Moscow University Physics Bulletin
Vol. 47, No. 5, pp. 78–81, 1992

Vestnik Moskovskogo Universiteta. Fizika
UDC 537.56:533.9

VISUAL OBSERVATION OF THE SPATIAL DISTRIBUTION OF OUTPUT RADIATION FROM A CERENKOV MICROWAVE OSCILLATOR BASED ON RELATIVISTIC ELECTRON BEAM

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A procedure is described for observation of the spatial distribution of microwave radiation generated by a relativistic heavy-current pulsed Cerenkov-type oscillator. The technique uses the microwave breakdown in air occurring under low pressure in a thin-layer chamber formed by the surfaces of two dielectrics.

The spatial distribution of output radiation is usually measured in order to determine the type and the power of oscillations generated by heavy-current relativistic microwave devices. The most complete picture of the spatial distribution of microwave radiation with good time resolution can be obtained with the use of semiconductor detectors on hot charge carriers [1], which collect part of the generated radiation received by the small antenna. A less labor-consuming method is the estimation of the microwave radiation directivity pattern according to the glow intensity of a panel consisting of a closely set small neon-glow lamps [2]. In [3] this task was accomplished by means of a thin plated dacron film with a high absorption coefficient. Also used for the same purpose could be liquid-crystal heat indicators and photoluminescent activated crystallophosphors [4]. Recently a number of experiments were carried out [5] in which the microwave breakdown in gases at various pressures (including air at atmospheric pressure) was applied for the diagnostics of sources of microwave pulses: the type of the generated oscillations was identified from the appearance of the ionized region and the output power was determined from the breakdown characteristics.

This paper reports an attempt to determine the spatial distribution of the microwave radiation with the aid of microwave breakdown in air in a low-pressure dielectric chamber with a small-size breakdown gap.

The experiments were carried out at a Tandem I heavy-current electron accelerator [6, 7] in which a Cerenkov oscillator, carcinotron, was employed as a microwave radiation source. The oscillator was intended for operation in the E_{01} mode of a circular waveguide. The wavelength of the generated microwave radiation was about 5.5 cm. Figure 1 a shows schematically the arrangement of the devices that measured the microwave radiation and also the results of measuring the directivity pattern by the detector on hot carriers which collected part of the generated microwave radiation received by the open end of the waveguide of size 7.2 × 3.4 cm. These measurements allowed the minimum power of the output microwave generation to be determined. In our case it was 10 MW. Microwave pulses with duration about 300 ns were measured in the experiments. In the presented schematic drawing of the preliminary experiments on microwave breakdown in air at pressures below the atmospheric pressure, use was made of a plane-parallel chamber made by dielectrics and placed across the beam of microwave radiation near the exit window. The size of the chamber was 27 × 23.5 cm and the spacing between the dielectric plates was 1 cm. The pressure in the chamber could be varied during the experiments. The integrated picture of microwave breakdowns in the cell is shown in the photographs below.

When the pressure in the chamber exceeded 400 Torr there was no breakdown in air. By gradually lowering the pressure we managed to obtain photographs, integrated over time, of the glowing regions of the gas. Figure 2 shows these photographs at pressures of 250, 100, and 50 Torr in the dielectric chamber. At 250 Torr the picture has a "focal-point" character. When the pressure lowers to 100 Torr one can distinguish two concentric glowing zones in the photograph. The diameter of the outer zone corresponds to the diameter of the azimuthally nonuniform formations in the photographs of the breakdown at a pressure of 250 Torr. The diameter of the inner glowing zone is rather close to the diameter of a region with a maximum radial component of the electric field for the operating mode E_{01} of the oscillator. The presence of the region of microwave beam localization with a larger diameter seems to be associated with the diffraction the working

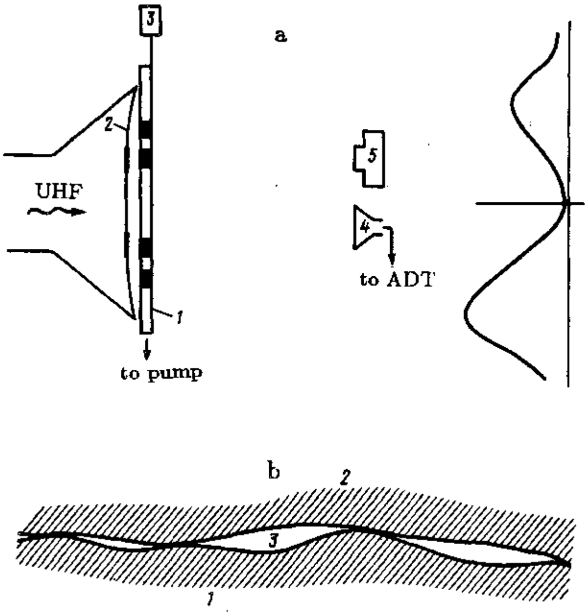

Fig. 1

(a) Schematic diagram of the experiments: (1) chamber formed by two dielectrics with controlled air pressure; (2) exit window; (3) leak; (4) detector of microwave radiation on hot charge carriers; (5) photographic camera. (b) Schematic representation of the contact surface of two dielectrics (1) and (2) forming microcells (3) with an air pressure below the atmospheric one.

