PROTON 36 MeV, 0.5 mA LINAC ISTRA-36 AS A DRIVER OF MULTIPURPOSE IRRADIATION TEST FACILITY

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Abstract

The design and construction in ITEP of multi-target irradiation installation on the basis of linear proton accelerator ISTRA-36 is begun. The average current of the accelerator beam will be increased from 1 up to 500 μA. The 36 MeV beam will be directed on the beryllium target, located in centre of subcritical reactor assembly. An opportunity of extraction of the 36, 10 and 3 MeV beams for production of a radionuclides, manufacture of emitters for tomography, performance of the element activation analysis, experimental irradiation of materials and products is provided.

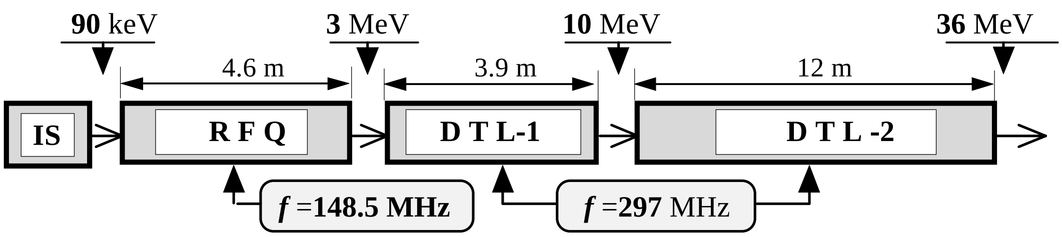
1 INTRODUCTION

Now the idea to use of an accelerated proton beam for decision of number of the nuclear power problems has received wide extension [1]. The questions of a structure of power installation on the basis of the accelerator - driver and subcritical reactor are heavily studied. From accelerator it is necessary to receive 10-250 mA proton beam current at energy 0.8-1.6 GeV. However the number of arising problems can be studied at small-scale installation, including in self both key elements: subcritical assembly and accelerator - driver with smaller current of a beam (≤ 1 mA) and energy of particles (a few tens of MeV). On beam with such parameters a production of the medical-biological purpose radionuclides, performance of the precision element analysis and radiating tests of materials and hardware are simultaneously possible. The named purposes will be served by multitarget test irradiating installation, creating in ITEP on the basis of linear proton accelerator ISTRA-36.

2 LINAC ISTRA-36

For a number of years follow according to Prof. I.M.Kapchinsky's ideas development of the high-intensity linac prototype - accelerator ISTRA-36 is conducted. The linac consists of 3 sections (see Fig.1): RFQ, DTL-1 and DTL-2. Matching horn at the input of section RFQ and dynamic matcher on its output [2] reduce losses of particles. RF frequency in sections DTL (297 MHz) is twice higher in compari-son with frequency of the resonator RFQ(148.5 MHz) This choice specially developed small-sized rare-earth lenses [3] have allowed to reduce diameters of the drift tubes and DTL resonators, but also to lower los-ses of RF power. The absence of outgassing materials in components of quadrupole lenses has enabled to simplify a design of drift tubes having their internal cavities open to high vacuum [4]. Use for all three accelerator's señtions of the of three-layer-metallic vacuum tanks, which simultaneously serve by RF resonators [5], has simplified a problem of heat removal.

The channels of RF supply are constructed on the basis of modernized domestic tube GI-27AM. The duration of RF pulse is chosen equal $\boldsymbol{t}_{RF}$ = 230 μs, from which for acceleration of a beam is allocated $\boldsymbol{t}_B$ = 150 μs. The value pulse beam current is I_P = 150 mA. The average beam current I_{AV} is defined by frequency of repeti-tion of pulses F : $I_{AV} = I_P \cdot \boldsymbol{t}_B \cdot F$. Available quantity of the RF output stage will allow to work with repetition rate of F = 25 Hz, that will ensure the average beam current $I_{AV} \geq$ 500 μA. The thermal characteristics of the resonators give scop for acceleration much greater average current: up to 5-10 mA. Thus, there is the oppor-tunity of further increase of a beam current in future.



RF generators

Fig.1. The block diagram of the accelerator ISTRA-36.
(IS - ion source, f - frequency of RF generators)

3 CIRCUIT OF IRRADIATION INSTALLATION

The general view of multitarget irradiation installation is submitted on Fig. 2. Linac is placed on two floors of an existing building beside room of subcritical assembly.

On the first floor is placed injector, sections RFQ and DTL-1. The beam is accelerated up to 10 MeV, rises on second floor on bend ion channel BC and after bending on 180° is injected in DTL-2. The output ion channel OC serves for transportation of proton flow to beryllium target (beam outlet-1, BO-1) or to station of the radionuclide production (BO-2).

