THE OBNINSK EGP–15 TANDEM (STATUS AND DEVELOPMENT)

V.S.Bashmakov, S.V.Bazhal, A.I.Glotov, V.K.Debin, A.S.Feigin, B.V.Kuprijanov, E.I.Lobanov, A.A.Malygin, V.A.Nikitin, V.A.Romanov, K.A. Rezvykh, V.I.Spirin, V.I.Volodin, IPPE, Obninsk, Russia

Abstract

The main parameters of EGP-15 tandem are presented and some trends of its future modernization are discussed.

1 MAIN CHARACTERISTICS OF ACCELERATOR

EGP–15 accelerator was designed and constructed by the SSC RF IPPE on the basis of the well known EGP–10 accelerator design developed at D.V. Efremov Institute of Electrophysical Facilities [1]. The accelerator is of vertical design. Diameter of the accelerator column is 1350 mm, its height (including high voltage electrode) being about 11 m. The column consists of six sections, each section 1.6 m long. High voltage terminal is 1450 mm in diameter and 1100 mm high. Vessel of about 12 m total height consists of 3 sections. The height of the upper and lower sections is respectively 3.5 m and 4.5 m; their inner diameter being 3 m. Height and inner diameter of the intermediate section are respectively 4.4 m and 4 m. N_2 and CO_2 insulation gas mixture is currently used. For the purpose of mass analysis of accelerated ion beams unilateral 90° analising magnet (1.5 m radius, peak magnetic intensity $1.5\ 10^4$ Oersted, $ME/Z^2 = 200$) is installed at the accelerator outlet. Magnetic analyzer is located on the rotating device, providing 180° slewing about vertical axis for its connection to three ion channels. During operation vacuum at the exit of the accelerating tube is $5\ 10^{-6}$ Pa with optimum stripping target thickness.

2 CHARGING SYSTEM

Two types of charging systems are possible to use: induction system and transport belt. Induction system was used to provide short circuit current up to 300 µA at the chain velocity of 15 m/s, but now it is out of operation. The charge transport belt was designed in co-operation with some other Russian institutions on the base of Kapron cloth of 0.2 and 0.5 mm thickness. In the process of the belt development the main attention was paid to its mechanical and dielectric strength and wear resistance. Raw rubber for the rubber mixture was chosen from the requirement of its appropriate wear resistance, strength and elasticity. Chosen materials were used for manufacturing 1.3 mm thick two–layer and 1.6 mm thick four–layer belts. Strength of the interlayer connection in these belts is 3.2÷3.4 kg/cm. Four–layer belt of this type is now used on the accelerator. Lifetime of the belt is over 8 thousand hours.

On the stage of new charge transport belt installation much attention was paid to the uniformity of charge distribution over the belt, since this parameter has a strong influence on the stability of the accelerated beam energy and position.

3 NEGATIVE ION INJECTOR

Only shortened horizontal section of the injector is currently used [2] with one sputter negative ion source of MISS 483 type designed by the Rossendorf Center, Germany.

For nuclear physics studies intensive light ion beams were needed. In particular it was necessary to have continuous and pulsed beams of hydrogen isotopes. Application of the sputter source for this purpose becomes inefficient. In this connection it was decided to make partial modification of the injector, i.e. to install beam buncher and hydrogen negative ion source of duoplasmatron type in vertical injection line.

The next stage of the injector modification will be the installation of several ion sources with the switching magnet.

