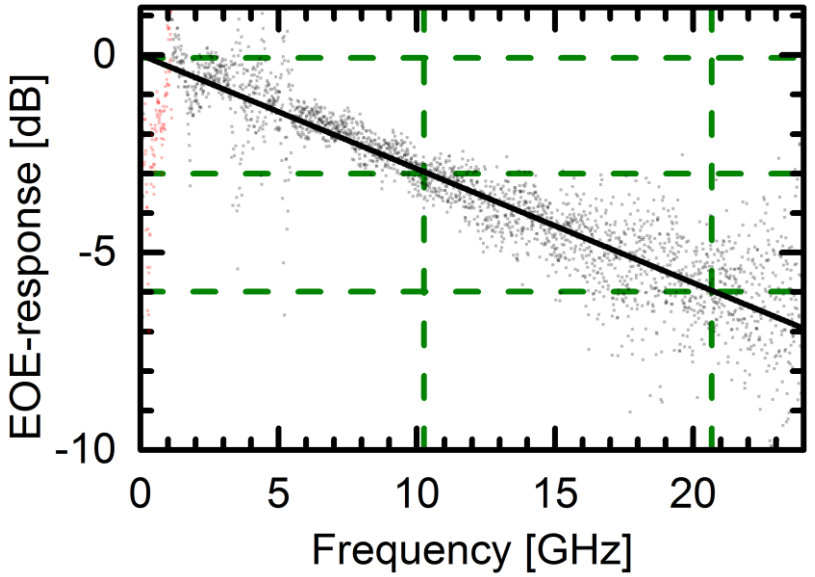
MZ-configuration



- Silicon waveguide filled with polymer
- Strong phase modulation due to chromophores inside the polymer
- Amplitude modulation by Mach-Zehnder-configuration (MZ-configuration)

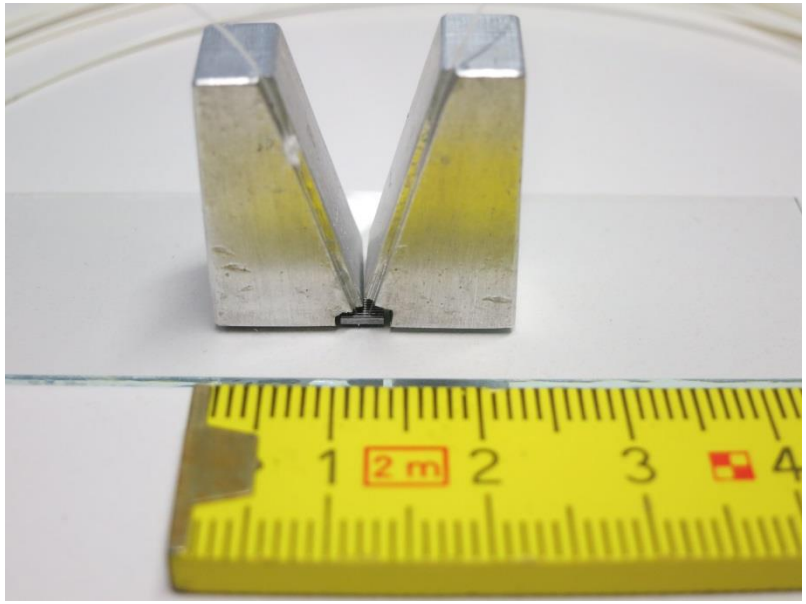
SOH-modulator performance in WDM system

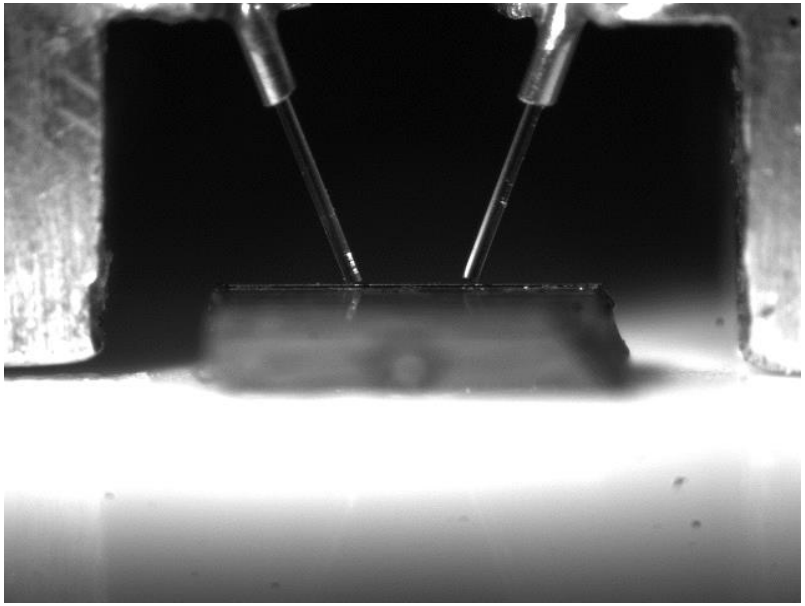




- Only 1 V needed to completely switch off SOH-modulator
- 22 dB extinction ratio
- 10 GHz 3 dB cutoff frequency in electro-optic-electro-response (EOE)

