Electrically programmable equivalent-phase-shifted waveguide Bragg grating for multichannel signal processing

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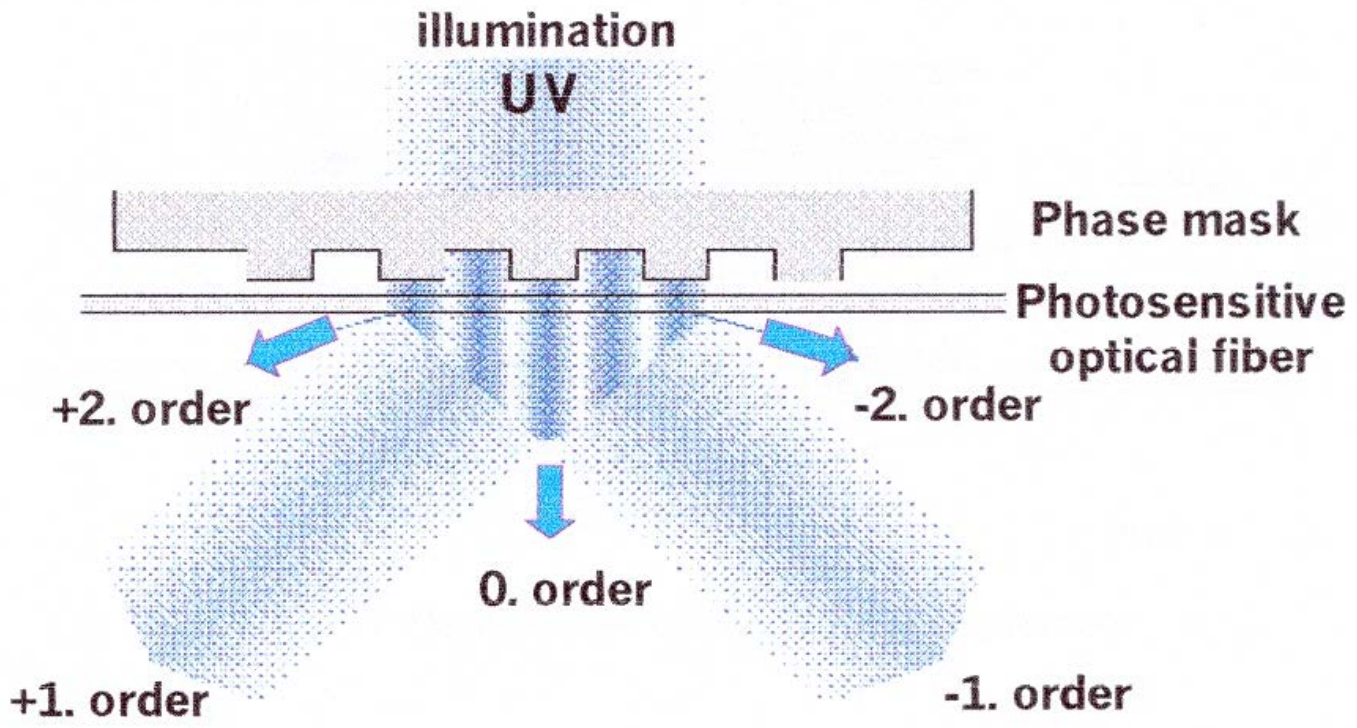
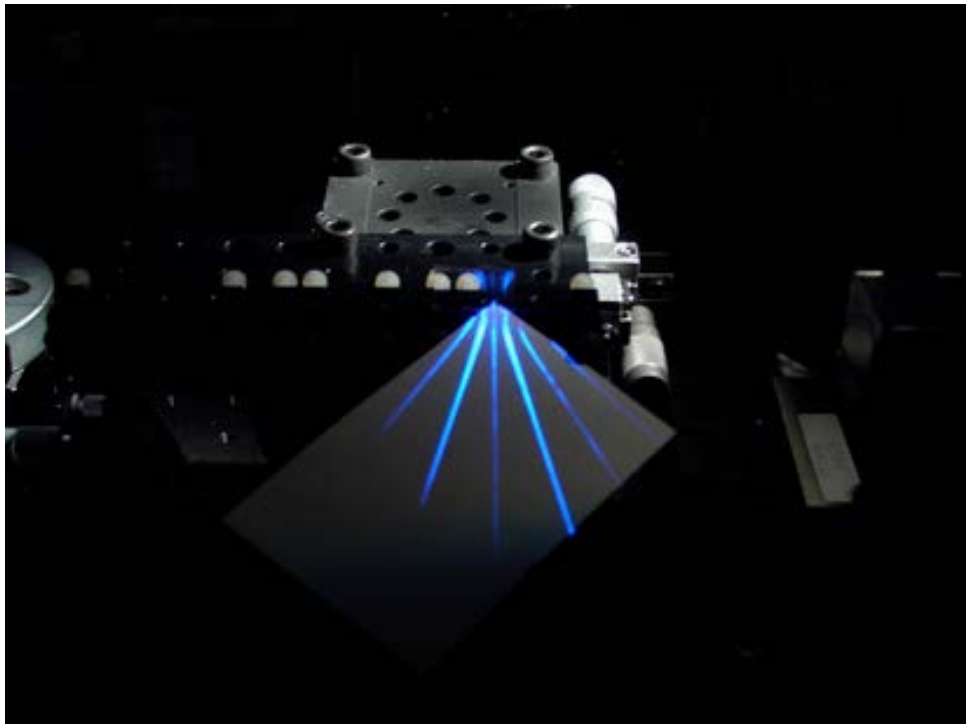
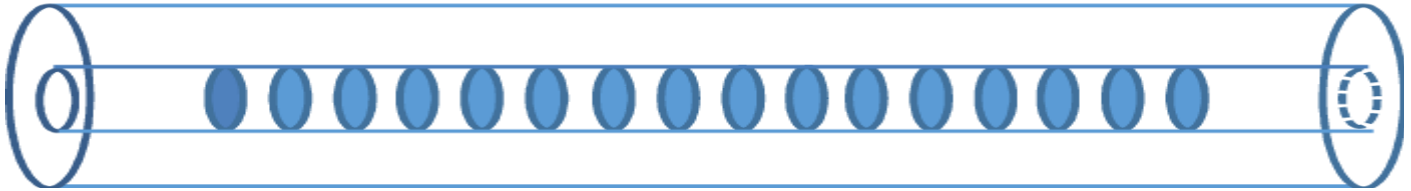
Outline

