Colliding pulse mode locking for an antiresonant cavity of a Nd:glass laser

J. M. Buchert, D. K. Basa, C. Tzu, and R. R. Alfano
Institute for Ultrafast Spectroscopy and Lasers, Departments of Physics and Electrical Engineering, the City College of New York, New York, New York 10031

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Mode-locking a Nd:silicate glass laser system by counterrunning pulses in a thin Kodak 9860 saturable absorber dye has produced considerably shorter pulses than that generated in a conventional standing-wave cavity configuration. The pulse duration of the pulse train was measured to be about 3.5 psec.

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High-power and short-duration optical pulses can be generated by passively mode-locking a neodymium glass laser using saturable absorber dyes. These pulses have been used to study nonlinear optical effects and kinetic processes in materials. The generation of shorter pulses is required to achieve higher resolution for time-resolved measurements. Over the years, various methods have been investigated to generate shorter pulses from glass lasers. This paper reports on mode-locking a neodymium silicate glass laser (Owen, Illinois) with a Kodak No. 9860 dye in a nonconventional design of an antiresonant cavity as suggested in the early seventies by Siegman.[1]

The schematic design of the antiresonant ring laser cavity used in this work is shown in Fig. 1. It consists of a thin 200-μm-thick saturable absorber flowing in a dye cell (transmission at 1.06 μm was 78%) placed near the center of the ring consisting of a 50/50 beam splitter with its rear AR coated and two 100% reflected mirrors with a 10-m radius of curvature. An aperture of diameter 2 mm was placed between the output 55% reflection flat mirror and the laser gain medium.

Little energy loss out of the external arm[1] was observed in TEM_{00} operation. With the cell centered in the ring, the laser produces a train of approximatley 30 pulses with a total output energy of about 15 mJ. The inset in Fig. 2 shows a typical pulse train. The laser was operated slightly above the threshold. The pulse durations were measured using a triangular two-photon fluorescence apparatus in a saturated solution of Rhodmaine 6G in methanol. The TPF tracks were measured and analyzed using a Hamamatsu C-1000 SIT video camera system coupled to a Hamamatsu temporal analyser minicomputer system with a resolution of a 1/2 psec. The pulse duration extracted from TPF correlation time as a function of the offset distance of the saturable absorber cell from the center of the antiresonant cavity is shown in Fig. 2. The pulse duration was consistently in the range of 3.5 psec. near the center of ring cavity. Pulse duration of 3.5 psec for the whole train indicates a 1-psec duration for a single pulse selected from the early part of the pulse train. A salient feature of the data displayed in Fig. 2 is that the pulse duration increases when the dye cell was offset by a few millimeters from the center of the ring. This leads to the pulse duration on the order of 10 to 12 psec. For comparison, the same laser rod placed in a conventional standing-wave mode-locking configuration generates 8-psec pulses for the trains. The offset from the center of the saturable absorber cell led to a decrease in stability of mode locking (double train generation).

The spectral width was measured by converting the 1.06-μm fundamental beam to a second harmonic beam in a KDP-type II crystal. The bandwidth varied from 6 to 8 Å in full width at half maximum different laser shots. The train of pulses was nearly bandwidth limited indicating the reduction of self-phase modulation effects inside the cavity. The same rod in a conventional standing-wave cavity produces pulses with a spectral width of 30–40 Å. Similar effects of decreasing the intercavity dispersion in the colliding mode was observed in the cw passively mode-locked dye laser.[2]

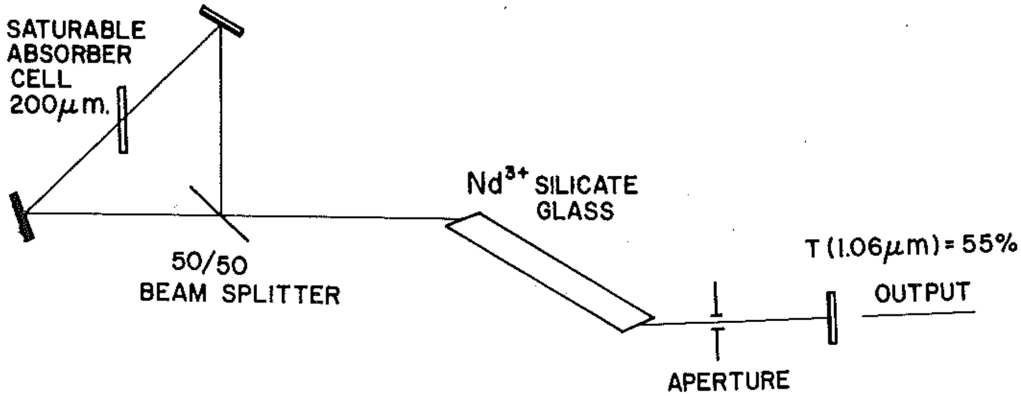

FIG. 1. Schematic diagram of the antiresonant mode-locked Nd:glass oscillator.

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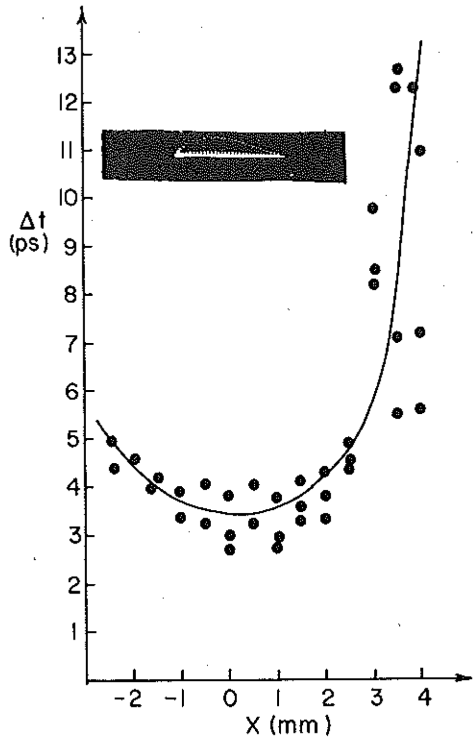

FIG. 2. Pulse duration Δt as a function of the displacement of the dye cell from the center of the antiresonant ring.

The mechanism behind the duration shortening of mode-locked pulses in an antiresonant system is associated with the counter-colliding pulse arrangement. The reduction most likely arises from phase conjugation via four wave-mixing and Kerr-induced coherent grating effects[5] where the waves intersect collinearly from opposite directions in a nonlinear medium, which in our case is the saturable absorber. Pulses colliding in a thin saturable absorber are about four times more intense as compared with a single beam because of the coherent interaction. The lifetime of the coherent spike (usually termed the "coherent artifact") is short on the order of $\Delta\omega^{-1}$. This time should be the order of the generated pulse duration. In addition, the increase stability is predicted by the theoretical analysis presented by Kuhlke *et al.*[3] and Stix and Ippen[4] and experimentally observed in this report and for a Nd:YAG(Yttrium aluminum garnet) by Vanherzeele *et al.*[6]

This work provides an improved laser glass oscillator with a better temporal resolution for investigating picosecond phenomena.

ACKNOWLEDGMENTS

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