3d magnetic field sensing using spin orbit torques

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Magnetic field sensors are essential for applications ranging from automotive systems to consumer electronics. We present magnetic field sensors that exploit spin-orbit torques (SOT) to detect all three components of an external magnetic field with a single device. Our approach is based on anomalous Hall effect (AHE) sensors combined with active offset compensation enabled by SOT and a spinning current technique. A spin-polarized current generated in a heavy metal layer exerts a torque on an adjacent ferromagnetic free layer, allowing controlled magnetization modulation and linear sensor response with intrinsic offset suppression. By optimizing the free layer design, including CoFeB/MgO structures with perpendicular anisotropy, we achieve sensors with linear ranges around 1 mT, which can be extended using multilayer stacks [1]. We demonstrate that the H_x and H_z field components can be separated: H_x is extracted from the difference of signals at opposite current polarities, and Hz from their sum. In order to realize offset compensation for the z-component a spinning current technique is applied. Additionally, we show that key magnetic parameters such as damping, field-like torque, and effective anisotropy at the elevated temperature during sensor operation due to the high currents can be extracted from the sensor response.

[1] Koraltan, Sabri, et al. "Skyrmionic device for three dimensional magnetic field sensing enabled by spin-orbit torques." arXiv preprint arXiv:2403.16725 (2024).