High-dynamic-range AC magnetic field sensing with NV centres

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Quantum sensing holds promise for several applications due to its potential for ultra-high resolution and exquisite sensitivity. For example, the electron spins of nitrogen-vacancy (NV) centres are used for magnetic [1] and temperature [2] sensing given its strong interaction with the environment. However, the downside of spin systems for sensing is the limited dynamic range, given its rotational symmetry: e. g. the phase of the spin can only be determined up to 2π at best. With NV centres, for DC magnetic fields, a dynamic range improvement of 2^6 was achieved [3], while a recent technique for AC magnetic fields increased this range by a theoretical maximum of $5,000$ times [4]. Here, we demonstrate a technique to increase the dynamic range for AC magnetic fields, which maximum enhancement is merely constrained by technical limitations.

For our experiments, we use individual electron spins of NV centres in phosphorus-doped diamond at room temperature. The used sample was epitaxially grown by chemical-vapour deposition onto a Ib-type (111)-oriented diamond substrate with enriched ^{12}C (99.998%) and a phosphorus concentration of 6×10^{16} atoms/cm^3 [5]. As demonstration, we measured AC magnetic fields with amplitudes ranging from about 1 nT to 12 μT (the maximum we can apply in our setup) with the same accuracy throughout the entire range.

Finally, we look into the sensitivity of high-dynamic range systems. It should be noted that the demonstrated technique is not limited to be utilised by NV centres or for AC magnetic field sensing. It is suitable for systems with limitations similar to the 2π-ambiguity, and any spin-sensed quantity can be measured, such as DC magnetic field and temperature.

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