

# A Silicon Photonic Wavelength Division Multiplex System for High-Speed Data Transmission in Detector Instrumentation

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## Introduction

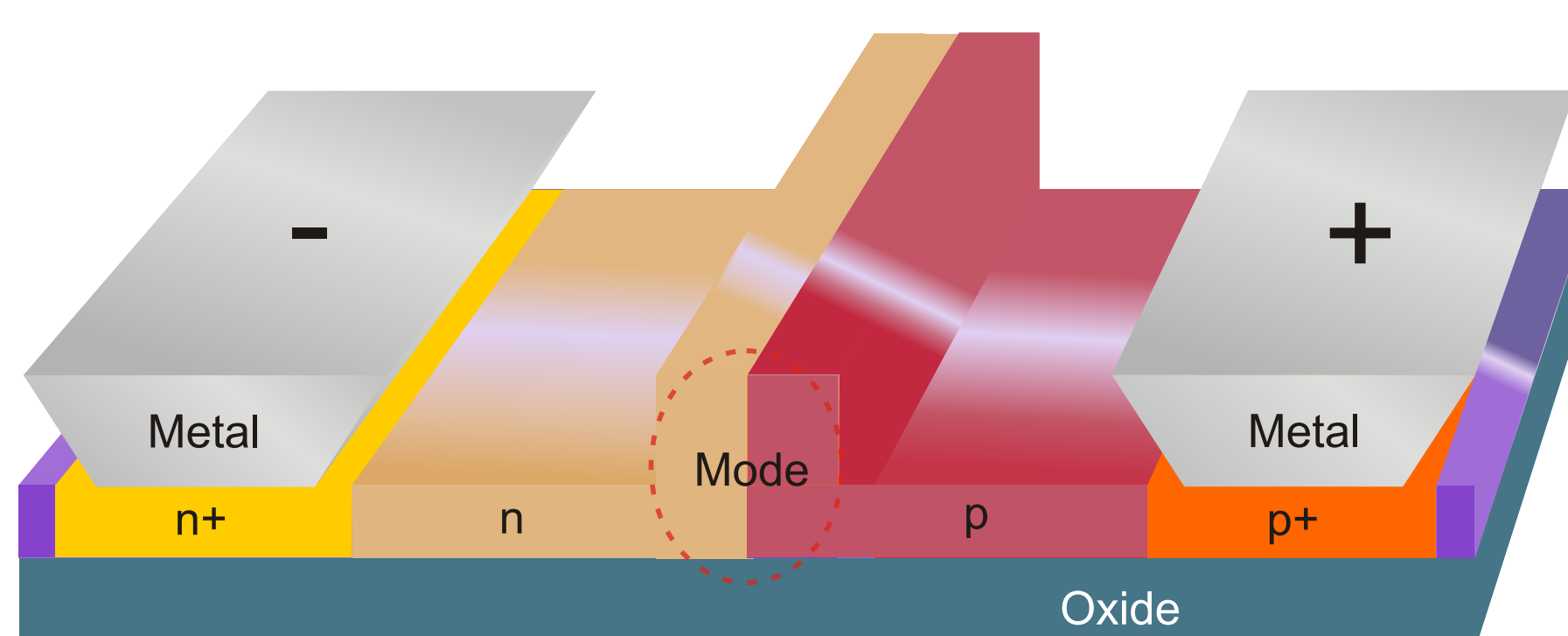
Current and future particle physics or photon science detectors easily generate raw data rates of hundreds of Tbit/s. Even with massive local data reduction, this is a major challenge for current optical links.

