Electron-beam-driven Metasurface Holographic Light Sources

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We report on the experimental demonstration of a flexible approach to the generation of optical radiation with prescribed wavelength, direction, divergence and topological charge, induced by the injection of free-electrons into holographic plasmonic metasurfaces. Appropriately structured gold surfaces produce visible/near-infrared light (including high-order vortex beams) at selected wavelengths in prescribed azimuthal and polar directions, with brightness up to two orders of magnitude higher than from an unstructured surface. We show further that several emitters to be closely integrated such that optical output can be spatially and spectrally modulated by a scanning electron beam.

The control of energy transfer and conversion, in particular the generation of light, in nano-scale systems is a technological challenge of great and growing importance. Recent advances in the understanding of light generation via free-electron proximity and impact interactions with nanostructured materials have enabled the development of nanoscale-resolution techniques for such applications as mapping surface plasmon modes, studying structural transformations in nanoparticles, and characterizing the dynamics properties of luminescent nano-materials. Here we experimentally demonstrate individual and interlaced arrays of selectively addressable free-electron-driven light sources based upon holographic surface structures.

For a given desired far-field output wavefront, the requisite surface structure is obtained interferometrically using the near-field distribution of divergent broadband emission emanating from the impact point of an electron beam on a surface as the reference beam. Designs are fabricated by focused ion beam milling in optically thick gold films, and probed in a scanning electron microscope (operating with a fixed spot of ~50 nm diameter, electron energy of 30 keV, and beam current ~10 nA) equipped with angle-resolved electron-induced radiation emission imaging capability.

Sources are engineered for near-infrared plane-wave and vortex (up to topological charge l = 10) output beams at prescribed output angles. We observe minimal cross-talk between holographic elements: the emission from a second mask overlapping a given target mask being attenuated by 3 dB relative to the target hologram when their centres are offset by only 12.5% of their diameter. Several independent sources can thus be interlaced over a given surface area, such that a scanning electron beam may sequentially or selectively target individual emitters to rapidly modulate the optical output signal over the half-spherical field of view.

With micron-scale dimensions and the freedom to fully control radiation parameters, holographic free-electron light sources offer novel applications in nano-spectroscopy, nano-chemistry and sensing, across a broad range of electron energies and target materials.