Frequency-Locking in Serially Coupled Spin-Transfer Nano-Oscillators

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More recently, the characteristics of microwave emission by spin torque induced magnetization precession in magnetic tunnel junctions (MTJ) have extensively been examined for radio frequency (rf) device applications[1]. Although the spin-transfer nano-oscillators (STNO) can present such an excellent frequency tunability in the GHz range and fully compatible with a high level of integration, there are two main drawbacks regarding the weak output power and broad spectral linewidth of the generation signals[2]. One of the solutions to overcome these problems is to synchronize many STNO devices by use of various local or non local mechanisms[3].

As one of the non local methods, we study on the interaction between electrically connected STNOs through spin transfer self-emitted microwave current. The fabricated device consists of a nominally 100 × 60 nm^2 elliptical nanopillar structure composed of SiO_2 substrate/Ta (5)/CuN (30)/Ta (5)/$Pt_{37}Mn_{63}$ (20)/$Co_{70}Fe_{30}$ (3)/Ru (0.8)/$Co_{60}Fe_{20}B_{20}$ (5)/MgO (1)/$Co_{60}Fe_{20}B_{20}$ (2)/Ta (10)/CuN (10)/Ru (7) (in nm). The STNO has the tunnel magnetoresistance (TMR) of 63 % and resistance-area (RA) product of 5 Ω · μm^2 in the parallel state. With respect to the microwave measurement, the device is connected to a ground-signal-ground (GSG) probe with coplanar waveguide (CPW) pattern. And the rf output spectra are monitored by a spectrum analyzer through the bias-tee circuit including a DC bias input and a rf output signal port. The output signals are amplified by a 40 dB preamplifier, but both the amplification and background noise are subtracted for the presented data. All measurements are carried out at room temperature.

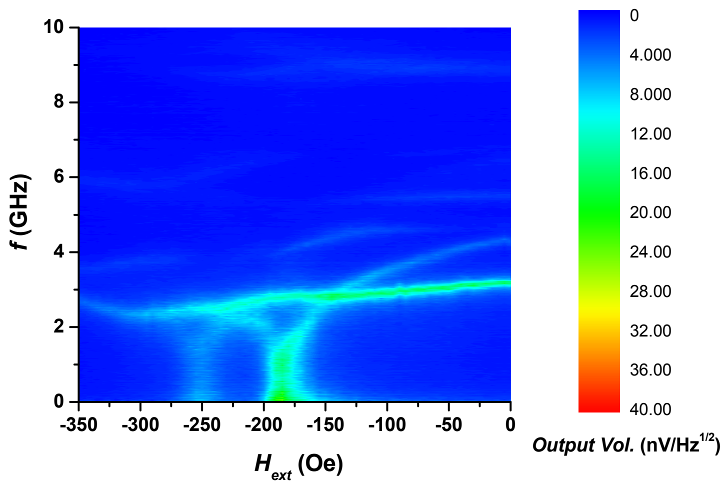

Fig. 1. Contour map of the emission voltage (in linear scale) as a function of the frequency and the external magnetic field under I = 0.5 mA.

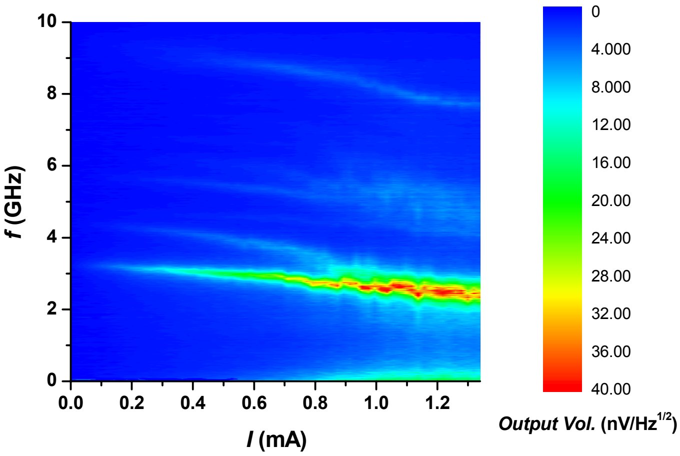

Fig. 2. Contour map of the emission voltage (in linear scale) as a function of the frequency and the bias current under Hext = -50 Oe.

In Fig. 1 and 2, we show a contour plot of microwave emission voltage of the two serially connected STNOs. All the rf spectra are obtained with the in-plane easy-axis external magnetic field. Considering Kittel's ferromagnetic resonance (FMR) formula, the field dependence of the measured frequency is interpreted as behavior of in-plane small angle precession. From Fig. 1, it should be noted that the signals of each STNO devices do not seem to be phase-locked state under the bias current of 0.5 mA with the external field range from -350 to 0 Oe. In order to enhance the coupling efficiency of coupled STNOs, we increase a bias current to induce the out-of-plane large angle precession which could deliver a more amplified spin transfer self-emitted microwave current to each other[4]. As a result, the coupled STNOs have a common fundamental frequency as increasing the bias current over 0.9 mA. However, this frequency-locking does not mean the exact phase-locking of the coupled STNOs. If the phase-locking would be occurred, the output power could be increased and the spectral linewidth could be reduced upto 4 times of the single STNO's[3]. Unfortunately, we do not confirm this estimation and it seems that a more detailed research would be needed to resolve this subject.

Reference

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