

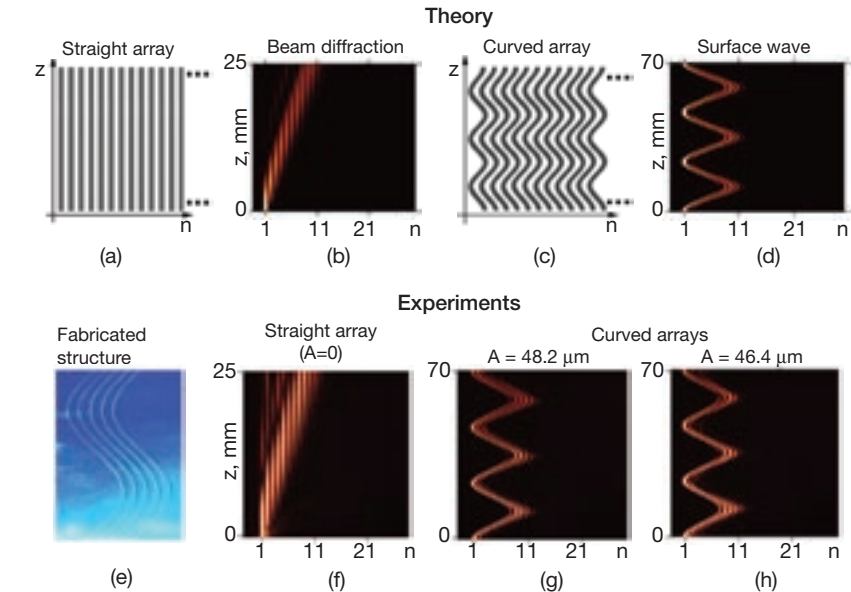
Defect-Free Surface Waves

Ivan L. Garanovich, Alexander Szameit, Andrey A. Sukhorukov, Stefan Nolte, Thomas Pertsch, Andreas Tünnermann and Yuri S. Kivshar

Interfaces between physical media can support a special type of localized mode known as surface waves. In solids, electronic surface waves generated in crystals at the edge of truncated periodic potential are commonly explained as the manifestation of either Tamm¹ or Shockley² localization mechanisms. Optical analogs of Tamm and Shockley states have also been studied extensively in different types of periodic photonic structures, where such optical surface waves are particularly attractive for optical sensing, measurement and characterization applications. Usually, a surface defect is required for surface waves to exist in straight photonic lattices composed of identical waveguides. Discrete optical surface solitons have been recently observed in nonlinear arrays, where such a defect is induced due to nonlinearity.³

Recently, we revealed that boundaries of modulated photonic lattices can support a new type of surface wave without any introduced or induced surface defects.⁴ In a lattice composed of identical straight waveguides, surface waves cannot exist and light always experiences strong repulsion from the surface and diffraction. In contrast, we predicted that, in a modulated lattice composed of waveguides with periodically curved axes, well-localized linear surface modes can exist, despite the fact that all the waveguides are still identical, and there are no defects.⁴

The appearance of these novel surface modes is a result of nontrivial modification of the diffraction properties in the vicinity of the lattice edge, which is introduced by the lattice modulation, and is completely different from the diffraction management studied previously in infinite lattices. We developed a general analytical theory of such novel surface modes, demonstrating their unique



Theoretical prediction (top) and experimental observation (bottom) of defect-free linear surface states in modulated semi-infinite photonic lattices. In (a) straight lattices without surface defects, beam always experiences (b) repulsion from the surface and diffraction. In contrast, we predict that in (c) modulated lattices, (d) a new type of surface wave is possible. (e) Microscope image of the fabricated curved array and (f-h) fluorescent images of beam propagation in arrays with different modulation amplitude A .

properties, which are distinct from both Tamm and Shockley surface waves.⁴

We have also observed such defect-free surface waves experimentally.⁵ We used the femtosecond laser direct-writing technique to create periodically curved waveguide arrays in silica glass samples. A special type of silica with high OH content was used, resulting in the formation of fluorescent color centers during the writing process. This makes it possible to measure fluorescence by launching into array light from a HeNe laser at 633 nm, and to directly visualize the beam propagation. Since the color centers are formed exclusively inside the arrays, a high signal-to-noise ratio is obtained. We confirmed the absence of any surface defects in our samples, and then studied the generation of surface waves in curved wave-

guide arrays. We showed that the degree of surface wave localization can be controlled by selecting the waveguide bending amplitude (g,h).

The ability to generate these novel surface waves in optics can aid the development of tools for studying of various surface phenomena. Similar effects can also occur for other types of modulated lattices in different physical systems. ▲

I.L. Garanovich (ilg124@rsphysse.anu.edu.au), A.A. Sukhorukov and Yu.S. Kivshar are with CUDOS at the Australian National University, Canberra, Australia. A. Szameit, S. Nolte, T. Pertsch and A. Tünnermann are with Friedrich-Schiller-University, Jena, Germany.

References

1. I.E. Tamm. *Z. Phys.* **76**, 849 (1932).
2. W. Shockley. *Phys. Rev.* **56**, 317 (1939).
3. S. Suntsov et al. *Phys. Rev. Lett.* **96**, 063901 (2006).
4. I.L. Garanovich et al. *Phys. Rev. Lett.* **100**, 203904 (2008).
5. A. Szameit et al. *Phys. Rev. Lett.* (in press).