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The High Precision of Magnetic Detection with Microwave Modulation in Solid Spin Assembly of NV Centres in Diamond

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Abstract : Solid-state quantum sensors are attracting wide interest because of their high sensitivity at room temperature. In particular, spin properties of nitrogen–vacancy (NV) color centres in diamond make them outstanding sensors of magnetic fields, electric fields and temperature under ambient conditions. Much of the work on NV magnetic sensing has been done so as to achieve the smallest volume, high sensitivity of NV ensemble-based magnetometry using micro-cavity, light-trapping diamond waveguide (LTDW), nano-cantilevers combined with MEMS (Micro-Electronic-Mechanical System) techniques. Recently, frequency-modulated microwaves with continuous optical excitation method have been proposed to achieve high sensitivity of 6 μT/√Hz using individual NV centres at nanoscale. In this research, we built-up an experiment to measure static magnetic field through continuous wave optical excitation with frequency-modulated microwaves method under continuous illumination with green pump light at 532 nm, and bulk diamond sample with a high density of NV centers (1 ppm). The output of the confocal microscopy was collected by an objective (NA = 0.7) and detected by a high sensitivity photodetector. We design uniform and efficient excitation of the micro strip antenna, which is coupled well with the spin ensembles at 2.87 GHz for zero-field splitting of the NV centers. Output of the PD signal was sent to an LIA (Lock-In Amplifier) modulated signal, generated by the microwave source by IQ mixer. The detected signal is received by the photodetector, and the reference signal enters the lock-in amplifier to realize the open-loop detection of the NV atomic magnetometer. We can plot ODMR spectra under continuous-wave (CW) microwave. Due to the high sensitivity of the lock-in amplifier, the minimum detectable value of the voltage can be measured, and the minimum detectable frequency can be made by the minimum and slope of the voltage. The magnetic field sensitivity can be derived from $\eta = \delta B\sqrt{T}$ corresponds to a 10 nT minimum detectable shift in the magnetic field. Further, frequency analysis of the noise in the system indicates that at 10Hz the sensitivity less than 10 nT/√Hz.

Keywords : nitrogen-vacancy (NV) centers, frequency-modulated microwaves, magnetic field sensitivity, noise density
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