INVESTIGATION OF BREAKDOWN IN N_2 UNDER THE INFLUENCE OF A PICOSECOND RUBY-LASER PULSE

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Marked progress has been made by now in the generation and amplification of picosecond pulses of optical radiation. This extends greatly the experimental possibilities of studying optical breakdown in transparent media. Breakdown in gases can be produced, by varying the conditions of the experiment, both via the avalanche mechanism and by direct ionization of the atoms or molecules in the field of the strong light wave, whose frequency is much lower than the ionization potential [1, 2]. As is well known [3], in the avalanche breakdown mechanism in a gas, the threshold breakdown intensity is determined by the condition $I_{thr} = A\Delta/P\tau$, where P is the gass pressure, Δ its ionization potential, and τ is the pulse duration. When the pulse duration τ is greatly reduced, the avalanche-brakdown threshold intensity increases sharply, and a decisive role in the breakdown development may be played by direct ionization in the field of the strong light wave [4]. For the latter case, the breakdown threshold depends little on the gas pressure P, whereas for the avalanche the breakdown threshold varies like 1/P. This makes possible an experimental verification of the predominant breakdown mechanism in gases at a specified radiation-pulse duration.

In the present study, we investigated the dependence of the breakdown threshold on the pressure in nitrogen gas at pressures from 2 to 10^4 mm Hg. The generation pulse duration ranged from 30 to 100 psec.

The experimental setup is illustrated in Fig. 1. The generator 1 was a traveling-wave ring laser in the ultrashort-pulse regime, similar to that described in [5]. Single pulses were separated from the trains by a known procedure using a laser-controlled discharge gap [6] to switch a Pockels cell. The separated cell was amplified by two stages of amplifier 6, each consisting of a ruby rod 240 mm long and 15 mm in diameter, with end faces cut at the Brewster angle. The breakdown was produced in chamber 13. The focal length of the focusing lens was F = 2 cm. The appearance of the breakdown was registered by a photomultiplier 17 in conjunction with an oscilloscope 18. The scattered laser light is completeley absorbed by filter 16 and does not strike the photomultiplier. The energy in the pulse was determined with a calibrated photocell 9 in conjunction with a high-speed oscilloscope 10 of type I2-7. The calibration was by means of calorimeter 15. The resolution time of the entire system,

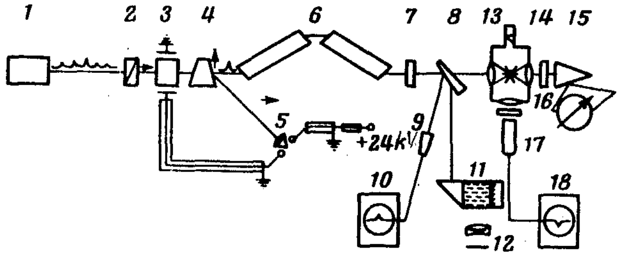

Fig. 1. Experimental setup: 1 - laser, 2 - Glan prism, 3 - Pockels cell, 4 - calcite prism, 5 - discharge gap, 6 - optical amplifier, 7, 14 - red filters, 8 - glass wedge, 9 - coaxial photocell, 10 - high-speed oscilloscope, 11 - cell with dye (rhodamine 6G), 12 - photographic camera, 13 - chamber, 15 - calorimeter, 16 - $CuSO_4$ filter, 17 - photomultiplier, 18 - low-frequency oscilloscope. The arrows indicate the polarization of the radiation

equal to 0.2 nsec, made it possible to monitor the time development of the separated radiation. The experiments, were performed with single pulses of duration shorter than the resolution time of the system for the photoelectric registration. The true duration was measured by the known procedure of "collision" of light pulses in a medium that luminesces following two-photon excitation [7]. The absolute magnitude of the luminescence intensity was used as an added control on the light-pulse power. The cross section area of the radiation flux at the focus of the lens was determined from the half-intensity level by direct photography of the focal spot and subsequent photometry. The experimental results are shown in Fig. 2.

