Wide-field AC Magnetic Field Imaging using Continuous-Wave Optically Detected Magnetic Resonance of Nitrogen-Vacancy Centers in Diamond

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A promising candidate for room temperature highly-sensitive magnetometry with high spatial resolution is the nitrogen-vacancy (NV) center in diamond. Scanning confocal microscopic techniques are typically used for conventional magnetometry. However, long measurement times are required to achieve a wide observation area and/or high sensitivity. There are advantages of using CCD/CMOS cameras to enable wide field of view and rapid acquisition time by detecting signals from NV centers many camera pixels simultaneously, so called wide-field imaging[1]. For cameras with slow response time, it is suitable to use continuous-wave optically detected magnetic resonance (CW-ODMR) to perform magnetic field imaging. However, by using conventional CW-ODMR techniques, only DC or low-frequency AC magnetic fields can be detected. Our group has recently developed a new measurement protocol using CW-ODMR to detect high-frequency AC magnetic fields by taking advantage of the zero-field splitting of the spin triplet states of the NV center[2]. By further applying a DC magnetic field the contribution from the different crystallographic axes of the NV center can be separated and focusing on one preferential axis the sensitivity can be increased[3]. These techniques are compatible imaging techniques using CCD cameras[2].

In this study, our home-built wide-field imaging setup is used together with our CW-ODMR protocol to measure the spatial-distribution of high-frequency AC magnetic fields. First, a bulk diamond sample was mounted on a microwave antenna with a copper wire placed on the sample surface. To separate the NV axes, a DC magnetic field was applied perpendicular to the preferential NV axis using a permanent magnet, thereby increasing detection range as well as sensitivity. Applying a microwave field together with the excitation laser induces transitions between the bright $|B\rangle$ and dark $|D\rangle$ states of the NV center triplet (Fig. 1(a)) resulting in two dips with a splitting of 9.67 MHz. By running a current through the copper wire, an AC magnetic field was applied with the same frequency of 9.67 MHz. This results in the dark and bright states being dressed, which splits up the resulting ODMR spectrum into four dips (Fig. 1(b)). By comparing CW-ODMR spectra with and without applied AC magnetic field, the AC magnetic field can be detected and estimated according to the protocol. Detection was observed both in wide-field view and windows of few pixels while averaging the signal over many pixels enabled rapid measurements. The spatial distribution of the AC magnetic field from the wire could be detected and mapped over the image area (Fig. 1(c)). These results indicate that AC magnetic fields in the MHz range can be detected, while the spatial distribution of the field frequency and/or field strength can be mapped as a wide-field image.

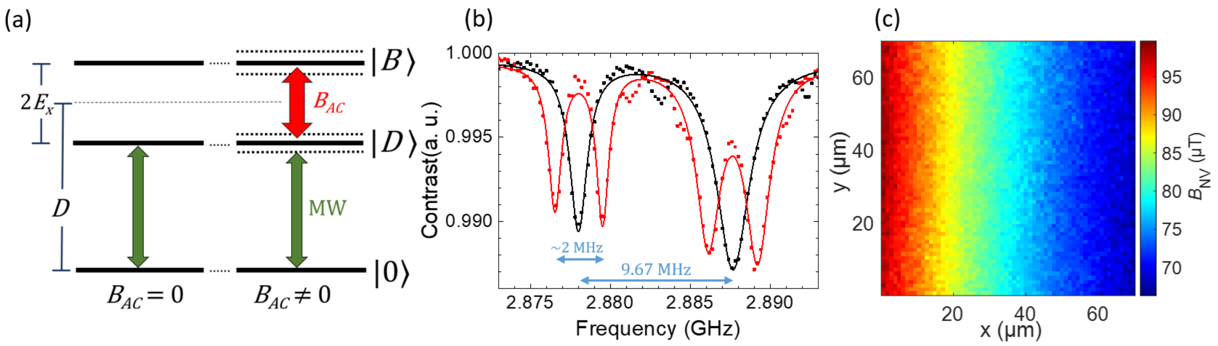

Fig. 1 (a) Energy levels of NV centers with and without AC *B*-field, showing the $|B\rangle$ and $|D\rangle$ states. (b) ODMR spectrum without (black) and with (red) AC *B*-field applied, fitted with Lorentzian curves. A DC *B*-field perpendicular to the NV axis is also applied to isolate the signal from the NV axis of interest. (c) Wide-field image of the spatial distribution of the AC magnetic field, which is emitted from copper wire that is running parallel outside the frame to the left.

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