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ABSTRACT

A modelocked, multiline oscillator was developed for use in laser-induced fusion investigations. A sodium chloride etalon provided the wavelength-dependent loss mechanism and an acousto-optic modulator was used for modelocking the laser.

A high-energy, short-pulse laser system¹ is being developed at this Laboratory as part of a program whose goal is the demonstration of laser-induced fusion. The laser system makes use of the efficient electron-beam-controlled discharge technique to deposit and store energy in large CO₂ amplifiers. It has been shown,² however, that on a time scale of one nanosecond or less, the extraction of the stored energy is limited by molecular kinetics when the device operates only on the usually dominant P(20) rotational transition at a wavelength of 10.59 μ m. Calculations^{3,4} indicate that this situation can be remedied by the use of a pulse whose spectral content consists of many of the CO₂ rotational transitions. Thus, the stored energy is simultaneously extracted from each inverted rotational level in the amplifier medium. There is no need to totally rely on molecular kinetics to provide "repumping" of the rotational inversions within the vibrational manifold.

To take advantage of the increased efficiency under multiline conditions, a modelocked oscillator, which has the required spectral content, has been developed. The laser is of the Lamberton-Pearson⁵ double-discharge configuration employing Rogowski profile electrodes of 60-cm length, spaced

by 1.5 cm with .02-mm-diameter tungsten preionization wires. The measured P(20) small signal gain of the oscillator was .035 cm⁻¹ using a gas mixture of 7:1:1::He:N₂:CO₂ when an excitation density of 350 J/l was applied from a low-inductance, two-stage Marx generator. Multiline operation was achieved by means of the wavelength-dependent loss provided by an intra-cavity solid NaCl Fabry-Perot etalon⁶ of 5-mm thickness. The laser was modelocked by a Ge Brewster angle acousto-optic modulator⁷ operating at 40 MHz and providing an 80-MHz loss modulation to the optical cavity. The device produced substantially 100% modulation with 100 W of drive power gated on for one msec and had an insertion loss of 35%. The cavity reflectors consisted of an internally mounted Ge output coupler of 98% reflectivity and a 100% reflectivity multilayer spherical reflector of 6-m radius of curvature. Their separation was 1.87 m. A 4.0-mm-circular intra-cavity aperture assured TEM₀₀ operation. Figure 1 shows a schematic diagram of the apparatus.

The spectral content and time behavior of the oscillator output pulses were investigated. The beam was focused on the input slit of a Jarrell-Ash Model 82-410, 0.25-m monochromator equipped with 100- μ m slits

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Fig. 1. Modelocked multiline oscillator schematic diagram.

and a 50-line per millimeter grating which was blazed for 10 μm . The monochromator possessed sufficient resolution to fully separate the various lines of the P and R branches of the 001-100 band which are spaced by a minimum of .02 μm . A high sensitivity pyroelectric detector was mounted at the output slit of the monochromator. Its output was displayed on a Tektronix type 7514 storage oscilloscope equipped with a type 7A22 variable bandwidth vertical amplifier module. The time behavior of the laser was monitored by means of a Rohin Corporation photon drag detector whose output was displayed on a Tektronix type 7904 oscilloscope with type 7A19 vertical amplifier and 7B92 sweep module for one nsec per division-deflection.

The operation of the oscillator first required reliable modelocked behavior on the P(20) line where the pulses had a measured full width at half maximum of 1.5 ± 0.5 nsec. The etalon was then tilted through the angular range of zero to five degrees with respect to the normal to the optic axis of the laser. Steps of 0.1 degrees were made while the output spectrum was measured from 10.40 to 10.70 μm . The pulse temporal behavior was simultaneously monitored to provide assurance that the laser was operating in the modelocked regime. A graph of the output in each line versus the optical path length in the etalon showed the expected quarter-wave periodicity

and allowed the choice of an etalon angle where three lines appeared simultaneously. Figure 2 shows a typical output spectrum while Fig. 3 shows the modelocked output train. The total energy in each pulse was approximately one mJ and was independent of the number of transitions that were forced to oscillate.

The three-line oscillator described here should be able to extract approximately 65% of the energy³ stored in the inverted population existing in a pumped, one-atmosphere CO₂ amplifier gas mixture. Further experiments planned are aimed at the achievement of at least five lines of comparable intensity in the output pulse. A double-section oscillator with 120 cm of active length and a low insertion loss modelocked will be used.

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Fig. 2. Measured relative output intensity vs wavelength of multiline, modelocked oscillator.

Fig. 3. Multiline oscillator, mode-locked output.

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