Imaging spin-wave damping using spins in diamond

Diamonds are one of the most valued gemstones in the world. Did you know that they can be used as ultrasensitive scanners? In this their recent work published in Advanced Quantum technologies, researchers from the van der Sar Lab, at the Quantum Nanoscience department of the TU Delft use diamonds to reveal magnetic waves that are hidden underneath wires on a chip.

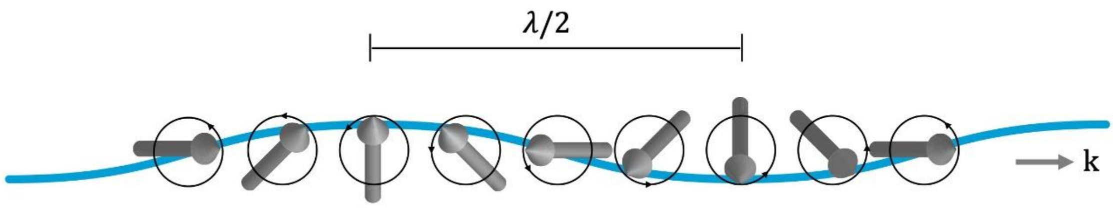
In ferromagnetic materials, atoms keep their magnetic moments -spins- aligned in one direction. But what if we perturb one of these spins? The others will notice and start rotating, creating a collective motion that we call *spin* wave. Such spin waves have huge potential to become an alternative to the electronics we use nowadays. They can be used to carry information without the heat dissipation of electric currents! Therefore, they could help in reducing the exploding energy consumption of today's computers. For this, it is crucial to understand how spin waves can be generated and detected efficiently. A key challenge is to the reduce the spin-wave damping, which determines how far spin waves can travel on a chip and the logical operations they can provide.

These spin waves are excited using metal electrodes on top of a magnetic chip. Using special microscopy techniques, spin waves next to the electrode could already be visualized… but what happens underneath the metal electrodes? That has been inaccessible, until now. In their work, researchers van der Sar and collaborators placed a thin diamond full of nitrogen-vacancy defects (NV) on top of their devices. These defects can be used as extremely sensitive magnetic field sensors that can image the spin waves via their magnetic field. Since magnetic fields penetrate metals, the NV centers in the diamond can measure the stray magnetic fields that are created by the spin-waves even if they are under the metallic electrode. This allows them to measure how metals affect the propagation of spin waves.

Using this method, they show that eddy currents in the metal damp the spin waves. Quantifying this damping mechanism had remained elusive in the past, and thanks to this work it can now be modelled and measured, allowing better design of spin-wave devices. Furthermore, they also show that this technique can uncover the presence of hidden defects that act as scattering centers. This implies that this method could be used to evaluate the quality of the devices, even if the magnetic material is buried under other layers!