## Vision

- Optical data transmission system based on **wavelength division multiplexing (WDM)**
- **Monolithically integrated** Mach-Zehnder modulators and optical (de-)multiplexers
- **Lasers** located off-detector
- **CMOS-compatible** fabrication of components for monolithic integration with detector electronics

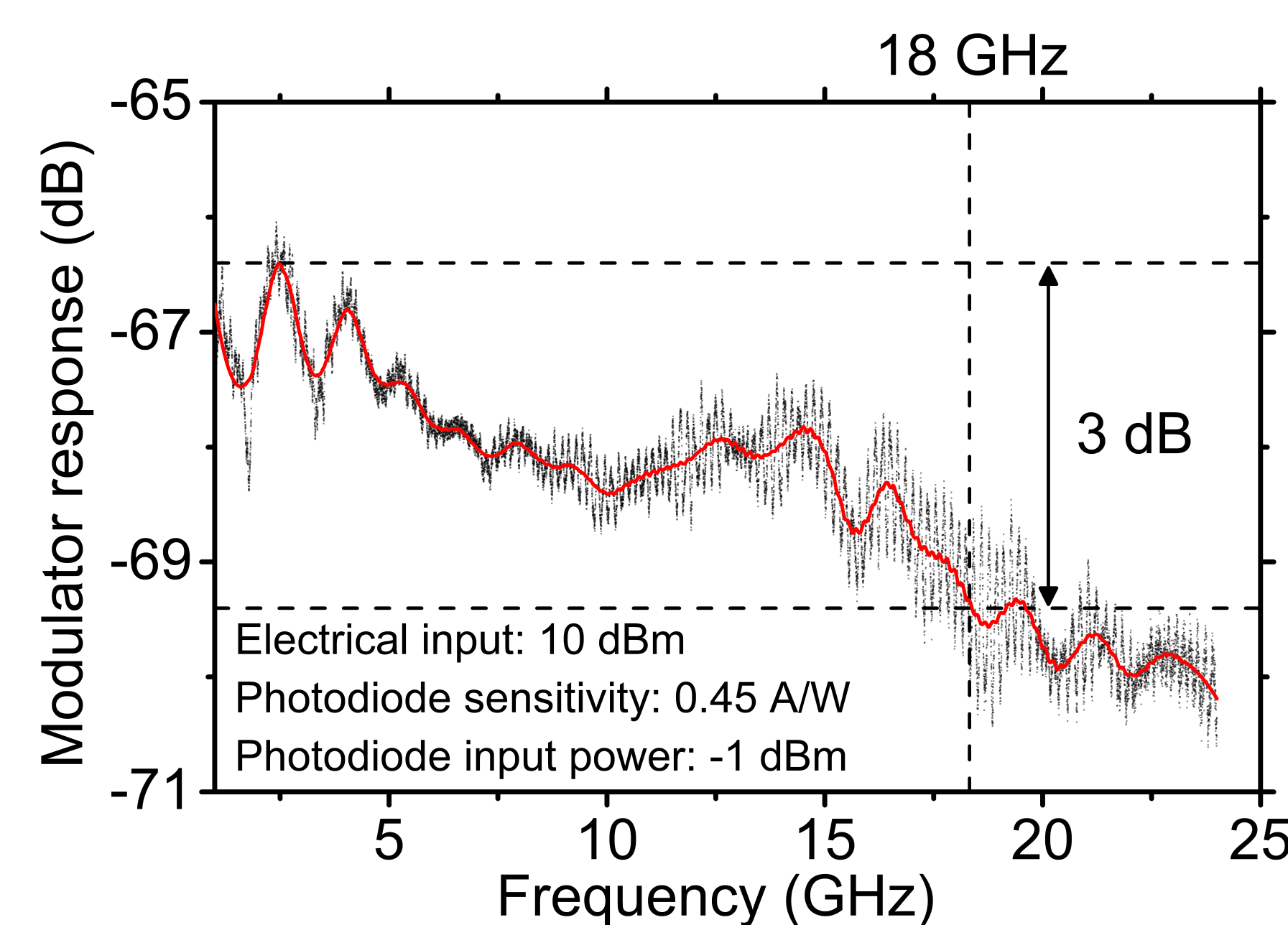
## Silicon modulators

- Phase modulation achieved through plasma-dispersion-effect in pn-junction, which is integrated in a waveguide
- Amplitude modulation obtained through MZI-structure



