Numerical Stability Computation of Ultrashort Pulse Generation in Erbium Fiber Laser Passively Mode locked through Nonlinear Polarization Rotation

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Abstract—Nowadays ultra-short pulse lasers are of the great interest in laser physics and material science. The popular scheme of ultra-short pulse fiber laser is based on nonlinear polarization rotation. However, the big drawback of this scheme is pulse generation dependence on resonator parameters. In our work, we have simulated process of pulse generation with different external parameters, such as dispersion, nonlinearity, birefringence, pump power and round-trip losses.

Keywords—femtosecond pulse, erbium fiber laser; nonlinear polarization evolution; mode-locking; stability; numerical methods.

I. INTRODUCTION

Usually optical schemes of ultra-short pulse lasers are rather difficult and make use of expensive components. Therefore, lasers based on nonlinear polarization rotation (NPR) in optical fiber become quite popular [2]. Such lasers have been widely investigated in recent years. Optical scheme of NPR-based fiber laser shown at figure 1(a). This scheme does not require specific components, has all-fiber format and could generate pulses as short as hundreds femtoseconds. In the figure, polarization controllers (PC) could be described as phase plate, which phase shift and optical axis position are variable. Linearly polarizing optical isolator along with PCs act as cross polarizers for low-intensity light. However, when optical intensity increases the effect of NPR becomes more significant and round trip resonator losses decrease, which could lead to passive mode locking. The main idea of this optical scheme have been proposed more than 20 years ago. However up to now there exists a significant problem – how to describe polarization controllers states, that could lead us to mode locking regime? Authors of [3] have suggested the simplification of nonlinear Shrödinger equation that describes process of pulse propagation inside the optical fiber. There theory could predict where laser is generating CW light, mode locking or produce an unstable wave train. Several states of PCs allow laser to mode locking, this states form complicated shapes in multidimensional parameter space that have been named stability regions. Nevertheless, within the limits of this model it is impossible to characterize mode-locking regime more precisely, i.e. calculate pulse energy or pulse to pulse peak power instability. In addition, such simple model has several physical disadvantages: for example, it claims that in case of nonebirefringent fiber there is no mode locking, whereas the theory predicts mode locking. In our work we made an attempt to use an another approach

II. NUMERICAL COMPUTAION

Thanks to numerical algorithms, it is possible to solve nonlinear Shrödinger equation without any simplification. Making use of this approach, we can solve not only eigen function problem but also analyze dynamic of laser radiation. This means that we can simulate starting of mode locking inside the laser, transition from single-pulse regime to multi-pulse regime and time-domain stability of generated pulses. We could calculate pulse stability dependence on external resonator parameters, which could allow us to introduce negative feedback for laser oscillations stabilization. We suggest localizing specific stability regions with help of Monte Carlo method. After rough approximation of stability regions forms, we could calculate shape dependence of these regions on different parameters e.g. total net dispersion, passive round trip losses, induced bend birefringence in optical fiber or pump power. Figure 1(b) represent typical form of calculated stability region of single pulse mode locking. Different positions of PCs result in different generated pulse energy that pointed out with pseudo color.

REFERENCES