

Quantum Computer in the Solid State

Performance and signal quality analysis of a photonic link from room temperature to 6K using laser-photodiodes

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MOTIVATION

- Deep-cryogenic photonic links for room temperature to cryogenic signaling in quantum computers
- Benefits of RF photonic over coaxial in cryogenic application
 - Low thermal coupling
 - Higher bandwidth, possibility of multiplexing
 - Immunity to electromagnetic interference
 - Lightweight and flexible, reduced signal loss
- Investigation of photodiodes at cryogenic temperatures

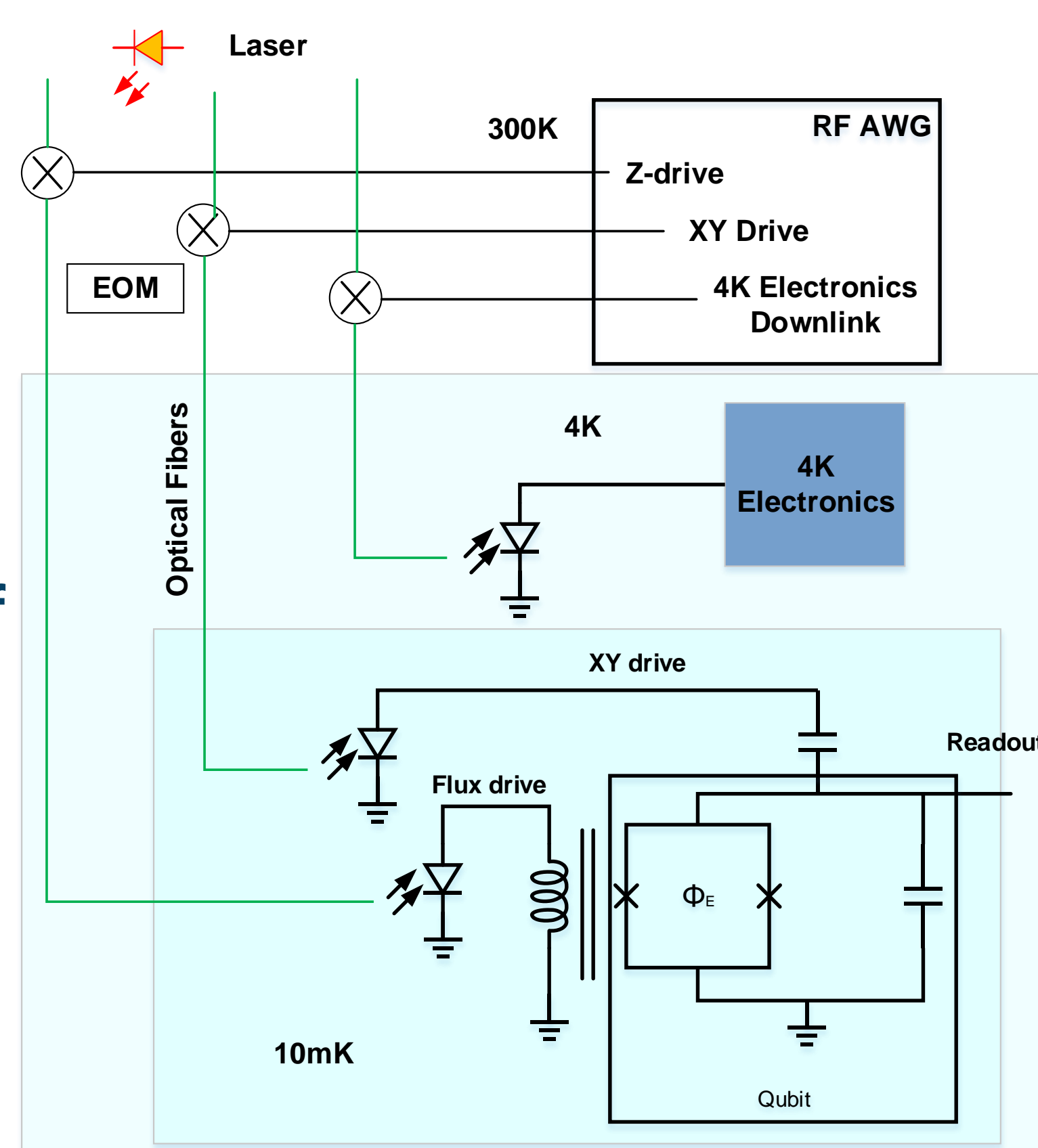
APPROACH

Signal requirements for qubit control:

