JÜLICH Forschungszentrum | ZEA-2 Electronic Systems

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# Quantum Computer in the Solid State

# Toward the approach of passive photonic links in quantum computers

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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

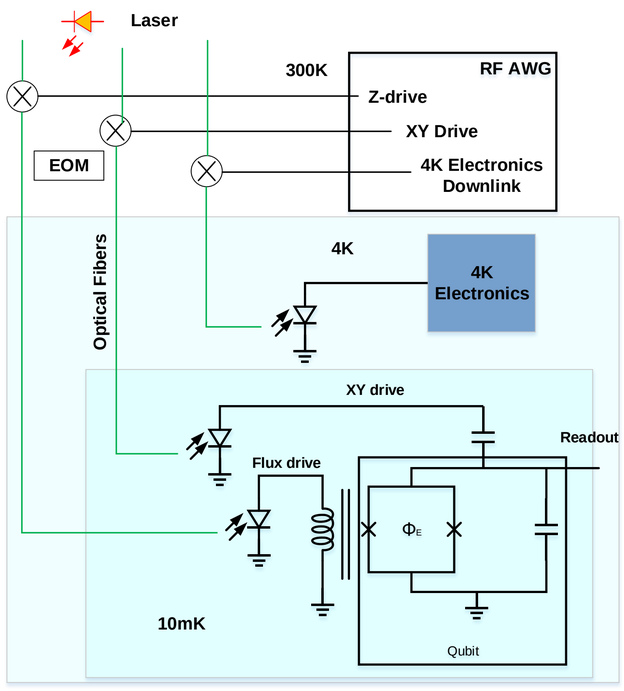
## APPROACH

**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

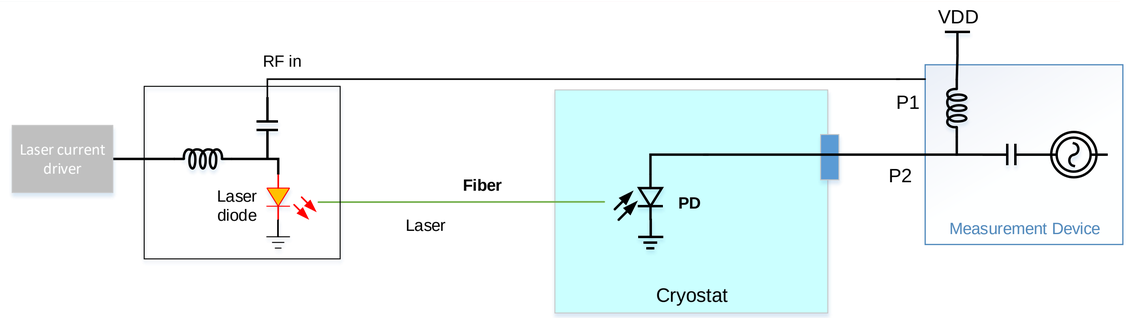


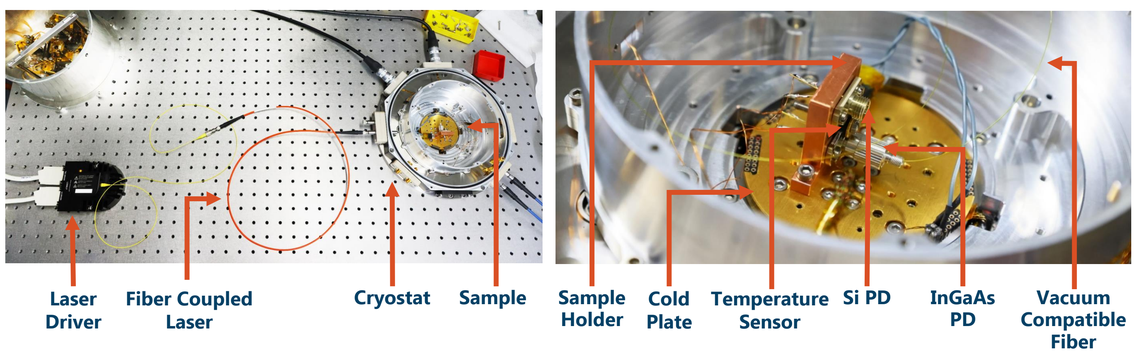

## METHODOLOGY

**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

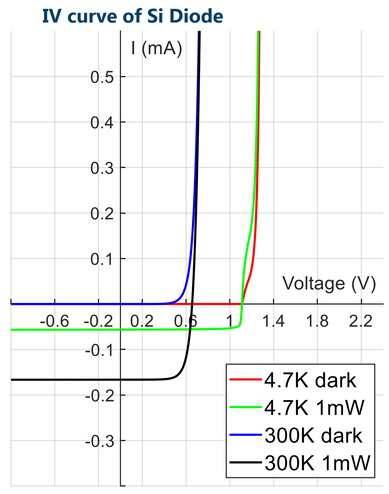
## SETUP AT FZJ ZEA-2

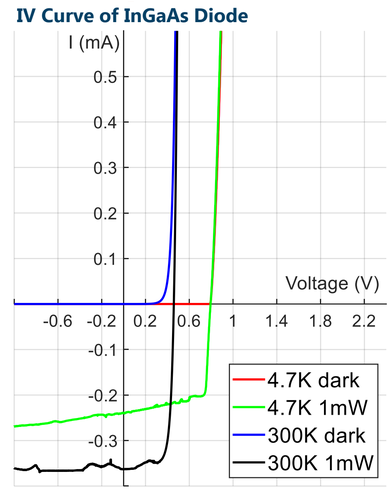