4 OPTIMIZATION OF HIGH VOLTAGE STRUCTURE OF ACCELERATOR

In order to increase operating voltage and improve the accelerator reliability it is suggested to replace round equipotential rings of 30 mm diameter on two column sections by the elliptical equipotential rings. The shape and dimensions of equipotential rings were determined using computer code for calculation of electrostatic field characteristics [3]. Shielding electrode, which is common for three column sections, provides high electric strength of the column in both lateral and axial directions

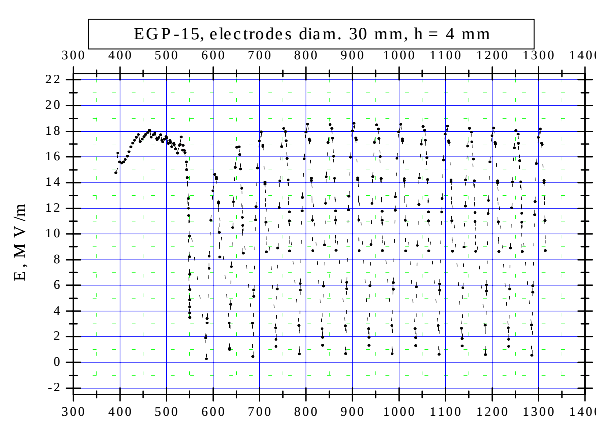

Fig. 1 Field pattern for the initial structure of the EGP–15.

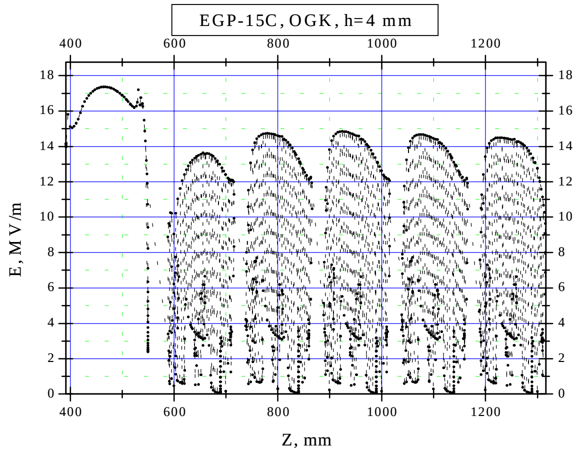

Fig. 2 Field pattern for new structure of the EGP–15.

and increased operating reliability of the accelerator. Figs. 1 and 2 show respectively field pattern for the initial structure of EGP–15 accelerator and new field pattern with changed equipotential rings. As a result of new design the column gradient decreased from 19 to 14.8 MV/m. In this case high–voltage terminal becomes a vulnerable element, and the energy dissipated over one insulation section W_{dsp} decreases by two times after the break–down to the vessel occurs. This leads to the increase of the operating

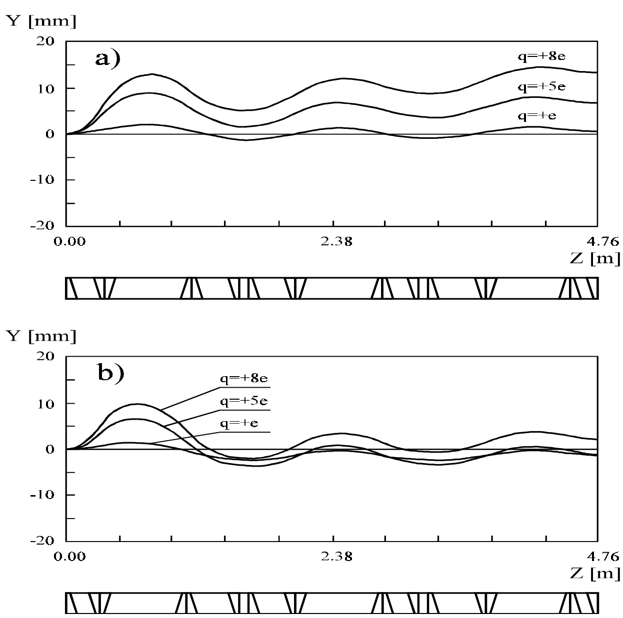

Fig. 3 Particles trajectories in the high–energy accelerating tube.

reliability of the internal structure of the column and accelerating tube.

5 ACCELERATING TUBES

The EGP–15 accelerator was designed for acceleration of wide range of ions. There are some features concerning multiple charged ion beam transport through high–energy accelerating tube.

