Directional control of spins to go more than Moore

The more transistors a microchip has the more powerful it is, but increasing this number is becoming more and more difficult. For this reason, new alternatives are needed. In their recent work, researchers from the van der Sar Lab at the Quantum Nanoscience department of the TU Delft and collaborators from QuTech make use of electron spins to explore new solutions to this problem.

To fit more transistors inside a chip the semiconductor industry started making them smaller, doubling the number of transistors per chip every two years, something called Moore's Law. But shrinking transistors is reaching a limit and is becoming more difficult. That is why new alternatives to classical electronics have been proposed; one of these is the use of spin waves as information carriers. But let us first take a step back and explain what spin waves are.

In ferromagnetic materials, atoms point their electron spins in the same direction, each of them acting as a small magnet. But what would happen if we perturbed one of them by changing its direction a bit? It would start precessing. Since spins act as small magnets, this movement would be transmitted to the neighbouring spins. This consecutive transmission will finally create a spin wave, which are the collective excitations of spins in a magnetic material.

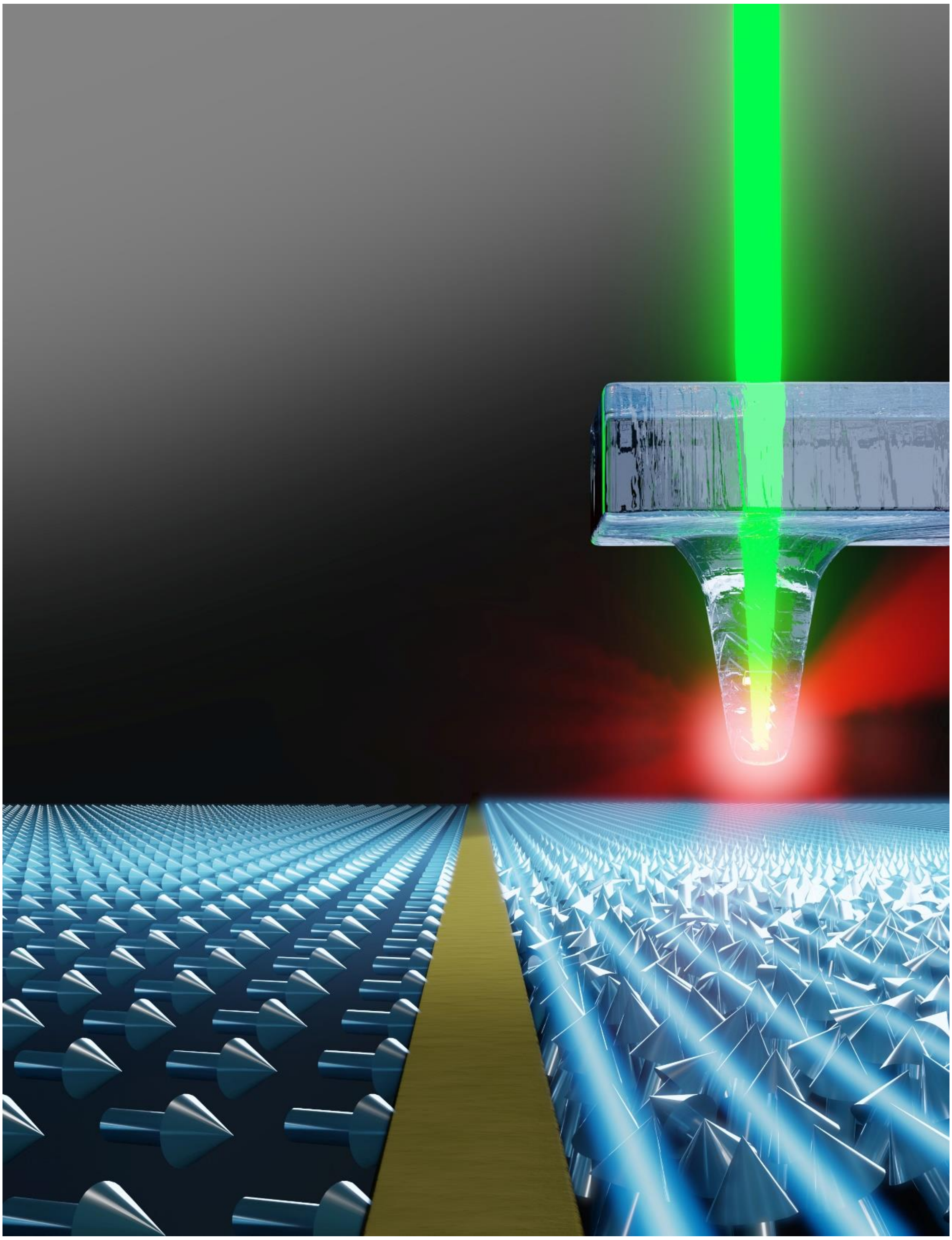
In quantum mechanics, waves can also be described as particles under the right conditions, in which the elementary particle of a spin wave is called a magnon. Magnons are the excitations of spin-wave modes, and their energy is directly proportional to the spin-wave frequency and energy. In their work, van der Sar and collaborators study how to excite these spin waves using an external excitation (a current through a stripline). They map the local changes in magnetic field created by the spin wave using nitrogen-vacancy centres defects in a nanoscale diamond tip!

