

FOR 2863 Meteracom Metrology for THz Communications



Mitigation of Thermal Crosstalk for Integrated THz-photonic Signal Processing

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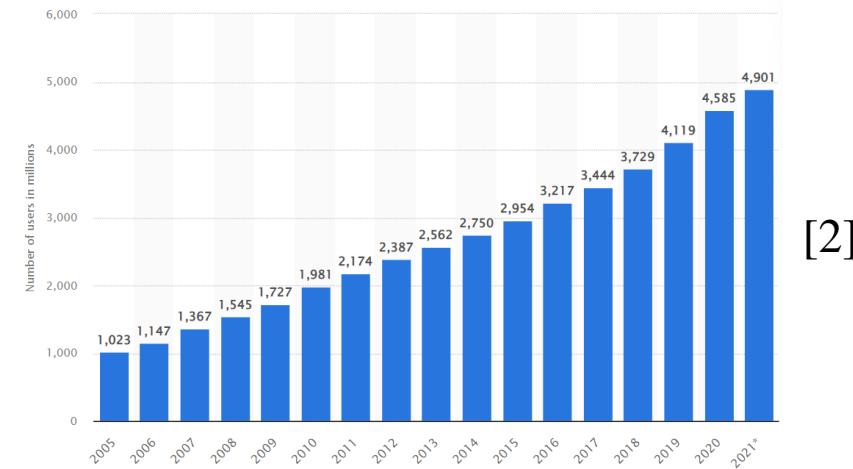
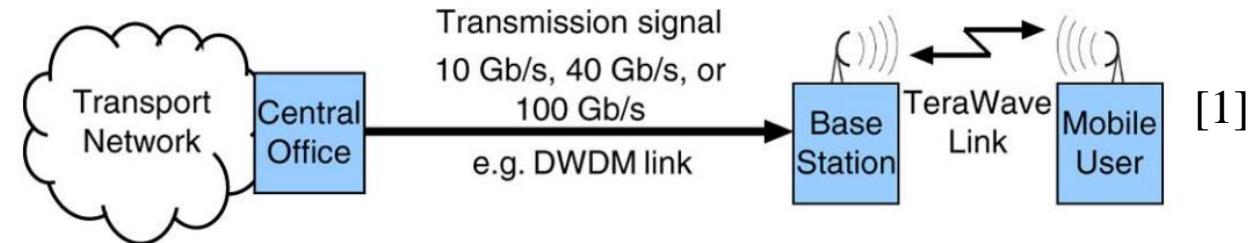
1st International Workshop on Metrology for THz Communications, Braunschweig, 28 June 2022

Outline

- ❖ Introduction
- ❖ Integrated heater designs
- ❖ Doped Si heater with deep trench
- ❖ Study of thermal crosstalk in photonic devices:
 - ❖ Avalanche photodetectors (APDs)
 - ❖ Travelling Wave Mach-Zehnder modulator (TW-MZM)
- ❖ Conclusion
- ❖ Acknowledgement

Introduction

- ❖ **THz-Photonic signal processing [1]:**
Wide bandwidth
Solution for high data traffic [2]
- ❖ **Integrated silicon photonics technology:**
Signal generation in THz range
- ❖ **Photonic phase shifters: sensing, processing [3]**



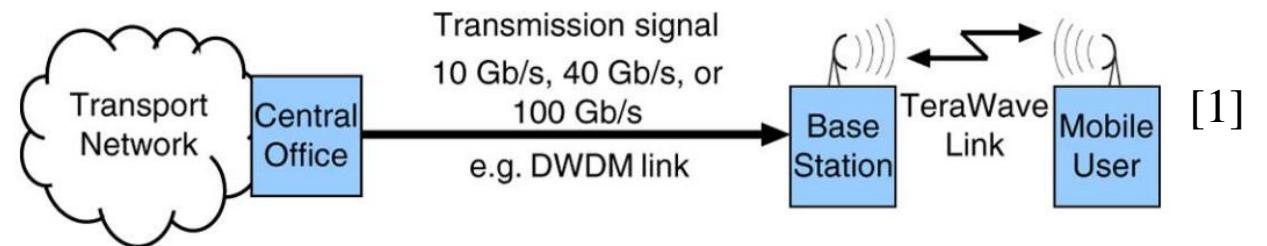
[1] T. Schneider *et al.*, "Link Budget Analysis for Terahertz Fixed Wireless Links," in *IEEE Transactions on Terahertz Science and Technology*, vol. 2, no. 2, pp. 250-256, March 2012.

[2] J. Johnson, "Global number of internet users 2005-2019" in Statista. <https://www.statista.com/statistics/273018/number-of-internet-users-worldwide/>

[3] B. A. Moller *et al.*, "Silica-waveguide thermooptic phase shifter with low power consumption and low lateral heat diffusion," in *IEEE Photonics Technology Letters*, vol. 5, no. 12, pp. 1415-1418, Dec. 1993.

Introduction

- ❖ Avalanche photodiode: high gain, high sensitivity [4]
- ❖ Mach-Zehnder modulator: high speed, high efficiency modulation [5]
- ❖ Issue: Thermal Crosstalk
- ❖ Solution: deep trench [5]

