Field-Modulated Lock-In FMR Spectroscopy: Design and Comparison with VNA-Based Measurements

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We present a broadband ferromagnetic resonance (FMR) measurement setup based on magnetic field modulation and lock-in detection [1], designed for sensitive characterization of ultrathin magnetic films and multilayers. The system employs a coplanar waveguide (CPW) excited by a microwave signal generator and a zero-bias Schottky diode detector for broadband microwave absorption measurements.

Measurement sensitivity is enhanced using low-frequency magnetic field modulation generated by dedicated Helmholtz coils integrated with an electromagnet [2]. The resulting modulated signal is detected by a phase-sensitive lock-in amplifier synchronized to the modulation frequency, enabling direct acquisition of the field derivative of the absorbed microwave power and effective suppression of background contributions.

The performance of the setup is validated using Co/Ni multilayer structures[3]. The obtained FMR spectra are directly compared with results from a conventional vector network analyzer (VNA) transmission-based configuration [4]. The comparison demonstrates a significantly improved signal-to-noise ratio and reduced sensitivity to background variations, while preserving consistent resonance field positions and linewidth trends [5].

The system allows flexible control of microwave frequency, static magnetic field amplitude, and field orientation, and is fully automated via custom control software. The presented setup provides a cost-effective, broadband, and robust alternative to VNA-based FMR techniques, well suited for high-throughput and wafer-level magnetization dynamics measurements.

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