DEVELOPMENT OF MICROWAVE INTERFEROMETER BASED ULTRA-HIGH SENSITIVITY FERROMAGNETIC RESONANCE MEASUREMENT APPARATUS FOR CHARACTERIZING DYNAMICAL PROPERTIES OF MAGNETIC NANODOT

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I. INTRODUCTION

Microwave Assisted Magnetic Recording (MAMR) technology is one of the promising candidates for increasing the recording densities of hard disk drives (HDDs). In the MAMR technology, a spin torque oscillator (STO) embedded right next to the write pole 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 cooperative phenomena between high frequency magnetic fields and spin dynamics, it is crucial to thoroughly characterize dynamical properties of both the STO and magnetic storage layer. 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 understanding of the results obtained by the standard oscillation spectrum measurement. Therefore, it is desirable to have other means for measuring high frequency dynamics of a magnetic nanostructure as a complementary measurement technique to independently characterize the magnetic layer of interest in the STO structure. For this purpose, we have explored a microwave interferometer based ferromagnetic resonance (FMR) measurement technique. As an initial feasibility study, a vector network analyzer ferromagnetic resonance (VNA-FMR) apparatus combined with a Mach-Zehnder type microwave interferometer was built, and its FMR sensitivity was examined. This combination successfully demonstrated an enhancement of the FMR sensitivity by as large as more than 40 dB compared with that of the standard VNA-FMR, with which we could clearly detect a FMR signal on as small as 100 nm diameter and 5 nm thick CoFeB single nanodot. We named this technique as Interferometric FMR (I-FMR) [1].

While the first feasibility study of the I-FMR technique showed a very significant sensitivity enhancement, the I-FMR apparatus itself was not ready for use as a practical characterization tool, as it required a manual adjustment of the microwave interferometer every time when the frequency is changed, which is a very tedious and time consuming step, thus seriously spoiling the usability of the I-FMR. In order to overcome this difficulty, we developed a second version of the I-FMR apparatus, in which the phase shifter and variable attenuator are motor controlled, thus the microwave interferometer can now be automatically adjusted without human intervention.

II. OVERVIEW OF THE NEW I-FMR APPARATUS

Fig. 1 shows the block diagram of the I-FMR technique. The stimulus signal generated by the VNA's built-in oscillator is split into two paths. The stimulus signal propagating along one path is coupled into a coplanar waveguide (CPW), on which a magnetic dot is fabricated. This CPW is placed in the gap of an electromagnet that can generate a bias magnetic field H_B of up to 21 kOe as well as a low frequency modulation field of about a few tens of Oe. The stimulus propagating along the other path goes through a phase shifter (PS) and continuously variable attenuator (VA). These two stimuli are combined by a power combiner (PC), which is a reversely connected Wilkinson power divider. The PS and VA are adjusted such that these two stimuli have the same amplitude and 180° opposite phase. Therefore, these two stimuli destructively interfere with each other so no stimulus signal should exit at the PC output under the ideal condition when no magnetic activity is excited in the magnetic dot. When a H_B satisfying the FMR

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resonant condition is applied, FMR is excited in the magnetic dot, absorbing the stimulus power, thus changing the transmission property of the CPW. This breaks the balance between the two stimuli, so the difference corresponding to the FMR signal exits the PC, which is amplified by a low noise amplifier and eventually detected by the VNA receiver.

The most important feature of the second version of the I-FMR apparatus is that a high precision stepping motor is attached to both the PS and VA, allowing the host computer to remotely control these two components. Using this, we implemented a program to automatically adjust the interferometer by iteratively adjusting the PS and VA such that the leakage of the stimulus is minimized.

Fig. 2 shows the comparison of the FMR spectra taken with the conventional VNA-FMR, first (manual adjustment) and second (automatic adjustment) versions of the I-FMR apparatuses. This figure shows that the sensitivities of the I-FMR for the first and second versions are about 41 dB and 36 dB higher than that of the conventional VNA-FMR. The second version of I-FMR shows about 5 dB lower sensitivity than the first version, which is considered to be caused by the thin flexible cables directly attached to the probes that attenuate the microwave stimulus. The development of the second version of the I-FMR apparatus is in the final phase, meaning that it is undergoing the system optimization to maximize the sensitivity, thus expected to be fully up and running shortly. Also, a new batch of samples have just been fabricated with an improved microfabrication process. The new samples are expected to solve the problem with the first batch of samples that had some redeposited magnetic residue during the dry etching process, which were also detected by the I-FMR measurement, thus obscuring the FMR signal of interest.

In this talk, the features and capabilities of the new I-FMR apparatus are presented, as well as some new measurement results taken on the new batch of sample to demonstrate the powerfulness of this new tool for characterizing magnetization dynamics of magnetic nanostructures.

REFERENCES

1) S. Tamaru et al., " Ultrahigh Sensitivity Ferromagnetic Resonance Measurement Based on Microwave Interferometer", *IEEE Magn. Lett.,* (5) 1-4, (2014).

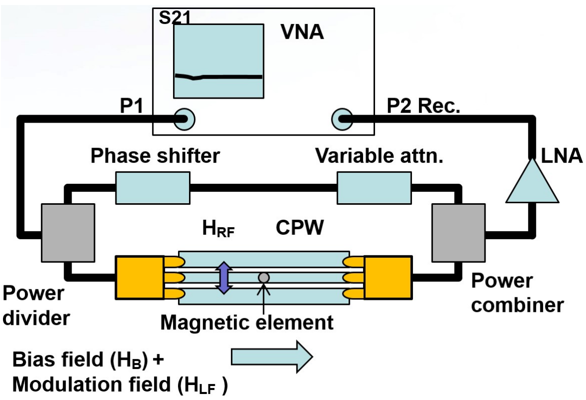

Fig. 1, Block diagram of the I-FMR apparatus

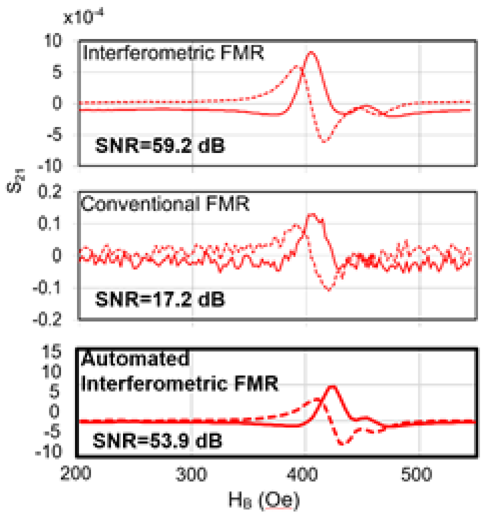

Fig. 2, Comparison of the FMR spectrum measured on a 800 nm diameter and 5 nm thick CoFeB single nanodot taken by the conventional VNA-FMR, first and second versions of I-FMR.