- Introduction to equivalent phase-shifted (EPS) Bragg gratings
- EPS Bragg grating design and performance evaluation
- Multichannel signal processing
- Conclusion

Introduction – fiber Bragg gratings







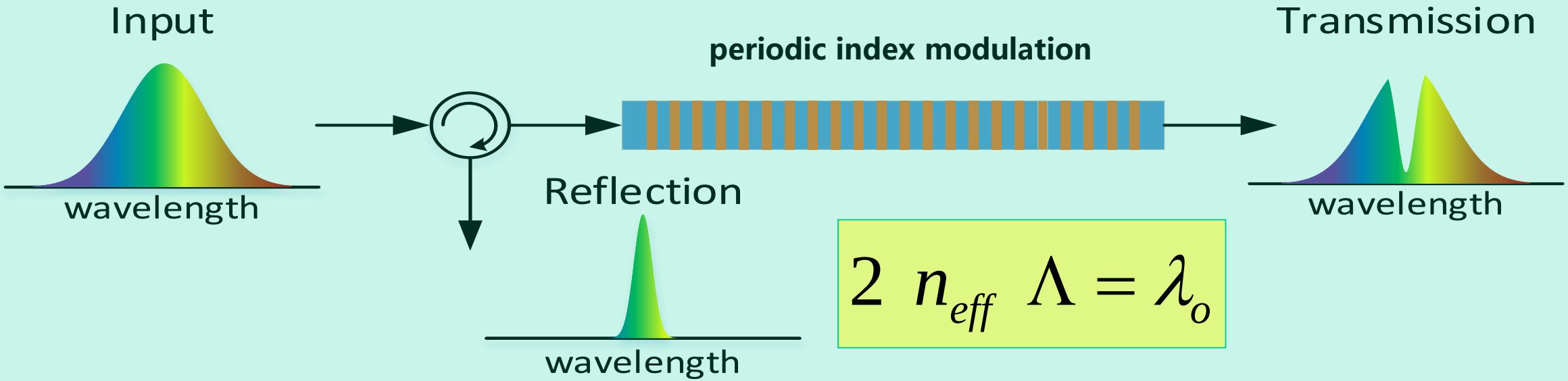
$$2\ n_{eff}\ \Lambda = \lambda_o$$

Bragg condition

K. O. Hill, Y. Fujii, D. C. Johnson, and B. S. Kawasaki, “Photosensitivity in optical fiber waveguides: Application to reflection filter fabrication,” Appl. Phys. Lett., vol. 32, pp. 647–649, 1978.