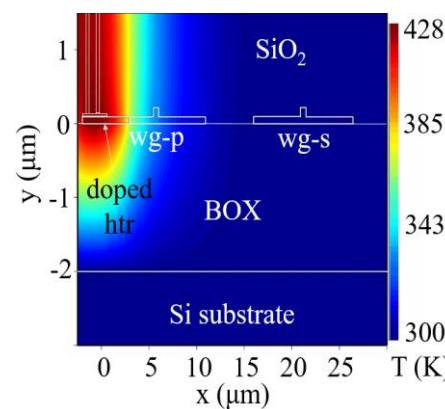
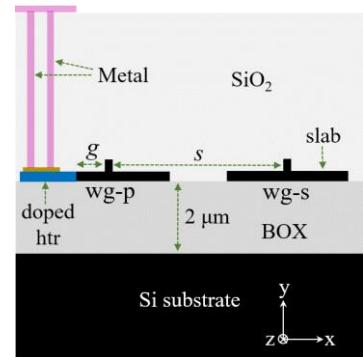
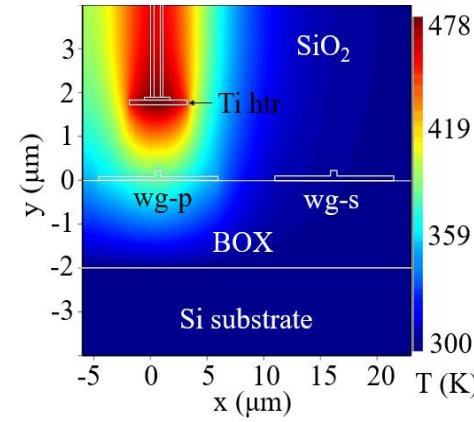
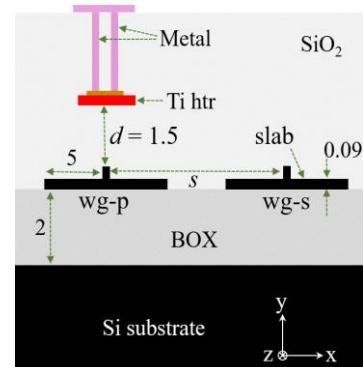


[1] T. Schneider *et al.*, "Link Budget Analysis for Terahertz Fixed Wireless Links," in *IEEE Transactions on Terahertz Science and Technology*, vol. 2, no. 2, pp. 250-256, March 2012.

[4] Z. Huang., *et al.*, "25 Gbps low-voltage waveguide Si-Ge avalanche photodiode," *Optica* 3, 793-798 (2016).

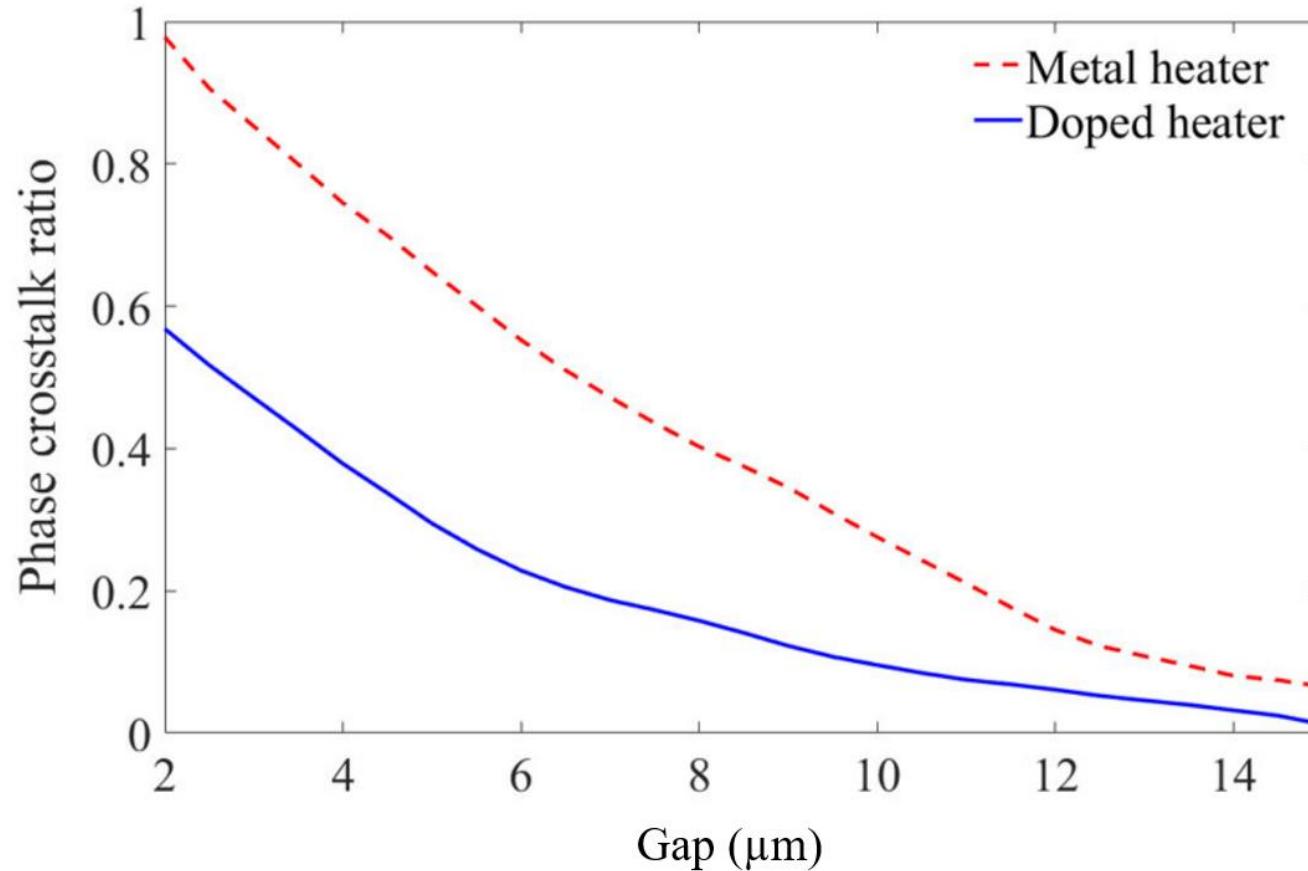
[5] S. De, R. K. Varshney and T. Schneider, "CMOS-Compatible Photonic Phase Shifters With Extremely Low Thermal Crosstalk Performance," in *Journal of Lightwave Technology*, vol. 39, no. 7, pp. 2113-2122, 1 April, 2021.

