frequencies, we have compared the conversion efficiencies expected from theory [4] (for pulses Gaussian in space and time) to the measured conversion efficiencies. The KD*P doubler converted less energy to 266 nm than expected, but the values are within a factor of three of the theoretical efficiencies. Similarly, the efficiency of the mixer is within a factor of two of theoretical predictions. The intensities in these crystals were only a few megawatts/cm^2, and no damage was observed; therefore it is likely that higher efficiencies, particularly in the KD*P crystal, might be safely achieved using tighter focusing or a more powerful laser of this type.

In conclusion, we have demonstrated that useful average powers can be generated at the 213 nm harmonic of a CW-pumped Nd:YAG laser operating at kilohertz average pulse rates. More than 1 mW of average power at 213 nm was obtained at pulse rates between 1 and 4 kHz. Since the peak powers here are of the order of 15 W instead of the tens of kilowatts obtained with conventionally Q-switched flash-pumped lasers or hundred of watts with a pulse burst laser [4] at the same average power, problems of sample damage and space charge in various microscopy applications are greatly reduced if this CW-pumped source is used as an illuminator.

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Fast Response of PLZT Pyroelectric Detectors to Megawatt CO_2 Laser Pulses

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Abstract—PLZT ceramic was used to make fast pyroelectric detectors. These detectors were able to: 1) respond to 10 ns events; 2) directly drive a 50 Ω CRO input with load resistors as small as 10 Ω; and 3) withstand irradiation with CO_2 laser pulses of 2 MW/cm^2 without cracking or need for repoling. The performance characteristics are described and are found to be in general agreement with a previously developed analysis.

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THE use of ceramic pyroelectric (PE) materials [1] for the detection of high power laser pulses was recommended by Beerman [2] who found that a 0.3 J CO_2 laser pulse with a duration of 200 ns shattered a single crystal $LiTaO_3$ detector, while a similarly constructed PZT detector survived 50 such pulses, even though PZT has a much lower Curie temperature T_c than $LiTaO_3$. Having had similar experience, we turned to the PLZT 8/65/35 ceramic, $Pb_{0.92}La_{0.08}(Zr_{0.65}Ti_{0.35})_{0.98}O_3$ [3], [4]. In this material, the PE coefficient [1] λ is 170 nC/cm^2 · K and the dielectric constant ϵ is 3800 [5]; the T_c value is 110°C [4], the volume specific heat c is 2.6 J/cm^3 · K [6], and the figure of merit material parameter [7] ξ, $\xi = \lambda/\epsilon_0 \epsilon c$ is 190 cm^2/C.

Fifteen samples were prepared with thicknesses d of 22–25 μm and areas A of 0.05–1.5 mm^2. The electrodes were vacuum deposited: InSb in front (radiation receiving), and gold on the back. Stainless steel lead wires, 8 μm in diameter,

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were attached to the electrodes with conductive epoxy. The samples were mounted in TO-5 transistor cases by their leads. The samples were poled in fields of 10-100 kV/cm, at room temperature, as well as while heating to different temperatures up to 170°C and subsequently cooling to room temperature under the applied voltage. The different poling procedures had no striking effect on the performance of the detectors [8] under step IR radiation signals from a blackbody [7], (except that 150 kV/cm was fatally destructive). A 20 kV/cm poling field was found both safe and sufficient. During the poling, the dc resistance of the samples, measured with a Keithley 616 picoammeter, increased by 3-4 orders of magnitude, reaching values of 10^{13}-10^{15} Ω. In these experiments we used the CO_2 TEA laser described in [9] in which the optical cavity was extended to 3 m to enable the insertion of a CW CO_2 discharge. When the CW discharge was on, single frequency lasing occurred and the laser could be operated with no mode-locked spikes in its output. The PE response of our detectors to the laser pulses was so strong that it could be measured with parallel load resistances R_L of 100, 30, and 10 Ω across the samples, when directly connected to 50 Ω plug-in inputs of Tektronix 7844 and R7912 oscilloscopes.