There are 3 channels of the beam's outlets for irradiation of specimens and production of a radio-nuclides (BO-2, BO-3 and BO-4). The beam with energy 10 MeV (and 3 MeV, large part of beam, accelerated in RFQ up to energy 3 MeV, passes through DTL-1 at absence in it of a RF field) can be directed from DTL-1 in horizontal plane to post BO-3, if the first BC magnet is switched off, and downwards in a base floor - if it is included in opposite polarity. By use of pulsing magnets is possible as serial, and in common-simultaneous extraction of a beam with any subdivision of total average current 500 μA between all 4 channels.

4 LINAC- DRIVER SUBCRITICAL BLANKET

If beam is directed on the beryllium target, surrounded by subcritical multiplying blanket on basis of uranium, enriched by isotope ^{235}U, and heavy-water moderator [6], we consider to have intensity of fast neutrons from target up to $3 \cdot 10^{14}$ n/s, and flux ofthermal neutrons in the area of experimental chan- nels - $(1.5\text{-}3) \cdot 10^{12}$ n/cm^{2}s. Factor of blanket multiplica- ion is 0.95-0.97. Thus becomes possible: experi- mental study of subcritical systems as the potential producers of energy, test of transmutation blanket models, use of installation as effective pulsed source [7] of cold and ultra cold neutrons for researches in the field of fundamental physics.

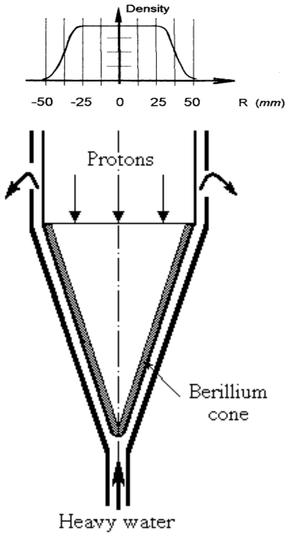


Fig. 3. Target unit and proton density distribution

On calculations, at swit-ched on octupoles(see Fig. 2) on internal surface of a conic target (diameter of the cone's base of 96 mm, the corner at top 24°) falls 98- 99 % of particles from their number in an output beam of the accelerator. Thus density of a proton flow in average part of a beam sec-tion (see Fig. 3) remains uniform. Such distribution is quite accep-table to imple-mentation of a satisfactory thermal mode of target.

The linac operation at raised average current in tandem with the target-blanket system will allow some special problems,to which particular interest is displayed at research of an opportunity creations of full-scale transmutation installation and power reactors, controlled by accele rators. These problems concerns: development of questions of safe mana-gement by real system, consisting of accelerator - driver and subcritical reactor; study potentially-dangerous events and emergencies (including, in mode of their imitations) and ways of their prevention; study of peculiarities of RF resonators excitation in mode, when the energy, going on acceleration of particles, is much more stored in field; reception of the information about operation's relia-bility of the perspective for high-current accelerators- drivers rare-earth quadrupoles and the open in high vacuum drift tubes.

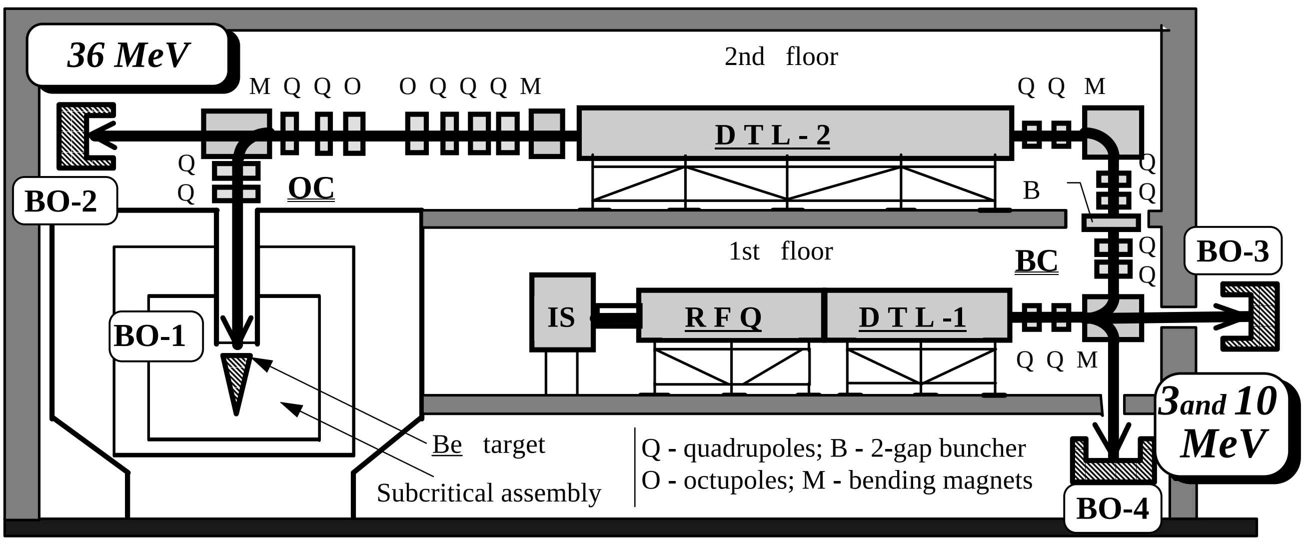


Fig. 2. The linac disposition and accelerated beam outlets.

