Comparison of the ion beam profile measuring methods

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Abstract. In this paper methodology for direct measurement of current distribution on a target surface biased to the negative potential by the 6 channel Bluetooth profile monitor is described. Also the beam trace in the target plane was monitored by photo camera. Examples of the current distributions on the target, depending on geometrical and physical parameters ion–optical system of Penning ion source were presented.

INTRODUCTION

Typically, measurement of the current distribution (or current density) at the target surface is performed by using different probes [1], or Faraday cups [2,3], or systems of the rotating disk collector [4], or systems of scintillation plates and the secondary electron multipliers [5,6]. However, at those cases, the target and the measuring system are located under a ground potential. Thus, such measurement methods are not applicable in studies of the current distribution at the surface of miniature linear accelerators targets [7], to which mostly is applied high negative potential relative to the ground. The current distribution on the target is estimated by the indirect measurements of either the visible column of the output ion beam or the distribution of the sputtered material on surface of the target by a profilometer [8].

In this paper methodology for *direct* measurement of current distribution on a target surface biased to the negative potential by the 6 channel profile monitor is described. This device has been used to obtain current distributions on the target. This distribution depends on geometrical and physical parameters of the ion–optical system (IOS) miniature linear accelerator (sealed-tube neutron generators based on Penning ion source).

EXPERIMENTAL EQUIPMENT AND MEASUREMENT TECHNIQUE

The experiments were carried out on the diagnostic facility "TPS–compact" mounted in a standard ISO vacuum element "6-waycross" [9]. Penning ion source [10] was installed trough dielectric spacers into vacuum chamber. Working gas is H_2. The special sectioned target (ST) was designed to record an ion beam current distribution. ST composed of a set of metal rings separated by Teflon dielectric spacers. All metal ring edges have been smoothed with a radius of 0.2 mm to reduce the electric field between the edges of sections target. The Teflon dielectric spacers were flushed into target and partially covered by the next collector ring, it has been done to reduce sputtering of the Teflon dielectric rings. To minimize the effects of secondary electron emission on the measurement results special magnets were located on the back side of ST.

Automated 6-channel ammeter for measurement the current distribution on the target under high negative (relative to ground) potential has been developed and tested to simplify the procedure of obtaining experimental data. The operation and the data transmission on the PC have been done by wirelessly via Bluetooth.The schematic diagram of current measurement from one collector ring of ST is shown in figure 1. Ion beam (1) is extracted and accelerated by the accelerating electrode (3) separated from the ion source by insulator (2), hit on the sectioned target (4). The target is consists of the6 parts, in accordance with the number of the conductors of theelectrical feedthrough(6) on the flange (5). To each electrical lead (Fig. 1 one of them marked (7)) using shunt resistance R^i_{sh} and capacity C^i_{sh} fed the same accelerating voltage as in the flange (5) and the electrode (3). The voltage drop on the shunt R^i_{sh} is supplied to one input of the amplifier К157УД2 (8). (9) is the input ofADC/DAC converter. There is a noninverting amplifier with a gain of U_{out}/U_{in}=150 ±10 in this connection diagram. The amplifier power is performed using the DAC Converter provided outputs 5V (10). Bipolar operational amplifier power organized by resistive divider, the midpoint of which forms an artificial common point (i.e., in our case under the accelerating potential).

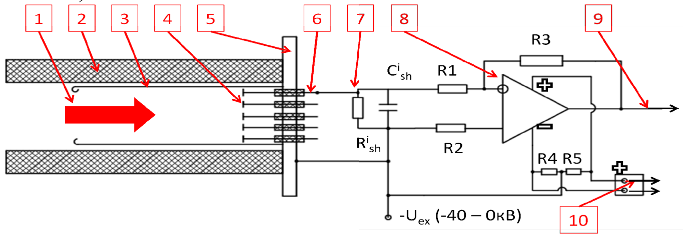

Figure 1 The schematic diagram of the current measurement from a one collector ring of ST (description in text).

Key features 6-channel ammeter: measurement range current – 5 μa – 0.2 A; number of measurements per second – 7 s^{-1}; gain constant – 150 ±10; ADC resolution-DAC measurements in the range from 0 to 5 – 8 bit; supply voltage – 9 V; offset voltage relative to the ground – up to -45 kV.

EXPERIMENT RESULTS

The experiments were performed for two variants of geometry of the IOS(Geometry №1:Focusing electrode diameter D_{fe}=20mm, Accelerating electrode diameter D_{ae}=20mm, Geometry №2 : D_{fe}=15mm, D_{ae}=10mm). As an example of above-described method, current distribution (for IOS geometry №1) on the target depending on the radial coordinate at different voltage discharge is shown in figure 2 (at pressure P = 2 mTorr and accelerating voltage $U_{extraction}$ = 20 kV). For visualization clearness, the beam profile is correlated with image of the sectioned target in this figure. The current density profile is approximated by Gaussian curve. The adequacy of this distribution applicability was tested using the goodness of fit Pearson. The full-width-at-half-maximum of the approximating curve $d_{FWHM}$was used for characterization the spot diameter, and current density value $j_{FWHM}$was used forcharacterization the flux density of ions at the target (see Fig. 2). The spot diameter d_{FWHM} dependences and the corresponding current density j_{FWHM} depending on accelerating voltages (at a pressure of p = 1 of mTorr and $U_{discharge}$ voltage = 2 kV) for different configurations of electrodes IOS were measured (see figure 3).

