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Silicon Photonics

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

National Centre for Advanced Integrated Photonics (NCAIP) Technical Capabilities

Heterogeneous Integration	**Si and III-V Fabrication at Nanyang Nano Fabrication Centre (N2FC)**	• Si fabrication: 150 mm and 200 mm wafers • III-V fabrication: 100 mm wafers and small dies **Research and Technology Demonstrations** Enabled by combined Si and III-V fabrication capabilities: • III-V quantum-cascade lasers, III-V multiple quantum well (MQW) devices, Heterojunction Bipolar Transistors, High Electron Mobility Transistors • Heterogeneous integration of III-V materials with silicon photonics • Metamaterials and topological materials **Heterogeneous Integration Approaches** • Monolithic integration of III-V materials on silicon • Heterogeneous integration via flip-chip bonding • Layer transfer and membrane technology • Strain-engineering techniques • Integration of emerging 2D materials, including hexagonal boron nitride (h-BN), and dichalcogenides (e.g. WSe_2, MoS_2)
	Flip-Chip Bonding	**Component Size** • Chip size (upper die): 0.2 x 0.2 mm – 50 x 50 mm • Substrate size (lower die): 0.2 x 0.2 mm – 100 x 100 mm • Total thickness: 0.03 – 10 mm **Bonding Arm** • Alignment accuracy: ±0.1 µm • Post-bond accuracy: ±0.5 µm • Force: 1 – 1000 N **Bonding Processes** • Flip-chip bonding, Die bonding, Pick-and-place, Thermocompression, Thermosonic, Reflow, UV curing, Adhesive bonding, Sintering **Materials** • Gold, Gold/Tin, Indium, Copper, Adhesives

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III-V Devices for Si-Photonics	**Tunable Lasers*** *By end of FY2026	• Max threshold current (Ith): 30 mA • Min power: 20 mW • Max linewidth: 10 kHz • Tuning range: 14 nm
	Frequency-Comb Lasers* *By end of FY2027	• Max threshold current (Ith): 30 mA • Min power: 20 mW • Max linewidth: 10 kHz • Tuning range: 14 nm • Multiwavelength: Up to 2 μm
	Communication-Band III-V Uni-Traveling Carrier (UTC) Photodetectors* *By end of FY2026	• Min InGaAs UTC bandwidth: 120 GHz • Min InGaAs UTC responsivity: 0.6 A/W
Quantum Photonic Devices and Platforms	**Integrated Photon-Pair Source**	• Peak spectral signal of ~24,000 detector counts from a single output arm at 3 mW off-chip pump power • Suitable for quantum communications and sensing
	Superconducting Nanowire Single-Photon Detector (SNSPD)	• Material: NbTiN • Can be fibre-coupled or waveguide-integrated • On-chip efficiency: 80% • Recovery time: 20 ns • Wavelength range: 500 nm – 3.7 μm • Optimised wavelength: 1.5 μm
Mid-Wave Infrared (MWIR) and THz Communications and Spectroscopy	**Quantum Cascade Laser Source**	• Single-mode and topological MWIR laser • Power: 5 mW
	Chip-to-Chip Bonding	• Ge/AlN on Sapphire or Si • Current yield: 70% (chip-on-chip)

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Mid-Wave Infrared (MWIR) and THz Communications and Spectroscopy	**Demonstrated Devices**	**THz High-Bandwidth Wireless Data Communication** • Waveguide Bandwidth: TE – 280 GHz, TM – 220 GHz • **Averaged TE/TM Bending Losses** 1. 90°, 0.3561 dB/turn 2. 180°, 0.3882 dB/turn • **Averaged Path Losses** 1. TE: 0.2190 dB/cm 2. TM: 0.1921 dB/cm **THz Topological Waveguides** • Waveguide Bandwidth 30 – 70 GHz • Propagation loss < 0.1 dB/cm • 0 radius bends, bending loss < 0.1 dB **Topological Antenna, Gain > 14 dBi** • Leaky-wave Antenna (LWA) • Beam Steering Antenna **THz Data Communication Platform (Wired/Wireless)** • Aggregated data rates ~ 1 Tbps (wired) • 3 – 6 wireless links, 72 Gbps single-link data rate
	Integrated Sensing Platforms for MWIR and THz	**MWIR and THz Spectroscope for Sensing*** • MWIR band range: 3 – 14 μm on Si photonics platform • THz spectroscopy between 0.1 – 1 THz on Si photonics platform *By end of FY2031
Emerging Photonics Materials and Devices	**Topological Electronic Materials**	• Material synthesis: Molecular Beam Epitaxy • Material characterisation: In-situ Angle-Resolved Photoemission Spectroscopy (ARPES) and Scattering-type Scanning Near-field Optical Microscopy (S-SNOM)
	Polaritonic Waveguides in III-V Quantum Wells or Perovskite Films	• Propagation range: 100 – 300 μm • π-phase shift: Within 10 μm • Modulation efficiency ($V_\pi L$): 2 V·cm
	MEMS-Based Optical Switching* *By end of FY2026	• Max switching speed: 600 ns