QUANTUM
OPPORTUNITIES + SHOWCASE

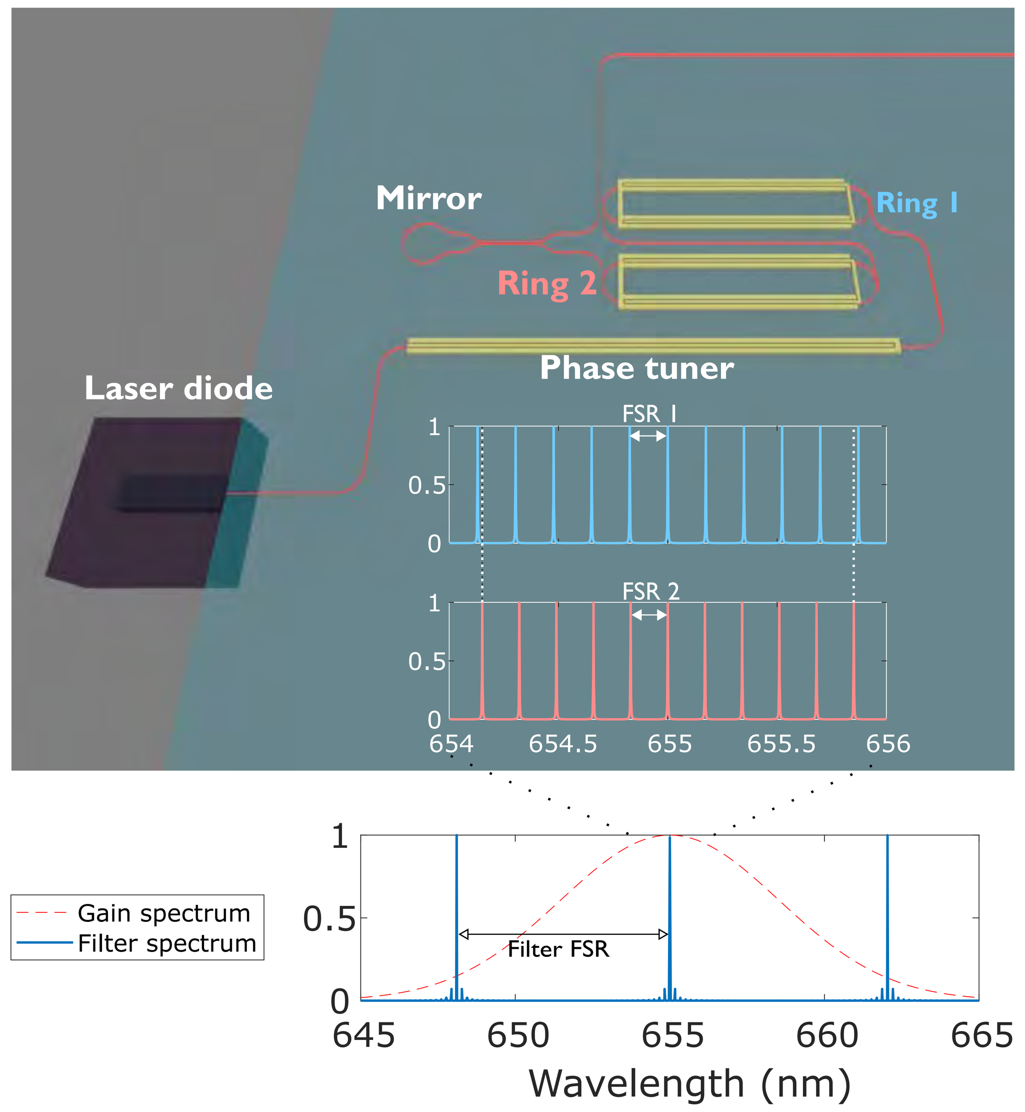
A hybrid integrated external cavity laser for atomic quantum technologies

