DESIGN AND CONSTRUCTION OF CDTC ACCELERATING SYSTEM

Yu.A.Svistunov, M.F.Vorogushin

D.V. Efremov Institute of Electrical and Physical Apparatus (NIIEFA)
P.O.Box 42 RU-196641, Saint-Petersburg, Russia

In paper [1] the new principle of contraband detection system and scheme of Contraband Detection Technological Complex (CDTC) of NIIEFA were proposed. The CDTC employs rf deuteron linac and matrix detection system. Beam of deuterons impinge upon a target giving birth pulsed neutron flow. Detection system registers gamma radiation which is appeared under interactions neutrons and nuclei of investigated object. CDTC is designed to detect explosives, fission materials and, in future, vegetables drugs. Accelerating system of CDTC is currently under construction and will be operated at a radio frequency 433 MHz. It consists of RFQ and alternating phase focusing IH-cavity with drift tubes as second stage acceleration. Final energy of deuterons will be 2.5 or 3.5 MeV. In this report are described briefly project of injector, results of modeling of electromagnetic fields and particle dynamics in RFQ and APF-resonators, thermal fields in RFQ and recent status of accelerating system.

1 INTRODUCTION

NPK LUTS (Scientific Production Complex of Linear Accelerators and Cyclotrons) is Division of D.V.Efremov Scientific Research Institute of Electrophysical Apparatus. CDTC is designed to detect explosives, fission materials and in future vegetables drugs. Conceptual scheme of CDTC was discussed in paper [1]. CDTC consists of linac to provide proton or deuteron beam, neutron producing target (berillium or carbon one), matrix detection system, system of processing of information, biological shield's blocks. For explosive monitoring is used PFNA method - pulsed fast neutron analysis. Matrix detection system detects secondary gamma radiation from investigated object. Secondary gammas are result inelastic scattering of fast neutrons on N, O, C nuclei during beam pulses. Intervals between pulses may be used to detect drugs with help short-lived isotope analysis. Fission is identified by detection and processing of energy's and temporal spectra of neutrons and gammas. As far as detection method uses pulsed neutron source then choice of accelerating system's type was produced between proton and deuteron linacs, linac of separate resonators and electrostatic accelerator with pulsed operation. Detailed analysis showed [2] deuteron linac with output energy 3.5MeV is optimal variant. It has simple RF system in comparison with linac with separate resonators and smaller gabarites and better reliability in comparison with electrostatic accelerator. CDTC accelerating system consists of 1MeV 433MHz RFQ and 433MHz IH-resonator with alternating phase focusing which accelerates deuterons from 1 up to 3.5MeV. Working frequency's choice is determined by previous developments of NPK LUTS, availability of RF power devices and requirement of installation's compactness.

2 INJECTION SYSTEM

Injector has duoplasmatron as deuteron source and electrostatic system of the beam forming and preacceleration [3]. Using of RFQ in frequency band 400-500MHz with 20-30mA pulsed current is proposed injection of the beam with high brilliance. Initial forming and acceleration to 60kV are produced by two-gaped high voltage system (see fig. 1). Electrostatic system of two lenses is used for matching of the size and orientation beam phase volume with RFQ acceptance. Potentials of the focusing electrodes are fed via high voltage lead-ins by separated feeding devices. As far as compensation of the beam charge is absent in injector tract it's length must be minimized. Injection system provides double-modulated beam with normalized emittance $4\pi\cdot 10^{-7}$ rad·m on the RFQ input. According to requirement of detection and processing system modulator of dicharge voltage divides the beam creating macro- and micropulses. Duration of macropulses is 100μsec. Duration of micropulses is 1.5-3 μsec. Interval between micropulses and length of micropulse are determined by trade-off between detector's possibility to process of maximal information against necessity to detect delayed neutrons under absence of the beam when fission are registered. Injector vacuum chamber consists of rectangular part with two coaxial flanges and the tubes-collectors which are welded at the side of the chamber. Two turbomolecular pumps provide pumping out of the chamber. Their velocity of pumping out is 900 l/s. Operational pressure inside vacuum chamber is near $7\cdot 10^{-6}$ Torr.

