Witten, Edward

Perturbative superstring theory revisited. (English) Zbl 1421.81101

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Powerful covariant methods to compute superstring scattering amplitudes in the RNS formalism were introduced in [*D. Friedan*, *E. Martinec* and *S. Shenker*, "Conformal invariance, supersymmetry and string theory", Nucl. Phys., B 271, No. 3–4, 93–165 (1986; doi:10.1016/S0550-3213(86)80006-2)] and have been widely used ever since. The principal objective in this paper is to give simpler and more direct demonstrations that multi-loop superstring amplitudes are gauge-invariant, satisfying space-time supersymmetry whenever it is expected, and having the infrared behavior such as seen in a field theory with the same massless particles and low energy interactions. These results can be made more transparent by formulating superstring perturbation theory in terms of super Riemann surfaces and supermoduli space in place of reducing everything to ordinary Riemann surfaces and moduli space. Some important ideas in this paper were introduced in the 1990s [*A. Belopolsky*, "De Rham cohomology of the supermanifolds and superstring BRST cohomology", Phys. Lett., B 403, No. 1–2, 47–50 (1997; doi:10.1016/S0370-2693(97)00445-0); "New geometrical approach to superstrings", Preprint, arXiv:hep-th/9703183; "Picture changing operators in supergeometry and superstring theory", Preprint, arXiv:hep-th/9706033]. The first completely consistent one-loop computations were performed in [*M. B. Green* and *J. H. Schwarz*, "Supersymmetric dual string theory. III: Loops and renormalization", Nucl. Phys., B 198, No. 3, 441–460 (1982; doi:10.1016/0550-3213(82)90334-0); *M. B. Green*, *J. H. Schwarz* and *L. Brink*, "$\mathcal{N} = 4$ Yang-Mills and $\mathcal{N} = 8$ supergravity as limits of string theories", ibid. 198, No. 3, 474–492 (1982; doi:10.1016/0550-3213(82)90336-4)], while the two-loop calculations were first fulfilled in [*E. D'Hoker* and *D. H. Phong*, "Lectures on two-loop superstrings", Preprint, arXiv:hep-th/0211111].

This paper consists of 10 sections together with four appendices. §2 reviews the bosonic string, which straightforwardly generalizes to superstrings in §3. In §4 and §5 the superstring analysis is extended to include external vertex operators, particularly incorporating the relevant aspects of the covariant quantization of superstrings and addressing the role of pictures. §6 computes the string propagator or, exactly speaking, the integration measure for a string propagating almost on-shell for a long proper time. §7 addresses BRST anomalies and introduces the massless tadpoles, which are most challenging for superstring perturbation theory. §8 investigates the spacetime supersymmetry of loop amplitudes and the vanishing of massless tadpoles, taking the heterotic string as the basic example of a string theory with spacetime supersymmetry, while §9 extends almost at once to oriented closed Type II superstring theory. The goal in §10 is to increase one's comfort level with the commuting $\beta\gamma$ ghosts of superstring theory.

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MSC:

81T30 String and superstring theories

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