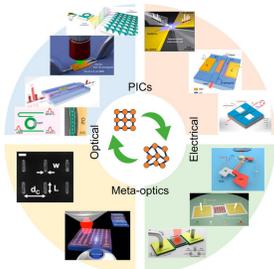




Nonvolatile electrically programmable integrated photonics empowered by phase-change materials

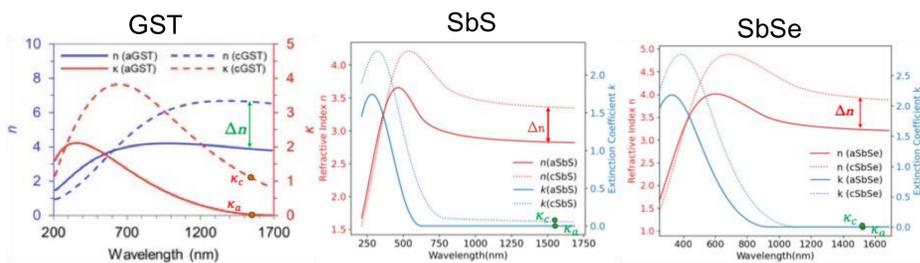
STUDENT: JAYITA DUTTA (PhD Candidate & UW-UPWARDS Fellow 2025-26, ECE)

Phase-change materials (PCMs) integrated programmable photonic integrated circuits (PICs)

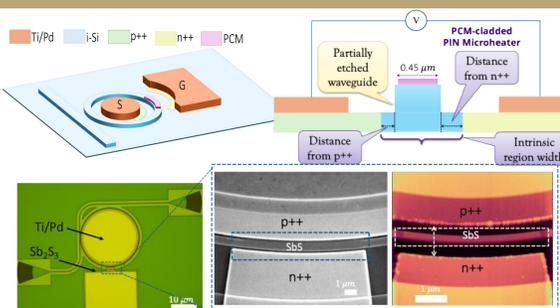


Challenges:

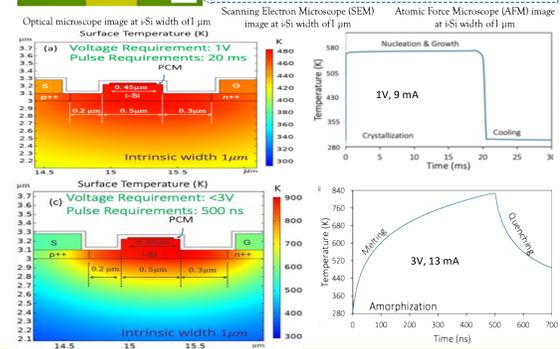
- Increase endurance: 1 billion cycle ✓
- Reduce loss to 0.01dB per unit ✓
- Sub-3V reconfiguration ✓
- High bit precision ✓
- Large scale Integration ✓



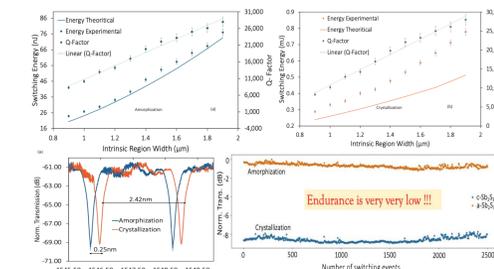
Low power actuation of Sb₂Se₃ - Si microring resonator by optimizing the PIN heater geometry



- Schematic, optical, SEM & AFM images of Sb₂Se₃ clad Si micro-ring resonator
- Electrically controlled by Si PIN microheater
- Heat transfer in COMSOL for reversible switching of PCM Sb₂Se₃
- Intrinsic width of PIN heater varied from 0.9 μm to 1.9 μm
- Lowest power actuation at CMOS voltage of <3V



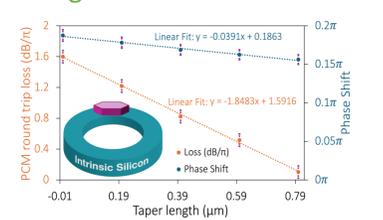
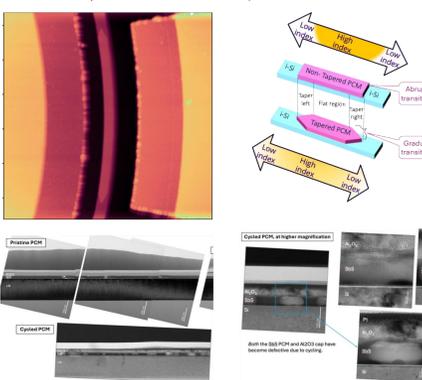
Electrical Programmability of photonic device at CMOS compatible voltage of <3V



