Deconstructing the vertex *Ansatz* in three-dimensional quantum electrodynamics

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We consider the problem of designing an *Ansatz* for the fermion-photon vertex function, using three-dimensional quantum electrodynamics as a test case. In many existing studies, restrictions have been placed on the form of the vertex *Ansatz* by making the unsubstantiated assumption that in the quenched, massless limit the Landau gauge Dyson-Schwinger equations admit a trivial solution. We demonstrate, without recourse to this assumption, the existence of a nonlocal gauge in which the fermion propagator is the bare propagator. This result is used to provide a viable *Ansatz* for part of the vertex function. [S0556-2821(98)00220-3]

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I. INTRODUCTION

Dyson-Schwinger equations (DSEs) provide a viable method for studying the nonperturbative behavior of field theories. In gauge field theories in particular, a common technique is to analyze the fermion propagator by truncating the infinite tower of DSEs at the level of the propagator DSEs. One then implements an intelligent *Ansatz* for the gauge boson propagator and boson-fermion vertex function [1].

For quantum electrodynamics in either three (QED3) or four (QED4) dimensions, there has for some years now been an ongoing program of improving the *Ansatz* for the fermion-photon vertex [2–6]. A principal goal of this program is to invent an *Ansatz* which respects the gauge covariance of Green's functions in accordance with the transformation properties discovered by Landau and Khalatnikov (LK) [7].

It has traditionally been common practice in DSE studies of QED3 or QED4 to assume, either implicitly or explicitly, that in the quenched (i.e. $N_f \to 0$), massless limit, the DSEs admit the trivial solution of bare fermion propagator and bare vertex in Landau gauge [2–5,8,9]. In the case of QED4, this assumption has recently been questioned by Bashir *et al.* [6], who use the one-loop perturbative correction to the vertex [10] to model an unknown additional transverse part of the vertex.

In this paper we explore the problem of constructing a viable vertex *Ansatz* for the case of QED3, without recourse to the above simplifying assumption. We choose to work with QED3 rather than its four dimensional counterpart because its benign ultraviolet properties render the integrals we encounter finite, obviating the need for awkward numerical regularizations. The four component version of massless QED3 which we consider here has an interesting chiral-like U(2) symmetry which, if dynamically broken, leads to dynamical mass generation. The evidence from both DSE and lattice calculations, suggest that this is almost certainly the case, at least for small numbers of fermion flavors [11]. Here, however, we shall be considering the chirally symmetric solutions, which must also respect the LK transformations, and can therefore be used to place restrictions on the allowed form of the vertex *Ansatz*.

We shall demonstrate the existence of a gauge in which massless QED3 admits a bare fermion propagator solution, though this may not be Landau gauge, even in the quenched case. The vertex function decomposes into two parts, an in principle known part which reduces to the bare vertex in the gauge mentioned, and an extra, unknown transverse part. By studying the gauge parameter dependence of the photon polarization scalar, we construct a computationally viable vertex *Ansatz* for the first of these two parts.

The massless fermion DSE for QED3 in Euclidean momentum space is

$$1 = i\gamma\cdot pS(p) + e^2 \int \frac{d^3q}{(2\pi)^3} D_{\mu\nu}(p-q) \times \gamma_\mu S(q)\Gamma_\nu(q,p)S(p), \tag{1.1}$$

where the Euclidean γ matrices satisfy $\{\gamma_\mu,\gamma_\nu\} = 2\delta_{\mu\nu}$. $D_{\mu\nu}$ is the photon propagator which, for the class of covariant, nonlocal gauges and for N_f fermion flavors takes the form

$$D_{\mu\nu}(k) = \frac{1}{1+N_f\Pi(k^2)} D^{\mathrm{T}}_{\mu\nu}(k) - k_\mu k_\nu \Delta(k^2), \tag{1.2}$$

where

$$D^{\mathrm{T}}_{\mu\nu}(k) = \frac{1}{k^2}\left(\delta_{\mu\nu} - \frac{k_\mu k_\nu}{k^2}\right). \tag{1.3}$$

The gauge choice

$$\Delta(k^2) = -\frac{\xi}{k^4}, \tag{1.4}$$

with ξ constant, defines the usual covariant gauge. The regulated photon polarization scalar [12] is given by