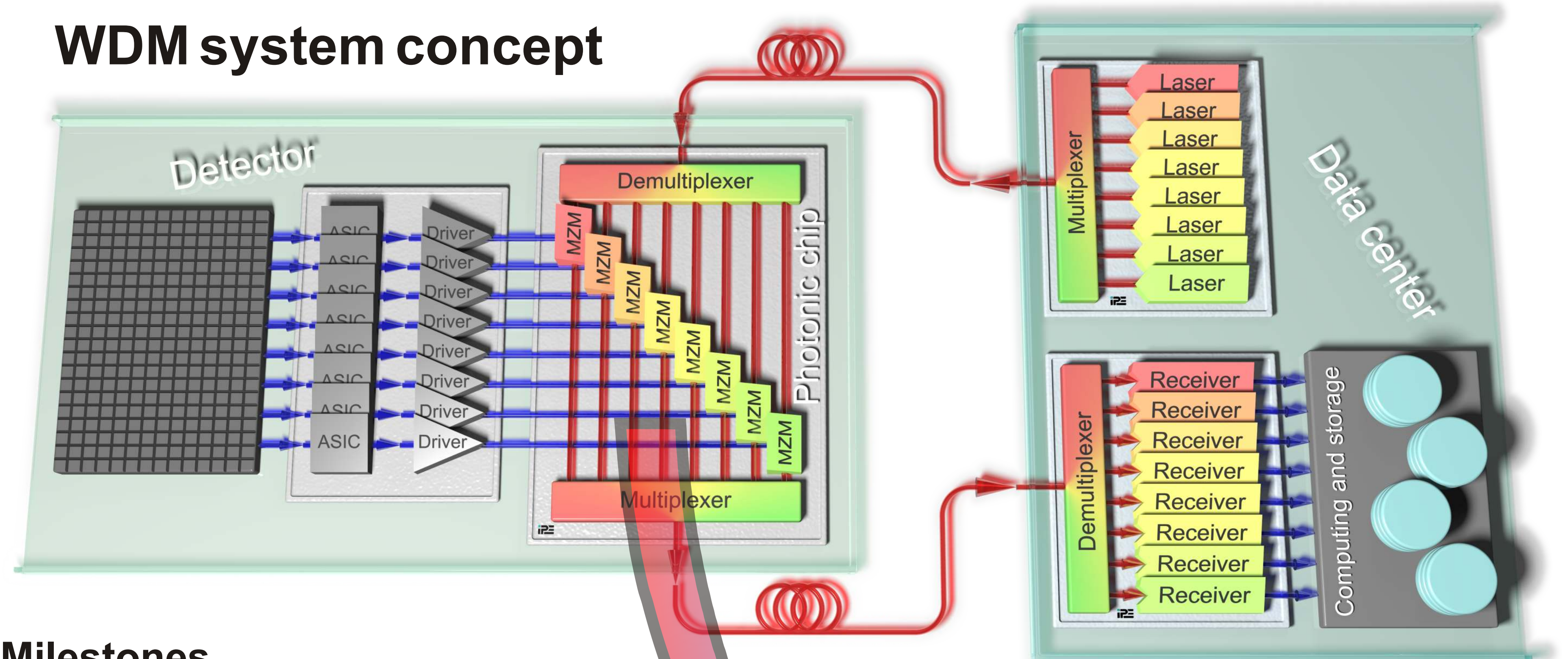
Artistic view of a pn-modulator

- Optical loss of 6.2 dB measured modulator occupying approximately 1.35 mm<sup>2</sup>
- 3 dB cut-off frequency of 18 GHz and an extinction ratio of 13.4 dB



Frequency response of pn-modulator (OpSIS)

