

# Nonequilibrium Quantum Dynamics in Trapped Ultracold Bosonic and Fermionic Mixtures: From Quenching Across Phase Boundaries to Pump Probe Spectroscopy

P SCHMELCHER<sup>1</sup>

<sup>1</sup>*Zentrum für Optische Quantentechnologien, and The Hamburg Centre for Ultrafast Imaging, Hamburg University, Hamburg, Germany. Contact Phone: +00494089986501  
Contact Email: pschmelc@physnet.uni-hamburg.de*

Our focus is the correlated non-equilibrium quantum dynamics for a binary mixture of ultracold trapped atoms. Three different scenarios will be addressed. First, we explore the quench dynamics of a binary Bose-Einstein condensate crossing the miscibility–immiscibility threshold. Increasing the inter-species repulsion leads to the filamentation of the density of each species, involving shorter wavenumbers and longer spatial scales in the many-body approach compared to mean-field theory. These filaments appear to be strongly correlated and exhibit domain-wall structures. We simulate single-shot images to connect our findings to possible experimental realizations.

In the second part of the presentation, we monitor the correlated quench induced dynamical dressing of a spinor impurity repulsively interacting with a Bose-Einstein condensate. Inspecting the evolution of the structure factor, three distinct dynamical regions arise upon increasing the interspecies interaction. These regions are found to be related to the segregated nature of the impurity and to the Ohmic character of the bath. In particular, for miscible components, polaron formation is imprinted on the spectral response of the system. We further illustrate that for increasing interaction, an orthogonality catastrophe occurs, and the polaron picture breaks down.

Next, we propose and investigate a pump-probe spectroscopy scheme to unveil the time-resolved dynamics of fermionic or bosonic impurities immersed in a harmonically trapped Bose-Einstein condensate. In this scheme, a pump pulse initially transfers the impurities from a noninteracting to a resonantly interacting spin state and, after a finite time in which the system evolves freely, the probe pulse reverses this transition. This directly allows us to monitor the nonequilibrium dynamics of the impurities as the dynamical formation of coherent attractive or repulsive Bose polarons and signatures of their induced interactions are imprinted in the probe spectra. The short and long time behaviour will be discussed, including enhanced energy redistribution processes and the formation of a steady-state characterized by substantial losses of coherence of the impurities.

## References

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