P20: Design of Microresonators for the Coherent Manipulation of Spin Systems in a TEM

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Electron spin resonance (ESR) is a powerful spectroscopic technique used to investigate spin systems in various fields such as physics, chemistry, and materials science. Recent advancements have demonstrated the feasibility of integrating ESR detection directly into a transmission electron microscope (TEM) [1]. This approach holds promise for complementing the high spatial resolution achieved in TEMs with the high spectral resolution of ESR [2].

A critical component of the described setup is the microresonator antenna, which determines the efficiency of microwave power delivery to the sample and the sensitivity of spin detection [3,4]. Prior work has successfully implemented a planar Ω-shaped microresonator optimized for 4.7 GHz operation, achieving spin sensitivities down to 10^{12} spins/Hz$^{1/2}$ [1]. The Ω-shaped microresonator antenna on a printed circuit board is shown in Figure 1. The chosen frequency requires a specific magnetic field for resonant spin manipulation and, therefore, determines the objective lens current. For 4.7 GHz, the microscope is operated in low-angle diffraction mode leading to limited spatial resolution.

Higher spatial resolutions can be reached by increasing the magnetic field, which shifts the resonance to a higher frequency. To drive and detect the spin systems at such high frequencies an specially designed antenna is needed. Note that ESR spin sensitivity is inversely proportional to the square of the applied magnetic field. Therefore, working at higher resonance frequencies not only significantly increases the spatial resolution of the electron beam but also improves spin sensitivity for conventional ESR tools.

This work focuses on the design and optimization of a 50 GHz microresonator antenna for TEM-based ESR experiments. Numerical simulations are used to refine the resonator geometry and evaluate electromagnetic field distributions [3,4]. Based on those simulations, a 50 GHz microresonator antenna will be fabricated and integrated into our current setup. The development of a 50 GHz ESR microresonator represents a significant step toward the implementation of an ESR setup, while maintaining the high spatial resolution of a TEM.

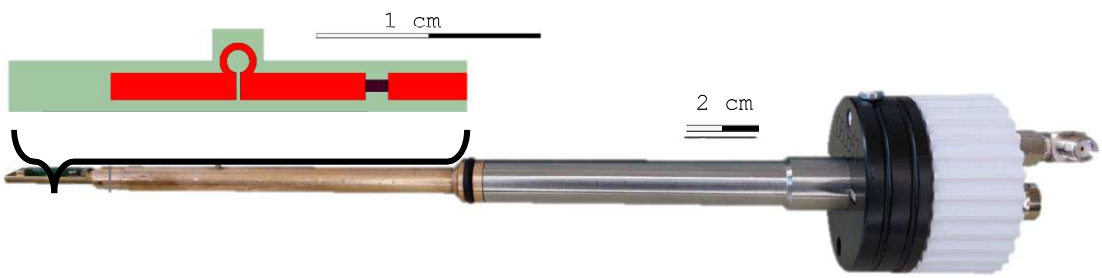

Figure 1. TEM holder with impedance matched microresonator on top.

[1] Jaroš et al., arXiv:2408.16492 (2024)
[2] Haslinger et al 2024 Quantum Sci. Technol. 9 035051
[3] Narkowicz et al., Journal of Magnetic Resonance 175, 275 (2005)
[4] Narkowicz et al., Review of Scientific Instruments 79, 084702 (2008)