5 PRODUCTION OF RADIONUCLIDES

36 MeV is energy, at which on a proton beam it is possible to make almost whole the radionuclide spectrum of medical-biological application and the significant part of industrial use nuclides. In Table are brought the most used and perspective radionuc-lides of the specified purposes. The optimum value of an average beam current for their production lays within the limits of 100-400 μA.

Radio nuclide	Half-life	Energy of protons (MeV)	Nuclear reaction
^{55}Co	18 hours	15-40	^{56}Fe(p,2n)
^{67}Ga	78.3 hours	15-35	^{68}Zn(p,2n)
^{68}Ge	288 days	13-35	^{69}Ga(p,2n)
^{68}Ga	68 min	-”-	-”-
^{81}Rb	4.7 hours	16-32	^{82}Kr(p,2n)
^{82}Sr	25.5 days	32-70	^{85}Rb(p,4n)
^{82}Rb	6.3 hours	-”-	-”-
^{87}Y	3.3 days	15-33	^{88}Sr(p,2n)
^{87}Sr	2.8 hours	-”-	-”-
^{123}I	13.3 hours	10-30	^{124}Xe(p,2n)
^{201}Tl	73 hours	14-35	^{202}Hg(p,2n)
^{203}Pb	52.1 hours	20-35	^{205}Tl(p,3n)

The proton beam with energy 10 MeV is convenient for manufacture of the main list of radionuclides, used for positron emission tomo-graphy. Among them are ^{11}C, ^{13}N, ^{15}O, ^{18}F, ^{19}Ne, ^{45}Ti, ^{62}Cu, ^{76}Br, ^{110}In. The values of beam current neces-sary for their production are 30-80 μA. In majority these nuclides have very short times of half-life: from a few tens of seconds up to several hours.

6 OTHER APPLICATIONS OF THE PROTON BEAM

The protons with energies of 3 MeV and 10 MeV can be used for performance of the element activation analysis, where with their help it is possible to determine impurity of one metals in other, to find out small gas impurity C, N, O, Cl in substances (sensitivity on nitrogen, for example, 10^{-5} %), to define amount of boron in silicon semi-conductors (sensitivity 10^{-6} %), to measure quantity of sulfur in petroleum (threshold of sensitivity 0,01 %).

The proton beams with energies of 3, 10 and 36 MeV can be used in study of radiating resistance of substances, materials, components and ready pro-ducts. Such beams will be very useful for decision of some problems which arise at development of space.

7 DEGREE OF READINESS OF INSTALLATION

In temporary room the sections RFQ and DTL-1 have mounted and started yet [8]. The protons are accelerated up to energy 10 MeV. The pulse current on DTL-1 output was measured 150 mA (average current ~ 1μA). In output beam practically all particles were accelerated.

Taking into account presence in the Institute of the most expensive main equipment (all resonators and drift tubes with rare-earth quadrupoles, the powerful RF stages, the vacuum and water-cooled pumps etc.) it is possible to estimate the linac readiness as 60 -70 %.

The basic decisions on accommodation of the accelerator and its technological systems in the dismounted reactor building are accepted, two-storey protective concrete hall is designed, in which accelerator will be installed.

8 NEAREST PROBLEMS

Simultaneously with end of the accelerator's structure it is necessary to transfer its systems in operation at raised average current 500 μA. First of all it concerns to injector and modulators of RF generators.It is necessary to develop the proton injector on the pulse repetition rate of 25 Hz and pulse current not less than 200 mA. Other problem consists in development of powerful adjustable modulators. It is necessary for indemnification of recession of the RF field in resonators at acceleration of such large value of current, as 150 mA.

9 CONCLUSIONS

The beam of linac ISTRA-36 will find application in decision as research, and practical applications, relating to nuclear power, to problem of transmutation of the radioactive wastes, to neutron physics, radiating medicine, to the activation analysis, radiating materials study. The greater part of accelerator equipment are manufectored, this fact and use of the technological systems and the buildings of the stopped reactor much reduce a total cost of a complex. The presence in ITEP of scientific and engineering experts in all named above directions puts the construction and use of the multitarget irradiation installation (at necessary financing) on real ground. Fast construction of the installation can become to the first in world working complex, that unite the accelerator - driver and subcritical reactor.

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