ACCELERATING STRUCTURE WITH SEPARATED MODULAR RESONATORS WORKING IN 300 MHZ FREQUENCY BAND, FOR HIGH POWER ELECTRON ACCELERATOR, ATENA

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Abstract

In the paper, a proposal of accelerating system based on a chain of separated resonators is presented, as a practical solution for high-power electron accelerator dedicated to radiation technology.

1 INTRODUCTION

Existing and continuously emerging new applications of electron beam processing technologies, evoke constant interest in design elaboration of various solutions of accelerators, appropriate for requirements of definite treatment technologies.

In the Soltan Institute since many years we are studying theoretically and experimentally accelerating structures for electrons and ions, and as effect of this activity numerous solutions of accelerating systems have been elaborated. Looking on the situation in development of accelerators for radiation technology, we came to conclusion that a modular system of separated resonators working in the frequency band around 300 MHz could be of practical interest.

Up to now, separated resonators structures were used in different accelerators for various reasons. As most interesting examples can be named PHERMEX and UNILAC accelerators.

In PHERMEX - electron accelerator generating intense X ray pulses – accelerating structure was composed of three separated resonators operating in 50 MHz frequency band. The main feature of this solution was to have very high energy gain on single resonator – 7 MeV, and to store in the structure, operating with long r.f. pulses, high energy in the field, and using it to accelerate short intense electron beam pulses. The use of separated resonators permitted to optimise beam dynamics with the help of external phase control.

In UNILAC – the heavy ion accelerator – after Alvarez sections, a chain of twenty single separated resonators was included. The r.f. system is working on 108 MHz frequency band, with high duty factor – 0.25. Usefulness of such system is oriented on achieving a convenient and continuous energy control of accelerated ions. Phase reference line and electronic executive system enable precise selection of parameters of r.f. signal supplying particular resonators.

These and other examples show that the experience with separated resonators systems can be also useful in some other applications, e.g. in high-power accelerators for E.B. treatment.

In this latter case, the main advantages of separated resonators structure, can be named in short:

- convenient r.f. supply coupling, with easy impedance matching for various beam loading
- distribution of r.f. power transmission on several vacuum windows, what increases reliability of operation at high average power
- high flexibility in energy and beam intensity control
- high thermal load capacity and facile efficient cooling
- modular construction facilitates installation and adaptation to particular treatment requirements

A crucial problem for practical usefulness of modular type accelerator is selection of optimal frequency band.
The choice is based on a compromise between different factors influencing operational parameters.
Using 300 MHz frequency band we gain moderated transversal dimensions of resonators, sufficiently big aperture for beam transmission, high accelerating field on the single gap at good transit time factor, easy adaptation of periodic focusing system etc. At present, there exist modern industry made generator tubes for this band, with sufficient peak and average output power.

2 SINGLE RESONATOR AS ACCELERATING UNIT

Taking as reference a classical cylindrical cavity, operating in TM_{010} field mode, we tried to find a compromise between resonator's most optimal parameters and its technical feasibility.
The analysis was done, using SUPERFISH code, and the selected solution was verified by model measurements.
The applied model approaches a technological solution, permitting to compose the structure's configuration using relatively simple modular subunits.
The basic data for two of possible geometries are presented on Tables 2.1, 2.2. and Fig. 2.1, 2.2.

Fig.2.1.