## WDM system concept

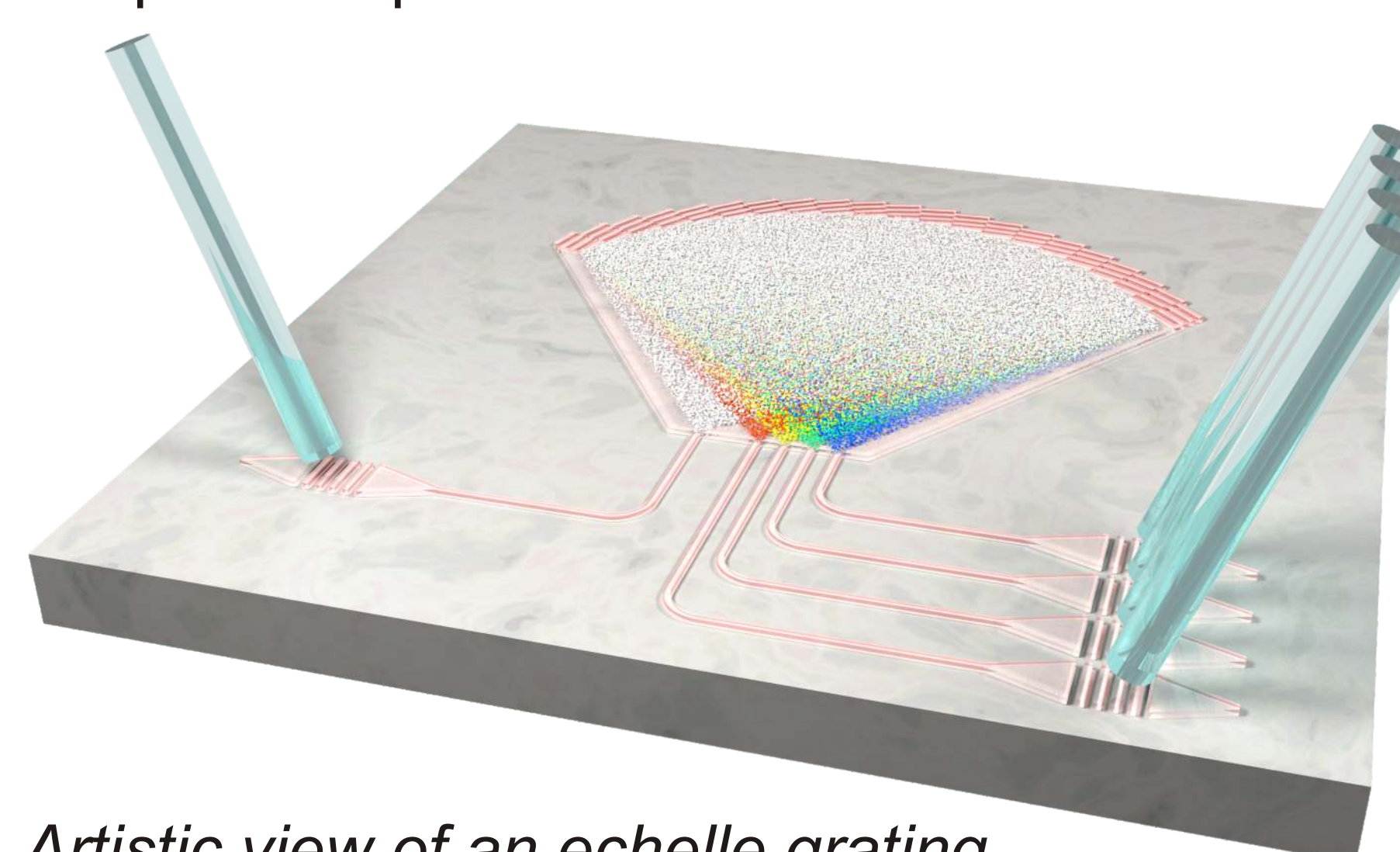


## Milestones

- Demonstrator: 160 Gbit/s per fiber
- Upgrade to 640 Gbit/s per fiber
- Future system up to **5 Tbit/s** per fiber using 64 channels and higher modulation formats

