# Bifurcations and multiple-period soliton pulsations in Mamyshev oscillator

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***Abstract* — We numerically examined multiple-period pulsation of the soliton parameters in a Mamyshev oscillator. We observed that the period of pulsation can be controlled by the spectral distance between the filters. The pulse energy fluctuations ranged from 2 to 47% of the maximum value.**

***Keywords— Mamyshev oscillator, nonlinear Schrodinger equation, bifurcations, multiple-period soliton pulsations***

## I. Introduction

Mamyshev oscillator becomes a popular solution for the generation of high-energy ultrashort pulses [1]. Apart from the practical applications, Mamyshev oscillator is an interesting nonlinear system, having a rich dynamics that includes not only the generation of a periodic train of well-shaped pulses, but also much more non-trivial examples. De facto, the generation of stable pulses is possible in a narrow range of the laser parameters and requires their careful adjustment and control.

In [2] the complicated pulsating behavior of solitons was observed for the standard model of mode-locked lasers - complex Ginzburg-Landau equation (CGLE). However, in the Mamyshev oscillator, the envelope of the wave packet undergoes strong changes inside the cavity, which makes it impossible to describe the resonator by the averaged CGLE model. Here, we use numerical model of a Mamyshev oscillator based on the conventional nonlinear Schrödinger equation. We demonstrate the multiple-period pulsations of the soliton parameters and examine key features of such pulsations for varying spectral distance between the filters.

## II. Numerical model

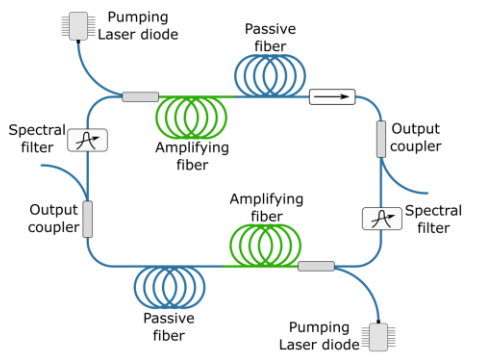


Fig.1. Scheme of the considered Mamyshev oscillator.

The scheme of the studied Mamyshev oscillator is depicted in Fig.1. The ring cavity includes 4-meters long PM SMF, two Yb-doped PM fibers 2.5 meters long each, and two Gaussian spectral filters. Spectral filters are located symmetrically around 1035 nm. The filters bandwidth was 0.17 THz and the spectral separation between filters was a tunable parameter. Output couplers ratio was 0.6 and 0.1. To model pulse propagation in active fibers we used generalized nonlinear Schrodinger equation, which includes saturated gain. Saturation energies corresponding to two gain fibers were $E_{sat1} = 10$ nJ and $E_{sat2} = 30$ nJ. The gain profile was assumed to be Lorentzian with 40 nm gain bandwidth.

To demonstrate various regimes of lasing, the distance between the spectral filters was changed from 0.2 to 0.5 THz with a step of 0.001 THz, while the other elements of the cavity remained constant. Gaussian pulse was used as a seed pulse.

## III. Results

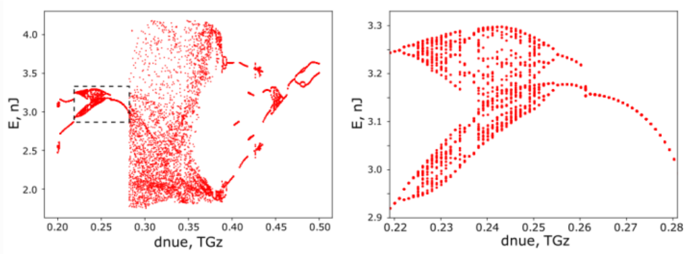


Fig.2. One-dimensional Poincare map. Energy versus distance between filters for pulsating and stationary solitons.

Figure 2 shows one-dimensional Poincaré map that was obtained as a result of a numerical experiment. It presents the value of energy E for each oscillation of the pulsating solutions versus the distance between the spectral filters. The figure shows that in this architecture there are stable, pulsating and chaotic solitons. Pulsation energy fluctuations ranged from 2 to 47% of the maximum value. The new periods in the soliton modulation appear at bifurcation points related to the certain values of the spectral distance between the filters.

## References

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