MATTHEW DAY, NIKOLAY VIDENOV, RAJIBUL ISLAM, DAVID CORY

Motivation and design

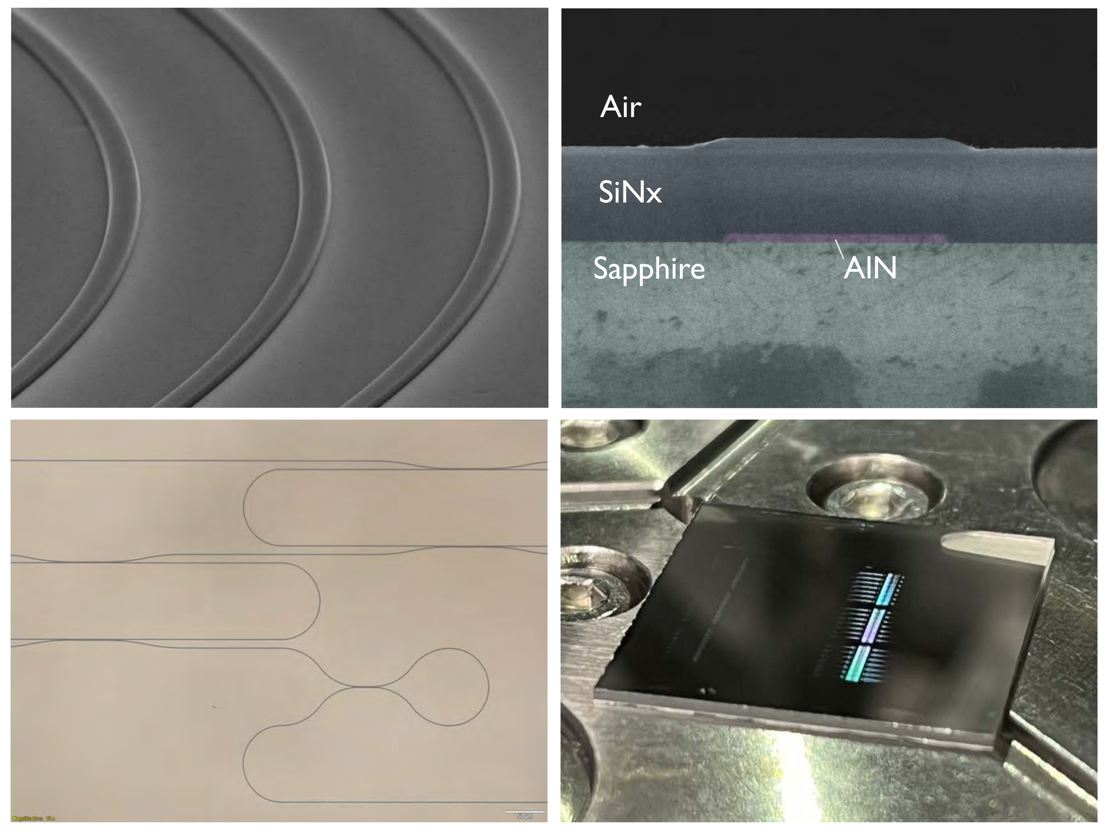
- Optical systems are a critical limiting factor in atomic quantum technologies
- Photonic integrated circuits offer a solution by reducing lab-sized optical systems to the chip-scale
- As a first step, we fabricate an external laser cavity in an aluminum nitride waveguide circuit and use it to demonstrate single-mode lasing of a diode

Figure 1 Principle of integrated external cavity diode laser. A laser diode is coupled into a waveguide. Two rings of slightly different dimension form a Vernier filter for selecting a single frequency mode of the diode gain spectrum, which is reflected back to the diode. Electrodes can tune the phase and wavelength of the cavity.



Fabrication

Figure 2 (Top L) AlN waveguide on sapphire, (Top R) False colour cross-section of AlN edge coupler, (Bottom L) External cavity in AlN waveguide circuit, (Bottom R) Array of 42 laser cavities on a single chip mid-fabrication.



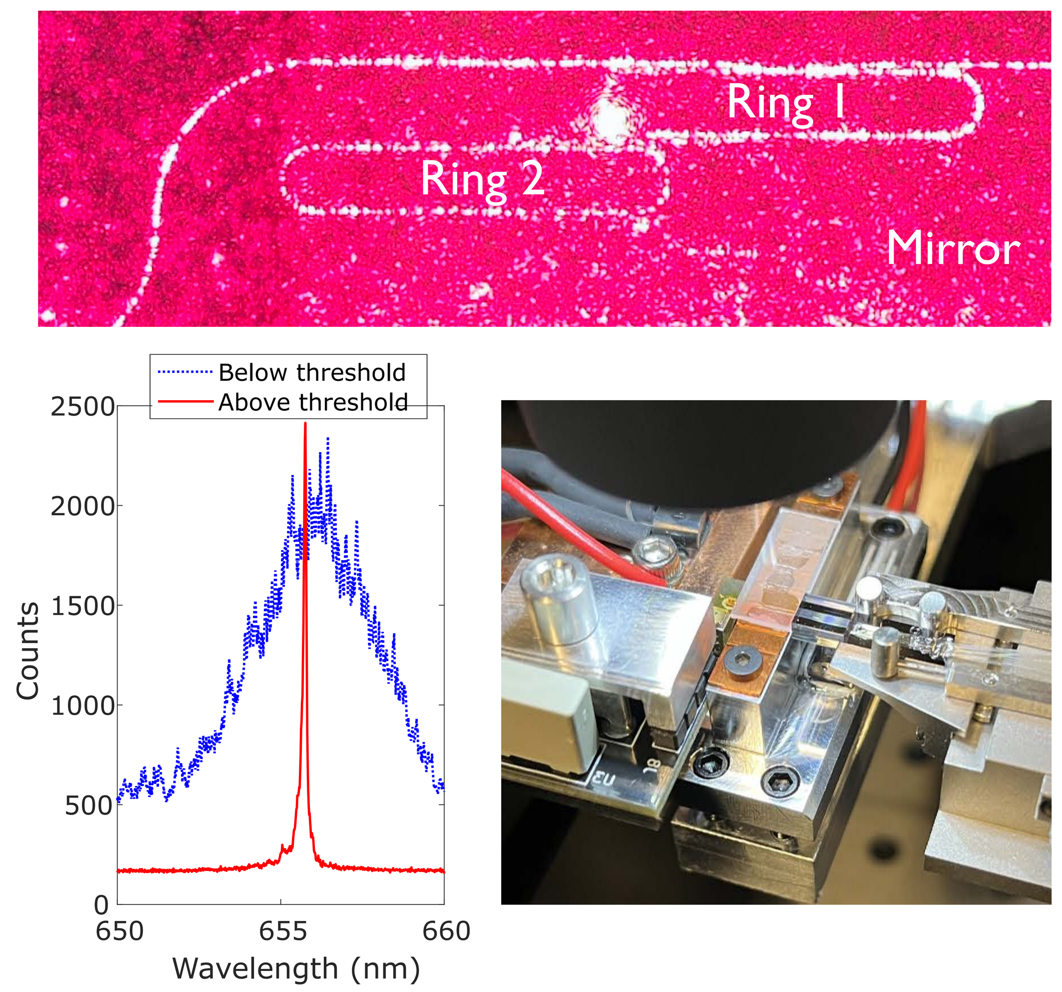
- AlN on sapphire waveguides are fabricated by first patterning a resist using electron beam lithography
- The resist is transferred into the AlN film using reactive ion etching
- Waveguides are clad in low-index silicon nitride to reduce losses and form a surface for electrode patterning
- Electrodes are patterned using UV lithography and metal lift-off
- Waveguide facets are exposed by dicing and polishing

