MAR17-2016-030214

Abstract for an Invited Paper
for the MAR17 Meeting of
the American Physical Society

Generation of entangled photon states in nonlinear nanostructures and metamaterials

ALEXANDER PODDUBNY, ITMO University Ioffe Institute, St. Petersburg, Russia

Entangled photon states are promising for quantum computing, cryptography and metrology. While room temperature quantum interference of light on a chip has been recently demonstrated, the light generation still relied on external bulk nonlinear crystals [1]. The practical development of compact and robust nonlinear quantum circuits calls for a versatile toolbox which can fully describe the generation and detection of entangled photons and plasmons. Here, we present theoretical and experimental results on entangled photon pair generation and sum-frequency generation in complex nonlinear nanostructures.

We formulate a general theoretical framework of integrated paired photon-plasmon generation through spontaneous wave mixing in nonlinear plasmonic and metamaterial nanostructures, rigorously accounting for material dispersion and losses in the quantum regime through the electromagnetic Green function [2]. As a specific application of our approach we design nonlinear metal/ dielectric plasmonic structures and predict photon-plasmon correlations with 70% internal heralding quantum efficiency. We reveal a novel mechanism of generation enhancement in a multi-layered metal-dielectric metamaterial, originating from the broadband phase synchronism at the topological transition to the hyperbolic dispersion regime. Next, we prove a general quantum-classical reciprocity relation between the spontaneous parametric down-conversion (SPDC) in an arbitrary nonlinear structure and the reverse sum frequency generation process. We formulate a quantum process tomography protocol to determine a biphoton state produced via SPDC by using only classical measurements. The classical reconstruction of amplitude and phase of biphoton wavefunction has been experimentally verified in a multi-channel integrated nonlinear waveguide array [3].

[1] J.S. Fakonas, H. Lee, Y.A. Kelaita and H.A. Atwater, Nature Photonics 8, 317 (2014).
[2] A. N. Poddubny, I.V. Iorsh, and A.A. Sukhorukov, Phys. Rev. Lett. 117, 123901 (2016).
[3] F. Lenzini, A.N. Poddubny, J. Titchener, P. Fisher, A. Boes, S. Kasture, B. Haylock, M. Villa, A. Mitchell, A. S. Solntsev, A.A. Sukhorukov, and M. Lobino, in preparation (2017).