Coherent control of nanoscale light localization: creating and positioning isolated sub-wavelength energy hot-spots

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We suggest a new paradigm for achieving prescribed localization of optical energy with nanoscale accuracy. Well isolated energy hot-spots as small as λ/10 can be created and positioned at the chosen meta-molecules on the metamaterial landscape.

In 2002, a method was suggested that based on tailoring phase modulation of ultrashort optical pulses in the time domain to achieve the spatial distribution of the excitation energy in complex nano-systems [1]. Here, in our new approach to control the prescribed optical energy localization, does not depend on a transient redistribution of energy between nano-objects and may be implemented with *continuous coherent optical sources*, making pulse excitation unnecessary. Implementation of the method requires only widely available instrumentation (a spatial light modulator and a continuous laser) that can be retrofitted to a conventional microscope. Moreover, it does not require the nanoscale system to be spatially inhomogeneous (such as a rough surface) and works with periodic, regular planar array of identical plasmonic resonators opening the opportunities for *microscopy, lithography and data storage applications* which will be discussed below. It is based on tailoring the spatial variation of the phase in the driving far-field to achieve the prescribed coherent control of localization and depends on the strong interactions between individual plasmonic resonators. This idea has a clear mechanical analogy in two coupled identical oscillators (modelling plasmonic resonators) that may be driven to vastly different amplitudes by setting up a phase delay between otherwise identical coherent mechanical forces driving them. We demonstrate this approach in a planar metamaterial, a two-dimensional array of nanoscale subwavelength meta-molecules excited by turns with spatially phase-modulated optical beam. We show that the near-field energy can be concentrated at chosen meta-molecules while a group of neighbouring meta-molecules remain unexcited. Now by simply adjusting the far-field spatial profile of the excitation beam, the nanoscale hot-spot can be moved between the chosen meta-molecules on the metamaterial landscape. We demonstrate that controllable nanoscale localization of optical energy can be achieved at an artificial nanostructured metamaterial surface, an array of altimetrically split-ring plasmonic resonators when such structure is illuminated with a coherent continuous light wave (a laser) those spatial variation of the phase at the metamaterial plane can be tailored.

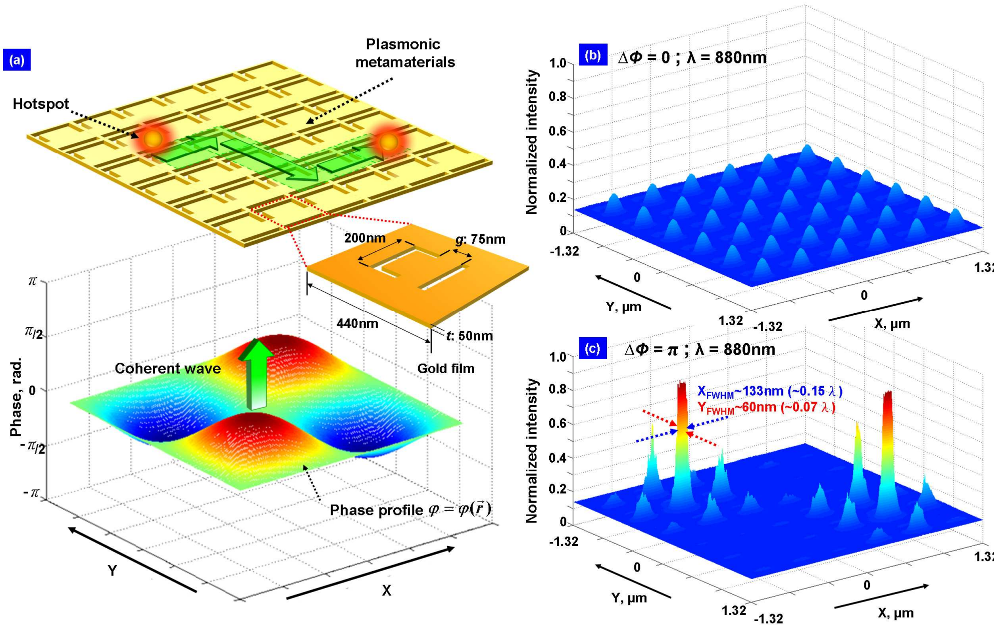

Figure 1. (a) A schematic diagram of the gold split-ring metamaterial and the applied sinusoidal phase profile of the incident wave. The wavelength of incident wave is 880nm and the maximum phase difference is denoted as $\Delta\varphi_{max}$. In (b) the applied phase is flat ($\Delta\varphi_{max} = 0$), and the energy distribution is homogeneous across different unit cells. With a large phase difference $\Delta\varphi_{max} = \pi$, the energy is concentrated in only a few of the unit cells, giving strongly localised peaks (c).

Reference

[1] M. I. Stockman *et al.*, Phys. Rev. Lett. 88, 067402 (2002).