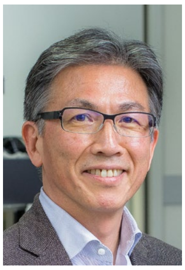
【Grant-in-Aid for Scientific Research (S)】

Broad Section D



Title of Project : Efficient spin current generation based on coherent magnetoelastic strong coupling state

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Research Project Number : 19H05629 Researcher Number : 60245610

Keyword : magnon-phonon coupling, acoustic cavities, spin current, strong coupling

【Purpose and Background of the Research】

One of the most fundamental forms of magnon-phonon interaction is an intrinsic property of magnetic materials, i.e. "magnetoelastic coupling". This particular form of magnon-phonon interaction has been known for more than a century and has important consequences for fundamental descriptions of the physics of magnetic materials and applications; where elastic excitation produces changes of effective magnetic fields or vice versa. More recently, magnon-phonon coupling was employed for the generation and investigation of pure spin currents (flows of angular momentum) in nonmagnetic materials. The proposed research project aims to clarify the effect of magnon-phonon interactions on spin current generation in both the weak and strong magnon-phonon coupling regimes. Enhancement of the magnon-phonon interaction, via implementation of acoustic wave reflectors, would directly improve the efficiency of spin current generation by minimizing energy losses, and thus enable us to explore the strong coupling regime.

【Research Methods】

In our experiments, we generate surface acoustic waves (SAWs) by injecting AC-voltage to interdigital transducers (IDTs). The SAWs then propagate over the surface and couple to a magnetic layer. However, this method is limited by the bi-directionality of the SAWs, which travel in opposite directions from IDTs, therefore only imparting half of the total phonon energy into the magnetic layer. Thus, it is crucial to minimize the losses of phononic energy in our transfer mechanism. However, we can completely overcome this limitation by adding acoustic reflectors to the ends of our IDTs as shown Fig. 1. If the distance between reflectors and IDTs is properly engineered, we can obtain constructive wave interference and hence increase the phonon coupling to our magnetic layer. By collecting the waves travelling in the opposite direction to our magnetic film, and directing them back towards the film, we can expect enhancements of the coupling strength by two to four times. The resulting structure is an acoustic analogue of an optical resonator formed between adjacent Bragg mirrors, and consequently allows us to enter the strong magnon-phonon coupling regime.

【Expected Research Achievements and Scientific Significance】

The minimization of energy losses in the magnon-phonon coupling would directly result in enhancement of spin current generation. We plan to extend our study and elucidate the level of spin current generation we can achieve when we are in the strong coupling regime of magnon-phonon interactions. In this regime, the spin current generation is predicted to depend not only on the minimization of energy losses, but also on the ultra-efficient cyclical transfer of energy within the magnon-phonon composite quasiparticle state, potentially leading to as-yet unknown regimes of spin current generation. Furthermore, we may take advantage of the strong magnon-phonon coupling regime to explore emergent quantum phenomena associated with the superposition state. Under the right conditions it could be possible to transfer information from the magnon to the phonon state and vice versa, in an encrypted system, representing a new paradigm of quantum information based on magnon-phonon coupling phenomena.

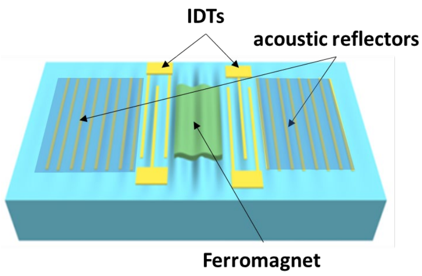

Fig. 1 Cavity device structure for strong magnon-phonon coupling

【Publications Relevant to the Project】

M. Xu, J. Puebla, F. Auvray, B. Rana, K. Kondou, and Y. Otani, "Inverse Edelstein effect induced by magnon-phonon coupling", Phys. Rev. B **97**, 180301(R) (2018).

【Term of Project】 FY2019-2023

【Budget Allocation】 137,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www2.riken.jp/lab-www/nanomag/