ELECTRON ACCELERATOR for TRANSMUTATION of FISSION PRODUCTS and NUCLEAR FUEL CYCLE ACTINIDES

G.I. Batskikh, B.V. Bekhtev, V.A. Boiko, V.V. Elian, A.V. Mishchenko
Moscow Radiotechnical Institute
USSR Academy of Sciences
Moscow, 113519

Abstract

The possibility of development of electron accelerators with the energy of 100 MeW and high (10 MW and 100 MW) mean power for fission products and nuclear fuel cycle actinides transmutation is discussed. It proved expedient (in terms of high efficiency) to design the first-stage accelerator(10 MW) as a racetrack microtron (RTM) and the second-stage on one (100 MW) - as a linac.

I. INTRODUCTION

Scientific studies on the long-term program of fission products and nuclear fuel cycle actinides transmutation impose certain specifications, especially on electron accelerators. E.g., an industrial plant demands electron beam with the mean current of 1 A and energy of 100 MeV. It rises a lot of rather complicated scientific, design and technological problems concerning both the acceleration technique and the technology of application of these beams. It was proposed to solve the above problems in two stages [1]: the first one should consist in the development of an electron accelerator with the energy of 100 MeV and beam mean current of 0.1 A in order to try off the main technical and technological approaches and also for experiments; the second stage would be aimed at developing an accelerator for industrial plant (mean current 1 A, mean power 100 MW).

Analysing possible solutions we found it worth while to refuse traditional approach (the pulse mode of operation in cm or dm accelerating frequencies wave band) and to pass over to the continuous mode of operation in the metre band.

The reason for selecting the RF system was an RF generator developed by MRTI for the accelerating-storage complex at IHEP (Serpukhov) with signal frequency 200 MHz and mean power in continuous mode 1 MW. A travelling wave linac with such power supply would comprise 15 accelerating sections, each section 14 m long. The electronic efficiency of such linac with the first stage parameters would be 0,6-0,7.

Instead of a linac for getting an electron beam with the first stage parameters we propose to apply an RTM, providing a high efficiency value and a considerable reduction of dimensions [2].

RTM AS THE FIRST STAGE ACCELERATOR

The analysis showed that to reach the given energy value, the RTM accelerating structure should comprise ten regular sections of disc loaded waveguide, each section 2 m long, and an injector section 8 m long. Fig. 1 shows the RTM scheme (the beam energy 100 MeV, extracted beam mean current 0.1 A).

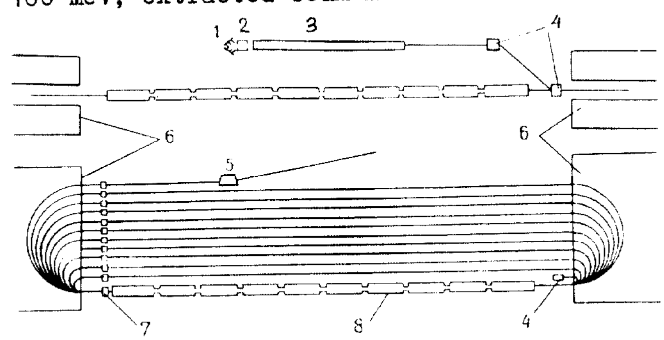

Fig. 1. RTM for nuclear fuel cycle products transmutation: 1 - electron gun, 2 - accelerating resonator, 3 - accelerating section of injector, 4 - beam parallel transmission magnets, 5 - output magnet, 6 - bending magnets, 7 - quadrupole lenses, 8 - accelerating sections

By means of the parallel transmission magnet system 4 the beam is injected into the bending magnet 6, which puts the beam to the axis of the linac 8.

The bunch focusing is provided by means of quadrupole lenses 7. The beam passes through ten orbits and gains the energy of

0-7803-0135-8/91$01.00 ©IEEE

100 MeV. The bending magnet 5 directs it to the target. To solve the first revolution problem one must provide high injection energy, at least the one close to the energy increase per revolution.

In the case under consideration (E = 9.8 MeV, λ = 1.5 m, the accelerator outer radius in the plane of orbits, r = 0.65 m), the injection energy value of 7 MeV would be enough to insert focusing and correlating devices.

There are several ways of beam injection into the RTM. We found preferable the scheme shown in Fig. 2.

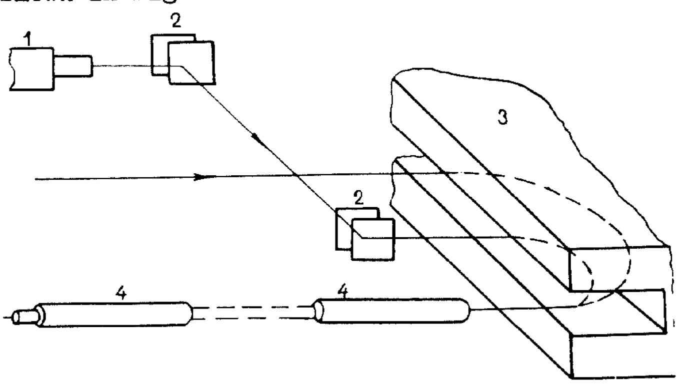

Fig. 2. Beam injection into the RTM: 1 - injector, 2 - beam parallel transmission magnets, 3 - bending magnet, 4 - linac sections

From the injector 1 placed above the microtron median plane the beam is injected into the bending magnet 3 by means of the parallel transmission system 2.

For the RTM with the output energy of 100 MeV and relatively small number of orbits it is quite easy to meet all the synchronism demands. But very important problem goes from the bending magnets fringe fields, which seems more solvable due to the large wavelength (λ = 1.5 m) and large enough separation between orbits.