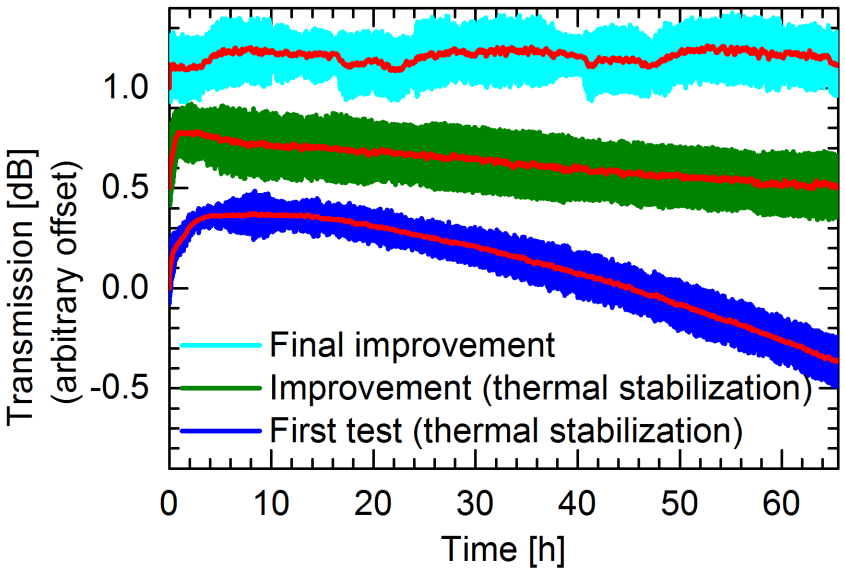
Fiber-to-chip Coupling

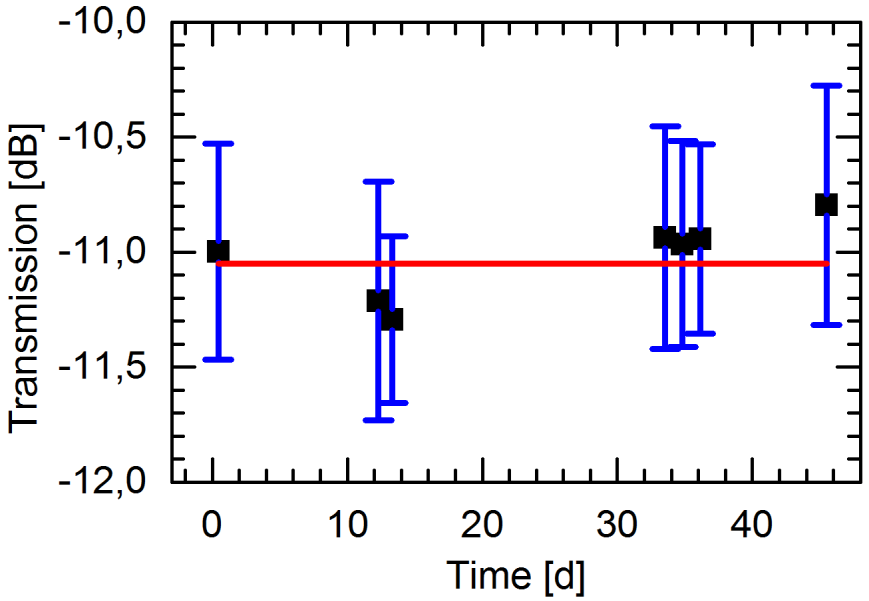




- Fixation of fibers by means of UV-curing adhesives
- Sub-micrometer precision alignment
- Vertical coupling with off-plane alignment for in-situ experiments

