Creation of D9-brane–$\overline{\text{D9}}$-brane Pairs from Hagedorn Transition of Closed Strings

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The one-loop free energy of closed strings diverges above the Hagedorn temperature. A 'winding mode' in the Euclidean time direction in Matsubara formalism becomes tachyonic above this temperature. Atick and Witten have proposed the Hagedorn transition of closed strings via condensation of this winding tachyon.[1] The sphere world sheet is no longer simply connected and it contributes to the free energy, since the insertion of the winding tachyon vertex operator means the creation of a tiny hole in the world sheet which wraps around the Euclidean time direction. We have not known the stable minimum of tachyon potential yet.

We have previously discussed the behavior of brane-antibrane pairs at finite temperature in the constant tachyon background, by calculating the finite temperature effective potential of open strings on these branes [2]. For the D9–$\overline{\text{D9}}$ pairs, a phase transition occurs at slightly below the Hagedorn temperature and the D9–$\overline{\text{D9}}$ pairs become stable above this temperature. On the other hand, for the Dp–$\overline{\text{D}p}$ pairs with $p \leq 8$, such a phase transition does not occur. We thus concluded that D9–$\overline{\text{D9}}$ pairs are created near the Hagedorn temperature.

Let us consider the relationship between above two phase transitions. Identifying the boundary of a hole created by winding tachyon vertex operator with the boundary of open string on D9–$\overline{\text{D9}}$ pairs, we present a conjecture that *D9-brane–$\overline{\text{D9}}$-brane pairs are created by the Hagedorn transition of closed strings.* We describe some circumstantial evidences for this conjecture. First, the thermodynamic balance condition on D9–$\overline{\text{D9}}$ pairs indicates that energy flows from closed strings to open strings, and open strings dominate the total energy. Secondly, one-loop free energy of open strings on a D9–$\overline{\text{D9}}$ pair approaches to the propagator of winding tachyon in the closed string vacuum limit. This is an example that we can identify the closed string sphere world sheet with winding tachyon insertion with the open string world sheet in the closed string vacuum limit. Thirdly, the potential energy a! t the open string vacuum decreases limitlessly as the temperature approaches to the Hagedorn temperature. It is natural to think that the open string vacuum becomes the potential minimum.

References

[1] J. J. Atick and E. Witten, *Nucl. Phys.* **B310** 291 (1988).

[2] K. Hotta, *JHEP* **0212** 072 (2002); *JHEP* **0309** 002 (2003) 002; *Theor. Phys.* **112** 653 (2004) 653.