ITEP Heavy Ion Alternating Phase Focusing Linac

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Abstract

The experimental RF heavy ion linac with charge to mass ratio up to 1/46 has been built to demonstrate some possibilities of the compact alternating phase focusing(APF) accelerator structure with high energy gain speed. The first experience on molibdenium and tungsten ions acceleration to 0.31 MeV/amu is considered. The linac consists of 90 kV electrostatic injector with the MEVVA ion source and 6m Wideroe-type drift tube APF 18.4 MHz resonant structure.

1 INTRODUCTION

Ever increasing interest of different brunchs of science and technology in accelerated heavy ions urges intensive investigations at ITEP applied linacs department in direction of creating accelerators to adequate up-to-date industrial facilities which make use of compact to the utmost utility and not expensive accelerators .

In conventional self-phasing RF accelerator structures ions are affected strongly by defocusing accelerating field forces. In low charged heavy ion linacs these forces are strong throughout the whole accelerator because of low speeds of velosity gain. It makes a typical RF self-phasing heavy ion linac for the energy of 1-2 MeV/u a huge and complicated machine which would be comparable with proton one for energies of tens and ever hundred MeV. In APF linacs self-phasing is replaced by alternating-sign phasing to avoid RF defocusing almost entirely at the cost of some accelerated current decreasing. The transverse and longitudinal focusing forces are produced by RF accelerating field by means of appropriate arranging the drift tubes and accelerating gaps length in such systems. So there is no need in any external focusing arrangements, accelerating field amplitudes may be increased up to 5-10 MV/m and the linac channel length decreased by a factor of 10-20 therefore. For some scientific and industrial problems APF linac advantages may be overrading.

In the late 1980s APF short 148.5 MHz linac sections for ions with charge to mass ratios 1/2 and 1/4 have been built and investigated [1-3]. Those works proved APF structures possibilities to reach very high energy gain speed (up to 7.5 MeV/m and more), reliability and relative technological simplicity. Since 1990s APF linac opportunities for very heavy ions are considered at ITEP too.

2 ACCELERATOR DESIGN

The 18.4 MHz APF heavy ion linac for the energy of 310 keV/amu has been constructed and put into operation at ITEP. It consists of 90 kV electrostatic injector with MEVVA-type ion source and 6m Wideroe-type accelerating structure.

For heavy metal ion production the MEVVA-type ion source developed at ITEP [4]. The source is operated in pulse mode and able to deliver metal ion beams of moderately charged up to some tens mA and offers a large variety of elements.

The twin transmission line (Wideroe-type) accelerating structure with drift tubes is located inside the 6m stainless steel vacuum tank of 0.7m in diameter which offers the service of external resonator surface too (see fig.1). The vacuum tank consists of six 1 m length and 6 mm wall thickness identical tubings joined together. Every tank has four large ports for a vacuum pumping, view windows and RF power driving, tuning and monitoring. The 50 uniform diameter drift tubes are arranged along the 5.5 m resonator accelerating channel. All the drift tubes are supported by stems mounted by turns on the two longitudinal resonant electrodes (copper pipes). The longitudinal positions of the drift tubes was defined by calculations and ensured by precise alignment. The drift tubes stems are bolted to the longitudinal resonant electrodes. Every drift tube stem has special technological circle tooth and is supplied with copper foil to provide reliable RF contacts with the longitudinal electrodes. All drift tubes alignment is occured by picking out suitable foil thickness. The resonator forced cooling was absent at that experimental stage because of high values of pulse period-to-pulse duration ratio (10000 and more). The APF linac technical parameters are listed in table 1.

Table 1: APF Linac Experimental Parameters

Accelerated ions	Mo, W
Minimum charge to mass ratio(q/A)	1/46
Input energy	1.9 keV/amu
Output energy	310 keV/amu
Frequency	18.4 MHz
Max.electric field on the axis	10.2 MV/m
Current pulse length	20-150 mcs
Q-factor	2000
Shunt impedance	82 MOhm
Aperture radius	5-16 mm

The gap field gradients are tilted from 4.0 to 10.2 MV/m on the initial 1.5 m length and keeped approximately constant then up to the channel exit.

The measured voltage distribution differed strongly from calculated one in some places along the accelerator

