Magneto-ionic voltage control of spin-wave phase with negligible amplitude modulation

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Precise control of spin-wave phases is essential for advancing wave-based computing architectures in magnonics [1,2]. Here, we demonstrate a novel approach for deterministic and fully reversible voltage control of propagating spin-wave phases via lithium-ion-based magneto-ionics. Using a 14-nm-thick CoFeB film as the spin-wave medium and a solid-state lithium phosphorus oxynitride (LiPON) electrolyte gate, we achieve cyclable phase shifts up to 2π at 2.25 V while preserving the spin-wave amplitude and propagation length.

The voltage-programmable phase shift arises from modifications of the spin-wave dispersion in the gated CoFeB region, driven by reversible electrochemical intercalation and deintercalation of lithium ions. This mechanism builds on prior magneto-ionic control of magnetization direction [3], skyrmion populations [4,], and RKKY coupling strength [5], but here it is harnessed to tune spin-wave phases. Importantly, cyclic voltammetry confirms minimal redox activity, ensuring that phase control is both rapid and durable. At elevated voltages (3 – 7 V), spin waves can be controlled on millisecond timescales.

Super-Nyquist sampling magneto-optical Kerr effect (SNS-MOKE) imaging of various CoFeB/LiPON devices (Fig. 1) reveals the spatially resolved phase manipulation, highlighting the potential of this approach for on-chip, voltage-programmable magnonic circuitry. These results provide a pathway toward reconfigurable spin-wave networks for future magnonic computing.

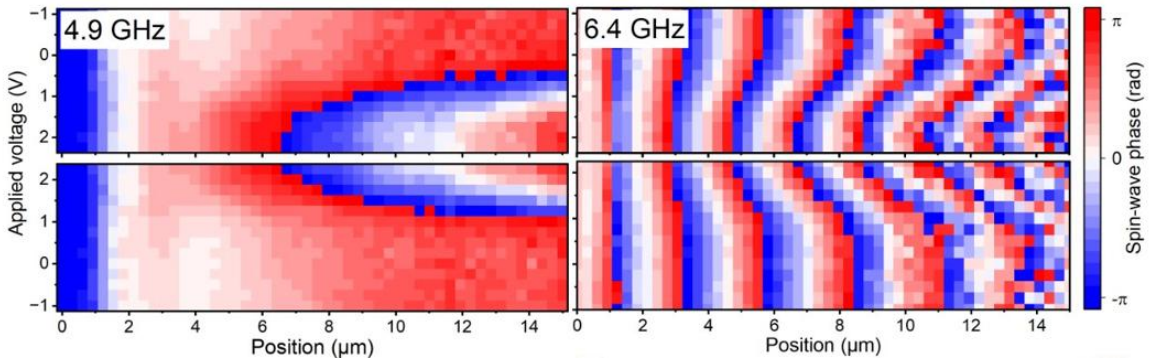

Fig. 1. SNS-MOKE maps showing the spin-wave phase as a function of the voltage applied across the magneto-ionic gate. The microwave antenna is positioned at 0 μm, and the gate edge is located at 2 μm. A magnetic field applied parallel to the antenna establishes the Damon–Eshbach geometry for spin-wave transport.

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