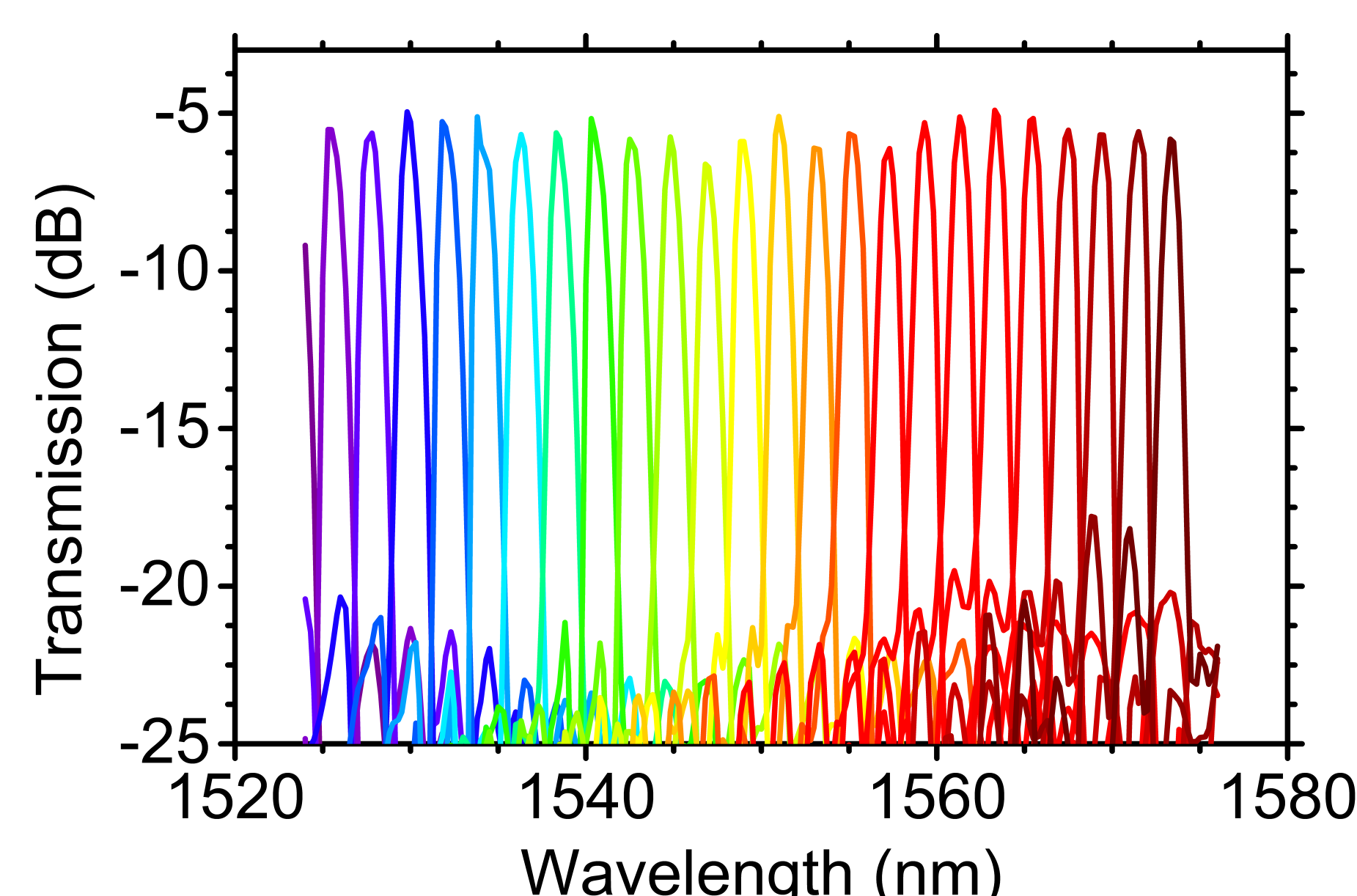
## Wavelength multiplexers

- Echelle gratings: curved diffraction grating in film waveguide
- Space requirements are scaling with operation parameters

