Physical reservoir computing based on spin torque oscillator

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Recently, spintronics devices have been applied to artificial neural networks (ANNs). Spintronics devices are considered to have high potential due to their small size and high non-linearity. Among various types of ANNs, reservoir computing (RC) [1] is an interesting target for applying spintronics devices. RC utilizes a dynamical system, called a reservoir, driven by a time series input. The input induces transient dynamics with fading memory in the reservoir. Nonlinear tasks such as speech recognition are performed by the function of fading memory inside the reservoir. The interesting point of the RC is that various physical systems can be used as a reservoir [2]. In fact, in recent years, we have performed the physical RC using a spin torque oscillator (STO) as a reservoir, and succeeded in the speech recognition task [3].

The figure-of-merit of the RC is examined by short-term memory task which evaluate fading memory quantitatively. In addition, the ability of non-linear transformation of inputs is evaluated by parity check task. These computational abilities are quantitatively characterized by the short-term memory and parity-check capacities. These capacities have been investigated in other physical systems [2,4], as well as numerical simulation in STOs [5]. However, there is no report investigating the capacities experimentally in spintronics.

In this study, we investigated computational capability of the physical RC consisting of a vortex type STO by evaluating these capacities quantitatively. The capacities were measured by output signal from the STO with respect to modulated inputs. First, we used the voltage as the inputs [6], where the modulated voltage induced the transient dynamics through spin-transfer effect. The short-term memory capacity was evaluated to be 1.8 which means that the STO roughly memorized two bits in the reservoir. Next, we used the microwave field with phase modulation to reduce the noise of the STO [7]. Optimizing the microwave amplitude, the short-time memory capacity was maximized to be 3.6. This value is two times larger than that of voltage input. The parity-check capacity was also evaluated for the first time, which was 3.1 at maximum. The results indicated that the reduction of the noise in the STO is a key for the improvement of computing capability of physical RC.

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