

KEY SYSTEMS OF AN 433 MHZ ION LINAC FOR APPLIED PURPOSES

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Abstract

Commercial compact RF ion linac for different purposes is being designed and fabricated by the Efremov Institute since 1990. This report briefly describes key blocks of linac such as injection system, low energetical RFQ, drift tube resonators with output energy 10...15 MeV, RF system. Concept of their construction and technical realization is elucidated. Status of promising researches on creation of commercial RF ion linac in the Efremov Institute is presented.

Introduction

NPK LUTZ subdivision of the Efremov Institute is developing technology of production of ion 433 MHz linacs. Sample of such linac had tested under laboratory conditions. It is 1.8 MeV RFQ for H^+ ion acceleration. [1] A new RFQ cavity with output ion energy 2 MeV had been fabricated. For accelerating of ions up to 10...15 MeV, 2 MeV RFQ linac may be used as initial part of accelerator (IPA). It is proposed to accelerate particles from 2 up to 15 MeV in the drift-tube H-resonator. Protons and deuterons with such energy can be used for medical isotope production, elemental analysis of materials, in PET-system and other special purposes. Principles of building of key systems of such linac is given below.

Injection's system

Injector includes system of ion obtaining and system of the beam formation and focusing. System of formation must provide adjusting of the output beam emittance to accelerator's acceptance. Best accordance of the beam with accelerating tract may be achieved if the ion beam has convergence to the axis and symmetry in xy-plane (z-the beam axis). System of the beam formation includes focusing lenses and sometimes accelerating gaps to accelerate the beam up to injection's energy. Usually space charge of the beam is only partially compensated and there are necessary to have magnetic or electrostatic lenses to avoid excessive broadening of the beam along injector. In our case a preference was given electrostatic formation's system Compact linac's injector includes SPS with extracting voltage 15...20 kV, bending magnet which separates ion beam H^+ or D^+ from impurity and helps to form the beam phase volume, electrostatic LEPT system that focuses and accelerates ion beam up to 60 keV. Last system includes set of electrodes. Number, placement and potentials of electrodes are determined by required output beam parameters. There is code for computer designing of LEPT system. [2] Reasons and advantages of such choice are:

1. moderate currents and moderate space charges accordingly in compact linac allow using of the beams with uncompensated charge;
 2. absence of collective effects, beam plasma oscillations and beam instabilities along injector;
 3. computations show that beam heating between source and first electrode of LEPT is small;
 4. it is easy to provide low gas pressure at accelerating resonator's input (near $5 \cdot 10^{-7}$ Tor);
 5. simplicity and reliability of construction.
- Other properties of injections system are given in paper TPH82 of Linac96 Conference.

Accelerating structure

Usually 2 MeV 433 MHz RFQ is used as initial part of 10...15 MeV accelerator. RFQ as IPA in our case has some peculiarities. [3]

1. Accelerating gradient is high enough for RFQ. It is more than 1 MeV/m.
2. RFQ cavities are fabricated from AM \bar{A} 6 aluminium alloy and their inner surfaces are covered by copper with help of electroplating.
3. Vacuum housing is absent. Requiring vacuum may be provided by indium packings.
4. System of RF feeding allows to depress parasite modes and discussed below.

It is proposed to accelerate ions from 2 up to 10...15 MeV in the drift-tube resonator. Usually Alvarez structure is used as second stage of accelerator. Disadvantages of Alvarez resonators as part of industrial installation are complexity of tuning, necessity of special arrangements for alignment of drift-tubes, hardness of intensity cooling under big average power and, as a consequence, high cost of fabrication and operation. In addition of Alvarez cavity drift-tube holders cannot be very thick and structure has not high mechanical stiffness, it feels jabs and vibrations. Instead of Alvarez here is proposed structure with crossed transversal holders (CTH), that works on π -mode (its cross-section is shown on fig. 1). Electromagnetic field distribution for operating type oscillation is according to H(TE) mode [4]. Structure consists from separate cells, each of them include broad outer cylindrical ring. Inside of rings drift tubes are fastened on massive holders. Cells can revolve each relatively others independently around longitudinal axis. Adjacent cells are oriented such that their holders are located at the right angle each to other (or nearly to this position). CTH-structure has high mechanical stiffness, may have intensive cooling and need not special arrangements for alignment. Its technology of fabrication is close to traditional technology waveguide's

fabrication. In our case CTH structure is aperiodical one, because alternate phase focusing (APF) is used and we need not magnetic lenses inside drift-tubes.

