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RF injection locking in vortex-STO with MgO capped FeB free layer

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Injection locking is one of the important approaches to realize spin torque oscillators (STOs) that can generate microwave signal with a narrow linewidth and a high output power [1]. Among various types of STOs, vortex-STO attracts special attention as the platform device for observing the injection locking because of the stable oscillation [2]. Dussaux et al. demonstrated the reduction of the linewidth from 5 MHz to 3 kHz in the vortex-STO having a Py free layer by injection locking technique [3]. However, the conditions required for injection locking, such as the input RF power (P_{rf}) or the radical linewidth of STO, have not been clarified yet.

In this work, we studied the injection locking in a vortex-STO by an RF current. We prepared a film of sub. / buffer / PtMn(15) / CoFe(2.5) / Ru(0.98) / CoFeB(3.0) / MgO(1.0) / FeB(3.0) / MgO(1.0) / Ta / Ru (nm), and micro-fabricated into circular-shaped MTJs of 300 nm in diameter. As shown in Fig. 1, the *R-H* curves measured by sweeping the in-plane magnetic field showed staircases in low fields, which is the characteristic of vortex generation. RF emission was measured under a dc voltage (V_{dc}) and a magnetic field perpendicular to the film plane. Figure 2(a) shows the power spectral density (PSD) without RF current. The spectrum exhibited a linewidth of 500 kHz and a high emission power of 1.0 μW at V_{dc}=290 mV. Even higher emission power up to 3 μW was also obtained at V_{dc}=450 mV (not shown). To observe the injection locking, an RF current was injected to the sample through a power divider. In order to distinguish the emitted RF signals from the injected RF current, f_{rf} was purposefully set at about twice the f_{STO} [3]. As shown in Fig. 2(b), linewidth was greatly reduced down to 5 kHz and the peak height was remarkably enhanced to 150 mW/GHz by the injection locking. This huge peak height is the highest value in the vortex-STOs reported. We will present the details of the P_{rf} and f_{rf} dependence of the injection locking.

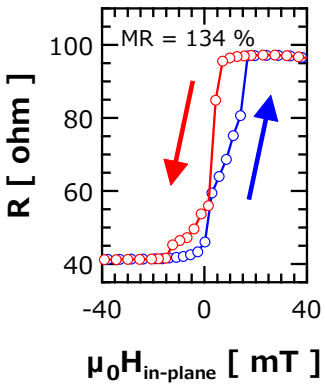

Figure 1 *R-H* curve of the vortex-STO under in-plane magnetic fields.

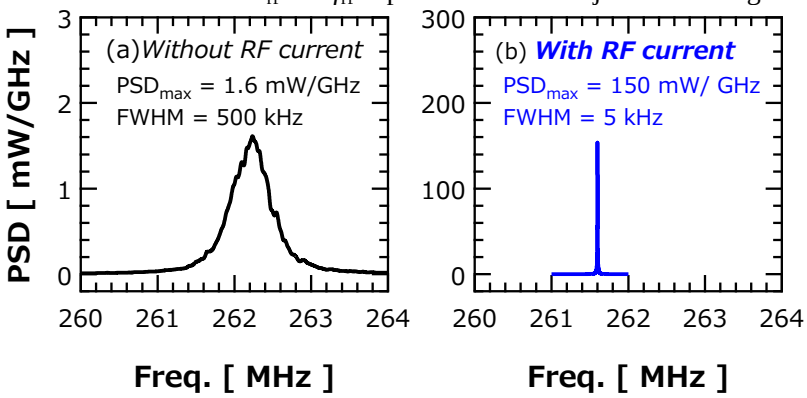

Figure 2 PSD of the vortex-STO (a) without RF current and (b) with RF current (f_{rf} = 523.2MHz and P_{rf} = -16 dBm). In both cases, the dc voltage of 290 mV and out-of-plane magnetic field of 320 mT were applied.

[1] J. Grollier, et. al., Phys. Rev. B **73**, 060409(R) (2006).
[2] A. Dussaux, et. al., Nature Commun. **1**, 8 (2010).
[3] A. Dussaux, et. al., Appl. Phys. Lett. **98**, 132506 (2011).

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