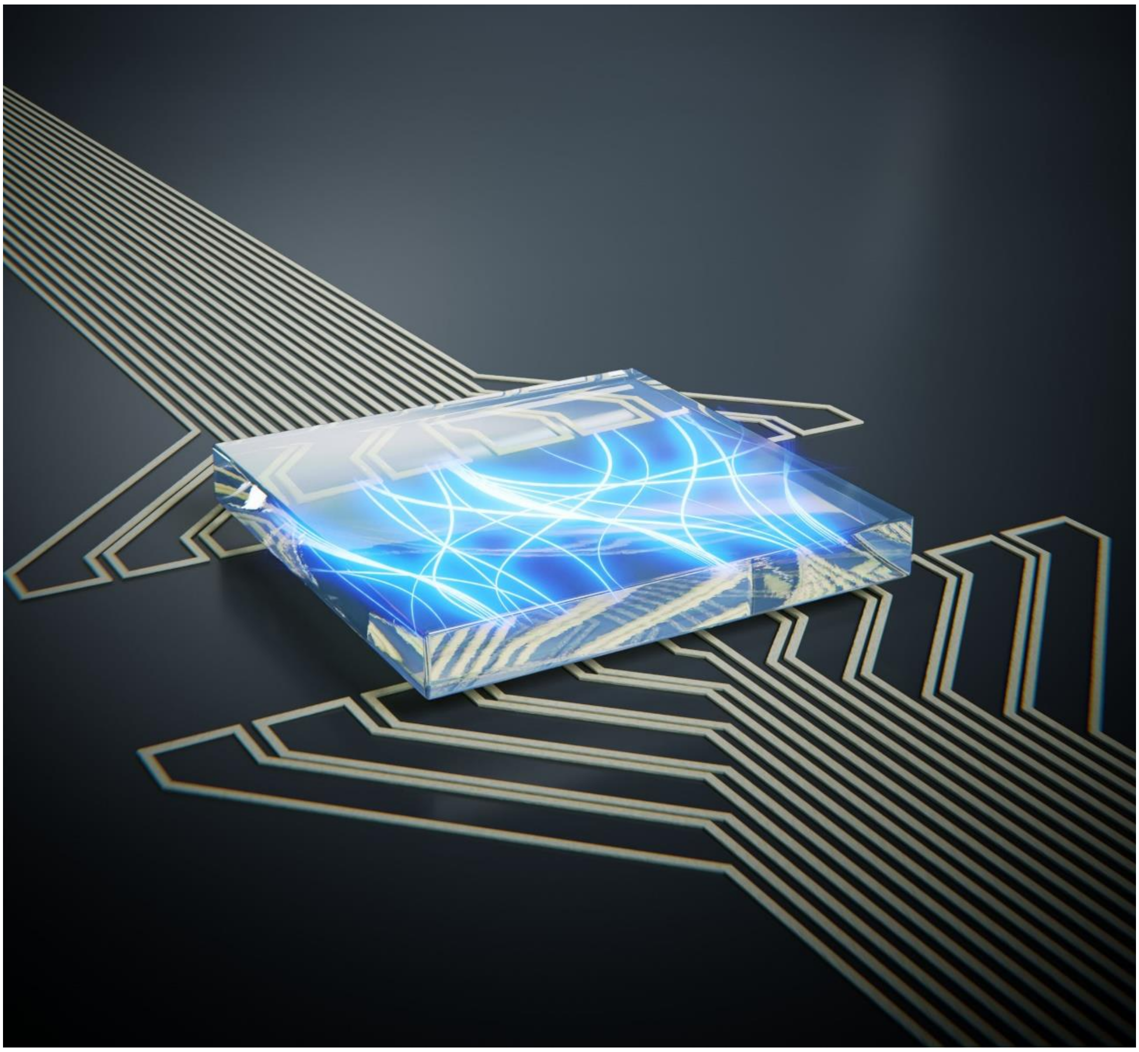
In conclusion, their work shines light on the mechanisms that influence the propagation of spin-waves and shows a new method to assess the quality of devices, serving as a further step towards future spin-wave devices. You can read the original work *Imaging Spin-Wave Damping Underneath Metals Using Electron Spins in Diamond* from Advanced Quantum Technologies: https://doi.org/10.1002/qute.202100094

IMAGES:

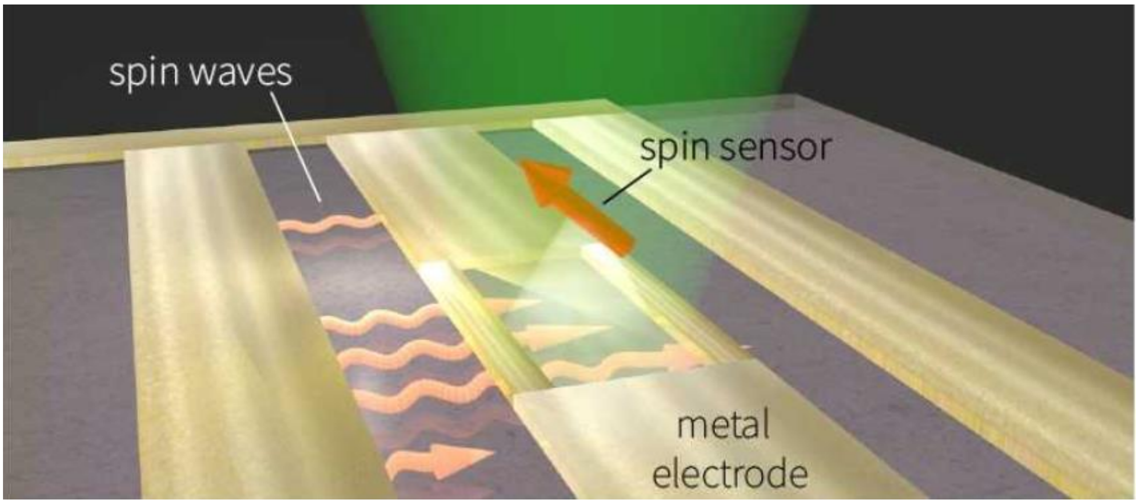


$$E_{\text{magnon}} = hf$$

Sketch of spin waves [1].



Artistic representation of spin waves traveling in a material [2].



Artistic representation of the experiment used in the original work [3].

[1] Courtesy of Dr. Samer Kurdi, researcher at van der Sar lab.

[2] Courtesy of Prof. Toeno van der Sar.

[3] Courtesy of Dr. Iacopo Bertelli, researcher at van der Sar lab.