PHYSICS

COLORADO STATE UNIVERSITY

CSU PRSE Magnetics Seminar

"Two-dimensional Mutually Synchronized Spin Hall Nano-oscillator Arrays for Highly Coherent Microwave Signal Generation and Neuromorphic Computing"

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Abstract

Mutually synchronized spin torque nano-oscillators (STNOs) are one of the promising platforms for bioinspired computing and microwave signal generation [1,2]. Using STNOs one can achieve 90% recognition rate in spoken vowels [3]. However, in order to do more complex tasks, larger scale synchronized oscillators are needed, something that is not easily done with the STNOs demonstrated so far. In my talk, I will describe a different type of spin current driven device called spin Hall nano-oscillators (SHNOs), which can generate microwave frequencies over a very wide frequency range [4]. The SHNOs are based on 50 – 120 nm wide nano-constrictions in Pt(5)/Hf (0.5)/NiFe(3) trilayers (all numbers in nm). When multiple nano-constrictions are fabricated close to each other (300 – 1200 nm separation) they can mutually synchronize and chains of up to nine nano-constrictions have been demonstrated to exhibit complete synchronization [5]. For the first time, we can now also synchronize two-dimensional SHNO arrays with as many as 8 x 8 = 64 SHNOs [6]. The mutual synchronization is observed both electrically and using scanning micro-BLS microscopy. Both the output power and linewidth of the microwave signal improves substantially with increasing number of mutually synchronized SHNOs, such that quality factors of about 170,000 can be reached. Following the approach of Romera et al [3], we also demonstrate neuromorphic computing using a 4 x 4 SHNO array with two injected microwave signals as inputs. Given their high operating frequency (~10 GHz), easy of fabrication, and highly robust synchronization properties, nano-constriction SHNO arrays are likely the most promising candidates for neuromorphic computing based on oscillator networks.

[1] J. Grollier, D. Querlioz, and M. D. Stiles, Proc. IEEE **104**, 2024 (2016)

[2] J. Torrejon et al, Nature **547**, 428 (2017)

[3] M. Romera et al, Nature **563**, 230–234 (2018)

[4] T. Chen, R. K. Dumas, A. Eklund, P. K. Muduli, A. Houshang, A. A. Awad, P. Dürrenfeld, B. G. Malm, A. Rusu, and J. Åkerman, Proc. IEEE **104**, 1919 (2016)

[5] A. A. Awad, P. Dürrenfeld, A. Houshang, M. Dvornik, E. Iacocca, R. K. Dumas, and J. Åkerman, Nature Physics **13**, 292–299 (2017)

[6] M. Zahedinejad, et al. arXiv:1812.09630 (2018)