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Spectrometer Application Report

Measuring Magnons, Spin Wave Brillouin Spectroscopy with the LightMachinery HyperFine Spectrometer

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Objectives of this technical note:

- *Optically probing magnons with unparalleled sensitivity.*
- *Determining if the acquisition speed allows for 2D mapping of magnons, in order to study spin wave propagation (e.g. in waveguides and switches).*

Background. A spin wave is the collective motion of electron angular momentum in a magnetic material. The quasi particles associated with such propagating magnetic moments are called magnons. Magnonics show great promise in information technology since magnons are less subject to dissipative processes than conventional charged-based electronics. Better understanding the propagation mechanisms of spin waves and how to manipulate them is key for the development of magnonic waveguides. Brillouin microscopy is a technique of choice for this purpose since it offers the necessary spatial and spectral resolution. In this brief note, we demonstrate spin wave measurements with the LightMachinery Brillouin system.

Experiment. The sample substrate is MgO, with a thin CoFe magnetic layer, and Cr capping layer. Permanent magnets positioned at different distances are employed to produce fields of ~100 mT and ~200 mT at the sample position, as measured with a gaussmeter. The inset of Figure 1 shows how the sample is mounted.

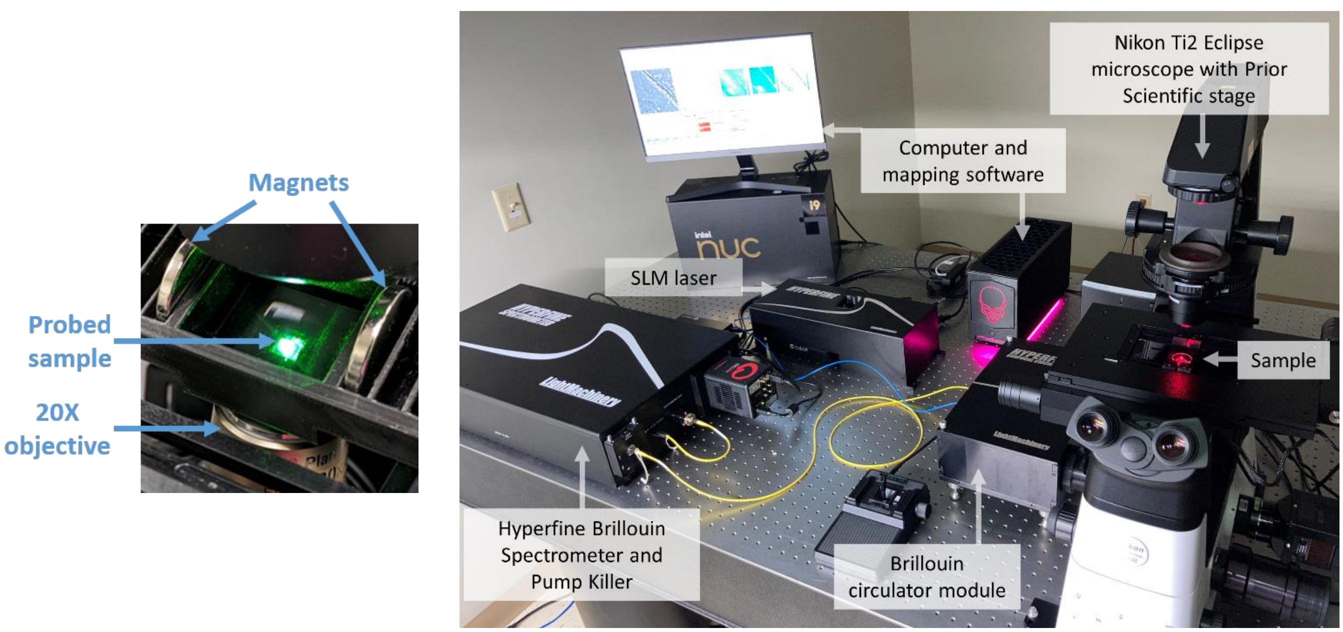

Figure 1. Left: Picture of sample mounted between two permanent magnets in Brillouin microscope. **Right:** Experimental setup for Brillouin spectroscopy. The single longitudinal mode laser, the Brillouin circulator module, the HyperFine spectrometer, and the Pump killer are fiber coupled. The Brillouin circulator module is coupled to the Nikon microscope via the left camera port.

