APF ACCELERATING STRUCTURES FOR LIGHT AND HEAVY IONS

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In recent years ion accelerators, which could have a number of applications in science and other fields are attracting ever growing attention. Accelerator centres all over the world have gained vast experience in acceleration of ions, using linear resonance accelerators and cyclic accelerators /1/ . But it should be mentioned that there are so far no well established schemes for acceleration of ions especially heavy ones, in the energy range up to 1.0-1.5 MeV per nucleon (MeV/u). In conventional linear resonance self-phasing accelerators the ions are strongly affected by the defocusing forces of the RF field, which in case of ions changes slowly. As a rule even in the most effective structures with RF, electrostatic and quadrupole magnetic focusing, stable acceleration of ions can be provided at the amplitude of accelerating field strength of 0.3-0.5 MV/m. It means that a self-phasing accelerator for heavy low charged ions to the energy of 1.0-1.5 MeV/u would be comparable in dimensions with a proton accelerator to the energy of tens or hundreds MeV.

Along with these projects a number of accelerator centres is developing light and heavy ion accelerators with alternating phase focusing (APF) structures in the initial part /2/ . In these structures self-phasing is replaced by alternating-sign phasing that gives an opportunity to avoid almost entirely defocusing caused by the RF field. Therefore the amplitude of accelerating field strength can be increased up to 5-10 MV/m and the length of the initial part of the accelerator decreases respectively by a factor of 10-20. In recent years it has been theoretically shown that in resonance APF accelerators the capture factor can be as high as 0.4 /3/ .

Theoretical and experimental studies at ITEP were aimed at investigating effective APF structures for ions with specific charge from 1/2 to 1/66 and comprised two main approaches.

The first approach involves development of APF structures for ions with low specific charge (1/20-1/66). It seems reasonable to choose for different structures the working frequency of the RF field to be 25 MHr and to use a multibeam scheme in order to increase the intensity of the accelerated beam /2,4/ . The main desigh parameters of two heavy ion accelerators are given in Table 1.

Specific charge, Z/A	1/20	1/66
Input energy, KeV/u	7.5	2.2
Output energy, MeV/u	1	0.7
Amplitude of accelerating field strength, MV/m	7	7
Number of beam channels	7	7
Aperture of channels, mm	12	6
Maximum electric field strength on the axis of a channel, KV/cm	150	150
Maximum current in a channel, mA	3	0.8
Accelerator length, m	4	8

In these accelerators it is planned to use a conventional quarter-wave oscillators and Wideroe structures. The measurements on models showed that in the oscillator structure the shunt impedance can reach 25-50 MOhm/m, the electrodes diameter being 70 mm.

The second approach was initiated by the intention to increase the capabilities of the existing proton linac-injector I-2

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and to use its equipment for the acceleration of ions with specific charge from 1/2 to 1/16. Among the requirements that had to be met were dimensions, location, input beam parameters, wave length and the existing RF power supply.

The manufactured APF structures for ions with specific charge 1/2 and 1/4 can be seen in Figs. 1 and 2. These are rectangular H-resonators, in which the electrode carring rods are mounted on the side plates. The resonators are installed in vacuum tanks (0.4 m in diameter). Frequency and field distribution tuning doesn't need preliminary simulation because the resonator is made of 3-4 adjustable plates and the main task during the tuning is to choose the right mutual location of the plates and the position of the electrode carrying rods. The side plates are fixed to the main bar by screwbolts. Special measures are taken to provide reliable contact. Longitudinal position of the electrodes was defined by calculations and ensured by precise alignment. The quality factor of the APF structure for ions with specific charge 1/4 is 4000, the shunt impedance - 60 MOhm/m.

The resonators underwent 500h beam tests with H_2^+ and He_4^+ ions /5,6/ . Stable acceleration was provided at rated field strength during 10 days on the round - the - clock basis.

The parameters of the APF structures for ions with specific charge 1/2 and 1/4 are given in Table 2. During the tests of the resonator developed for He_4^+ beam the RF power was increased for some periods by 20--30% over the rated value, that opens an opportunity to increase the acceleration rate up to 9-10 MeV/m.charge.

In Table 2 one can also find the design parameters of the APF structure for O_{16} ions. In this resonator O_{16}^+ ions are accelerated at first 0.5 m to the energy of 0.33 MeV/u , then (after the stripper) the ions with equilibrium specific charge 1/4 are accelerated to the energy of 1.5 MeV/u. The share of ions with equilibrium charge is approximately 50% of the input beam, and the total energy increase is 23.3 MeV/nucleus.

Specific charge, Z/A	1/2	1/4	1/16
Input energy, MeV/u	0.35	0.17	0.044
Out. energy, MeV/u	1.5	1.5	1.5
Working wave length, m	2.02	2.02	2.02
Maximum RF power consumed (pulse), MW	0.44	1	-
Minimum diameter of channel aperture, mm	16	8	4
Maximum field strength on the axis, MV/m	17	17	19
Resonator length, m	0.45	0.75	1.1
Number of accelerating gaps	10	19	39
Diameter of the electrodes, mm	70	50	30-50

High acceleration rate and relative simplicity make APF structures attractive and offer a new approach to the development of the initial part of a heavy ion accelerator to the energy of 1-1.5 MeV/u.

For acceleration of various ions in the existing proton accelerator equipped with the APF structure it is possible to maintain in operation injection and beam transport systems because the optimum conditions for stable acceleration of ions are provided by the APF structure. The APF structure is located in the matching channel and is individual for each type of ions.

In experiments with He_4 at I-2 linac the structure was installed between the preinjector and the first resonator. At the output of the APF structure 2.5 mA He_4^+ beam was detected. After stripping He_4^{2+} ions were injected into the first resonator, which was used only as a focusing channel. The ions were accelerated in the second resonator. The output current of the He_4^{2+} beam was 1 mA.

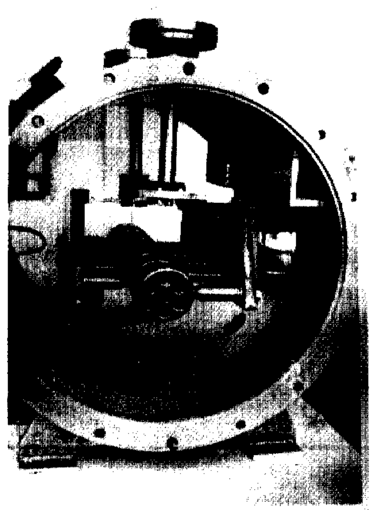

Fig. 1
APF structure for ions with Z/A = 1/2

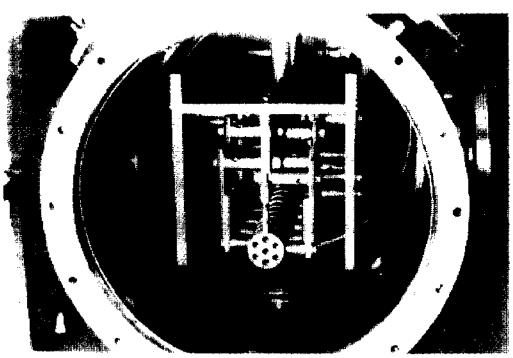

Fig. 2
APF structure for ions with Z/A = 1/4

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