Nonlocal Metasurfaces Performing Optical Signal Processing on Two-Dimensional Images

Hoyeong Kwon*[(1)], Andrea Cordaro[(2,3)], Dimitrios Sounas[(1,4)], Albert Polman[(3)], and Andrea Alù[(1,5)]
(1) The University of Texas at Austin, Austin, TX 78712, USA
(2) University of Amsterdam, 904 Science Park, 1098 XH Amsterdam, Netherlands
(3) AMOLF, 104 Science Park, 1098 XG Amsterdam, Netherlands
(4) Wayne State University Detroit, MI 48202, USA
(5) Advanced Science Research Center, City University of New York, New York, NY 10031, USA

Recently, the importance of signal processing to achieve high speed, large data processing is getting significant to satisfy the current needs of industry and technology. However, optical signal processing using integrated circuits is inherently limited in speed and requires large power consumption. Also, conventional optical Fourier systems are not attractive due to their size, which makes it hard to integrate them in larger systems. For this reason, there has been an interest in replacing the current signal processing systems with a single or multilayered metasurfaces, in an effort to develop simple, planar integrated systems with low loss, and nearly luminal speed. Several recent studies have shown the successful use of metasurface, for example, a photonic differentiator, but they are also limited by anisotropy and narrow angular spectrum, which make them unattractive for a practical implementation.

For this reason, we recently proposed a new type of the metasurface design in the radio-frequency spectrum, utilizing the nonlocal response of Fano resonances, which overcomes the limitations of the aforementioned studies. By matching the zero or unitary transmission peaks of the Fano resonance at normal incidence, we proposed a system that realizes n^{th} differentiation, or n^{th} integration. Following this work, we propose here the two-dimensional version of nonlocal metasurfaces operating at optical frequencies, composed of nanostructured amorphous Silicon (a-Si) gratings, which realize a polarization independent, isotropic optical signal processing near the speed of light. Our results provide an efficient, practically integrable platform for optical signal processing and suggest efficient functionalities for edge enhancement in the case of an illuminating image with arbitrary polarization and large resolution. We believe that these results, when practically implemented and applied to realistic imaging systems, may provide an exciting opportunity for imaging and analog signal processing.