Integrated heaters designs



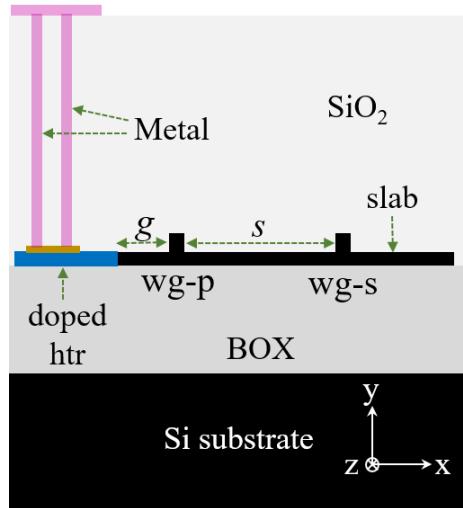
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Integrated heaters performance comparison

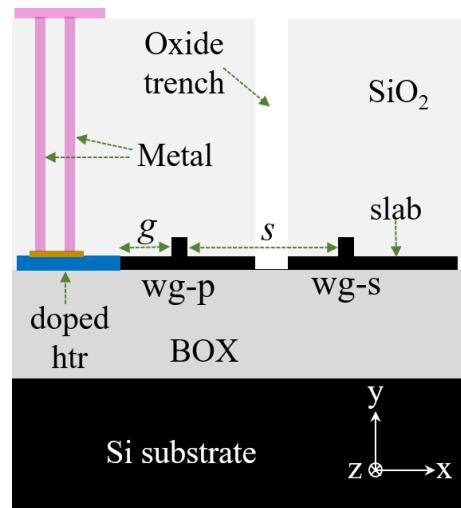


[5] S. De, R. Das, R. K. Varshney and T. Schneider, "CMOS-Compatible Photonic Phase Shifters With Extremely Low Thermal Crosstalk Performance," in *Journal of Lightwave Technology*, vol. 39, no. 7, pp. 2113-2122, 1 April, 2021.

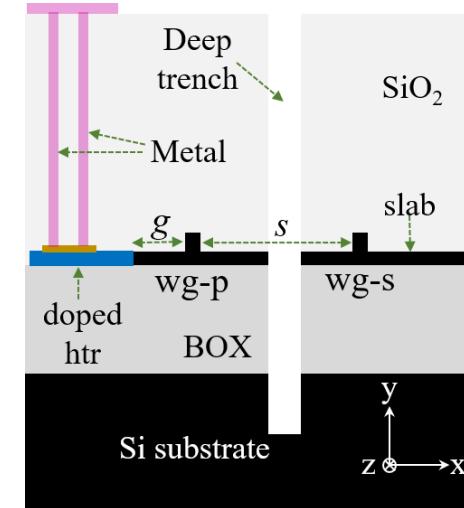
Doped silicon heater with trench designs



