ADVANCES AT NPK LUTS 433 MHZ ION LINAC

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Abstract

There are presented intermediate testing results of 433 MHz compact linac wich is being worked out by Linear Accelerator and Cyclotron Division (NPK LUTS) of the Efremov Institute for applied purposes. Technical parameters of 1.8 MeV ion RFQ are given. Results of measurements of vane voltage, beam current and energy under accelerator's testing are discussed. It supposed a new RFQ of 2 MeV output energy will be mounted at the nearest time.

Introduction

During last years Linear Accelerators and Cyclotron Division of the Efremov Institute is working out commercial RF ion linac for different applications.[1] Now had worked out, fabricated and researched injection's system, 433 MHz RFQ with 1.8 MeV output energy, Rf system having endotron BM-105 as output cascade of power's amplifier. These blocks were mounted and installation had tasted. Brief description of accelerator's stand is given below.

Injection's system

Injector includes following main elements.
- SPS with Penning geometry of discharge chamber, source is placed inside of vacuum volume;
- Bending magnet, wich has demountable poles face to form beam with energy up to 20 keV and to seperate impurities;
- Electrostatical system of focusing and preacceleration up to 60 keV, that includes collection of ellectrodes with variable potentials.

Metalohydride system of purification produces preliminary purification of hydrogen. Magnetic field of discharge chamber is formed by poles of bending magnet. Permanent magnets KC-37 type created an induction of magnetic field wich must be 0.15 Tesla if H^- beam is produced. Magnitude of current and quality of obtained beam depend on relation of partial pressures of hydrogen and cesium in a source. Optimization of this relation allowed to obtain H- ion current 60 mA when discharge current was 190 A and discharge voltage was 140 V. Length of current pulse is 100 microseconds. Maximal current of H^+ ion was 100 mA. Injector's vacuum system has two turbomolecular pumps and supports pressure $5*10^{-7}$ Tor near injector output. Measuring system allows to measure emittances in XX' and YY' planes and distribution of current's density in beam cross section. Results of measurements of normalized emittances are:

A. Regime without cesium: I=15 mA, $E_{nx}=2.1*10^{-7}$ rad*m, $E_{ny}=1.1*10^{-7}$ rad*m.
B. Regime with addition of cesium: I=40 mA, $E_{nx}=3*10^{-7}$ rad*m, $E_{ny}=2*10^{-7}$ rad*m.

Accelerating structure

Accelerating structure is four-chamber's RFQ . Its cross section is given on fig.1. Geometrical and physical parameters are given in table 1 . First sample of RFQ was fabricated from aluminium alloy D-16.An accuracy of producing of vane modulation is 10...20 microns. Inner surfaces of cavity will be covered by copper using electroplating. Resonators tuning is effected in a step by step fashion with help of following operations:
1. field's symmetrization of cavities quadrdnts;
2. tuning of connection's elements;
3. check of symmetrization and procedure's repeating;
4. determination of electromagnetical axe of cavity;
5. measuring of longitudinal field's distribution.

Table 1. RFQ Specification.

Accelerated particles	H^+ or H^-
Operating frequency	433 MHz
Input ion energy	60 keV
Output ion energy	1.8 MeV
Number of periods	220
Vane length	1552 mm
Total length	1590 mm
Pulse current	up to 60 mA
Beam Transmission at 40 mA	87%
Intervane voltage	98kV
Final sinchronous phase	30^o
Phase beam length	40^o
Average bore radius	3.5 mm
Minimal bore radius	2 mm
Output normalized emittance	10^{-6} rad*m
Cavity RF power (without beam)	250 kW
Quality factor (for D16)	3800

As result of repeating of tuning cycle resonance frequency 433.3 MHz had been established. Dipole modes had eigenfrequencies 420.47 and 433.37 MHz respectively. Differences of magnetic field's amplitudes in cavity's quadrdnts were about $\pm 2\%$, inclination of electromagnetic axe to geometric one was less then 0.2^o, and small shift field's axe took place.

RF system

RF power system includes following fundamental units: master oscillator, preliminary cascade of amplification of power, final one, pulse source of anode supply, source filament supply, source of cynchronizing pulses. Output amplifier is endotron type device BM-105. It's operating parameters are given in Table 2.

Table 2. BM-105 specifications.

