Nanosecond phase ordering in ultra-large arrays of beyond 100,000 spin Hall nano-oscillators

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Mutually synchronized spin Hall nano-oscillators (SHNOs) [1] can be used for neuromorphic computing [2,3]. However, the number of mutually synchronized SHNOs remains limited to 50 in chains [4] and 64 in 2D arrays [2]. To synchronize larger arrays, one must increase the oscillator coupling strength, for example, by packing them more closely, which requires smaller SHNOs. Here, we present our ongoing progress on how to shrink the width of nano-constriction SHNOs to allow us to synchronize orders of magnitude more oscillators. Using different seed layers and replacing the W layer in W/CoFeB/MgO-based SHNOs with a $W_{88}Ta_{12}$ alloy [5], we demonstrated 10 nm SHNOs operating at threshold currents as low as 26 μA [6]. Armed with these new SHNOs, we then fabricated very large SHNO arrays and found that we can synchronize over 100,000 SHNOs [7]. BLS microscopy show that the phase ordering happens on nanosecond time scales with the synchronization time t_{sync} decreasing linearly with the drive current, and logarithmically with array size, such that 100 SHNOs synchronize in 12 ns and 105,000 SHNOs in 45 ns. We have also demonstrated how we can control the sign and phase of the coupling between SHNOs using a combination of spin-wave-mediated coupling and voltage-controlled magnetic anisotropy [8]. Taken together, these results pave the way towards SHNO-based Ising machines [9].

References:

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