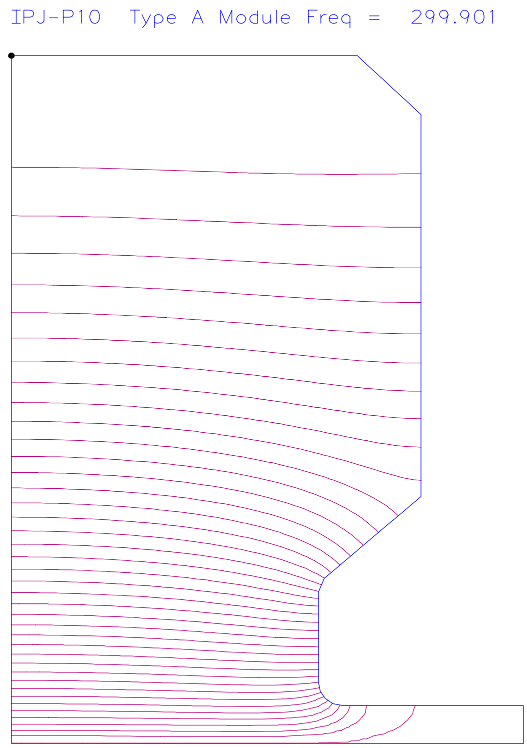

Table 2.1.

Frequency(starting value=(300.000) = 299.90090MHz
Beta = 0.9800000 Kinetic energy = 2.057 MeV
Normalization factor for E0=5.986MV/m = 39064.129
Transit-time factor = 0.8352296
Stored energy = 6.0786488 Joules
Normal-conductor resistivity = 1.79186 microOhm cm
Operating temperature = 30.0000C
Power dissipation = 233.7718 kW

Fig. 2.2.

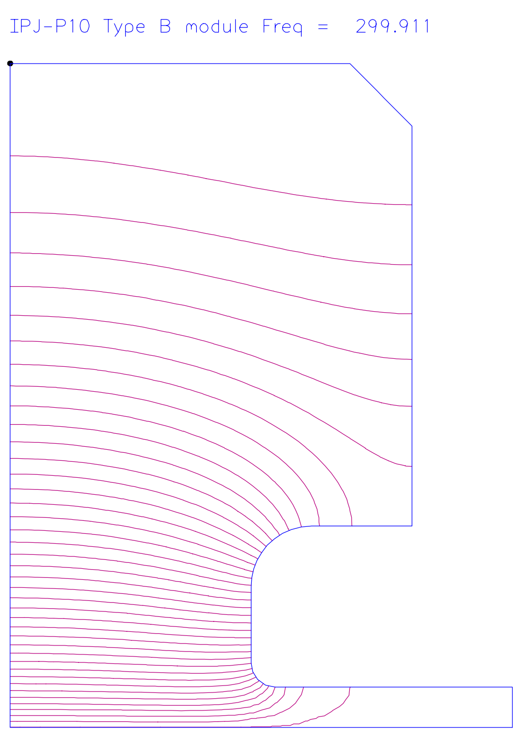

Table 2.2.

Field normalization(NORM=1):EZEROT=5.00000MV/m
Frequency = 299.91092 MHz
Beta = 0.9800000 Kinetic energy = 2.057 MeV
Normalization factor for E0 = 5.620 MV/m= 37107.707
Transit-time factor = 0.8896054
Stored energy = 5.3450819 Joules
Normal-conductor resistivity = 1.79186 icroOhmcm
Operating temperature = 30.0000 C
Power dissipation = 245.9194 kW
Q=40957.5 Shunt impedance = 32.114 MOhm/m
Rs*Q = 188.652 Ohm Z*T*T = 25.415 MOhm/m
r/Q=155.129 Ohm Wake loss parameter = 0.07308 V/pC
Average magnetic field on the outer wall =9975.23 A/m,
Maximum magnetic field on boundary =20740.45A/m,
Maximum electric field on boundary =19.471MV/m,
1.1269 Kilp.

3 BEAM DYNAMICS AND TRANSPORT IN THE STRUCTURE

Electron beam acceleration, focusing and transmission from the gun throughout a chain of five modular resonators were investigated, using modified versions of codes E-GUN/SLAC, TRANSPORT/CERN and home elaborated programmes considering space charge effects. Periodic focusing system was adopted.[1]

Accelerating field as function of input phase, beam envelopes for currents in the range 0.1 to 5 A and behaviour of emittance in course of acceleration were studied and optimized. Examples of results are presented on Fig. 3.1, 3.2, 3.3.