RTM Accelerating System

In the RTM discussed the accelerating system comprises ten sections. Each section should be characterised by the following specifications:

Electron energy increase per section	0.98 MeV
Circulating current	1 A
RF power supply	1 MW
Signal frequency	200 MHz

For maximum efficiency the accelerating structure should be a disc loaded waveguide with travelling wave mode of operation. From calculations it follows, that high current load combined with low frequency of the RF power supply permit to get an untraditionally high efficiency value (0.98).

RTM Injector

Specifications of the injector accelerating section:

Output electron energy	7 MeV
Accelerated current	0.1 A
RF power supply	1 MW
Frequency	200 MHz
Input electron energy	400-500 KeV

In the injector accelerating section banching is practically absent because of the low field strength. So all the problems concerning the bunch parameters should be solved in the preliminary buncher comprising two resonators with a common wall. The negative bias is supplied to a cathode, mounted at the side wall of the first resonator. The desired current cut-off angle for the cathode should be found out by the bias adjustment. Small power is supplied to the first resonator (tens of kW). The second resonator is supplied with a relatively high power (hundreds of kW). Electron bunches pulsing with RF field frequency are accelerated to several hundreds of KeV to get necessary phase width.

An electron source with a laser driven photocathode makes it possible to get short current pulses (length from several tens of picoseconds up to several nanoseconds).

RTM Bending Magnets

The development of RTM bending magnets does not seem to meet many difficulties but the dimensions problem: the last orbit diameter 5.05 m, and the magnet field induction 0.14 T in the gap 4-5 cm wide.

RTM RF System

RF System design parameters:

Number of amplification channels	11
Output power per channel, kW	1000
Signal frequency, MHz	200
Bandwidth for 3dB level, MHz	$\geqslant$ 1

Voltage amplitude RF output error at 50, 100, 150 Hz, per cent	≤ 0.1
Phase deviation at frequency 50 Hz, deg.	< 0.025
Deviation of phase difference of input and output RF voltage at each RF channel (per 24 hours), deg.	±2

All the RF power amplification channels are identical in design (Fig. 3, 4).

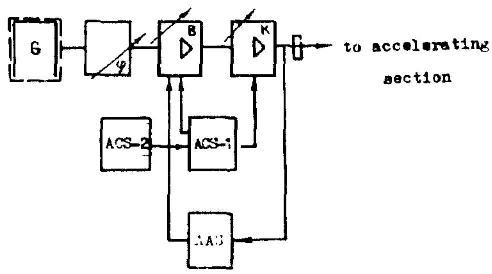

Fig. 3. RF channel: G - generator, B - transistor oscillator, φ - quick phase shifter, K - klystron amplifier, AAS - amplitude and phase automatic adjustment system, ACS-1, ACS-2 - lower and upper level automatic control system

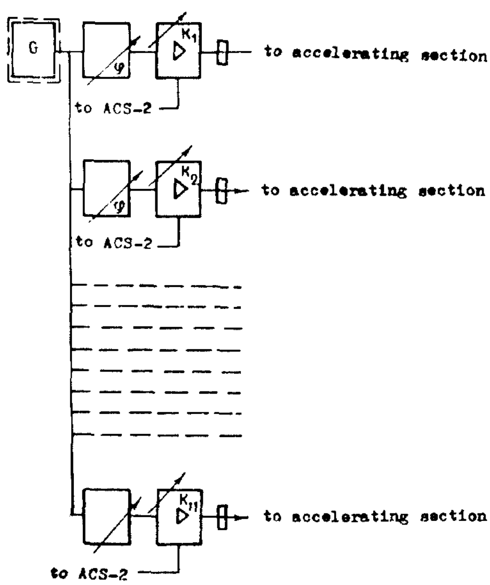

Fig. 4. RF power supply system: G - generator, ACS-2 - upper level automatic control system, K-1K11 - klystron amplifiers, φ - phase shifter

The klystron specifications are the following:

Signal frequency, MHz	200
Output power, kW	1000
Amplification, dB	35-40
Beam voltage, kB	45
Efficiency, per cent	50-60
3dB level bandwidth, MHz	1.5
Warranted service period, h	2.000
Estimated service period, h	10.000
Length, m	3.5

SECOND STAGE ACCELERATOR

An electron beam with the energy of 100 MeV and the mean current of 1 A is needed from the second stage accelerator.

Generally speaking, an accelerator with the described RF generators can be designed as a travelling wave linac. In the RTM discussed each accelerating section provides the energy of 1 MeV under the circulating current of 1 A. A linac comprising 100 such sections would make it possible to get a beam with the above parameters. This accelerator would be more than 200 m long.

CONCLUSION

The short preliminary discussion of various problems connected with the development of electron accelerators with unprecedently high mean electron beam power (10 and 100 MW) proves the task to be technically solvable. The main feature of the proposed accelerators is their high efficiency of RF-electron beam power transformation (0.94 and 0.98), which is of great importance for needed beam power level. But there remains a lot of research work to be done, concerning the theory and experiments on the beam dynamics, technical and economic aspects, to prove their practical feasibility.

REFERENCES

[1] "AEC formulates Long Range Programm for RED on Partitioning and Transmutation Technologies", Atoms in Japan, Vol. 32, No. 11, pp. 4-12, November 1988.

[2] Разрезной микротрон-инжектор для синхротрона "Пахра"/В.И.Алексеев, К.А.Беловинцев, В.А.Бойко и др.// ЖТФ.- Т. 46. - Вып. I2.- С. 2558-256I.