Highly sensitive diamond quantum magnetometer with large sensor volume

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Nitrogen-vacancy (NV) centers in diamond are promising solid-state quantum magnetometer working at room temperature. The quantum magnetometer is a magnetometer that measures the magnetic field by using the energy change of qubits[1]. By constructing an appropriate measurement system, it is possible to achieve highly sensitive sensing with measurement noise reduced to the quantum limit. Thanks to the property of the diamond that is a wide bandgap semiconductor, the quantum coherence of the qubits maintains under a wide range of temperatures and pressures, including under room temperature and atmospheric pressure. This characteristic enables us to use the sensor for various applications including operating in vivo and in extreme environments.

One of the important steps towards the practical use of the diamond quantum magnetometer is to improve the sensitivity. Because the sensitivity of the diamond quantum magnetometer increases as the number of NV centers increases[2], a large sensor volume is required to achieve high sensitivity. We have developed a technology of the diamond quantum magnetometer to achieve high sensitivity by improving the control and readout of the qubit with a large sensor volume, such as enhancing a microwave and an effective photoexcitation method[3]. In parallel to these improvements, we are also improving the quality of the diamond quantum magnetometer such as the density and coherence time of the NV center. Our institute has a technology of electron irradiation with high temperature and ion implantation. We constructed an evaluation system suitable for the material evaluation of the diamond quantum magnetometer, and are researching the relationship between NV center generation efficiency and coherence time by the electron beam irradiation.

Another important point towards the practical use of the diamond quantum magnetometer is noise rejection from the signal. The diamond quantum magnetometer potentially achieves highly sensitive magnetic field sensing without any magnetic shield because the Zeeman shift of the qubit even occurs under a strong magnetic field. To realize this, we constructed a gradiometer system that cancels environmental magnetic field noise for DC magnetic field sensing, and a dynamical decoupling system that works as a noise rejection filter for AC magnetic field sensing.

Reference

1) C. L. Degen *et al.*, Rev. Mod. Phys. **89**, 035002 (2017)
2) J. M. Taylor *et al.*, Nat. Phys. **4**, 810 (2008)
3) Y. Masuyama *et al.*, Rev. Sci. Instrum. **89**, 125007 (2018)