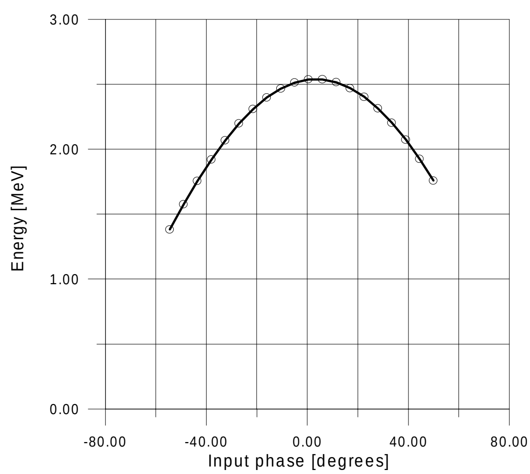

Fig.3.1.

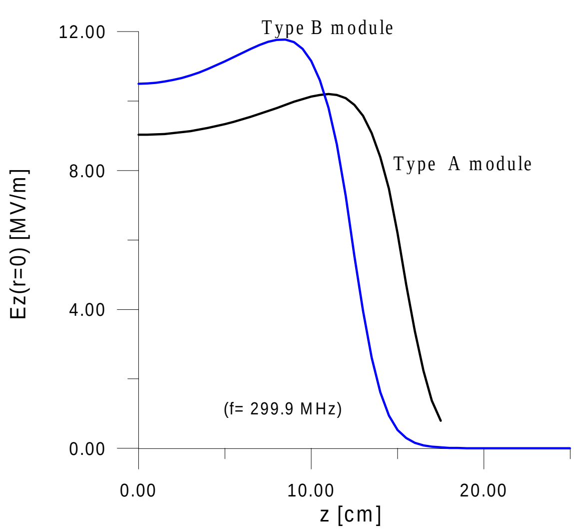

Fig.3.2.

4 R.F. SYSTEM

Several governing factors was taken into consideration in designing the r.f. power supply system.

- estimated power level for field excitation and beam loading
- c.w. or pulse mode of operation
- selection of adequate power sources
- frequency and phase control system

From computer simulation and model measurements it was estimated, that a peak power supplying unit resonator should be at the level of 1 MW for energy gain over 2 MeV. Assuming the average power of modular end-stage amplifier as 20 kW, we get duty cycle $2\cdot 10^{-2}$. In this way the pulse operation is adopted for a prototype.

According to it, proper tubes for the power amplifiers were selected. There are high-gain tetrodes of Thomson (TH 571A) or Lamina (Q-30) production. For prematural testing, a lower power model was built using the tetrode Q-12. It was operated in grounded screen-grid mode, with folded • /2 circuit.

One of important features of separated resonators structure is the phase control system. In principle it gives a broad possibility for optimal phase control, but there are numerous additional factors which should be also taken into account, as a variable beam intensity, output energy stabilization, and preservation of good energy spectrum etc. A prototype system of data acquisition, processing and phase shifters' remote control, is under elaboration.

5 OUTPUT BEAM TRANSPORT AND MONITORING

At the accelerator output there are installed: quadrupole magnet, straight beam monitor, 90^0 beam bending magnet with energy selecting slit system, deflected beam monitor and scanning horn. Such a beam outlet system enables stabilization of energy and low energy dispersion.

Discontinuity of the scanned beam trace depends on spot density in the scan. To assure overlapping of the spots from pulse to pulse, the spots of the diameter where intensity is reduced to 50% FWHM should create a train of tangential circles.

Beam scanning may also be accomplished in another way, when the beam is swept through the window during each pulse. In such a case the beam within the scan is continuous.

The machine is also foreseen to operate with conversion of scanned electron beam into bremsstrahlung. Preliminary study of such a beam converter has been described elsewhere.[2]

REFERENCES

[1] U. Rohrer (PSI) – Graphic Transport, Version 2.02 for Microsoft Windows 3.1.

[2] S.Kuli• ski et al. – ECAART97, Computer simulation of e^-/X converter.