Macro-magnetic simulation of reservoir computing utilizing spin-dynamics in magnetic tunnel junctions

阪大基礎工 [1], 京大理 [2], 東大情理工 [3], 産総研スピン [4], 阪大 CSRN[5]

°古田大志 [1], 藤井啓祐 [2], 中嶋浩平 [3], 常木澄人 [4], 久保田均 [4], 後藤穣 [1,5], 鈴木義茂 [1,5], 三輪真嗣 [1,5]

Osaka Univ. [1], Kyoto Univ. [2], The Univ. of Tokyo [3], AIST[4], CSRN-Osaka[5]

°T. Furuta[1], K. Fujii[2], K. Nakajima[3], S. Tsunegi[4], H. Kubota[4], M. Goto[1,5], Y. Suzuki[1,5], S. Miwa[1,5]

E-mail: furuta@spin.mp.es.osaka-u.ac.jp

Neural network is a mathematical model of machine learning, which emulates a human brain. It possesses non-linear elements as a synapse in a human brain. Reservoir computing [1] is a kind of the neural network. In the reservoir computing, we do not have to optimize the non-linear elements and only optimize a linear transform matrix to obtain output from the non-linear elements. Therefore it is easy to conduct learning in the large physical reservoir computing system. Recently, it has been reported that reservoir computing can be feasible using spin dynamics in magnetic tunnel junctions (MTJs) [2]. However, while voice recognition was demonstrated, figure-of-merit of the reservoir computing using MTJs are not clear. In this study, we conducted macro-magnetic simulation for the reservoir computing in MTJs to clarify the figure-of-merit.

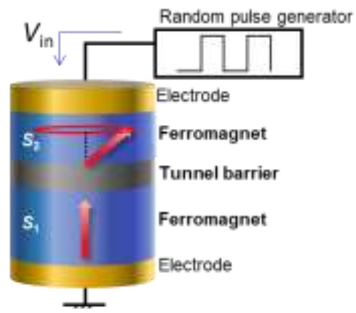

Fig. 1 Schematic of the computation model

Figure 1 is the concept of our simulation system. Random pulse voltage V_{in} is applied to MTJ. MTJ resistance is defined as reservoirs. The same physical parameters of the MTJ are employed as our previous study [3]. Figure 2 shows external input s_{in} corresponding to V_{in}, training output for learning y_{train} and trained output y_{out}. y_{train} is training output to evaluate short term memory capacity defined as the following equation; $y_{train}(T) = s_{in}(T-1)$. In the presentation, we report short term memory and parity check capacities, which is the figure-of-merit of the reservoir computing. A part of this work was supported by JSPS-KAKENHI (JP26103002) and the MIC.

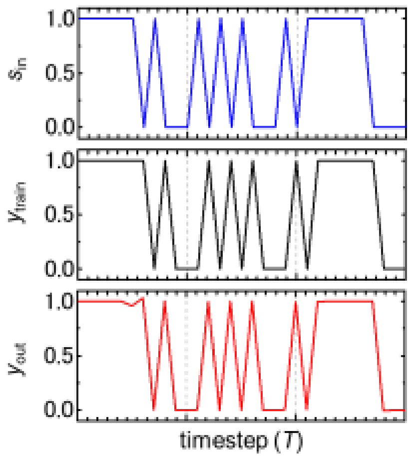

Fig. 2 Input s_{in}, training output y_{out}, and trained output y_{out}.

[1] H. Jaeger and H. Haas, Science **304**, 78 (2004).
[2] J. Torrejon *et al.* Nature **547**, 428 (2017).
[3] S. Miwa *et al.*, Nat. Mater. **13**, 50 (2014).