- **XY-Drive:** 4-8 GHz, -70 dBm
- **Z Drive:** pulse, 0.5-1 GHz, -50dBm
- **Readout:** RF reflectometry

The higher quality signaling of photonic link^{[1] [2]} can be exploited:

- In driving signals to electronics in 4 K Stage
- For XY drive
- For Z-Flux drive

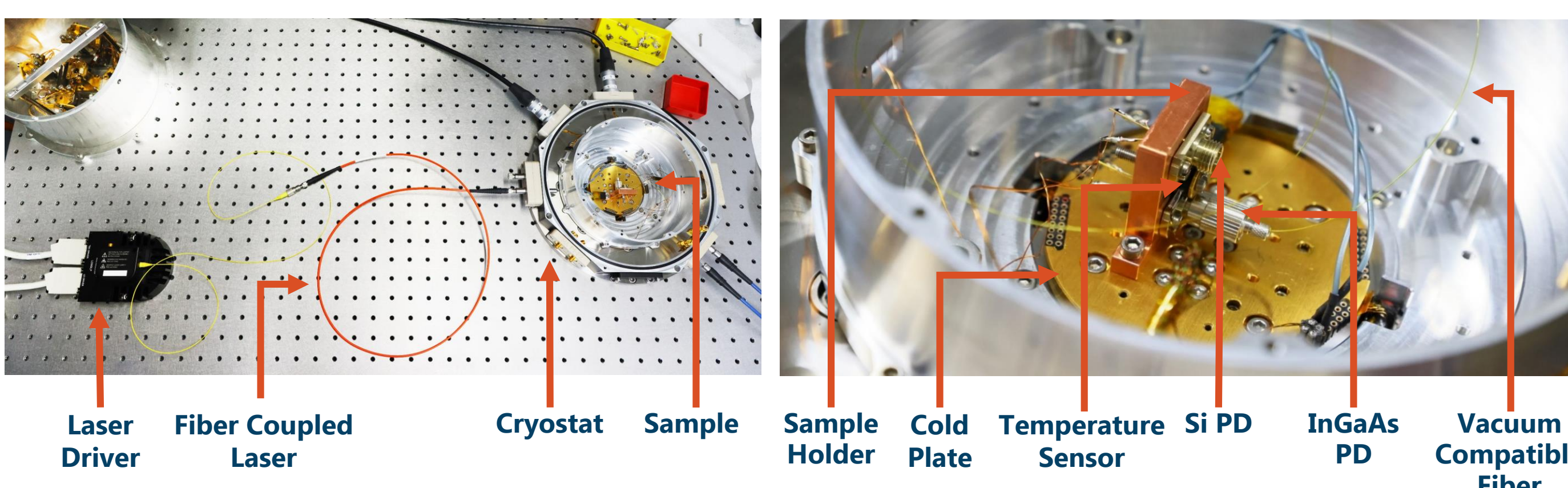
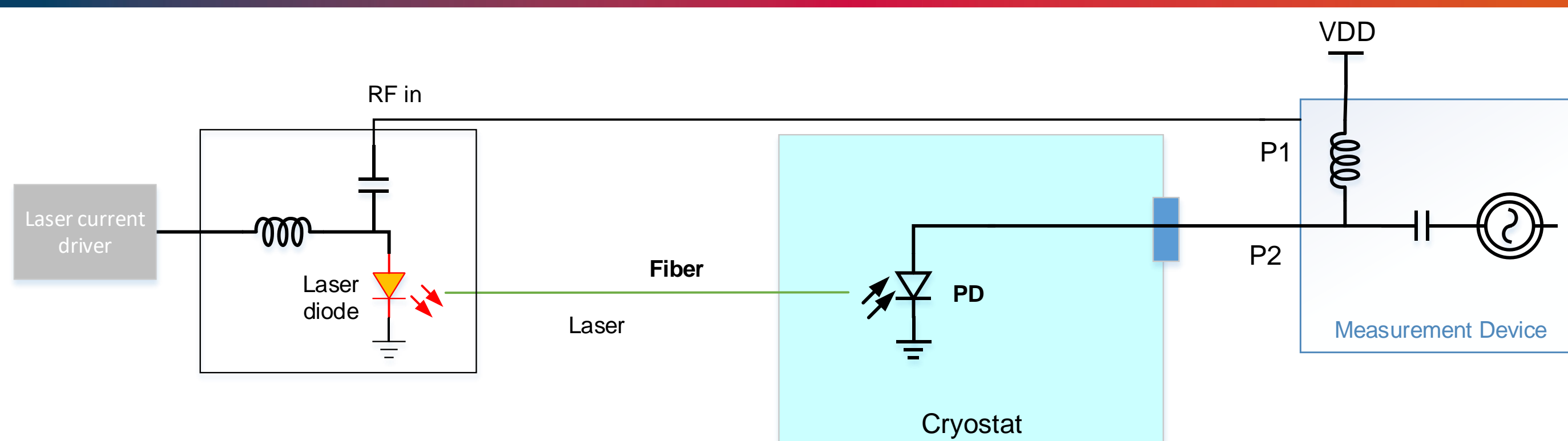


