28th SUMMER SCHOOL-CONFERENCE ON DYNAMICAL SYSTEMS
AND COMPLEXITY, CHANIA, CRETE, 18 - 26 JULY 2022

Nonlinear Photonic Metasurfaces: Multistability via Input Intensity, Angle, and Wavelength

CONSTANTINOS VALAGIANNOPOULOS

Department of Physics
Nazarbayev University, Nur-Sultan KZ-010000, Kazakhstan
konstantinos.valagiannopoulos@nu.edu.kz

Rigorous treatment of the electromagnetic interactions with nonlinear materials can be very challenging due to the inherent complexity of media with environment-varying behavior. However, such an effort can be substantially assisted by spatially restricting the nonlinearities to metasurfaces; indeed, the intensity-dependent properties will concern only the imposed boundary conditions and, thus, there will be no need to solve nonlinear wave equations into volumes. In this talk, Kerr-nonlinear boundaries with homogenized surface conductivities will be considered and the developed fields will be evaluated analytically or semi-analytically.

It has been found that the same input parameters can lead to several distinct output responses in the steady state, namely, the examined setups exhibit multistability with respect to the intensity, the angle and the wavelength of the incoming signal. The devices decide their response based on the past input values; in other words, they “remember” the excitation history and, therefore, provide a platform for the design of novel photonic memory elements.

The first problem concerns a Kerr-nonlinear metasurface that is obliquely illuminated by an electromagnetic wave [1]. The investigated layouts show hysteresis for changing the impinging beam angle by keeping a fixed intensity profile; accordingly, the considered setups remember the history of illumination incidence. The reported findings may open new unexplored avenues toward the design of photonic systems supporting a wide range of fixed-power memory operations from switching and sensing to information storage and data writing.

The second problem investigates two planar coupled nonlinear metasurfaces [2] which are found to manifest significant multistability regarding their transmissivity.This characteristic is owed to the discontinuous variation of the response once the nature of the material changes from dielectric to plasmonic and vice-versa, occurring at different levels of incoming power. The conditions for giving sizable hysteresis loops, with respect to either the input intensity or its operational wavelength, are determined and expected to assist the modeling of nonlinear metasurfaces.

The third problem examines, in a semi-analytical manner, nanotubes with nonlinear admittance that are fed centrally by a wire antenna of various angular momenta [3]. Interestingly, some of the potential radiation patterns of the considered cylindrical devices, despite their homogeneous and isotropic nature, are azimuthally rotated, even for symmetric excitations. Such a feature of several alternative stable solutions with different amplitudes and angular tilts may provide a promising route for designing reconfigurable optical setups with versatile memory.

References

[1] C. Valagiannopoulos, A. Sarsen, and A. Alù, "Angular Memory of Photonic Metasurfaces", *IEEE Trans. Antennas Propag.*, **69**, 7720 (2021).

[2] C. Valagiannopoulos, "Multistability in Coupled Nonlinear Metasurfaces", *IEEE Trans. Antennas Propag.*, DOI: 10.1109/TAP.2022.3145455 (2022).

[3] A. Abrashuly and C. Valagiannopoulos, "Photonic memory with nonlinear plasmonic nanotubes", *APL Photonics*, **9**, 101111 (2021).

Acknowledgement

This work was partially supported by Nazarbayev University Faculty Development Competitive Research Grant No. 021220FD4051 ("Optimal design of photonic and quantum metamaterials").