No trench



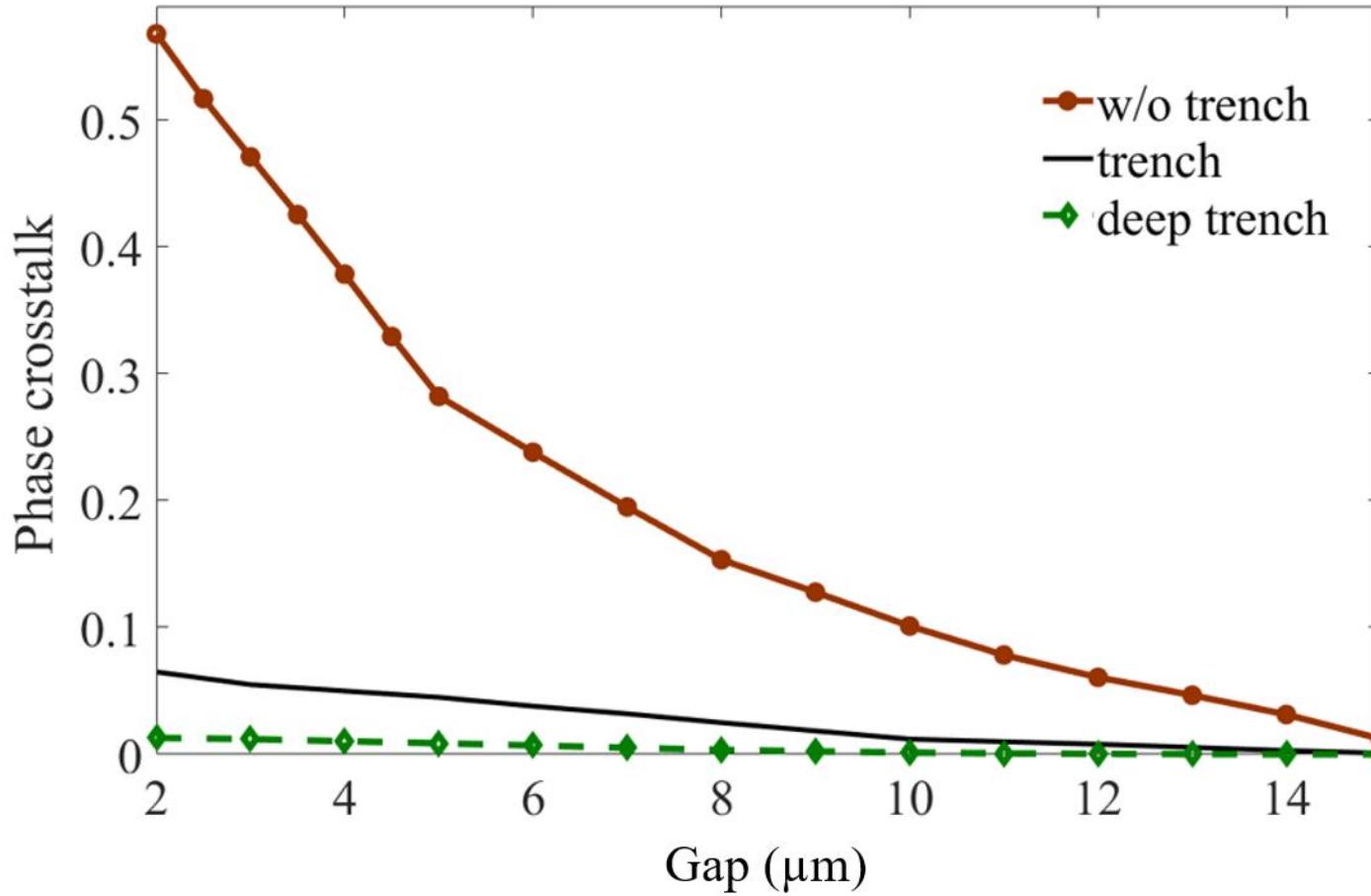
Oxide trench



Deep trench

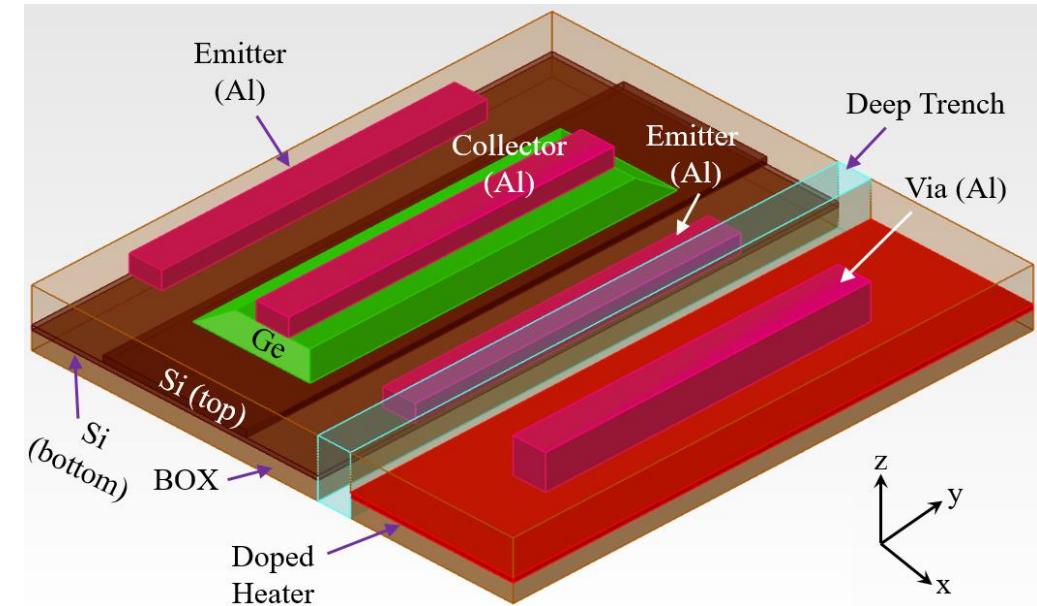
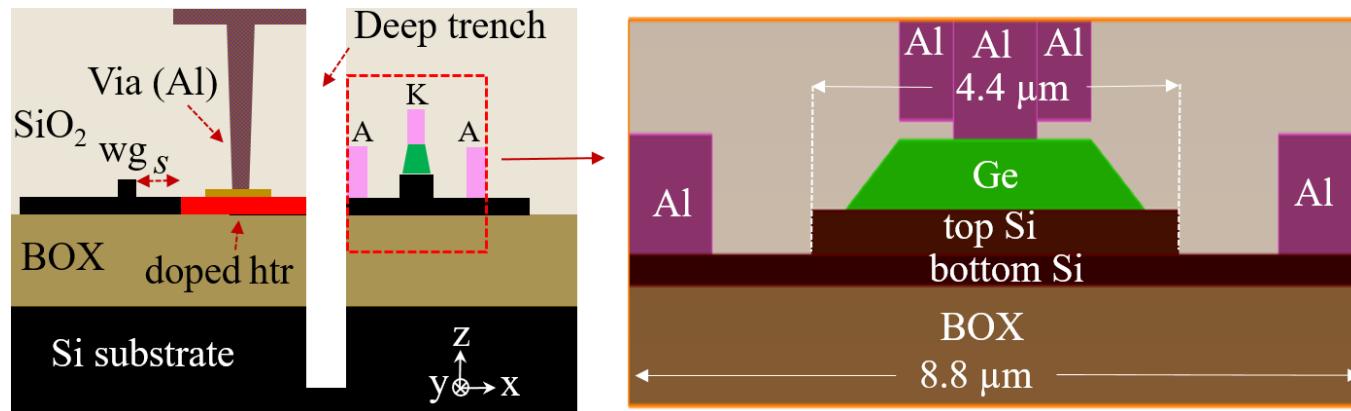
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Doped silicon heater with deep trench design



