Scattering of classical and quantum states of light with angular momentum by dielectric micro/nanoresonators

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The angular momentum of photons[1] affects the interaction between a beam of light and a dielectric particle acting as an optical micro/nanoresonator, which introduces new possibilities to manipulate optical information (encoded in the angular momentum) at very small scales and to gain information about the particle. In this contribution, we discuss some of these possibilities for illumination with classical and quantum states of light.

We consider as resonators dielectric spherical particles of radius ≈250nm-5μm illuminated by light with zero total angular momentum but with spin angular momentum [2]. The projection of the latter into the direction of propagation of the beam gives the helicity Λ. We first study theoretically and experimentally the backscattering of a classical beam with Λ=1 by a micrometer-sized particle. The strength of the backscattering shows a complex and fast dependency on the frequency of the illumination laser. This complex behaviour can be explained by decomposing the backscattered light into the components with helicity Λ=1 and Λ=-1. We show that the Λ=-1 component exhibits spectrally-fast oscillations that are induced by interferences between the multiplicity of higher order modes of the nanoresonator. Theoretical calculations using Mie's theory are in very good agreement with the experimental results. Further, we discuss how the observed response introduces a new tool to characterize the spherical resonators, as indicated by a simple analytical equation that connects the periodicity of the oscillations with the size and dielectric constant of the spherical nanoparticle.

We then consider pulsed illumination of spherical nanoresonators of radius ≈250nm by the two-photon entangled state $|\Psi_+^i >= \phi\,[|+>|+> + |-> |->]$, where ϕ defines the envelop and frequency of the incident pulse and $|+>$ and $|->$ corresponds to one-photon states of helicity Λ=1 and Λ=-1, respectively. Due to the spherical symmetry of the nanoresonator, the scattered radiation can be decomposed into two well-defined output states which, for quantum information purposes, should retain a high degree of purity. Recent experiments, however, indicate that this is not always the case [3]. We analyse the loss of purity induced by the scattering process and show that it can be neglibible for adequately chosen conditions. However, it can also become significant when the illumination excites two (or more) spectrally-narrow optical resonances of the nanoresonator. We explain this result by a simple analytical model that shows that the frequency-dependence of the optical response induces a time delay and a frequency shift between the two output states, which results in the undesired loss of purity. Minimizing this effect when engineering the optical response of the nanoresonators is important for quantum information applications.

References

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