Integrated materials for quantum information

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The advantage of an integrated platform: programmable nanophotonic processor

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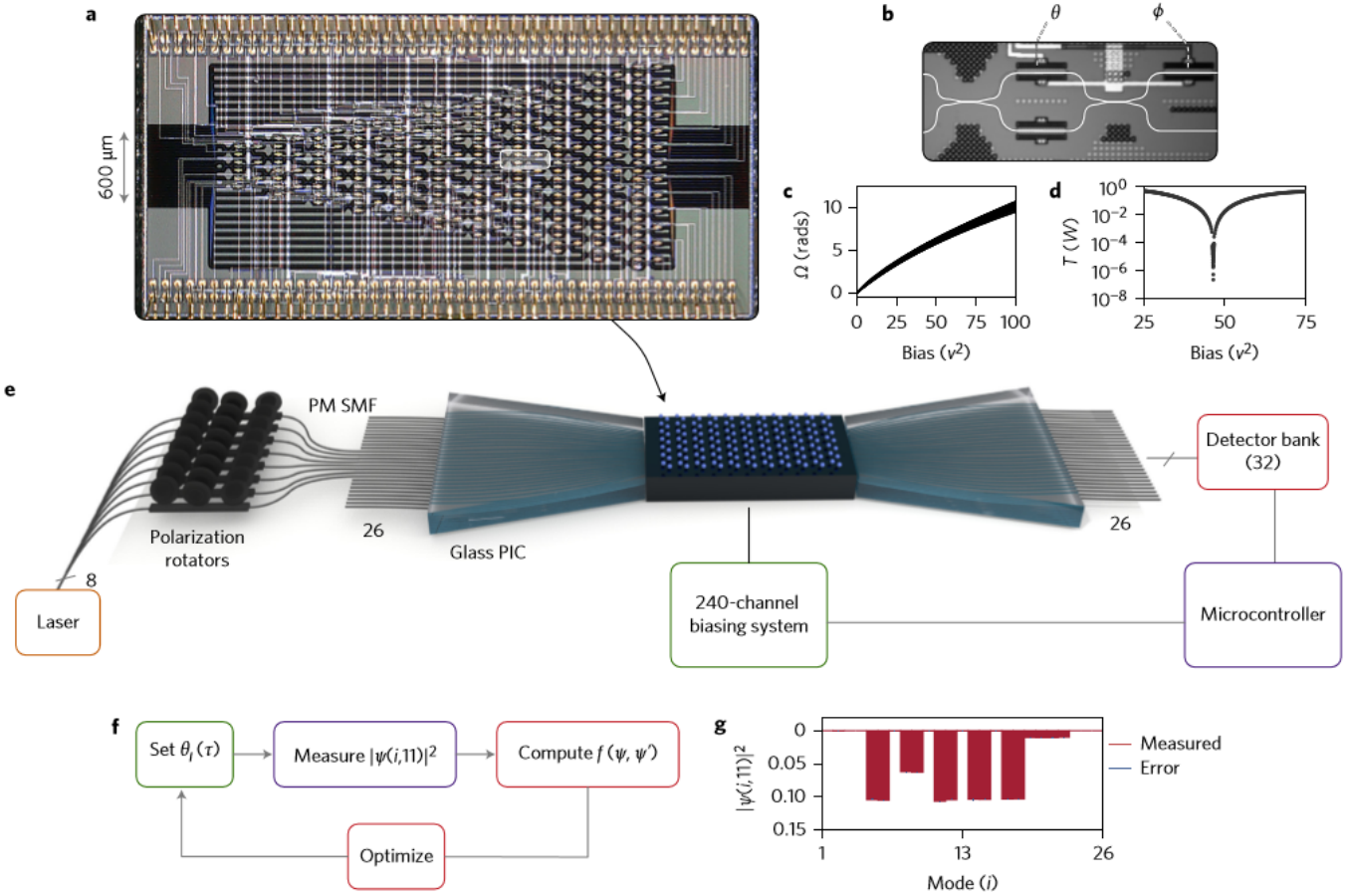

- 176 individually tunable phase modulators and 88 interferometers
- Detectors are array of 32 InGaAs photodiodes
- 4.9 mm× 2.4 mm.

N. C. Harris, G. R. Steinbrecher, M. Prabhu, Y. Lahini, J. Mower, D. Bunander, C. K. Chen, F. W. Wong, T. Baeher-Jones, M. Hochberg, S. Lloyd, and D. Englund, "Quantum transport simulations in a programmable nanophotonic processor," *Nature Photonics*, vol. 10, 2017.

