

PHOTODISSOCIATION IODINE LASER USING COMPOUNDS CONTAINING GROUP-V ATOMS

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We investigate the possibility of using as the active medium of a photodissociation iodine laser compounds containing a bond of the iodine atom with a group-V element (P-I, As-I, Sb-I). Lasing was obtained with 16 compounds of this type. Certain operating features of lasers based on the new substances are discussed.

Recently, in connection with progress on laser heating of plasma for the purpose of initiating thermonuclear reactions, the problem of developing a high-power photodissociation iodine laser operating in the nanosecond pulse regime has been discussed in the literature [1]. Lasers of this type, which make use of the dissociation of the compounds CF_3I and C_3F_7I and some analogous compounds with the C-I bond, have a number of unique features that distinguish them noticeably from neodymium-glass lasers. One of the main tasks in this connection is that of increasing the laser efficiency, which is presently estimated at 0.5% [1], which is approximately the same as that of neodymium lasers used in plasma heating experiments. The efficiency of a photodissociation laser can be increased in principle by broadening the absorption spectrum of the working medium (in particular, by using a mixture of such media), and also by using various chemical reactions that accompany the photolysis [2, 3]. This raises the question of increasing the number of working media capable of releasing excited iodine atoms $I^*[5^2P_{1/2}]$ during the photolysis process.

We report here the first case of lasing by using photolysis of a number of compounds containing an iodine atom bonded with an atom of group V, viz., P-I, As-I, and Sb-I. The hitherto known photodissociation lasers operated with media containing the bond C-I. We show thus that photolysis with predominant production of excited iodine atoms I^* is not restricted to substances with the C-I bond, and therefore a significant increase in the number of working media for photodissociation iodine lasers is perfectly realistic.

We obtained lasing with the following substances: 1) with the As-I bond: $(CF_3)_2AsI$, $CF_3(C_2F_5)AsI$, $CF_3(C_3F_7)AsI$, $(C_2F_5)_2AsI$, and $(C_3F_7)_2AsI$; 2) with P-I bond $(CF_3)_2PI$, $CF_3(C_2F_5)PI$, $CF_3(C_3F_7)PI$, $(C_2F_5)_2PI$, $(C_3F_7)_2PI$, $CF_3(CH_3)PI$, $CF_3PI(CN)$, $CF_3(CF_2Cl)(CFH)PI$, F_3PI , and OPF_2I ; 3) with Sb-I bond: $(CF_3)_2SbI$.¹⁾

The investigations were performed with the following experimental setup: a quartz laser cell 25 cm long and of 7 mm i.d. was placed in a planar resonator with mirrors spaced 85 cm apart and with mirror transmission coefficients 0.2% and 11%; the pumping was with an IFP-5000 xenon flash lamp supplied from 50 and 5 μF capacitors, with a light-flash duration at half-intensity ($\tau_{1/2}$) equal to ~ 40 and ~ 5 μsec , respectively. The electric energy fed to the lamp ranged from 200 to 1000 J. In a number of experiments we used a liquid filter (0.02 - 0.003% solution of $NaNO_3$ in distilled water); the absorption spectrum of the filter is shown dashed in Fig. 1. The laser pulse was registered with an FD-9 photodiode and an SI-17 oscilloscope. The generation energy was registered with a KIM-1 calorimeter, which could measure a radiation energy $\sim 10^{-3}$ J.

The absorption spectra of all the investigated compounds (with the exception of F_3PI and OPF_2I), unlike those of compounds with C-I bonds,

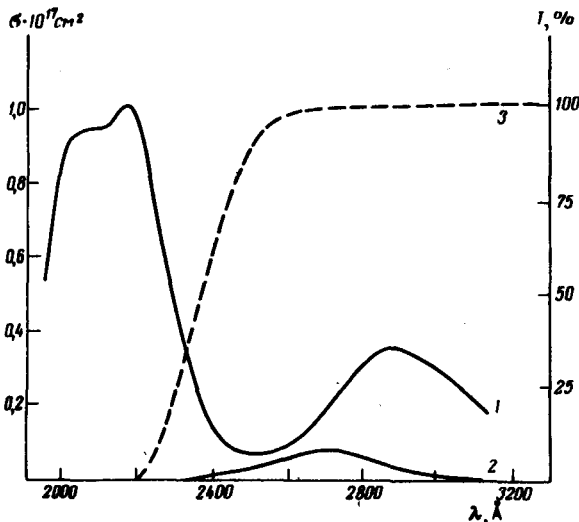


Fig. 1. Absorption spectra: 1 - $(CF_3)_2AsI$, 2 - $n-C_3F_7I$, 3 - filter.

