Violation of non-Abelian Bianchi identity and Abelian monopoles without gauge-fixing

T. Suzuki [1], M. Hasegawa[2] and K. Ishiguro[3]

[1] *Professor Emeritus, Kanazawa University, Kanazawa 920-1192, Japan*

[2] *Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna, Moscow 141980, Russia*

[3] *Integrated Information Center, Kochi University, Kochi 780-8520, Japan*

Bonati et al. [1] have proved an interesting relation that the Abelian monopole is given by the violation of non-Abelian Bianchi identity (VNABI). Abelian monopoles extracted naively without performing any gauge-fixing are shown to be equivalent to VNABI coming from the singularity of non-Abelian gauge fields themselves [2]. In this report we study the properties of Abelian monopoles without gauge-fixing numerically.

We perform Monte-Carlo simulations based on the first principle calculation of QCD without any gauge-fixing. We generate configurations for the SU(2) quenched Iwasaki gauge action [3]. The parameters are listed in the table 1.

β	lattice spacing [fm]	Volume	# of conf.
1.10	0.1068(8)	$16^3 \times 48$	19515
1.28	$6.35(5) \times 10^{-2}$	$24^3 \times 72$	6812
1.40	$4.65(2) \times 10^{-2}$	$24^3 \times 72$	6927

Table 1: SU(2) quenched Iwasaki gauge action

First, we estimate the scalar mass as a glueball defined by VNABI by computations of correlation functions of gauge invariant operator $J^\mu(s)J_\mu(s)$. $J_\mu(s)$ is VNABI, and it is defined by as follows,

$$J_\mu(s) = \frac{1}{2} J_\mu^a(s)\sigma^a, \tag{1}$$

$$J_\mu^a(s) = (1/2)\epsilon_{\mu\alpha\beta\gamma}\partial_\alpha n_{\beta\gamma}^a(s+\hat{\mu}). \tag{2}$$

A color component $J_\mu^a(s)$ of the lattice VNABI is integer. This corresponds to the Dirac quantization condition between electric and magnetic charges. The eq.(2) leads us to the Abelian conservation rule: $\partial'_\mu J_\mu^a(s) = 0$, and $\partial'_\mu J_\mu(s) = 0$. The scalar mass M_g is computed by the correlation functions of the operators,

$$\mathrm{Z}\exp(-M_g\Delta t) \sim \left\langle \sum_{\vec{x}}\sum_{\vec{x}'} \mathcal{O}(\vec{x},t)\mathcal{O}(\vec{x}',t') \right\rangle - \left\langle \sum_{\vec{x}} \mathcal{O}(\vec{x},t) \right\rangle^2. \tag{3}$$

Here $\mathcal{O}(s) \equiv J^\mu(s)J_\mu(s)$ is gauge invariant scalar operator, and $\Delta t = |t-t'|$.

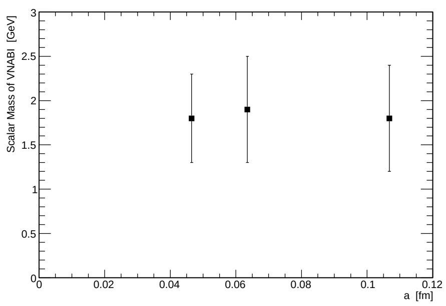

Figure 1: The scalar mass defined by VNABI vs lattice spacing.

We evaluate the scalar mass by fitting a single exponential function $\mathrm{F}(x) = \mathrm{B}\exp(-\mathrm{M}_g x) + \mathrm{C}$ to the correlation function of $J^\mu(s)J_\mu(s)$. The number of configurations used for this analysis are from 500 to 1000. Figure 1 shows the preliminary results. The masses of three β still have large errors, but the results show the scaling behavior within error bars.

The numerical simulations of this work were done using RSCC computer clusters in RIKEN and SX-8, SX-9 and PC clusters at RCNP and CMC of Osaka University. The authors would like to thank RCNP and CMC for their support of computer facilities. M. H. would like to thank the Kanazawa University for their hospitality.

References

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