Shaping the Wavefront of Entangled Photons

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Quantum technologies hold great promise for revolutionizing future photonic applications, such as cryptography, spectroscopy, sensing and imaging. Yet their implementation in real world scenarios is still held back, mostly due to the fragile nature of quantum states of light. In many such applications, photons are sent through dynamically changing medium, such as Earth's atmosphere, which degrades the system performance due to scattering and aberrations [1,2]. Over the past few years, several approaches have been demonstrated for undoing the effect of scattering of single and entangled photons, by directly shaping their spatial distribution [3-6]. Here we demonstrate an alternative approach, where rather than shaping the entangled photons directly, we tailor their correlations by shaping the wavefront of the bright classical pump beam that stimulates their generation, via spontaneous parametric down conversion (SPDC) (fig 1a). We show that even though the wavelength of the pump beam is half the wavelength of the entangled photons, they scatter by the diffuser at the exact same way, and therefore yield the same random spatial distributions, coined speckle patterns (fig 1b,c). The identical patterns of the pump speckle and the two-photon speckle indicate that shaping the pump beam yields identically shaped spatial correlations of the entangled photons. Thus, by focusing the pump beam using classical wavefront shaping optimization, the two-photon speckle is simultaneously focused (fig 1d). Since the entire optimization process is done on the classical pump beam, the optimization efficiency and its speed are identical to those of standard wavefront shaping techniques. Specifically, the optimization is not limited by the low signal-to-noise ratios (SNR) associated with quantum-light signals, allowing us to demonstrate, for the first time, focusing of spatial correlation of entangled photons passing through a dynamically moving diffuser (figure 1e).

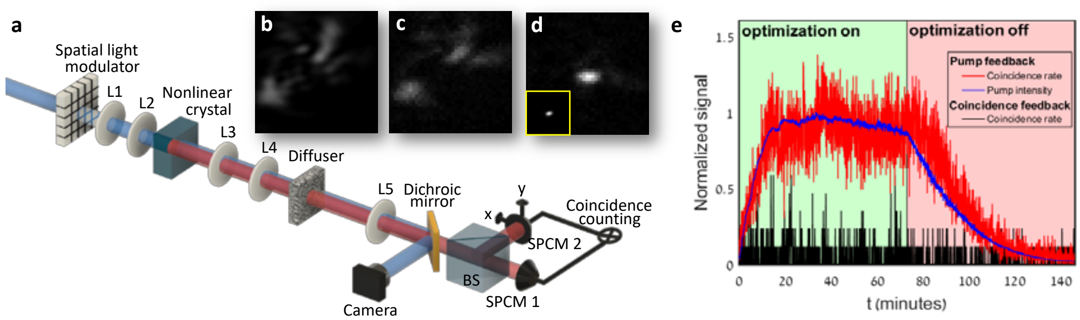

Figure 1. (a) Spatially entangled photons are created by pumping a PPKTP crystal with a 404nm continues-wave laser. Both the pump beam and SPDC light pass through a diffuser, which is placed at the image plane of the crystal and of the SLM planes, and measured in the far-field. The pump beam and SPDC light pass through the same diffuser, forming identical speckle patterns in the intensity (b) and coincidence (c) patterns, respectively. By using classical wavefront shaping on the incident pump beam, a single speckle grain is enhanced (inset of panel d), causing an enhancement of the quantum correlations at the desired area as well (d). Since the efficiency of the optimization is identical to the efficiency of classical wavefront shaping, we were able to demonstrate real-time optimization for a moving diffuser, resulting in an enhanced signal of the intensity measured at the focused spot (blue curve) and of the corresponding two-photon coincidence signal (red curve). The black curve shows that the optimization does not work if the coincidence signal is used for the optimization feedback, since coincidence SNR is too low for direct optimization.

References

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