Experiment No. 23

Ferromagnetic Resonance (FMR)

Basic description Ferromagnetic resonance (FMR) is a widely used technique for the characterization of ferromagnetic samples. The magnetic moments inside the sample are excited by a small AC magnetic field with frequency in the microwave range leading to a precession of the magnetic moments around the equilibrium direction of the magnetization. By measuring the resonance frequency of this precession, magnetic parameters of the sample can be inferred. Ferromagnetic resonance allows the determination of the equilibrium direction of the magnetization vector, the measurement of magnetic anisotropies, or gives insights in to the dynamical properties of the magnetization, like for example the gyromagnetic ratio or the damping parameter. Ferromagnetic resonance is applicable to a broad spectrum of samples ranging from macroscopic objects down to ultrathin films with thicknesses of several atomic layers, or nano-structured magnetic devices. Ferromagnetic resonance is often applied within the field of spintronics, for example for the initial characterization of samples or for the generation of spin-currents to test certain spin-effects, like the spin Hall effect.

Physical content In this experiment the basics of ferromagnetism will be introduced and, based on a model of the various energy terms inside a ferromagnetic material, the resonance condition of ferromagnetic resonance will be derived. This result will in the experiment be applied to two ferromagnetic samples which will be characterized regarding effective magnetization and damping parameters. Furthermore the basics of microwave generation, guidance and detection will be introduced. The lock-in detection technique is essential for measurements of ferromagnetic resonance and will be studied in detail in this experiment.

Measurement setup The sample under investigation is placed between the pole pieces of an electromagnet on a microwave stripe line. Using a microwave generator a small microwave current will be generated in this microstrip line, which in turn creates a small magnetic field with frequency in the microwave range at the sample position. The microwave power absorbed by the sample is measured with a Schottky detector and recorded depending on the externally applied magnetic field using a data acquisition system.

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