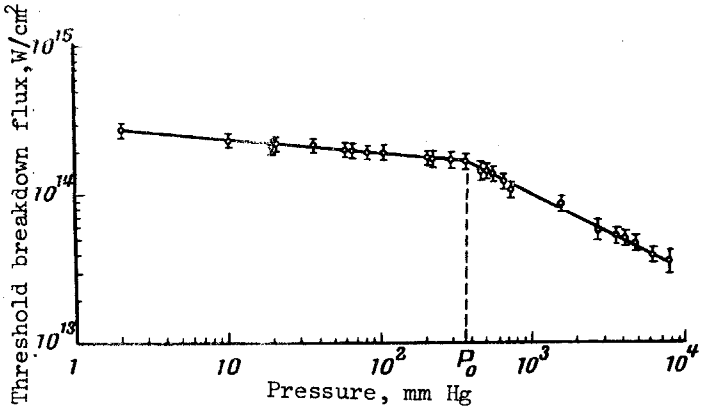

Fig. 2. Experimental dependence of threshold breakdown flux in N_2 vs. gas pressure. The error in the determination of the absolute value of the flux amounts to 30%.

The data pertain to the case when the optical pulse duration amounted to 5×10^{-11} sec, and the cross section area in the focal region was 3×10^{-6} cm^2.

As seen from the data of Fig. 2, at high pressures there is a strong dependence of the breakdown threshold on the pressure, $I \sim P^{-0.5}$. Such a dependence is characteristic of the avalanche breakdown mechanism in molecular gases, and was observed earlier in experiments on the breakdown produced by nanosecond pulses [8]. A comparison of the breakdown threshold intensities obtained by us in this region of of pressures with data on breakdown produced by nanosecond pulses [8] shows that shortening of the pulse duration τ leads to an increase of the threshold intensity in accordance with $I \sim 1/\tau$. A similar result for a neodymium-glass laser was obtained in [9].

At pressures lower than P_0 = 360 mm Hg, the dependence of the threshold intensity on the pressure becomes much weaker. This indicates that the breakdown mechanisms are interchanged at the point P_0. At low pressures $P < P_0$ the breakdown is effected via the mechanism of direct photoionization of the molecules in the field of the strong light wave.

The experimental dependence of the breakdown threshold on the pressure turns out to be somewhat weaker than that predicted by the theory [2, 4]; this apparently can be attributed to the total ionization of the gas particles at the threshold intensity values. The experimental photoionization probability w_0 per unit time per atom, obtained under the assumption that the within the pulse duration time $\tau = 5 \times 10^{-11}$ sec total ionization of the atoms takes place in the focal volume, equals $w_0 = 1/\tau = 0.2 \times 10^{11}$ sec^{-1}. Calculation in accordance with the theoretical formulas of [2] for the threshold flux intensities yields a value w_0 =

4.6×10^{11} $\sec^{-1}$. Taking into account the very strong dependence of w_0 on the field intensity, the difference between the calculated and experimental values of w_0 is small and may be connected, in particular, with the error in the experimental determination of the absolute value of the threshold radiation-flux density.

It is interesting to note that under the conditions of our experiment the parameter γ introduced in [2] is close to unity, i.e., the case realized in the experiment is intermediate between multiquantum ionization and direct tunneling of the electrons in the field of the strong light wave.

The results obtained in this investigation offer evidence that the transition to picosecond pulse durations will make it possible to observe directly the photoionization that leads to breakdown, in the field of a strong electromagnetic wave, in the region of relatively high pressures of the investigated gases. The cascade breakdown mechanism is completely excluded in this case. It becomes possible to carry out the investigations both in the region of multiphoton ionization, and in the region of direct tunneling of the electron in the field of the strong electromagnetic wave.

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SINGULARITIES IN THE BEHAVIOR OF SURFACE IMPEDANCE OF TIN UPON ESTABLISHMENT OF A STANDING SOUND WAVE AND QUANTUM OSCILLATIONS OF THE SPEED OF SOUND

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In astudy of electromagnetic excitation of sound [1] in tin situated in a magnetic field, we observed three interesting singularities having apparently a common nature.

The setup consisted of an ordinary radio-spectrometer with a Pound-Knight generator. It made it possible to study both the real and the imaginary part of the surface impedance of the samples. The samples were in the form of discs of 18 mm diameter and 0.5 - 1 mm thickness. The normals to the planes of the discs were parallel to the [010] axis of the crystal.

By varying the direction of polarization of the incident electromagnetic wave relative