The PE response to single IR laser signals was previously analyzed as a function of the parameters of the signal, its rise time t_{rs}, fall time t_{fs} and duration $\mathcal{T}$ and of the electronic and thermal time constants τ_e, τ_T of the PE detector [10]. With $\tau_e \ll \tau_T$, two cases were distinguished. First, when $\tau_e \ll (t_{rs}, t_{fs}, \mathcal{T})$. In this case the PE response exactly depicts the signal, having identical time parameters $t_r = t_{rs}$, $t_f = t_{fs}$, $\mathcal{T}$. If the signal $F(t)$ reaches a peak value at $t = t_{ps}$, then the PE voltage response also reaches a peak value V_p

$$V_p = V(t_p) = \xi \tau_e F_p = (\mathcal{M}/cd) R_L F_P. \tag{1}$$

Here $\tau_e \equiv R_L C$, where C is the capacitance of the sample and F_P is the peak power flux absorbed by the sample. The second case is the instance when $\tau_e \gg (t_{rs}, t_{fs}, \mathcal{T})$. This was shown to produce a response $V(t)$ which rises as long as the signal persists, and at the end of the signal reaches a peak value

$$V_P = V(\mathcal{T}) = \xi E_a / A, \tag{2}$$

proportional to the total energy E_a absorbed from the signal. After the end of the signal, the response decays exponentially to zero with fall time $t_f = \tau_e \propto R_L$. The shape of the rising part of $V(t)$ and t_r depends on the shape of the signal, and e.g., for a rectangular signal, the rise of the detector response is linear and $t_r = 0.63$.

Both described cases were observed in our PLZT detectors. The first case is represented in Fig. 1(a) which is the PE response of our sample 6 ($A = 1.8 \times 10^{-3}$ cm^2, $d = 23$ μm, $\tau_e = 9$ ns) to a 200 ns (full width at half maximum [FWHM]) CO_2 laser pulse of ~2 MW/cm^2 intensity. On the photon drag detector response [Fig. 1(b)] one can see three independent wave trains of different amplitudes, each consisting of a separate train mode-locked pulse. The short spikes are spaced by ≃15 ns and are ≲2 ns in duration. This output waveform was characteristic of our free running TEM_{00} mode CO_2 TEA laser [9]. The PE detector response follows very closely the first (highest) signal of $t_{rs} \simeq 50$ ns, having similar rise and fall

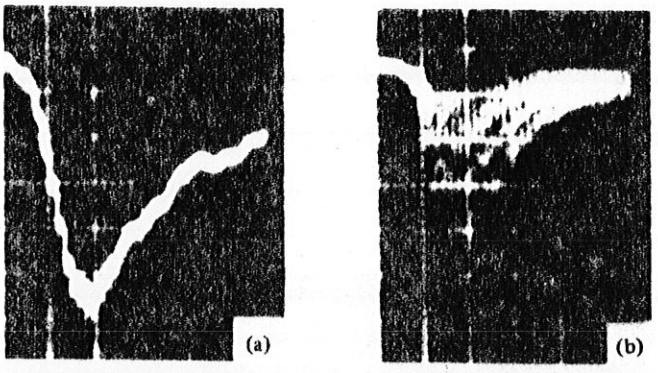

Fig. 1. (a) PE; and (b) photon drag detector response to mode-locked CO_2 TEA laser pulse. Horizontal scale is 100 ns/div, and vertical–20 mV/div.

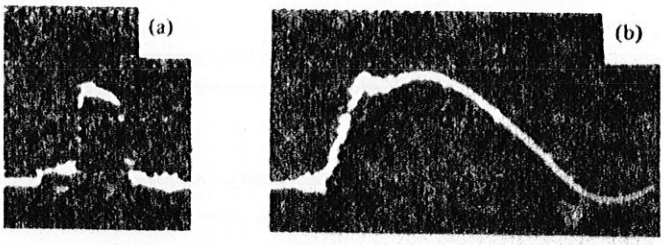

Fig. 2. (a) Photon drag (amplified); and (b) PE (direct) detector response to a square section of the CO_2 TEA laser pulse switched onto with an electrooptic shutter pulse. Horizontal scale is 50 ns/div, and vertically, a) 100 mV/div, b) 20 mV/div.

times and a slightly larger half width of ~250 ns. The widened tail of the response is due to the onset of the piezoelectric ringing [11]. The 15 ns spacings between the spikes in the signal appear as steps on the PE response trace.

