# "Photonic" cat states from strongly interacting matter waves

**Uwe R. Fischer and Myung-Kyun Kang**

*Seoul National University, Department of Physics and Astronomy*
*Center for Theoretical Physics, Seoul 08826, Korea*

We consider ultracold quantum gases of scalar bosons, residing in a coupling strength–density regime in which they constitute a twofold fragmented condensate trapped in a single well [1]. It is shown that the corresponding quantum states are, in an appropriate Fock space basis representing (modified) Schwinger bosons, identical to the photon cat states familiar in quantum optics, which correspond to superpositions of coherent states of the light field with a phase difference of $\pi$. In marked distinction to photon cat states, the very existence of matter wave cat states however crucially depends on the many-body correlations of the constituent particles. We consequently establish that the quadratures of the effective "photons," expressing the highly nonclassical nature of the macroscopic matter wave superposition state, can be experimentally accessed by measuring the density-density correlations of the interacting quantum gas [2, 3].

[1] Philipp Bader and Uwe R. Fischer, *Fragmented many-body ground states for scalar bosons in a single trap*, Phys. Rev. Lett. **103,** 060402 (2009).

[2] Myung-Kyun Kang and Uwe R. Fischer, *Revealing single-trap condensate fragmentation by measuring density-density correlations after time of flight*, Phys. Rev. Lett. **113,** 140404 (2014).

[3] Uwe R. Fischer and Myung-Kyun Kang, *"Photonic" cat states from strongly interacting matter waves*, Phys. Rev. Lett. **115,** 260404 (2015).