LINEAR ACCELERATOR BASED ON PARALLEL COUPLED ACCELERATING STRUCTURE*

Yu. Chernousov, V. Ivannicov, I. Shebolaev, ICKC, Novosibirsk, RUSSIA
A. Levichev, V. Pavlov, A. Barnyakov, BINP, Novosibirsk, RUSSIA.

Abstract

Linear accelerator based on parallel coupled accelerating structure and RF-controlled electron gun is developed and produced. The structure consists of five accelerating cavities. The RF power feeding of accelerating cavities is provided by common exciting cavity which is performed from rectangular waveguide loaded by reactive pins. Operating frequency is 2450 MHz. RF-controlled Electron gun is made on the basis of RF triode. Linear accelerator was tested with different working regimes. The obtained results are following:

- energy is up to 4 MeV, accelerating current is up to 300 mA with pulse duration of 2.5 ns on the half of the width,
- energy is up to 2.5 MeV, accelerating current is up to 100 mA with pulse duration of 5 μs,
- energy is up to 2.5 MeV, accelerating current is up to 120 mA with pulse duration of 5 μs and beam capture of 100%.

The descriptions of the accelerator elements are given in the report. The features of the parallel coupled accelerating structure are discussed. The results of the measuring accelerator's parameters are presented.

INTRODUCTION

Compact linear electron accelerators have wide scientific and industrial applications. The more often linacs are used with energy up to 10 MeV, average beam power up to several kilowatts. In present there are two type of accelerating structures with travelling wave and standing wave. But all of these structures have sequential RF power feeding of the accelerating cells. This is cause of some problems. To supply the accelerating structure total RF power has to go from the first accelerating cell. As the power is attenuated along these structures the initial value of the power must be very high, therefore, there are breakdowns and thermal surface damage in the first accelerating cell. When the breakdown is happened in one of the accelerating cell the operating RF pulse is terminated because of all storage energy of the structure is dissipated in it. Developing of *accelerating structure with given distribution of the power along the cavities is very difficult task. Also there is problem of high order modes, vacuum pumping and etc.

The linear electron accelerator based on new type accelerating structure is developed and produced by Budker Institute of Nuclear Physics of SB RAS, Institute of Chemical Kinetics and Combustion of SB RAS and Institute of Catalysis of SB RAS [1]. The main elements of accelerator are parallel coupled accelerating structure, injector, waveguide track with vacuum RF window, focusing system and klystron KIU-111. The klystron's frequency is 2450 MHz, average power is 5 kW with pulse power of 5 MW [2]. The main goal of our efforts is to test new ideas and devices which are used in the accelerator. The mass of these elements are used in such accelerator for the first time and have some advantages.

PARALLEL COUPLED ACCELERTING STRUCTURE

The scheme of parallel coupled accelerating structure is shown in the Fig. 1 and Fig. 2. RF power from a klystron feeds the exciting cavity (1) through inductive coupling window (7). The exciting cavity supplies the accelerating cavities (2). The RF connection of the exciting cavity with the accelerating cavities is provided by magnetic field through coupling slots (5). The focusing alternative magnetic field is created along the beam axis by periodic permanent magnets (3) with radial magnetization inserted in the iron yoke (4). This kind of focusing provides large enough magnetic field while keeping the weight of the focusing system considerably small. The cupper pins (6) are used to tune the exciting cavity (1) at the resonance frequency.

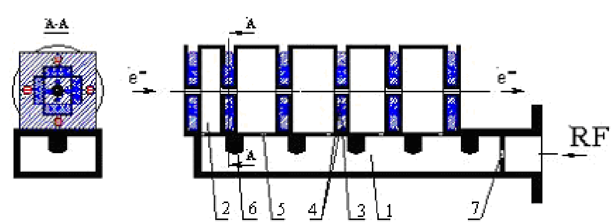

Figure 1: Scheme of the parallel coupled accelerating structure.

