



Interconnect-Free Multibit Arithmetic and Logic Unit in a Single Reconfigurable $3 \mu\text{m}^2$ Plasmonic Cavity

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All 2-Input Logic Gates and a Half-Adder in a Single Reconfigurable Plasmonic Cavity

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Abstract:

Main text

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Supplementary Materials:

[Materials and Methods](#)

[Figures S1-S6](#)

[Movies SMI](#)

Author Contributions. ED, AB designed the experiments. RM, SB synthesized the Au microplatelets. UK, ED conducted the sample preparation and nanofabrication steps. AB, SV implemented the experimental optical set-up. UK, SV performed the optical experiments. ED, UK processed the data. CG, AC, UK, GCdF developed the simulations tools and performed all GDM calculations. ED developed the gate mapping and drafted the manuscript, which was amended by all co-authors. All co-authors have given approval to the final version of the manuscript.

References and Notes:

1. M. M. Waldrop, The semiconductor industry will soon abandon its pursuit of Moore's law. Now things could get a lot more interesting. *Nature* **530**, 144-147 (2016).
2. R. T. Kouzes, G. A. Anderson, S. T. Elbert, I. Gorton, D. K. Gracio, The changing paradigm of data-intensive computing. *Computer* **42**, 26-34 (2009).
3. H. J. Caulfield, S. Dolev, Why future supercomputing requires optics. *Nat. Photonics* **4**, 261-263 (2010).
4. Y. L. Fu *et al.*, All-Optical Logic Gates Based on Nanoscale Plasmonic Slot Waveguides. *Nano Lett.* **12**, 5784-5790 (2012).
5. P. Singh, D. K. Tripathi, S. Jaiswal, H. K. Dixit, All-Optical Logic Gates: Designs, Classification, and Comparison. *Adv. Opt. Tech.*, 275083 (2014).
6. M. Zhang *et al.*, Electronically programmable photonic molecule. *Nat. Photonics* **13**, 36-+ (2019).
7. B. C. Han, Y. Liu, All-optical reconfigurable non-inverted logic gates with a single semiconductor optical amplifier. *AIP Adv.* **9**, (2019).
8. R. Salem *et al.*, Signal regeneration using low-power four-wave mixing on silicon chip. *Nat. Photonics* **2**, 35-38 (2008).
9. D. A. B. Miller, Are optical transistors the logical next step? *Nat. Photonics* **4**, 3-5 (2010).
10. M. P. Nielsen, X. Y. Shi, P. Dichtl, S. A. Maier, R. F. Oulton, Giant nonlinear response at a plasmonic nanofocus drives efficient four-wave mixing. *Science* **358**, 1179-1181 (2017).
11. A. Silva *et al.*, Performing Mathematical Operations with Metamaterials. *Science* **343**, 160-163 (2014).
12. D. R. Solli, B. Jalali, Analog optical computing. *Nat. Photonics* **9**, 704-706 (2015).
13. N. M. Estakhri, B. Edwards, N. Engheta, Inverse-designed metastructures that solve equations. *Science* **363**, 1333-+ (2019).
14. Y. C. Shen *et al.*, Deep learning with coherent nanophotonic circuits. *Nat. Photonics* **11**, 441-+ (2017).
15. S. Molesky *et al.*, Inverse design in nanophotonics. *Nat. Photonics* **12**, 659-670 (2018).
16. A. F. Koenderink, A. Alu, A. Polman, Nanophotonics: Shrinking light-based technology. *Science* **348**, 516-521 (2015).
17. H. Wei, Z. X. Wang, X. R. Tian, M. Kall, H. X. Xu, Cascaded logic gates in nanophotonic plasmon networks. *Nat. Commun.* **2**, (2011).
18. S. Viarbitskaya *et al.*, Tailoring and imaging the plasmonic local density of states in crystalline nanoprisms. *Nat. Mater.* **12**, 426-432 (2013).
19. S. Viarbitskaya, O. Demichel, B. Cluzel, G. C. des Francs, A. Bouhelier, Delocalization of Nonlinear Optical Responses in Plasmonic Nanoantennas. *Phys. Rev. Lett.* **115**, 197401 (2015).
20. A. Agreda *et al.*, Spatial Distribution of the Nonlinear Photoluminescence in Au Nanowires. *ACS Photonics* **6**, 1240-1247 (2019).
21. U. Kumar *et al.*, Designing Plasmonic Eigenstates for Optical Signal Transmission in Planar Channel Devices. *ACS Photonics* **5**, 2328-2335 (2018).
22. T. Feichtner, O. Selig, B. Hecht, Plasmonic nanoantenna design and fabrication based on evolutionary optimization. *Opt. Express* **25**, 10828-10842 (2017).
23. C. Girard, P. R. Wiecha, A. Cuche, E. Dujardin, Designing thermoplasmonic properties of metallic metasurfaces. *J. Opt.* **20**, (2018).