- Endurance is **very low** and loss is very high (1.6 dB/π)
- At l = 0.9 μm, Δn = 0.25nm
- **SET:** 1.6 V, 15 mA, 20-ms, 0.48 mJ
- **RESET:** 2.75 V, 25.7 mA, 500-ns, 35.33 nJ

Lower PCM induced loss by taper engineering

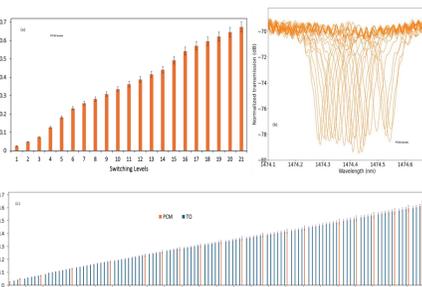
8-10% taper engineering reduces PCM induced losses by 90 % from 1.65 dB/π to 0.1 dB/π with switching voltage < 3V but low endurance



Thinner Alumina gets degraded over repeated cycling causing smaller atoms like 'S' to escape

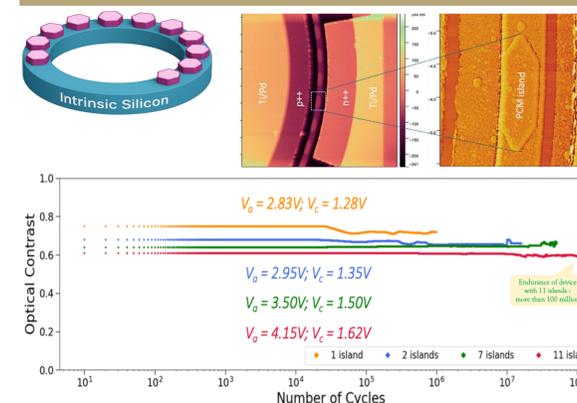
Thicker Alumina : 40 nm to 100 nm improves endurance of tapered PCM to 1 million cycles

Low-power 7-bit hybrid volatile/non-volatile tuning of Si Microring Resonator (MRR)

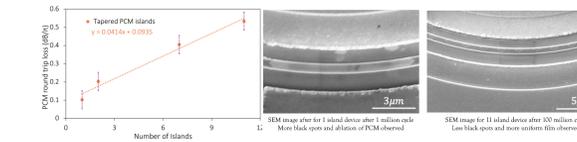


- 22 non-volatile PCM levels
- 105 volatile thermo-optic (TO) levels
- PCM tuning: Reset Pulse, 2.45V – 2.65V
- TO tuning, DC voltage 0.85V – 1.5V

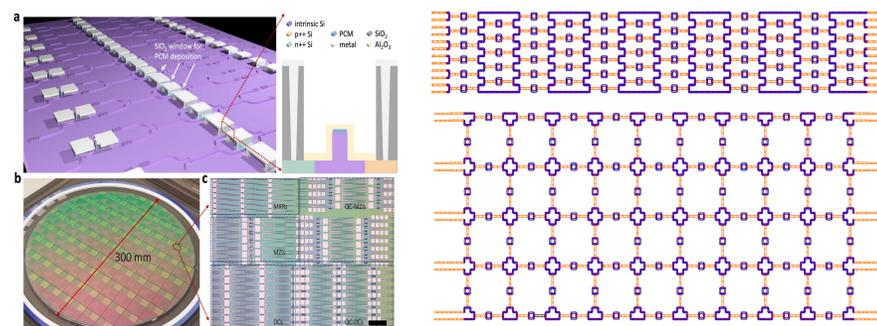
How to push the endurance further? 100 million!!!



- Segmenting reduces elemental migration and helps to improve endurance
- With thicker Alumina, tapered segmented PCM endurance is 100 million
- HfO₂ capping layers → larger modulation and endurance beyond 1 billion



Future Direction : Low loss high endurance large scale programmable circuits



- Non-volatile reversible switching with PCM on Intel fab
- Large scale PCM based reconfigurable network on Intel chips

Funding/Fellowship/Collaboration

