Metamaterial Light Sources Driven by Electron Beams

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Abstract: We demonstrate a new generation of free-space and fibre-coupled tuneable light sources based on nanostructured photonic metamaterials driven by free-electrons beams. Emission wavelengths are determined by metamaterial resonant modes and electron energies.

The development of nanoscale light (ultimately laser) and surface plasmon ('spaser') sources for numerous potential nanophotonic applications is currently pursued with considerable effort. We report here on an experimental demonstration of the fact that free-electrons interacting with planar photonic metamaterials can induce emission of light at wavelengths determined by the metamaterial design parameters.

The structures used in our experiments were arrays of asymmetrically-split ring (ASR) resonators, which support *collective* trapped-mode plasmonic resonances. The rings were milled by focused ion-beam through ~70nm of gold evaporated either on Si_3N_4 membranes or directly onto the cross-sectional faces of optical fibres. The metamaterials were excited using a scanning electron microscope employing beam trajectories both perpendicular and parallel to the metamaterial surfaces, as illustrated in Fig. 1.

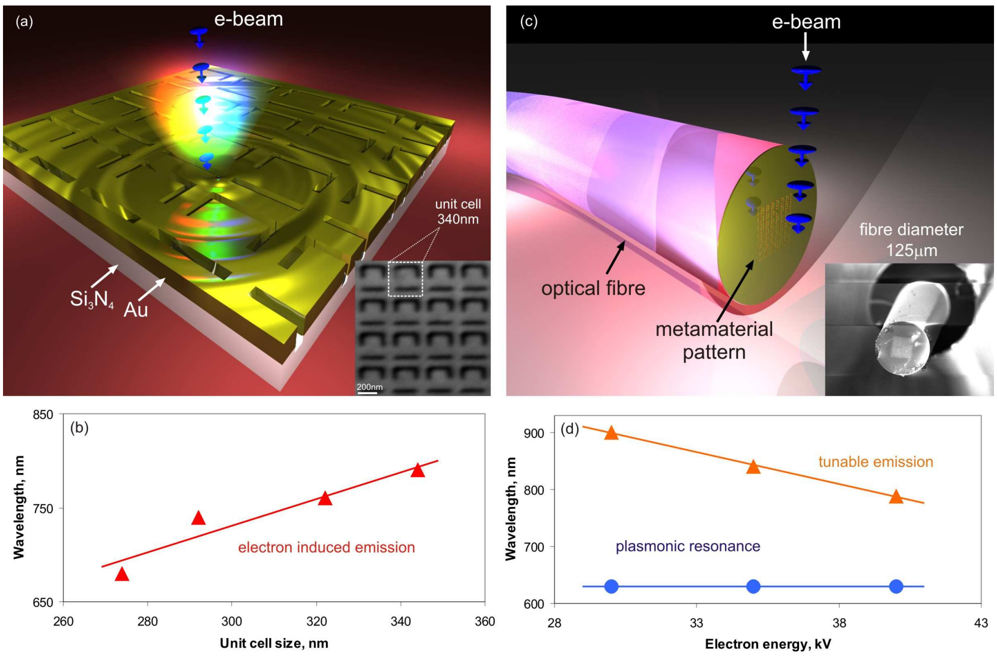

Fig. 1*: (a) Gold ASR metamaterial on a Si_3N_4 membrane excited by normally incident electrons; (b) Wavelength of electron-induced emission as a function of metamaterial unit cell size for the configuration shown in (a); (c) Fibre-coupled gold ASR array excited by electrons with a trajectory parallel to the metamaterial surface; (d) Wavelength of electron-induced emission (unit cell size ~300 nm) as a function of electron acceleration voltage for plasmonic resonance and tuneable emission modes excited in the configuration shown in (c).*

The free electrons excite the plasmonic modes of the metamaterial structures, which subsequently decouple to light waves propagating out of the metamaterial plane. Emitted light is collected for spectroscopic analysis either using a parabolic mirror located directly above the sample, or via the optical fibre.

In summary, we show that low energy beams of free-electrons can excite the collective plasmonic modes of planar photonic metamaterial arrays, thereby driving resonant light emission at wavelengths determined by the structural design parameters of the metamaterial, which may be adjusted for operation across the visible to IR range and beyond.