METHODOLOGY

To fully understand the behavior of the photodiode in low temperature:

- **2 Photodiodes:** Commercial Si and InGaAs
- **DC Analysis:** IV curve, responsivity and linearity of diodes
- **AC Analysis:** Frequency response (S21 measurement)
- **Equipment:** Semiconductor device analyzer, network analyzer

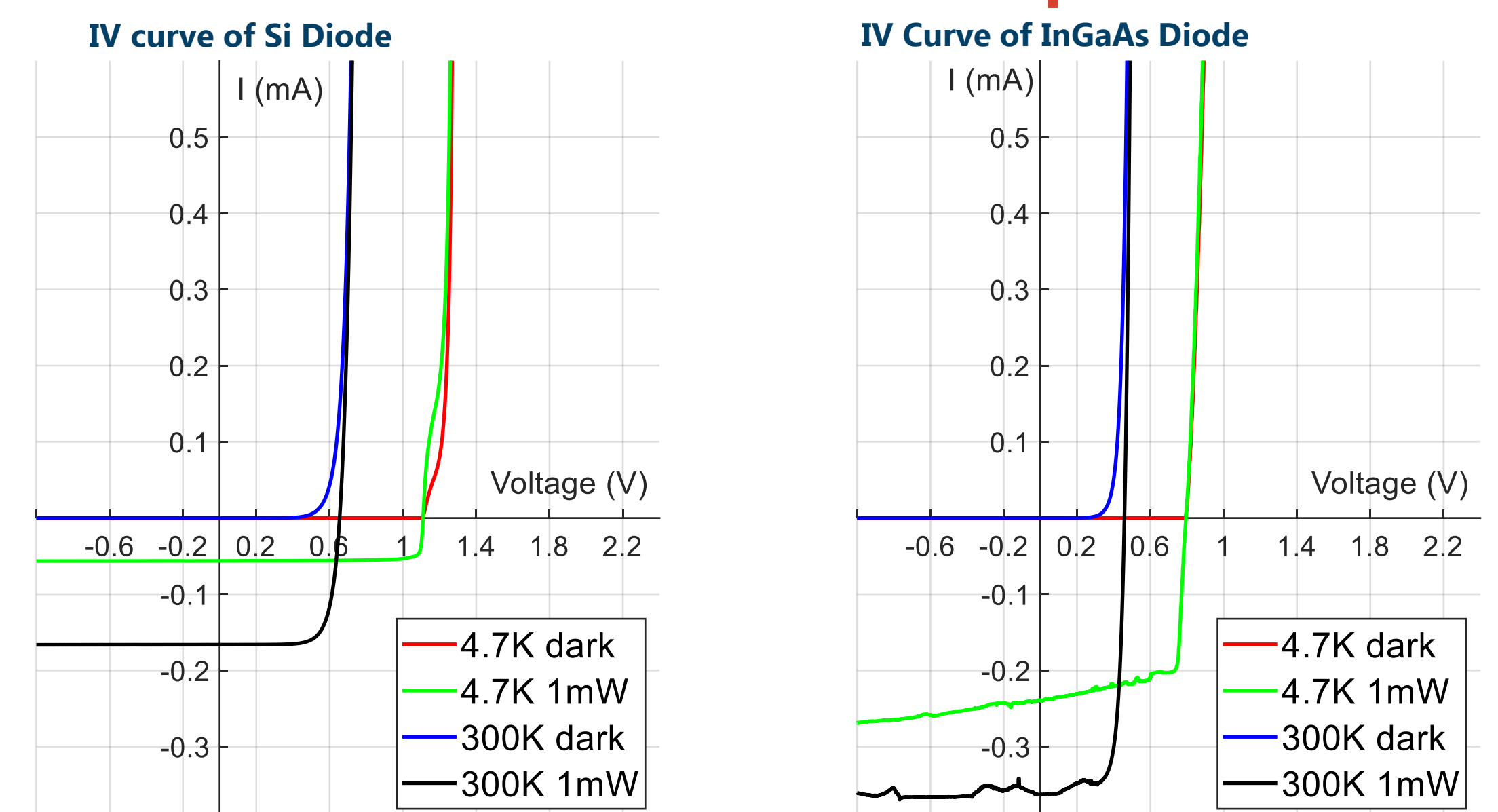
SETUP AT FZJ ZEA-2



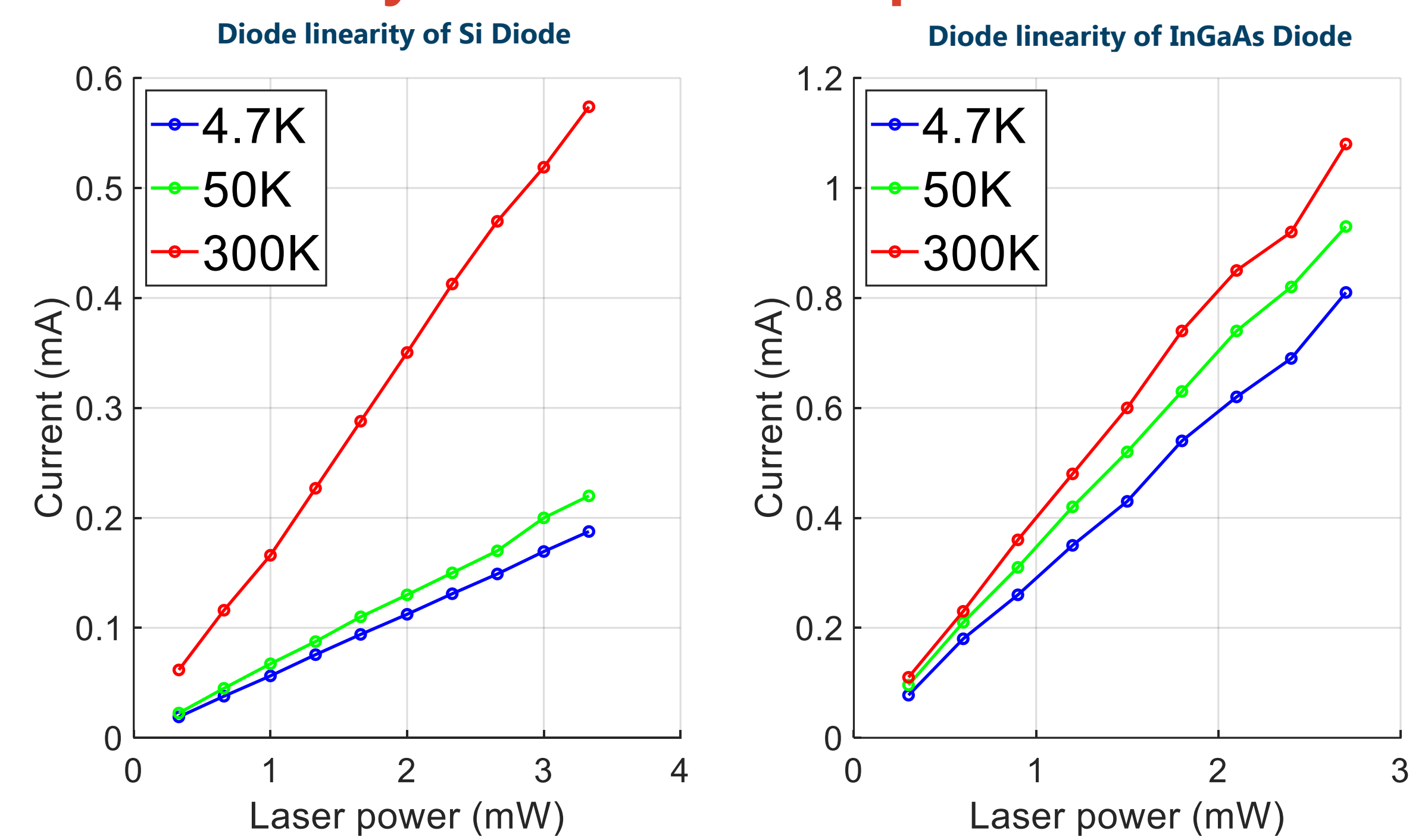
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DC MEASUREMENT