The sample is excited with a focused single longitudinal mode laser at 532nm (Cobolt Samba) using a 20X objective. The laser power at the sample position is approximately 20 mW. The same objective is employed to collect the Brillouin signal in a backscattering geometry. The Brillouin spectra are excited, collected, and analyzed using the Brillouin HyperFine spectrometer (HF-8999-PK-532) and the Brillouin confocal microscope (HF-9000). Figure 1 presents the experimental setup.

The Brillouin confocal microscope comprises an inverted research grade Nikon Ti2 Eclipse, a motorized Prior Scientific stage, and a Brillouin circulator module that enables confocal excitation/collection. The Brillouin HyperFine spectrometer comprises a Pump Killer module to suppress the unshifted laser line (~ 60 dB suppression) while transmitting the Brillouin signals to the spectrometer module. The latter is composed of a VIPA to disperse the Brillouin spectrum in the vertical direction, providing high resolution but overlapping the orders. An echelle grating separates the overlapping orders in the horizontal direction and enhances the contrast. Using this strategy, 0.25 GHz of FWHM resolution can be achieved. The spectrometer used in this study has a resolution of 0.5 GHz. The resulting 2D light pattern is captured by a Hamamatsu Orca-Fusion CMOS sensor and then converted into a linear spectrum.

Results and discussion. The spin wave Brillouin spectra are shown in Figure 2, in which the magnon signals are clearly observed. The Brillouin shift measured (15.15 GHz and 20.96 GHz) are consistent with the expected values[1] for this sample and these magnetic fields (~100 mT and ~200 mT, respectively).

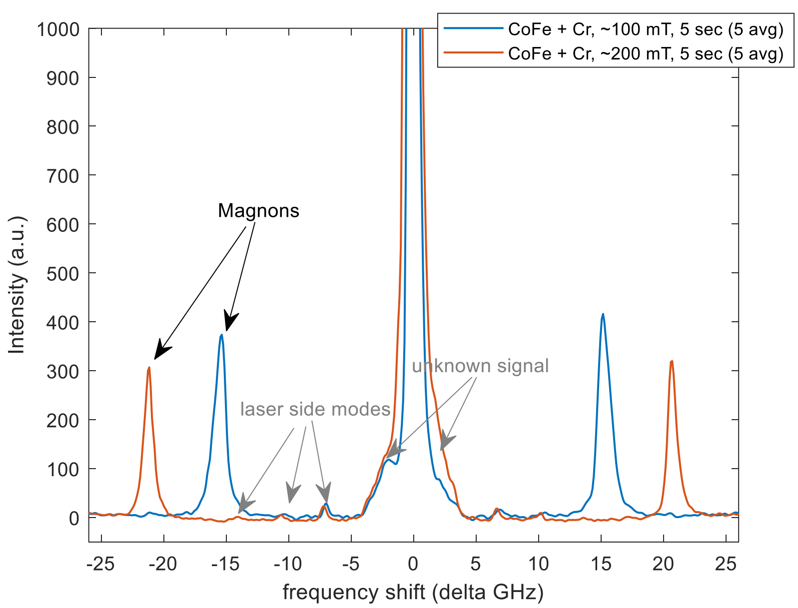

Figure 2. Spin wave Brillouin spectra of the CoFe sample for two different magnetic fields. Experimental conditions: backscattered geometry, sample at normal incidence, ~20 mW at the sample, 5 sec exposure averaged 5 times, 20X objective.

[1] As determined independently by our collaborators.

It is worth noting that the polarization of the Brillouin signal associated with magnons is rotated by 90 degrees with respect to the incident light (in contrast to phonon signals). This is highly advantageous in terms of minimizing the elastic scattering signal, often overwhelmingly strong in Brillouin spectroscopy. However, for the measurements presented here, we did not take full advantage of this characteristics since we did not include a high-contrast polarizer in the collection arm. If we had done so, in combination with the Pump Killer, we expect that elastic scattering would have been even more suppressed. It is also worth noting that this polarization behavior means that one can switch straightforwardly between measuring magnons and measuring photons with the HF-9000 simply by including or not the QWP in the dedicated slot.

The spectra presented in Figure 2 correspond to 5 averages of 5 seconds. In fact, reasonable magnon signals were observable with as little as 500 ms exposure despite using a very moderate laser power of 20 mW. Such acquisition speed is well suited for 2D imaging of magnonic devices, confirming that the HF-8999-PK-532 and HF-9000 are instrument of choice for spin wave Brillouin spectroscopy research.