2D-TOMOGRAPHY OF THE PROTON BEAM IN THE VACUUM INSULATED TANDEM ACCELERATOR*

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Abstract

For the development of a promising method for the treatment of malignant tumors - boron neutron capture therapy - the accelerator-based epithermal neutrons source has been proposed and created in the Budker Institute of Nuclear Physics [1,2]. With different parameters of the proton beam - the energy and current of the beam, the parameters of the ion-optical system, the parameters of the ion source - the conditions for beam transportation change - its size, angular divergence, and position relative to the axis of the accelerator. For optimal conduction of the beam along the path, two-dimensional tomography of the beam can be used - using a cooled diaphragm with a diameter of several millimeters installed on a vacuum three-dimensional motion input, and a Faraday cup, fast chord measurements are carried out, on the basis of which the beam profile is restored. The beam profile obtained in this way is somewhat different from the profile obtained by measuring the phase portrait of the beam using a wire scanner [3]. The advantage of this method is a relatively short time to restore the profile, depending on the diameter of the cooled diaphragm hole.

INTRODUCTION

Charged particle accelerators are widely used in scientific research, medicine, and other applications. Tandem accelerators are high-voltage electrostatic accelerators in which the high-voltage potential is used twice: first to accelerate negative ions, and then, after changing the polarity of their charge in the high-voltage terminal, to accelerate positive ions. Since power density of the proton beam can reach tens of kW/cm^2 there are mechanisms, influencing on the transportation of the beam, such as parameters of the H^- source (accelerating and extracting potentials, voltage of the discharge), focusing and correctors values and energy of the beam there is a need to diagnostic beam with such power and transport it through the high-energy beam line correctly, without heating vacuum chambers. For solve this task it was proposed and realized fast diagnostic of the beam profile, size and destination – two-dimensional tomography.

THE EXPERIMENTAL SCHEME

The studies were carried out at the accelerator neutron source of the Budker Institute of Nuclear Physics (Novosibirsk, Russia). The source diagram is shown in Fig. 1 and its detailed description was given in [1]. A tandem accelerator with vacuum insulation was used to obtain a stationary proton beam with an energy of 0.6 to 2.3 MeV and a current of 0.3 to 10 mA, that is, a tandem accelerator of charged particles with an original design of electrodes.

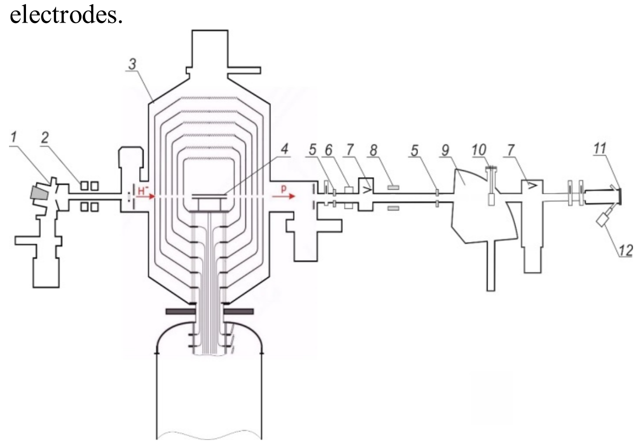

Figure 1: A diagram of an accelerator based source of epithermal neutrons. 1 - H^- source, 2 – magnetic lense, 3 – vacuum-insulated tandem accelerator, 4 – gas stripping target, 5 – cooled diaphragm, 6 –NPCT contactless beam sensor (Bergoz, France), 7 – movable Faraday cup 8 – corrector, 9 – bending magnet, 10 – cooled beam receiver with a diaphragm, 11 – lithium target, 12 – Hikvision video camera.

H^- beam, extracted from H^- source *1*, focusing by a magnetic lense *2* and injected in the accelerator *3*. Inside the accelerator H^- stripping by an argon target *4*, transform into proton with probability 90÷95% [4], and accelerates to the energy equal to the double potential of the accelerator. After the accelerator proton beam goes through cooled diaphragm *5* and its current measuring by a contactless beam sensor *6*. Then proton beam goes through bending magnet *9* and small part of it pass through the cooled diaphragm with aperture of 2 mm *10*, installed on the vacuum three-dimensional motion input. Finally, it comes to the Faraday cup (lithium target *11*, electrically isolated from rest part of the facility). Camera *12* detect luminescence of the lithium target [5], caused by the proton beam bombardment.