IV Measurement of Si and InGaAs photodiodes



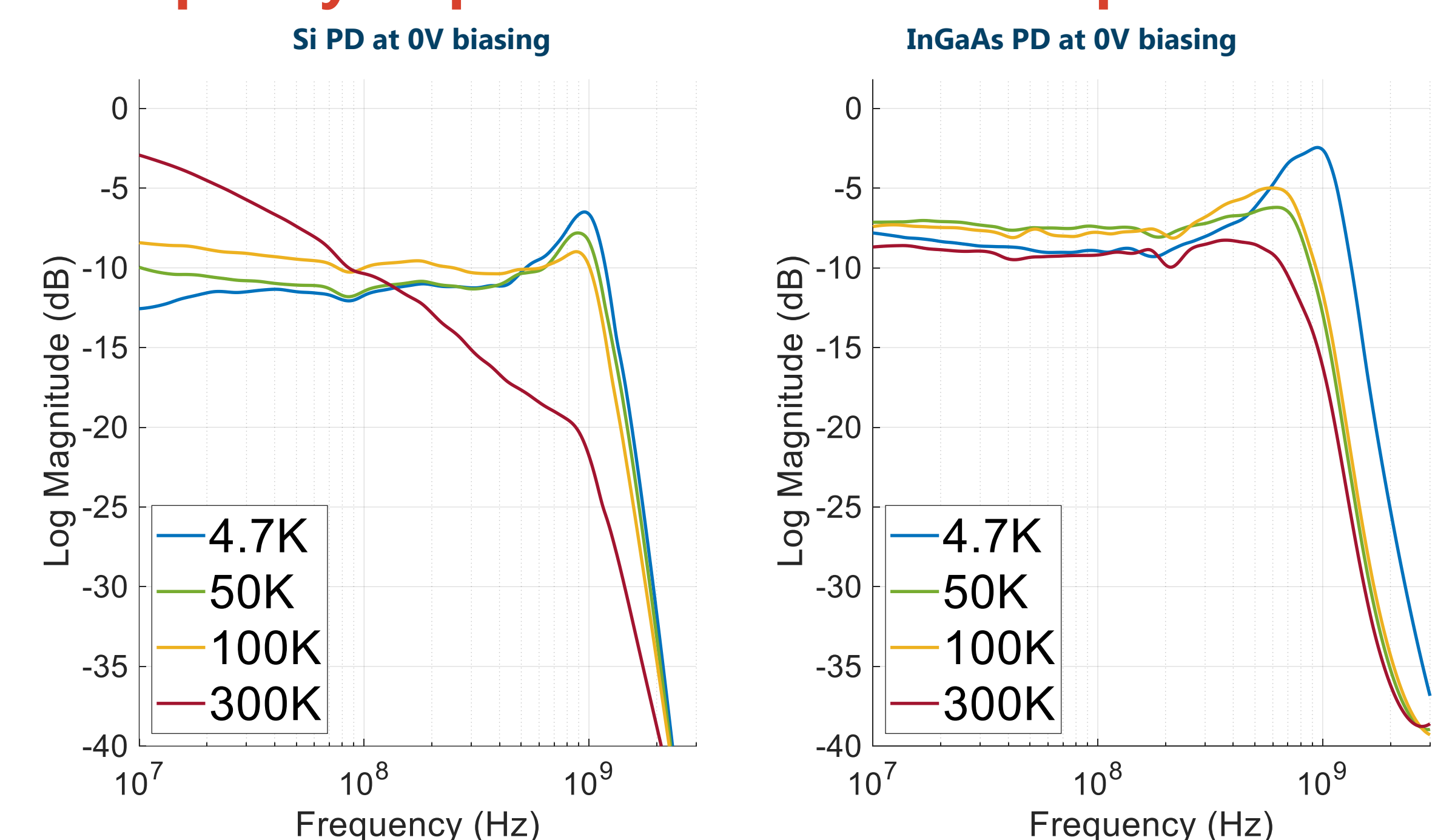
Linearity of Si and InGaAs photodiodes



- Threshold voltage increase and reduction of current in cryogenic
- Si PD has more current reduction due to indirect bandgap

