Improvements of the Sensitivity of the High-Field Electron Paramagnetic Resonance Spectrometer Using Nanofabricated Mesh

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Abstract:

Sensitivity of 1 mm electron paramagnetic resonance spectrometer depends on critical coupling reached at the entrance of the resonator for different samples. An invented asymmetric mesh [1] was made using laser cutting and it worked perfectly at 95 GHz and 170 GHz electron paramagnetic resonance frequencies. However, at 240 GHz the wavelength is small enough that the imperfections of the manufacturing (see Figure 1) do not allow to use it for the samples with different losses using the same principle as the meshes in [1].

Summary of Research:

Using nanofacilities at Cornell University, a similar mesh was made using lift off procedures from silver put on the fused silica substrate (this material has no electron paramagnetic resonance signal).

Usage of the mesh outlined allowed to use the same tuning procedures as for 170 GHz and 95 GHz, where laser cutting of the mesh out of nonmagnetic stainless steel was proved to be a successful solution (probably because the accuracy of laser cutting is enough for wavelength of 2 mm, which corresponds to 170 GHz and 3 mm, which corresponds to 95 GHz).

In addition to this expected advantage, the signal to noise ratio was found to increase 2-3 times. During the previous work with stainless steel mesh, this ratio was already risen perceptibly and no increase was expected, that is why this increase is associated probably with higher quality of the resonator. (See Figures 3 and 4 for comparison.)

From the comparison of Figure 3 and Figure 4, it is possible to see the influence of the quality of the mesh (the mesh serves as the lower mirror in the resonator) to the quality of the spectrum. This improvement would be obvious for optical spectroscopy where the accuracy is comparable to wavelength, but for the case of microwave it may be explained as the consequence of the lesser amount of higher order harmonic excitation in the resonator, which ultimately leads to better profile of the fundamental mode of Gaussian beam.

References:

Figure 2: Photo of the mesh made with nano accuracy.

Figure 3: Electron paramagnetic resonance spectrum of biological sample recorded with old stainless steel mesh.

Figure 4: Electron paramagnetic resonance-spectrum of the same sample recorded with nanofabricated mesh.