MULTIELECTRODE CAPILLARY DISCHARGE

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Abstract

A new design for a multi-electrode capillary source based on a low-threshold slipping surface discharge is described. The plasma parameters of this source are presented. This capillary discharge can be used as a promising source to solve the problem of creating x-ray lasers.

In recent years, electric discharges excited inside dielectric capillaries have been adopted as a method for creating the active media for x-ray lasers [1] and for transmitting short wavelets of laser radiation in the so-called laser accelerators of electrons [2].

The main disadvantages of conventional capillary systems are their rapid destruction (usually, after one or several discharge pulses) and relatively short lengths of discharge gaps. To increase the capillary system resource, Askaryan proposed using a capillary with liquid walls. The idea consisted in renewing the capillary walls when liquid flows in the rotating capillary and was realized in [3, 4].

The paper describes the design of a capillary plasma source with solid walls (a multielectrode spark gap) which makes it possible to increase significantly both the device resource and capillary length. The results of measurements of the parameters of the produced plasma both inside and outside the capillary are presented.

The distinguishing feature of the plasma source proposed consists in the use of a low-threshold slipping surface discharge to initiate the capillary discharge in the multielectrode system. This is a fresh approach to using this phenomenon, which was previously used as a source of a hot dense collisionless plasma and ionizing UV radiation [5], a source of cumulative shock waves [6], or a method of igniting a burning gas mixture [7].

The new capillary source is constructed with coaxial geometry (Fig. 1). The outer electrode is a cylinder which has an outer diameter of 12 mm and an inner diameter of 9 mm. The cylinder contains a 6-cm-long ceramic pipe; the outer and inner diameters of this pipe are equal to 9 and 4.5 cm, respectively. In turn, the ceramic pipe contains 8 cylindrical electrodes 4 mm in length and 4.5 mm in diameter. The outer continuous electrode (which serves as a reverse current path) is galvanically connected to the last inner electrodes. A high-voltage pulse is applied between the first inner and outer electrodes. Power from a power source is delivered to the capillary in such a way that the first electrode is connected to the cable core and the outer electrode is connected to the cable braid, being its extension.

When the high voltage pulse is applied, the discharge is initiated as follows. First, because of the capacitive coupling between the inner electrodes and also between the inner and outer electrodes, the power-source voltage almost completely drops across the first gap. As a result, a discharge slipping on the surface of the dielectric pipe is initiated in this gap. Upon breakdown, the first gap becomes shorted and breakdown conditions are fulfilled for the next gap, and so on. Thus, a breakdown wave starts to propagate between the electrodes. Owing to the given configuration of the electrodes, even for relatively low applied voltages it is possible to produce relatively long plasma objects inside the capillary. Our measurements show that the breakdown voltage for a multielectrode capillary with length L is sufficiently low and can be estimated by the formula

\[ U_{br} = \alpha L \text{ [kV]}, \]  

(1)
where $\alpha \sim 1$ kV/cm.

Figure 2 shows a schematic of the experiment. A capillary source 1 was placed in a metal cylindrical chamber 2 which was evacuated to deep vacuum ($p \leq 10^{-5}$ torr); in some experiments, the chamber was filled with hydrogen at a pressure of $p \sim 10^{-3}$ torr. The amplitude of high-voltage pulses applied to the capillary was 20 kV, and the pulse duration was about several microseconds.

The parameters of the plasma produced by the capillary source were measured by probes 7, an ion analyzer