

1) Project Goals

- Design a compact RF PCB to interface wirebonded photonic dies to lab instruments (VNA, Optical Scope, laser sources, Spectrum Analyzer), with clean RF modulation and stable biasing.
- Establish a benchtop workflow to measure EO response of a Mach–Zehnder Modulator (MZM) and bandwidth/linearity of (balanced) Ge photodiodes near 1550 nm.
- Reach ~2 GHz end to end electrical bandwidth in the current chain (extendable), while preserving signal integrity and enabling DC bias injection where needed.
- Validate and characterize Modulator and Photodetectors

2) System Under Test (SUT)

- PIC: MZM and ring resonator structures with grating couplers; separate test structures for balanced Ge PDs (AMF, 28 G class and in house designs).
- Optical: C band (~1520–1620 nm) operation; OSA scans show MZM transfer fringes and ring notches around ~1550–1557 nm depending on biasing and thermal drift.
- Electrical: Single ended instruments adapted to differential DUT ports via splitter/balun topologies and Bias Tee's.

3) Benchtop & Measurement Workflow

- Instruments: Anritsu MS46122A VNA for RF stimulus/measurement; OSA for spectral scans; tunable laser & polarization control for fiber to grating coupling.
- Single ended & differential: VNA output split to two paths; each arm passes through a BiasTee (for DC bias injection/blocking) and is recombined with a balun or connected as a differential pair at the die.
- Bias Tee usage: Series capacitor in the RF-through path, inductor to DC port/ground for bias; chosen to present high impedance in band at the DC leg and low impedance to RF on the AC leg.
- Calibrations: SOLT/TRL at SMA plane; de-embedding of fixtures/tapers recommended to reference the measurement plane at the bond pads.

4) RF PCB Design Highlights

- Connectors: Surface mount SMA chosen (mechanical clearance for metal bracket/Peltier stack) with appropriate pad/land pattern and robust solder anchoring.
- Impedance control: 50 Ohm microstrip/CPWG; via stitch ground fences along RF traces; continuous ground return around launches and tapers.
- Linear tapers: Pad to line mismatch managed with an 8 mil & ~30 mil taper sized per stackup; checked with impedance profile spreadsheet to keep reflections small across 100 MHz - 3 GHz.
- Grounding & pours: Layer1 ground pour tied with dense via stitching; stackup aligned to fab house standards; keepouts (RF sensitive areas) for bond wire loops.
- Mechanical: Local board 'depression' to nest a ~0.7 mm thick die; thermal path compatible with Peltier stage; clearance for bond wedge and microscope access.

5) Front-End Electronics (TIA & Buffer)

- TIA choice: OPA858 as a wideband transimpedance stage for PD characterization.
- Initial design points: $R_f = 100\text{--}200\ \Omega$ with $C_f \gg 0.5\ \text{pF}$ targeting $\sim 1\text{--}2\ \text{GHz}$ electrical bandwidth.
- Stability verified by ensuring total input capacitance (PD junction + package + opamp input) with C_f sets a dominant pole well below opamp GBWP limits.
- Second stage: Non-inverting unity gain buffer (configure carefully to avoid loading). R_g/R_f selected for modest gain to preserve flatness and phase margin.
- Key checks: Estimate $f_{-3\ \text{dB}} \gg 1/(2\pi \cdot R_f \cdot C_{\text{tot}})$, where C_{tot} includes PD C_j (order $0.2\text{--}0.5\ \text{pF}$ for a fast Ge PD), input/package capacitances, and effective C_f . Validate loop stability via noise gain and ensure peaking $< \sim 1\text{--}2\ \text{dB}$.
- Experimental measurements will further guide component selection and feedback.

6) Signal Integrity Clarifications Solved

- Differential signaling over coax: Each leg is on its own $50\ \Omega$ coax; the 'return' is the coax shield.
- Proper balancing and termination at the DUT ensure equal/opposite currents; a balun or true differential driver avoids common mode.
- SMA compatibility: Differential pairs can terminate to two adjacent SMAs or a dual launch; what matters is consistent reference to ground and tight symmetry.
- Bias Tee orientation: Inductor to the DC/bias port and ground, capacitor in series on the RF path; purpose is bias injection and DC blocking without disturbing in band RF.

7) Photonics Characterization Notes

- MZM vs. ring traces: Similar looking OSA traces can occur on log scale; rings introduce sharp notches while MZM shows sinusoidal fringes. Thermal detuning can shift features within $1520\text{--}1620\ \text{nm}$.
- Coupling strategy: Use paired grating couplers for the device under test; ensure polarization alignment (TE for typical Si photonics gratings).
- Why $1550\ \text{nm}$: Eye safety and fiber component availability; atmospheric & fiber low loss windows; common for LiDAR/telecom experiments. (Automotive applications).

8) Data Processing & Sanity Checks

- FFT & dBm: Remove DC, apply a Hamming window, scale for window loss, and use Parseval checks to match time domain and frequency domain power (error within $\sim \pm 0.5\ \text{dB}$).
- Frequency axis: Ensure binning matches sampling (N , f_s) for correct mapping up to Nyquist.
- Noise floor shifts typically trace back to incorrect scaling or window normalization.
- SNR, SNDR, THD, Power, Losses etc

9) Outcomes to Date

- Settled on SMT SMA launches, 50 Ohm CPWG with via fences, and linear tapers sized to the die pad geometry and stackup.
- Defined benchtop topology for single ended & differential drive with bias Tee's for clean biasing.
- Established TIA baseline and a buffered second stage approach for additional voltage gain while keeping the TIA output lightly loaded.
- Clarified ring/MZM spectral behavior, fiber/grating alignment, and polarization handling at 1550 nm (+/- 10nm)

10) Current Jobs, Open Issues & Next Steps

- Perform SOLT/TRL calibration and short fixture de-embedding; collect EO S21, S11, S22 of the MZM and PD bandwidth with uncertainty bars.
- Modulator and PD BW, SNR, SNDR
- Validation, evaluation and characterization are on-going