The advantage of an integrated platform

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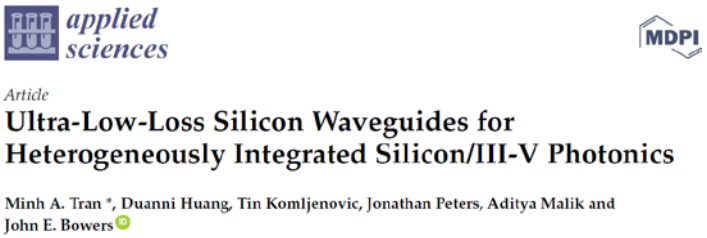
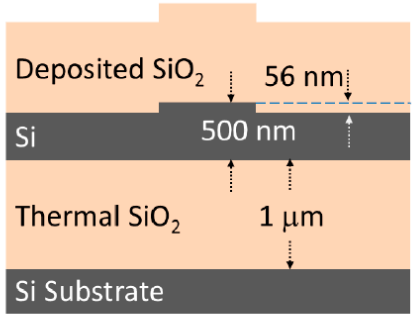
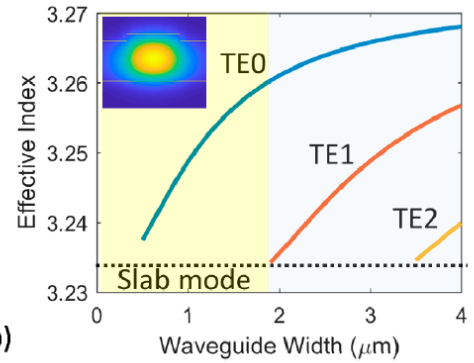
- **Integration** enables leveraging of existing technology in a compact form factor
- **Conventional semiconductor** materials at room temperature hold a natural edge in this space
- **Scalability** is an important issue for the implementation of quantum information components
  - Ability to mass produce quantum chips is of great importance
- **Data rates/bandwidth** can be increased with chip-scale implementation
- **Loss** is an important issue for integrated optical components
  - Can be be mitigated with proper designs (rib waveguides, low index contrast etc.)





(a)



(b)

Challenges of an integrated platform

- **Achieving second order nonlinearity**
  - Spontaneous parametric downconversion can be method of choice for entanglement
- **Switching**
  - Integrated switches which meet performance specs are lacking
- **Pump filtering**
  - Stray pump photons can wreak havoc
- **Heterogeneous integration**
  - Multiple materials needed
  - Example – integrated photonics used to address super-conducting qubits
- **Detectors**
  - Cryogenics can solve problem but are costly and large
  - Other solutions?

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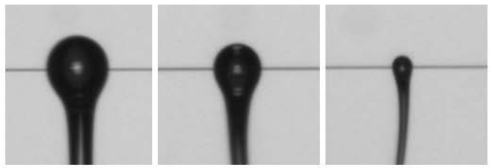
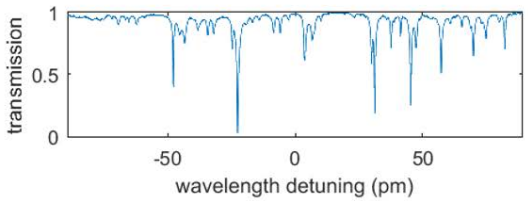
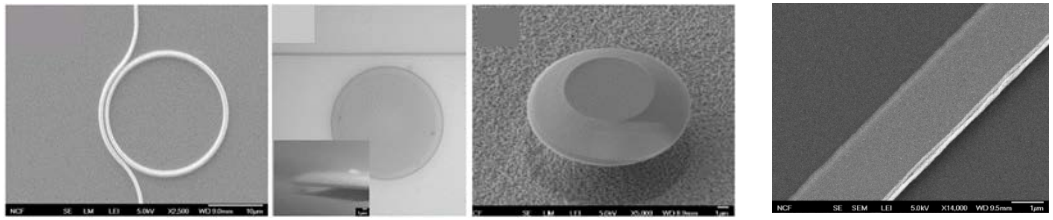
Integrated Ge-Se-Sb/S devices for quantum information

Juliet Gopinath & Won Park



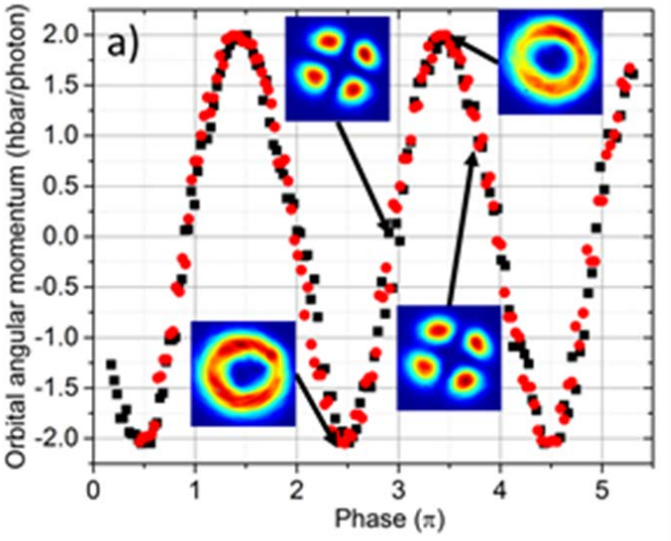




Optics Express **25**, 15581(2017)
Photonics Technology Letters **28**, 2720 (2016)