consist of two bands. The positions of the absorption bands of all the investigated molecules are practically the same, and the relative shift is within ~ 100 Å. A typical absorption spectrum is shown in Fig. 1, with $(CF_3)_2AsI$ as an example. Experiments have shown that the working absorption band is a long-wave band with maximum at $\lambda_{max} \sim 2900$ Å, $\sigma_{max} \sim 3.5 \times 10^{-18}$ cm², and half-width $\Delta\lambda \sim 500$ Å. For comparison, Fig. 1 shows the absorption spectrum of $n-C_3F_7I$. It is precisely this band which is responsible for the photodissociation of the molecules listed above, with formation of the excited atoms $I^* [^2P_{1/2}]$. The photodissociation products corresponding to the second short-wave absorption band are still unknown, but in most cases they produce harmful effects and decrease the generation energy.

A feature of all the investigated compounds containing group-V atoms is that starting with certain values of the pump energy the generation pulse begins to terminate abruptly, apparently as a result of thermal decomposition (pyrolysis) of the working medium. For $(CF_3)_2AsI$, for example, this termination of the lasing pulse is observed at a pump energy ~ 400 J. The usable pump energy can be increased appreciably either by diluting the working medium with an inert gas, or by reducing the duration of the flash lamp. Thus, if $(CF_3)_2AsI$ is diluted with xenon [$(CF_3)_2AsI:Xe = 1:20$], the electric pump energy corresponding to the onset of pyrolysis is approximately doubled in comparison with the non-diluted $(CF_3)_2AsI$, and reaches ~ 800 J. At shorter pump pulses ($\tau_{1/2} \sim 5$ μ sec) the resistance of the substances to pyrolysis is greatly increased. In this regime, the generation energy continues to grow up to pump energies ~ 1600 J.

The endurance to thermal damage of the working medium is increased also when the structure of the molecule is made more complicated. For example on changing from $(CF_3)_2AsI$ to $(C_3F_7)_2AsI$, the onset of pyrolysis shifts from ~ 400 to ~ 1000 J. The dependence of the lasing energy of $(CF_3)_2AsI$ on the pump energy with and without a filter is shown in Fig. 2. We see that the curves have a complicated nonmonotonic character, something not observed previously in compounds with the C-I bond.

Among the investigated compounds there are also some (e.g., $(CF_3)_2AsI$) capable of recovering their lasing ability, and can therefore be used repeatedly. Thus, Fig. 3 shows the dependence of the $(CF_3)_2AsI$ on the number of the flash and compares it with the result for $n-C_3F_7I$. The pressure of the $n-C_3F_7I$ was chosen to make the ratio of the maximum absorption cross sections of $(CF_3)_2AsI$ and $n-C_3F_7I$ approximately 4:1. We see that, unlike $n-C_3F_7I$, the compound $(CF_3)_2AsI$ can withstand ~ 20 flashes of the lamp without a noticeable decrease in the lasing energy.

More detailed investigations of the operating features of the described compounds will be published separately.

