Non-reciprocal spin-wave propagation in spin-Hall oscillators: a two-dimensional analytical model

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Non-reciprocity is an important feature of wave propagation in media and is typical of spin-wave propagation in ferromagnetic media [1,2] leading to potentially several physical and technological implications.

We have thus developed a two-dimensional analytical model for describing non-reciprocal spin-wave modes propagation in spin-Hall oscillators with oblique magnetization and in the presence of interfacial Dzialoshinski-Moriya interaction (*i*-DMI). We have found that the wave mode excited by the spin-Hall current is the solution of a generalized confluent Riemann equation and its 2D profile (see Figure 1) exhibits a non-reciprocal propagating behavior depending on the *i*-DMI constant *D*. According to analytical calculations and micromagnetic simulations, we have also shown that the dependence of the threshold current on the external magnetic field is not affected by the *i*-DMI amplitude. Spin-Hall oscillators can be employed as generators of non-reciprocal spin-wave modes for signal processing applications.

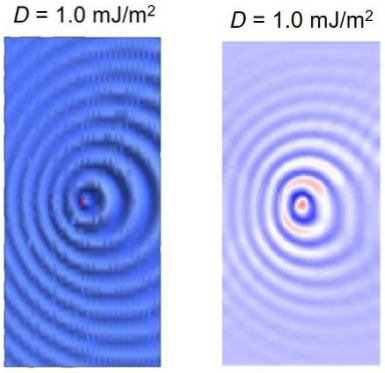

Figure 1. Left to right: Spatial profile of the excited wave mode according to the analytical model and to micromagnetic simulations.

[1] R. Verba, V. Tiberkevich, and A. Slavin, Appl. Phys. Lett. **107**, 112402 (2015).
[2] A. Giordano *et. al.*, Sci. Rep. **6**, 36020 (2016).