Preservation of quantum entanglement in transmission through metallic films

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We study the robustness of quantum entanglement in transmission through a thin, planar gold film and compare the results with these obtained with periodic array of subwavelength metallic nanostructures. This is done in order to investigate the need of plasmonic resonances for survival of quantum entanglement. At normal incidence, the transmission coefficient is not a function of polarization and we demonstrate theoretically and experimentally that entanglement is preserved also with the continuous metallic film.

We studied the survival of quantum entanglement after the interaction of polarization-entangled photons with a flat, thin film of gold and a nanostructured metallic film, in function of the angle of incidence. We used two identical type-I BBO-crystals with orthogonal orientations to produce the near-infrared polarization-entangled photon pairs. Photons are produced by the process of parametric downconversion inside the crystals. The sample is placed through one single path among the two possible optical paths of degenerate photons pairs. Furthermore, in order to perform a polarization measurement, we place one quarter waveplate and one half waveplates in front of a polarizing beamsplitter along each optical path. Photons are finally detected with four single-photon counting modules and coincidences are recorded using a field-programmable gate array coincidence counter. We used the code developed by Paul Kwiat's quantum information group [1] to realise quantum tomography of the polarization-entangled photons with and without the sample, in order to determine the quantum state of the pairs before and after their interaction with the thin gold film. With this estimation of the quantum state, we evaluated different quantum features of the system, like the entanglement of formation, the experimental state fidelity with respect to the maximally entangled Bell state theoretically produced, and with the state obtained without the sample.

As shown in the literature, nanostructured metallic films enable coupling of light with localized surface plasmons which leads to enhanced transmission at resonance [2-4] and preservation of entanglement[5,6]. The result of our experiment is in line with literature.

Our experimental and theoretical results on flat gold films show that, at normal incidence, coincidence counting decrease with the introduction of the sample. However, the sample does not affect the entanglement because the polarization of transmitted photons is left unchanged. When increasing the angle of incidence, the difference between transmission coefficients for s and p polarizations becomes different from zero and causes a decrease of entanglement, as the sample starts to behave as a partially polarizing device. In comparison to nanostructured samples, our results on the flat, thin film of gold indicate that the interaction with surface plasmons at resonance only improves the rate of the correlation detection but the plasmonic excitations are not responsible for survival of entanglement.

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