First Order phase transition in Maxwell-Chern-Simon QED$_3$ in covariant gauge

Yuichi Hoshino,Tomohiro Inagaki,Yuichi Mizutani
Kushiro National College of Technlogy,Hiroshima University

October 19, 2013

Abstract

We study the first order phase transition which is caused by tiny value of the Chern-Simon term above which the chiral order parameter vanishes and parity violating phase remain in three dimensional QED with Chern-Simon term.

1 Introduction

IN 1995 Kondo and Maris discussed the parity violating effects of Chern-Simon term in three dimensional QED with Chern-Simon term in Dyson-Schwinger equation with four component fermion and non-local gauge.They argued that there exists critcal value of Chern-Simon coefficetnt θ_c above which the chiral order parameter vanishes and parity violating phase remains.Below the critical value θ_c chiral symmetry and parity are both broken.In 2011 Raya and his coworkers tried this problem in the Laddar Landau gauge.They obtained the value about $\theta_c = .008e^2$.In the gauge covariant approximation which satisfy Ward-Takahashi identity we would like to solve this problem and test the gauge invariance of the results .

2 results

We adopted the Ball-Chiu ansatz for the vertex which satisfy Ward-Takahashi identity for the vertex function and the fermion propagator.

$$(p-q)_\mu \Gamma_\mu(p,q) = S^{-1}(q) - S^{-1}(p). \tag{1}$$

Simplest solution of this equation was given by Ball,Chiu(1980).Assuming the following form of the vertex function

$$\Gamma^L_\mu(p,q) = a(p,q)\gamma_\mu + b(p,q)(p+q)\cdot\gamma(p+q)_\mu - c(p,q)(p+q)_\mu, \tag{2}$$

Their solution is given

$$\Gamma_\mu^L(p,q) = \frac{A(p)+A(q)}{2}\gamma_\mu + \frac{A(p)-A(q)}{2(p^2-q^2)}(p+q)\cdot\gamma(p+q)_\mu$$
$$- \frac{B(p)-B(q)}{p^2-q^2}(p+q)_\mu. \tag{3}$$

We apply these to the Dyson-Schwinger equation in Euclidean space

$$D_{\mu\nu}^{-1}(p) = D_{0,\mu\nu}^{-1}(p) - Z_1 e^2 \int \frac{d^3q}{(2\pi)^3} Tr[\gamma_\mu S(q)\Gamma_\nu(q,k)S(k)], \tag{4}$$
$$S^{-1}(p) = S_0^{-1}(p) + Z_1 e^2 \int \frac{d^3q}{(2\pi)^3}\gamma_\mu S(q)\Gamma_\nu(q,p)D_{0,\mu\nu}(k), \tag{5}$$

with $k_\mu = (q-p)_\mu$.The general form of the dressed fermion propagator $S(p,\xi)$ and the photon propagator $D_{\mu\nu}(p,\xi)$ with massless loop correction is given by

$$S(p,\xi) = \frac{i\gamma\cdot pA(p,\xi)+B(p,\xi)}{p^2A^2(p,\xi)+B^2(p,\xi)},$$
$$D_{\mu\nu}(p,\xi) = (\delta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2})D^T(p) - \frac{\epsilon_{\mu\nu\rho}p_\rho}{p^2}D^O(p) + \xi\frac{p_\mu p_\nu}{p^4}$$
$$D^T(p) = \frac{p^2+c|p|}{(p^2+c|p|)^2+\theta^2p^2}, D^O(p) = \frac{\theta p^2}{(p^2+c|p|)^2+\theta^2p^2},$$

where c is a vacuum polarization function for massless loop $\Pi^T(p) = e^2/8|p|$,$c = e^2/8, D^O(p)$ is a parity odd part of the photon propagator.There is a nice explanation about gauge covariant approximation and the Ball,Chiu type vertex function in Ref[1].Fortunately we find the resonable solution of Dyson-Schwinger equation in which the discontinuity of the chiral order parameter $\langle\bar{\psi}\psi\rangle$ at θ_c indicates first order phase transion in quenched Landau gauge and the case with screening effect by massless fermion loop which was first analysed by Kondo and Maris.The value of θ_c is about $\theta_c \simeq .01e^2$ in both cases.At present we could not get the final answer for the BC vetex by round off error comes from third terms in $\Gamma_\mu^{BC}(p,q)$. Detailed results may be shown in[4].

3 References

[1] C.S.Fischer,R. Alkofer,T, Dahm, and P.Maris,Phys.Rev.**D70**:073007,(2004).
[2] K.I Kondo,P.Maris,Phys.Rev.Lett.74(1995)18-21,Phys.Rev.D52(1995)1212-1233.
[3]S.S.Madrigal,C.P.Hofman,A.Raya,J.Phys.Conf.Ser.287:01208,2011.
[4] Y.Hoshino,T.Inagaki,Y.Mizutani in preparation.