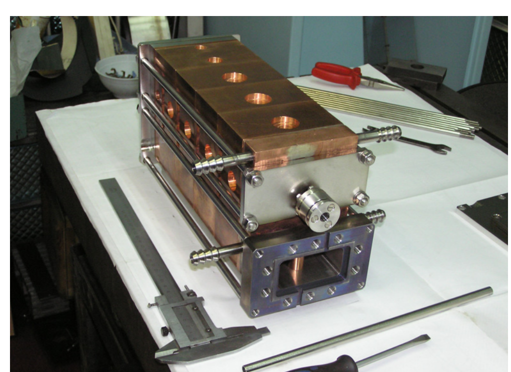

Figure 2: Parallel coupled accelerating structure.

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Due to the scheme of RF power supplying this accelerating structure has some advantages versus structures with sequential power feeding. There is no need to have a high power in the first accelerating cavity. So the overvoltage and breakdown problems, thermal surface damage near the coupling slots are absent. The design of parallel coupled accelerating structure allows us to create compact periodic permanent magnet focusing system based on the permanent magnets with radial magnetization (see Fig. 1). The accelerating cavities are not connected with each other by electric field therefore aperture of the drift tubes between cavities is limited only by the beam focusing. By changing the coupling factor between exciting and accelerating cavities it is possible to make the free power distribution along the structure. If breakdown is happened in one of the accelerating cavities the storage energy only this cavity is dissipated, and only in this cavity. So the working RF pulse is not terminated but only amplitude of reflected signal is slightly changed, as it is presented on the Fig. 3.

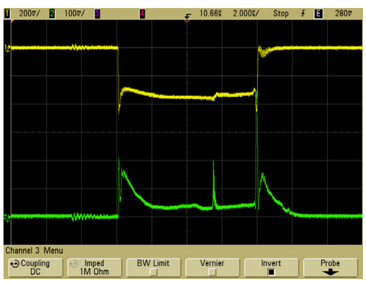

Figure 3: Breakdown in one of the accelerating cavities: 1 - signal from klystron; 2 - reflected signal from accelerating structure.

The accelerating structure can be used as for high average current with high average power as for short nano- and picoseconds duration current pulses with high amplitudes.

INJECTOR

Injector is the electron gun with DC voltage of 50 kV and pulse current up to 1 A. It is based on RF triode GS-34 and shown on the Fig. 4.

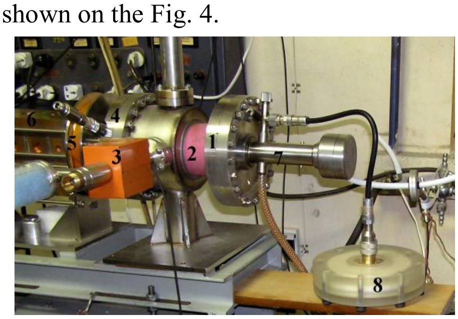

Figure 4: Injector: 1- cathode-grid unit, 2 – ceramics, 3 – vacuum pump, 4 – bunching cavity, 5 – matching solenoid, 6 - accelerating structure, 7 – coaxial cavity for RF beam control, 8 – antenna type RF lead.

Injector can work with following regimes: short pulses with duration of about nanoseconds, long pulses with duration of microseconds and long pulses with RF control for a beam π-chopper. Under using RF control the beam is modulated by coaxial cavity on bunches with length equaled to half wavelength of RF field. Due to this feature, the beam capture can be achieved up to 100%.

The cathode-grid unit 1 (see Fig. 4) is under potential of -50 kV. So, to feed the coaxial cavity 7 the antenna-type coaxial lead (8) was developed and produced. It is shown on the Fig. 5. The antenna-type lead consists of two symmetrical parts of coaxial half-wave resonator. The resonator is cut along perpendicular to the longitudinal axis plane of symmetry. The solid dielectric disk is located between the halves.

The Fig. 6 shows the measured bandpass characteristics. The reflection coefficient S_{11} at the operating frequency is 0.098 and the transmission coefficient S_{21} is 0.976. Bandwidth at the attenuation level of -3 dB is more than 1800 MHz (73%).


Figure 5: Antenna type RF lead.

