design of hollow-cathode laser tubes, appears when two cathodes are facing each other. At a position of the hole, therefore, the hollow-cathode effect disappears, i.e., the larger the total area of hole, the more notable the reduction of the hollow-cathode effect. The hybrid hole system saves the loss of effective cathode area and therefore the hollow-cathode effect, resulting in recovery of gain. Another interpretation is also possible; the saving of loss of the effective cathode area is equivalent to a recovery of active cathode length, resulting in an increase in total gain.

We have also obtained white light laser operation by the Mark II laser tube, but its performance did not exceed that of the Mark I. This fact suggests that more careful design for the diffusion holes is necessary since the evaporation of Cd metal is not obtainable by sputtering action, and there is a limitation on the amount by which the hollow-cathode surface area can be reduced.

We have successfully achieved a concentric cylinder type white light laser: by applying a new concept. The conclusions obtained from this study are as follows.

1) White light laser action has been obtained in a concentric cylinder tube using both a perforated and slotted hollow-cathode.
2) The new hybrid hole system which carries out the negative glow confinement and diffusion of Cd vapor separately has characteristics suitable for white light laser oscillation.
3) The main source preventing a white light laser oscillation is not a lack of Cd vapor but a decrease of the hollow-cathode effect.

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REFERENCES


Optically Pumped CHCIF₂ and C₂H₅I Submillimeter Wave Lasers

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Abstract—Submillimeter wave laser action is reported for the first time in chlorodifluoromethane and ethyl iodide. Five new laser transitions have been produced by optical pumping with a chopped CO₂ laser.

Optical pumping of vibrational-rotational transitions of polar molecules to produce coherent submillimeter wave (SMMW) radiation from pure rotational transitions has been a prolific research area over the past decade [1]. Two additional submillimeter wave laser molecules are reported in this paper.

Optical pumping with an electrically chopped CO₂ laser produced three new laser transitions in chlorodifluoromethane (CHCIF₂) gas and two in ethyl iodide (C₂H₅I) vapor.

The experimental setup has been previously described [2]. The SMMW laser is a metallic waveguide unoptimized 3.5 mm output-hole-coupled resonator with plungers; it measures 90 cm long and 25.4 mm in diameter. Coincidences between the pump laser and the absorption lines were first identified by synchronously detecting the output of a microphone [3] with a lock-in amplifier as the CO₂ laser was tuned by manually turning the grating. For these recordings, the CO₂ laser was electrically chopped at 40 Hz in a quasi-CW mode with about 3 ms pulse length. The coincidences of CHCIF₂ in

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The 9-μm R-region and C₂H₅I in the 10-μm R and P-regions are shown in Figs. 1 and 2. Coincidences in the branches not shown resulted in a less than 0.1-mV microphone signal. Those pump lines that produced SMMW laser action are indicated in Table I and were determined with a spectrum analyzer. The SMM wavelengths were measured to an estimated accuracy of ±0.5 μm unless otherwise specified, with a scanning Fabry–Perot interferometer with metal mesh reflectors of 84-μm grid constant. The laser was operated in a sealed-off mode, and optimum pressures were measured with a capacitance manometer.

For these two molecules, SMMW laser action occurred for the pump laser in an electrically chopped mode at 10 Hz, but not in a true CW mode. In this case, the optical pumping is attributable to an approximately 100-μs (FWHM) power spike occurring at the leading edge of the CO₂ signal. The pulse height was determined with a HgCdTe detector to be about 2.5-3 times the normal CW power. The 9R(4) and 9R(44) pump lines themselves were operational only on this power spike. The peak pump powers coupled into the SMMW resonator are listed in Table I. The relative SMMW strengths were determined with a 5-mm aperture Golay detector. Using a pulsed calibration of the Golay cell at 0.9 μm [4] and assuming a SMMW pulselength equal to the CO₂ pulselength of 100 μs, we estimate a lower limit of 0.2 mW for relative SMMW strength equal to 1 in Table I.

CHClF₂ is an asymmetric top molecule (Ray's asymmetry parameter κ = -0.60) with dipole moment of 1.42 Debye [5] and fundamental vibrations reported at 400, 417, 598, 812, 836, 1108, 1312, 1350, and 3024 cm⁻¹ [6]. The absorption of the CO₂ pumped 9R lines is attributed to the very strong C-F symmetric stretch vibration at 1108 cm⁻¹ [6]. The low-intensity absorption coefficient at the 9R (32) CO₂ laser line has been reported to be about 0.01 cm⁻¹ · torr⁻¹ [7]. This gives a point of reference for the strength of the other lines as determined by the microphone.

C₂H₅I is a slightly asymmetric top molecule (κ = -0.986) [8] with dipole moment of magnitude 1.91 Debye [5]. The CO₂ lines overlap the 955 cm⁻¹ absorption band which, from low-resolution spectroscopic studies [9], has been attributed to the C-C symmetric stretching vibration.

