Detection of Spin System Dynamics in TEM

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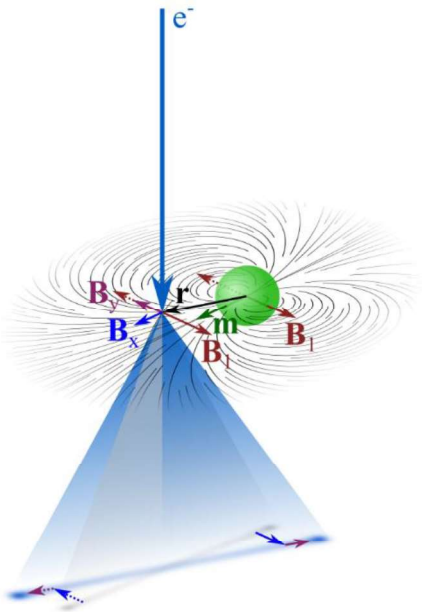

Figure1: The spin state magnetization $\mathbf{m}$, driven by MW field $\mathbf{B}_1$, generates dynamic magnetic fields $\mathbf{B}_x$ and $\mathbf{B}_y$, leading to an electron beam deflection.

Microwave (MW) spectroscopy plays a crucial role in condensed matter physics, where techniques such as electron spin resonance and ferromagnetic resonance are utilized to determine key specimen properties. Spin states are altered by their local environment, providing spectroscopic insights into the atomic and chemical structure of the probed sample. However, these methods lack nanoscale spatial resolution, as the measured signal is averaged across the entire specimen [1].

We present a novel approach [2] utilizing MWs (~4.7 GHz) for the excitation [3] and a free-space electron probe for the spatially resolved detection of spin systems, see Figure 1. MW pumped spin-state transitions alter the local magnetic field, inducing subtle shifts in the electron probe's momentum, which we detect with prad sensitivity.

With a lateral resolution of ~30 µm, this method advances MW-driven spin studies, potentially enabling atomic-scale investigations using a highly controlled electron probe [4].

[1] BOERO, G., et al. Electron-spin resonance probe based on a 100 µm planar microcoil. Review of scientific instruments, 2003, 74.11: 4794-4798.

[2] JAROŠ, Antonín, et al. Sensing Spin Systems with a Transmission Electron Microscope. arXiv preprint arXiv:2503.06761, 2025.

[3] JAROŠ, Antonín, et al. Electron Spin Resonance Spectroscopy in a Transmission Electron Microscope. arXiv preprint arXiv:2408.16492, 2024.

[4] HASLINGER, Philipp; NIMMRICHTER, Stefan; RÄTZEL, Dennis. Spin resonance spectroscopy with an electron microscope. Quantum Science and Technology, 2024, 9.3: 035051.