The second case is presented in Fig. 2. The PLZT sample 7 ($A = 4 \times 10^{-3}$ cm^2, $d = 22$ μm, $\tau_e = 60$ ns) was irradiated by a close-to rectangular, 35 ns pulse with 5 ns rise and fall times, depicted by the photon drag detector response shown in Fig. 2(a). This pulse was obtained by suppressing the TEA laser's self-mode locking with an intracavity CW discharge and by then switching out the desired pulse with an electrooptic shutter [9]. The PE response [Fig. 2(b)] is seen to rise linearly during 45 ns duration of the laser pulse and the 63 percent rise time of the response is 30 ns. The fall of the response is obscured by the onset of piezoelectric ringing with a period of 300 ns, and the fall time was not measured. Piezoelectric ringing was pronounced in our samples because they were freely suspended on their leads. This problem can easily be reduced using other detector mounting techniques [12].

The direct response traces of Figs. 1 and 2 are not the ultimate in the IR detection ability of the PLZT. By the use of proper electronics—amplifiers, devices to switch off the response at the end of the signal, careful impedance matching, etc.,—both the sensitivity and speed of response can be enhanced by orders of magnitude. From (1) and (2) one could assume that PE detectors can be used to measure both the peak power and the overall energy absorbed from the single laser pulses by simply switching from $\tau_e < t_{rs}$ (small R_L and/

or C) to $\tau_e > t_{FS}$ (large R_L and/or C). However with the V_P = 110 mV of Fig. 1(a) and 38 mV [Fig. 2(b)], (1) and (2) yield $F_P = 6.4 \times 10^4$ W/cm^2 for the irradiation with the mode-locked pulse, and $E_a/A = 2 \times 10^{-4}$ J/cm^2 for the modulated square pulse. With ~50 percent of the impinging power known to be reflected by the InSb front electrode and allowing 20 percent for other optical losses (in-line and side transmission, reradiation) these results are still five times lower than those obtained with a slow black-absorbant power meter (e.g., Tachisto 100 thermopile). Apparently, the values of ϵ, λ, and c are irrelevant because they were measured in much slower processes. Thus the photometric application of (1) and (2) requires a proper calibration of the PE response. With this calibration, these equations may then also be used in a dynamic method [1], [12] to measure the fast-process values of λ, ϵ, and c from the PE response.

In conclusion we point out that the 8/65/35 PLZT ceramic proved to be a valuable material in the PE detection of megawatt infrared pulses. In spite of its high dielectric constant (70 times that of $LiTaO_3$) this PLZT can be used to detect 10 ns events, is able to withstand prolonged irradiation without developing cracks or faults, and preserves its polarization even under such severe irradiation conditions that cause the InSb electrode to partially evaporate. Because of this reevaporation, the InSb front electrode is not appropriate for multiple use even with 10^4 W/cm^2 pulses and should be replaced by a more damage resistant material, possibly sputtered indium-tin oxide.

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New HF Laser Pumped Molecular Lasers in the Middle Infrared

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Abstract—Stimulated emission has been observed in five molecules optically pumped by a pulsed HF laser. Emission was observed in $^{15}N_2O$, $^{14}N^{15}NO$, and $^{15}N^{14}NO$ at 4.6 μm, HCOOH at 5.7 μm, and in $^{13}CS_2$ at 6.9 μm. Lasing pulse shapes and delays after the pump pulse were measured. Lasing due to rotational relaxation induced by collisions with He was observed in $^{15}N^{14}NO$.

RECENTLY many new laser wavelengths in the middle infrared have been produced using CO_2, HF, and other lasers to pump various molecules [1]. Here we report five molecules which have lased due to optical pumping w 0.75 J multiline HF laser. The molecules $^{15}N^{15}NO$, $^{14}N^{1}$ $^{15}N^{14}NO$, HCOOH, and $^{13}CS_2$ lased in the wavelength 4.6–6.9 μm.

The pump laser was a 0.75 J HF oscillator-amplifier s which has been described previously [2]. A 2-m focal lens was used to focus the good mode quality output fr laser through a 1-mm hole in one of the two gold-coated mirrors. A KBr Brewster window sealed the 1-m lon the output end and a 2-mm hole in the output mirror output coupling. The signal was isolated with variou and was detected with a fast photoconductive HgC tector having good response to 19 μm. A 0.5 monochromator was used to measure wavelengths.

Three isotopes of N_2O—$^{15}N^{15}NO$, $^{14}N^{15}NO$, and ^{1}

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