Pulse output power	1.2 MW
Pulse length	24 μsec
Efficiency of anode circuits	30%
Frequence's diapason	400...500 MHz
Pulse input power	1 kW

Really we used mode 433.3 MHz with pulse length 50...100 μsec. Output power is 500 kW if pulse length 100 μsec and output power is 365 kW if pulse length 130 μsec. Average power remains constant and it is equal to 6 kW.

Three of modulators of master oscillator, preliminary and output amplifier's cascades are fulfiled as circuits with full discharge of accumulating condencer and they are hooked up to the load via pulsed transformers. RF system have control systems of field's amplitude and frequency. Control systems compensate fast and slow deviations of field's frequency and amplitude. Four of RF power's lead-ins into RFQ cavity via hybrid ring suppress spurious dipole modes.

Working time of RFQ cavity under high level of power was about 120 hours. Cavity are served by six pumps HMT-0.25 type and magnitude of pressure they are maintained is 10^{-6} Tor. Power's level in the RFQ cavity was measured via brake radiation's spectrum of electrons. They are appeared as result field's and secondary emission. Results of measurements are represented on fig. 2. These measurements allow to estimate intervane voltage that depends on level of RF power in the cavity. 98 kV voltage corresponds to 250 kW of RF power.

Measurement of proton's energy

Time of work with beam was limited 30 hours. 10...15 mA beam was injected into RFQ cavity with 60 keV energy. Experimental procedure of proton energy's measurement is based on gamma-radiation's monitoring of nuclear reactions Al(p,γ)Si, Al(p,pγ)AlMg. Sources Co-57 (122 keV), Cs-137 (662 keV), Mn-54 (843 keV), Zn-65 (511 keV and 1115 keV) and K-40 line of natural noise were used for spectrometer's calibration. Typical spectrum of γ-radiation is represented on fig. 3. Energy of accelerated protons is estimated on relation of 843 keV and 1368 keV partial γ-peaks.

Calculations show that beam energy is near 1.7 MeV. RFQ cavity, that is described here, was first experimental sample. It's surface was not polished and not covered by copper. On account of periodical RF break downs accelerator worked unstable and intervane voltage did not achieve nominal one with the beam presence. These factors and initial shift between beam and resonator axes did not allows to obtain output current in pulse more then 15 microampers.

Perspectives

Now the new RFQ cavity with output energy 2 MeV had been fabricated from AMG-6 aluminium alloy. Such accelerator may be used for express analysis of materials. It may be analysis of a secondary radiation. For example, γ or X-ray analysis or analysis of radiation due to neutron activation. Other blocks of measuring complex: camera of interactions and measuring and process data system had been fabricated too. For accelerating $H^{\pm}$ ions from 2 up to 10...15 MeV, 2 MeV RFQ linac may be used as initial part of accelerator. It is proposed to accelerate particles from 2 up to 10...15 MeV in the drift-tube resonator. Protons and deuterons of such energies can be used for medical isotope production, elemental analysis of materials and other special purposes. Usually Alvarez structure is used as second stage of accelerator. Instead of Alvarez NPK LUTS proposes structure with crossed transversal holders (CTH), that works on π-mode (see fig. 4). Electromagnetic field distribution for working type oscillation is according to H(TE) mode. Samples of CTH-structure had fabricated, tuned and tested in the Efremov Institute.[2] Structure consists from separate cells, each of them includes broad outer cilindrical ring. Inside of rings drift tubes are fastened on massive holders. Cells can revolve each relatively others independently around longitudinal axe. CTH-structure has high mechanical stiffness, may have intensive forced cooling and need not special arrangements for alignment. It's technology of fabrication is close to traditional technology of waveguide fabrication

Perspective of improving of RF system are considered in paper TPH81 of Linac 96 conference.

Conclusion

At present separate units of 2 MeV installation have been tested. At the next time a test of whole installation will be produced. To make a compact commercial linac, it is obvious that new injector and RF system should be made. These units are worked out now. Instead of endotron type BM-105 we will use device KIWI and compact preliminary amplifier.

References

[1] Yu.V.Afanasiev, Yu.P.Vakhrushin, M.F.Vorogushin, Yu.N.Gavrish, V.A.Kassirov, V.I.Korobov, V.G.Mudrolubov, Yu.A.Svistunov, A.P.Strokach, M.A.Chernogubovsky Development of Working on Creation of RF Ion Linac for Applied Purposes. Proceeding of XIV National Accelerator Conference, Protvino, 25-27 okt.,1994. Vol.3, p.60 (in Russian).

