Magnon transistor for next generation computing

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Advanced electronics uses the charge of conduction electron as an information carrier, and the nanotechnology allows a robust control of charge flow. Electronics developed highly integrated systems such as LSI which leads to a laptop computer and a smart phone. We are facing the drastic change of CPS/IoT society. The developments of semiconductor technology suggest a new class of devices such as the wearable and CPS/IoT devices, and generate enormous amount of information up to YB (10^{24}B). While, the CPS/IoT society requires a clean energy source and more energy efficient devices for the signal processing. The electronics is now facing the dilemma: realization of the fast processing and low energy loss operation.

A research field which seeks for a ultralow power consumption device by manipulating spin waves in micro fabricated devices is now called "magnonics or magnon spintronics", in which a spin-wave is treated quantum mechanically and described by a quasi-particle of "magnon".[1] The crucial difference of magnonics from electronics is that a flow of magnon is a flow of angular momentum and generate no Joule heating.[2–4] Furthermore, magnons have a potential to transmit information with GHz-THz carrier frequencies. Magnon can be created by electric microwave in general, however magnon is also possible to be generated by thermal and optical methods. Magnonics now becomes a multi-disciplinary research field including electronics, magnetics, thermal engineering, and optics, and shows a potential to create multi-functional device principles.[5,6] For example, there is the possibility to create a non-Boolean magnon transistor and a neuron-like signal processing with multi-input/output architecture [7].

In this background, a new type of magnon transistor was proposed using a magnon nonreciprocity discovered in an anisotropic ferromagnetic Fe waveguide 8). Since the cubic anisotropy of Fe allows four different magnetization directions for a fabricated waveguide, a magnon generated by the source antenna shows an asymmetric wavefront, according to the magnetization directions; the magnon densities of top and bottom sides of the waveguide, at the detection antenna, exhibit a strong nonreciprocity (edge-mode magnon nonreciprocity). By combining the two units of Fe waveguide, the XOR and XNOR gates can be constructed. With a similar way, the combination of three units provides AND, NAND, OR, and NOR gates. Logic gates using the edge-mode magnon nonreciprocity allow a no-field operation and a simple architecture. To construct next generation magnonic computing, these logic architectures suggest the important progress of magnon transistor: reconfigurable and nonvolatile operations.

References

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