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Number squeezed matter waves

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Matter wave optics with ultracold samples has reached the point where non-classical states can be prepared and their fascinating properties can be explored. In optics, parametric down conversion is routinely used to generate light with squeezed observables as well as highly entangled photon pairs. The applications of these non-classical states range from fundamental tests of quantum mechanics to improved interferometers and quantum computation. Therefore, it is of great interest to realize such non-classical states with matter waves. Bose-Einstein condensates with non-zero spin can provide a mechanism analogous to parametric down conversion, thus enabling the generation of non-classical matter waves. We observed magnetic field dependent spin resonances, where vacuum fluctuations are amplified to macroscopic clouds. The process acts as a two-mode parametric amplifier and generates two clouds with opposite spin orientation consisting of the same number of atoms. At a total of $\sim$10000 atoms, we observe a squeezing of the number difference of -6 dB below shot noise, including all noise sources. In the future, these nonclassical matter waves can be used as a source for Bell pairs of neutral atoms as well as an input for Heisenberg limited atom interferometers.