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ATMOSPHERIC PRESSURE GAS LASERS

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Professor of Electrical Engineering

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I. Mode Locking and Cavity Dumping

In an effort to produce short high-power pulses from a CO_2 laser, Y. Manichaikul, continuing work by E. E. Stark, Jr. of this laboratory, has successfully mode locked and cavity dumped a TEA CO_2 laser. For the mode-locking modulator he used an antireflection-coated Germanium crystal and for the cavity dumping he employed a combination of a GaAs electro-optic switch and Germanium polarizer. The laser discharge was of the pin type employing one discharge tube of 85 cm active length. The cavity length was 3.8 m. The peak power of the mode-locked pulse was greater than 10 kilowatts and the pulse length was less than 4 nanoseconds. Manichaikul is now engaged in building a mode-locking oscillator with a 3-electrode, Rogowski profile discharge system from which considerably higher powers are expected. He is planning to use the pulses thus produced in an amplifier for studies of nonlinear amplification.

A draft of a paper by Manichaikul and Stark describing the details of the work is attached.

II. Closed-Form Analysis of Electron Distribution and Pumping Rates

In cooperation with Professor W. P. Allis, Professor H. A. Haus has carried out an analysis of the electron distribution in a high-pressure lasing discharge coupled to an analysis of the pumping mechanisms of the vibrational levels. Nighan[1] and others have carried out such an analysis by using cross sections published in the literature and analyzing the resulting equations by computer. Making certain approximations, they were able to obtain closed-form expressions for all pertinent parameters, which greatly facilitates the understanding of the processes taking place. We intend to test the results of the analysis in an experimental study of an E-beam system, which is currently constructed within the

Research Laboratory of Electronics. We have already applied the equations to further an understanding of the capillary CO_2 laser as recently described by Bridges et al.[2] In particular, the exceptionally high gains observed in a flowing capillary laser were explained by use of the expression obtained from the closed-form analysis. A paper dealing with this problem will be submitted with our next semiannual report.

References

1 W. L. Nighan, Phys. Rev. A 2, pp. 1989-2000, November, 1970.

2 T. J. Bridges, E. G. Burkhardt, P. W. Smith, Appl. Phys. Letters 20, 403 (1972).

Talks

1 W. P. Allis and H. A. Haus
Electron Distribution and Lasing Efficiency of Vibrationally Excited Diatomic Gas, Oct. 1972, 25th Annual Gaseous Electronics Conference, Univ. of Western Ontario, London, Ontario, Canada.

2 H. A. Haus (invited talk)
Electron Distribution and Vibrational Excitation in Diatomic Gas Discharges. Conference on High Power and Tunable Lasers, January 1973, U.S.C., Los Angeles, California.

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FORCED MODE LOCKING AND CAVITY DUMPING OF A TEA CO_2 LASER

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A single short pulse of width less than the round-trip transit time of a transversely excited laser can be produced by means of simultaneously mode locking and cavity dumping of the laser. Using the above method, single pulses less than 4-nsec wide, with peak power greater than 10 kW have been produced from a TEA CO_2 laser.

Selection of a single pulse out of a train of mode-locked pulses by an electro-optic switch outside the laser cavity has been reported.[1] If the maximum power is limited by the mode-locking crystal, then a combination of mode locking and cavity dumping is capable of achieving higher pulse power because the peak power in the pulse is the pulse power inside the cavity. Pulse selection outside the cavity sacrifices power in proportion to the mirror reflectance. We report the production of single-nanosecond pulses less than 4-nsec wide by means of simultaneously mode locking and cavity dumping of a TEA CO_2 laser.

The cavity in the experiment was 3.8 m long. It had one pin-resistor discharge tube[2] filled with a flowing gas mixture of $He:N_2:CO_2$ operating at 200 Torr, an antireflection-coated acousto-optic loss modulator, a GaAs crystal, and a Brewster-angle Ge polarizer. One end mirror was flat and 99.6% reflecting. The other mirror was 8% transmitting, 92% reflecting and its radius of curvature was 4 m.

When 2 W of rf driving power at 18.7 MHz was supplied to the germanium acousto-optic loss modulator, mode locking of the laser was observed. The germanium modulator had acoustic resonance frequencies that occurred at intervals of 210 kHz. The 18.7 MHz rf driving frequency was an acoustic resonance frequency of the germanium modulator and corresponded to an optical length of 4.0 m for the cavity.

Eight percent of the power inside the cavity was transmitted through an end mirror to a gold-doped germanium detector at a temperature of 77°K. Signals from this detector were used to trigger a high-voltage supply for the GaAs crystal, thereby converting it into a quarter-wave plate.[3, 4] The triggering level and delay time could be changed but were generally adjusted so that the GaAs crystal was converted into a quarter-wave plate when the radiation inside the cavity was at a maximum. The polarization of the radiation reflected from the flat end mirror was rotated 90°, thereby causing 80% of the power to be reflected off the germanium Brewster-angle polarizer and out of the cavity. The dumped pulse passed through calibrated attenuators and was detected by a copper-doped germanium detector at 4°K.

