Figure 1:

Schematic image to show the principle of optical ruler displacement metrology using monolithic metasurface interferometer. No associated data.

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Figure 2:

(1) Figure 2A: Simulated *x*-*y* cross-section of intensity distribution of the *y*-polarized component of the optical field created by the metasurface at different incident polarizations (x-polarization, left and right handedness circular polarization, +45° and -45° linear polarization). The subfigures in \*.tif format are used to produce the figure 2A in the main text.

(2) Figure 2B: Experimentally measured *x*-*y* cross-section of intensity distribution of the *y*-polarized component of the optical field created by the metasurface at different incident polarizations. The subfigures in \*.tif format are used to produce the figure 2B in the main text.

(3) Figure 2C: Simulated line-scan intensity profiles for different incident polarizations. The \*.txt files are used to produce the figure 2C in the main text. Also included is the \*.tif file for the 2D maps (inset).

(4) Figure 2D: Retrieved phase profiles using the intensity data in Fig. 2C. The \*.txt files contain the phase data from eq. (s7) to produce the figure 2D in the main text.

(5) Figure 2E: Retrieved local wavevector profiles using the phase data in Fig. 2D. The \*.txt files contain the wavevector data from calculation to produce the figure 2E in the main text. Also included is the \*.tif file for the 2D maps in area of interest (inset).

(6) Figure 2F: Experimentally measured line-scan intensity profiles for different incident polarizations. The \*.txt files are used to produce the figure 2F in the main text. Also included is the \*.tif file for the 2D maps in area of interest (inset).

(7) Figure 2G: Retrieved phase profiles using the intensity data in Fig. 2F. The \*.txt files contain the phase data from eq. (s7) to produce the figure 2G in the main text.

(8) Figure 2H: Retrieved local wavevector profiles using the phase data in Fig. 2G. The \*.txt files contain the wavevector data from calculation to produce the figure 2H in the main text. Also included is the \*.tif file for the 2D maps in area of interest (inset).

(9) Figure 2I: SEM image of the 1D optical ruler nanometrology sample and its zoom-in view.

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Figure 3:

(1) Figure 3A: Demonstration of the optical ruler displacement sensing at a piezo stage step size of 3 nm and the linear fitting in short distance. The \*.txt files are used to produce the figure 3A in the main text.

(2) Figure 3B: Demonstration of the optical ruler displacement sensing at a piezo stage step size of 1 nm and the linear fitting in short distance. The \*.txt files are used to produce the figure 3B in the main text.

(3) Figure 3CD: The \*.tif file shows the simulated x-y cross-sections of intensity distribution of the y-polarized complex optical field component created by the metasurface at the distance of ~10 µm from the metasurface to produce the figures in figure 3C. The \*.txt file is used to produce the 1D autocorrelation curve in figure 3D.

(4) Figure 3EF: The \*.tif file shows the simulated x-y cross-sections of local wavevector distributions to produce the figures in figure 3E. The \*.txt file is used to produce the 1D autocorrelation curve in figure 3F.

(5) Figure 3GH: The \*.tif file shows the experimentally measured x-y cross-sections of intensity distribution of the y-polarized complex optical field component created by the metasurface at the distance of ~10 µm from the metasurface to produce the figures in figure 3G. The \*.txt file is used to produce the 1D autocorrelation curve in figure 3H.

(6) Figure 3IJ: The \*.tif file shows the experimentally measured x-y cross-sections of local wavevector distributions to produce the figures in figure 3I. The \*.txt file is used to produce the 1D autocorrelation curve in figure 3J.

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Figure 4:

(1) SEM image of the 2D random optical ruler nanometrology sample and its zoom-in view.

(2) Figure 4BCD: Experimentally measured *x*-*y* intensity maps in free space at ~10 µm above the metasurface illuminated by coherent light source at the wavelength λ = 800 nm (Figure 4B); retrieved phase maps (Figure 4C) and local wavevector maps (Figure 4D). The \*.tif files are used to produce the figure 4B, 4C and 4D in the main text.

(3) Figure 4E: Calculated cross-sections of the autocorrelation function along *x*-direction of the wavevector maps and the exponential fitting in small distance. \*.txt files contain the data to produce the figure 4E in the main text.

(4) Figure 4F: Calculated cross-sections of the autocorrelation function along *y*-direction of the wavevector maps and the exponential fitting in small distance. \*.txt files contain the data to produce the figure 4F in the main text.

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Figure S1:

Schematic image to show the experimental setup for optical ruler metrology. No associated data.

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Figure S2:

(1) Figure S2A: Calculated intensity maps of the superoscillatory field at a distance of ~10µm from the metasurface at different noise level of the detector: 0% (column 1), 5% (column 2), 10% (column 3), and 20% (column 4). The \*.tif files are used to produce the figures in figure S2A.

(2) Figure S2B: Calculated wavevector maps at different noise level of the detector based on the intensity data in Figure S2A. The \*.tif files are used to produce the figures in figure S2B.

(3) Figure S2C: Calculated autocorrelation curves at different noise level of the detector based on the wavevector data in Figure S2B. The \*.txt files contain the data to produce the figures in figure S2C.

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