# Short-wavelength spin-wave generation by a microstrip line

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## Introduction

Spin-wave-based devices are currently studied as possible candidates for beyond-CMOS computing, and both spin-wave-based logic gates [1] and non-Boolean, wave-based approaches [2] have been proposed. Spin waves can be generated in a number of ways, including spin torque oscillators (STOs) [3], magnetoelectric (ME) cells [4], and waveguides. Exchange-dominated short-wavelength ($\lambda$<100 nm) spin waves have to be generated by nanoscale structures, where the antenna sizes are comparable to the wavelength.

Here, we study nanoscale microstrip lines (MSL) as potential sources of exchange-dominated spin waves. Since MSLs can generate wide wavefronts, they can be energy efficient compared to point sources (such as STOs). They are also more straightforward to design and fabricate. For proof-of-principle experiments, waveguides can be combined with Brillouin Light Scattering (BLS) techniques [3] with no electromagnetic coupling between the generation and the measurement sides.

## Results

We used micromagnetic simulations to estimate the intensity and wavelength of spin waves generated by a MSL depending on multiple parameters. The geometry of the setup is depicted in Fig. 1. To saturate the magnetic film, a magnetic field $B_{bias}$ is applied in-plane parallel to the line.

As a first approach, we calculated the magnetic field generated by the MSL applying Ampere's law numerically, ignoring the effect of the ground plane and the dielectric, and assuming homogenous current distribution in the wire. For the simulations, we assumed a 1 mA current.

The magnetic field generated by the MSL has two components: $B_x$ is symmetric and $B_z$ is antisymmetric. We found that both components contribute to the wave generation, which results in anisotropic spin-wave generation (Fig. 2).

We found that the wavelength of the generated spin waves is independent of the physical dimensions of the MSL in the investigated range of the physical dimensions, it only depends on the applied biasing magnetic field $B_{bias}$ and the frequency f, as can be seen in Fig. 3 and Fig. 4.

However, there is a strong correlation between the spin-wave amplitude and the physical dimensions of the MSL. Figs. 5-7 show the amplitude of the generated spin waves in function of the MSL dimensions. We also found that placing the MSL centered at the edge of the magnetic film the spin-wave amplitudes are considerably higher at small wavelengths compared to placing it in the middle.

## Conclusion

We are not aware of any prior work using waveguides for generating short-wavelength exchange waves. Our simulation studies show that this relatively straightforward device is a promising experimental test system and may potentially serve in novel devices as well.

## Acknowledgment

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## References

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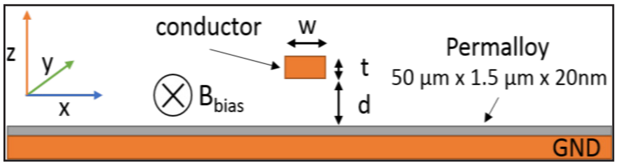

Fig. 1. Geometry of the MSL (cross section).

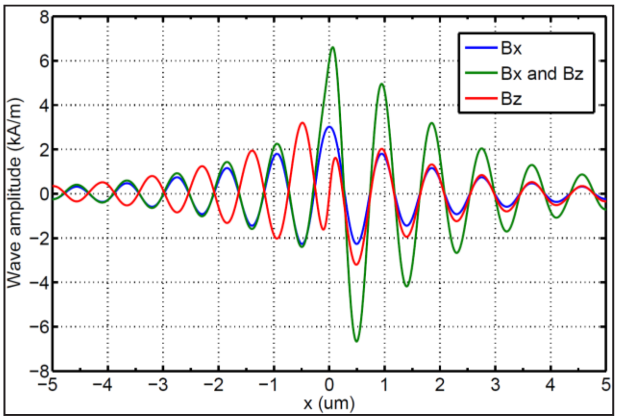

Fig. 2. Anisotropic spin-wave generation by the MSL centered at x = 0 µm (green), and spin waves generated by applying only the x (blue) or z (red) field component of the line.

