Quantum Physics

Two-photon speckle as a probe of multi-dimensional entanglement

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We calculate the statistical distribution P_2(I_2) of the speckle pattern produced by a photon pair current I_2 transmitted through a random medium, and compare with the single-photon speckle distribution P_1 (I_1). We show that the purity Tr rho^2 of a two-photon density matrix rho can be directly extracted from the first two moments of P_1 and P_2. A one-to-one relationship is derived between P_1 and P_2 if the photon pair is in an M-dimensional entangled pure state. For M>>1 the single-photon speckle disappears, while the two-photon speckle acquires an exponential distribution. The exponential distribution transforms into a Gaussian if the quantum entanglement is degraded to a classical correlation of M>>1 two-photon states. Two-photon speckle can therefore discriminate between multi-dimensional quantum and classical correlations.

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