

The use of a broadband amplifier makes it possible to maintain the generation of the chosen oscillation mode with sufficient variation of its frequency. The results of these experiments will be presented in our next paper.

- [1] I.A. Kovan and A.M. Spektor, Zh. Eksp. Teor. Fiz. 53, 1278 (1967) [Sov. Phys.-JETP 26, 747 (1968)].
- [2] L.I. Artemenkov et al., Experiments on equilibrium in the Tokamak TO-1 without a jacket, using feedback. Proc. Fourth Internat. IAEA Conf. on Plasma Physics and Controlled Thermonuclear Fusion, 1971, C-28/s-z.

#### EXCITATION OF AN EXPLOSION WAVE BY INITIATING A CHAIN REACTION IN A GAS MIXTURE WITH CO<sub>2</sub>-LASER RADIATION

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We report here for the first time a chain reaction initiated by CO<sub>2</sub>-laser radiation and accompanied by an explosive wave. We have observed that when a mixture of H<sub>2</sub> and BCl<sub>3</sub>, which do not react with each other, is exposed to radiation from a CO<sub>2</sub> laser (wavelength 10  $\mu$ ), a vigorous chemical reaction is initiated by dissociation of the BCl<sub>3</sub> molecule by the laser radiation. The front of the reaction propagates in the form of a cylindrical explosive wave.

It is known that irradiation of gaseous BCl<sub>3</sub> by a CO<sub>2</sub> laser leads to dissociation of the molecules of this gas [1]. The laser radiation frequency coincides with the vibration frequency  $\nu_3$  of the BCl<sub>3</sub> molecule, and the dissociation occurs via cascade population of the upper vibrational levels of the molecules and represents predissociation during vibration, i.e., a nonradiative transition from higher vibrational levels  $n\nu_3$  to the continuous spectrum adjacent to the dissociative vibration limit  $\nu_2$ . In the case of  $\nu_2$  vibrations, the boron atom leaves the plane of the molecule. The detachment of the boron atom leads to disintegration of the molecule and to the appearance of atomic chlorine.

The appearance of the atomic chlorine upon dissociation should lead to the occurrence of chemically active centers. Therefore irradiation of stable gas mixtures containing BCl<sub>3</sub> can initiate chemical reactions, some of which are quite vigorous.

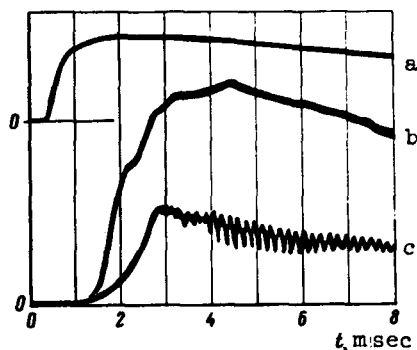
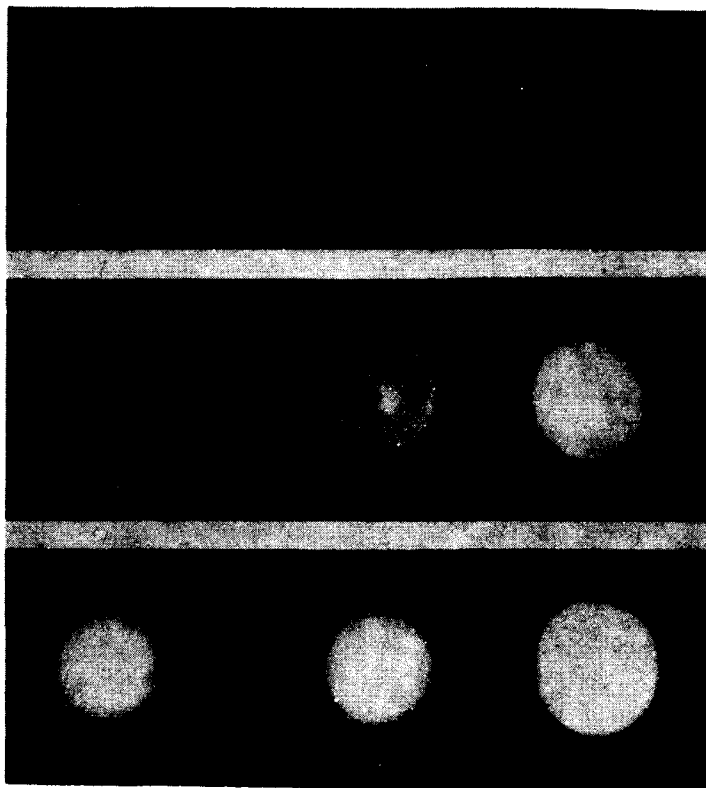


Fig. 1. Waveform of irradiating 10- $\mu$  pulse (a) and time dependences of the intensity of the visible luminescence (b) and of the gas pressure (c).

The experiment was performed for a mixture with H<sub>2</sub>:BCl<sub>3</sub> ratio 20:1, at a total pressure 1 atm. We used a pulse-fed CO<sub>2</sub> laser. The emission pulse was close to rectangular with a rise time  $\sim 0.5$  msec, duration 30 msec, and power up to 600 W. The laser radiation was collimated with a system of salt lenses into a practically-parallel beam of 0.3 cm diameter, and was directed along the axis of a cell with the investigated mixture. The cell was a thick-wall brass cylinder 10 cm long and with inside diameter 4 cm. The entrance window of the cell was sealed with a plate of crystalline ZnSe, and the output and side windows were covered with NaCl plates.