3 RFQ

RFQ provides acceleration of deuterons from 0.06 to 1MeV. Resonator consists of four identical chambers, two cavities at the ends and matching section at input of resonator. Length of vanes is 2.3m. 3D modeling of electromagnetic RFQ fields and calculation of main electrodynamic parameters were produced with ISFEL3D finite elements code. With regard to relatively big length of RFQ and small average radius of aperture (3.5mm) dense grid was used, including 2800000 mesh points. There was considered a part of construction for cross-section [4]. Dipole and quadrupole mode selection is produced by suitable boundary conditions. Final step of modeling included optimization of length for cavities on the ends and matching section to minimize nonuniformity intervane voltage along RFQ. Study of 2D-model (infinite RFQ) gives distance between working quadrupole mode and nearest dipole one - 12.1MHz but 3D model gives distance decreasing to 3.5MHz under nonchange of Q-factor practically. View of RFQ fabricated from chromium copper is shown on fig. 2. Thermal irregularities, deformations and parameters of cooling system which must provide their compensation are determined with code complex ANSYS [4]. Cooling system has four Π-shaped copper tubes soldering in resonator body near pedestal of vanes. Tubes are connected with each other in parallel. Pump with water pressure 4atm may provide thermal gradient along RFQ 1.5°C. In this case thermal deformations lead to maximal change intervane gap 1.7mkm only. Such alteration don't lead any essential change resonant frequency. Way of the RFQ fixing providing minimal deformations of construction by the action of gravity was determined with help of modeling too.

4 ALTERNATING-PHASE FOCUSING RESONATOR

Alternating-phase focusing (APF) resonator provides deuteron acceleration from 1 to 3.5MeV. Advantages of IH-type resonators structure developing in NPK LUTS, its tuning procedure and energy range for applications were considered in paper [6]. View of resonator is shown on fig. 3. Under maximal meaning of electrical field on beam axis 120kV/cm resonator has 54 accelerating gaps and drift tubes which are supported by cross rods (holders), two cells at the ends and beam channel of alternate inner diameter. Cells on the ends of resonator may have tuning cross-shaped elements. Number and length of accelerating gaps, inner diameters of drift tubes are determined under beam dynamic analysis. Total resonator length is 1.0m. Last cell has 100mm length, two holes for power lead-ins and two holes for vacuum pumps joining. Sizes of rods intervals between them, inner diameter of resonator, geometry of tuning cells at the resonator's ends are determined by RF fields modeling for given working frequency and oscillation's type. Working type of oscillations is p-type. Modeling is produced with help ISFEL3D code. 3D model had 1093356 mesh points. One need a few iterations for determination of inner resonator diameter with final result 70mm. Frequency gradient due to change of inner diameter is 8.5MHz/mm. Results of particle dynamics modeling were considered in paper [5]. As far as both RFQ and APF-resonator have high working radio frequency 433MHz phase beam length of the beam is increased greatly under transition between RFQ and APF-resonator. Consequently distance between last RFQ accelerating period and first accelerating gap of APF-resonator must be minimized if special ways of matching don't used (bunching and so on).

5 STATUS

Now RFQ had manufactured just as one of two 25kW power modulator of RF system, amplification line of RF system including master oscillator, preamplifier, amplifier of 400kW pulsed power, control system and feeding system of injector. It is expediently to build up RF system multisectioned accelerator as separate amplificating lines. As output amplifier of the line had been worked out endotron (coaxitron) type device KIWI and other device CONGRESS where summation of power of the four multichannel tetrodes was used. Both of type devices were tested successfully. Method of directional selective coupling was used for RFQ feeding to eliminate undesirable modes. APF-resonator is manufactured now just as the new injector. It is planned to test 1MeV RFQ on the laboratory stand by H_2^+ ion beam in 2002. Testing of accelerating system CDTC with RFQ and APF-resonator will be produced in 2003.

