Production of Picosecond Pulses by Mode Locking an Nd:Glass Laser with Dye #5

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Abstract—An Nd:phosphate glass laser was mode locked with Kodak heptamethine pyrylium dye #5. The emission from the laser consisted of a train of approximately 100 pulses. The pulse duration of a single pulse selected from different parts of the train was consistently less than 4.5 ps. The smallest pulse duration measured was 2.4 ps.

OVER the past decade, the neodymium glass laser mode locked with Kodak dye #9860 has proven to be the workhorse for investigating picosecond phenomena [1], [2]. The optical pulses generated by this laser were of high peak power (~2 GW) and short duration (~7 ps). These pulses facilitated the study of nonlinear optical effects and kinetic processes in materials. The generation of shorter pulses is required to achieve maximum resolution for time-resolved measurements [2].

In 1977, Reynolds and Drexhage [3] reported on synthesizing a series of heptamethine pyrylium dyes that absorb in the infrared and that were much more stable than Kodak dye #9860. Recently, Kopainsky *et al.* [4] reported on measuring the absorption recovery (bleaching) times of four of these saturable absorbers: #5, #15, #18, and #9860. The recovery times were measured to be 2.7, 4.0, 4.1, and 6.5 ps, respectively.

This paper reports on mode locking an Nd:phosphate glass laser with the faster recovery time Kodak dye #5. Measurements are reported on the characteristics of the pulses generated from the laser mode locked with dyes #5 and #9860.

A conventional design mode-locked glass laser was used in these studies. The laser consisted of a 1 m long cavity with a 60 percent dielective output reflector and a 99.8 percent dielective rear reflector, a K-1 Korad power supply, a K-1 Korad laser head with a 7 in X $\frac{1}{2}$ in Brewster angle cut phosphate rod, and an optical dye cell. A Lasermetrics electronic single-pulse selector (8601) and Pockel cell were used to select a single pulse from the train. Pulses were selected from different positions of the train using the variable delay of the pulse selector. Pulses could not be selected earlier than the tenth intense pulse in the train because of the inherent limitations of the Lasermetrics electronic pulse selector.

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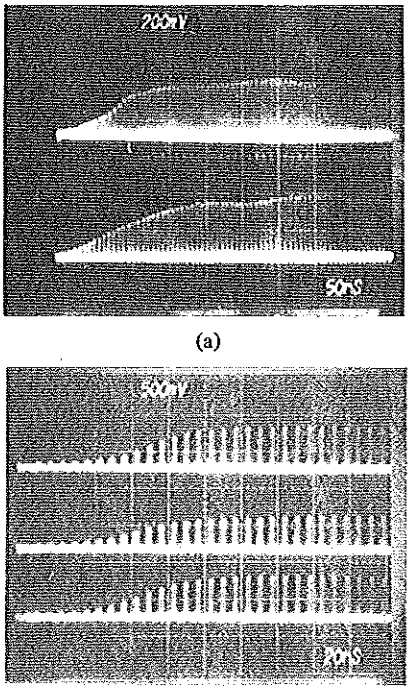

Fig. 1. Oscilloscope traces of mode-locked pulses emitted from an Nd: phosphate glass laser via dye #5: (a) 50 ns/cm and (b) 20 ns/cm.

The dye #5 was obtained from samples prepared by Kodak [3]. The dyes #5 and #9860 were dissolved in 1,2-dichloroethane solvent. The transmission was set to 70 percent at 1.06 μm in a 1 cm cell. The pulse duration was measured using a triangular arrangement for two-photon fluorescence (TPF) [5]. The TPF medium was rhodamine 6G dissolved in ethanol. The TPF track was measured and analyzed using a Hamamatsu C-1000 SIT video camera coupled to a Hamamatsu temporal-analyzer minicomputer system. The digitized data were displayed on a video monitor and chart recorder. The pulse energy was measured using a Laser Precision energy meter (RK-3230). The time development of the laser pulse train was measured using an ultrafast Hamamatsu (R1328U) photodiode coupled to a Tektronix 7904 oscilloscope.