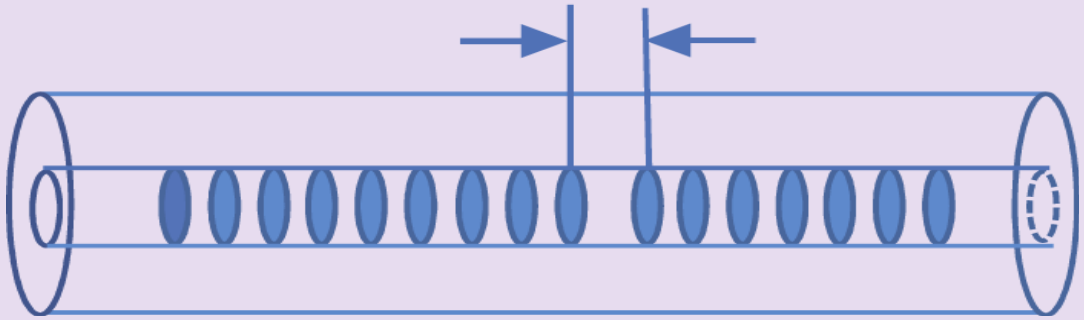
Introduction – fiber Bragg gratings

✓ **Uniform fiber Bragg grating**

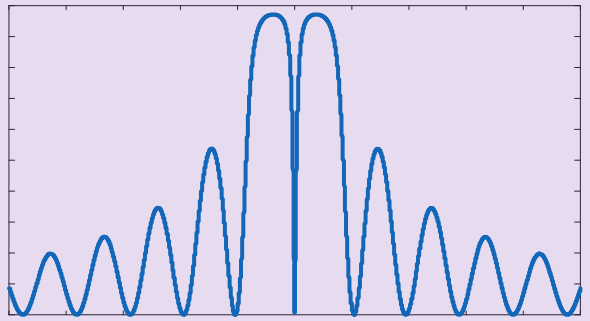


$$2\ n_{eff}\ \Lambda = \lambda_o$$

✓ **Phase-shifted fiber Bragg grating**



Reflection spectrum



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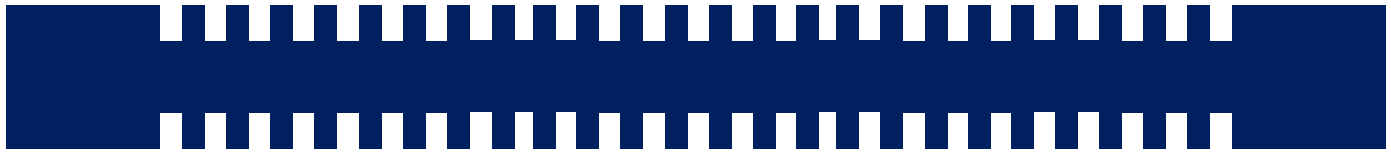
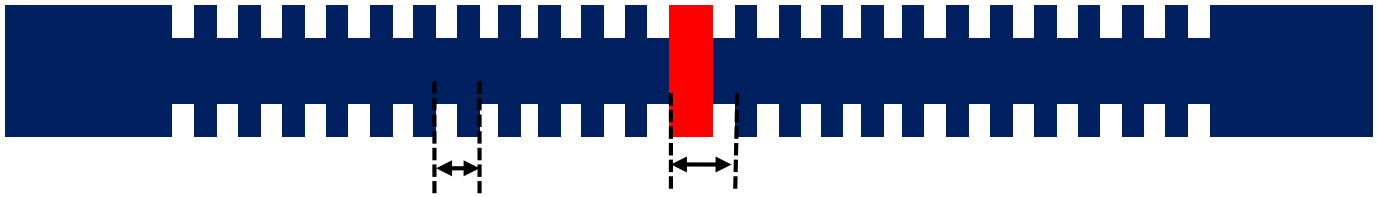
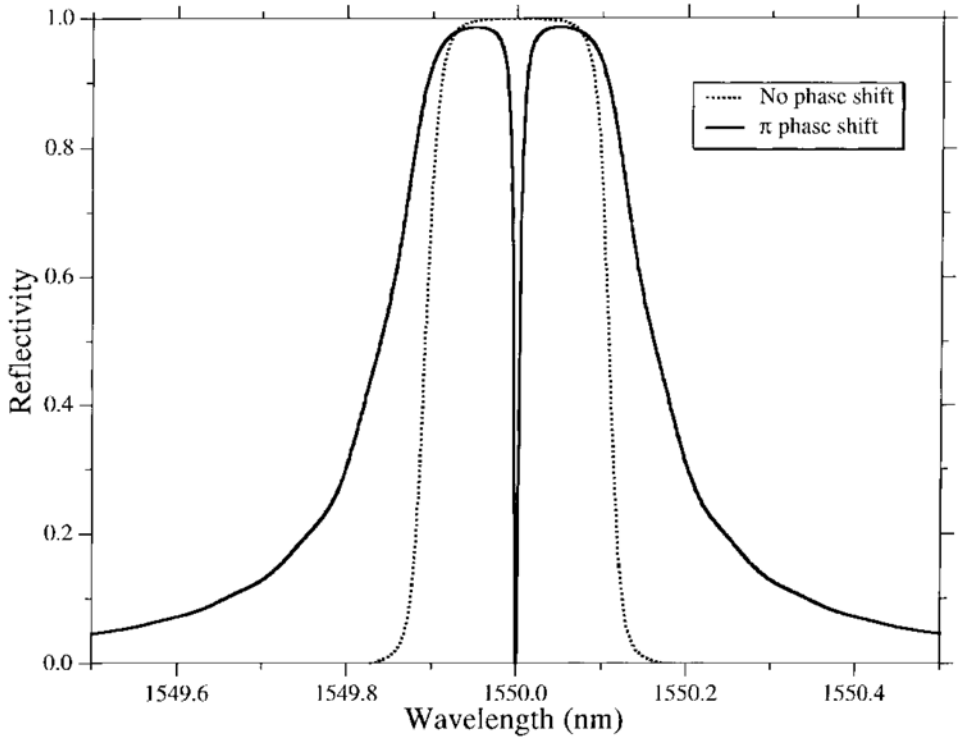
Introduction – waveguide gratings

✓ **Uniform waveguide Bragg grating (through edge corrugations)**



✓ **Conventional phase-shifted waveguide Bragg grating**

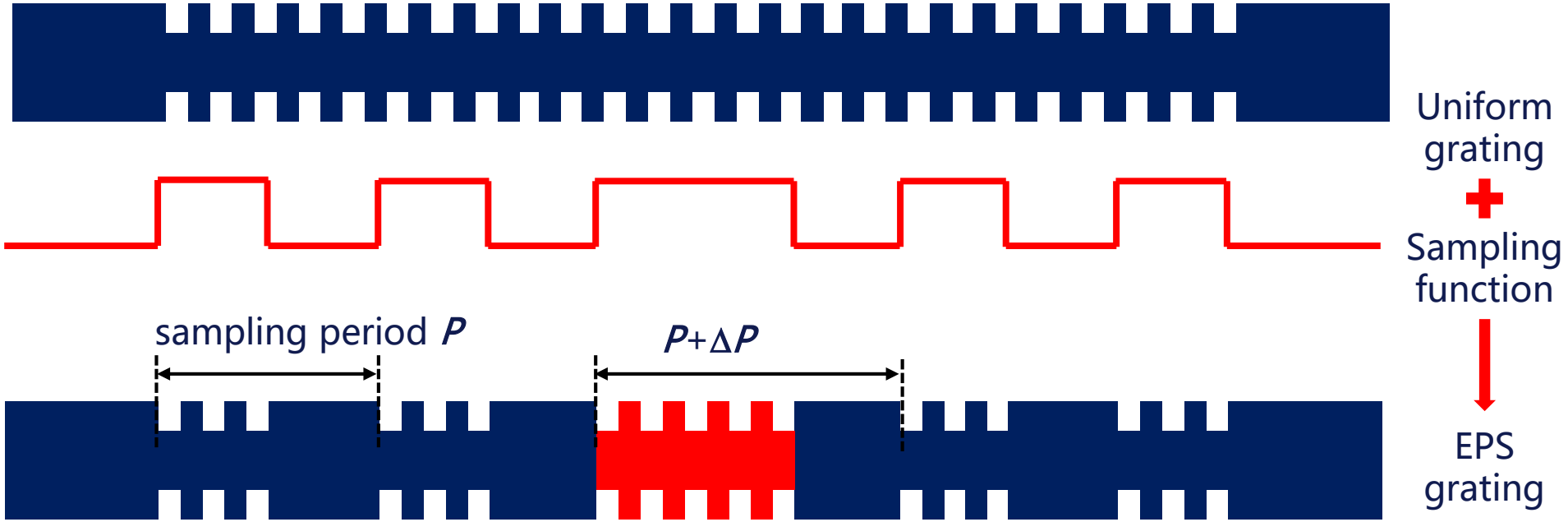




Need very high fabrication accuracy (nm range)

