Appearance of electric conductivity following resonant action of infrared laser radiation

V. T. Galochkin, S. I. Zavorotnyĭ, V. N. Kosinov, A. A. Ovchinnikov, and A. N. Oraevskiĭ

P. N. Lebedev Physics Institute, USSR Academy of Sciences
(Submitted June 28, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 3, 153–155 (August 5, 1975)

It was observed recently that polyatomic molecules such as SF_6, BCl_3, and others begin to fluoresce when acted upon resonantly by IR radiation.[1,2] Even though the exact mechanism of the described phenomenon is not yet clear, its nonthermal nature is quite fully understandable. In the present study we have observed a new effect connected with onset of conductivity in a gas consisting of SF_6 or BCl_3 molecules acted upon by IR radiation.

The experimental setup, which consists of three principal parts (cell C with the medium, radiation source (*S*), and recording circuit), is shown in Fig. 1. The cell is made of stainless steel and is a cube 60 mm on each side. The inside cavity is made up of three through holes of 25 mm diameter. These holes are used for the windows, electrodes, and for the gas inlet. Tungsten electrodes (E) in the form of hemispheres of 8 mm diameters are mounted on Plexiglas insulators and placed at the center of the cell 5 mm apart. The windows for the entrance of the laser radiation are made of sodium chloride, and the window for the observation of the fluorescence is made of lithium fluoride. The radiation source (S) is a pulsed CO_2 laser of tunable frequency, with a lasing pulse duration 4 μsec. A spherical mirror M ($R = 3000$) focuses the laser radiation on a germanium plate placed in front of the cell window. To prevent the laser radiation from falling on the electrodes, a slit diaphragm (D) measuring 2×8 mm is placed in front of this plate. The image of the slit is projected after a number of reflections on a calorimeter (Cal) and a photoreceiver (Rec), the resolution time of which is not worse than 10^{-7} sec. Part of the radiation passing through the cell is absorbed in an opaque absorber. The fluorescence is registered with an FÉU-18A photomultiplier (PM) mounted flush on the upper face of the cell. The circuit used to register the current through the medium consisted of the following elements: a voltage source (0.5–3.0 kV), a charging resistor R_1 (2×10^9 Ω), a decoupling capacitor C_1 (100 pF), an electrostatic voltmeter (*V*), and a resistor R (5 kΩ). The capacitance of the system of electrodes plus the voltmeter capacitance amounts to 1 + 17 pF. The voltage pulse is picked off the resistor R and is fed jointly with the photomultiplier signal to a two-beam S8-2 oscilloscope.

Preliminary investigations have shown that when the gases SF_6 and BCl_3 (pressure up to 20 Torr) are exposed to CO_2 laser radiation, at the considered cell geometry, a conductivity corresponding to a resistance 10^6 Ω is observed in the medium. Thus, the employed parameters of the electric circuit, with allowance for the electrode and signal-cable capacitances, make it possible to register the signals without significant distortions, with characteristic times from 10^{-7} to 10^{-3} sec.

Figure 2 shows the family of current and fluorescence oscillograms observed by us for SF_6 at a pressure 4 Torr for different irradiation energies. It is seen that the fluorescence intensity correlates with the value of the current in the gas. A decrease of the irradiation energy causes a decrease of both the fluorescence intensity and the current. Figure 3 shows a family of current oscillograms at various values of the voltage on the electrodes. The observed values of the two maxima of the medium conductivity are proportional to the voltage, i. e., the conductivity obeys Ohm's law. Similar results were obtained also for BCl_3. When the

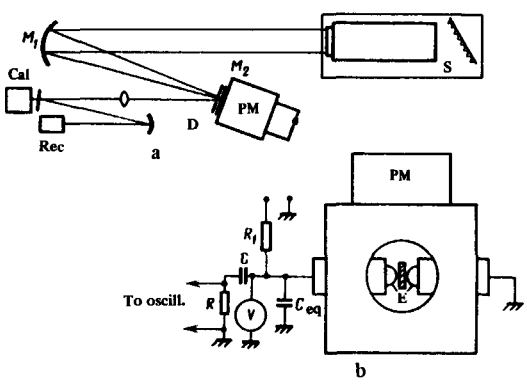

FIG. 1. Diagram of experimental setup: a) arrangement of optical elements, b) electric circuit.

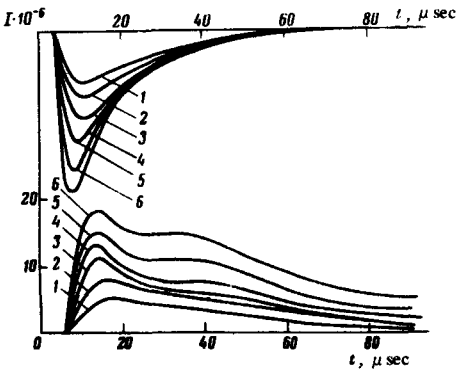

FIG. 2. Oscillograms showing the intensities of the fluorescence (upper curves) and of the current (lower curves) as a function of the irradiation energy in SF_6 (SF_6 pressure 4 Torr). Curves 6 correspond to an irradiation energy ~ 72 mJ.

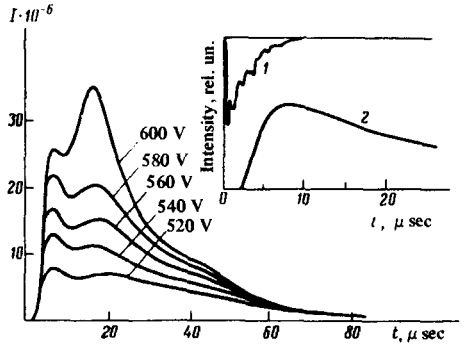

FIG. 3. Oscillograms of the current vs. the applied voltage. The top figure shows oscillograms of the CO_2 laser pulse (1) and of the visible fluorescence (2).

CO_2-laser frequency is changed, both the fluorescence and the current vanish. No such phenomena were observed in non-absorbing gases (N_2, O_2, He). The onset of photoconductivity cannot be attributed to the photoeffect on the electrodes irradiated by the fluorescence light. The work function for tungsten corresponds to the red boundary ~2700 Å of the photoeffect. Additional investigations have shown that the wavelengths of the fluorescence do not contain noticeable components in the range 2200–2800 Å. The polarization of the vibrationally-excited gas can likewise hardly explain this phenomenon, for this would call for the value of ϵ of the medium to increase by 1.36 times. It should be noted that all the current variations in the medium were investigated in the absence of breakdown.

As to the possible mechanism of the described phenomenon, we can state the following: This is not ordinary multiphoton ionization, since the electric and optical field intensities are not high enough for this purpose. The phenomenon consists either of production of ions following dissociation of molecules, or of ionization produced by collisions of vibrationally-heated molecules.

[1]N. V. Karlov, Yu. N. Petrov, A. M. Prokhorov, and O. P. Stel'makh, ZhETF Pis. Red. **11**, 220 (1973) [JETP Lett. **11**, 135 (1973)].

[2]N. G. Basov, V. T. Galochkin, S. I. Zovorotnyĭ, V. N. Kosinov, A. A. Ovchinnikov, A. N. Oreavskiĭ, A. V. Pankratov, A. N. Skachkov, and G. V. Shmerling, ZhETF Pis. Red. **21**, 70 (1975) [JETP Lett. **21**, 32 (1975)].