How 'quantum' is the free radiation field?

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Abstract
In the past two decades there has been important progress in the development of stochastic electrodynamics as a foundation for quantum mechanics [1]. Based on the hypothesis of the zero-point electromagnetic radiation field in permanent interaction with (otherwise classical) matter, the theory is able to reproduce, under minor additional conditions, both the Schrödinger and the Heisenberg formalism. Characteristic quantum features, such as entangled states, the spin of the electron and the corresponding spin-symmetry connection, are explained as a result of this interaction, which has a marked effect on both matter and field. This line of work has allowed us to establish contact with (nonrelativistic) quantum electrodynamics, as exemplified by the correct prediction of atomic radiative corrections, without the burden of infinities.

In this talk we take the theory one step further and establish contact between stochastic electrodynamics and quantum optics. A related line of work was initiated four decades ago by T. H. Boyer [2], and E. Santos [3], leading to what is called stochastic optics [4]. The purpose of their approach was to offer realistic explanations consistent with experiment, using a formalism in terms of a stochastic c-number field instead of non-commuting field amplitudes. Experiments designed to observe both the wave and the corpuscular properties of light were subject to a heuristic description from the standpoint of stochastic optics, by incorporating the zero-point field to produce qualitative changes in the behavior of the entire (field+setup) system with respect to the classical (with no zero-point field) counterpart. A review of the related literature shows considerable success in explaining qualitatively the wave and particle behavior of light signals, yet a finer analysis shows discrepancies with the observed results.

The approach followed in this talk takes us back to the original idea of adding the zero-point field to a given external radiation field and comparing the statistical properties of the combined field with those provided by quantum optics. We use the simplest approach possible in order to establish a clear comparison between the SED and the quantum results without losing sight of the underlying physics. Two specific cases are studied in detail: the coherent state and the squeezed state of light. Besides showing a striking coincidence of results between the two treatments when properly carried out, this exercise has the value of attesting the relative simplicity and physical transparency of the stochastic treatment in comparison with the quantum one, and of throwing some light on the meaning of the possible variations produced by the detection process.