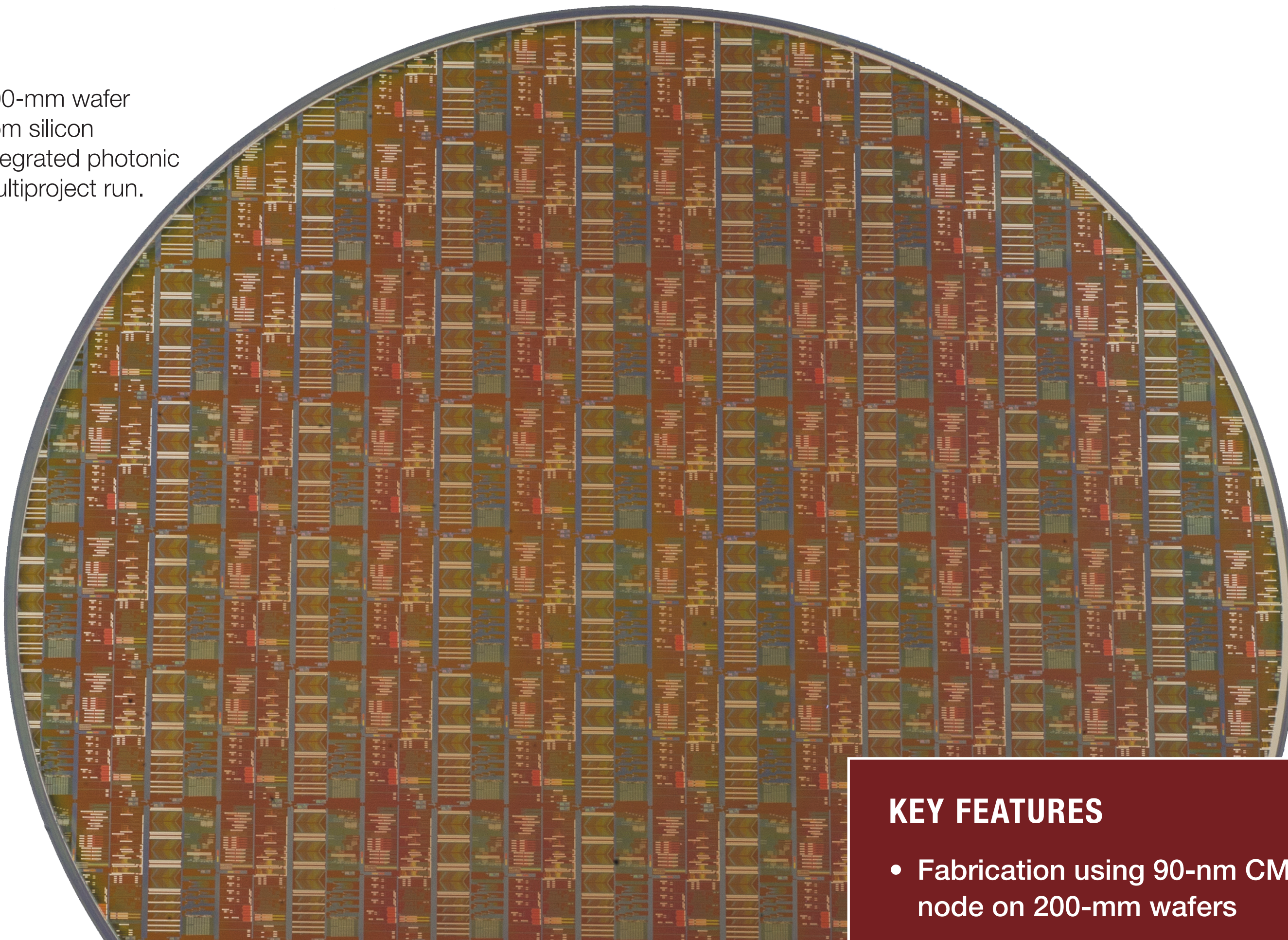
MICROELECTRONICS LABORATORY

SPOTLIGHT ON

Silicon & Silicon Nitride Integrated Photonics



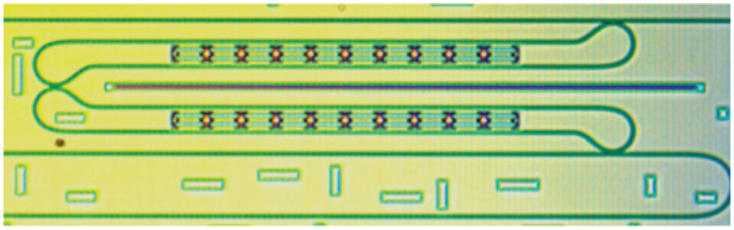
200-mm wafer from silicon integrated photonic multiproject run.