Results

Single-mode lasing

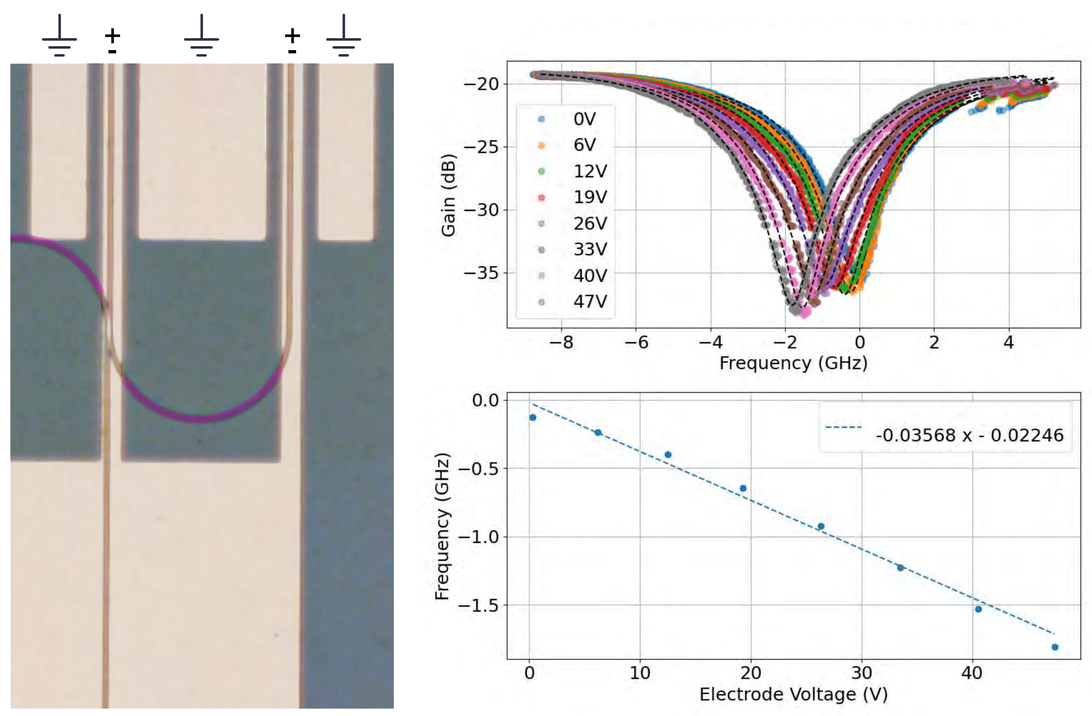
- A gain chip with 655 nm central wavelength is edge-coupled into an AlN waveguide chip
- Feedback is observed with light circulating in both rings simultaneously
- A single-frequency spectrum is measured at 655.954 nm, narrowing the laser linewidth below the spectrometer resolution

Figure 3 Observation of single-mode lasing in AlN photonic chip. (Top) Laser light circulating in both filter rings, (Bottom L) Resolution-limited lasing spectrum, (Bottom R) Measurement setup with diode, chip and fiber array.



Electro-optic tuning

Figure 4 Preliminary demonstration of electro-optic tuning in a racetrack resonator. (Left) False colour image of electrodes (beige) over AlN waveguides (purple) on SiNx cladding (blue), (Right) Racetrack transmission spectrum for increasing applied voltage.



- Elecro-optic tuning of a racetrack resonator has been observed at 852 nm
- The resonance of the racetrack can be linearly shifted by 35 MHz/V
- Further work is required to increase the electro-optic response, test at visible wavelengths and integrate with a laser cavity

Acknowledgments: *This research was undertaken thanks in part to funding from the Canada First Research Excellence Fund, [list others as appropriate].*