Quantum sensing with both high sensitivity and large range

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Ultra-high resolution and sensitivity are two cornerstones for quantum sensing. An example of a quantum sensor is the electron spin of a nitrogen-vacancy (NV) centre, which is utilised for magnetic [1] and temperature [2] sensing. For sensors, the ratio between the largest possible range and the sensitivity in this range, called the dynamic range, is rather important. The limitation of spin systems for sensing is the small range, given the rotational symmetry of the phase of the spin: it can be found within 2π at best, which limits the dynamic range. In previous research, with the electron spin of NV centres, this ratio was improved by 26 times for DC magnetic fields [3], while a recent technique for AC magnetic fields increased the range by a theoretical maximum of 5,000 times, but its sensitivity worsened [4]. Here, we demonstrate a technique to increase the range for AC magnetic fields beyond the limit of the standard measurement, while the sensitivity is practically unaltered, both unique features of our algorithm, thus maximally improving the dynamic range.

For our room-temperature experiments, we use individual electron spins of NV centres in phosphorus-doped diamond. 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]. The results in Fig. 1 show two orders of magnitude improvement over previous work [6].

Finally, we investigate the algorithm in detail with simulations to explain its workings. 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.

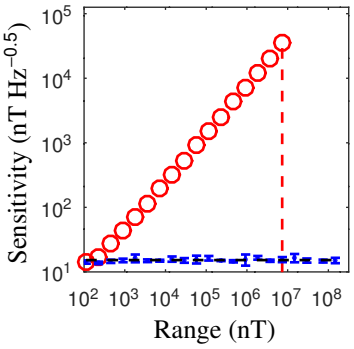

Figure 1: Sensitivity vs range for a standard measurement (red circles) and for our algorithm (blue dots). The sensitivity for the latter is rather independent of the range. Please note that for the same technical constraints, the standard measurement reaches its maximum range sooner (vertical red dashed line).

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