Introduction – waveguide gratings

✓ Equivalent-phase-shifted (EPS) waveguide Bragg grating

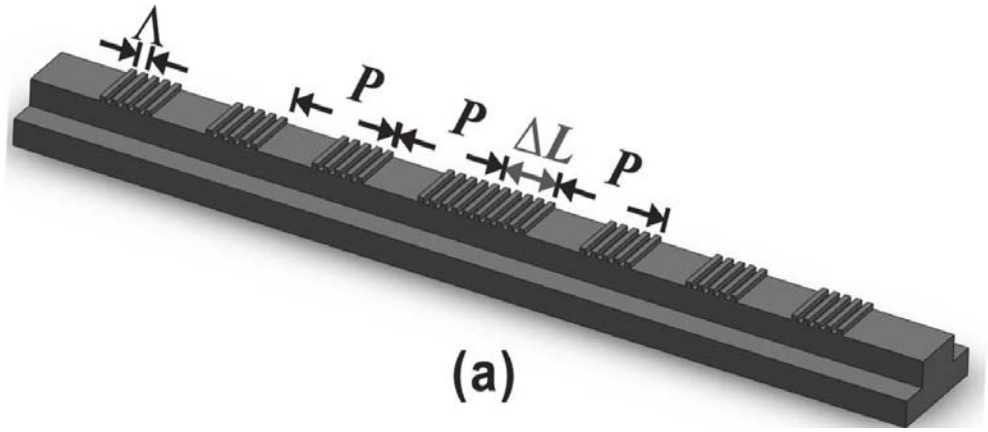


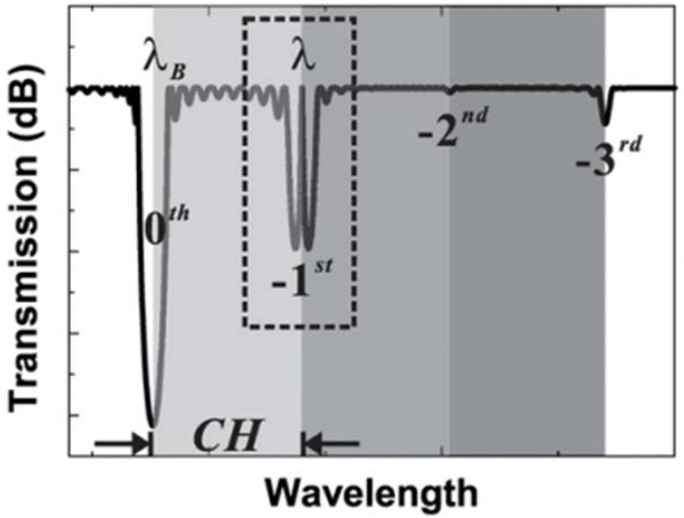
$$\theta = 2m\pi\frac{\Delta P}{P}$$

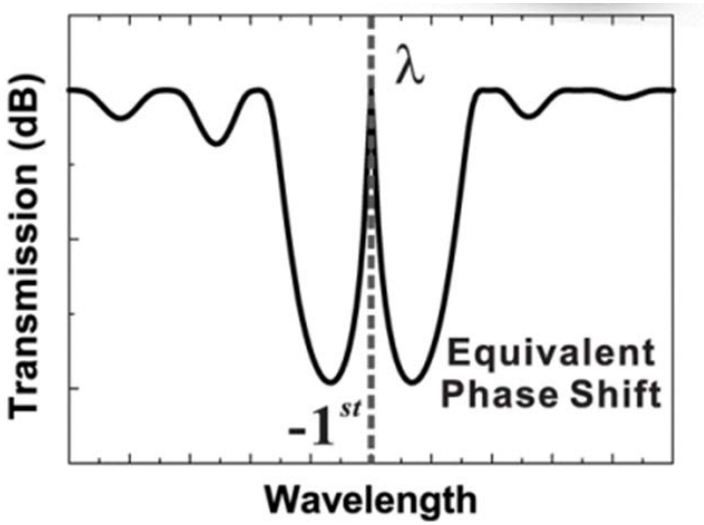
equivalent phase shift

Introduction – waveguide gratings

Grating	Phase-shifted block length	
Conventional phase-shifted grating	¼ λ	Need high fabrication accuracy (nm range)
EPS grating	hundreds of λ	Reduced by three orders of magnitude (μm range)

