Two dimensional circuit with magnetic quasi-particles

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Lead author Qi Wang. Credit: TUK/Koziel

Whether smart phone, computer or dialysis machine – there is no electronic device without chips and their electronic components inside. The individual circuit elements are therefore often wired using three dimensional so called bridge constructions. Currently, physicists at Technische Universität Kaiserslautern (TUK) are working on a more efficient variation, where specific quasiparticles named magnons instead of electrons are being used. They have shown for the first time, in an initial model, that magnon current flow is possible in an integrated magnon circuit, in which case the components are only being connected two dimensionally. These investigations have been published in *Science Advances.*

A technical revolution came when the US engineer Jack Kilby developed the integrated circuit in the 1960s. Initially assembled in a pocket calculator. "These circuits then set the stage for today's consumer electronics," says Associate Professor Andrii Chumak.

In the current study, the lead author Qi Wang worked on a new generation of circuits. "Information can be transported in the form of intrinsic angular momentum," says Chumak. "These quantum particles are magnons."

They can transport significantly more information when compared to electrons and require substantially less energy, as well as produce less wasted heat. This makes them rather interesting, for example for faster and more efficient computers, particularly in mobile applications.

In the now published study, the scientists have for the first time described the magnon integrated circuit in which information is carried by these particles. In this case, conductors and line crossings connect the individual switching elements, as in the case of electronic circuits. The researchers have developed such a junction for magnons in their simulations. "We have included this phenomenon into our calculations, which is already well-known in physics, and will be placed into application for the first time in magnonics," says Qi Wang. "When two magnon conductors are placed closely together, the waves communicate to a certain point with each other. This means that the energy of the waves will be transferred from one conductor to the next." This has been used in optics applications for quite some time.

The team lead by Chumak harnessed this method for the wiring of circuit elements on a magnonic chip in a novel way. Notably, they can be used for junctions without any three-dimensional bridge construction. This is necessary in classical electronics to guarantee the flow of electrons between several elements. "In our circuits, we use two dimensional connections in which the magnon conductors only need to be placed close enough to each other," says Qi Wang. This connection point is referred to as a directional coupler. The researchers now intend to layout the first magnonic circuit with the help of this model.

These novel circuits could contribute significantly to saving material and, therefore, cost. In addition, the size of the simulated components is within the nanometer regime, which is comparable to modern electronic components; however, the information density using magnons is significantly greater.

More information: Qi Wang et al. Reconfigurable nanoscale spin-wave directional coupler, *Science Advances* (2018). DOI: 10.1126/sciadv.1701517

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