Abstract—We analyze regular and chaotic dynamics of optical solitons and solitons of matter waves in a cavity with periodically oscillating mirrors. For wide-aperture nonlinear cavities different types of spatial vector solitons are found. Their collisions can change the soliton type.

Keywords—Fermi-Ulam problem; dynamical traps; Rabi oscillations

I. Introduction

The problem of Fermi [1] and Ulam [2] of dynamics of particles colliding with moving bodies was intensively investigated in application to various fields of physics [3]. However, as far as we know, a similar problem with the replacement of particles by solitons was not studied yet. It is of interest because, e.g., oscillations of cavity mirrors could serve as energy source and present an additional way to form cavity solitons, as compared with traditional using of coherent holding radiation in driven nonlinear interferometers or media with optical gain in lasers with saturable absorption.

Solitons differ from particles in the Fermi-Ulam problem by their finite dimensions; additionally, generally speaking, they could be destroyed in the process of collisions with moving walls. The goal of the present talk is to study the nonlinear dynamics of solitons of Bose-Einstein condensate or optical solitons in dynamical cavities or waveguides with oscillating mirrors. The governing equations can be found in [4] where strong Rabi oscillations of populations of Bose-Einstein condensate levels in a dynamical trap were found.

II. “Longitudinal” Solitons

For strong transverse confinement due to “linear” factors, the dynamics of solitons is described by the nonlinear Schrödinger equation with nonstationary boundary conditions. Reflection from an oscillating mirror can accelerate or decelerate solitons depending to the oscillation phase at the moment of collision. Correspondingly, there are regimes of regular (periodic and quasi-periodic) and chaotic (Fig. 1) motion of the soliton bouncing between two oscillating mirrors, similar to the case of classical particles [2, 3].

III. “Transverse” Solitons

For a trap with oscillating mirrors, resonance occurs when the oscillation frequency is close to the difference of frequencies of the cavity longitudinal modes. Then it is possible to develop a simplified two-level model [4] and take into account the transverse phenomena in the wide-aperture trap. Corresponding analytical solution reveals existence of families of bright spatial vector solitons including those with in-phase and antiphased components. It is shown numerically that soliton type can be changed in result of collisions of solitons.

This work was partially financially supported by the Program of the Russian Academy of Sciences “Fundamental problems of nonlinear dynamics in mathematical and physical sciences” and by Government of Russian Federation, Grant 074-U01.

References