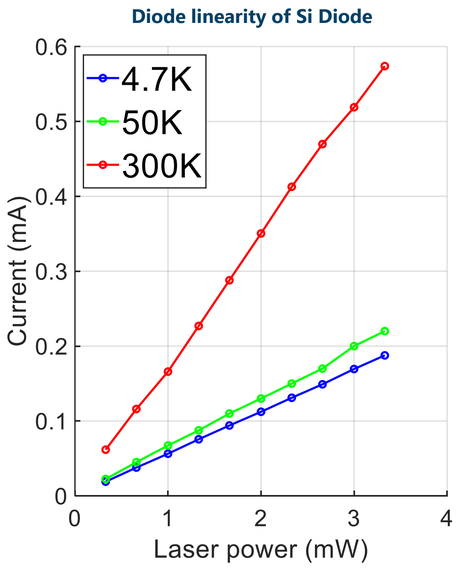

## DC MEASUREMENT

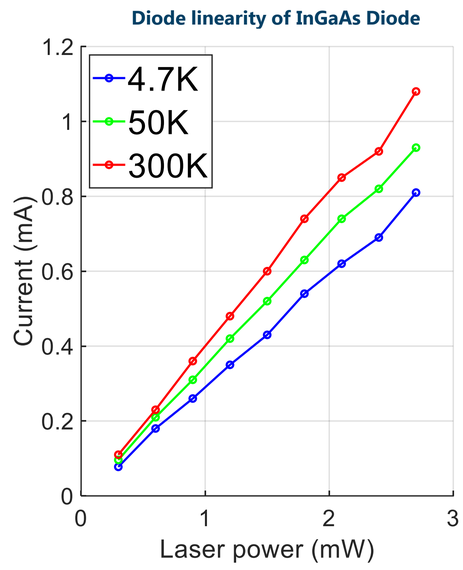
### IV Measurement of Si and InGaAs photodiodes




### Linearity of Si and InGaAs photodiodes

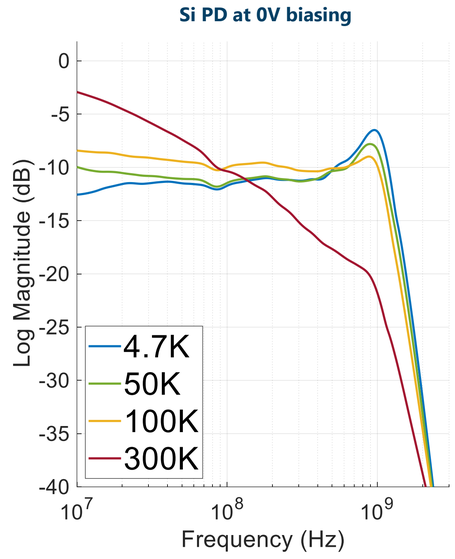


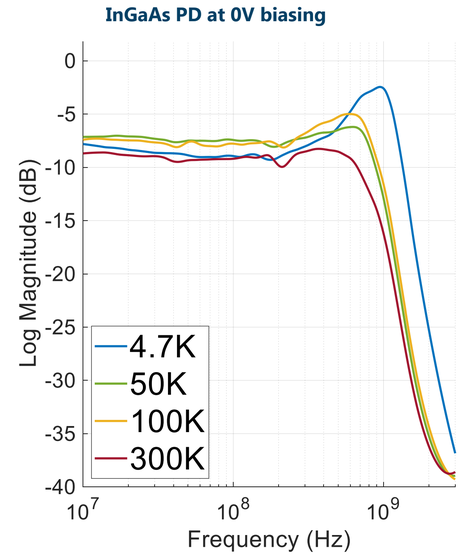




- Threshold voltage increase and reduction of current in cryogenic
- Si PD has more current reduction due to indirect bandgap

## 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

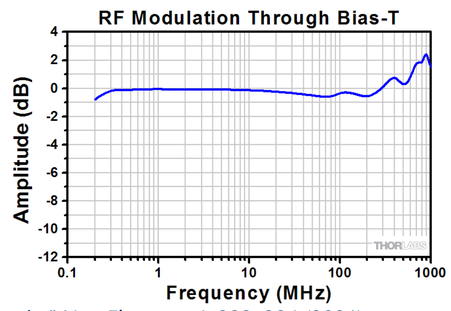



Fig. Frequency response of LDM9LP

## 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)

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