MULTIPASS RF ACCELERATOR FOR ACCELERATION OF PROTONS AND DEUTERONS

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Abstract

Here the project of 13-16.5 MeV proton-deuteron accelerator is described. It is proposed to be used as accelerator-injector, or neutron source and also can be utilized for isotopes production for PET. The accelerator is 30 MHz RF cavity with four 0.5-1.6 MeV accelerating gaps and drift tubes of corresponding length. The beam from ion source will be bunched before injection into accelerator. After the direct passage of first four accelerating gaps the beam is bent by ≅225° and returned again into the cavity on the next level. After the next passage of four accelerating gaps the beam is bent again by ≅225° and returned into the cavity. Thus, it crosses the cavity four times perpendicular to its axis on different levels with corresponding change of drift tubes length. As a result protons and deuterons can achieve 13-16.5 MeV energy in the same structure, correspondingly. The preliminary design of cavity was calculated using special computer code SLANS, developed at BINP. The effective shunt impedance of accelerating structure is about 1 MOhm with Q-factor about 20000. The pulsed power of losses does not exceed 1.5 MW.

1 INTRODUCTION

Protons and light ions accelerators with energy of particles of about 10 MeV have different applications. Such an accelerator with energy ~ 10 MeV can be used as injector into proton medical synchrotron on energy 70-250 MeV, for example. Protons with energy higher than 12 MeV can be used also for isotopes production. Deuterons can be used for neutron generation.

One of possible variants of such ~ 10 MeV machine is a single cavity accelerator with particles passing one or more times through it. It should provide the acceleration of protons and deuterons in the same structure.

2 ACCELERATOR DESIGN

The schematic view of accelerator complex is given in Fig. 1. The bunched beam from ion source passes through first four accelerating gaps and then the beam is bent through ≅ 225° by magnets and returned again into the cavity on the next level. After the next passage of four accelerating gaps the beam is bent again through ≅ 225° and returned into the cavity. Thus, it crosses the cavity four times perpendicular to its axis on different levels with corresponding change of drift spaces and magnetic field in elements of bending channels. Magnetic channels include magnets (2, in Fig. 1) with R = 0.3 m and R = 0.5 m, B_{max} = 1.5 T, lenses (3, in Fig. 1) and bellows for optimal RF phase adjustment.

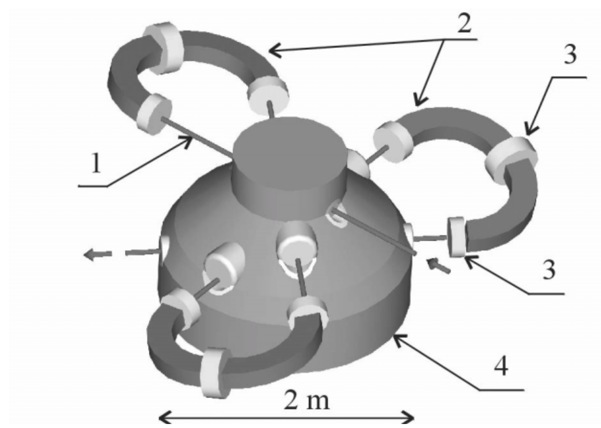

Fig. 1 Schematic view of accelerator complex. 1 – beam path, 2 – bending magnet, 3 – lenses/diagnostics, 4 – cavity.

As concerning the cavity design, one of the first factors affecting its geometry is a problem of first passage of first accelerating gap. Particles from ion source usually have energy in 0.05-0.1 MeV range, so they are slow. To obtain the time of flight $\tau \leq T/2$, where $T = 1/f$, the corresponding relation between value of accelerating voltage, RF frequency and length of accelerating gap should be chosen. Another problem is high electric fields, which should not exceed 35 MV/m locally and 16 MV/m in average along the high voltage gap at f~30 MHz. [1]. Therefore and from designer's point of view the lower limit on central drift space is 10 cm approximately; despite the particle motion calculations give it equal to several centimeters.

After consideration, the length of first accelerating gap was chosen to be equal to 7 cm at a frequency f = 30 MHz and acceleration voltage U = 1 MV. The longitudinal particle motion in longitudinal electric field $E = E_z(z,t)$ is described by the system of equations [1]:

$$\frac{d\varphi}{dz} = \frac{2\pi}{\beta\lambda}$$

$$\frac{d\beta}{dz} = \frac{1}{\beta}\frac{q}{m_0 c^2}E(z)\sin(\varphi + \varphi_0) \quad (1)$$

$$\beta << 1$$

Where $\beta = v/c$, $\lambda = c/f$ – wave length, q – electric charge of particle, E(z) – electric field along the beam axis, $\varphi = \omega t$, φ_0 – initial phase of RF voltage, m_0 – rest mass of particle.

This system (1) was solved numerically in order to get a cavity suitable for acceleration of protons to energy higher than 12 MeV and deuterons in the same structure for injection energy 50-100 keV. Special computer code SLANS was used for calculations of the cavity. After solving the system (1) together with calculations of cavity parameters (successive approximations) some preliminary design of cavity have been defined. The cavity cross-section is given in Fig. 2.

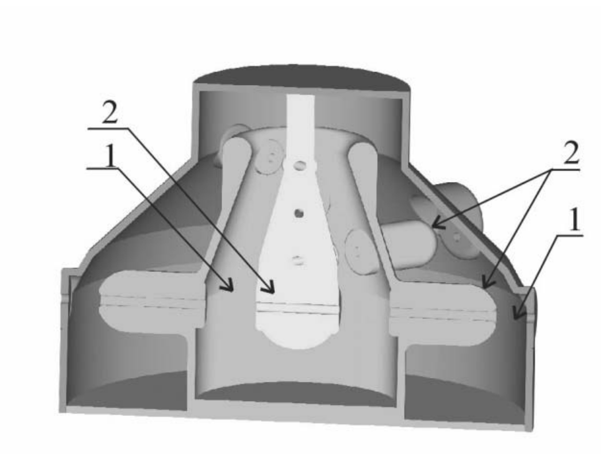

Fig. 2 Accelerator cross-section on fourth beam passage
1 – accelerating gap, 2 – drift space

The parameters of cavity are given in Table 1 and below.

Table 1

First mode, MHz	30
Stored energy, J	130
Q-factor	18500
Shunt impedance Rsh, MOhm	1
Power losses, MW	1.3
Height, m	1.4
Max. Diameter, m	2

1st passage

U1 = 0.99 MV	Gap1 =7.0 cm	Drift1 = 8.7 cm
U2 =1.40 MV	Gap2 =12.0 cm	Drift2 = 11.5 cm

2nd passage

U1 = 0.89 MV	Gap1 = 21.0 cm	Drift1 = 17.8 cm
U2 = 1.52 MV	Gap2 = 13.0 cm	Drift2 = 27.0 cm

3st passage

U1 = 0.69 MV	Gap1 = 13.0 cm	Drift1 = 35.5 cm
U2 = 1.60 MV	Gap2 = 15.0 cm	Drift2 = 36.5 cm

4th passage

U1 = 0.48 MV	Gap1 = 12 cm	Drift1 = 42.5 cm
U2 = 1.62 MV	Gap2 = 21 cm	Drift2 = 42.3 cm

Thus the preliminary geometry of RF cavity has been defined. Protons can achieve 13 MeV energy in this structure; deuterons can achieve 16.5 MeV energy. The more detailed particle dynamics calculations are the subject for further investigations.

REFERENCES

[1] A.D. Panfilov, “Pulsed RF proton accelerator-injector to synchrotron” PhD thesis, Novosibirsk, 1978