A MULTIPLE-BEAM ION RF ACCELERATOR WITH ALTERNATING-PHASE FOCUSING : STATUS REPORT

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Abstract

This report reviews the design and operating characteristics of A Multiple-beam Ion RF Accelerator with Alernating-Phase Focusing main systems. The installation consists of a microwave ion source, accelerating section with removable RF module, two RF power generators (cw 38 MHz for ion source and pulsed 50 MHz for accelerating resonator), vacuum system, high voltage equipment.

During the last decade a growing interest is observed in production of intense sub-ampere ion beams with MeV energies by radiofrequency (RF) accelerators, including radiofrequency quadrupole linacs (RFQ), Alternating-Phase Focused linacs and Variable Phase linacs. At the same time, in order to increase total beam current it was suggested to accelerate simultaneously a number of ion beams, that became a basis for Multiple-Beam Accelerators development [1, 2, 3]. Besides a total beam current increasing, due to the space charge limits bypassing, and rising of " RF efficiency " of the machine [4] , there is a possibility to form an extended radiation zone without special output techniques.

In a Multiple-Beam Ion RF linac, which is under investigation in MEPI [3] , the transverse stability of particles is provided due to the Alternating-Phase Focuing. The installation contains a microwave (RF) ion source, accelerating section (AS), two RF power generators to supply RF source and AS, vacuum system, high voltage and auxiliary equipment.

RF ion source consits of the glass discharge chamber (length 60 mm, diameter 40 mm) placed in $\lambda/2$ coaxial meter range resonator (length 300 mm, diameter 150 mm) inside a cylindrical spiral center guide of it. The resonator is under high potential and is mounted on insulator inside the vacuum tank (length 500 mm, diameter 500 mm). The extraction electrode, fixed on the output end of resonator with an insulator, has 7 beamlets 2 mm in diameter (one at center and six at the 30 mm diameter circle). The RF power input is realized as a drive loop, which has no connection with cavity, so that RF power generator has a potential of a ground.

At first runnings of RF ion source a pulsed RF plasma discharge was used. In this case we achieved the total current up to 40 mA of protons and 20 mA of Ar (pulsed RF power 30 kW at 150 MHz , pulsed high voltage at cavity - 90 kV) . At the same time , most of known RF ion sources are operating with continious (cw) RF plasma discharge, but in centimetre wavelength range. Because they have, as a rule, small crossection of discharge chamber, or it has no axial symmetry, such a sources cannot be used for a multiple-beam injector directly. So, the results of investigation of our meter range RF ion source cw operation are of certain interest. On cw testing and optimization of gas pressure and RF power levels the 7 kV dc industrial voltage supply was used. It was connected to the resonator and some part of it was applied to extraction electrode. When feeding the cavity from standard cw RF signal generator (output power less than 2 W) at 150 MHz we have got total dc current up to 0.3 mA for protons, 0.2 mA for He and 0.1 mA for Ar . Further 38 MHz cw RF power generator was used (the spiral in cavity was replaced). The total dc current of 6 mA for protons was obtained with RF power of 80 W . The further increasing of RF power level have led to sharp reduction of current, which apparently is due to the fact, that the value of resonator voltage is not enough to compensate the transverse RF defocusing of ions. With a large pulsed high potentials at cavity the total current was increased by a factor of 5 - 10. The nearlest plans are to improve high voltage part of ion source in order to increase extraction potential up to 15 - 20 kV (now it doesn't exceed 5 kV).

The multichannel accelerating section contains cylindrical vacuum and RF cavity (length 550 mm, diameter 400 mm), inside of which the removable accelerating module is placed. The module includes special flange, fixed at the cavity input, on which 6 (3 + 3) longitudinal $\lambda/4$ rods are symmetrically mounted. Each drift tube has 7 beamlets (8 mm in diameter) and 3 support legs, by which the tubes are fixed, in turn, on corresponding set of three rods. The section is excited on π- mode and has special tuning elements, connected to the rods. These elements allow to compensate in a wide

(± 25 %) range capacitive load changing, which is due to the fact, that a number of drift tubes in module depends on ion mass, and so may be varied. To increase frequency inductive tuning guides of special form were used, to low it - capacitive plates [5] (similar capacitive elements were used later in the variable energy RFQ [6]). Shunt impedance of resonator is equal to 50 MΩ/m, Q-factor - 2000.

The beam dynamics calculations were made in terms of the polyharmonical theory of axisymmetric accelerating field focusing [7-10] some results are given below.

Sort of particles	H	He	Ar
Channel length, m	0.51	0.51	0.51
Input energy, MeV	0.03	0.095	0.095
Output energy, MeV	0.7	0.54	0.61
Longitudinal capture	210	110	60
Transverse acceptance, mrad cm	1.0	0.35	0.15
Energy spread at output, %	4.0	3.7	4.5
Number of drift tubes	10	12	32

The evaluation of a beams influence on each other have shown that it is negligible.

The accelerating section is driving by 200 kW multistage RF power generator, operating at 50 MHz with 150 μsec pulse. In the final stage of amplifier four triods with oxide coated cathodes parallel running in output resonant circuits were used. In order to minimize the size of amplifiers, an input and output resonant circuits were made in the form of helix and spiral lines. In addition, an alternative autogenerator RF power supply system, using only one generator tube was developed. In this scheme, to get stable excitation on the fundamental mode, two feedback coupling loops with contrary winding were introduced into the cavity.

Performing testing of accelerating section and RF power generator we have observed stable operation at 200 kW RF power level without breakdowns or faults during lasting time.

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