Large gauge hierarchy in gauge-Higgs unification

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We study a nonsupersymmetric five dimensional $SU(3)$ gauge theory on $M^4 \times S^1/Z_2$ and discuss the possibility to realize the large gauge hierarchy in the scenario of the gauge-Higgs unification.

In the gauge-Higgs unification, the Higgs field corresponds to the Wilson line phases, which are nonlocal quantities. Due to the nonlocality, there is a remarkable feature in the gauge-Higgs unification, *that is*, the Higgs potential induced at the quantum level does not suffer from ultraviolet effects. Accordingly, the Higgs mass obtained from the effective potential is finite. The Higgs potential and the mass are calculable. That is why the gauge-Higgs unification can provide us with a natural framework to address the gauge hierarchy problem.

We find two models, in which the large gauge hierarchy can be realized. In order to point out the essential point, let us suppose that the effective potential is given by

$$V = -A\phi^2 + B\phi^4 + D\phi^4 \ln\left(\phi^2/M_c^2\right), \tag{1}$$

where M_c is related with the compactification scale, $M_c = L^{-1} = (2\pi R)^{-1}$. We notice that in the gauge-Higgs unification, the coefficients in the effective potential are given by the discrete values in terms of the flavor number. This is a remarkable feature hardly observed in the usual quantum field theory.

- Model I is given by setting $A = 0$ in Eq. (1). The potential minimum is given by

$$\langle\phi\rangle \simeq M_c \exp\left(-\frac{B}{2D} - \frac{1}{4}\right).$$

We observe that if $B/D \sim 3 \times 4\pi^2 \gg 1$, the large gauge hierarchy is naturally achieved. Let us note that the vanishing mass term, $A = 0$ is not the fine tuning of the parameter, but just the choice of the flavor set of the massless bulk matter.

- Model II is given by the case where the mass term is given by

$$A \simeq \langle\phi\rangle \simeq \mathrm{e}^{-2\pi RM}.$$

Here, M is the bulk mass of massive fermions. Since the magnitude of $\langle\phi\rangle$ is controlled by the mass term in the effective potential, we can have the large gauge hierarchy for the appropriate large values of $2\pi RM \simeq 30 \sim 40$.

In the paper (hep-th/0609067), we have shown the examples of the flavor set to realize the large gauge hierarchy in the two models and also discussed the size of the Higgs mass in each model. In the model I, the Higgs mass is inevitably smaller than than the massive vector bosons, while in the model II, we can obtain the consistent Higgs mass with the experimental lower bound, and show that the Higgs mass becomes heavier as the compactified scale is smaller.