Surface Waves in Two-dimensional Modulated Photonic Lattices

Ivan L. Garanovich[1], Alexander Szameit[2], Andrey A. Sukhorukov[1], Matthias Heinrich[3], Felix Dreisow[3], Thomas Pertsch[3], Stefan Nolte[3], Andreas Tünnermann[3], and Yuri S. Kivshar[1]

1. Nonlinear Physics Centre and Centre for Ultra-high bandwidth Devices for Optical Systems (CUDOS), Research School of Physics and Engineering, Australian National University, Canberra, ACT 0200, Australia
2. Solid State Institute and Physics Department, Technion, 32000 Haifa, Israel
3. Institute of Applied Physics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Applying an external driving to a periodic potential drastically modifies both propagation and localization of waves. One important example is dynamic localization (DL), the suppression of broadening of a wave packet during its motion in a periodic potential under the action of an externally applied periodic field [1]. The same effect can occur for optical beams in curved waveguide arrays, where the waveguide bending [see Fig. 1(a)] mimics the effects of the driving field, leading to the cancellation of diffraction [2,3]. Importantly, DL was predicted to occur in multi-dimensional systems, and it was observed in both one- [2] and two-dimensional [3] modulated waveguide arrays. DL was also studied at the boundaries of one-dimensional lattices, where lattice modulation was shown to facilitate the formation of families of new type of defect-free linear surface modes [4,5]. Therefore, an important question is whether such surface modes can also be supported by two-dimensional modulated lattices.

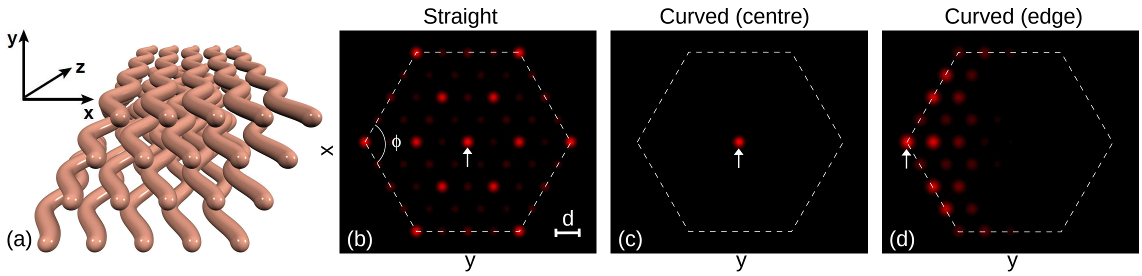

Fig. 1 (a) Sketch of a periodically curved hexagonal waveguide array. The insert shows the orientation of the coordinate axes. (b-d) Numerical simulations of the beam propagation in the array with hexagonal-shaped boundaries (marked with a dashed line). The waveguide spacing is $d = 22\,\mu$m. Arrows mark the waveguide which is excited at the input facet. (b) Output diffraction profile in the straight array. The propagation distance is one modulation period. (c) Output beam profile in the curved array in the regime of dynamic localization when the central waveguide is excited. The propagation distance is ten modulation periods. (d) The same as (c) when the edge waveguide is excited.

In this work, we reveal substantial differences between the dynamic localization at surfaces of one- and two-dimensional modulated lattices. We study the generation of surface waves in two-dimensional periodically-curved hexagonal waveguide arrays [see a sketch in Fig. 1(a)]. We find that *no localized surface modes* exist in two-dimensional modulated lattices, in a sharp contrast to one-dimensional lattices [4, 5]. In Figs. 1(b-d) numerical simulations of beam propagation are shown for hexagonal arrays exhibiting hexagonal-shaped boundaries with 5 waveguides at each facet. In the straight array, the beam experiences strong diffraction broadening [Fig. 1(b)]. In the curved array with modulation parameters tuned to the DL regime [3] light beam remains localized and diffraction is completely suppressed after each bending period when the light beam is launched into the *central waveguide* [Fig. 1(c)]. In contrast, when the light beam is launched into the *edge waveguide* of the same curved array it diffracts away from the initially excited lattice site [Fig. 1(d)]. This delocalization occurs, even though the effective coupling is canceled inside the structure [3] in the DL regime, since the additional dimensionality allows light to propagate *along the boundaries* of the two dimensional structure [see Fig. 1(d)].

We analyze the propagation of surface waves for different edge angles ϕ [Fig. 1(b)] in hexagonal lattices and in quasi-one-dimensional zig-zag arrays. In our experiment, we apply the femtosecond laser direct-writing technology to fabricate the waveguide arrays in fused silica glass, and generate the surface waves by launching laser light into a surface waveguide. Our results introduce novel opportunities for the generation and control of two-dimensional optical surface waves.

References

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