Multiparameter quantum metrology with an array of EPR entangled BECs

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In 1935, Einstein, Podolsky, and Rosen (EPR) conceived a gedanken experiment which became a cornerstone of quantum technology and still challenges our understanding of reality and locality today. While the experiment has been realized with small quantum systems, a demonstration of the EPR paradox with massive many-particle systems remains an important challenge, as such systems are particularly closely tied to the concept of local realism in our everyday experience and may serve as probes for new physics at the quantum-to-classical transition.

We have realized the EPR experiment with spatially separated atomic Bose-Einstein condensates [1]. Entanglement between the condensates results in strong correlations of their collective spins, allowing us to demonstrate the EPR paradox between them. Our results represent the first observation of the EPR paradox with spatially separated, massive many-particle systems. They show that the conflict between quantum mechanics and local realism does not disappear as the system size is increased to more than a thousand massive particles.

Furthermore, entanglement in conjunction with individual manipulation of the condensates on the quantum level allows us to implement novel protocols for multiparameter quantum metrology [2]. We report experimental demonstrations of joint quantum-enhanced estimation of multiple parameters [3], exploiting the entanglement between the sensor condensates (see Figure). Our experiments constitute an important proof of concept for quantum enhanced field sensors and imaging devices.

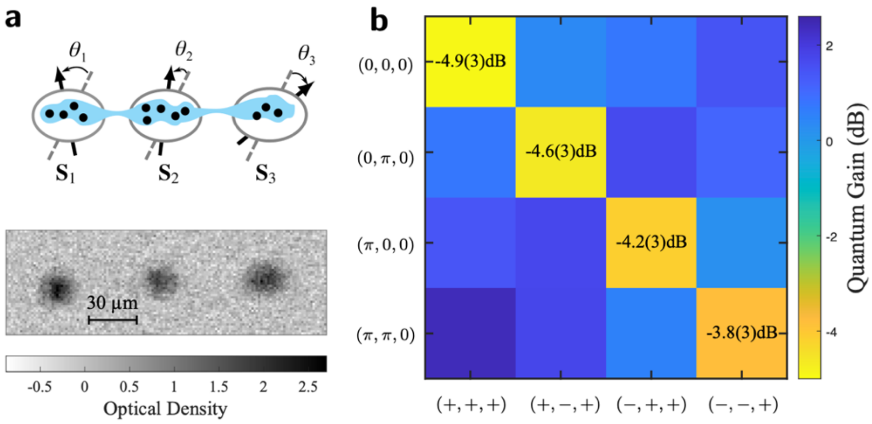

Figure: Joint multiparameter estimation with three entangled atomic sensors. (a) Schematic of the three entangled sensor spins on which three local parameters are imprinted (top) and absorption image of the three atomic clouds (bottom). (b) Matrix of metrological gains compared to the standard quantum limit for different sensor preparations and estimated parameter combinations.

REFERENCES

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