Ion charge variation occurring in the terminal results in dependence of the ion trajectories in the stationary electric field on the charge state [4]. In order to increase electric strength of the tube it is equipped with the electrodes having transversal components of accelerating field (i.e. inclined fields are applied). However, it is well known that the ion trajectories dependence on the charge state proves to be most strong just in such accelerating structures [3], resulting under some conditions in the total loss of the beam [5].

Evaluation of the effect of dissipation processes in the stripper on the beam transport, previously made for the EGP–15 tandem accelerator, has shown, that even if additional optical elements are installed in the terminal the increase of Br^{+9} ion beam cross section with the energy of 75 MeV at the exit of the accelerating tube, may reach 10 mm and more [6]. Therefore it was important to choose such inclined electrode structure, which should not impact multiple charged beam, the electric strength of the tube being kept. Fig. 3 presents particles trajectories for different charge states in the EGP–15 accelerating tube adjusted for the single charged ions (3a) and multiple charged ions (3b). As it can be seen from the Fig. 3b, the displacement of multiple charged ions is about 2 mm, this value being quite acceptable.

The tube electrodes were made of stainless steel and the insulating rings were made of glass and porcelain. The tube was cemented using PVA adhesive.

6 ION–OPTICAL SYSTEM FOR BEAM MATCHING

Unrestricted impact on the beam caused by the strong aperture lens, formed by the equipotential surfaces of the electric field at the entrance of low–energy section of the accelerating tube, is a serious problem concerning tandem ion optics [7]. In order to solve this problem there are widely used injection systems, in which metallic grid is provided in the plane of the tube entrance electrode [8]. It is to be admitted that undoubtedly improving ion–optical characteristics of the low–energy accelerator section, the grided accelerating tube injection has some significant drawbacks, caused by beam-grid interaction.

Therefore, within the framework of activities aimed at the increase of maximum voltage of the EGP–15 tandem accelerator studies were made on the possibility of application in the existing low–voltage injector of an optical system having open tube entrance. It is free from the above mentioned drawbacks and provides reliable matching of the beam characteristics with the accelerator channel. In order to eliminate the dependence of the open tube entrance first order optical properties from the accelerating voltage, at least the proportionality of the accelerating tube entrance/exit particles energies should be maintained for the fixed position of the aperture lens object plane. These conditions can be met using three–electrode zoom lens. We have proposed and calculated the optical system for the beam matching on the basis of this lens [9]. It was demonstrated that optical magnification module of the proposed device is close to

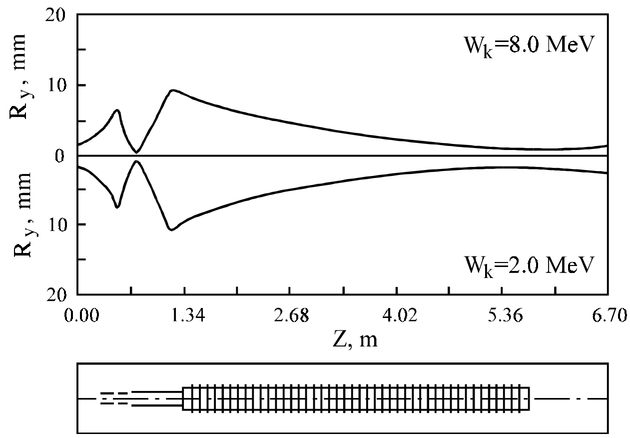

Fig. 4 Beam envelopes in the low–energy optical channel.

