Structure of the baryonic flux tube in $N_f = 2$ lattice QCD at finite temperature. *

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We study the flux tube profile in the baryonic system in full QCD at finite temperature on $N_t = 8$ lattice. We fix the maximally Abelian gauge and measure the monopole and the photon parts of the Abelian action density, the color electric field and the monopole current on both sides of the finite temperature transition. We demonstrate the disappearance of the flux tube in the high temperature phase.

1. INTRODUCTION

Lattice studies of the baryonic system consisting of three static quarks (3Q) are important for clarification of the baryon structure. Recently there appeared a number of papers devoted to the studies of the 3Q system at zero temperature [1,2,3,4]. It was concluded that the flux tube has a Y-shape, at least at large distances.

In this paper, we study the flux tube profile in the baryonic system in full QCD at finite temperature on $N_t = 8$ lattice. We fix the maximally Abelian gauge and measure the monopole and the photon parts of the Abelian action density, the color electric field and the monopole current on both sides of the finite temperature transition. We demonstrate the disappearance of the flux tube in the high temperature phase.

2. SIMULATION DETAILS

To study QCD with dynamical quarks we consider $N_f = 2$ flavors of degenerate quarks, using the Wilson gauge field action and non-perturbatively $O(a)$ improved Wilson fermions [5]. Configurations are generated on the $16^3 \times 8$ lattice at $\beta = 5.2$, $0.1330 \leq \kappa \leq 0.1360$, corresponding to temperatures below and above the finite temperature transition at $\kappa T = 0.1344$ ($T_c = 213(10)$ MeV) [6]. Details of the simulation can be found in [9]. We fixed the maximally Abelian (MA) gauge on generated configurations employing the simulated annealing algorithm [6]. The Abelian projection procedure [10] defines the diagonal link matrices

\[ u(s, \mu) = \text{diag}\{u_1(s, \mu), u_2(s, \mu), u_3(s, \mu)\}, \]

\[ u_1(s, \mu) = e^{i \theta_1(s, \mu)}. \]

*Talk given by Y. Mori. at Lattice’03.
We study the Abelian action density
\[ \rho_{ab}(s) = \frac{\beta}{3} \sum_{\mu > \nu} \sum_l u_l(s, \mu \nu), \]  
(1)
where \( u_l(s, \mu \nu) \) is the Abelian plaquette variable,
the Abelian color electric field
\[ E_l(s, j) = i \bar{\theta}_l(s, j 4), \]
(2)
where \( \bar{\theta}_l(s, \mu \nu) \) is the regular part of the
Abelian plaquette angle, \( \theta_l(s, \mu \nu) = \bar{\theta}_l(s, \mu \nu) + 2\pi n_l(s, \mu \nu) \), and the monopole current
\[ k_l(s, \mu) = -\frac{i}{4\pi} \epsilon_{\mu \rho \sigma} \partial_\rho \bar{\theta}_l(s + \hat{\mu}, \rho \sigma). \]
(3)
Correlators with the baryonic source are defined as follows:
\[ \langle \rho_{ab}(s) \rangle_{3Q} = \frac{\langle \rho_{ab}(s) P_{3Q} \rangle}{\langle P_{3Q} \rangle}, \]
(4)
where
\[ P_{3Q} = \frac{1}{3!} |\epsilon_{lmn}| P_l(\vec{s}_1) P_m(\vec{s}_2) P_n(\vec{s}_3) \]
(5)
\[ P_l(\vec{s}) = \prod_{t=1}^{N_t} u_l(\vec{s}, t, 4), \]
\[ \langle E(s, j) \rangle_{3q} = \frac{\langle \frac{1}{4!} |\epsilon_{lmn}| E_l(s, j) P_l(\vec{s}_1) P_m(\vec{s}_2) P_n(\vec{s}_3) \rangle}{\langle P_{3Q} \rangle}, \]
(6)
\[ \langle k(s, j) \rangle_{3q} = \frac{\langle \frac{1}{4!} |\epsilon_{lmn}| k_l(s, j) P_l(\vec{s}_1) P_m(\vec{s}_2) P_n(\vec{s}_3) \rangle}{\langle P_{3Q} \rangle}. \]
(7)

The Abelian field can be decomposed into the monopole and photon parts, and the monopole and photon observables can be defined similarly to eqs. 1-3.

3. NUMERICAL RESULTS

First we discuss the structure of the baryonic flux tube in the confinement phase. Fig. 1 shows the monopole and photon parts of the color electric field at \( T/T_c = 0.87 \). The color index of the color electric field (see eq. (6)) coincides with that of the topmost quark (top row) or of the leftmost quark (bottom row).

The same conclusions can be drawn from the Fig. 2 where the distribution of the monopole and photon parts of the action density is depicted. Fig. 3 shows the monopole
Monopole current (right), obtained from the monopole component of the Abelian gauge field at $T/T_c = 0.87$. One can see circulating monopole currents around the color electric field in each slice. In the plane where the color electric field is divided into two parts, the circulating monopole current is not a perfect circle anymore. This indicates a possibility of forming two circulating currents if the distance between quarks would be made larger.

Next, we show how the profile of the flux tube changes when the temperature increases and crosses over to the high temperature phase. From Fig. 4 one can see that the squeezed color electric field (the monopole component) disappear at $T > T_c$. In contrast, the photon component of the color electric field, depicted in Fig. 4(right), does not show any essential changes when the temperature increases.

ACKNOWLEDGEMENTS

This work is supported by the SR8000 Supercomputer Project of High Energy Accelerator Research Organization (KEK). A part of numerical measurements has been done using NEC SX-5 at RCNP of Osaka University. T.S. is partially supported by JSPS Grant-in-Aid for Scientific Research on Priority Areas No.13135210 and (B) No.15340073. The Moscow group is partially supported by RFBR grants 02-02-17308, 01-02-17456, 00-15-96-786, grants INTAS–00-00111.

Figure 3. Monopole current (right), obtained from the monopole component of the Abelian gauge field at $T/T_c = 0.87$

Figure 4. Evolution of the color electric field (monopole component) with temperature.

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