Colored Noise Induced Synchronization of Ultra-low Power Consumption Spintronics Stochastic Neurons

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Superparamagnetic tunnel junctions (SMTJs) are nanodevices that can oscillate without driving signals [1] due to their ultra-low energy barriers. Similar to a human brain, when this stochastic characteristic is controlled by external information-carrying signal, SMTJs can process the neuromorphic computing tasks. Thus, it makes them be considered as a promising candidate for physical AI [2]. To control the randomness of the SMTJs, a noise-induced phase-locking method was proposed [3]. SMTJs can be phase-locked to subthreshold driving signal; thus, the ultra-low power consumption synchronization can be realized. It is also implied that the background noise, except the thermal noise, can be utilized to replace the artificially generated electric noise [3]. However, the studied noise is confined to Gaussian-distributed white noise.

Compared with white noise, natural noises generally have "color" [4]. This is because the color of light defines the color of noise with the same power spectral density. For example, the fluctuation of device performance and the Brownian motion of electrons can cause different colored noise, so SMTJs will inevitably be affected in practical applications. Therefore, it is necessary to investigate the effect of colored noise on SMTJs' subthreshold synchronization.

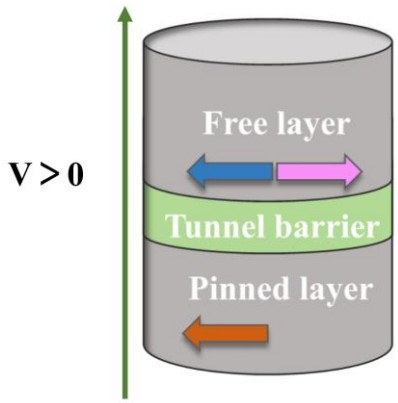

Figure 1 Schematic view of SMTJ. When the magnetization of the free layer and the pinned layer is in the same direction, the SMTJ presents a low resistance state, and vice versa (high resistance state).

This work numerically studied the SMTJs, as shown in Fig. 1, based on the experimental data [3]. Under the subthreshold driving voltage, the influence of red, pink, blue, and violet noise, which is the most widely observed colored noise, on SMTJs is analyzed quantitatively.

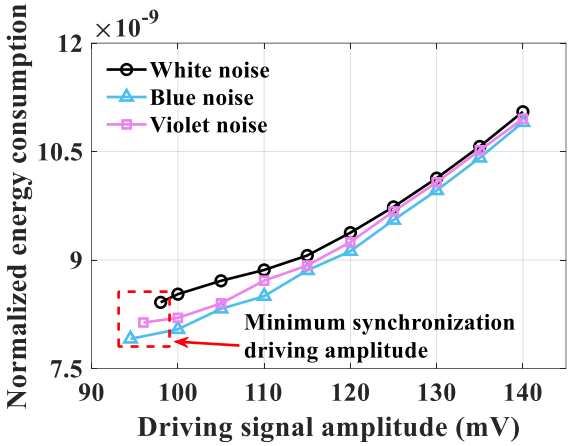

Figure 2 Normalized energy consumption of STJ versus 1 MHz subthreshold driving amplitude in the synchronization region.

The results show that red and pink noise can suppress the subthreshold synchronization of SMTJs, while violet and blue noise can phase-lock SMTJs into a subthreshold signal with lower energy than white noise, as shown in Fig. 2. Especially considering the coupling of STMJs and electronic devices, red and pink noise will further increase the power consumption of STMJs under subthreshold driving signals. In this case, injection of blue and violet noise can mitigate this additional power consumption increase.

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Reference:

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