Interpretation of self-field quantum electrodynamics

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The remarks in the preceding Comment by M. D. Crisp [Phys. Rev. A **43**, 4058 (1991)] do not really apply to self-field quantum electrodynamics.

The approach to quantum electrodynamics (QED) based on nonlinear self-field equations for the electron's ψ field, obtained by eliminating the electromagnetic field A_μ, has its own complete interpretation. It is a deterministic field theory. Crisp[1] makes statements taken from standard practice of probabilistic quantum theory that are irrelevant to our formulation. These points have been discussed in detail in Refs. 1–6 and 11 cited by Crisp in Ref. 1. Here, in brief, are our responses.

(1) In the self-field QED, $\psi(\mathbf{r},t)$ in Eq. (1) of Ref. 1 is a complex wave field, not a normalized probability amplitude, which can *surely* be expanded in a Fourier series. In fact Fourier expansion is the standard tool in any wave theory. We then give definite physical meaning to coefficients $\psi_n(\mathbf{r})$ that satisfy coupled nonlinear equations. Schrödinger already recognized very early that the most important features of an atomic field and external disturbance are their Fourier coefficients.[2]

(2) The sum $\sum_n$ in Eq. (2) of Ref. 1 is, in general, over a continuous spectrum; there are no discrete eigenvalues because the natural linewidths are included. Thus the remarks about "limited selection of frequencies" is incorrect. It is not clear how Crisp gets this idea.

(3) Expansion equation (2), which Crisp suggests and uses, on the other hand, refers to standard superposition of stationary states with coefficients having the interpretation of probability amplitudes. In expansion equation (2) of Ref. 1 the unperturbed functions ψ_n are picked as the basis, and the coefficients adopt to it. In our expansion [Eq. (1) of Ref. 1] the frequencies are picked as the basis, and the coefficients adjust to it. Expansion (2) is never used in a classical wave theory. Crisp himself has pointed out[3] the difficulty of interpreting the coefficients c_n used in expansion (2) in the context of his neoclassical theory, which is related to our approach.

(4) The expansion (1) of Ref. 1 is over real values of E_n. What is complex is the calculated energy shift ΔE in first order of iteration of the S matrix. It is well known that in the S-matrix formulation, which we use, the decaying states correspond to complex poles. Our E_n are not "eigenstates of a Hermitian operator," nor did we state so. Put in other words, an isolated atomic system with the self-field included is a dissipative system because of spontaneous emission;[4] hence its energy cannot be represented by a Hermitian operator. Again it is well known in wave theory that certain frequencies become complex due to instability and describe growing or decaying modes.

Having answered these four "technical" remarks, we agree, concerning the last section of the author, that our use of the word "illegal" superposition referring to his original works, Ref. 5, was wrong and we apologize. What we meant is that for a nonlinear equation the superposition of solutions of the linear equation for this particular problem is not the method of maximum "efficacy," the adjective suggested by Crisp. Efficacy of a formalism is to be decided in part by the soundness and interpretability of the results obtained. We believe our approach is such a theory.

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[4]A. O. Barut, Found. Phys. **17**, 549 (1987).
[5]M. D. Crisp and E. T. Jaynes, Phys. Rev. **179**, 1253 (1969).

