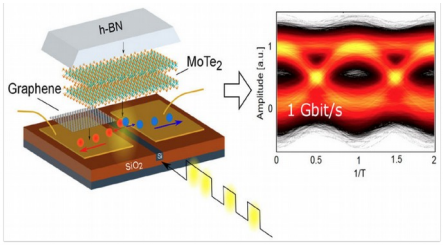
Master / Semester Thesis

Multi-scale simulation of single-photon avalanche detectors

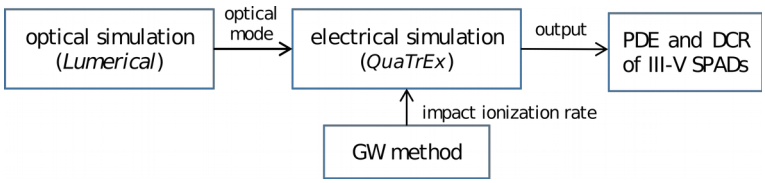
Background:
Design of waveguide integrated single-photon avalanche detectors (SPADs) with high detection efficiency and speed is crucial for photonic quantum information processing and quantum key distribution. Recently, experimental works have been proposed for waveguide integrated photo-diode based on 2D materials [1]. However, such studies on waveguide integrated III-V SPADs are still missing, though they are important material choices for near-infrared bands.



P. Ma, N. Flöry et al., ACS Photonics 5, 1846 (2018).

Goal:
In this project, we aim to develop a multi-scale simulation framework that is suitable for design of waveguide integrated SPADs, i.e. it should be able to calculate several device performance parameters such as photon detection efficiency (PDE) and dark count rate (DCR). Ideally, these parameters will be optimized using the established simulation framework.

Methodology:
For modeling of waveguide integrated SPADs, one runs coupled opto-electrical simulations: we plan to use *Lumerical* for calculation of optical modes and our in-house code for solving electrical transport problem. Furthermore, the impact ionization rates of the investigated III-V material will be calculated based on GW approximation using our in-house code [2,3]. A Python/Matlab-based pipeline will also be developed to couple *Lumerical* and QuaTrEx to perform 3D opto-electrical simulations.



Type of work
Theory (20-30%), model development (40%), simulation & analysis (40%).

Prerequisites
You have (1) knowledge in opto-electronics and semiconductor physics, (2) with Python and programming.

Status: Available
Looking for 1 Master student
Interested candidate please contact: Dr. Jiang Cao jiacao@iis.ee.ethz.ch
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References:
[1] Ma, P., Flory, N., Salamin, Y., Bäuerle, B., Emboras, A., Josten, A., Taniguchi, T., Watanabe, K., Novotny, L. and Leuthold, J., 2018. Fast MoTe2 waveguide photodetector with high sensitivity at telecommunication wavelengths. Acs Photonics, 5(5), pp.1846-1852.
[2] Cao, J., Ziogas, A., Deuschle, L., Ding, Q., Vetsch, N., Winka, A., Maillou, V., Maeder, A. and Luisier, M., 2023, December. Ab initio quantum transport simulations of InAs avalanche photo-diodes within the GW approximation. In 2023 International Electron Devices Meeting (IEDM) (pp. 1-4). IEEE.
[3] Deuschle, L., Maeder, A., Maillou, V., Vetsch, N., Winka, A., Cao, J., Ziogas, A.N. and Luisier, M., 2024, November. Towards Exascale Simulations of Nanoelectronic Devices in the GW Approximation. In 2024 SC24: International Conference for High Performance Computing, Networking, Storage and Analysis SC (pp. 988-1003). IEEE Computer Society.