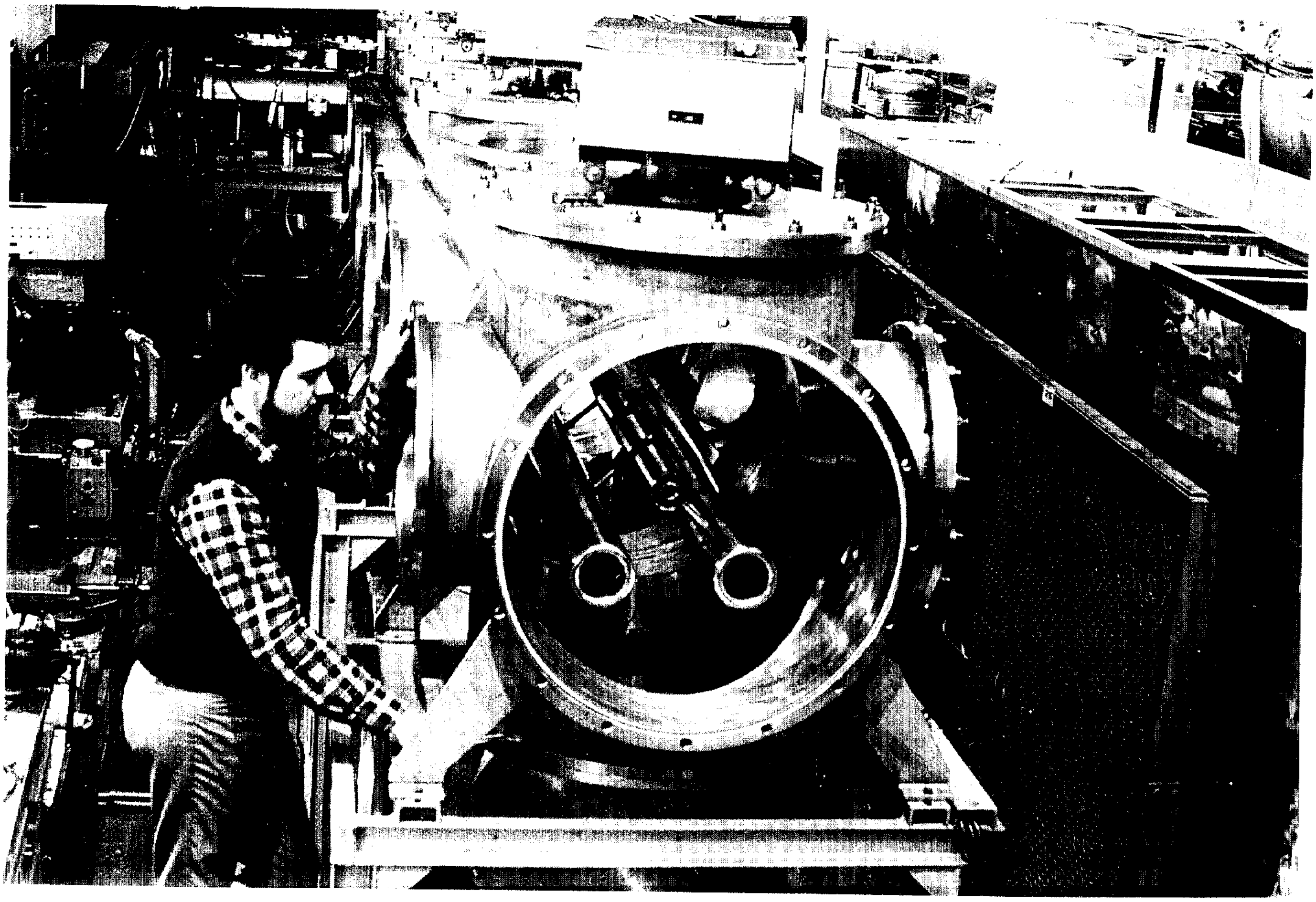

Figure 1: 18.4 MHz APF accelerating structure

axis. So the adjustments have been made by changing some gaps and drift tubes length at some input and intermediate accelerating periods.

3 FIRST EXPERIMENTS

Here, the aim was twofold. In the first place the main technical details with APF linac technological systems operating in independent modes and than their joint working with different ion species acceleration modes have been studied. The design charge to mass ratio(q/A) had been adopted as 1/46 which corresponded with tungsten(W^{+4}_{184}) ions acceleration. But the different species such as W^{+5} , Mo^{+3} and Mo^{+4} ions have also been accelerated by appropriate changing injection voltage and RF power consumption levels. So accelerated ion species were within the range from 1/24 (for Mo^{+4}_{96} ions) to 1/46. The total pulse RF power consumption level varied from 0.7 to 2.0 MW.

The 18.4 MHz RF system provides a 0.2 ms peak pulse power up to 2.5 MW and contains the driver and final amplifier with the positive feedback coupling loop to work at self-exited mode. The RF power is fed through a cable to the cavity.

The accelerator vacuum system comprised of two rotary pumps, eight 500 l/s turbomolecular and ten 400 l/s electrocharging pumps which promised to get the working vacuum 3.10^{-4} Pa.

The accelerated W^{+4} ions intensity reached 5.10^{8} ions/pulse at the first stage.

The other special purpose program was to investigate different modes of thin polymer films irradiation for particle-track membranes(PTM) producing technology development[5]. The accelerated heavy metal (Mo and W) ion beams have been used for PTF thin films irradiations. Heavy ion intensities varied over the wide range from 10^{6} to 5.10^{8} ions/pulse. The type PTF film photo after the tungsten ion irradiation and etching processes is shown at fig.2.

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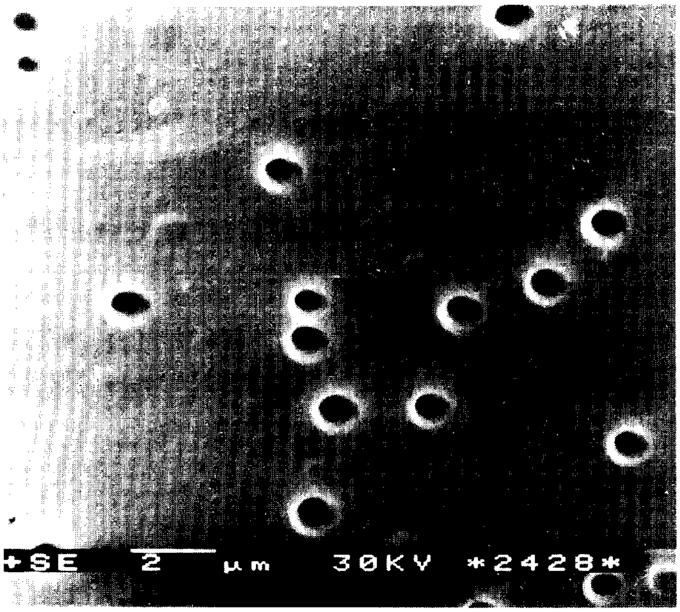

Figure 2: Polymer film after tungsten ion bombarding and etching

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