Chaotic Behavior of Spin-Torque Oscillator with Feedback Circuit

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Non-linear magnetization dynamics in nano-scale devices are important research field for next-generation computing [1]. Spin torque oscillator (STO) is an attractive candidate due to its small size, low power consumption, and high non-linearity [2]. Various non-linear phenomena, such as synchronization and chaos, in the STO dynamics are expected to improve computing performance [3]. Recently, we have numerically showed that electric current injection by a delayed feedback circuit can manipulate the non-linearity and give rise to chaos [4]. The delayed feedback systems have been experimentally investigated as well [5,6], however, chaotic behavior has not been reported yet. In this work, we investigate chaotic behavior of the STO dynamics by using an improved feedback circuit.

Figure 1 shows a schematic illustration of the delayed feedback circuit connected to a vortex-type STO. An auto-oscillation of the vortex core was excited as reported previously [5]. The output signal generated from the STO was fed back as microwave field through a transmission line with time delay of about 150 ns. The magnitude of the feedback signal was controlled by an attenuator with the rate r_{Att}. Figure 2 shows power spectra of the STO with various r_{Att}. With decreasing r_{Att}, the number of the peaks increases, whose frequency is associated with the delay time of the feedback circuit. The spectral linewidth of the main peak decreased with decreasing r_{Att} to 20 dB. At lower attenuation (r_{Att} =12 dB), the spectral linewidth increased. These systematic spectral changes are similar to those observed in other feedback systems with chaos [7]. It is suggested that our feedback system shows chaotic behavior.

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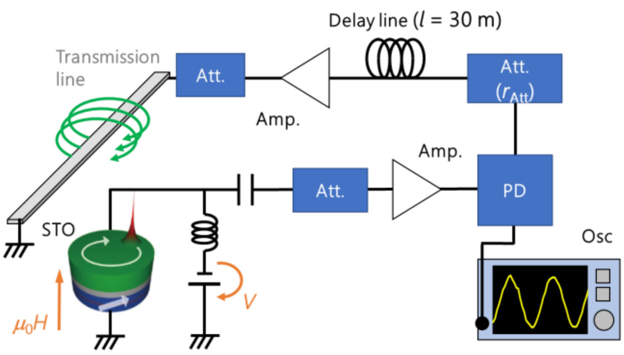

Figure 1 Schematic illustration of feedback circuit connected to the STO. The out-of-plane external magnetic field $\mu_0 H$ = 600 mT and voltage V = 400 mV were applied to the STO to excite auto-oscillation of vortex core.

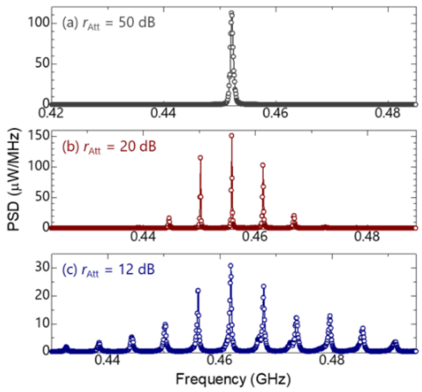

Figure 2 Power spectrum density (PSD) as a function of frequency of vortex core in the STO. The attenuation rate r_{Att} = 50, 20, and 12 dB for (a), (b), and (c), respectively.