Development of microwave interferometer based ultra-high sensitivity ferromagnetic resonance measurement apparatus

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Microwave assisted magnetic recording (MAMR) is one of the promising candidates for increasing the recording density in hard disk drives (HDD). In the MAMR technology, a spin torque oscillator (STO) embedded in the HDD slider generates a microwave field, which is applied to the storage layer of the HDD media to temporally decrease the coercivity during the magnetization switching process. Because this technology takes advantage of the cooperative phenomenon between high frequency magnetic fields and spin dynamics, it is crucial to thoroughly characterize dynamical properties of both the STO and magnetic storage layer. However, the high frequency characterization of the STO is particularly challenging due to its small dimension and multilayer structure that complicate the behavior at high frequencies, thus making it difficult to come up with a clear interpretation of the results obtained by the standard electrical characterization techniques such as oscillation spectrum or thermally excited mag-noise measurements. Therefore, it is desirable to have other means for measuring high frequency dynamics of a magnetic nanostructure as a complementary technique.

For this purpose, we have developed a technique to measure ferromagnetic resonance (FMR) with a high sensitivity based on microwave interferometer, which we named as Interferometric FMR (I-FMR), whose block diagram is shown in Fig. 1 [1]. The basic idea of this technique is as follows. The stimulus signal from P1 is split into two paths, and they destructively interfere with each other such that ideally no stimulus signal exits the power combiner when no magnetic

activity is excited. When the FMR condition is met, the stimulus signal of the path going through the coplanar waveguide (CPW) excites FMR on the magnetic element, thus the balance between the two paths is broken. As a result, only the difference signal reflecting the FMR response of the magnetic element exits the power combiner, which is amplified and eventually detected at P2. The first I-FMR demonstration showed a large sensitivity enhancement of as large as about 40 dB (x 100) compared with the conventional vector network analyzer FMR (VNA-FMR) as presented in Fig. 2, which allowed a clear resolution of the Kittel mode FMR signal on a 100 nm diameter and 5 nm thick CoFeB single nanodot. Following this demonstration, we have developed the second version of the I-FMR apparatus. The main difference between the first and second versions is that the first version required manual adjustments of the interferometer every time when the frequency is changed, which is a very tedious and time consuming step, while this adjustment is fully automated in the second version without largely sacrificing the sensitivity, thus making this system a powerful tool for the high frequency characterization of nano-scale magnetic elements.

In the presentation, I will first give the system overview of the second version of the I-FMR apparatus, then will show some FMR spectra measured on nano-scale magnetic elements under various conditions to shed new lights on the magnetization dynamics.

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Reference

1) 1) S. Tamaru et al., IEEE Magn. Lett., (5) 1-4, (2014)



Fig. 2, Comparison of the FMR spectrum measured on a 800 nm diameter and 5 nm thick CoFeB single nanodot taken by the conventional VNA-FMR, first and second versions of I-FMR.