Observation of double-charge discrete vortex solitons in hexagonal photonic lattices

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Abstract: *We present the first experimental observation of stable double-charge discrete vortex solitons generated in optically-induced hexagonal photonic lattices.*

Some of the most spectacular experiments in the field of nonlinear dynamics of coherent light and matter waves in periodic potentials refer to the properties of vortices and vortex flows in optical lattices [1, 2, 3, 4]. Self-trapped phase singularities in the form of isolated discrete vortices have been studied in optically induced square photonic lattices [2, 3]. Recently, the lattices of non-square symmetry, such as hexagonal or honeycomb lattices, attracted more interest, revealing new vortex forms, such as the multi-vortex localized states [5, 6].

Besides that, the most remarkable phenomenon of hexagonal lattices is that raising the topological charge may increase the stability of the vortices. In particular in a six-site configuration, double charge vortices may become stable, while single-charge vortices are unstable [7]. This has no counterpart in homogenous media, where the growth rate of the modulation instability increases with vorticity [1].

We would like to emphasize that the observation of vortex solitons requires stretching of the hexagonal lattice. This is due to the anisotropic nature of the nonlinear response, which strongly affects the symmetry of the induced refractive index structure [8]. As a result, the modulation along the optical axis is much stronger than along the diagonals and therefore the coupling between the refractive index maxima is very asymmetric. The effect of anisotropy can be compensated by stretching the lattice along its vertical direction to achieve symmetric coupling [6].

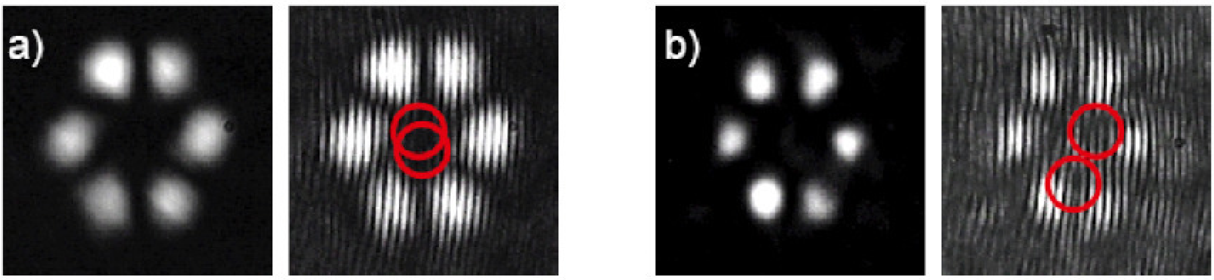

Figure 1: Experimental observation of a double charge discrete vortex soliton. Intensity profile and phase interferogram of the input beam (a) and the generated double charge discrete vortex soliton (b).

In this contribution we demonstrate experimentally that in focusing nonlinear media, double charge discrete vortex solitons are stable, whereas single charge vortices are unstable under the same conditions. We show that the stability is determined by the inter-site power exchange and provide a simple stability criterion for the soliton.

As an example, Figure 1 shows a discrete double charge vortex soliton and its corresponding phase pattern with red circles indicating the phase singularities inside the structure.

We then extend our analysis to the defocusing case and find that the stability properties are reversed. This results in a stable single charge vortex soliton and an unstable double charge vortex.

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