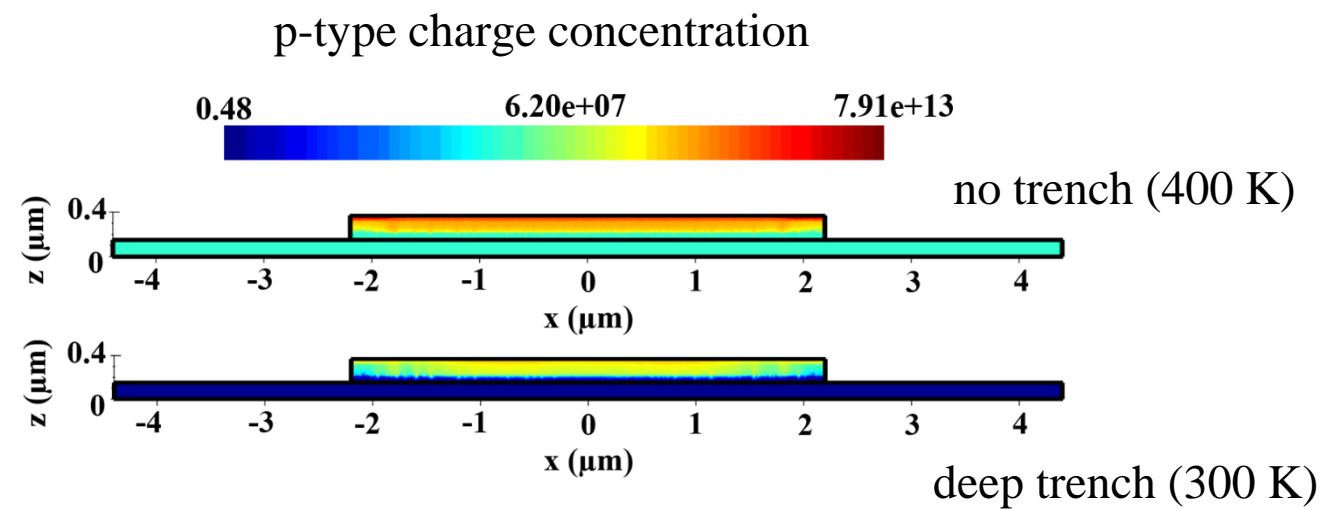
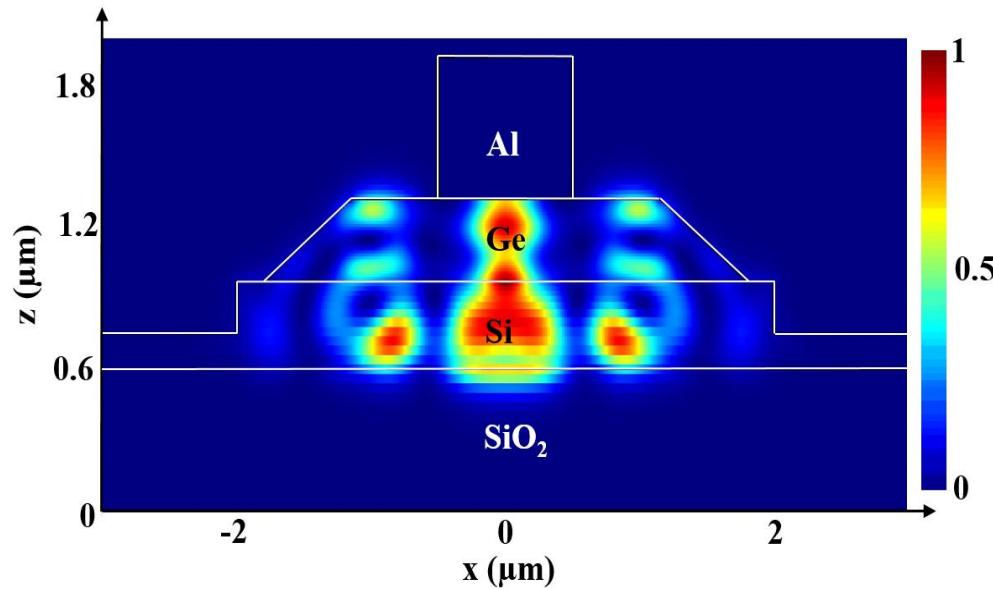
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APD: Device design



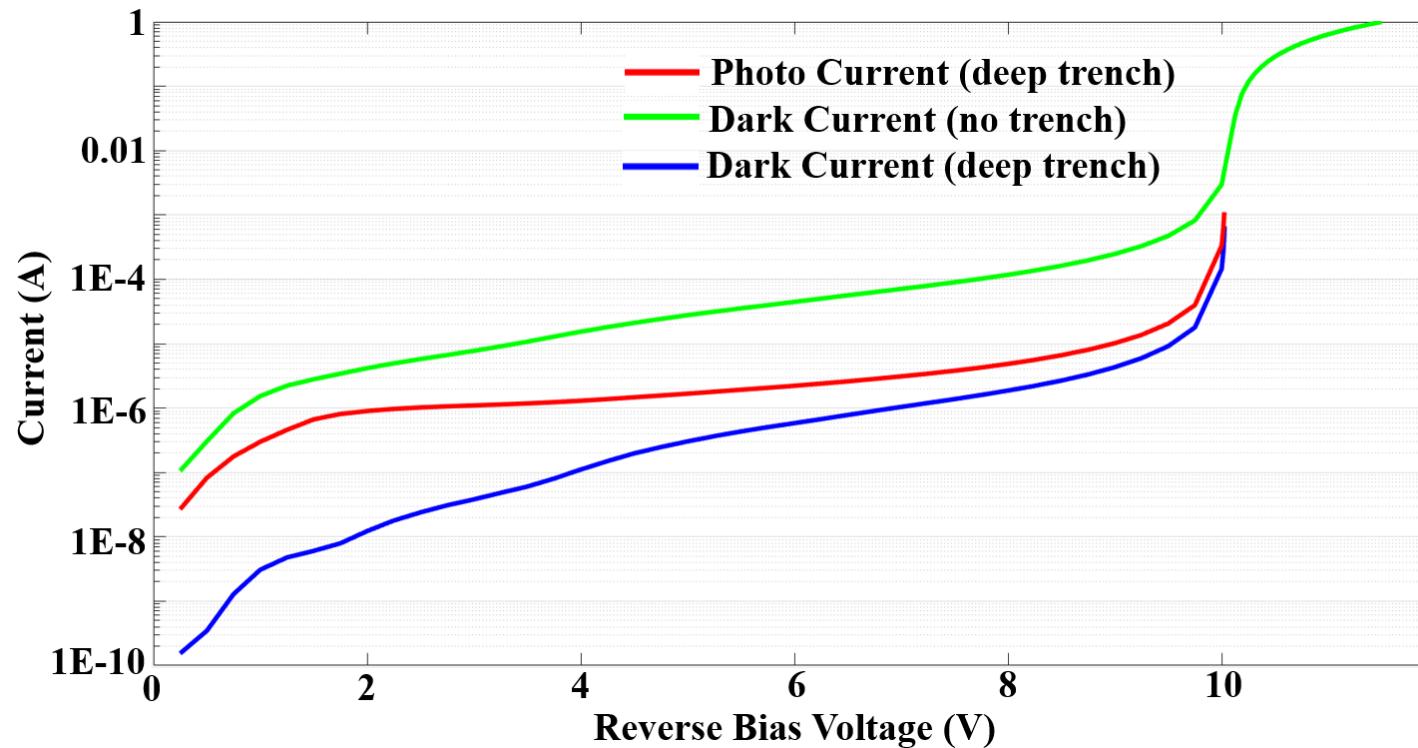
[6] S. De, R. Das, K. Singh, Y. Mandalawi, T. Kleine-Ostmann, T. Schneider, "Temperature insensitive Avalanche Photodetectors", *OSA Advanced Photonics Congress*, 24th - 28th July, 2022. (accepted)