They generate spin waves that move in a certain direction relative to the excitation stripline. Since magnons are the elementary particles of spin-waves, this can be interpreted as a magnon gas at one side of the stripline, and they find that this gas is denser than expected! Moreover, they find that this high-density magnon gas can be controlled relative to the excitation stripline, something that has remained elusive until now and is a key requirement for new electronic devices like magnon transistors.

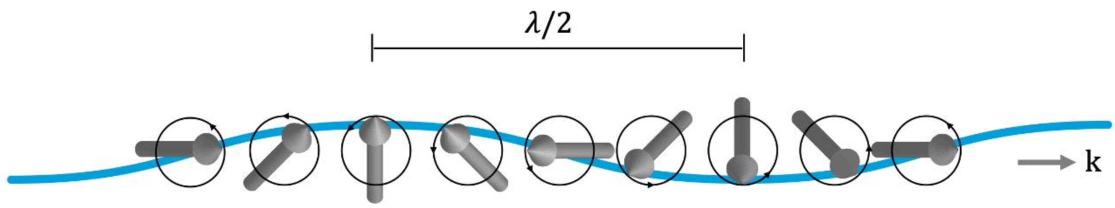
Their work opens the door to the exploration of other stripline configurations that could yield to a high control of spin transport, offering new opportunities of going beyond Moore's Law. You can read the original paper *Directional Excitation of a High-Density Magnon Gas Using Coherently Driven Spin Wave* from Nano Letters:

https://doi.org/10.1021/acs.nanolett.1c02654

IMAGES:

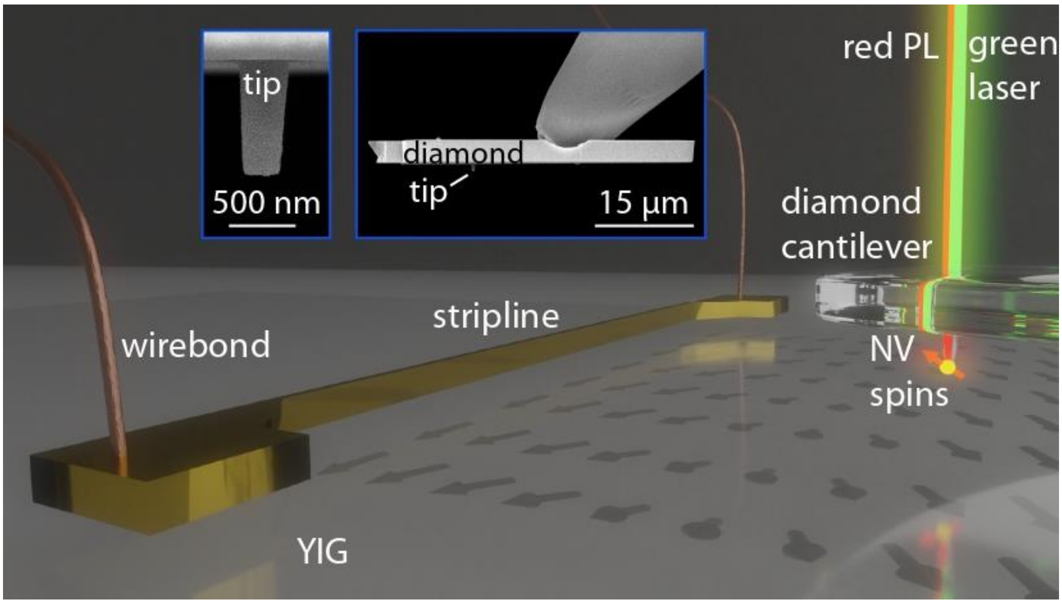


Artistic representation of the device used to do the experiments [1].



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

Sketch of a spin wave [1]



Artistic representation of the setup [1]

[1] Courtesy of Dr. Samer Kurdi.