Color-Coulomb string tension in the confinement and deconfinement phases

Y. Nakagawa, A. Nakamura[1], T. Saito and H. Toki,
Research Center for Nuclear Physics, Osaka Univ. Ibaraki, Osaka 567-004, Japan
[1]Institute for Information Science and Education, Hiroshima University, Higashi-Hiroshima 739-8521, Japan

We have investigated the scaling behavior of the color-Coulomb string tension in the confinement and deconfinement phases using quenched $SU(3)$ lattice gauge simulations[1, 2]. The color-Coulomb potential, defined by the Faddeev-Popov operator, is an important quantity in discussing the confinement scenario in Coulomb gauge, and also from a phenomenological point of view. We have confirmed the scaling behavior of the instantaneous color-Coulomb string tension in the confinement and deconfinement phases.

In the confinement phase, the instantaneous color-Coulomb potential behaves as a linearly rising potential at large distances. As a consequence, there exists the non-vanishing color-Coulomb string tension for several coupling constants (β's) investigated in this work, the values of which are approximately 2 times as large as that of the Wilson loop string tensions. The variation of color-Coulomb string tension on the lattice cutoff is also found to be small. These results are qualitatively consistent with those obtained by the same analysis in the $SU(2)$ lattice calculations in Ref. [3]. Note that if one employs gluon propagators to extract the instantaneous part, then the value of the color-Coulomb string tension tends to become smaller than that obtained from the Polyakov loop correlator.

Even in the deconfinement phase, it is observed that the color-Coulomb string tension remains finite. This may be an acceptable result because the instantaneous part is constructed in terms of the Faddeev-Popov matrix with the derivative operator in the spatial direction; i.e., the instantaneous part is not sensitive to the system temperature. Nevertheless, we should also note that the thermal fluctuation to the vacuum polarization still produces a color-screened dynamics.

It is found that the thermal behavior of the color-Coulomb string tension is understood by assuming the magnetic scaling, $\sim g^2(T)T$, which is actually identified as an infrared regulator or a pole mass of the spatial gluon propagator. If this is a possible interpretation, then we can mention the following two points. Firstly, we conclude that the color-Coulomb string tension in the deconfinement phase is a kind of the thermal quantity and survives in the high temperature limit as being the same as the case of the spatial Wilson loop. Secondly, because the magnetic scaling originates in the infrared sensitivity of the thermal QCD, in the case of Coulomb gauge, the instantaneous part of the gluon propagators reveals such infrared behavior.

In the Coulomb gauge confinement scenario discussed by Gribov and Zwanziger [4], the linearity of the instantaneous part for large quark separations is conjectured to be ascribed to a singularity emerging from the gauge configurations with a low-lying eigenvalue of the Faddeev-Popov operator. Hence, it is an important task that the distribution of the eigenvalues of the Faddeev-Popov operator in Coulomb gauge is investigated by the lattice simulation. The $SU(3)$ lattice study along this line is also being undertaken.

In the present work, we focused the calculation of the instantaneous part only and did not deal with the vacuum polarization (retarded) part, being of little significance in the view of understanding color confinement in Coulomb gauge. However, the vital change concerning the QGP phase transition seems to be relevant to the vacuum polarization part, a role of which ought to be discussed in a subsequent study.

In a phenomenological point of view, it is interesting that there remains the thermal string tension. If this is regarded as the indication that confining features survive above the critical temperature, then this observation may provide some insight into understanding the strongly correlated QGP. It has been tried the description of equation of state in the quasiparticle model with the dispersion relation of Gribov type. However, in other cases, it is not obvious how the confining property in the thermal phase affects physical spectroscopy. Nevertheless, in Coulomb gauge, it is significant that these findings are achieved by classifying the time-time gluon propagator into the instantaneous and non-instantaneous parts.

The simulations were performed on SX-5(NEC) vector-parallel computer at the RCNP of Osaka University.

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