Tuning of CTH-resonator may divide on following operations conventionally:

- establishing of the identity of working type of oscillations;
- compensation of the field decreasing at edges of resonator;
- compensation of the field decreasing along resonator;
- compensation of field modulating in APF structure;
- obtaining of resonant frequency in resonator.

Such dividing of operations is conventional for irregular resonator. Identity of working type of oscillations is realization of base type of oscillations with minimal frequency and experimental obtaining of the field in each gap. There are always places of resonator, where field is absent, because cells have weak connection and structure can have ununiformities, for example, long drift-tubes. Therefore long resonator is tuned sequentially. It is divided on few parts and it's length is increased step by step in process of tuning. It is convenient to begin tuning with terminal's cells, placing holders under right angle and increasing angle's changing when gaps and drift-tubes will decrease. Compensation of field decreasing on cavity edges is made by placing of tuning cross-like elements on faces of long drift-tubes. Such elements equal own frequencies of terminal's cells and regular ones. Selection of tuning element's sizes, their angular positions are determined by experiment. After preliminary tuning final levelling of the field was produced. Near gaps with big field's amplitude angular shifts of cells are increased and near gaps with small field's amplitude angular shifts are decreased. The tuning must take account that change of angle turn between cells creates change of field not only in gap between these cells but on entire tuned part of resonator. Therefore increasing of turn pair of cells must be accompanied by decreasing of angular shift of other part on this section. It is hardness that fields distribution is sensitive to the angular turns. Serious problem of multigap's resonator is dividing of types oscillations and high sensitivity of field's distribution to perturbation of cell's own frequencies. In spite of this tuning of 59-gaps structure with operating frequency 866 MHz was made successfully. This resonator was 1/2 scaled model of 433 MHz cavity that is intended for acceleration of protons from 2 up to 10.6 MeV. Model had been fabricated from D-16 aluminium alloy. As result of final tuning irregularities of gap's field were not higher then $\pm 5\%$ and distance between operating type oscillation and next parasite type one was 4.1 MHz. These results are good enough. Experimental data, obtaining under researching of 866 MHz resonators with 59 aluminium alloy cells, 6 copper cells and results of mathematical modelling had shown that shunt-impedance considered H-cavity is comparable or more then Alvarez cavity's shunt-impedance for energetical diapason 2...15 MeV. Shunt-impedance will higher in few times, if proposed structure used for acceleration with constant phase, but not acceleration with help of APF. In this case for stabilization of

radial motion in H-resonator must be used quadrupole lenses in the drift-tubes.

RF system

It is expediently to build up RF system multisectioned accelerator as separate amplifying lines. Dividing of RF power is made on low level. As output amplifier of line had been worked out endotron type device «Kiwi» of output pulsed power 450 kW and preamplifier of output power 2 kW. Functional scheme of endotron «Kiwi» is given on fig. 2.

Main characteristics of endotron are given in table 1.

Table 1. Main parameters of device «Kiwi».

Operating frequency	433 MHz
Input pulse power	0.8 kW
Output pulse power	450 kW
Average power	8 kW
Anode voltage	12 kV
Length of pulse	up to 130 μ sec
Efficiency	50%
Band of operating frequencies	± 10 MHz

In such type devices resonance circuits hook up to directly electrodes of grid operated tube inside vacuum volume. It allow to lower energy accumulated in scheme, active part of tube is used entirely and as result, total size of cascade are decreased significantly and broad band of operating frequencies is achieved. On the output of endotron ferrite circulator is installed to preserve device from overload when break-down in the cavity take place. RF system for accelerator cavity's feeding must have enough high power feeder, have not break down problem and to favour eliminating of undesirable modes in cavity. Last problem take place for four-vane RFQ (or drift-tube H-resonator), these are used in our case.

