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Rotation of the 10 keV Electron Beam By 360° Using PVC Tubes

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Abstract. We measured the time dependence of the passage of an electron beam with an energy of 10 keV and a beam current of about 1.8 μA through PVC tubes bent into rings by 360°. The tubes with the following parameters were used: one with the inner diameter of the tube 2.8 mm, the diameter of the ring 75 mm; and another with an inner diameter of 4 mm, and a ring diameter of 150 mm. In both cases, the current of transmitted electrons was about 15% of the incident current. Measurement of the electron spectrum for a ring of smaller diameter showed that all electrons that passed through it lose their initial energy.

1. Introduction

First results in the field of sliding interaction of charged particle beams with dielectric surfaces were obtained in paper [1], which described the effect of control (guiding) of an ion beam using a polymer film with nanocapillaries. The first research results in the field of controlling electrons with energies below 1 keV using nanocapillaries were presented in 2007 in studies [2, 3]. In the course of the research, it was concluded that with an increase in the energy of electrons, the effect of guiding worsens up to its complete disappearance. A similar conclusion was made in [4–6] after studying the passage of charged electrons through glass cone capillaries with an energy of no more than 1 keV. Since 2016 there is studies on the control of charged electrons with an energy of 10 keV using glass converging capillaries [7]. Control of the electron beam was observed at channel inclination angles from –0.57° to +2°.

2. Experiment

This work presents the results of a study of the time dependence of the passage of an electron beam with an energy of 10 keV and a beam current of about 1.8 μA through PVC tubes bent into rings by 360°. We used two tubes with the following parameters: one with the inner diameter of 2.8 mm, the diameter of the ring 75 mm; another with an inner diameter of 4 mm, and a ring diameter of 150 mm. A schematic representation of the experimental setup for a ring with a diameter of 75 mm is shown in Fig. 1. Electron beam generated by an electron gun (1), passes through a system of electromagnetic lenses (2) and a collimator 1 mm in diameter (3). Then the formed beam (4) enters the test sample (6) fixed in a movable holder with a goniometer (5). The front end of the channel is closed with a grounded metal mask that has a hole 2.8 mm in diameter. The mask shields the face of the channel preventing it from being blocked. To measure the current of the primary beam incident into the tube, there is an additional 2.8 mm in diameter through hole in the mask. The current of transmitted electrons (7) is recorded by a copper plate (10) and a Keithley 6482 picoammeter (11). The spectrum of radiation generated in the plate (9) is measured by an XR–100SDD semiconductor solid–state detector (8). To suppress the output of secondary electrons from the copper plate, a brass grid (12) with a voltage of 400 V is installed directly in front of it. The vacuum in the chamber is ~ 10^{-6} torr. The measurements were carried out for 6 hours.

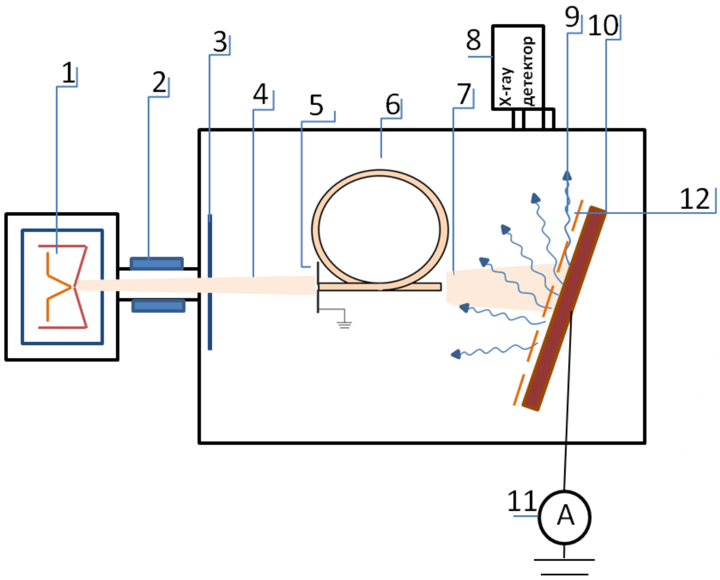

Fig. 1. Scheme of the experimental setup.

