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Imaging and Collecting Spatially Structured Arrays of Ultrashort Pulses for Ultrahigh Information Rate Optics: Numerical Simulation and Modeling

Abstract

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Imaging and Collecting Spatially Structured Arrays of Ultrashort Pulses for Ultrahigh Information Rate Optics: Numerical Simulation and Modeling

Introduction

We propose augmentation of the principal investigator's "parent" contract with the Air Force by supporting one additional graduate student whose responsibilities would include numerical simulation and modeling. The discipline/area of research is Physics.

We have recently achieved experimental demonstration of kinematic modelocking in a figure eight nonlinear loop mirror laser realized in erbium doped optical fiber.[1] This work provides a simple but convincing demonstration of the use of a highly nonlinear optical system to sense motion of a remote object. The student would use numerical simulations, as well as participation in the experimental work, to model this behavior and provide an understanding of the as yet unexplained mechanism of this modelocking. Possible relevance of this work to our other ongoing research would also be examined.

Research Activities in which Student will Participate

Current work addresses: (1) a kinematically modelocked nonlinear loop erbium fiber laser; (2) a stable soliton laser source; and (3) modeling of coupled soliton states in multicore optical fiber. Recent work has addressed: (1) spectrally, temporally and spatially resolved four wave mixing signals for studying the nonlinear susceptibility near a semiconductor band edge, and (2) a dual beam modelocked laser oscillator that experimentally demonstrates reconfigurable coupled pulse pairs formed through balanced attractive and repulsive interaction between pulses within the laser oscillator. The overall goal of the group is one of exploring novel physical mechanisms of this type for the purpose of accessing high data rate observation and communication.

The student would participate in this work, placing a particular emphasis on numerical simulation of the kinematically modelocked laser. This work would include examining the considerable remaining uncertainties concerning the origin of this modelocking. Possible topics include expanding the range of velocities over which kinematic modelocking is useful. For example, recent work suggests an improved understanding can be gained from examining the apparent connection between the Doppler shift produced by the moving object and the maximum frequency shift caused by cavity pulling.[2] The student would explore the implications of this finding and also seek possible advantages emerging form the use of coupled cavity laser oscillators that support oscillation of coupled pulse arrays.

In our kinematically modelocked laser oscillator, modelocked operation of the laser occurs over selected ranges of motion of the external reflector. The initiation of the modelocked condition within one pass through the resonator is unusual for kinematic modelocking, and the high output power level is also unusual for erbium doped optical fiber lasers. The high power is useful in enhancing signal levels. The initiation of modelocking within one transit of the laser structure indicates a capacity to respond very rapidly to variations in the external environment. More thorough analysis appears to be called for by these findings.

We recognize that the range of velocities to which kinematic modelocking is sensitive is quite limited. However, the phenomena provides a useful focal point for research on the use of highly nonlinear ultrafast technology for sensing motion in a remote environment. We anticipate means may be found to broaden the range of dynamical behavior and structural detail that can be remotely and rapidly sensed and communicated. Thus, this is a fertile area for the graduate student supported by this augmentation award to explore.

The laser oscillator constructed in our laboratory is shown in Fig. 1. The laser is a basic figure 8 structure with a 53-47 beamsplitter at the center of the figure 8 pattern. The length of the nonlinear loop is 2 meters. A directional isolator and a polarization controller are included in the same loop as the gain medium, which is erbium fiber, providing greater than 38 dB gain. Pump light is directed oppositely to the direction of the laser propagation and is introduced in this same loop via a wave division multiplexer coupler. The pump light is derived from a cw Ti:sapphire laser pumped by a argon ion laser operated on all lines. The Ti:sapphire laser utilizes approximately 8 watts average power and delivers approximately 800 mW output.

A sample of the laser emission is coupled out via a 90:10 output coupler, collimated and directed to an external plane mirror mounted on an acoustic shaker. The retroreflected return light from the plane mirror is redirected back into the figure 8 laser as illustrated in Fig. 1. We find for mirror velocities of the order of 6 cm/sec, modelocking of the oscillator occurs. Experiments have also been performed examining the dynamics of the turn on and turn off of the modelocking by using a fast 2x2 electro-optic switch (rise time < 30 nsec) to shift the emission from the laser from the moving mirror to an identical stationary mirror. The turn on of the modelocking is found to be surprisingly fast, occurring in less than one round trip of the laser oscillator (total path of about 9 meters). The turn off of the modelocking is much slower, occurring in about 1 msec. The average output power produced by the laser, 70 mW, is unusually large for lasers of this type. We attribute this in part to the location of the gain in the section of the loop that does not provide the nonlinear loop function.

This is the first demonstration, to our knowledge, of modelocking of a nonlinear loop mirror laser where the gain is not included in the nonlinear loop. Theoretical calculations have been made indicating that such lasers should exhibit modelocking[3], but none prior to the laser we describe here have been shown to do so. Part of the work of this study would be to clarify the reason for these observations. We note incidentally that the very large gains available from erbium fiber provide a means of introducing large amplification of both the light coupled out of the laser oscillator and the return light from the reflecting target. This feature should allow the examination of moving targets with much lower unamplified return signal than the moving mirror currently being used as the target in these experiments.

References

1. "High power passively mode-locked Er-doped fiber laser," Song Wu, Richard L. Fork and Theordore Morse, submitted to CLEO'93.

2. "Experiments on kinematic modelocking of a ring dye laser," J.P. Bernardin and N.M. Lawandy, Optics Communication 94, 445-457 (Dec. 1, 1992).

3. "Self-starting mode-locked laser with a nonlinear ring resonator," A.G. Bulushev et al, Optics Letters 16(2) 88 (1991).