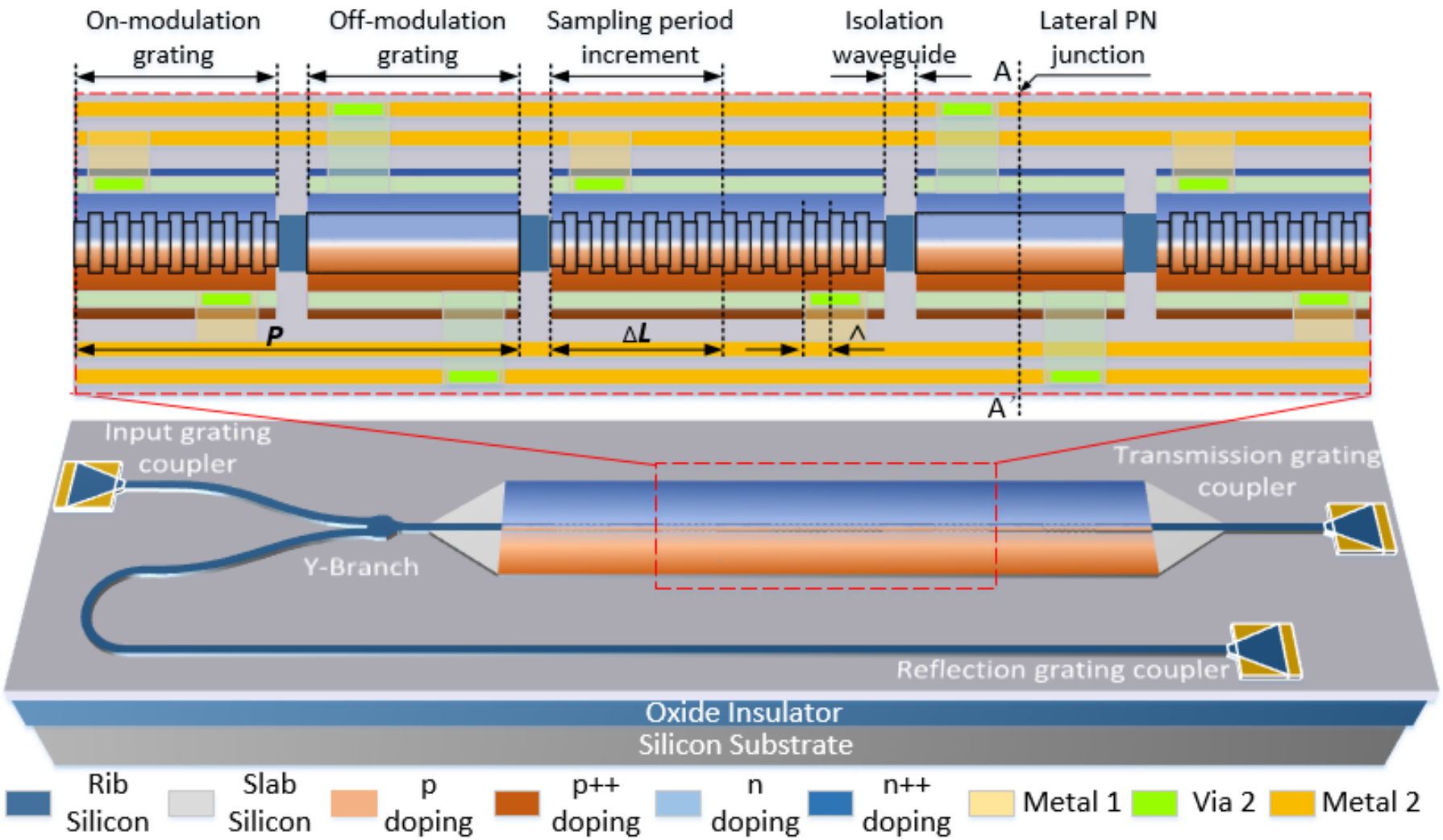




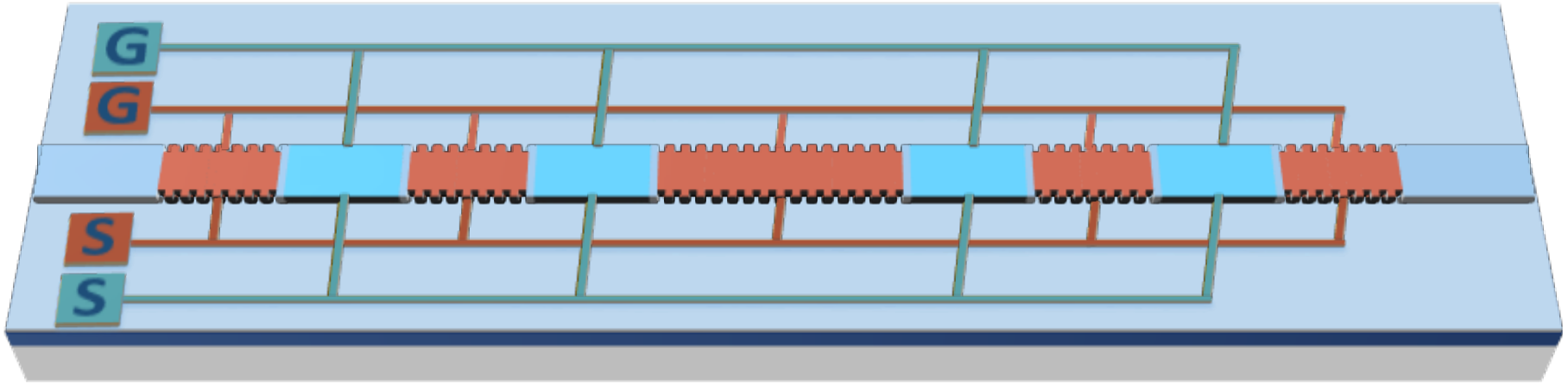


After fabrication, non-programmable

Programmable EPS grating design

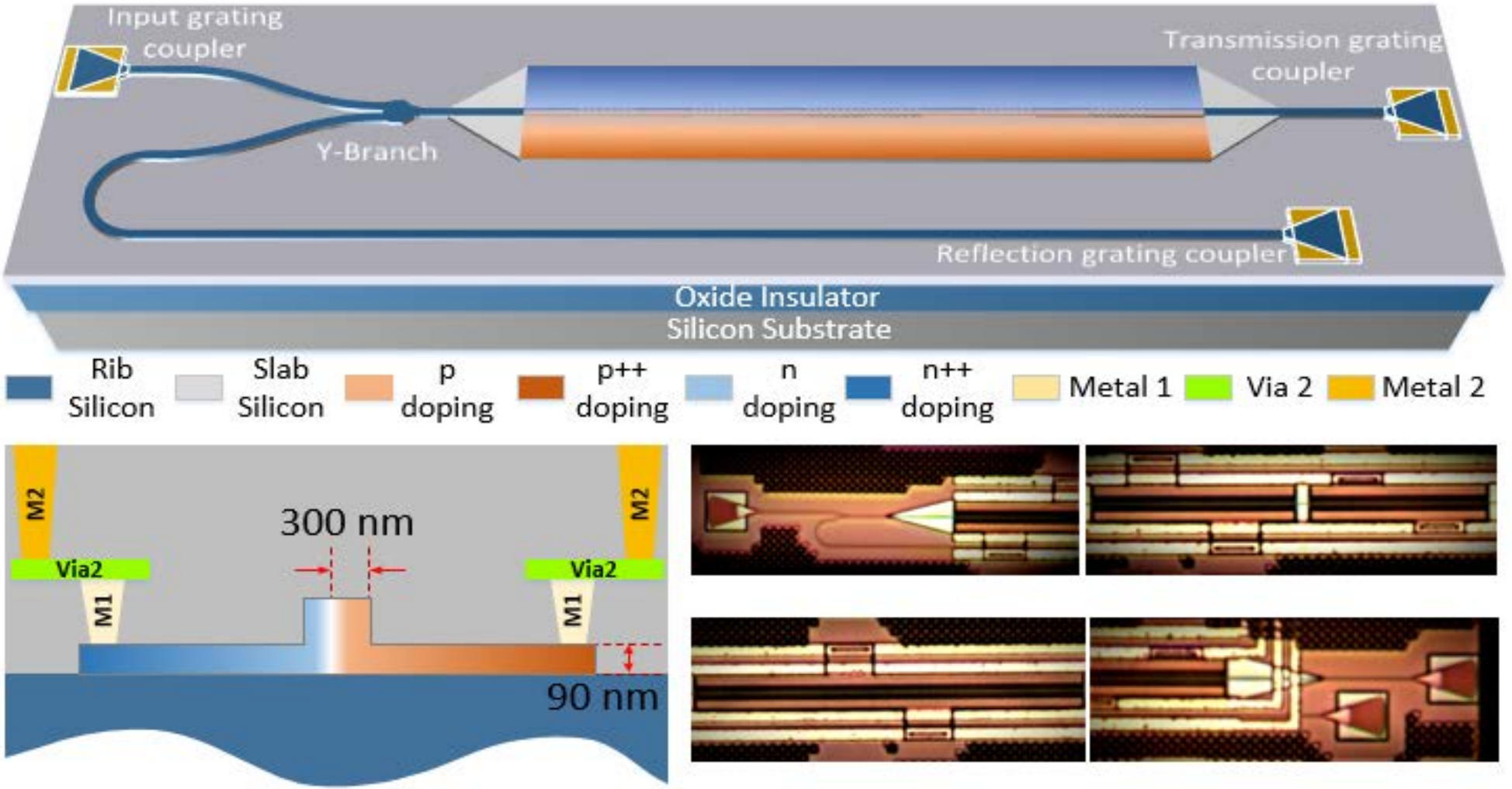


Programmable EPS grating design



Wafer → Grating → Doping → Independent Electrodes → Voltage Control → Programmable EPS Grating

