Title	ダイヤモンド中のNV中心を用いた熱マグノンの計測
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Abstract

Current of thermally induced magnon has recently been considered as a medium for transporting information with low energy dissipation. It has been demonstrated that thermal magnon can transmit information as far as 40 μm at room temperature and more than 100 μm at 23 K. In the past few years research has been focused on understanding the nature of thermal magnon transport and how it interacts with environment. Several researches have demonstrated that thermal magnon can transfer its angular momentum to other spin system, a phenomenon known as thermal spin transfer torque.

Recently, electron spins ($S = 1$) associated to nitrogen-vacancy (NV) defect center in diamond have attracted a great attention from spintronics research community due to its ability to sense the dynamics of spin system with exceptional sensitivity. NV center in diamond is well known to have excellent characteristics compared to other spin-based sensor, among them are ambient temperature working condition, long coherence time, and wide band (DC to GHz) magnetometry capability. It has been demonstrated recently that electron spins associated to diamond with NV center can be well coupled with magnetostatic spin waves due to the closeness of their energy, which is within several GHz regime. Detection of thermal magnon with the same technique possesses additional challenge as its energy, defined by k_BT, is far above the NV spin energy.

In this dissertation we explore an unprecedented technique in detection of thermal magnon using electron spins in diamond with NV centers as a quantum sensor. We employ a diamond beam ($2.5 \times 0.1 \times 0.1$ mm^3) with (110) crystal orientation hosting a layer of NV spin ensemble at the depth of about 30 nm beneath the surface of the diamond. As a material for the investigation of thermal magnon we use yttrium iron garnet (YIG) ($Y_5Fe_{12}O_3$) which is well known as an ideal test bed for studying magnon transport due to its electrically-insulating characteristic. Thermal magnon is generated by introducing non-equilibrium temperature condition in YIG. We make use of magnetostatic surface spin wave (MSSW), generated in YIG by a coherent microwave source, as a mediator for the detection of the thermal magnon.

A home-build scanning confocal microscope, equipped with a high-speed multichannel pulse generator, is employed to optically manipulate and detect the states of the NV spins under the influence of thermal magnon and MSSW. We found that the dynamics of magnetostatic surface spin wave is modulated under the alteration of temperature gradient in YIG. This modulation is observed as a change in the contrast of the optically detected magnetic resonance (ODMR) of the NV spins as temperature gradient is applied to the YIG. Moreover, we found that the strength of oscillating magnetic field generated by the MSSW which drives the NV spins to their two-level transition ($m_s = 0 \leftrightarrow 1$), Rabi oscillation, is enhanced or diminished with the variation of temperature gradient applied to the YIG. We interpret this as a generation of thermal magnon current that induces an additional magnetic damping torque that modify the dynamics of the MSSW. We estimated the magnetic damping torque parameter from the thermal magnon to be $\sim 10^{-4}$, in a good agreement with the known value of damping parameter of YIG. We confirm our investigation with the conventional electrical spin wave resonance technique through the observation of spin wave resonance linewidth and found a modulation of resonance linewidth as a function of temperature gradient.

The technique discussed in this dissertation is expected to open new possibilities towards a better understanding of thermally induced magnon transport and its interplay with magnetostatic spin wave. Moreover, the technique can be extended to study magnon transport locally at smaller scale in nanometer regime by employing NV center hosted in a nanometer-sized diamond.

Keywords: thermal magnon, nitrogen-vacancy (NV) center in diamond, magnetometry, magnetostatic surface spin wave, thermal spin transfer torque.