[2] S.A.Minaev, Yu.A.Svistunov, S.A.Silaev Modeling and Testing of APF Cavity RF Field. Proceedings of Second International Workshop: BDO-95, July4-8, St.Petersburg, p.130.

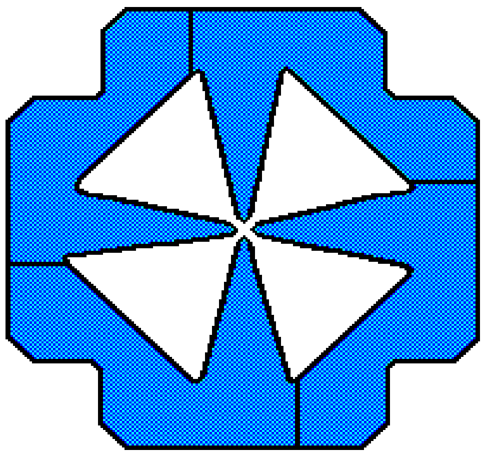

Fig. 1. Cross-section of RFQ cavity.

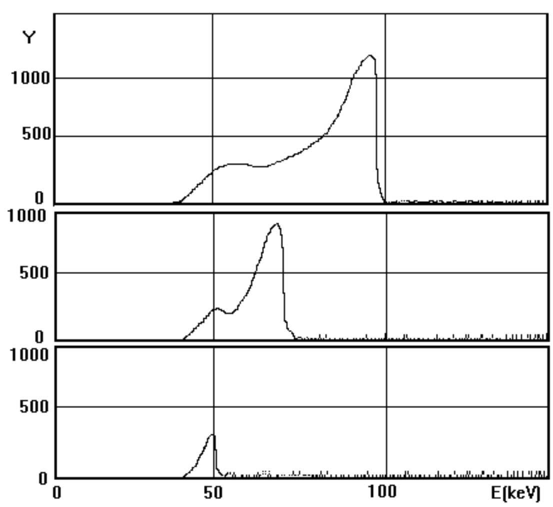

Fig. 2. Energetical spectrum of brake radiation for 0.8, 0.4 and 0.25 nominal meaning of RF power.

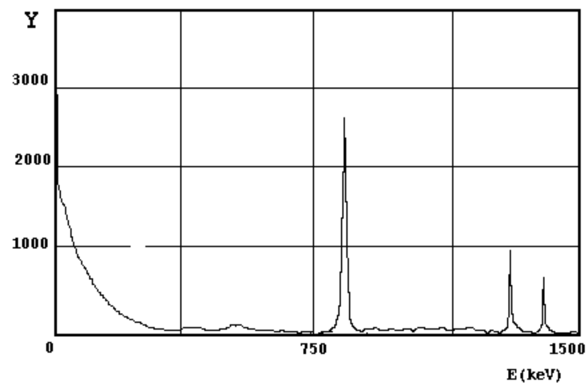

Fig. 3. Energetical γ-spectrum of nuclear reactions by accelerated protons.

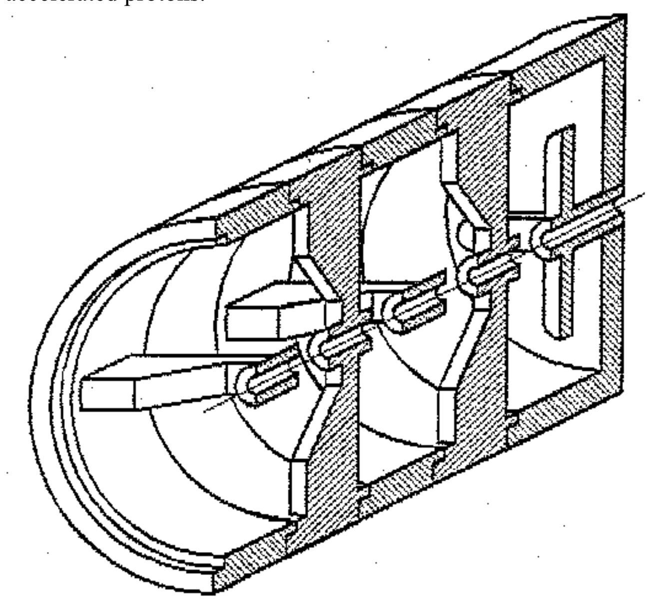

Fig. 4. Accelerating structure with crossed transversal holders.