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Quantum atom optics with BEC: Fisher information for entangled non-Gaussian many particle states

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Our results build on the successful generation of spin squeezed states utilizing the quantum dynamics in an interacting two component Bose gas. The initial state is close to an unstable fixed point of the underlying classical system and thus the dynamics leads to squeezing for the initial time (harmonic regime) but generates non-Gaussian states for longer times. With this new method we generate 6dB spin squeezed states on a short time scale. The novel way of squeezing generation also allows the exploration of over-squeezed states i.e. transient non-Gaussian states towards the generation of cat states. We will report on our results preparing and characterizing these transient non-Gaussian states. They reveal variances which are larger than the classical shot noise limit thus suppression of fluctuations cannot be employed as an entanglement witness. We therefore developed a novel method for detecting the presence of entanglement by extracting from the experimentally detected distribution functions a bound of the Fisher information present in the system. With that we confirm that the entanglement is still present although the states are not spin squeezed. Furthermore interferometry beyond classical limits with these novel states is demonstrated by employing maximum likelihood estimation of the interferometric phase. We will also present a general approach which allows the upscaling of squeezed states to large atom numbers by employing the concept – divide and conquer. We explicitly demonstrate 5dB squeezing for more than 13000 particles. We use this resource and combined this with swapping the squeezing to magnetically sensitive states for demonstration of quantum enhanced magnetometry with high spatial resolution.