TRANSIENT TIME OF SELF-SYNCHRONIZED SPIN TORQUE OSCILLATOR

S. TSUNEGI[1], E. GRIMALDI[2], R. LEBRUN[2], H. KUBOTA[1], K. YAKUSHIJI[1], J. GROLLIER[2], A. FUKUSHIMA[1], S. YUASA[1] and V. CROS[2]

1) AIST, Tsukuba, Japan, tsunegi.sb@aist.go.jp

2) CNRS/Thales, Palaiseau, France

I. INTRODUCTION

Spin torque oscillators (STOs) with large non-linear characteristics have been studied in detail in the last decade, with the expectation of developing new microwave spintronic devices for next generation[1]. Earlier studies revealed that the large non-linearity enables to achieve synchronization among STOs, where the STO phase is synchronized with those of other STOs or with the external rf signals.[2,3] Recently, we succeeded in demonstrating self-synchronization of STO by using a delayed feedback circuit. In this case, both stationary point and stability are strongly dependent on the phase difference between the STO and the feedback current.[4] Such synchronizing phenomena are important for developing high frequency devices as well as for some applications such as reservoir computing which uses a system of nonlinear transient states as its basis [5]. In the reservoir or neural computing, transient time is a factor that cannot be overlooked. The time usually is investigated through analysis of amplitude noise in the single STO [6], but little is known for synchronized STO. In this work, we focused our attention on investigating the transient time τ of the self-synchronized STO.

II. EXPERIMENTS

The STO used was vortex based STO. The stack of the STO consists of buffer/PtMn(15nm)/CoFe(2.5 nm)/Ru(0.9 nm)/CoFeB(2 nm)/MgO(1.1 nm)/FeB(4 nm)/MgO(1.1 nm)/Ta(5 nm)/Ru(5 nm). The self-synchronization was carried out in the delayed feedback circuit, where the emitted rf current from STO was reflected at the close end and re-injected into STO. The phase difference $\Delta\phi$ can be controlled by changing the feedback time of the re-injected current. The transient time was evaluated by analyzing the auto-correlation function of the amplitude noise.

III. RESULT AND DISCUSSION

Figure 1 shows the dependence of transient time on the phase difference between the STO and feedback current. Interestingly, the transient time oscillates periodically with the phase difference. Similar behavior is observed for stationary point (not shown). The transient time behavior is explained by the Thiele model where rf spin transfer torque is taken into account.[4] Such transient time modulation will be a key issue in rf spintronics applications such as neuro-inspired STO based devices.

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Sumito Tsunegi
E-mail: Tsunegi.sb@aist.go.jp
tel: +81-29-861-5381

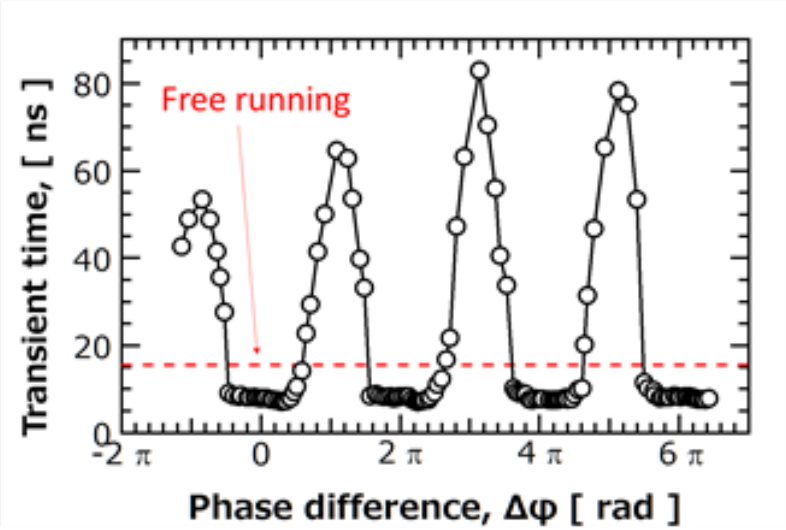

Fig. 1 The dependence of transient time on the phase difference. The red line indicates that of the free run STO.