PULSE BROADENING IN INJECTION MODE LOCKED TEA CO_2 LASERS

F.A. Van GOOR
Department of Applied Physics, Twente University of Technology, Enschede, The Netherlands

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The broadening mechanism on the output pulses of an injection mode locked TEA CO_2 laser has been studied by varying the width of the injected gaussian pulses.

Injection mode locking of large-aperture TEA CO_2 lasers makes it possible to generate nanosecond pulses with high intensities [1–3]. It was shown by Dyer and Perera [6] that by injection mode locking the width of the amplified pulse depends on many variables, such as the width of the injected pulse from the master oscillator and the gas pressure of the slave oscillator. They studied the broadening of a gaussian pulse, for various gas pressures of the slave oscillator.

In this paper we show both theoretically and experimentally how the width of the output pulse from the slave oscillator will depend on the width of the gaussian pulses in the injected pulse train, keeping the gas pressure as well as the other parameters constant. The experimental configuration is schematically shown in fig. 1. The pulse train coming from a small AM mode locked TEA CO_2 laser has been injected into a $5 \times 5 \times 60\ cm^3$ slave oscillator, having a very uniform discharge [8], through a small hole ($\phi = 1$ mm) in the center of the back-reflecting mirror of the unstable resonator. The input energy of the slave oscillator was about 100 J/liter in a $1:1:3 = CO_2 : N_2 :$ He mixture

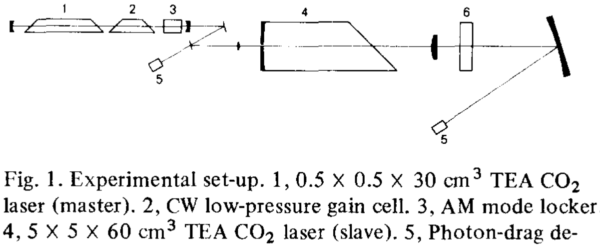

Fig. 1. Experimental set-up. 1, $0.5 \times 0.5 \times 30\ cm^3$ TEA CO_2 laser (master). 2, CW low-pressure gain cell. 3, AM mode locker. 4, $5 \times 5 \times 60\ cm^3$ TEA CO_2 laser (slave). 5, Photon-drag detector. 6, Attenuator.

at 1 atm. total pressure, producing a total output energy of 12 J. The cavity length of the slave oscillator was tuned to be equal to the length of the master cavity. The width of the injected pulses could be varied by changing the RF-power of the power oscillator which drives the mode locker.

The insertion of the CW low-pressure gain cell in the cavity of the master oscillator improves the reproducibility and makes it possible to generate pulses with widths from about 1 ns (FWe-1) up to pulse widths equal to the round-trip time (12.6 ns (FEe-1) in our experiment) [7].

The widths of the master and slave pulses were measured respectively with two photo-drag detectors and a Tektronix transient digitizer. The observed pulses were found to follow very accurately a gaussian shape (see fig. 2).

In order to study pulses in the non-saturated regime, only the width of the first detectable pulse from the train is monitored. Fig. 3 shows the results of the measurements.

The pulse evolution in a resonator with only a gain medium can be understood with a simple theory as described in refs. [5] and [6].

After n roundtrips a gaussian pulse,

$$E(t) = \exp(-\gamma t^2),$$

has been amplified according to

$$E'(t) = \exp(-\gamma' t^2),$$

with

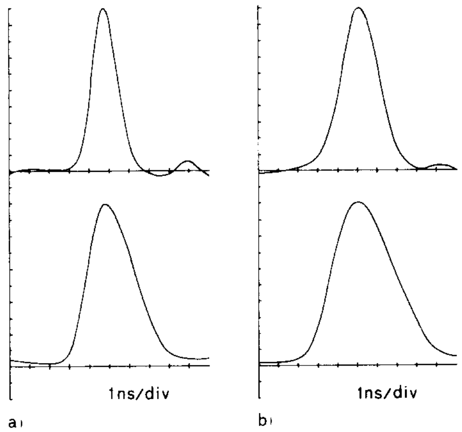

Fig. 2. Normalized, first detectable pulses from the master (upper trace) and the slave (lower trace) oscillator. a. High RF power to the mode locker. b. Low RF power to the mode locker.

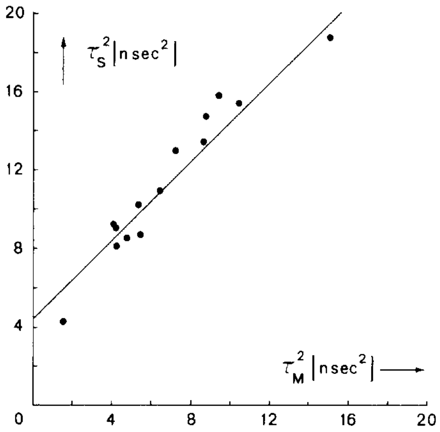

Fig. 3. Width of the pulses generated by the slave oscillator (τ_S) as a function of the width of the injected pulses (τ_M). (Full width at e-1 intensity).

$$\frac{1}{\gamma'} = \frac{1}{\gamma} + \frac{16l}{\Delta\omega_a^2} \sum_{i=0}^{n} g_0(i),$$

where $\Delta\omega_a = 2\pi\Delta\nu_a$ is the band width of the homogeneously broadened gain medium; l is the length of the medium, $g_0(i)$ is the time-dependent small-signal gain.

Assuming a linearly increasing small-signal gain at a rate $\dot{g}_0$, one can show that

$$\frac{1}{\gamma'} = \frac{1}{\gamma} + \frac{16l}{\Delta\omega_a^2} \left\{ g_{th} + \dot{g}_0 \frac{(t - T_{th})^2}{2T} \right\},$$

where $g_{th} = (1/2l)\ln(1/R)$, gain at threshold; R, the effective reflectivity; $T_{th} = g_{th}/\dot{g}_0$, time when theshold is reached; $T = 2L/c$, round-trip time; L, cavity length; t, delay between injected pulse train and output of the slave oscillator.

By substituting $\tau_M \equiv \sqrt{2/\gamma}$ and $\tau_S \equiv \sqrt{2/\gamma'}$, it follows:

$$\tau_S^2 = \tau_M^2 + \frac{8l}{\pi^2 \Delta\nu_a^2} \left(g_{th} + \frac{\dot{g}_0 (t - T_{th})^2}{2T} \right).$$

Using our experimental parameters, L = 189 cm, l = 60 cm, $R \approx 0.25$, $\dot{g}_0 \approx 1.3 \times 10^{-4}$ cm^{-1} ns^{-1}, $\Delta\nu_a \approx$ 5 GHz, $t \approx 750$ ns, it is found that

$$\tau_S^2 = \tau_M^2 + 4.4.$$

This line, also plotted in fig. 3, is in good agreement with the experiment.

In conclusion, the width of the pulses generated by injection mode locking is broadened during the build-up time of the gain. Furthermore, the direct pulse-width measurements confirm the validity of this simple theory for predicting the widths of pulses generated by injection mode locking a TEA CO_2 laser.

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