“Remote Control” of coherent light absorption with entangled photons

Charles Altuzarra[1,2], **Stefano Vezzoli**[1], **Joao Valente**[3],
Cesare Soci[1], **Daniele Faccio**[4], **Christophe Couteau**[1,2,5], **and Nikolay I. Zheludev**[1,3].
[1]Centre for Disruptive Photonic Technologies, Nanyang Technological University, 637371, Singapore
[2]CINTRA, CNRS-NTU-Thales, CNRS UMI 3288, Singapore
[3]Optoelectronics Research Centre and Centre for Photonic Metamaterials,
University of Southampton, Southampton, UK
[4]Institute for Photonics and Quantum Sciences and SUPA, Heriot-Watt University, Edinburgh EH14 4AS, UK
[5]Laboratory for Nanotechnology, Instrumentation and Optics, ICD CNRS UMR 6281,
University of Technology of Troyes, Troyes, France
Author e-mail address: charles003@e.ntu.edu.sg

Abstract: Using a source of entangled photons we show that polarization-sensitive detection of the photons can be used to switch “on” and “off” absorption of the other photon in a thin plasmonic metamaterial film.

OCIS codes: (160.3918) Metamaterials; (240.6680) Surface plasmons; (310.6628) Subwavelength structures, nanostructures; (120.3180) Interferometry; (270.0270) Quantum optics; (030.1670) Coherent optical effects; (130.4815) Optical switching devices;

Plasmonic metamaterials have great potential for building devices that can control and manipulate light at the nanoscale. To this extent the field of quantum plasmonics has focused in large part on the conservation of quantum states of light upon conversion of photons into plasmons. Recent findings include conservation of entanglement in plasmonic nanohole arrays and observation of two photon/plasmon interference in plasmonic waveguides.

More recently, we have shown coherent perfect absorption of single photons using the interference of path entangled single photons in a plasmonic perfect absorber. This implies that a single photon can be absorbed into a single plasmon with nearly 100% probability.

Here we show the first experimental demonstration of controlling coherent absorption of a plasmonic metamaterial remotely by acting on the polarization of entangled photon pairs. By introducing one of the entangled photons in an interferometer, we demonstrate that by measuring the polarization state of its twin photon, we can nonlocally control absorption and plasmon generation in the metamaterial absorber.

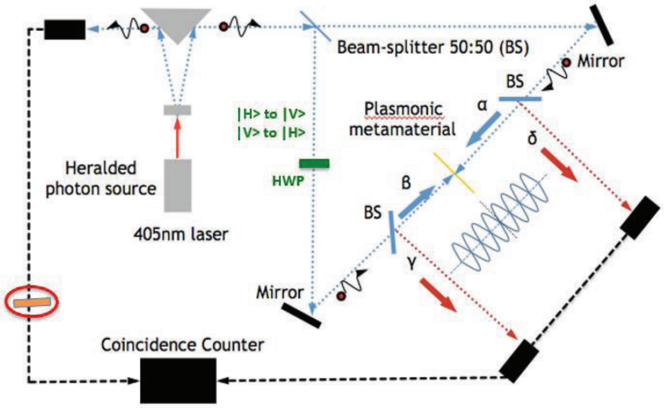

Fig.1 - Entangled photon pairs are generated. One of the photons of each pairs goes into an interferometer while the other photons are used to nonlocally control coherent absorption at a metamaterial. The coincidences between the nonlocal photons and the photons at the output of the interferometer are measured.

978-1-943580-11-8/16/$31.00 ©2016 Optical Society of America

The experimental scheme in Figure 1 shows polarization entangled photon pair generation by spontaneous parametric down conversion (SPDC) of a pump laser (continuous wave, 405 nm) in a β barium borate (BBO) crystal. One of the photons of each pair is injected into an interferometer where it interferes at the location of the metamaterial. The other photon of the pair is measured outside the interferometer. Coherent perfect absorption relies on placing a subwavelength absorptive material with 50% absorption at the node of the field in the standing wave created by interference of the two optical paths. In our case the absorptive material consists of a nanostructure fabricated on a subwavelength thick freestanding layer of gold and tailored to be 50% absorptive for both horizontal and vertical polarizations at the wavelength of the entangled photons.

Figure 2a shows the visibility of entanglement in the horizontal-vertical (HV) and +45 and -45 (+/-45) bases. A bell parameter of $2.657 > 2$ is measured, confirming the entanglement photon pairs. Measurements of coherent perfect absorption performed with one of the entangled photons are shown in Figure 2b. In the 45 basis set (blue dots) we have observed the characteristic behavior of coherent perfect absorption where absorption can be modulated by positioning the sample in the node or antinode of the field of the standing wave. However, in the H or V basis set coherent perfect absorption can be inhibited by making a measurement on the nonlocal photons of the entangled pairs. This proves remote control of photon absorption and plasmon generation.

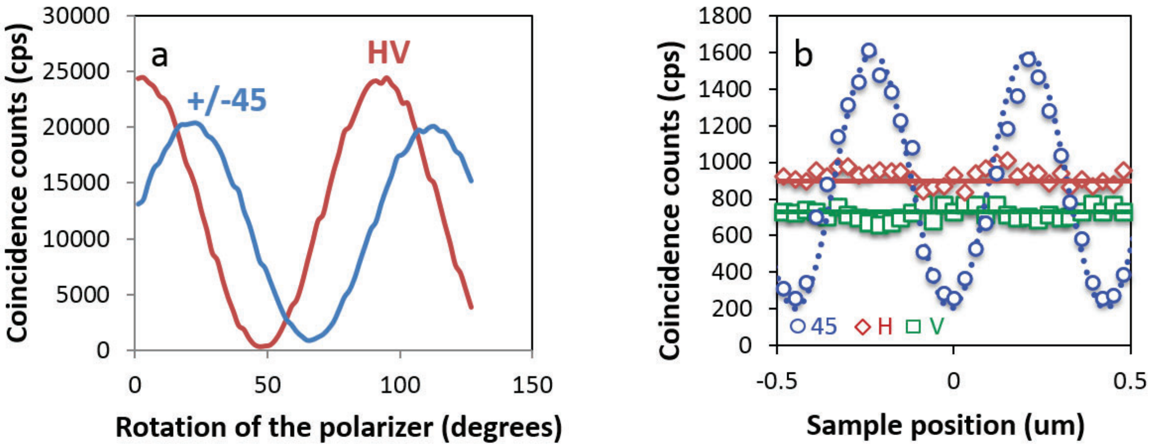

Fig. 2 – (a) Visibility bell measurements on the photon pairs satisfy the conditions for quantum states of light ($2.657 > 2$). (b) Measurement at the output of the interferometer with nonlocal control of plasmonic absorption by measuring specific polarization states.

In conclusion, we demonstrated an experimental implementation of nonlocal control of coherent absorption by using polarization entangled photon pairs. The measurement on the nonlocal photons defines the absorption and dissipation of light in the metallic metamaterial nanostructure. This first demonstration of a nonlocal quantum plasmonic switch opens up new opportunities for quantum gating in quantum computation.