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Distributed quantum sensing in noisy environments with trapped ions

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Quantum sensing is a promising application of quantum technologies. The aim is to exploit the quantum nature of sensors to provide an increase in sensitivity of precision measurements. With several demonstrations of elementary quantum networks, e.g. [1, 2, 3], a natural question is whether distributed quantum sensors can provide an advantage for sensing fields with arbitrary spatial profiles. A recently published scheme [4] proposes a method of designing entangled states of distributed sensors that are robust to noise fields that are spatially distinct to the signal. This is due to being in a decoherence free subspace with respect to the noise fields. In this research, a proof-of-principle demonstration of the scheme is implemented, in which it is shown that three co-trapped entangled Ca40+ ions maintain optimal sensitivity to the strength of an artificially imprinted spatially quadratic magnetic field, in the presence of overwhelmingly noisy constant and gradient magnetic field noise sources. It is found that the prepared entangled state of the ions outperforms all unentangled estimation strategies.

[1] L. J. Stephenson et al., High-rate, high-fidelity entanglement of qubits across an elementary quantum network, Phys. Rev. Lett. 124, 110501 (2020)
[2] M. Pompili et at., Realization of a multinode quantum network of remote solid-state qubits, Science 372, 259 (2021)
[3] V. Krutyanskiy et al., A telecom-wavelength quantum repeater node based on a trapped-ion processor, arXiv:2210.05418v1 (2022)
[4] P. Sekatski et al., Optimal distributed sensing in noisy environments, Phys. Rev. Res. 2, 023052 (2020)

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