Commun. Math. Phys. 139, 353–375 (1991)

Communications in Mathematical Physics

© Springer-Verlag 1991

The Polyakov Path Integral Over Bordered Surfaces

II. The Closed String Off-Shell Amplitudes

Zbigniew Jaskólski

Institute of Theoretical Physics, University of Wrocław, ul. Cybulskiego 36, PL-50205 Wrocław, Poland

Received November 17, 1989

Abstract. Following the general scheme of the convariant path integral quantization of gauge systems, two alternative formulations of the first quantized closed bosonic string in a position representation are presented. In both approaches the covariant path integral representations of the propagator and of the higher order off-shell amplitudes are constructed. For a wide class of gauges the explicit formulae for off-shell amplitudes are obtained. This paper is the continuation of our previous work where the corresponding problems in the open string case were considered [20].

1. Introduction

In the past few years, the elegant and self-contained S-matrix formulation of the interacting bosonic closed string was developed [1]. The basic ingredients of this formulation are the on-shell amplitudes defined by means of the Polyakov path integral over closed surfaces [2] with a prescribed topology and with vertex functionals [3] corresponding to ingoing and outgoing on-shell particle states. This is however thoroughly perturbative formulation and it is an important problem to derive an underlying theory the perturbative expansion of which we have. Despite numerous attempts this goal is not yet completely achieved. One possible way to go beyond the perturbative formulation is to understand whether the Polyakov on-shell amplitudes could be constructed from simpler pieces. If we adapt the ordinary field theoretical scheme of perturbation expansion these building pieces should be interpreted as Green functions (off-shell amplitudes) in a covariant second quantized string theory. The basic idea of the off-shell formulation proposed by Cohen, Moore, Nelson, and Polchinski [4] is that the off-shell amplitudes can be expressed by the Polyakov path integral over bordered surfaces without making use of string fields. Considering the simplest Green functions: the off-shell propagator and the off-shell three string vertex one can try to derive some information about an underlying string field theory [5].