# Q 34: Quantum Technologies – Sensing I

Time: Wednesday 14:30–16:30 Location: P 5

**Invited Talk** Q 34.1 Wed 14:30 P 5

**Spectral Peaked Optical Frequency Comb for Highly Sensitive Cavity Ring-down Spectroscopy** — •Hideki Tomita[1], Norihiko Nishizawa[1], Shotaro Kitajima[1], Ryohei Terabayashi[1], Ningwu Liu[1], and Hisashi Abe[2] — [1]Nagoya University, Nagoya, 464-8603, Japan — [2]National Metrology Institute of Japan, AIST, Tsukuba, 305-8563, Japan

Optical frequency combs represent a breakthrough in many research fields. To apply the comb to highly sensitive cavity-enhanced spectroscopy such as cavity ring-down spectroscopy, a specific mode of the comb must be selected and efficiently coupled to a high-finesse optical cavity. We have developed a spectrally peaked optical frequency comb using the novel phenomenon of spectral peaking (N. Nishizawa, et al., Advanced Photonics Research, (2025) https://doi.org/10.1002/adpr.202500022). In this comb, the background pedestal components of the generated spectral peaks can be suppressed. This presentation discusses the principle and fundamental characteristics of the spectral peaked optical frequency comb and shows current progress in its application to cavity ring-down spectroscopy and the future prospects.

Q 34.2 Wed 15:00 P 5

**Quantum limits of photon-induced near-field electron microscopy** — •Hao Jeng — Department of Ultrafast Dynamics, Max Planck Institute for Multidisciplinary Sciences, Göttingen D-37077, Germany — IV. Physical Institute, University of Göttingen, Göttingen D-37077, Germany

The principles of quantum metrology imply that the sensitivity of current electron microscopes can be improved substantially. An increase in sensitivity would effectively reduce the number of electrons needed, which is crucial for electron microscopes because many specimens are too fragile to survive the constant bombardment by swift electrons. In this contribution, we analyse the fundamental quantum limits for a particular type of electron microscopy known as "photon-induced near-field electron microscopy". We derive bounds on the quantum Fisher information of the system, identify probes that attain these bounds, and find ways to surpass the limits of our instrument using non-classical states of electrons and light.

Q 34.3 Wed 15:15 P 5

**Towards the detection of biomagnetic fields using widefield quantum sensing** — •Mokessh Kannah Ciwan[1], Baha Sakar[1], Benno Scharpf[1], Evgeniya Kirilina[2], and Nabeel Aslam[1] — [1]Felix-Bloch-Institute for Solid State Physics, University of Lepzig, Leipzig, Germany — [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

In this study, we demonstrate the use of nitrogen-vacancy (NV) centers in diamond for widefield magnetometry with a large field of view (FOV, 0.8 x 0.8mm). This substantial FOV enables the simultaneous characterization of multiple NV centers. For sufficient illumination and spin-state manipulation, we utilize a laser with a power output of 2 Watts and a large homemade omega loop structure to deliver microwaves with high powers homogeneously across the entire FOV. Using a CCD camera to recollect the NV fluorescence, we aim to detect biomagnetic fields in the microtesla regime with a spatial resolution of $\sim$1.5 $\mu$m.

Q 34.4 Wed 15:30 P 5

**Nonlocal cancellation of optical rotations in fructose solutions** — wen-chia lo[1,2], •chao-yuan wang[1,2], yu-tung tsai[1,2], sheng-yao huang[1,2], kang-shih liu[1,2], yun-hsuan shih[1,2], ching-hua tsai[1,2], and chih-sung chuu[1,2] — [1]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan — [2]National Center for Excellence in Quantum Information Science and Engineering, National Tsing Hua University, Hsinchu 30013, Taiwan

Entanglement, one of the most representative phenomena in quantum mechanics, has been widely used for fundamental studies and modern quantum technologies. In this paper, we report the observation of nonlocal cancellation and addition of optical rotations with polarization-entangled photons in fructose solutions. The entanglement also enables probing optical activities at a distance by joint measurements on the entangled photons. The good agreement between the experimental results and theoretical predictions demonstrates the potential for extending these measurements to other chiral molecules, with a sensitivity that improves as the number of entangled photons increases.