AC MEASUREMENT

Frequency response of Si and InGaAs photodiodes



- Both photodiodes shows higher bandwidth in cryogenics due to the decrease in junction capacitance with temperature

Devices used from Thorlabs:

- Lasers: LP904, LPSC-1310
- Modulator: LDM9LP
- Photodiodes: FDS02, FGA01

References:

- [1] Usami, K. & Nakamura, Y., "A photonic link for quantum circuits", Nat. Electron. 4, 323-324 (2021)
- [2] Lecocq, F. et al., "Control and readout of a superconducting qubit using a photonic link", Nature 591, 575-579 (2021)

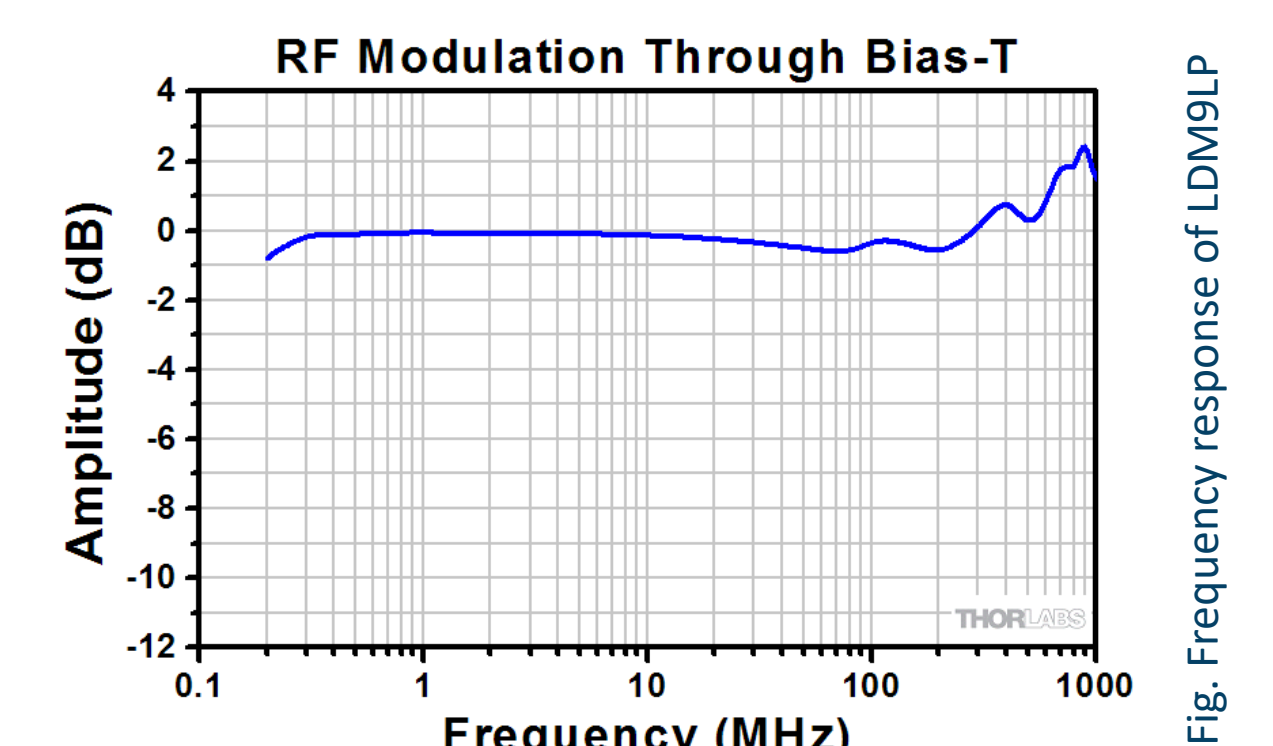


Fig. Frequency response of LDM9LP