6 REFERENCES

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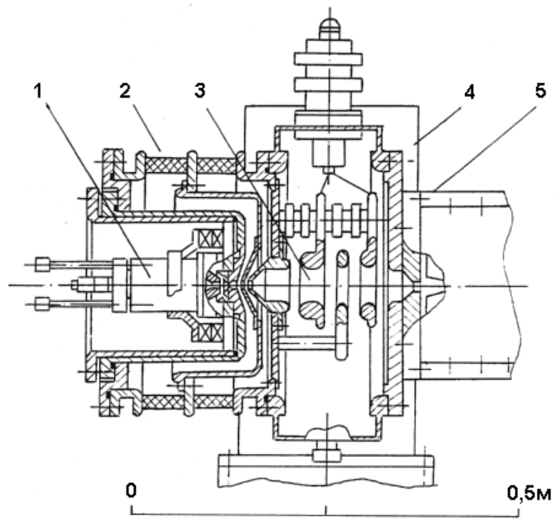

FIG. 1 View of ion D_1^+ injector: 1 - ion source; 2 - system of initial forming of the beam; 3 - electrodes of preaccelerations system; 4 - vacuum chamber; 5 - RFQ.

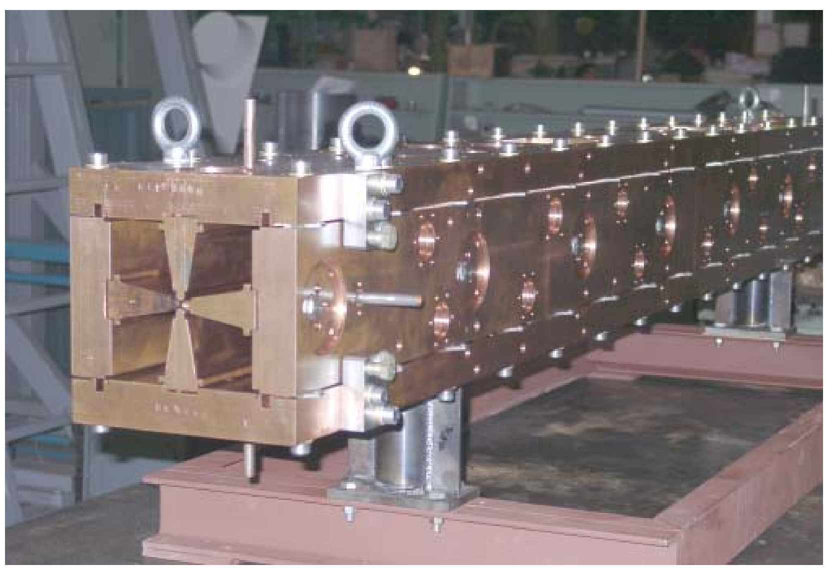

FIG. 2 View of RFQ.

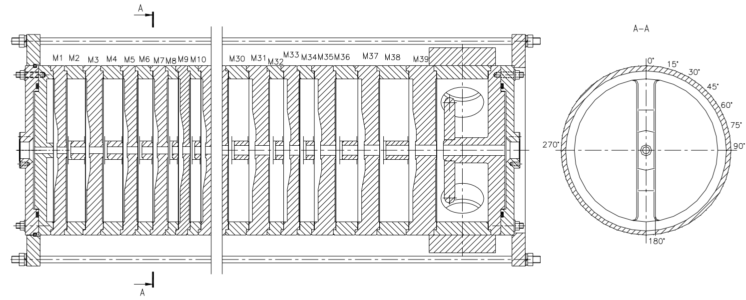

FIG. 3 Alternating phase focusing section (IH-resonator).