Fishing for Carbon Nanotubes with a Photonic Metamaterial Net

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Abstract: We experimentally demonstrate that plasmonic metamaterials can optically harvest single-walled carbon nanotubes from colloidal suspension. We investigate whether this phenomenon could provide a new technique for nanotube purification via plasmon–exciton resonance interactions.

A plasmonic metamaterial film on the tip of an optical fibre immersed in a colloidal suspension of carbon nanotubes (CNTs) efficiently collects a deposit of nanotubes when the metamaterial is illuminated with laser light through the fibre (Fig. 1a). It has recently been shown that photonic metamaterials provide a unique platform for manipulating optical forces on the nanoscale [1] and the present effect is driven by near-field interactions between the carbon nanotubes and the localized plasmonic modes of the metamaterial. We consider that within this effect, interactions between metamaterial plasmonic and CNT excitonic resonances may facilitate a new technique for selective refinement of CNTs.

The metamaterials structures employed here were fabricated by focused ion beam milling in 50 nm gold films deposited on cleaved end faces of single-mode optical fibres. They comprise periodic square arrays of asymmetric split ring slits supporting a collective Fano-type resonsnce in the near-infrared range. Semidonducting CNTs (commercially synthesized using the electric discharge method and suspended in water with ionic sufactants) were utilized in dilute concentraions of order 10 µg/ml. The metamaterial was illuminated using a 1550 nm laser diode with reflected power being monitored via an optical circulator as an indicator of CNT coating density.

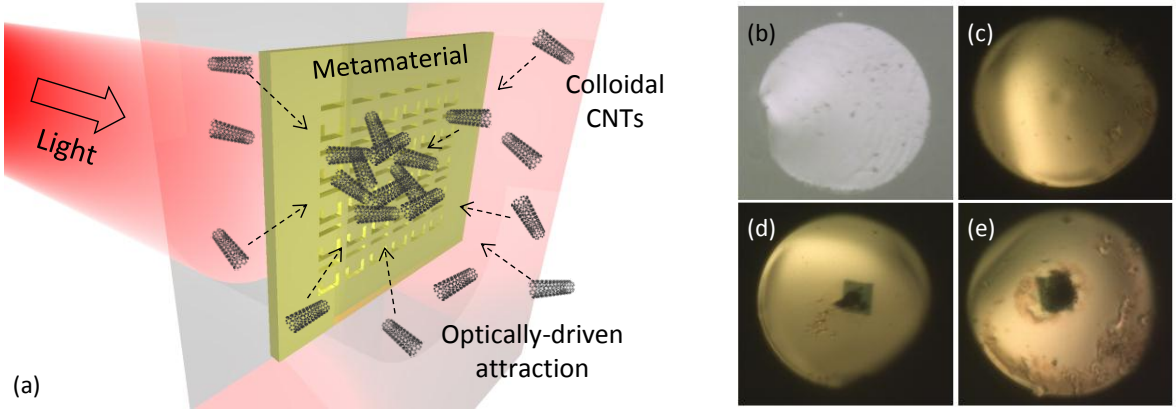

Figure 1: (a) Artisitic impression of optically-driven carbon nanotube harvesting from suspension by a photonic metamaterial. (b-e) Optical microscope images of fibre end faces after laser excitation in CNT suspension: (a) Bare cleaved fibre at 5 mW laser power; (b) Fibre coated with unstructured 50 nm gold flat film at 5 mW; (c, d) Metamaterials on fibre cores at 5 and 20 mW respectively.

Figures 1b-e show optical microscope images of fibre/metamaterial samples after 20 minutes in the CNT suspension at laser excitation levels of 5 and 20 mW, alongside images of bare fibre and unstructured gold film control samples subjected to the same procedure. In the latter two cases not CNTs are deposited on the fibre tip but on resonantly illuminated metamaterial samples, where the strucutre generates strong local fields and attractive near-field optical and thermo-diffusive forces [2], CNTs are deposited on the fibre core area to a density that increases with time and laser power.

References:

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