Metamaterial Coherent Plasmonic Absorption With a Single Photon

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Abstract: With a plasmonic metamaterial absorber of sub-wavelength thickness we demonstrated that coherent absorption can be observed even with a single photon that could be coupled with nearly 100% probability into a localized plasmon.

Recent studies provided unexpected but strong evidence that the quantum properties of light are conserved when photons are converted into surface plasmon polaritons, paving the way for active and ultrafast quantum plasmonic technologies [1]. At the same time, many technologies like photovoltaics [2] or photocatalysis, depend on the absorption of light. Nanostructured "perfect absorber" metamaterials and textured surfaces have been developed to facilitate absorption.
Recently, coherent perfect absorption (CPA) from a standing wave has been shown to deliver either nearly total absorption or full transmission of the incident light, depending on the mutual phase of α and β beams, see Fig. 1 a) [3]. However, the quantum nature of this process has not yet been explored. Here we report an investigation into the CPA process using single photons from spontaneous parametric down conversion and a plasmonic metamaterial absorber.

In the experiment a single photon is launched into a Sagnac interferometer via a lossless 50/50 beam-splitter and it generates a coherent superposition state of probability wavefunctions at the metamaterial film. The metamaterial absorber is a free-standing 50nm thick gold film, perforated with an array of asymmetric split ring structures, which provide the desired optical properties congruent with CPA.
With a single photon entering the device at a time, we observe periodic oscillation in the output photon count rate as the phase shift between two input channels changes. The overall modulation was measured to be between 90% and 10%, as shown in Fig.1b).

In conclusion, we show that, while absorption of photons from a travelling wave is probabilistic, standing wave absorption can be deterministic, with nearly unitary probability of coupling a single quantum of light into a single localised plasmon mode.

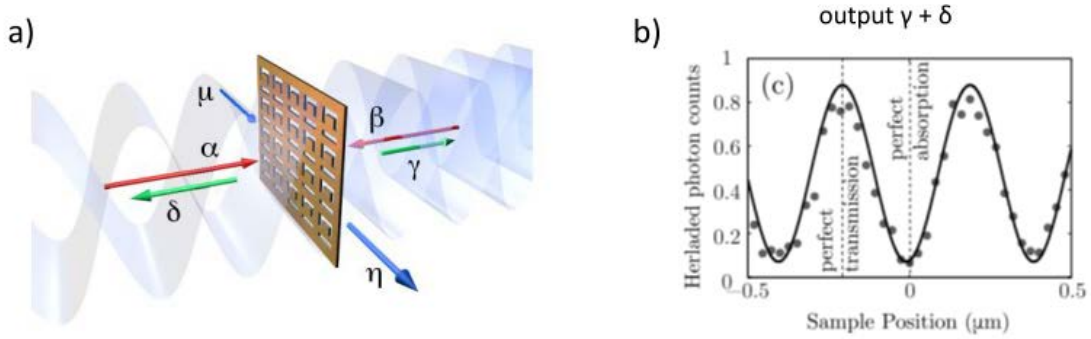

Figure 1. a) Schematics of the CPA process. b) Total output photon count rates in channels γ and δ, normalised to the input photon count rates in channels α and β as functions of the metamaterial absorbers position along the single photons (probability wavefunction) standing wave.

References:

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