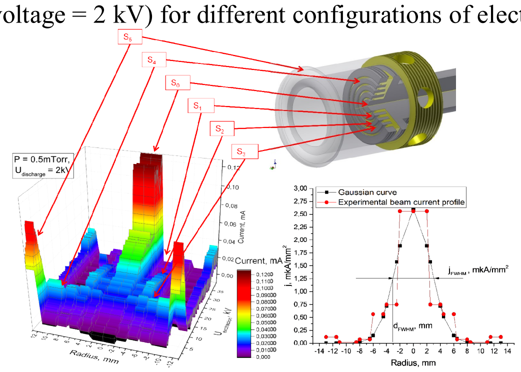

Figure 2A typical beam current profile view depending on discharge voltages (pressure P = 2 mTorr and accelerating voltage $U_{extraction}$ = 20 kV).

The beam profile is correlated with image of the sectioned target.

The beam current density profile and its approximation by Gaussian curve. Geometry №1.

For second part of experiments special accelerating electrodes with the rectangular cutout on the side surface near the end were designed. It is provided a visual observation of the luminous beam trace near the target. This method is described in [12]. Images of beam spot on the target and beam trace in accelerating electrode depending on accelerating voltage is presented on figure 4. Digital image processing of the ion beam spot was produced in a graphics editor "Image J" in the following sequence: 1) the distribution of luminescence intensity on the vertical cross section of the target was constructed; 2) luminescence intensity was approximated also by Gaussian curve; 3) beam diameter was characterized also by the full-width-at-half-maximum of the this curve.

There are two emission regions on the target: the most beam intense central region (inside spot) and less intense - peripheral region (outer spot) in figure 4.The presence of both internal and peripheral areas of the glow can try to associate with the existence of chromatic aberrations in the accelerating system. Beam diameter dependence from the accelerating voltage for the two geometries IOS is shown in figure 4. As can be seen, beam trace diameter on the target was d_{FWHM} = (7,0±0,5) mm the peripheral region and d_{FWHM} = (5,0±0,5) mm for the central (by p = 1 mTorr, $U_{extraction}$=40 kV, $U_{discharge}$ = 2 kV, geometry IOS №1).The value of absolute error was determined by the method of processing photographic images. It is interest to note that the value beam trace diameter in the central region within the measurement accuracy coincides with the diameter of the beam on the target, measured by registration of the distribution of current over its surface. As can be seen from Fig. 4 (for the geometry IOS №2) when the magnitude of the extracting voltage is about 30 - 40kV, the two regions of beam trace run into one, the diameter of the trace in the target is d =(5,1±0,5)mm. Thus, the beam trace photo in the plane of the target and the direct measurement of the current density distribution are complementary methods for the study of IOS, which is under a high negative potential relative to the grounded ion source.

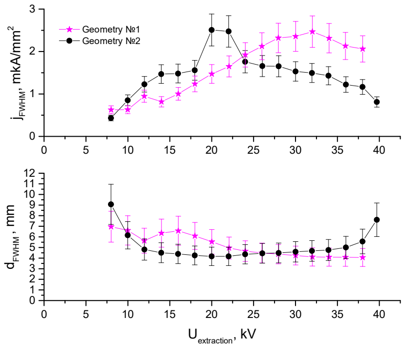

Figure 3 The d_{FWHM} spot diameter and corresponding current density j_{FWHM} depending on accelerating voltages (p = 1 mTorr and $U_{discharge}$ = 2 kV) for two configurations of electrodes IOS

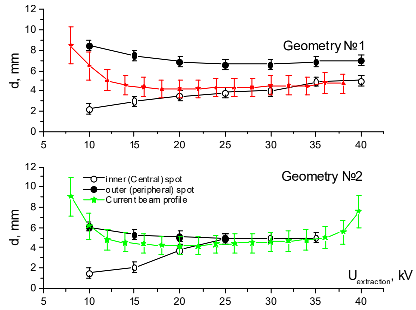

Figure 4 Comparison of the ion beam profile measuring methods. Beam diameter dependence from the accelerating voltage for the two geometries IOS

CONCLUSION

The methods of direct measurement of current distribution on a target which live-line under a high negative potential relative to the earth was developed and tested . The measurements were conducted using a 6-channel meter, sending the measured data via a wireless Bluetooth connection. The beam trace in the target plane was monitored by photographic. Examples of the current distributions on the target, depending on geometrical and physical parameters ion–optical system of Penning ion sourcewere presented. It is shown that beam trace photo in the plane of the target and the direct measurement of the current density distribution are complementary methods for the study of ion–optical system, which is under a high negative potential relative to the grounded ion source.

ACKNOWLEDGMENTS

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