These new laser results may be used as a test of the application of the proposed set of selection criteria for predicting efficient CW FIR laser candidates [10]. 1) The dipole moment should be ≥ 1; this criterion is satisfied for both CHClF₂ and C₂H₅I. 2) The vibrational absorption should be less than ±60 MHz from the CO₂ laser line center. This criterion is probably satisfied by a number of absorptions in both molecules as indicated by the size of the microwave signals; however, more detailed measurements are required to determine the exact frequency difference. This second criterion has recently been refined by adding that the transition band moment of the pumped vibrational mode should be large (μ₀ > 0.2 Debye) [11]. Although the vibrational band moments have not been measured for either new molecule, μ₀ has been estimated for the CHClF₂ 1108 cm⁻¹ band to be near 0.3 Debye [7]. 3) The modified final criterion [11] is that the molecule should generally have less than six atoms with at least one heavier atom. This criterion is satisfied by CHClF₂ but not by C₂H₅I. In summary, CHClF₂ appears to satisfy the selection criteria, although C₂H₅I clearly does not. CHClF₂, according to the criteria, might be expected to produce strong CW laser action; however, the absorption of CHClF₂ does not overlap with very many CO₂ pumping lines providing less of a probability of hitting SMMW lines with optimum molecular
parameters. The fact that $\text{C}_2\text{H}_2\text{I}$ does not produce strong CW lasing despite the larger number of microphone coincidences is in agreement with predictions of the criteria.

Photoacoustic spectroscopy and a search for laser action in several gases, including CHClF$_2$, has just been reported by Li and Davis [12]. The lack of SMMW laser action for CHClF$_2$ in their experiment may be attributed to insufficient pump power or higher losses in their dielectric waveguide. Although these new lines in CHClF$_2$ and C$_2$H$_2$I are weak compared to the 496-μm CH$_3$F transition, they may satisfy a need for additional specific laser wavelengths and could prove useful in spectroscopic analyses of these molecules.

**References**


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**Atomic Lead Photodissociation Laser**

H. HEMMATI AND G. J. COLLINS

Abstract—Stimulated emission has been observed on the 405.8, 368.3, and 364.0 nm lines of neutral atomic lead following photodissociation of lead dibromide and lead diiodide molecules with the 193 nm output of an ArF laser. Two-photon dissociation processes are involved in the excitation mechanism.

RECENTLY the ultraviolet wavelength rare gas-halide lasers have generated renewed interest in electronic transition photodissociation lasers. In particular, several atomic transition lasers excited through photodissociation of monohalide and triiodide vapors of the metals have been demonstrated [11]-[6]. E. J. Schimitschek and co-workers have also demonstrated a diatomic electronic transition photodissociation laser in HgBr by dissociating HgBr$_2$ molecules [7]. Optically pumped metal halide photodissociation lasers of this type possess very low thresholds and the laser medium can be produced at relatively low temperatures. The intense radiation of the excimer laser may be converted to a more useful wavelength region of the spectrum and considerable narrowing of the emission is usually observed via this selective excitation. For instance, since some of the atomic photodissociation laser transitions are resonance transitions they are potentially applicable to trace element detection. Finally, the study of the photodissociation yields important information regarding the dissociation processes and collisional physics.

Early photolysis studies of PbX$_2$ (X = Cl, Br, and I) indicate that if PbX$_2$ vapor is irradiated with short wavelength light (λ < 210 nm), bands characteristic of the PbX radical and X, molecules and a number of Pb lines appear in the emission spectrum [8]-[10]. We optically excited PbX$_2$ molecules with a 193 nm ArF laser to study the feasibility of achieving stimulated radiation in Pb and PbX. The PbX emission appears to be weak and linearly dependent on the primary excitation intensity, whereas the X, band and atomic lead lines are quadratic and even cubic functions of the excitation radiation.

We report strong superfluorescent stimulated emission for three Pb(I) transitions-405.8 (7s$^5$P$_1 \rightarrow 6p^2$ $^3$P$_2$), 368.3 (7s$^5$P$_0 \rightarrow 6p^2$ $^3$P$_2$), and 363.96 (7s$^5$P$_1 \rightarrow 6p^2$ $^3$P$_1$) nm—which are produced by optical pumping of vapor phase lead diiodide (PbI$_2$) and lead dibromide (PbBr$_2$) molecules. An ArF laser operating at 193 nm was used as the selective photolysis source. A schematic of the potential energy curves relevant to the dissociation process is shown in Fig. 1. Two of the transitions (405.8 and 364.0 nm) as well as several near infrared and ultraviolet laser transitions originating in the atomic lead spectrum have been reported previously in discharges with...