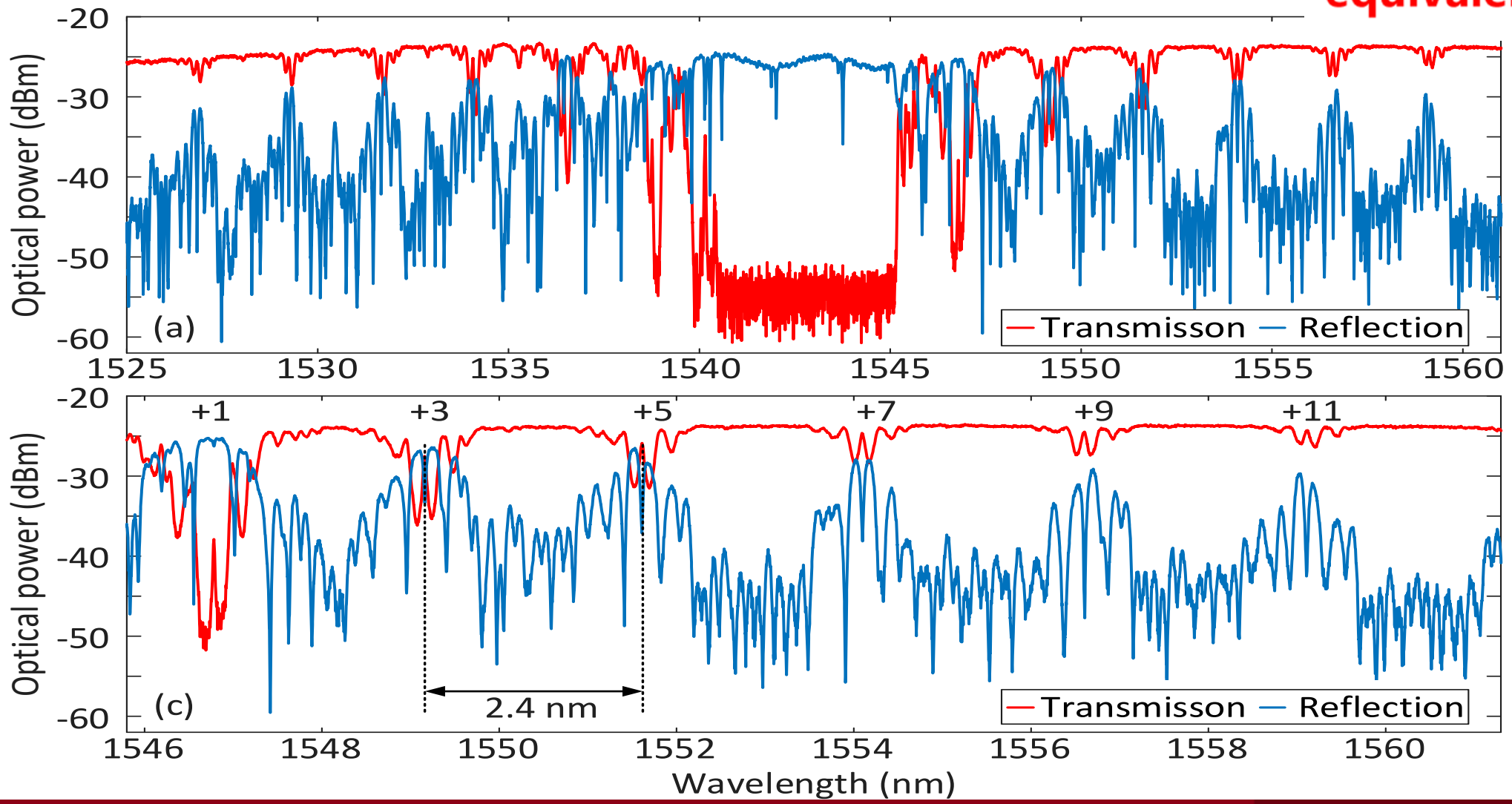
Programmable EPS grating design



Performance evaluation: static state

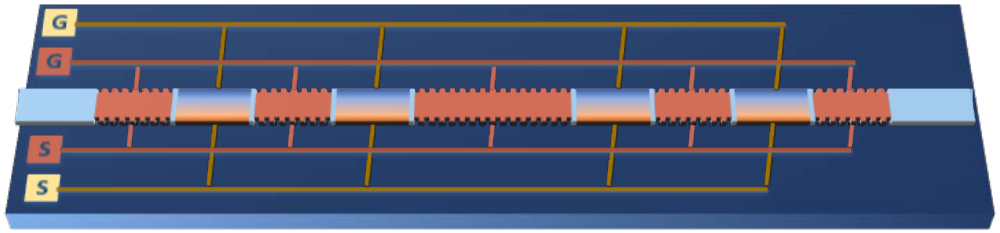
$$\theta = 2m\pi\frac{\Delta P}{P}$$

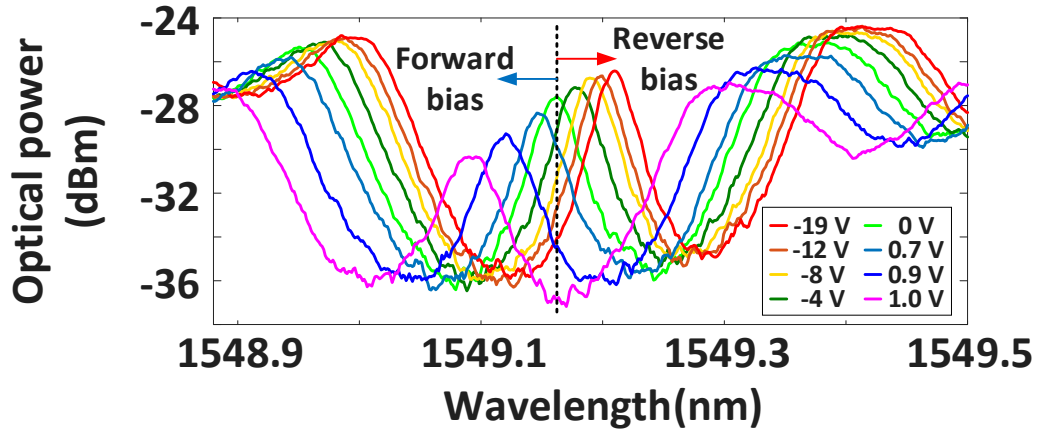
equivalent phase shift



Performance evaluation: independent tuning

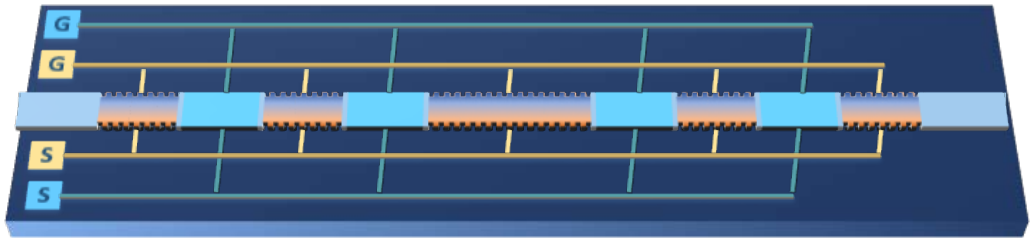
