Colloquium on Solid-State Physics

Department of Physics
WS 2022/23

Thursday, 2nd February 2023, 17.15 h
Lecture Hall III, Department of Physics, Garching

A spin-wave imaging platform based on nitrogen vacancy spins in diamond

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Abstract:

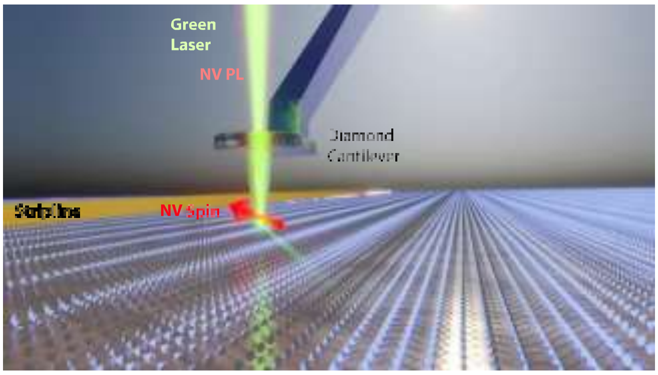

Figure: A diamond cantilever, with NV(s) implanted ~20 nm below the tip surface, is mounted in an AFM setup and used for probing the stray field of spin waves that are excited by a gold stripline. The NV spins are initialized using a green laser and read out via spin-dependent photoluminescence (PL).

Magnetometry based on nitrogen-vacancy (NV) spins in diamond has recently emerged as a powerful tool for probing spin waves [1] – the elementary excitations of coupled spins in magnetically ordered materials. In this talk I will focus on how we utilize scanning NV magnetometry – in which we use a NV sensor spin(s) that are shallowly embedded in the tip of a diamond scanning probe – to image spin waves in a thin film magnetic insulator. I will focus on two studies:

(1) I will show how microwave excitation of low-wavenumber spin waves leads to a high-density and, most surprising, a unidirectional gas of incoherent magnons [2]. We find that the enhanced magnon density extends unidirectionally over hundreds of micrometres from the excitation stripline. Furthermore, we demonstrate how the spatial decay of the stray fields reveals the wavenumber content of both coherently excited spin waves with a well-defined wavenumber as that of the incoherent magnon gas.

(2) I will show how we can use our single-NV sensor as a wavelength filter to characterize frequency- degenerate spin wave modes [3]. With the NV probe in contact with the magnet we observe a mixture of thermal and coherently driven spin waves and when we retract our tip we suppressed the small- wavelength modes, leaving only the coherently driven mode visible. We also show that our in-contact scans at

low microwave drive power surprisingly show occupation of the entire isofrequency contour of the two-dimensional spin-wave dispersion despite our one-dimensional microstrip geometry.

These results reveal the power of scanning NV-magnetometry as a tool for spin-wave probing. Whilst showcasing that (1) coherently driven, low-wavenumber spin waves are efficient generators of a non-equilibrium magnon gas in target directions and that (2) nanoscale control over the NV-sample distance enables wavenumber-selective imaging of magnetization oscillations. Our results open new avenues for local control of spin transport and for imaging other coherent spin-wave modes.

References:

[1] I. Bertelli et al. *Sci. Adv.* **6** eabd3556 (2020).

[2] B. G Simon*, S. Kurdi* et al. *Nano Lett*. **21** 8213 (2021).

[3] B. G Simon*, S. Kurdi* et al. *Nano Lett*. **22** 9198 (2022).

[4] B. A. McCullian et al. *Nat. Comm*. **11** 5229 (2020).

There will be coffee, tea, and cookies in front of the lecture hall at 17.00 h