Ultrasensitive magnetometer using a single trapped atomic ion

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The precision, and thus the sensitivity of magnetometry scales as $1/\sqrt{T_2}$ with the phase coherence time T_2 of the sensing system. Typical quantum sensing protocols prolong T_2 of the quantum states used for sensing by using dynamical decoupling (DD), that is, applying a continuous or pulsed electromagnetic driving field. In the case of pulsed DD, the required repetition rate of pulses -- with each pulse having a well defined pulse area -- is proportional to the frequency of the field to be detected with high sensitivity, thus effectively limiting the frequency range of the sensor. To achieve a long coherence time T_2 using continuous DD, the amplitude of the driving field has to be kept highly stable for time T_2, another technologically challenging problem.

Here, we implement a decoupling scheme using two continuous decoupling fields in an atomic 4-level scheme. Thus, fluctuations of the amplitude of the decoupling fields no longer limit the coherence time. Instead, T_2 is determined by the frequency stability of the driving fields which is straight forward to maintain with high precision using, for instance, a commercial atomic clock. Using a single trapped $^{171}Yb^+$ ion as a sensor, we experimentally attain a sensitivity of 4.6 pT/√Hz, to our knowledge an unprecedented value realized with a single atom. The detected magnetic field is an alternating-current (AC) magnetic field near 14 MHz. Based on the principle demonstrated here, the sensitivity together with its tuneability from nearly direct-current to the gigahertz range could be used for magnetic imaging in as of yet inaccessible parameter regimes.

References

[1] I. Baumgart, J.M. Cai, A. Retzker, M.B. Plenio, Ch. Wunderlich, Phys. Rev. Lett. **116**, 240801 (2016).