- ✓ Applying and tuning a bias voltage to the PN junctions in the on-modulation grating sections

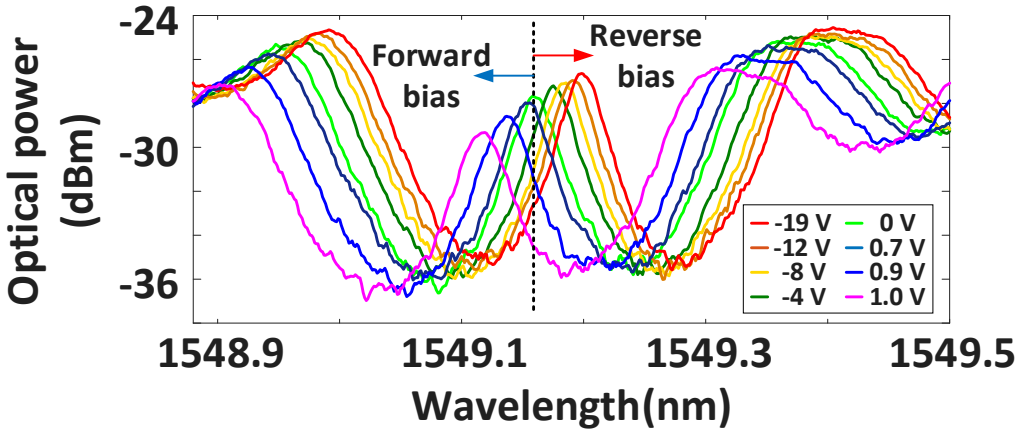




+3rd channel spectral response tuning

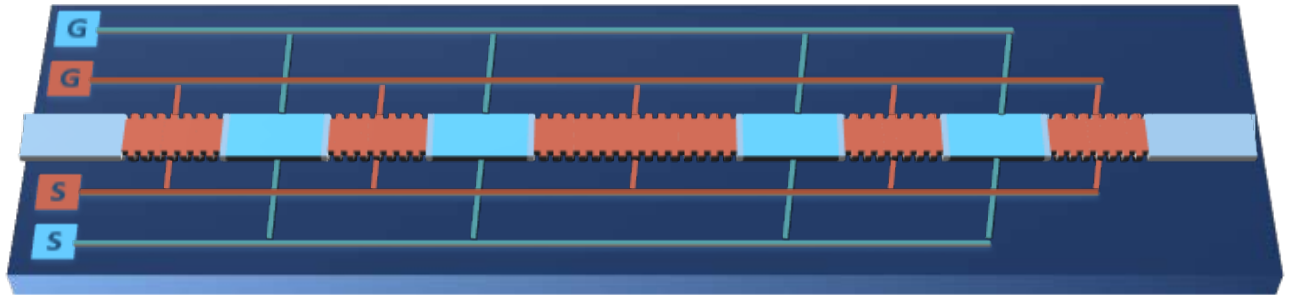
- ✓ Applying and tuning a bias voltage to the PN junctions in the off-modulation grating sections