To measure the time dependence of current flow through a PVC tube (ring diameter 150 mm, inner diameter 4 mm), we mounted a Faraday cup and a Keithley 6482 picoammeter on the output end of the tube (Fig. 2).

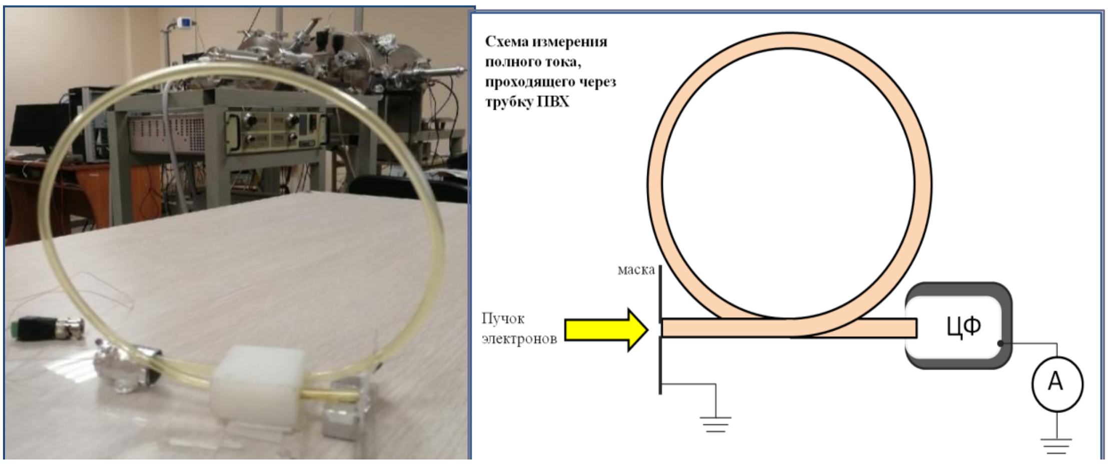

Fig. 2. Scheme for measuring the passing current as a function of time on the above, photograph of the implementation of the scheme on the below.

3. Results and discussion

Fig. 3 shows the data on the measurement of the time dependence of the passage of electrons through a PVC tube with a diameter of 75 mm. The current of the incident electron beam is 1.8 μA.

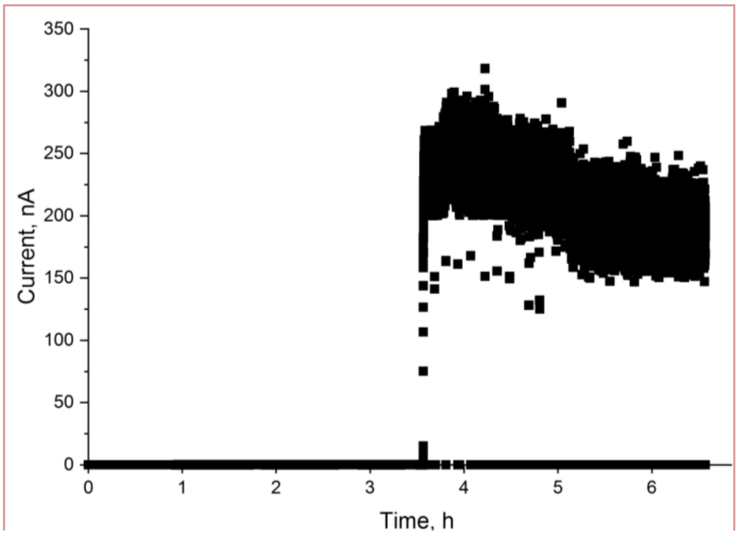

Fig. 3. Dependence of electron current transmission on time (Incident beam current 1.8 μA, tube diameter 74 mm, internal diameter 2.8 mm).

Note that the passage of electrons through the channel began approximately 3.5 hours after the beginning of the experiment. Then there was a sharp rise in the passed current, which then decreased with time. Fig. 4 shows the spectrum of electrons passing through a metal tube for two minutes and the spectrum of electrons passing through a curved PVC tube for 10 minutes (diameter of the curved tube 75 mm). The spectrum for a ring of smaller diameter shows that all electrons passing through it lose their original energy.

