外国語要旨

学位論文題目：The Lattice Approach to Five Dimensional Gauge Theories
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The aim of the particle physics is to reveal fundamental particles and their interactions. The Standard Model (SM) of particle physics explains the interactions between fundamental particles well and is consistent with experimental results so far. However, more fundamental theory is considered to exist because SM still has some problems. A variety of theories such as String theory, Super Symmetric theory, Extra-dimensional theory so on are studied as beyond the SM. In this thesis, I explain a study of 5-dimensional theory which is one of the Extra-dimensional theories. The goal of this study is to find out whether there is Spontaneous Symmetry Breaking (SSB) and dimensional reduction in non-perturbative region of 5-dimensional pure $SU(2)$ lattice gauge theory for orbifold. This study has done by Mean-Field expansion and Monte Calro simulation.

5-dimensional gauge theories are being studied well as extensions of SM. 5-dimensional theories here mean the theory of one time dimension and four spatial dimensions. We can only perceive one time dimension and three spatial dimensions and still we can consider one extra dimension existing in a way we cannot recognize. The motivations of considering 5-dimensional theory are that the quadratic divergence of Higgs mass which is one of the problem of SM can be avoided and that the origin of Higgs field is explained by identifying Higgs field with some of the 5th components of gauge field. This identification is called Gauge-Higgs Unification (GHU). Higgs field can cause SSB and particles obtain masses. Many perturbative studies of GHU model have been done. However the perturbative study can deal with only weak coupling region. Therefore, I have done the non-perturbative study by using lattice gauge theory in the case that the 5th dimension has orbifold boundary conditions. Mean-Field study indicates that SSB occurs with orbifold but not with torus boundary conditions. The parameters of the model are the size of 5th-dimension N, the lattice coupling β and anisotropy parameter γ. The parameter γ shows the difference of the scale size (lattice spacing) between 5th dimension and other dimensions. When $\gamma > 1$, the scale along 5th dimension is larger than other dimensions.

The lattice gauge theory is the gauge theory defined on discretized space-time. The physical observables are obtained by taking continuum limit if it exist. Otherwise an effective theory for finite lattice spacing might exist. The advantage of the lattice gauge theory is that it can study large parameter region and can introduce gauge invariant cut-off.

From the Mean-Field study, I will show that the static potential along 4-dimensional hyperplane on the orbifold boundary is 4-dimensional Yukawa potential and gauge boson mass can be extracted from the potential. This means there is SSB and the result is different from the one of perturbative study in which fermions are needed for SSB. I also found that there is dimensional reduction to 4-dimensional gauge-scalar theory near the phase transition. Higgs boson mass which is consistent with the experimental result is easily obtained. This is also the difference with perturbative study where Higgs boson mass tends to be too small. Moreover, there is 2nd order phase transition lines for $\gamma < 0.6$ and one can take a continuum limit which does not depend on ultraviolet cut-off in this region. I show that taking the continuum limit around $\gamma = 0.5$. I can get the 1st excited Z boson mass around 1 TeV. Although the convergence of Mean-Field expansion has to be verified, the Monte Calro study also shows that there is SSB and confirms Mean-Field study.

The advantage of this model is that it has only three parameters and at least in the Mean-Field has the parameter region in which renormalizable continuum limit exists and one can have a physical Higgs boson mass. Also because the 1st excited Z boson mass is around 1 TeV, it is possible to be verified by experiments.