Lattice calculations of QCD color-dependent forces

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Nonperturbative study of color QCD forces between static quarks is important for understanding quark confinement and hadron phenomenology. The behavior of a heavy-quark potential that is defined by the closed gauge-invariant Wilson loop, has been studied extensively in lattice simulations; the heavy-quark potential is a linearly rising potential, which can be explained with the Coulomb term and the linear term with the string tension. In most previous studies of heavy-quark potentials, a color singlet channel, which yields a physical potential, has been investigated. There are, however, several other color channels between two quarks. According to the $SU(3)$ color decomposition for a quark-antiquark sector $q\bar{q}$, $3 \otimes \bar{3} = 1 \oplus 8$. The octet channel is significant for the extensive analysis of J/ψ photoproduction [1, 2]. Furthermore, we have $3 \otimes 3 = \bar{3} \oplus 6$ for a quark-quark sector qq, and in particular, the antisymmetric qq channel plays an essential role in the phenomenology of penta-quark hadrons [3, 4], in which the existence of a highly correlated diquark is assumed [4]. Since the usual Wilson loop cannot give the color-decomposed potentials separately, the lattice study along this line was considered as very difficult.

In this report, we study the behavior of the color-decomposed $q\bar{q}$ and qq potentials at zero temperature in the quenched $SU(3)$ lattice gauge simulation. Numerical results of the color decomposed potentials are displayed in Fig. 1. It is shown that the antisymmetric qq channel behaves as a linearly rising potential at large quark separations. We further find that the $q\bar{q}$ octet and qq symmetric channels have the complex dependence on the distance; at short distances they are repulsive forces, while at large distances, they show linearly rising feature. Ratio of string tensions between $q\bar{q}$ singlet and qq antisymmetric potentials is described in terms of the Casimir factor.

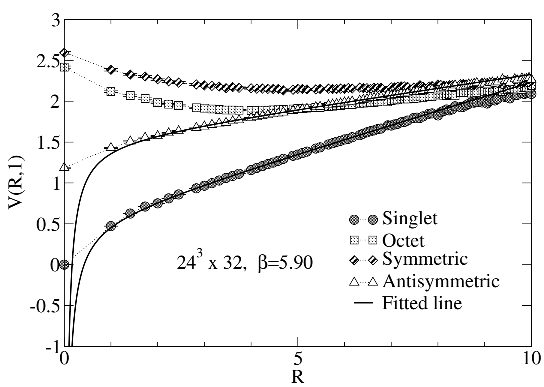

Figure 1: Singlet and octet potentials for $q\bar{q}$ sector and symmetric and antisymmetric potentials for qq sector. The solid curves represent the fitted results for the two attractive channels. The $\hat{R}$ with physical dimension is set as $\hat{R} = aR$ where the lattice cutoff a is approximately $0.124 fm$ for this lattice simulation.

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

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