Emitting atom pairs in strongly correlated momentum states

M. Bonneau[1], F. Borselli[1], M. Maiwöger[1], P. Haslinger[1], T. Zhang[1], J. Schmiedmayer[1]

[1]Atominstitut, TU Wien, Stadionallee 2, 1020 Wien, Austria.

Vienna Center for Quantum Science and Technology.

We are developing in Vienna a source of momentum-entangled twin atoms. Twin atoms are the atomic analog of the twin photons generated through parametric down-conversion, which are widely used in optical quantum technologies.

Twin atoms are emitted from a source Bose-Einstein condensate (BEC) through an atomic four-wave mixing process, where the non-linearity is provided by the interatomic interactions. The geometry of the experiment sets the phase-matching conditions and therefore defines the signal and idler modes populated by the atoms. Over the past years it was experimentally demonstrated that twin atoms share some properties with twin photons: their relative intensity is squeezed and they exhibit momentum correlations [1]. We report here the emission of twin atom beams in a double-well trapping potential, a geometry where the twin beams are expected to be Bell-entangled (see fig. 1).

We trap and manipulate the atoms with an atom chip, which consists of a surface with micro-fabricated structures generating magnetic fields. It permits implementing fast and accurate deformations of the magnetic potential. With the atom chip we perform high-fidelity quantum optimal control of the BEC's motional state [2]. We thus initialize the twin-atom source. We then characterize the correlation properties of the emitted twin atoms.

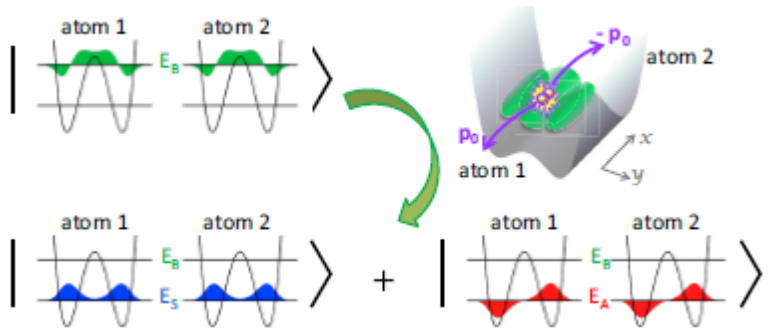

Figure 1. When a BEC is prepared in the second excited state of the double-well potential (in green), four-wave mixing occurs. The outputs modes have opposite momenta $\pm p_0$ along the weakly trapping x axis, and, due to conservation of the spatial wave-function parity, can only be either both in the ground state (in blue) or both in the first excited state (in red) of the double-well potential [3].

[1] R. Bücker et al., *Twin-atom beams*, Nat. Phys. **7**, 608–611 (2011).

[3] S. Van Frank et al., *Optimal control of complex atomic quantum systems*, Sci. Rep. **6**, 34187 (2016)

[2] M. Bonneau et al., *Characterizing twin-particle entanglement in double-well potentials*, Phys. Rev. A **98**, 033608 (2018)