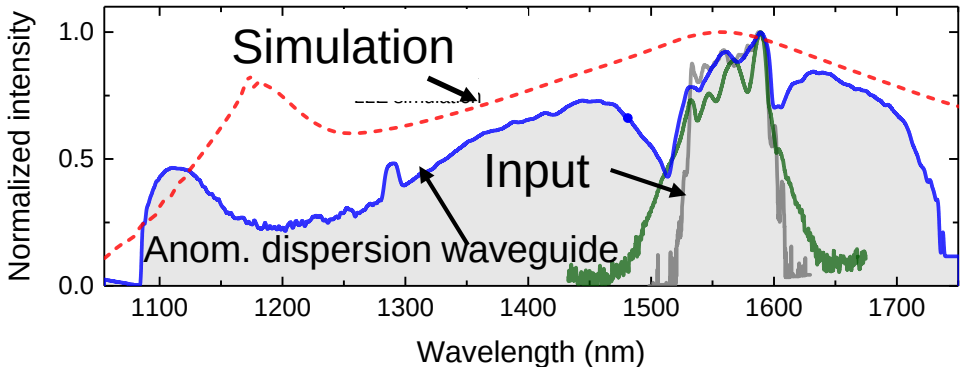
Optical orbital angular momentum

Juliet Gopinath & Mark Siemens (DU)



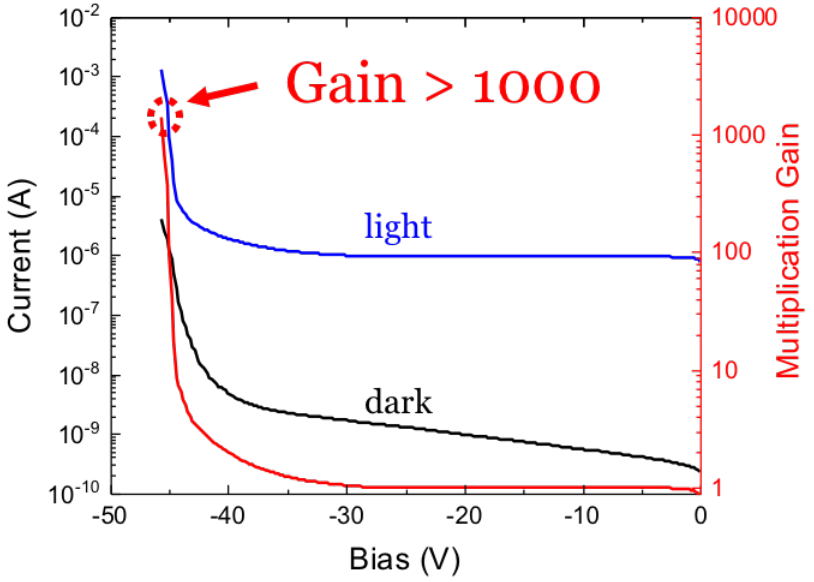
Optics Letters **41**, 5736 (2016)
Optics Letters **41**, 3213 (2016)
Optics Letters **41,** 5019 (2016)

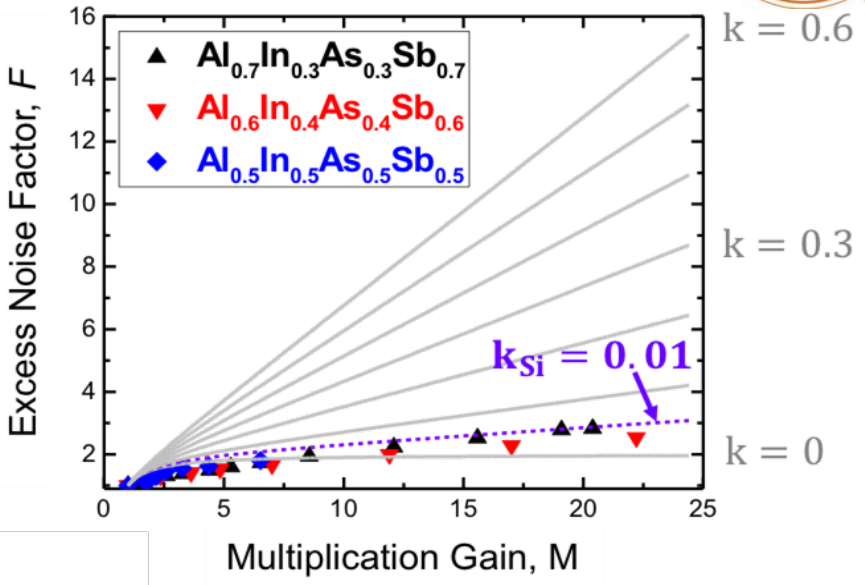
Supercontinuum



AlInAsSb: first low noise III-V APD alloy system

Seth Bank, UT-Austin; Joe Campbell, UVA





- Engineer impact ionization on few atom scale with digital alloys → first low noise III-V APD alloy family!
  - Accessible wavelengths: ~1-5 μm
  - Comparable noise to silicon!
  - Direct bandgap → up to 10-20x BW of Si
  - Record temperature stability of $V_{breakdown}$
  - Single photon counting at 300K
  - RAISE-TAQS: photon number resolution