Flat-band compactons in a two-dimensional driven-dissipative Lieb lattice

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In systems with flat bands [1], where energy does not depend on momentum and kinetic energy is zero, the physics is dominated by interactions, disorder and dissipation. This property enables many important effects such as fractional quantum Hall physics, high temperature superconductivity and unconventional magnetism. The corollary of the massively degenerate spectrum is the existence of compact localized states (CLS) - single-particle eigenstates confined to a few lattice sites with stronger-than-exponential localization [2,3]. Both the flat band and CLS are made possibly by an underlying topology or symmetry of the lattice. In general, localized interactions break the single particle spectrum so that flat band behavior cannot be expected to persist. However, under some circumstances the highly localized CLS may persist into the interacting regime as compact localized solitons, or compactons [4]. This can have implications for the physics of interacting particles in flat bands.

Here we study flat band sates of a 2D Lieb lattice of polariton micropillars [3]. Compared to previous works on 2D flat bands we are able to study the nonlinear response of single isolated CLS to an external coherent drive. We observe compactons (Fig. 1 c,d) that emerge at zero threshold from the CLS, are embedded within dispersive band states, and are localized in two dimensions [4]. They are an example of a class of compacton has been studied extensively in theory but not observed until now. In contrast to gap solitons [5] the localization comes from the topology of the lattice and no energy gap is required to isolate the nonlinear states. Unlike the 1D case [5], our 2D flat band is embedded within a continuum of dispersive bands in the spectrum [4]. Nevertheless the compacton remains highly localized and may be regarded as a kind of nonlinear bound state in the continuum (BIC) [1]. We further find that when pumping a combination of CLS and dispersive states the driven-dissipative nature of the system causes a sudden preferential population of the compacton above a threshold power (Fig. 1f), appearing as a kind of nonlinear self-localization. Experimental results agree well with numerical simulations of the lattice (Fig. 1g,h).

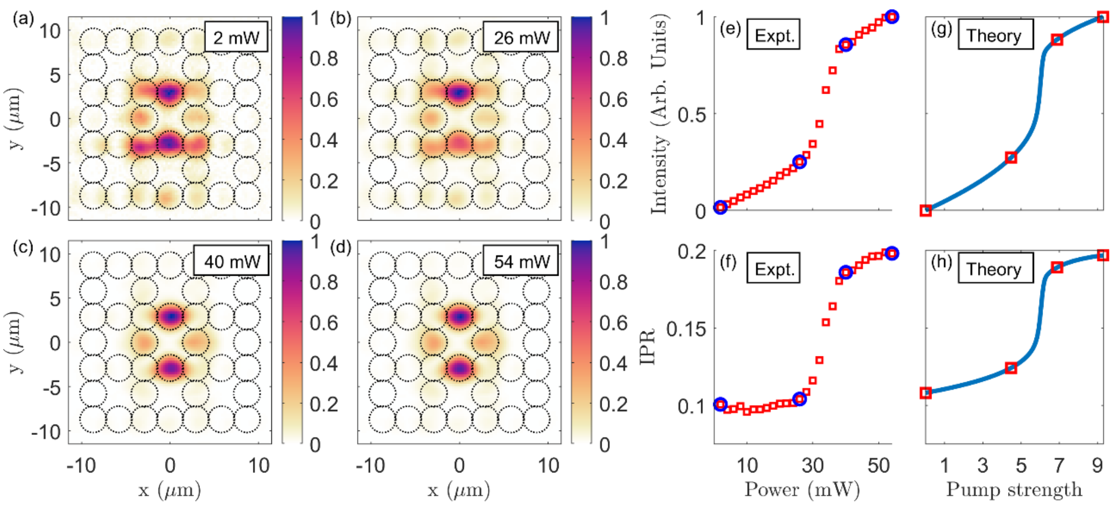

Figure 1: (a-d) Occupation of lattice sites at different pump powers. (e,f) Experimental total intensity and inverse participation ratio [2] quantifying the degree of localization. (g,h) Numerically simulated equivalents to (e,f).

Our results open new perspectives for experimental study of the physics of quantum particles where interactions, drive and dissipation are the dominant energy scales. Furthermore, CLS were also proposed for applications in quantum state preparation, all-optical logic gates and dense spatially multiplexed information transport [1]. Our work is a stepping stone to exploring these applications, where the preservation of the compact localized structure in the nonlinear regime will be highly beneficial.

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