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# Spin Torque and Spin Hall Nano-Oscillators with Single Magnetic Layers

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### ABSTRACT

Spin-torque oscillators (STOs) are capable of producing tunable broadband high-frequency signals within a nanometer-sized region. In this thesis, novel designs for STOs will be discussed; the common theme of these designs will be their use of only one ferromagnetic (FM) material. This work was motivated by the need to understand the fundamental magnetization dynamics in such devices, improving signal quality, and reducing the complexities of device fabrication in comparison to conventional nanocontact (NC-)STOs based on a multilayered spin-valve structure.

**Single-layer NC-STOs:** The multilayered spin-valve structure in NC-STOs may be replaced by a material stack with a single FM layer, reducing the number of metallic layers as well as the total thickness of the devices. Spin-transfer torque (STT) can be efficiently created at the interface to the FM layer underneath the nanocontact, leading to the production of microwave signals in zero applied field.

**Spin Hall effect (SHE) driven dynamics:** A charge current flowing through platinum establishes spin accumulation at the edges of the material due to the SHE. This can be used for STT-driven magnetization dynamics in an adjacent FM layer. These so-called spin Hall nano-oscillators (SHNOs) operate with the current flow being directed in-plane, simplifying nanofabrication and allowing for direct optical access to the active area. SHNO devices are designed in two device geometries: One uses pointed gold electrodes to inject current into an extended active area, while the other focuses the current at a nanoconstriction.

**Implementation of Heusler alloys:** The magnetodynamics of STOs are governed by the properties of the FM free layer. The ease of fabrication of single-layer NC-STOs and SHNOs opens up the possibility of implementing nonconventional ferromagnets with unique magnetic properties. One such material is the epitaxially grown half-metallic half-Heusler alloy NiMnSb, which has a fundamentally lower magnetic damping than permalloy, leading to microwave emission spectra with ultralow linewidths.

**Mutual synchronization of SHNOs:** The mutual synchronization of STOs is accompanied by an increase in the output power and a decrease in the linewidth, thereby drastically improving the overall quality of the microwave signal. Here, the mutual synchronization of up to nine serially connected nanoconstriction SHNOs is demonstrated, which potentially opens up the possibility of implementing these devices in, for example, spin-wave-based computing.

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**Keywords:** Spintronics, Spin Torque Oscillators, Spin Hall Effect, Synchronization, Half-Heusler Alloy