APD: Optical mode profile and charge profile



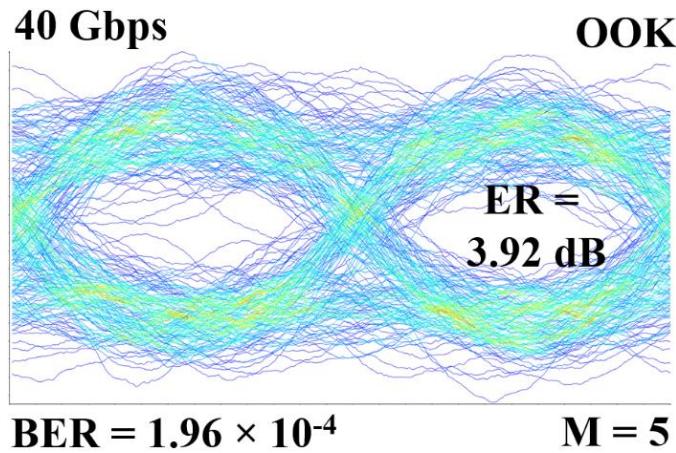
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APD: Dark current and photocurrent analysis

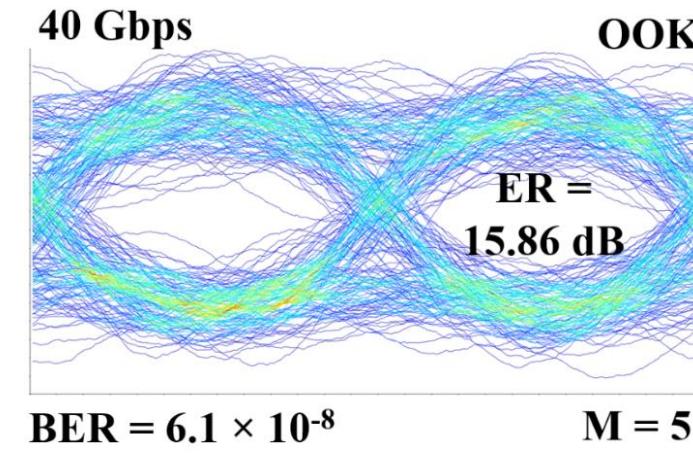


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APD: Data transmission analysis



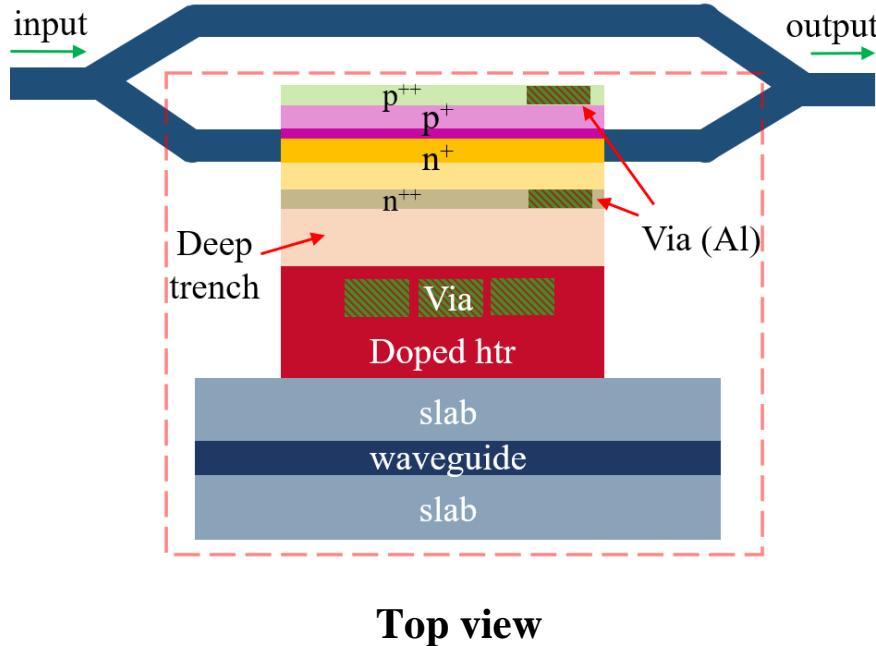
No trench



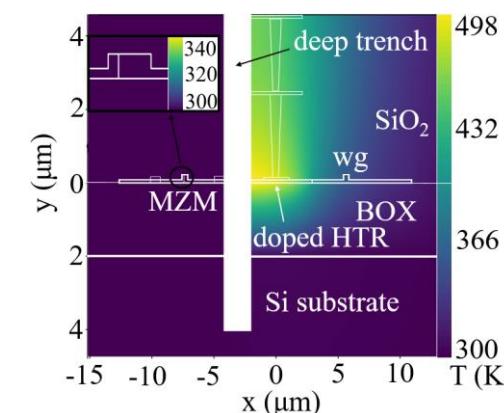
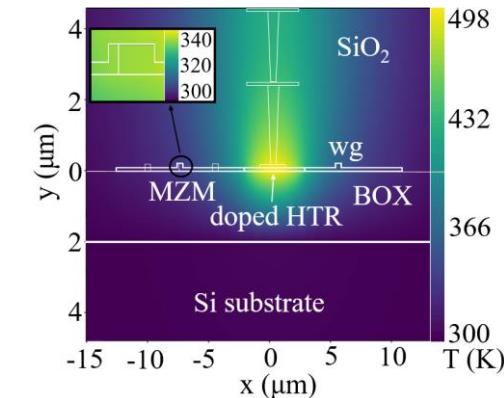
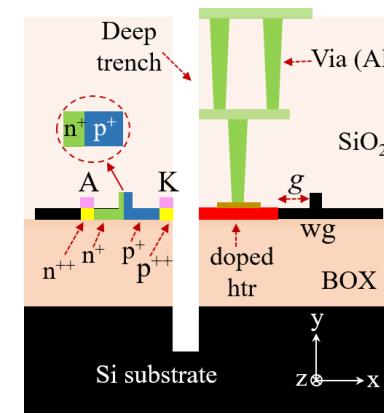
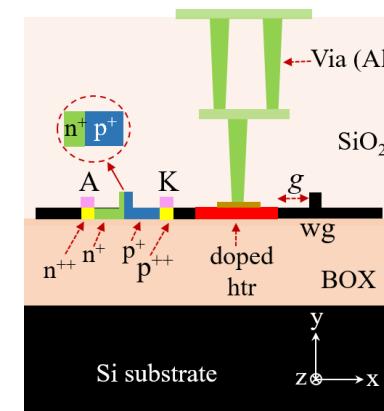
Deep trench