Figure 1 shows a display on a dual trace Tektronix 556 oscilloscope. The upper traces are signals from the copper-doped germanium detector, and represent the power reflected off the germanium Brewster-angle polarizer. The lower traces are signals from the gold-doped germanium detector and illustrate the building up of power inside the cavity. The combined risetime of the gold-doped germanium detector and the oscilloscope is greater than 10 nsec and is much greater than the width of the mode-locked pulses (<4 nsec). Figure 1a shows signals from the two detectors in the absence of cavity dumping. Forced mode locking of the laser can be seen from the lower trace in Fig. 1a. A small reflection from the germanium Brewster-angle polarizer can be seen on the upper trace in Fig. 1a. Figure 1b shows signals from the two detectors when the cavity dumping was turned on. The lower trace in Fig. 1b shows initial mode locking, then cavity dumping and rebuilding of radiation inside the cavity. A sharp mode-locked and cavity-dumped pulse can be seen as the upper trace in Fig. 1b.

Figure 2 shows a typical mode-locked and cavity-dumped pulse displayed on a Tektronix 454A oscilloscope. The pulse was detected by the copper-doped germanium detector with a risetime of approximately

1 nsec. The oscilloscope has a risetime of approximately 2.5 nsec. The pulse had peak power greater than 10 kW and its width on the oscilloscope was 4 nsec. It has been reported that a train of 1-nsec pulses has been obtained by supplying only 0.5 W of driving power to a germanium acoustic-loss modulator.[5] Therefore we believe that the width of our mode-locked and cavity-dumped pulse must be smaller than 4 nsec and the peak power higher than 10 kW.

We wish to thank Professors H. A. Haus, P. W. Hoff, and E. V. George for their advice and Mr. F. Barrows for his invaluable technical help.

[*] Now at Los Alamos Scientific Laboratories, Los Alamos, New Mexico.

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4. E. E. Stark, Jr., Sc. D. Thesis, Department of Electrical Engineering, M.I.T., September 1972, pp. 69-71.
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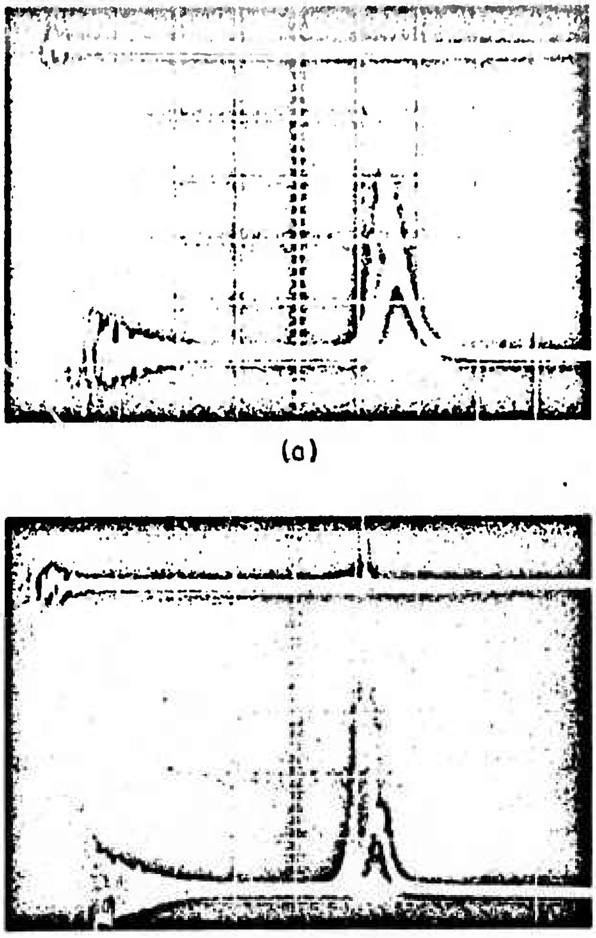
Fig. 1. Display on a dual-trace oscilloscope. Upper traces are signals from the Ge:Cu(Sb) detector. Lower traces are signals from the Ge:Au detector. Scale: 1 μsec/div.

(a) No cavity dumping

(b) Cavity dumping

Fig. 2. Typical mode-locked and cavity-dumped pulse with peak power greater than 10 kW. Scale: 10 nsec/div. The picture has been traced over by pen.



(a)

(b)

Fig. 1

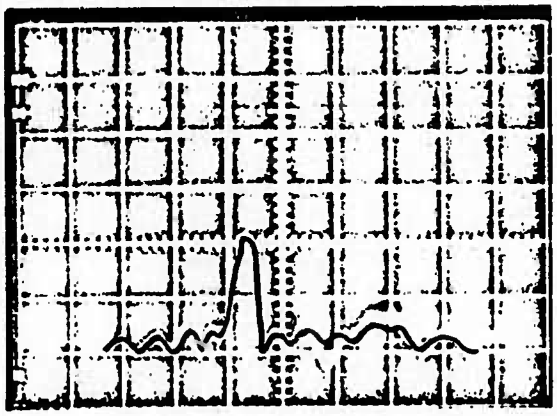


Fig. 2