Experimental proof of energy backflow and gigantic local wavevectors in super-oscillatory optical field

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It is commonly believed that only the non-propagating electromagnetic field in the vicinity of nanostructures can be structured on sub-wavelength level and thus could be decomposed into plane waves with wave-vectors exceeding that of incident light creating the high spatial frequency near-field. Here we show that super-oscillatory fields in free space could feature energy backflow and gigantic local wavevectors that are several times higher than that of incident light. With the aid of an appropriately designed plasmonic metasurface, we experimentally measured phase of the super-oscillatory field and visualized fast-variation phase singular points. Unlike conventional phase measurement techniques where an interferometry setup is usually required, our metasurface serves as a built-in interferometer which is capable of retrieving the phase by simply adjusting the incident polarizations and recording the corresponding intensity components.

Figure 1(a) shows the schematic of experimental arrangement and SEM image of the sample. When *x*-polarized light illuminates the metasurface, the E_y component diffracting from the two set of slit-antennas orienting at ±45 ° has a phase difference of π which could act as a binary phase grating to create the super-oscillatory field with appropriately optimized mask, as shown in Fig. 1(b). In the meantime, the E_x component is in-phase, thus forming a plane wave considering the mask period is in subwavelength scale only creating the zero-diffraction order. Similarly, with *y*-polarization illumination, a plane wave could be generated in E_y. Futhermore, with cicular polarization illumination, the E_y component is the superposition of the plane wave and the super-oscillatory field to be measured (there will be a $\pm\pi/2$ phase delay depending on the handedness of the circular polarization light). In this way, the phase information of the super-oscillatory field is encoded into the intensity patterns and therefore could be retrieved by measuring a set of intensities with *x*-, *y*- and circular polarization illuminations and without the necessity to build up a rather complex interferometry setup. An exampled super-oscillating retrieved phase is shown in Fig. 1(c) where the singular points are highlighted with green circles which coincide with the low-intensity regions. Excellent agreement is found between simulation and experiment.

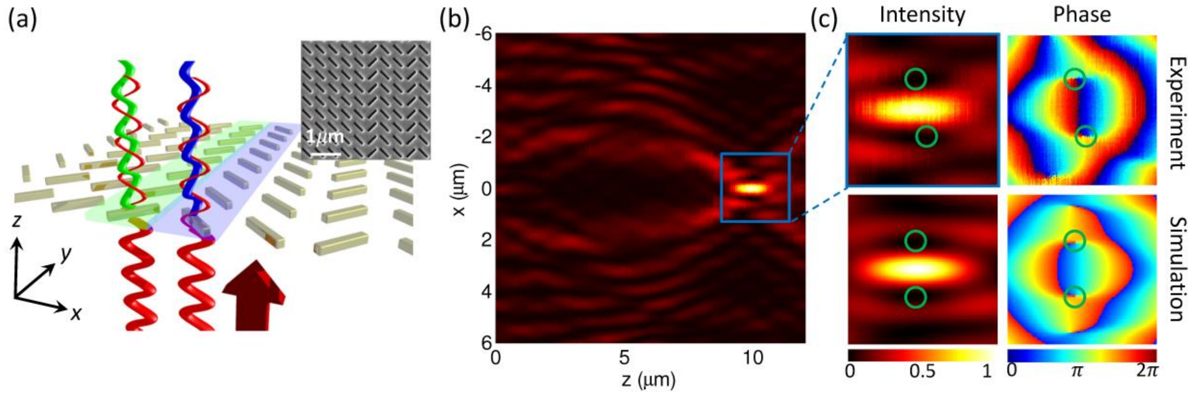

Fig. 1 (a) Schematic for the phase retrieval setup. Inset shows the zoom-in SEM image of sample. (b) The intensity distribution of super-oscillatory field E_y in the longitudinal plane. The hotspot is generated at z=10 μm. (c) Zoom-in view of the intensity and phase distribution near the super-oscillatory hotspot. The phase singular points are highlighted with green circles.

References

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[2] G. H. Yuan, S. Vezzoli, C. Altuzarra, E. T. F. Rogers, C. Couteau, C. Soci, and N. I. Zheludev, "Quantum super-oscillation of a single photon," Light: Sci. & Appl. 5, e16127 (2016).