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TW-MZM: Device design and thermal characterization

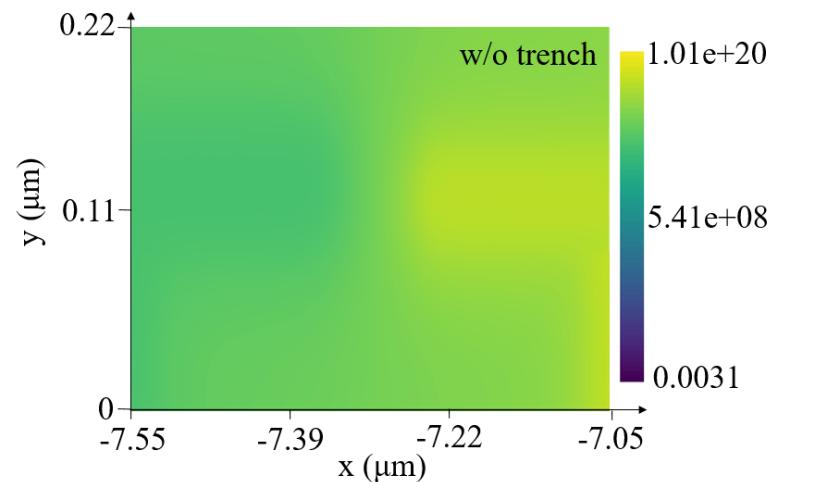


Top view

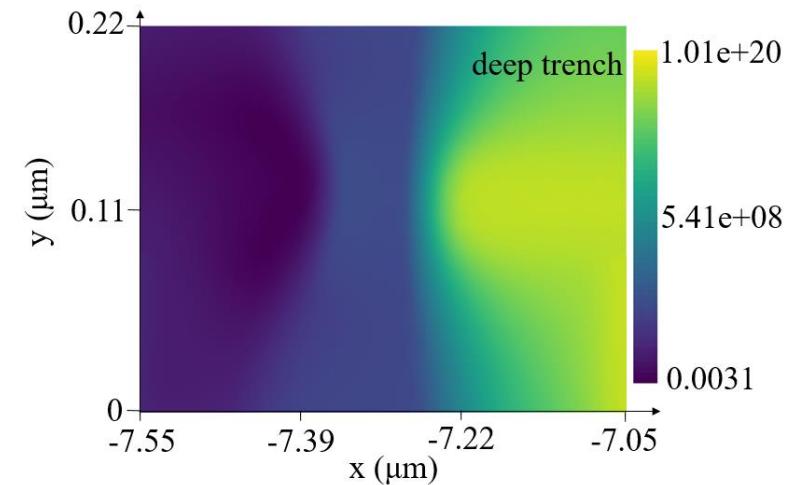
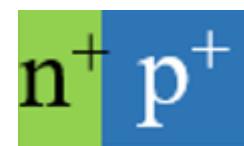


[7] S. De, R. Das, T. Kleine-Ostmann, and T. Schneider, "Athermal Travelling Wave Mach-Zehnder Modulators for Optical Interconnects," in *OSA Advanced Photonics Congress 2021*, OSA Technical Digest (Optica Publishing Group, 2021), paper NeF1B.4.

