The first experimental generation of bright gap solitons in a Bose-Einstein condensate with repulsive atomic interactions was achieved in 2004 [1]. This counter-intuitive "self-focusing" of a BEC is possible due to anomalous dispersion properties of the matter wave in a periodic potential of a 1D optical lattice.

The generation procedure [1] involves loading the condensate into a ground (Bloch) state of the optical lattice and adiabatic acceleration to the band edge. Our aim was to model this process using the 1D mean-field Gross-Pitaevskii equation for the condensate wavefunction. We have demonstrated that the efficiency of the gap soliton formation can be greatly improved by preparing the initial state via interference of two BEC wavepackets counterpropagating at quasi-momenta corresponding to the opposite edges of the same Bloch-wave gap [2].

The shape of a gap soliton can be controlled through matter-wave dispersion management (Fig. 1). This involves modifying the curvature of the spectral bands and is possible in systems that allow fine-tuning of the band-gap properties in the wide range of parameters. We found that optical double-period superlattices represent an ideal system for the dispersion management due to high sensitivity of dispersion at the edges of Bloch-wave minigaps to the shape of the superlattice potential [2].

Nonlinear dynamics of the matter-wave Bloch states at the edge of a Brillouin zone can provide an alternative method for generation of gap solitons through the development of modulational instability. By using the non-polynomial mean-field model, we demonstrated that the recently observed instability of the Bloch states of a repulsive Bose-Einstein condensate in a moving one-dimensional optical lattice [3] can lead to dynamical localization of a condensate in the form of gap soliton trains. We studied the characteristic features of the localization under realistic experimental conditions, including the process of adiabatic loading and acceleration to the band edge (see Fig. 2). A paper summarizing our results is being prepared for submission. Currently, in collaboration with the ACQAO theory node at the University of Queensland (M. Davis and A. Bradley), we are investigating the influence of the finite temperature effects on the dynamics of Bloch states and formation of soliton trains.

References