Proposed feeding scheme is satisfying these requirements. As far as accelerated beam in RFQ is remaining unbunched on one third of the cavity's length and is exiting wide spectrum of frequencies, methods of their difference may by not good enough. Here is proposed to use directional selective coupling. Method of directional selective coupling use field's correlation in such regions where coupling is maximal at operating mode and vanishes at undesirable ones. [5] Feeding system's scheme is shown on fig. 3. It contains directional couplers (DC), equal length's feeders l_1, \dots, l_4 and l_5, l_6 to attain equal amplitudes of cophasal excitation at equal coupling loop's spaces. In exact symmetrical case all mentioned undesirable modes except quadrupoles with even number of longitudinal alterations are not exited. For exact symmetrical case only quadrupole modes with even number of longitudinal variations are exited and feeder-loop's matching on operating mode reveals in full decoupling of matched load $m1, m2, m3$. Coaxial hybrid ring briges are used for the couplers.

Conclusion

Here were considered peculiarities of key systems of compact 433 MHz RF linac. At present these and others blocks are working out or are operating as parts of laboratory's installation. Creation of compact commercial machine may be ended during year or two under necessary financial support.

References

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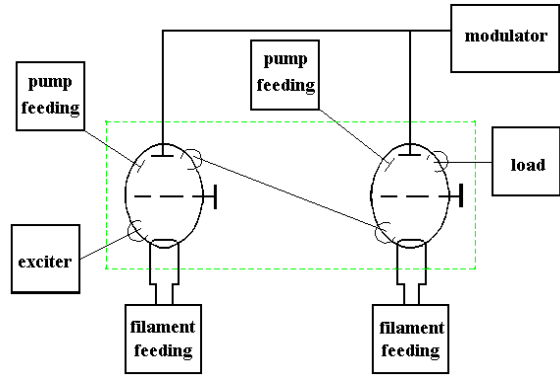


Fig. 2. Functional scheme of endotron.

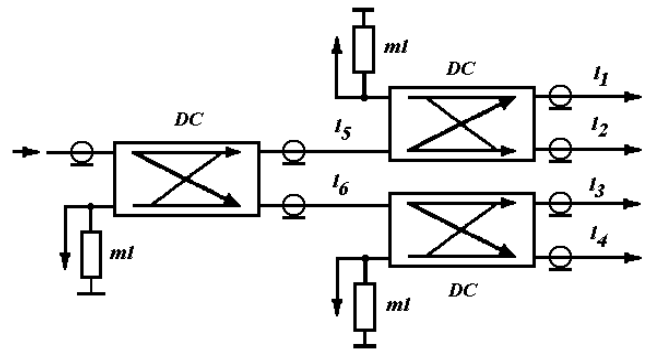


Fig. 3. Scheme of feeding system.

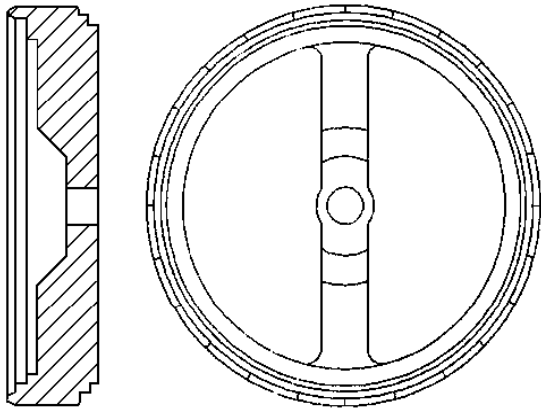


Fig. 1. Cell of accelerating structure.