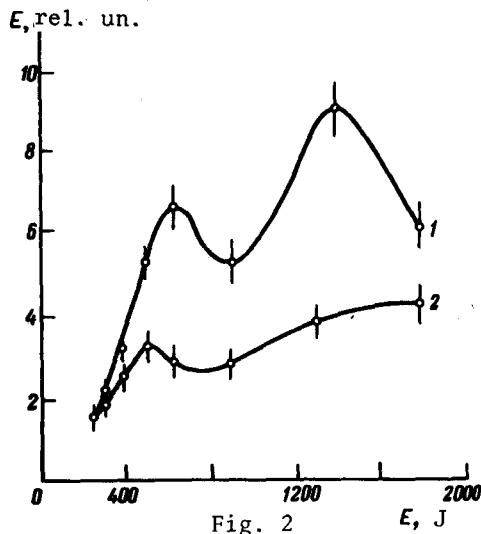


Fig. 2

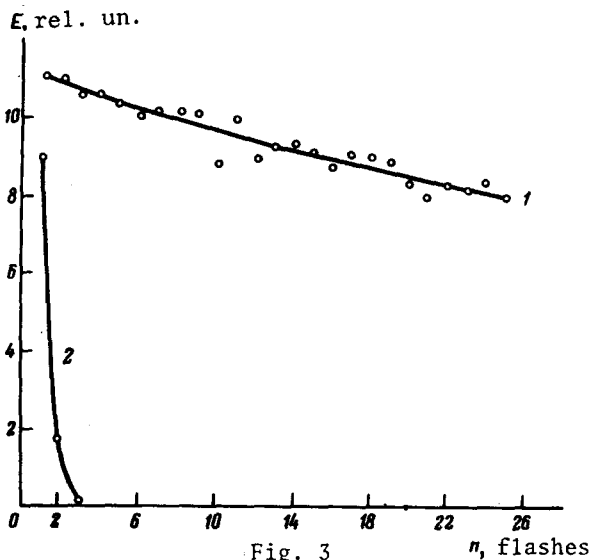


Fig. 3

Fig. 2. Generation energy vs. electric energy of illuminating lamp for $(CF_3)_2AsI$ at $P = 0.03$ atm: 1 - with filter, 2 - without filter.

Fig. 3. Generation energy vs. number of lamp flashes: 1 - $(CF_3)_2AsI$, $p = 0.015$ atm; 2 - $n-C_3F_7I$, $P = 0.06$ atm.

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- [1] K. Hohla, *Laser + Elektro - Optic*, No. 3, 29 (1972).
 [2] T. L. Andreeva, S. V. Kuznetsova, A. I. Maslov, N. I. Sobel'man, and V. N. Sorokin, *ZhETF Pis. Red.* 13, 631 (1971) [*JETP Lett.* 13, 449 (1971)].
 [3] K. Hohla and K. L. Kompa, *Chem. Phys. Lett.* 14, 445 (1972).

ZEEMAN EFFECT ON ACCEPTOR CENTERS AND NEGATIVE MAGNETORESISTANCE IN TELLURIUM

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Experimental data are presented to show that the negative magnetoresistance in tellurium has no noticeable anisotropy and does not differ significantly from the negative magnetoresistance in other semiconductors. On the other hand, it is shown theoretically that the Zeeman splitting of acceptor states in tellurium is essentially anisotropic and is practically nonexistent at $H \parallel C_3$. Thus, the Toyozawa's theory of negative magnetoresistance does not hold for tellurium.

Negative magnetoresistance of semiconductors was first observed in tellurium [1] and was subsequently investigated in detail both in tellurium [2, 3] and in many other semiconductors. The negative magnetoresistance effect is usually explained with the aid of Toyozawa's mechanism [4], namely the decreased scattering of carriers with spin flip by the magnetic moments of the localized electrons, owing to the splitting of the impurity levels in the magnetic field. According to [5], we have then

$$-\frac{\Delta\rho}{\rho} \sim M^2 \sim B_j(x), \quad (1)$$

where $B_j(x)$ is the Brillouin function, $x = j\mu_B gH/kT$, and $\mu^* = jg\mu_B$ is the effective magnetic moment. For a number of semiconductors, the negative magnetoresistance is approximately described by formula (1), and in this case μ^* is usually much larger than for free carriers (see, e.g., [5, 6]).

In the present communication we present experimental data, together with their quantitative analysis, which show that negative magnetoresistance in tellurium does not differ from that in other semiconductors, for H either parallel or perpendicular to C_3 , and the dependence of the negative magnetoresistance on H and T in weak magnetic field is described approximately by formula (1). It follows from the theoretical calculations presented below, however, that the character of the Zeeman splitting of the impurities in tellurium is essentially different from that in other semiconductors, and cannot explain the negative magnetoresistance.

Theory. The structure of the valence band of tellurium is shown schematically in Fig. 1. Its characteristic feature is the absence of spin degeneracy of the holes [7]. The impurity levels corresponding to the extrema at the points $K_0 \pm \kappa_0$ split into symmetrical and antisymmetrical states [8]. According to [3], this splitting equals $2\Delta = 0.16$ meV at an ionization energy $E_i = 1.47$ meV. Each of these levels is doubly degenerate because of invariance and the time reversal that connects the points K_0 and $-K_0$. Calculation shows that the splitting of the impurity levels in a longitudinal magnetic field is described by the formula

$$E = \pm \left[\left(\frac{1}{2} G \mu_B H_x \right)^2 + \Delta^2 \pm G \mu_B H_x |\delta| \right]^{1/2}. \quad (2)$$

Here G is a constant that determines the relative shift of the bands at the points κ_0 and $-\kappa_0$ in a field $H \parallel C_3$, and $G = 5$ according to [9]; δ is a constant that determines the mixing of the