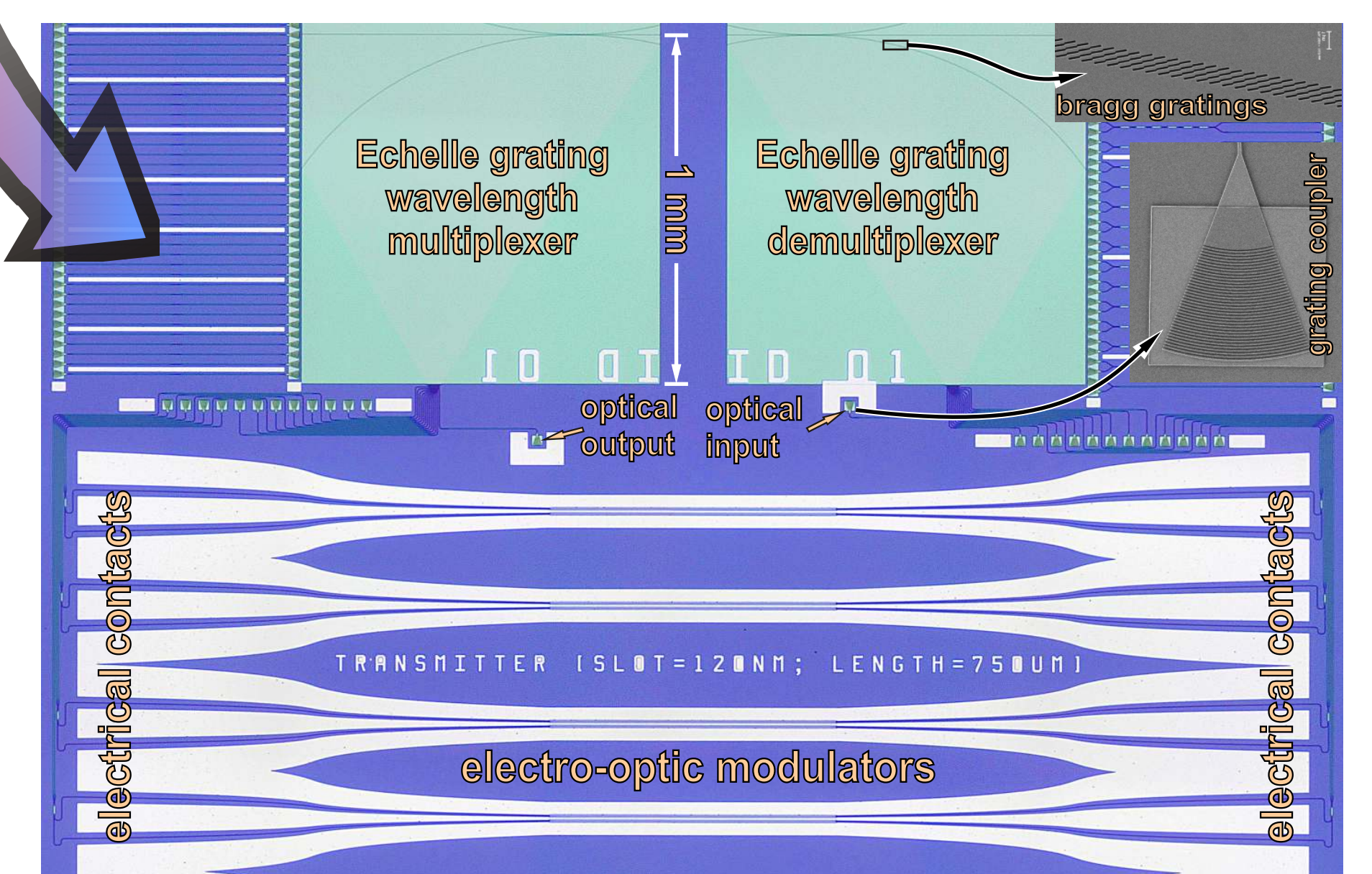


Artistic view of an echelle grating

- Echelle grating with 45 channels on an area of 0.5 mm<sup>2</sup>
- 5 dB on-chip loss and 16 dB average adjacent-channel crosstalk measured