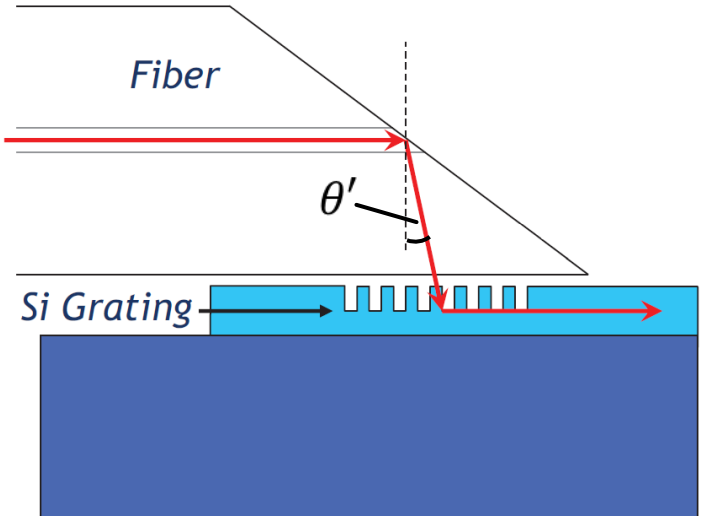
Optoelectronic packaging stability

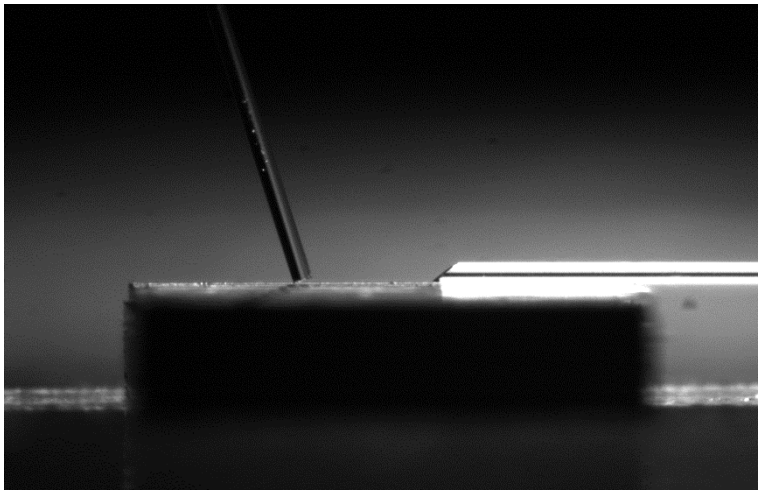




- Higher stability due to continuous improvement of packaging procedure
- Ongoing stability tests shows no degradation after 44 days
- Temperature stability experiments still ongoing

Planar optoelectronic packaging



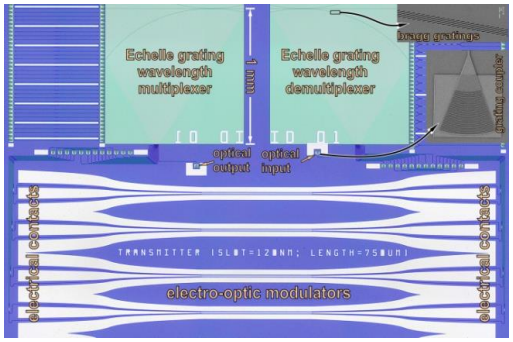


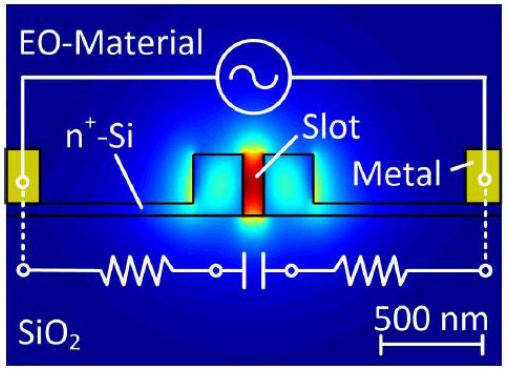
B. Snyder et al., *IEEE Trans. Compon. Packag. Manuf. Technol.* **3**, 954 (2013)

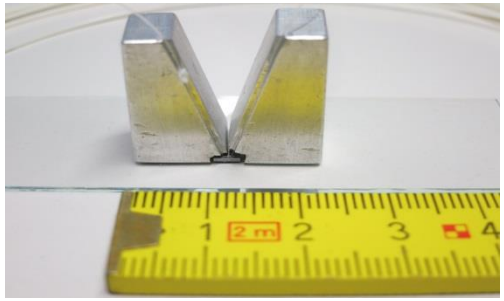
- Compact packaging through total internal reflection at the angled end of the polished fiber
- 4.5 dB optical attenuation compared to 5.5 dB at vertical packaging
- Polishing process has a high yield already

Summary

- Silicon photonics for high speed interconnects
- Demonstration of 4-channel WDM chip
- WDM system is working with less than 25 dB of suppression ratio
- Silicon-Organic-Hybrid modulator needs 1.0 V for reaching 22 dB of extinction ratio
- Optoelectronic packaging shows no degradation for 44 days
- Space efficient planar packaging is 1 dB less lossy than vertical packaging







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Thank you for your attention!