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1 ***qq*-character** [2]

We studied a two-parameter deformation of Seiberg–Witten curves which is called as qq-character [2]. We showed that in the A_n type quiver gauge theory the qq-character can be calculated from the refined topological string theory with two kinds of the toric A-branes. Through this study, we proposed the novel rule of the geometric transition in the refined topological string theory.

2 **Non-perturbative topological string theory** [3, 5]

We studied the quantization of the mirror curve of local $\mathcal{B}_3$ in the B-model topological string theory [3]. We calculated the quantum mirror map which can be written in a closed form by utilizing the S-duality. From this expression, we found that the quantum mirror map describe a Hofstadter model. Since the quantization of the mirror curve is related to a non-perturbative topological string theory, I can use the knowledge of well-known condensed matter physics to study the non-perturbative topological string theory.

I also studied the geometric transition in the non-perturbative topological string theory [5]. I calculated the free energies of the non-perturbative topological string theory on local $\mathcal{B}_3$, and found that under the appropriate parameter correspondence this expression agrees with the free energy of the non-perturbative topological string theory on the resolved conifold with the toric A-brane. It is difficult to see the S-duality in the non-perturbative topological string theory with the toric A-branes, however, this result enables to see the S-duality from the closed topological string theory that we can see the S-duality easily.

3 **M-string** [4, 6]

In order to understand the dynamics of multiple M5-branes, I studied M-string [6]. M-string is an almost tensionless string which is viewed as the boundary of a M2-brane suspended between the slightly separated M5-branes. I calculated the partition function of M-string in the presence of A_1 singularity from the refined topological string theory by using the geometric engineering, and found that the supersymmetry of M-string gets enhanced in the special values of the Kähler parameters. This result is consistent with the geometric transition.

We also studied a brane system of M-string with a codimension-2 defect which is realized by inserting an additional M5-brane[4]. In our paper, we proposed that the defect corresponds to the toric A-brane in the refined topological string theory. In order to confirm the correspondence, we calculated the partition function of the refined topological string theory with the toric A-brane by using the geometric transition. We also calculated the partition function of the world-sheet theory of M-string with the defect. We found the agreement between two results.

4 **Quantum quench** [1]

In order to study how a subsystem thermalizes, we studied two types of global mass quench in a two-dimensional bosonic theory on a lattice [1]. In this study, we calculated the entanglement entropies. In numerical calculations, we observed that the entanglement entropy grows linearly in time at first. After a typical time, the entanglement entropy depends on the subsystem size. Furthermore, the entanglement entropy oscillates in the certain global mass quench.