

Quantum Physics

An Introduction to the Quantum Theory of Nonlinear Optics

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This article provides an introduction to the quantum theory of optics in nonlinear dielectric media. We begin with a short summary of the classical theory of nonlinear optics, that is nonlinear optics done with classical fields. We then discuss the canonical formalism for fields and its quantization. This is applied to quantizing the electromagnetic field in free space. The definition of a nonclassical state of the electromagnetic field is presented, and several examples are examined. This is followed by a brief introduction to entanglement in the context of field modes. The next task is the quantization of the electromagnetic field in an inhomogeneous, linear dielectric medium. Before going on to field quantization in nonlinear media, we discuss a number of commonly employed phenomenological models for quantum nonlinear optical processes. We then quantize the field in both nondispersive and dispersive nonlinear media. Flaws in the most commonly used methods of accomplishing this task are pointed out and discussed. Once the quantization has been completed, it is used to study a multimode theory of parametric down conversion and the propagation of quantum solitons.

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