Using vacuum three-dimensional vacuum input proton beam current measured and two arrays of the proton currents obtained.

RESULTS

An example of the image obtained given in the Fig. 2. The easier way to obtain necessary information of the proton beam profile is find peak current, passing through

* Work supported by the RFBR project no. 19-72-30005.
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the cooled diaphragm and measure two orthogonal chords, passing through this point. Results of measurements, obtained in three different modes, are given in the Fig. 3. Yellow line obtained for the proton beam current 1 mA, green line obtained for the proton beam current 3 mA and blue line obtained for the proton beam current 3 mA with stronger focusing parameters, set by magnetic lense (*2* in Fig. 1). Solid line are Gaussian distributions, approximated for the measured values, which are shown as dash line.

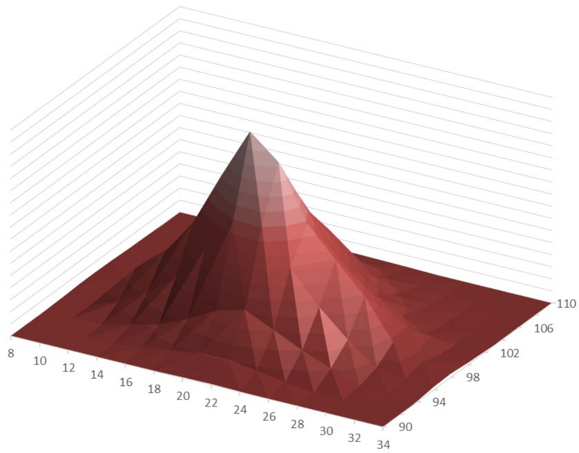

Figure 2: Result of the two-dimensional tomography for the proton current 1.2 mA. X and y axes are coordinates of the diaphragm, z axis is current distribution.

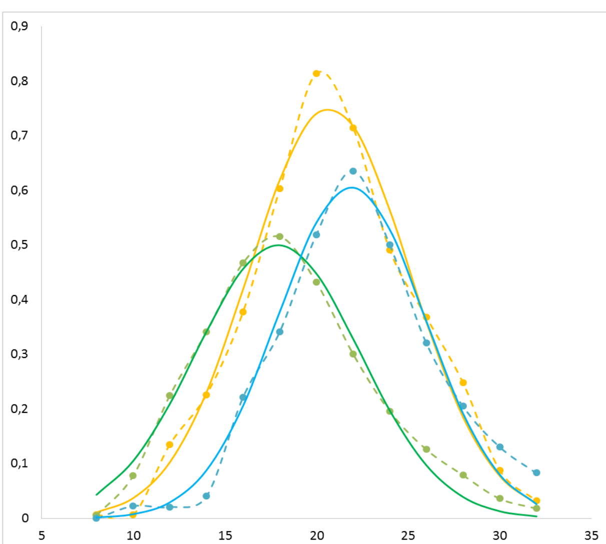

Figure 3: Profile of the proton beam passed through the peak of the beam. Solid line is approximation by the Gauss distribution, dash line are measured values. Yellow line is 1 mA, green one is 3 mA, blue one is 3 mA with a stronger focusing parameters.

CONCLUSION

The Budker Institute of Nuclear Physics operates a vacuum insulated tandem accelerator, in which transporting the proton beam with high power density – it can reach few tens of kW/cm^2. To provide fast measurements of the proton beam profile at bending magnet the two-dimensional tomography diagnostic was implemented. For the measuring two main chords, passing through the peak current, it takes around 1-2 minutes, which is fast relatively to the time of irradiations and experiments in the facility. The beam profile obtained in this way is somewhat different from the profile obtained by measuring the phase portrait of the beam using a wire scanner [3], but it can be used for the adequate estimation of the beam site relatively to the beam transport channel and beam size.

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