TW-MZM: Active region charge profile



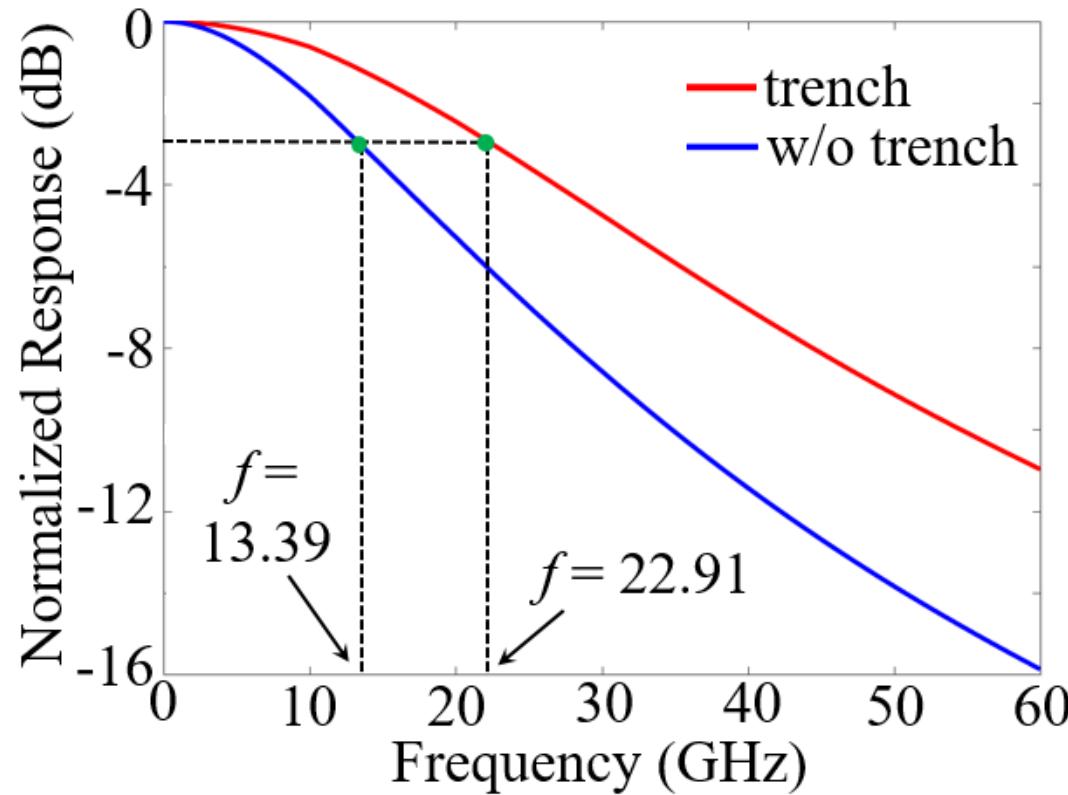
No trench



Deep trench

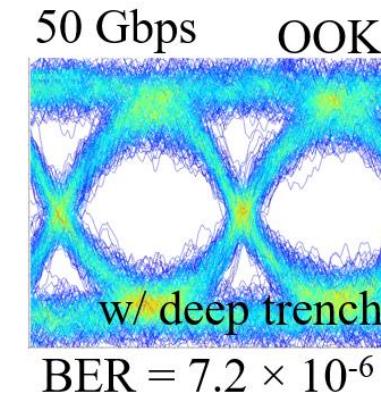
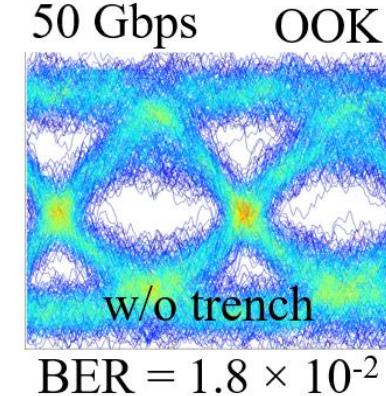
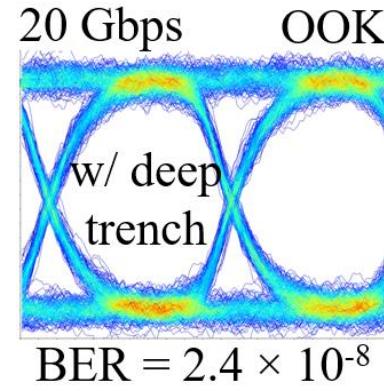
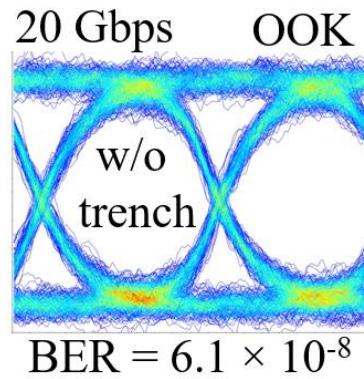
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TW-MZM: Device bandwidth estimation



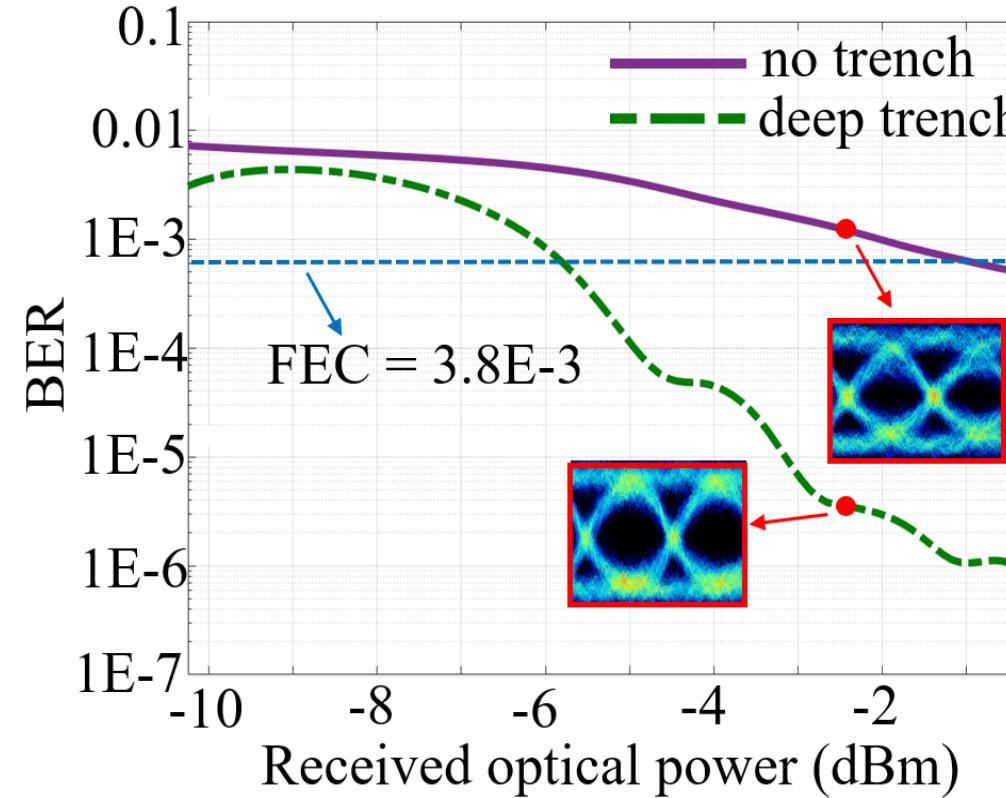
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TW-MZM: Device data transmission



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TW-MZM: Device data transmission



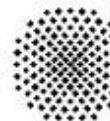
[8] S. De, R. Das, T. Kleine-Ostmann and T. Schneider, "Effect of Thermal Crosstalk on Travelling-wave Mach-Zehnder Modulator," *2021 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC)*, 2021, pp. 1-1.

Conclusion

- ❖ Integrated silicon photonics: THz communication
- ❖ Deep trench: Power efficient
 - Mitigation of thermal crosstalk in photonic devices
 - (a) APD: Reduced dark current, photocurrent, improved BER, ER
 - (b) TW-MZM: Bandwidth enhancement by 71%, low BER
- ❖ Proposed design applications: High-bandwidth, densely packed circuits
 - System-level analysis

Acknowledgement

Thank you very much for your Attention



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