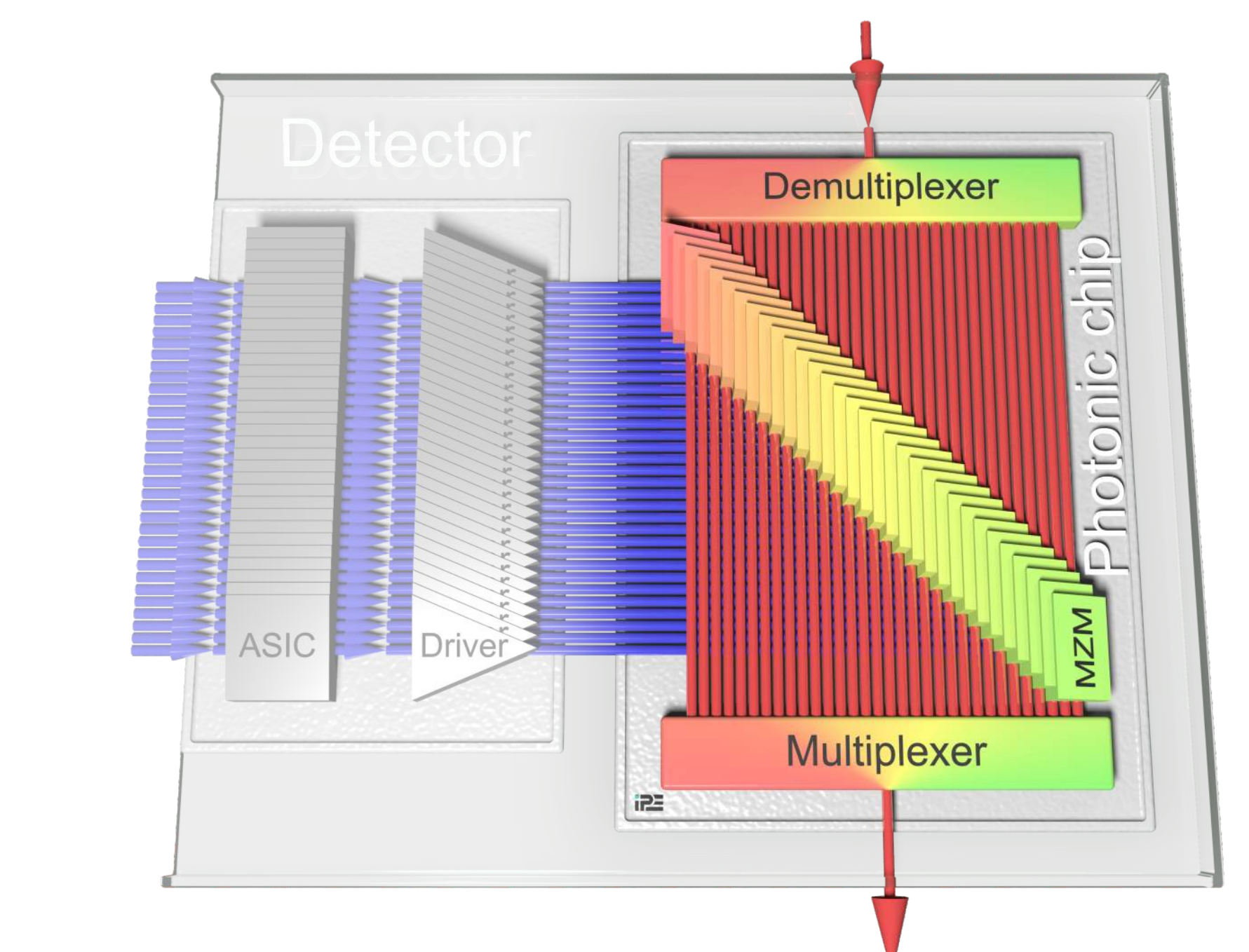
Section of the transmission spectrum of a 45-channel echelle multiplexer (design KIT/IPE, production IMS CHIPS)



Prototype of a 4-channel WDM system with monolithically integrated electro-optic modulators and wavelength (de-)multiplexers (design KIT/IPE, production IMS CHIPS)

## Conclusion

- Electro-optic pn-modulators demonstrated with a 3 dB cut-off frequency of **18 GHz**
- Wavelength division (de-)multiplexer with **45 channels on 0.5 mm<sup>2</sup>** designed and fabricated: loss 5 dB, crosstalk 16 dB
- **5 Tbit/s silicon photonic wavelength division multiplexing systems seem feasible on a size of 4 cm<sup>2</sup>**



64-channel WDM system for a transmission rate of up to 5 Tbit/s