

# Localisation vs heating of Bose-Einstein condensates in optical lattices

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A striking manifestation of the interplay between the periodicity of the optical lattice and nonlinearity of the matter wave is formation of bright atomic solitons in a Bose-Einstein condensate (BEC) with *repulsive* nonlinear interactions [1]. This nonlinear localisation occurs within the *gaps* of the band-gap spectrum of the matter Bloch waves due to the anomalous diffraction of matter waves at the edge of the Brillouin zone (BZ). The observation of a single gap soliton [1] required preparation of a *small* condensate at the BZ edge in a one-dimensional (1D) lattice moving with a constant velocity. In contrast, a large BEC prepared at the BZ edge exhibits dynamical (modulational) instability [2], which causes significant loss of condensed atoms to the thermal fraction. By modeling the mean-field dynamics of the BEC beyond the onset of dynamical instability, we have demonstrated that the modulational instability can lead to the localisation of a BEC in the form of *gap soliton trains* [3]. However, it remained unclear whether the formation of a soliton train at the BZ edge could still occur in the presence of the enhanced heating.

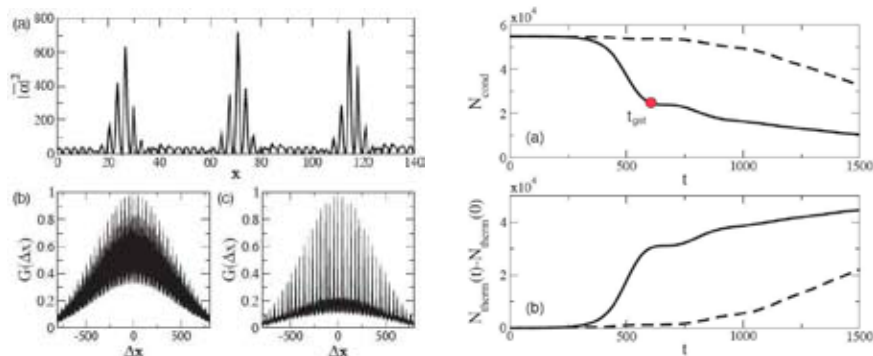


Figure 1: Left: Localisation signatures with initial phase imprinting. Shown are (a) BEC density after 366 ms at the BZ edge and averaged density correlation function (b) before and (c) after the soliton train formation. Right: Loss of BEC atoms (top) and growth of the thermal fraction (bottom) during 2.4 s of the BEC evolution at the BZ edge with (dashed) and without (solid) phase imprinting. The red dot marks the time of the soliton train formation.

By performing stochastic Wigner simulations of the atomic field, we analysed quantum effects in the dynamics of a BEC at the edge of the Brillouin zone of a 1D optical lattice [4]. We found that quantum fluctuations trigger the dynamical instability of the Bloch states of the BEC which leads to the generation of arrays of *gap solitons*. The formation of the soliton trains can be accelerated by an initial periodic phase imprinting [Fig. 1(a)]. Our simulations of the instability-induced growth of the thermal fraction [Fig. 1(right panels)] confirmed that there are regimes in which the anomalous heating *does not suppress the formation of the soliton train*. The solitons are clearly seen in the simulations equivalent to a “single shot” experiment. However, without the initial phase imprinting, they are no longer detectable after averaging over many realisations. Instead the spatial density correlation function can provide a clear, experimentally detectable signature of the nonlinear localisation both with [Fig. 1(b,c)] and without phase imprinting [4].

## References

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