Observation of dipolar transport in one-dimensional photonic lattices

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PII: S2095-9273(17)30053-1
DOI: http://dx.doi.org/10.1016/j.scib.2017.01.035
Reference: SCIB 60

To appear in: *Science Bulletin*

Received Date: 27 December 2016
Accepted Date: 20 January 2017

Please cite this article as: C. Cantillano, L. Morales-Inostroza, B. Real, S. Rojas-Rojas, A. Delgado, A. Szameit, R.A. Vicencio, Observation of dipolar transport in one-dimensional photonic lattices, *Science Bulletin* (2017), doi: http://dx.doi.org/10.1016/j.scib.2017.01.035

Noname manuscript No.
(will be inserted by the editor)

Observation of dipolar transport in one-dimensional photonic lattices

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Received: 27-Dec-2016/ Revised: 19-Jan-2017/ Accepted: 20-Jan-2017

Abstract We experimentally study the transport properties of dipolar and fundamental modes on one dimensional (1D) coupled waveguide arrays. By carefully modulating a wide optical beam, we are able to effectively excite dipolar or fundamental modes to study discrete diffraction (single-site excitation) and gaussian beam propagation (multi-site excitation plus a phase gradient). We observe that dipolar modes experience a larger spreading area due to an effective larger coupling constant, which is found to be more than two times larger than the one for fundamental modes. Additionally, we study the effect of non-diagonal disorder and find that while fundamental modes are already trapped on a weakly disorder array, dipoles are still able to propagate across the system.

Keywords Photonic lattices · Waveguide arrays · Wave propagation · Integrated optics

1 Introduction

Waveguide arrays and photonic lattices are an important field of study where many fundamental and applied problems can be investigated in a rather simple configuration [1,2]. Most of the theoretical and experimental efforts have been focused on studying transport and localization properties in various contexts, such as complex beam steering [3–5], Bloch oscillations [6–8], dynamic localization [9,10], relativistic emulations [11], discrete solitons [12–14], and many more. Recently, even the absence of transport and linear localization in complex lattice geometries was investigated [15–20].

Importantly, almost all previous works have considered single-mode waveguides only. This somehow reduces the complexity of the studied problem, allowing a more direct verification of theoretical results on simpler experimental setups. But, optical waveguides could also host higher order modes. Their excitation could promote richer dynamics and new interesting phenomena, as it has been suggested for cold-atoms loaded in optical potentials [21–24] (in that context, dipolar modes are known as p-modes). However, in general, a precise excitation of different modes or complex spatial structures may be simpler using light than atoms [15], as we will show along this work.

In this work, we present a first systematic study on the diffraction properties of dipolar modes in coupled waveguide arrays. We find that dipoles form another first tight-binding band, that is fundamentally distinct from the higher-order bands of continuous periodical systems [25]. Our waveguide arrays are fabricated using a very precise femtosecond-laser technique [26], which produces micrometer waveguides disposed on a given two-dimensional transversal pattern. Light propagating on these waveguides is well trapped in space, allowing a theoretical description based on coupled-mode theory, due to the weak coupling interaction between neighboring waveguides. By using a green laser beam and a modulation setup, we are able to effectively excite fundamental and dipolar modes, and study their dy-

Camilo Cantillano · Luis Morales-Inostroza · Bastián Real · Rodrigo A. Vicencio
Departamento de Física, MSI-Nucleus on Advanced Optics, and Center for Optics and Photonics (CEFOP), Facultad de Ciencias, Universidad de Chile, Santiago, Chile
E-mail: rvicencio@uchile.cl

Santiago Rojas-Rojas · Aldo Delgado
Center for Optics and Photonics and MSI-Nucleus on Advanced Optics, Universidad de Concepción, Casilla 160-C, Concepción, Chile

Alexander Szameit
Institute for Physics, University of Rostock, D-18059 Rostock, Germany