Lincoln Laboratory is fabricating silicon (Si), silicon nitride (SiNx), and aluminum oxide (Al_2O_3) photonic integrated circuits (PICs) on 200-mm-diameter wafers in its 90-nm silicon foundry. These PICs have demonstrated low waveguide losses and state-of-the-art active and passive component performance. In addition, our electron-beam lithography capabilities enable sub-90-nm features as needed.

KEY FEATURES

- Fabrication using 90-nm CMOS node on 200-mm wafers
- Class-10 clean room, ISO-9001 certified, Defense Microelectronics Activity Trusted Foundry
- Open process development kits (Cadence-based + design guides) for active and passive processes
- Component and system design, packaging, control, and characterization resources

Active and Passive Fabrication



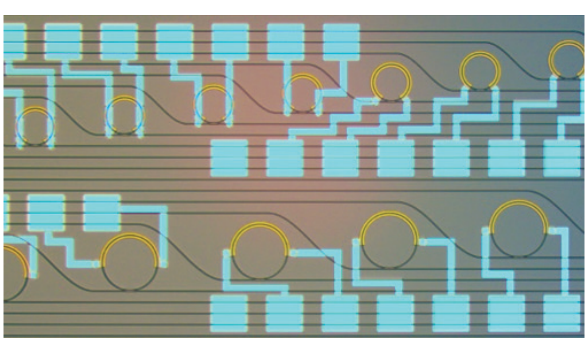
Optical microscope image of narrowband optical filter fabricated in our active silicon photonics process.

Our library of passive devices available on both Si and SiNx processes includes low-loss, high-performance waveguides, ring filters, adiabatic and directional couplers, and waveguide crossings, among other devices.

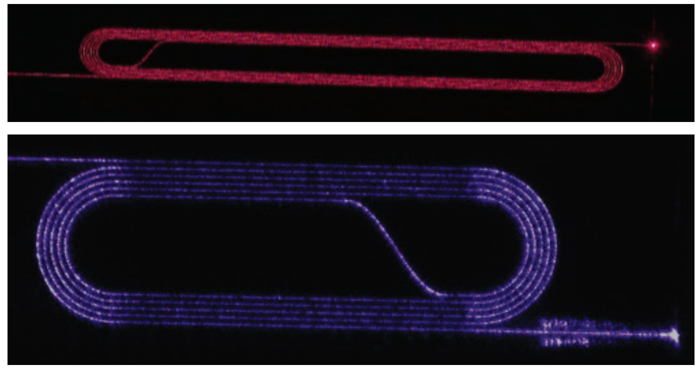
Our active SiNx process can handle high optical powers and uses thermal tuners to make low-speed switches, modulators, and filters. The process has ring filters with intrinsic quality factors (Q) greater than 1 million and thermal tuners capable of sweeping over a 2π phase shift at frequencies up to 10 kHz.

Our active Si photonics process features a variety of state-of-the-art devices, including tunable filters with optical passbands < 1 GHz, Mach-Zehnder modulators with VπL < 1 V/cm, modulators with 3-dB bandwidths > 20 GHz, and photodiodes with responsivities of 0.8 A/W. The Si PIC process has two metal layers. We have produced large-scale integrated circuits in both active processes.

We have conducted initial demonstrations of heterogeneous integration, including wafer-scale 3D integrated Si photonics with CMOS electronics; Si photonics integration with through-wafer millimeter-scale mechanical structures, and integration of SiNx photonics with III–V devices (e.g., lasers and optical amplifiers).



Optical microscope image of thermally tunable microring resonators in the active SiNx process.



Optical microscope image of 633-nm light propagating through passive SiNx waveguides (top) and 405-nm light propagating through passive Al_2O_3 waveguides (bottom).

Propagation Losses

Waveguide Material	Wavelength (nm)	Measured Loss (dB/cm)
Silicon Nitride	1550	0.2
	1092	<0.1
	633	0.3
	461	<6–8
Al_2O_3	461	0.8
	405	1.7
	369	3.1

Component Information

- Low waveguide losses and state-of-the-art component performance
- Si device library focused on telecommunication wavelengths (1550 nm)
- Al_2O_3 and SiNx device libraries covering a variety of wavelengths from 400 nm to >1600 nm
- Gold-free metallization and CMOS-compatible fabrication of all components

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