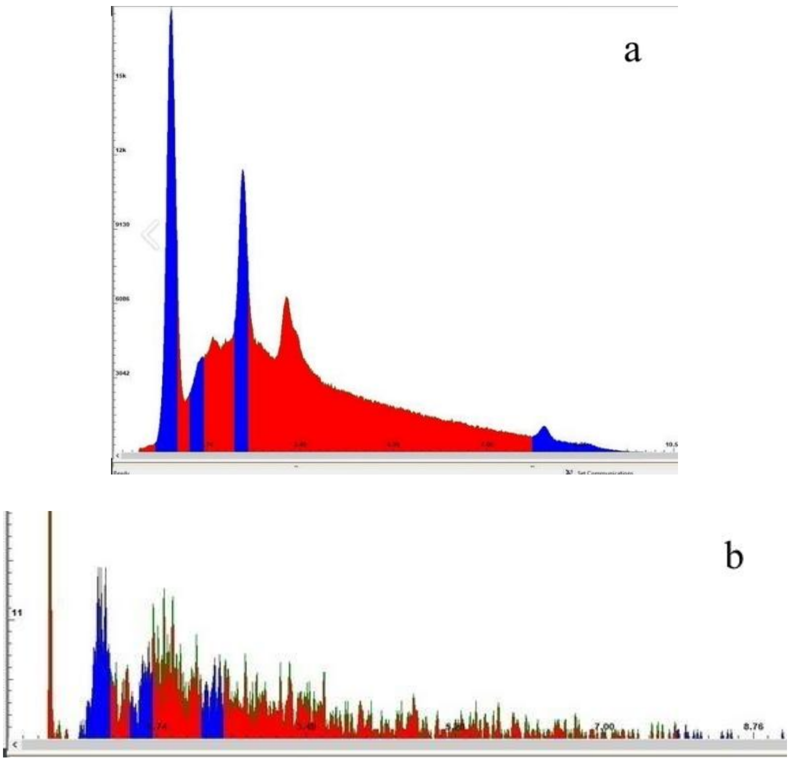

Fig. 4. a) Spectrum of electrons passing through a metal tube. Average current 1uA. The collection time is 2 minutes. b) The spectrum of electrons that have passed through a curved tube. The collection time is 10 minutes. (Incident beam current 1.8 μA, ring diameter 150 mm and tube inner diameter 4 mm).

Fig. 5 shows the time dependence of the passage of electrons through a hollow PVC ring with a diameter of 150 mm and an inner tube diameter of 4 mm. It should be noted that the incident current was unstable. Also several times the tube was. The measurements were carried out for 5 hours.

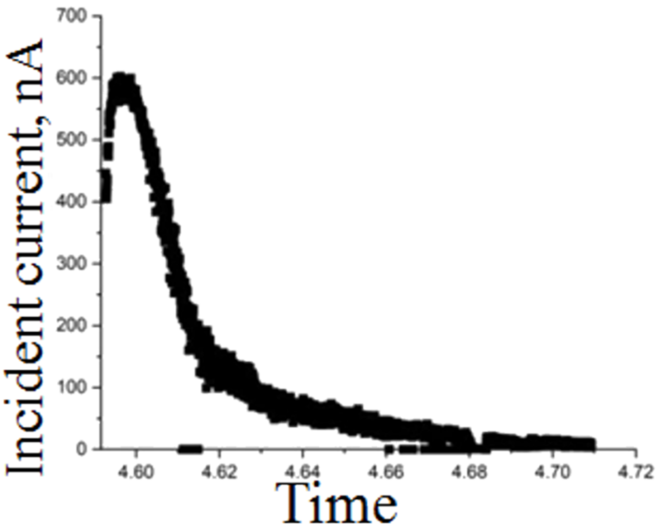

Fig. 5. Time dependence of the incident beam current. The falling current was unstable, and the tube was moved several times.

4. Conclusions

We measured the time dependence of the passage of an electron beam with an energy of 10 keV and a beam current of about 1.8 μA through PVC tubes bent into rings by 360°.

The tubes with the following parameters were used: one with the inner diameter of the tube 2.8 mm, the diameter of the ring 75 mm; and another with an inner diameter of 4 mm, and a ring diameter of 150 mm. In both cases, the current of transmitted electrons was about 15% of the incident current. Measurement of the electron spectrum for a ring of smaller diameter showed that all electrons that passed through it lose their initial energy.

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