Q 34.5 Wed 15:45 P 5

**Improving NV Center Magnetometry via Wavelet Enhancement and Memory-Based Protocols** — •Matteo Slaviero, Ekrem Taha Güldeste, Justus Tonhäuser, Baha Sakar, and Nabeel Aslam — Felix Bloch Institute for Solid State Physics, Leipzig University, 04103 Leipzig

Wavelet analysis offers a powerful approach to enhance the sensitivity of magnetic field measurements based on nitrogen-vacancy (NV) centers in diamond. In our work, we apply wavelet-based denoising to photoluminescence (PL) traces acquired in optically detected magnetic resonance experiments, where measurement precision is fundamentally limited by photon shot noise. By exploiting the multi-resolution analysis via wavelet decompositions, we selectively suppress noise components while preserving the PL variations that encode the physical quantity of interest. By incorporating appropriate a priori knowledge, wavelet analysis can enable adaptive thresholding to enhance the readout signal. In parallel, we employ sequences that benefit from the increased spin lifetimes of the nuclear spins in the vicinity of the NV. Our results demonstrate a unified approach that combines quantum memory exploitation and wavelet-based enhancement to push the limits of sensitivity and spectral resolution in quantum sensing with NV centers.

Q 34.6 Wed 16:00 P 5

**Time-Efficient Nanoscale NMR Using Solid-State Spin Sensors** — •Tobias Spohn[1], Nicolas Staudenmaier[1], Philipp J. Vetter[1], Timo Joas[1], Thomas Unden[2], Ilai Schwartz[2], Philipp Neumann[2], Genko Genov[1], and Fedor Jelezko[1] — [1]Institute of Quantum Optics and Center for Integrated Quantum Science and Technology (IQST), Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]NVision Imaging Technologies GmbH, Ulm D-89081, Germany

Nuclear magnetic resonance (NMR) spectroscopy using solid-state spin sensors offers a powerful platform for detecting nuclear spins at the micro- and nanoscale. While many nanoscale experiments rely on a single sensor spin, employing spin ensembles can substantially enhance sensitivity, particularly when signals arise solely from statistically polarized nuclear spins.

Here, we introduce multipoint correlation spectroscopy, a protocol that integrates the strengths of correlation spectroscopy and quantum heterodyne detection to achieve time-efficient measurements of statistically polarized nuclear spin samples with spin ensembles at the nanoscale. We develop a theoretical framework for this method and demonstrate an experimental proof of concept using a nitrogen-vacancy center in diamond. Our implementation achieves a frequency estimation uncertainty at the single-hertz level, underscoring the potential of this technique for temporally efficient, high-precision nanoscale NMR spectroscopy.

Q 34.7 Wed 16:15 P 5

**Understanding the disorder robustness of Over-Un-Twisting echo protocols** — •Vineesha Srivastava[1,2] and Klemens Hammerer[1,2] — [1]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck 6020, Austria — [2]Institute for Theoretical Physics, University of Innsbruck, Innsbruck 6020, Austria

Precision in phase estimation using Ramsey interferometry is limited by quantum projection noise, constraining classical-spin protocols to the standard quantum limit. Entanglement generated through one-axis twisting (OAT) can overcome this limitation, and, in principle, enable sensitivities up to the Heisenberg limit, motivating enhanced Ramsey-echo protocols that apply OAT interactions before and after the phase imprint to surpass simple squeezing schemes.

In earlier work, a variational framework for such echo protocols revealed a previously unknown over-un-twisting (OUT) protocol, in which the initial squeezing is reversed using twice the interaction time. Remarkably, recent experiments on dense room-temperature nitrogen - vacancy ensembles have demonstrated a doubly inverting echo analogous to the OUT protocol, exhibiting disorder-robust signal amplification, which is an effect not fully explained by current theory.

In this work, we investigate the microscopic origins and limits of this robustness. Using cumulant-expansion techniques, we analyze how inhomogeneous spin - spin couplings modify the nonlinear echo dynamics and identify regimes in which OUT-like protocols preserve their metrological advantage.