Superoscillatory nanometrology

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Abstract: Superoscillatory field created by Pancharatnam-Berry phase metasurface contains structured elements with orders of magnitude smaller than the wavelength of light. It is used as “optical ruler” for nanoscale diaplacement metrology with resolution of 2.3 nm.

Here we report a new concept of optical nanoscale displacement sensing based on the observation of “optical ruler” attached to the moving object. The “optical ruler” is a complex superoscillatory electromagnetic field pattern formed by multiple interference of waves in free space. Such pattern contains structured elements on the scale with orders of magnitude smaller than the wavelength of light that gives access to nanoscale displacement sensitivity.

We use a Pancharatnam-Berry phase metasurface simultaneously as the source of the superoscillatory electromagnetic field and platform for monolithic interferometry. Figure 1(a) shows the schematic for superoscillatory nanometrology. The key element is a delicately designed metasurface interferometry – mounted on an independent platform (A) – which can create a superoscillatory field and simutaneously measure its intensity and phase profiles with proper control of incident polarization (left/right-handed circular polarization, *x*/*y*/±45° linear polarization). Due to its propagating wave nature, the superoscillatory field can be projected by an imaging sytem into the optical far-field and detected by a CCD detector mounted on the second platform (B). The local wavevector distributions can be retrieved by intensity maps and the relative lateral displacement of the two platforms can be measured by precise positioning of the wavevector peaks. In our experiment, when the metasurface is moved in the *x*-direction with a step size of 20 nm, the retrieved wavevectors near the superoscillatory spots are recorded and shown in Fig. 1(b). The left, right, and mean peak positions are linearly fitted and all the slopes are close to 1 revealing a good fidelity of the nanoscale metrology.

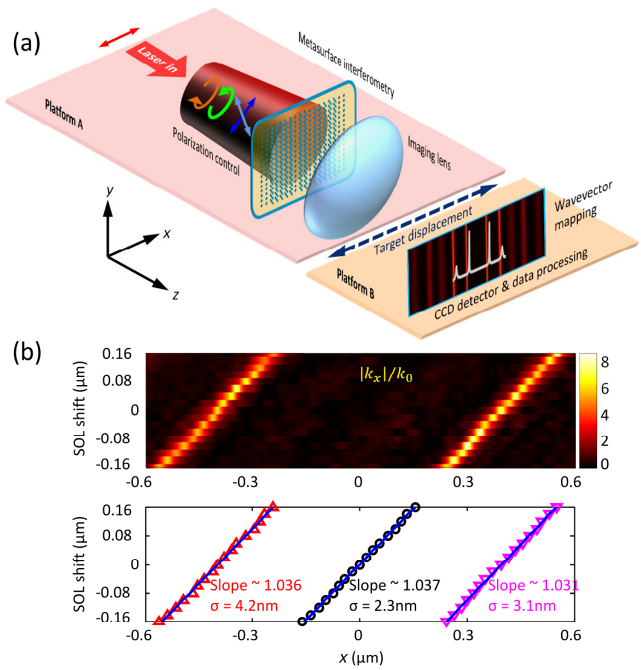

Fig. 1 (a) Schematic for superoscillatory nanometrology with monolithic metasurface interferometry. The Pancharatnam-Berry phase metasurface is comprising of two types of slit anetannas with the same dimensional (length 400 nm, width 50 nm) but different orientations (±45°), and it can create a superoscillatory field in *y*-polarization and a reference plane wave in *x*-polarization when excited by *x*-polarized light. The superoscillatory field contains features (phase singularities and high local wavevectors) with orders of magnitude smaller than the wavelength of light (800 nm here). (b) Proof-of-concept demonstration of superoscillatory metrology. From intensity mapping, the lateral displacement between platform A and B with a step size of 20 nm is reasonably measured by retrieving the peak positions of wavevectors distributions of the superoscillatory field.