Nonlinear AlGaAs nanoantennas for sum-frequency light and heralded photons generation

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We demonstrate experimentally the generation of heralded photons with non-classical correlations via spontaneous parametric down-conversion in AlGaAs nanodisks. A quantum-classical correspondence establishes the AlGaAs nanoresonators as nanoscale nonlinear sources of efficient sum-frequency and difference frequency conversion. Nanoscale nonlinear sources have recently attracted great interest for classical and quantum applications, due to the possibility of enhanced wavelength mixing at the nano-scale [1]. In this context, an important role is played by all-dielectric and semiconductor resonant nonlinear nanophotonics, where optical interactions between magnetic and electric resonances at the subwavelength scale enable high figures of merit due to low losses and high directionality [1, 2]. It was shown that AlGaAs nanodisks can provide high efficiency of the second-harmonic generation (SHG) of the order of 10^{-4},10^{-5} [2,3]. These record-high figures open a wide range of possible applications, including nonlinear imaging and holography [4]. In this work, we show experimentally that the strong quadratic nonlinearity in AlGaAs nanodisks allows for sum-frequency generation (SFG) with nontrivial polarization dependencies (Fig. 1a,b,c), and high biphoton generation rate (Fig. 1d,e) with strong non-classical polarization and angular correlations. By using the classical-quantum analogy between SFG and spontaneous parametric down-conversion (SPDC) [5], the experimental rate can be compared with predictions. The integrated generation of heralded photon pairs through SPDC was measured with a rate in the range of 30 Hz [see Fig. 2(b)]. If we normalize such rate to the generation volume, we obtain a figure of merit 100 times higher than record SPDC on-chip sources [6]. Our calculations predict that optimized structures could dramatically improve the SPDC rate and suggest that nonlinearity at the nanoscale can be employed for efficient generation of quantum states.

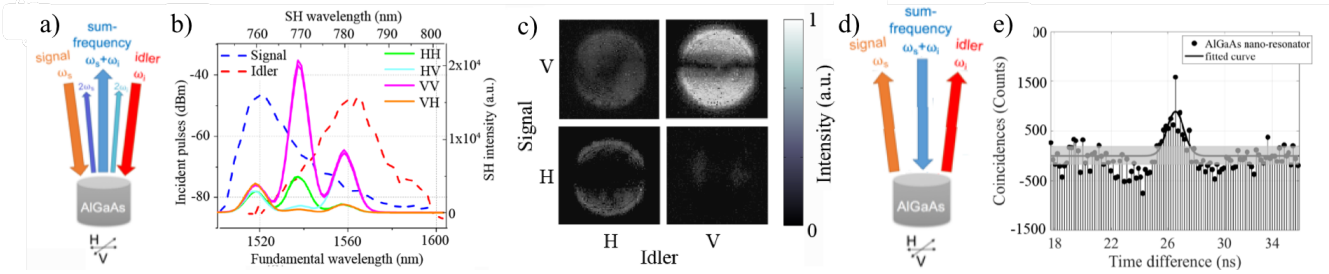

Figure 1: (a) Schematic of SFG with signal and idler beams in an [100] AlGaAs nano-resonator. The horizontal (H) and vertical (V) polarization axes are parallel to the crystalline axes of the AlGaAs lattice. (b) AlGaAs nano-resonator SFG reflection spectra at 770 nm and signal / idler SHG spectra at 760 / 780 nm; the plot shows 4 combinations of H and V polarizations of signal and idler beams, respectively. (c) SFG directionality diagrams for the polarization combinations shown in (b) (d) Schematic of SPDC with signal and idler beams in an [100] AlGaAs nano-resonator. (e) Coincidence rate of the photon pairs generated via SPDC vs the time difference between the arrival of signal and idler photons to the single-photon detectors.

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