Fig. 2. Motion picture of propagation of cylindrical wave of reaction in a gas mixture  $\text{BCl}_3:\text{H}_2 = 1:20$  at 1 atm pressure. The time interval between frames is 250  $\mu\text{sec}$ .



A high-speed piezoelectric pressure pickup was located at the side wall of the cell. Visible radiation as well as the IR absorption spectra of the gas mixture were also observed. The visible radiation was registered both through the side window with an FEU-62 photomultiplier and from the end of the cell with the aid of a high-speed motion picture camera (SKS-1M).

When the radiation is turned on, an explosive reaction is produced in the  $\text{H}_2:\text{BCl}_3$  mixture and is accompanied by intense visible glow and a sharp increase of pressure. The glow is produced after some delay. The delay depends on the partial pressure of the  $\text{BCl}_3$ , on the intensity of the laser radiation, and also on the purity of the initial reagents. The glowing region propagates from the axis to the periphery of the cell in the form of a cylindrical shell. As it propagates, this region becomes narrower and brighter. The glow is maximal when the glowing region reaches the cell walls. The pressure becomes maximal at the same time and reaches 40 - 50 atm. The time of propagation of this glow wave is 1.5 msec. During this entire time the gas in the beam zone continues to glow. When the glowing layer reaches the cell walls, its glow is extinguished. At the same time, secondary glow is produced at the center of the cell, with a diameter exceeding that of the laser beam. The secondary glow continues for several milliseconds.

A spectroscopic investigation of the absorption-line intensity of the  $\nu_3$  vibration of the  $\text{BCl}_3$  molecules during the time of explosion shows that this gas vanishes irreversibly during the time of propagation of the explosion wave.

Figure 1 shows plots of the laser-radiation intensity (a), glow brightness (b), and gas pressure (c) against the time. One division corresponds to 1 msec. Figure 2 shows a motion-picture photograph of the propagation of the reaction wave. The time between frames is 250  $\mu\text{sec}$ .

The observed dynamics of the laser-initiated reaction is analogous to the processes of propagation of combustion waves in laminar flows in closed vessels [2]. In our case, apparently, chain reactions involving formation and decomposition of higher boranes (boron hydrides) and chlorination of hydrogen are initiated on the combustion-wave front by the appearance in the laser-beam zone of atomic chlorine and of the active radicals  $\text{BCl}$  and  $\text{BCl}_2$ .

Knowledge of the dynamics of the explosion makes it possible to find the flame velocity and to calculate the combustion velocity in the first wave of the reaction; the latter turns out to range from 0.5 to 2 m/sec. It can also be assumed that the secondary glow contains reaction waves having large combustion velocities at the cell walls, leading to the appearance of pressure waves, which are clearly seen in Fig. 1c.

Thus, irradiation with a powerful laser beam at  $10.6 \mu$  wavelength has made it possible to observe initiation of chain reaction in a mixture of the gases  $\text{BCl}_3$  and  $\text{H}_2$ . Experiments of this type point to the possibility of controlling chemical reactions with lasers.

- [1] N.V. Karlov, Yu.N. Petrov, A.M. Prokhorov, and O.M. Stel'makh, *ZhETF Pis. Red.* 11, 220 (1970) [*JETP Lett.* 11, 135 (1970)].
- [2] B. Lewis and G. von Elbe, *Combustion, Flames, and Explosions of Gases*, Academic, 1961.

#### LAYERED COMPOUNDS OF $\text{NiCl}_2$ AND $\text{CoCl}_2$ WITH GRAPHITE AS TWO-DIMENSIONAL HEISENBERG FERROMAGNETS

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$\text{NiCl}_2$  and  $\text{CoCl}_2$  have a layered structure with layers of metallic ions alternating with layers of chlorine. There is ferromagnetic interaction between metallic ions of the same layers, and a weaker antiferromagnetic interaction between neighboring layers [1]. In compounds of  $\text{NiCl}_2$  and  $\text{CoCl}_2$  with graphite, the chloride layers are separated by one or two layers of graphite, which weaken greatly the interaction between the magnetic layers, so that these compounds can be regarded, with good approximation, as two-dimensional paramagnets.

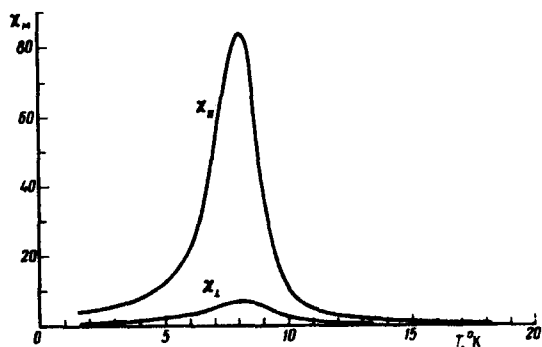


Fig. 1. Temperature dependence of the molar magnetic susceptibility of the compound of  $\text{CoCl}_2$  with graphite (per g-mole of  $\text{CoCl}_2$ ) in the zero external field.

The investigated compounds were obtained by heating pyrolytic oriented graphite with the metal in a chlorine stream. The reaction temperature was  $650^\circ\text{C}$  for both compounds, and the reaction time was 9 hours. After the termination of the reaction, the samples were washed with hydrochloric acid, the chloride content was ascertained, and the distances between the layers of the metallic ions and the graphite were determined by x-ray diffraction. The  $\text{NiCl}_2$  and  $\text{CoCl}_2$  layers in the investigated compounds were separated by two layers of graphite, and the interaction between the metallic-ion layers was negligibly small [2]. The chloride content was 14.5% for the sample with  $\text{NiCl}_2$  and 8.5% for  $\text{CoCl}_2$ . The structure