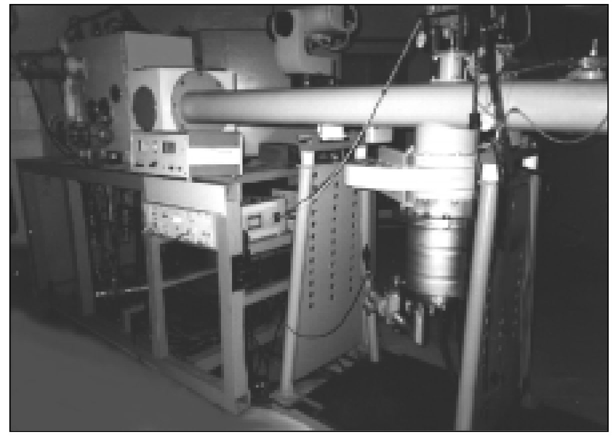

Fig. 5 System for irradiation of film materials.

one, while the matching voltage changes almost linearly with particles energy under the terminal. Fig.4 shows the beam envelopes in the optical channel of low–energy stage of the EGP–15 tandem, obtained for two energy modes, corresponding to 8.0 and 2.0 MeV particles energies in the terminal. The evaluation was made in the assumption that the beam was transformed in the object diaphragm plane into a crossover with $r_o = 1.5\ 10^{-3}$ m, its normalized emittance was $3\ \pi$ mm mrad $(\mathrm{MeV})^{0.5}$, and the particles energy at the entrance of the zoom lens is 30 keV. As it can be seen from the Figure, the shape of the beam is slightly influenced by the terminal voltage, and its cross section dimensions at the tube entrance are sufficient for passing the stripping target channel (6 mm in diameter).

7 IRRADIATION OF FILM MATERIALS ON THE EGP–15

Considerable attention was paid to design, manufacture and adjustment of technological film materials irradiation system for track membranes production (Fig. 5). By now the works are completed. Test Irradiation of 10, 20 and 30 μm thick Lavsan films were carried out. They were irradiated by oxygen and silicon ions. In the nearest future 10 μm Lavsan film will probably be irradiated for the purpose of the track membranes commercial production.

In order to assure high quality of the track membranes, the following modifications were made:

- ion beam stabilization at the entrance of irradiation chamber;
- ion beam monitoring in the process of adjustment works;
- improvement of vacuum in the irradiation chamber;
- monitoring and stabilization of the film movement speed;
- system for ion beam distribution monitoring in the process of irradiation, etc.

REFERENCES

1. Ivanov A.S., Kirshin G.F., Latmanizov V.M., et al, EGP–10 type charge–changing electrostatic accelerator, Atomnaya Energiya, v.34, No.5, p.p.401–403;
2. Bashmakov V.S., Glotov A.I., Kupriyanov B.V., Matveyev V.M., Sarytchev S.A., Low–voltage injector of EGP–15 accelerator, Proceedings of X Workshop on electrostatic accelerators, Obninsk, 1992, p.p.195–206;
3. Rezvykh K.A., Romanov V.A., EGP-15 tandem high voltage structure optimization experience. Proceedings of XV Workshop on charged particles accelerator, Protvino, 1996, v.1, p.p.192–195;
4. Larson J.D., Beam transport through electrostatic accelerator and matching into post accelerator, N.I.M., 1986, v.A244, p.p.192–200;
5. Friedrich M., Ion–optical studies on acceleration of heavy ions in the EGP tandem generator, PTE, 1983, No.3, p.p.25–27;
6. Bazhal S.V., Burushkin O.S., Romanov V.A., On application of the envelope method for evaluation of multiply charged ions optics in the charge–changing accelerators, IPPE preprint No.2332, Obninsk, 1993;
7. Larson J.D., Resolving beam transport problems in electrostatic accelerators, Rev. de Physique Appliquee, 1997, 12, p.p.1551–1561;
8. Purser K.H., Heavy ion injection for tandem accelerators, Nuclear Instrument Methods, 1977, v. 146, p.p.115–119;
9. Bazhal S.V., Romanov V.A., On application of zoom electrostatic lens for matching ion beam to the optical channel of low–energy stage of charge–changing accelerator, Proceedings of XV Workshop on accelerators of charged particles, Protvino, 1996, p.p. 201–205.