Typical pulse trains emitted from the laser mode locked with dye #5 are shown in Fig. 1. The pulse trains were very reproducible from shot to shot. The threshold voltage required to reach lasing was higher (3.4 kV) using dye #5 by about 10 percent over the threshold voltage (3.1 kV) using dye #9860. The

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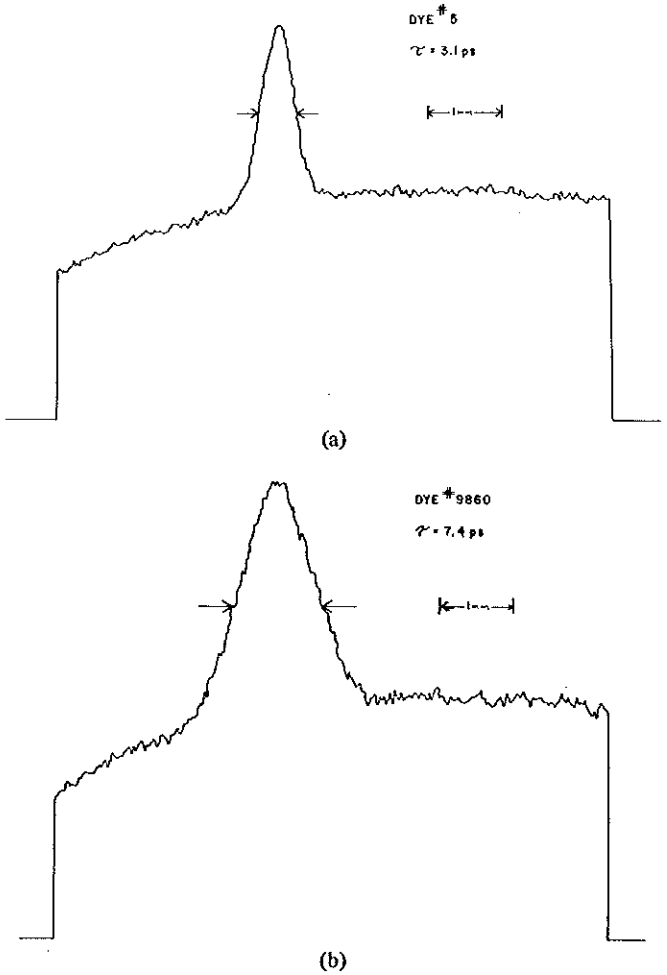

Fig. 2. Chart recorder traces of TPF patterns for laser emission mode locked by (a) dye #5 and (b) dye #9860 from a single pulse selected from approximately the same region of the pulse train ≈12.

typical energy of a selected single pulse was 0.5 mJ. Fig. 2 shows the TPF traces of the autocorrelation function of a single pulse at 1.06 μm using dyes #9860 and #5. The pulse durations of the TPF profile, as shown in Fig. 2, are measured to be 7.4 and 3.1 ps, respectively. A pulse could not be selected earlier than the tenth pulse in the train due to limitations of the single pulse selector. The TPF contrast ratio was measured to be 2:1, consistent with an ideal mode-locked multiple transverse mode pulse for minute misalignment in the TPF apparatus [6].

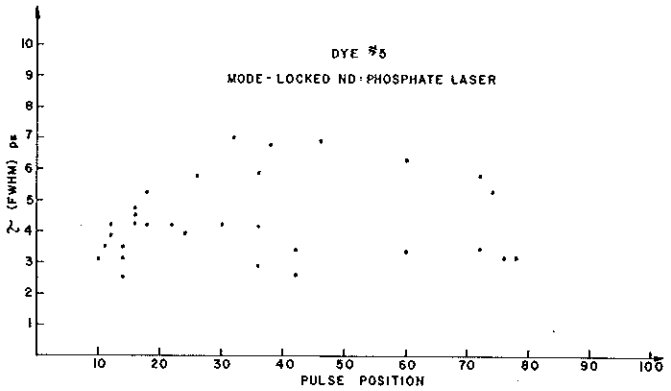

Fig. 3. Pulse duration evolution of a single pulse selected from a pulse train produced by dye #5 versus pulse position in the pulse train.

Fig. 3 displays the pulse duration measured for a single pulse as a function of position in the pulse train of the laser emission mode locked by dye #5. The pulse starts with an ~3 ps duration near the beginning of the train and becomes ~4.5 ps toward the end of the train. The transmission stability of the solution in the cell without flowing did not change by more than 1 percent after two days of use.

In conclusion, the use of dye #5 for mode locking an Nd:phosphate glass laser produces a stable short light pulse at 1.054 μm of duration of less than 4.5 ps. Occasionally pulses as short as 2.4 ps were observed. Using a second-harmonic generator, pulses of less than 2 ps are expected.

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