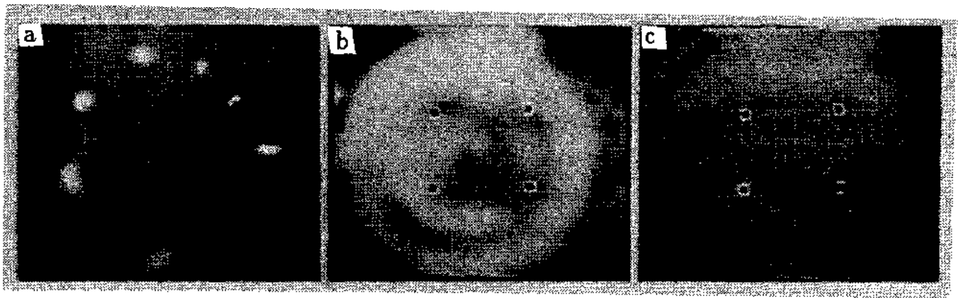

Fig. 2

Integrated (over time) photographs of the breakdown in air in a plane-parallel dielectric cell at different air pressures: (a) 250 Torr, (b) 100 Torr, and (c) 50 Torr.

wave undergoes at the output horn. This is accompanied by loss of contrast of the image and merging together of the glowing zones. When the air pressure is 50 Torr, we observe the development of microwave breakdown over the entire volume of the cell and information on the microwave field structure is lost.

Analysis of the experimental results suggests that the determination of spatial distribution of the microwave radiation with the aid of air breakdown in a plane-parallel chamber using integrated photographs of ionized regions requires a rigorous choice of the critical pressure. At a pressure below the critical one, the conditions for a breakdown become less stringent and the intense glow zone covers more and more space in the chamber. One can also estimate the minimum power of radiation of a high-frequency oscillator from the presence of a microwave breakdown in a plane-parallel chamber at a pressure of 100 Torr. With consideration for the data from [8] the minimum power in our experiments was 20 MW. This estimate is in agreement with measured data obtained with the aid of a detector on hot carriers.

The experimental procedure for visual observation of the spatial distribution of the oscillator output

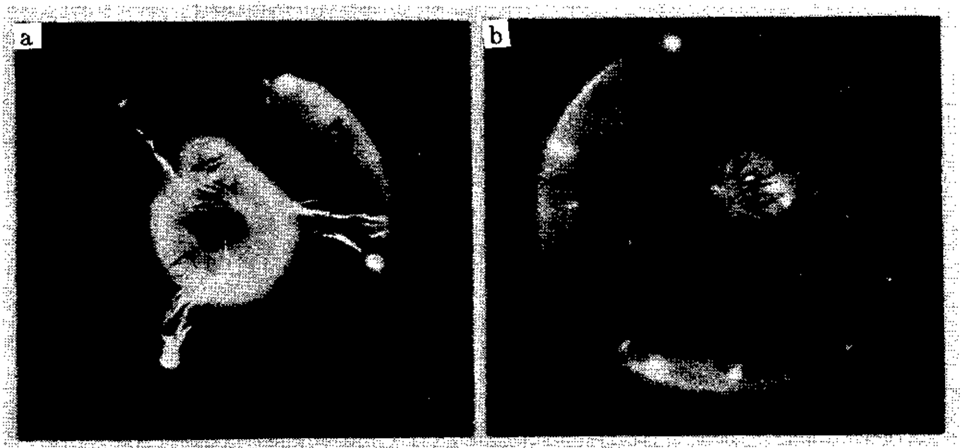

Fig. 3

Photographs of a two-layer exit window for microwave radiation: (a) breakdown in the presence of microwave radiation; (b) in the absence of microwave radiation.

radiation power from integrated photographs of the microwave breakdown can be considerably simplified if the single-layer exit window for microwave radiation, which separates the vacuum part of the setup from the surrounding medium, is replaced with a double-layer window (see Fig. 1 a). In our experiments the double-layer exit window was made of a 5 mm thick teflon sheet and a 0.1 mm thick dacron sheet with microcells formed between the two surfaces (Fig. 1 b). The space between the dielectrics was pumped out, through several holes in the teflon less than 0.2 mm in diameter, by the basic pumping system of the accelerator.

One of the integrated photographs of the breakdown in a system of two-layer exit window for microwave radiation (teflon-dacron) is shown in Fig. 3 a. Figure 3 b shows a photograph of the same system in the absence of microwave radiation, when the retardation system of the microwave oscillator was replaced with a section of a smooth waveguide. One can see traces of exposure to the cathode flame plasma and also manifestations of deposition of the electron beam on its way out of the microwave oscillator. Therefore, the appearance of a glow zone on the photograph of Fig. 3 a ($P_{\mathrm{UHF}} \neq 0$) is indeed related to a microwave breakdown between the teflon and dacron surfaces. This conclusion is also supported by a gradual accumulation of products of oxidation of the dielectric materials of the chamber between the teflon and dacron layers, which must in time result in an increase of the sensitivity of the recording chamber [8]. The clear-cut picture of the microwave breakdown obtained in the experiments with a two-layer window helps identify quite reliably the operating mode of the oscillator as E_{01}. The diameter of the glowing zone then corresponds to the peak energy flow for the oscillator operating mode.

One of the disadvantages of the proposed method of visual observation of microwave radiation spatial distribution is uncertainty in its sensitivity. This is associated both with the unknown average gas pressure in the microcells between the surfaces of the dielectrics and with the complicated mechanism of the breakdown, in which the contribution of the interaction of electrons with the dielectric surface may be quite considerable. The latter is, in particular, indicated by the fact that in the fields typical of the experiment the amplitude of electron oscillations is comparable with the size of the microcells and sometimes even exceeds it.

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