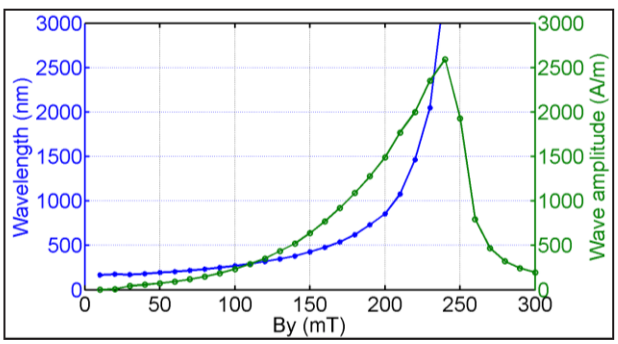

Fig. 3. Wavelength and amplitude of the generated spin waves in function of $B_{bias}$ (f = 15 GHz, w = 100 nm, d = 100 nm, t = 50 nm)

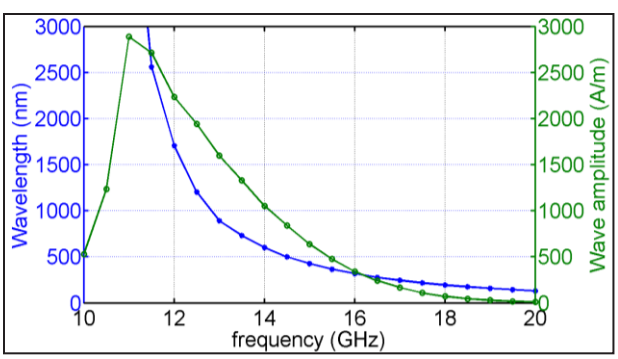

Fig. 4. Wavelength and amplitude of the generated spin waves in function of frequency f ($B_{bias}$ = 150 mT, w = 100 nm, d = 100 nm, t = 50 nm)

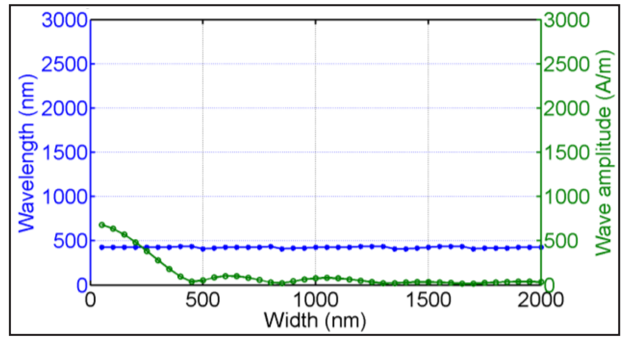

Fig. 5. Wavelength and amplitude of the generated spin waves in function of microstrip width w ($B_{bias}$ = 150 mT, f = 15 GHz, d = 100 nm, t = 50 nm, constant current)

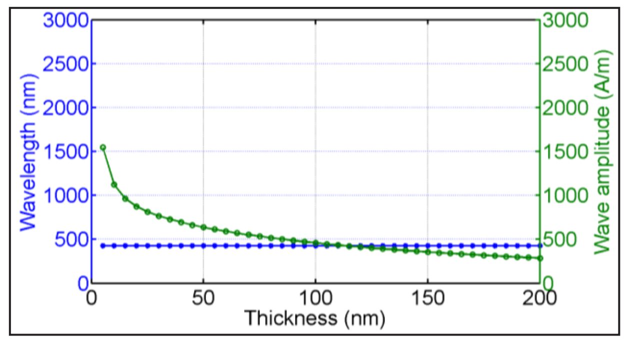

Fig. 6. Wavelength and amplitude of the generated spin waves in function of microstrip thickness t ($B_{bias}$ = 150 mT, f = 15 GHz, w = 100 nm, d = 100 nm, constant current density)

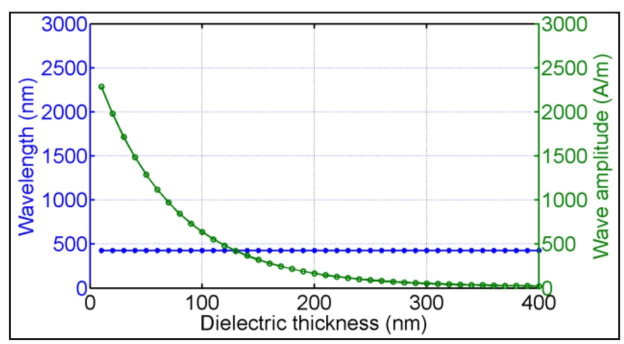

Fig. 7. Wavelength and amplitude of the generated spin waves in function of dielectric thickness d ($B_{bias}$ = 150 mT, f = 15 GHz, w = 100 nm, t = 50 nm)