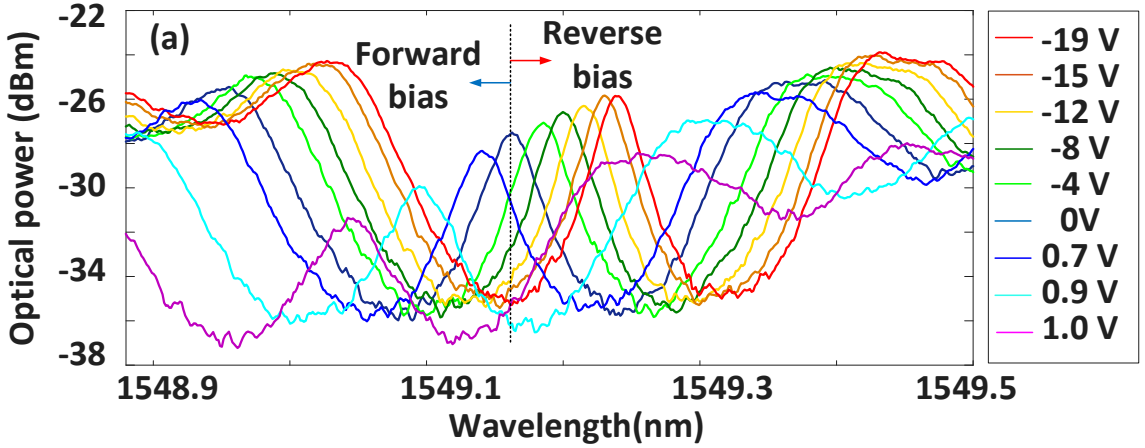


+3rd channel spectral response tuning

Performance evaluation: joint tuning

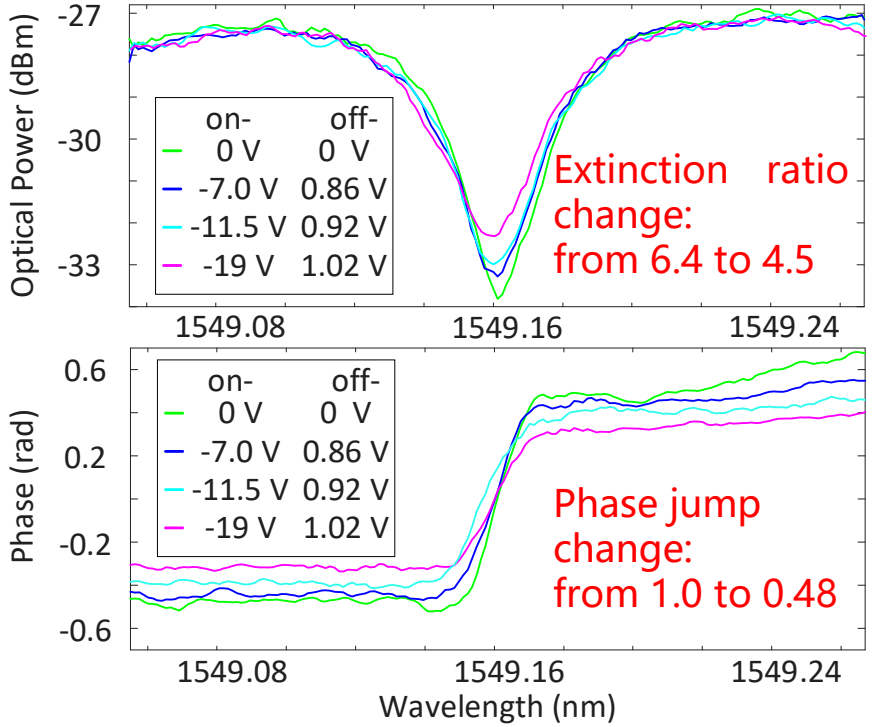


✓ 1. The two bias voltages are simultaneously and synchronously changed from −19 to +1 V.

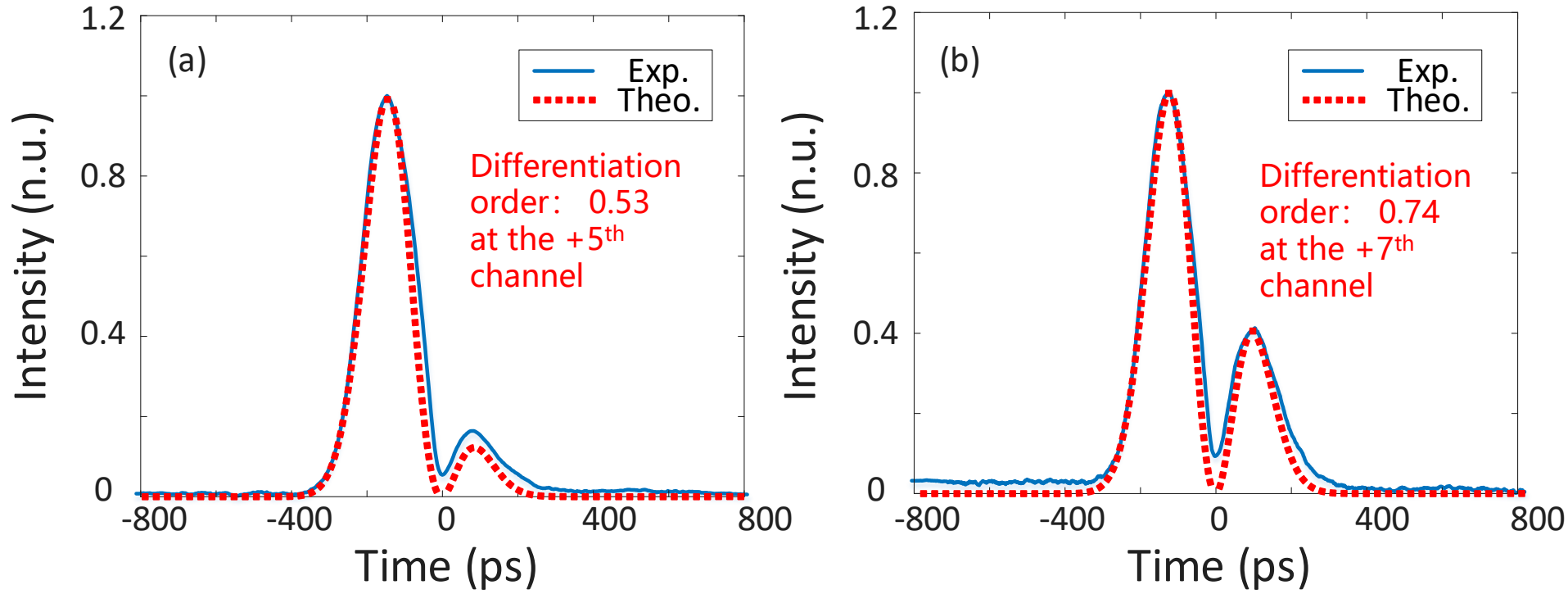


+3rd channel spectral response tuning

✓ 2. Tuning the extinction ratio while the 3rd channel notch wavelength is maintained unchanged for different bias voltages.



Multichannel signal processing: temporal differentiation



A multichannel temporal differentiator with a channel spacing of 2.4 nm is experimentally demonstrated. The figure shows the measured temporally differentiated pulses corresponding to a differentiation order of (a) 0.53 at the $+5^{th}$ channel, and (b) 0.74 at the $+7^{th}$ channel.

Conclusion

- ✓ A silicon-based on-chip electrically programmable EPS waveguide Bragg grating was designed, fabricated and experimentally demonstrated.
- ✓ By incorporating the programmable EPS grating in a microwave photonic system, a multichannel microwave photonic differentiator was experimentally demonstrated.
- ✓ Incorporating more independent control sections would enrich the functionality.

Thank you

Acknowledgements

CMC Microsystems

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