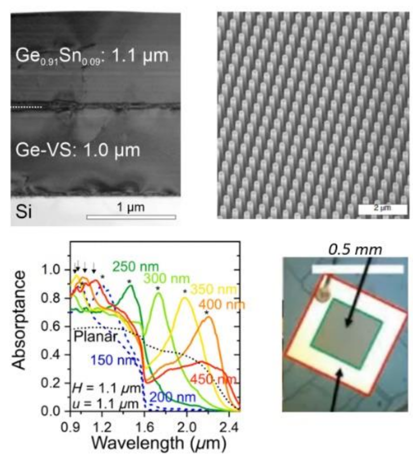
Master / PhD Thesis Project

Group IV single photon detectors

Detection of single photons boosted the development of quantum information processing, as well as finding a wide range of applications in astronomy, sensing, metrology, LiDAR, and biosensing technologies.(*1*) Single photon detectors (SPDs) require high quantum efficiency (>90%), low dark count rates, and ultra-fast response. State of the art superconducting nanowire SPD (SNSPD) can deliver superior performance from visible to infrared (up to ~2 µm) wavelength, however their high cost and cryogenic operation (4 K) limit their widespread applicability.

An alternative, yet promising approach relies on the ability to detect near-infrared single photons at room-temperature in devices made of vertical III-V semiconductor nanowire (NW) arrays.(*2*) The one-dimensional geometry of the NWs strongly enhances light absorption, while providing spectral tuning of the absorption peak across a broad wavelength range(*3*) that is mainly limited by the band gap of the semiconductor material. Over the last decade, tremendous progress was made in the epitaxial growth of group IV GeSn semiconductors grown on a Si wafer, resulting in a direct band gap material when the incorporation of Sn increases above ~9 at.%.(*4*) Photodetectors, lasers, and LEDs operating from short-wave infrared (SWIR: 1.5-3 µm) to mid-wave infrared (MWIR: 3-8 µm) are now available using direct band gap GeSn semiconductors.



The student will overcome the boundaries of the current single photon technologies by fabricating GeSn NW array infrared SPD operating at 300 K. Starting with a doped p-i-n GeSn thin film heterostructure, electron beam lithography (EBL) and reactive ion etching (RIE) will be performed to define the top-down etched array of GeSn NWs. Next, a transparent planarization layer and electrical contacts will be deposited to complete the SPD fabrication. Detection of SWIR single photons will be performed by using a single photon laser as emission source.

For more information on this topic please read these recent publications (available on demand):

1. C. J. Chunnilall, I. pietro Degiovanni, S. Kück, I. Müller, A. G. Sinclair, *Optical Engineering*. **53**, 081910 (2014).
2. M. E. Reimer, C. Cher, *Nat Photonics*. **13**, 734–736 (2019).

3. A. Attiaoui *et al.*, *Phys Rev Appl*. **15**, 014034 (2021).
4. O. Moutanabbir *et al.*, *Appl Phys Lett*. **118**, 110502 (2021).

Possible collaboration and networking. Collaborations with Canada (Polytechnique Montréal) and The Netherlands (Eindhoven University of Technology) for atomic-level characterization of materials and devices. Sweden (KTH), The Netherlands (Delft), and Germany (Paderborn) for complementary single photon measurements.

Possible extension as a PhD: Yes.

Required skills: Interest in performing collaborative experiments in the lab (materials growth, fabrication of devices and measurement), background in solid-state physics.

Starting date: Spring 2023.

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