Application Note MS22

ANPz51 Enabling Tuning of a Fabry-Pérot Resonator for High Field / High Frequency EPR

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Thanks to the recent development of high field magnets, highfield/high-frequency electron paramagnetic resonance (HFEPR) has seen a continuous growth in the last decades. One of the limitations that still exist is the relatively low power of high-frequency microwave sources of only a few milliwatts (as compared to the hundreds of mW of a usual X-band source). The standard method to enhance the microwave power on the sample is the use of a cavity. Unfortunately, the linear dimension of a cavity and its fabrication tolerances are mutually coupled and proportional to the wavelength. In the case of HF-EPR operating in the frequency range of 200-300 GHz, this translates to cavity sizes of one millimeter, which makes fabrication and sample loading very difficult.

The solution developed by Petr Neugebauer and co-workers [1] is to replace the single mode cavity with a broad band Fabry-Pérot (FP) resonator. The solution (with respect to single mode cavities) allows for measuring larger samples (crystals), easier loading, and also supports multi-frequency HFEPR, hence measurements at several microwave frequencies. The FP resonator consists of two opposing mirrors: a semitransparent, flat mirror (between the sample space and the corrugated taper - a gold mesh in this case) and a spherical one at the bottom of the resonator (see Figure 1).

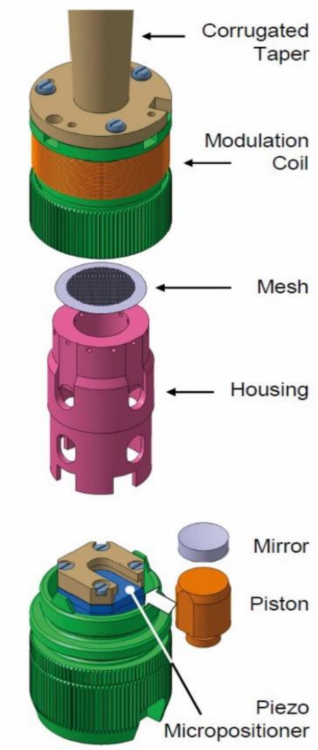

Figure 1: The construction of the Fabry-Pérot resonator. The ANPz51 moves the mirror and hence, tunes the resonator.

The figure of merit of a FP resonator is not the quality factor *Q* (as in case of a cavity), but the finesse F which is linked to the quality factor via $F = Q/n$ where n is the resonance mode. Choosing the right fine tuning of the resonator is critical, because the finesse strongly depends on it. Hence, a positioner with large working range, but very high precision is needed that can operate at low temperatures and high magnetic fields.

With the ANPz51 positioner, the group was able to move the spherical mirror of the resonator in a 3 mm range to find the right mode and fine-tune its position with a precision much better than 1 µm. The low temperature compatibility of the positioner allows the tuning procedure to be performed in situ at a certain measurement tempera+ture and high magnetic field applied.

To demonstrate the performance of the setup they measured the cyclotron resonance on single crystal natural graphite. Figure 2 shows the results and illustrates well the increased sensitivity. In order to obtain signals with comparable intensity, it was necessary to use modulation amplitudes four times larger for the previously used transmission setup than for the Fabry-Pérot, resulting in overmodulated signals in the first case as indicated by the increased line width. More interestingly, weaker cyclotron-resonance harmonics could be observed at low field with the FP resonator. This allows approaching closer to the *K* point, a particularly relevant issue for better understanding of the properties graphite [2].

In summary, the use of a low temperature positioner with high precision over a long working range is essential for the realization of this new setup that increases the sensitivity of HP-EPR by at least a factor of four.

References

[1] P. Neugebauer and A.-L. Barra, Appl. Magn. Reson. (2010).
[2] M. Orlita, P. Neugebauer, C. Faugeras, A.-L. Barra, M. Potemski, F. M. D. Pellegrino, and D. M. Basko, Phys. Rev. Lett. 108, 017602 (2012).

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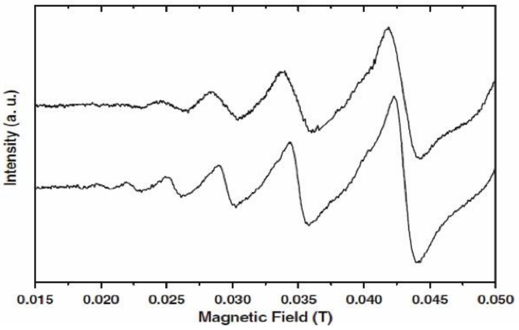

Figure 2: Single-crystal cyclotron resonance of graphite at 283.2 GHz and 7.5 K for a magnetic field perpendicular to the carbon sheets. Upper spectrum recorded using a cavity in a transmission setup (modulation amplitude, 28 G); lower spectrum recorded with the Fabry– Pérot cavity (modulation amplitude, 6.8 G).