SEMINAR NOTICE

Department of Physics and Engineering Physics University of Saskatchewan & QuanTA: Centre for Quantum Topology and Its Applications

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SPEAKER: Sigurd Flagan, Physics Dept, University of Calgary

TOPIC*:* *Nonlinear Optics in Diamond Nanophotonic Devices*

DATE: Tuesday March 18th, 2025

TIME: 3:30-4:30 p.m. **PLACE:** ***Physics 103***

Diamond's excellent optical, thermal, and mechanical properties make it an attractive platform for a myriad of photonics applications. Furthermore, the diamond lattice hosts a variety of defect centres, where considerable attention has been paid to nitrogen-related defects, such as substitutional nitrogen (NS) and the nitrogen-vacancy (NV) centre. The highly coherent electron spin associated with the NV centre has successfully been used in quantum sensing and networking applications, with excellent outcomes. While their internal spin- and optical properties are well understood, the effect of these defects on the nonlinear optical properties of the host diamond crystal is not well understood. In this work, we demonstrate that the presence of charged defects leads to novel optical nonlinear phenomena in diamond nanophotonic devices.

Pristine diamond is centrosymmetric material – whose vanishing $\chi^{(2)}$ prohibits second-order nonlinear interactions. Despite this limitation, we have demonstrated second-harmonic generation (SHG) in a doubly-resonant microdisk cavity [1]. This normally forbidden process can arise from several sources of crystal symmetry breaking whose relative contributions are typically difficult to disentangle. By introducing an auxiliary green laser "control" field that we observe to have the effect of modulating $\chi^{(2)}$ experienced by a telecom input. We credit the observation of SHG to the presence of charged crystal defects, like Ns and NV centres. The green laser quenches the SHG signal, which we attribute to the photoionisation of NV centres [2], and removing the green laser recovers the original SHG signal, allowing for deterministic all-optical switching of the device's $\chi^{(2)}$.

Photoionization of Ns and NV centres alters the charge environment and creates local electric fields. In a second closely related experiment, we demonstrate cavity-enhanced third-harmonic generation in a fibre-taper-coupled photonic-crystal cavity and show that crystal defects once again play a critical role in the device's properties. Under prolonged high-power IR excitation on resonance, we observe blue-shifting of the cavity resonance by more than the cavity linewidth. We attribute this frequency shift to the photorefractive effect – a novel phenomenon in diamond devices. Photorefraction arises due to optically induced charge-redistribution, which modulates the refractive index via the electro-optic effect. Unlocking second-order interactions in diamond by defect engineering paves the way for the realization of frequency converters and optical modulators.

[1] S. Flågan, J. Itoi, P. K. Shandilya, V. K. Kavatamane, M. Mitchell, D. P. Lake, P. E. Barclay, arXiv:2412.06792. **[2]** P. K. Shandilya, V. K. Kavatamane, S. Flågan, D. P. Lake, D. Sukachev, P. E. Barclay, arXiv:2411.10638.