Quantitative 3D phase imaging of plasmonic measurfaces

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Coherence-controlled holographic microscopy (CCHM) is a real-time, wide-field, and quantitative light microscopy technique enabling 3D imaging of electromagnetic fields, providing complete information about both their intensity and phase. These attributes make CCHM a promising candidate for performance assessment of phase-altering metasurfaces, a new class of artificial materials that allow manipulating the wavefront of passing light and thus providing unprecedented functionalities in optics and nanophotonics.

In our study, we report on our investigation of phase imaging of plasmonic metasurfaces using holographic microscopy. We demonstrate its ability to obtain phase information from the whole field of view in a single measurement on a prototypical sample consisting of silver nanodisc arrays (left panel in the figure below). The experimental data were validated using FDTD simulations and a theoretical model that relates the obtained phase image to the optical response of metamaterial building blocks. Finally, in order to reveal the full potential of CCHM, we employed it in the analysis of a simple metasurface represented by a plasmonic zone plate. By scanning the sample along the optical axis we were able to create a quantitative 3D phase map of fields transmitted through the zone plate. 3D visualization of the measured total phase distribution in the half-space above the plasmonic zone plate formed by alternating rings of silver plasmonic discs with two different plasmon resonance energies is shown in the right panel of the figure below. The presented results prove that CCHM is inherently suited to the task of metasurface characterization. Moreover, as the temporal resolution is limited only by the camera framerate, it can be even applied in analysis of actively tunable metamaterials.

State-of-the-art techniques for the phase imaging are in general inferior to CCHM: First, ellipsometry provides a poor lateral resolution and involves troublesome inverse analysis. Second, scanning near-field optical microscopy is inherently slow, difficult to use in some in-situ studies, and its spectral window is currently limited to the infrared region. Third, currently-available interferometric techniques, among other things, suffer from their inability to characterize more than one spot of the sample at a time. CCHM has none of these limitations and as such presents a considerable progress for the quantitative phase imaging in the important and vivid field of photonic metasurfaces and other optical systems.

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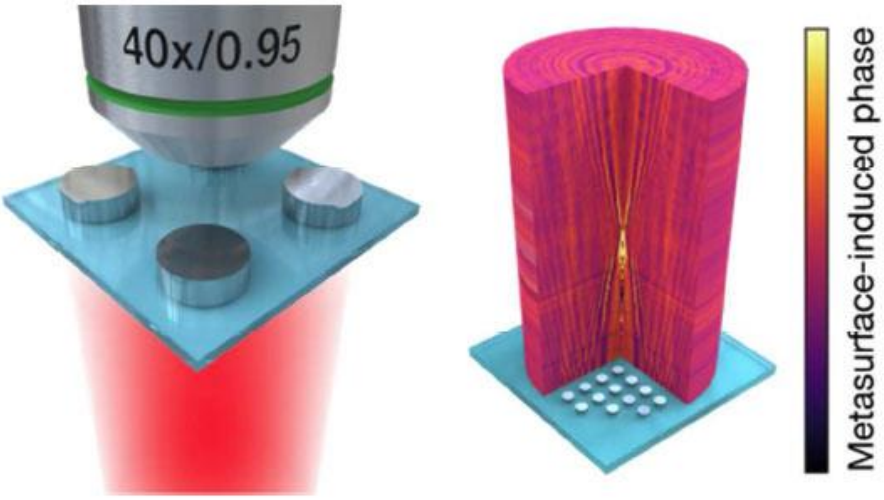
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Metasurface-induced phase