Quantum atom optics using dissociation of a molecular BEC

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Producing and utilising quantum mechanical correlations between entangled particle pairs is a major theme in the ACQAO research program. Here, we report on our progress in the study of atom-atom correlations produced through dissociation of a BEC of molecular dimers. Owing to the analogy with the famous parametric down-conversion in photonics, molecular dissociation plays one of the central roles in quantum atom optics. In the case of molecules made of fermionic atoms, it also serves as an ideal playground for developing the new paradigm of *fermionic quantum atom optics*.

1. In view of the planned experiments with fermionic ^{6}Li at the SUT Node of ACQAO, we have commenced studies of dissociation of lithium molecular dimers into correlated fermionic atoms. As a first step we have studied the dynamics of dissociation and analysed the resulting atom correlations [1] using a simple analytically soluble model that relies on the undepleted molecular field approximation. Further details can be found in the ACQAO 2005 Annual Report.

2. We have also studied dissociation of a BEC of molecular dimers made of bosonic atoms, using first-principles positive-P simulations [2]. Further details can be found in the ACQAO 2005 Annual Report. Due to the exact nature of the method, we can investigate the correlations in both momentum space (which was the focus of Ref. [2]) and in position space. In 2006 we have finalised the analysis of the full spatial structure of the correlations in trapped inhomogeneous systems and simulated typical experimental procedures that involve time-of-flight expansion and absorption imaging [3].

3. In addition, we have implemented the pairing mean-field theory for the studies of molecular dissociation in one, two, and three spatial dimensions [4]. The pairing mean-field approach is intermediate between the exact first-principle methods and the crude undepleted molecular field approximation in that it takes into account the molecular depletion and atomic pair-correlations, but assumes that the molecular BEC remains in a coherent state at all times. While being an approximate theory, it is far less computationally demanding than exact first-principle methods, while still giving reasonably accurate predictions for dissociation durations corresponding to $\sim 50\%$ conversion.

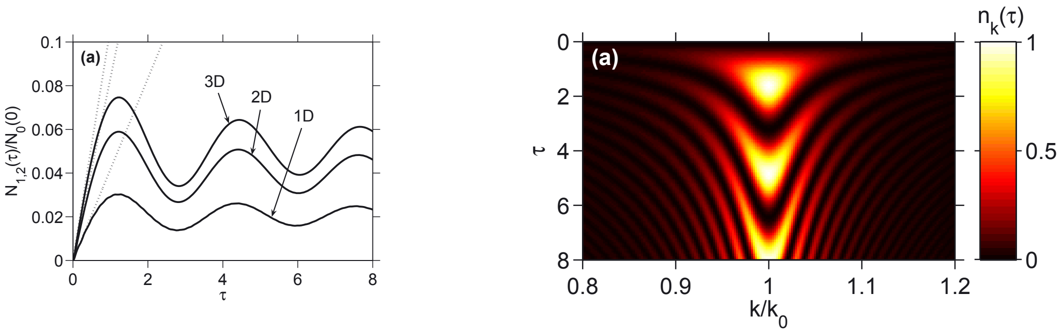

Figure 1: Left: Total number of fermionic atoms in each spin component $N_{1,2}(\tau)$ $[N_1(\tau) = N_2(\tau)]$ relative to the total initial number of molecules $N_0(0)$ as a function of a scaled time τ, in dissociation of molecular BEC in 1D, 2D and 3D, for a dimensionless detuning $\delta = -16$. Right: Radial dependence of the spherically symmetric 3D momentum distribution $n_{\mathbf{k}}(t)$ as a function of the scaled time and a scaled absolute momentum k/k_0, where $k = |\mathbf{k}|$.

References

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