Thesis Summary

Neutrinos and lepton number oscillations in quantum field theory
（場の量子論に基づくニュートリノとレプトン数振動）

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Neutrino physics has changed significantly since the discovery of flavor oscillations by Super Kamiokande and the Sudbury Neutrino Observatory. Starting with the work of Pontecovo, the theory of neutrino flavor oscillations in quantum mechanics has been established for some time. However, a consensus for the theory of neutrino flavor oscillations in quantum field theory has not been reached and is an active area of research.

We developed a formulation of neutrino flavor oscillations based on lepton family numbers in quantum field theory. We will start with a derivation of lepton family number for neutrinos with Majorana masses. Then, we will derive the lepton family number for neutrinos with Dirac masses. The main result of those derivations are a Majorana expectation value from our original work and a Dirac expectation value that is new for this thesis.

Some important results from of the expectation values are time dependent oscillations, total lepton number violation or conservation, and the recovery of the quantum mechanics formulation in the ultra-relativistic limit. We also compare the Majorana expectation value and the Dirac expectation value, which is a new comparison for this thesis. We compare them in two ways, first by studying the total lepton number and second by comparing the low momentum phenomenology. For total lepton number, we find the Dirac expectation value to conserve total lepton number, whereas the Majorana expectation value violates total lepton number. In the low momentum phenomenology our formulation has three interesting properties, we can distinguish the neutrino mass type, differences from the neutrino mass hierarchy are enhanced, and the Majorana phases can play an important role to the Majorana Expectation value.

Lastly, we prove our formulation is the same in the Schrödinger and Heisenberg pictures. We study a non-trivial relationship between the Fock spaces of the operators, which is not usually considered in high energy physics. That non-trivial relationship leads to a Bogolyubov transformation that connects the operators of the Fock spaces. This is sometimes considered in Thermal field theory and gives an interesting theoretical background to our model.