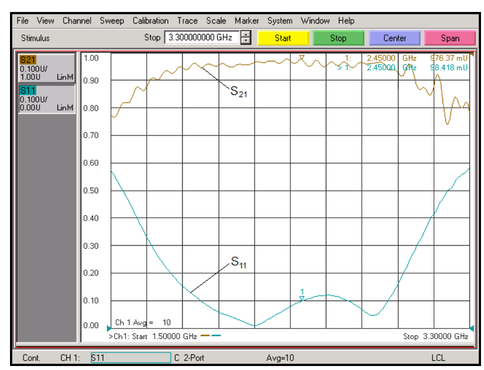

Figure 6: The transmission S_{21} and reflection S_{11} coefficients of the lead.

ACCELERATOR MEASUREMENTS

Accelerator was tested under three regimes.

The first regime is characterized by short beam pulse with duration of 2.5 ns on the half of width (see Fig. 7). The beam energy is about 4 MeV, beam current amplitude is about 300 mA. The Fig. 8 shows the cross section of the beam profile.

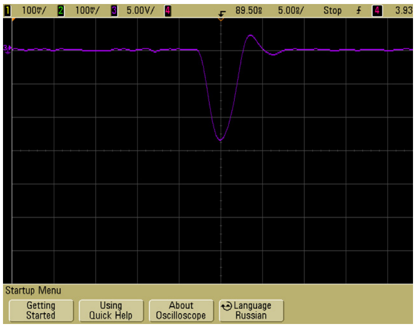

Figure 7: Oscilloscope of the accelerated beam current with duration of 2.5 ns (100 mA per cell).

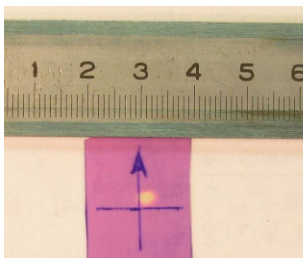

Figure 8: Cross section of the beam profile with pulse duration of 2.5 ns.

In the second regime the beam duration is 4 µs, energy is 2.5 MeV, beam capture is about 50%. Oscilloscope of the beam current and cross section of the beam profile are shown on the Fig. 10 and Fig. 11 correspondingly.

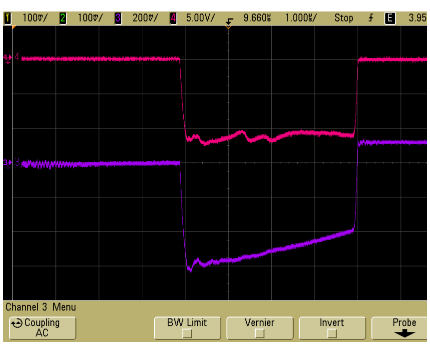

Figure 9: Oscilloscope of the accelerated beam current with duration of 4 µs: 3 – emission beam current (180 mA per cell), 4 – beam current in the end of accelerating structure (100 mA per cell).

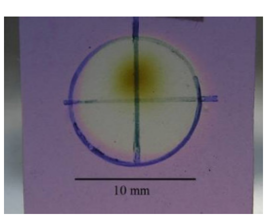

Figure 10: Cross section of the beam profile with pulse duration of 4 µs.

In the third regime the injector operated with RF control. The energy is equaled to 2.5 MeV. The feature of this regime is beam capture of 100%. Oscilloscope of the beam current and cross section of the beam profile are shown on the Fig. 12 and Fig. 13 correspondingly

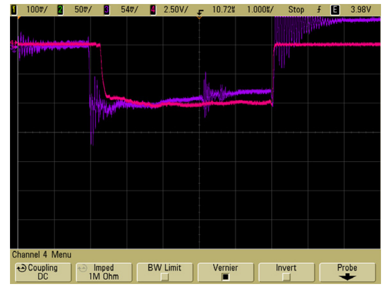

Figure 12: Oscilloscope of the accelerated beam current with RF control: 3 – emission beam current (50 mA per cell), 4 – beam current in the end of accelerating structure (50 mA per cell).

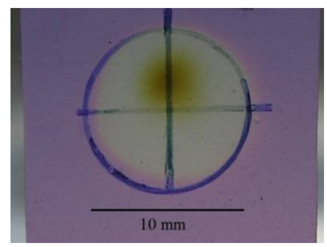

Figure 13: Cross section of the beam profile with RF control.

CONCLUSION

Linear electron accelerator based on parallel coupled accelerating structure and injector with RF control for a beam π-chopper is made, tested and measured. The beam energy is 2.5-4 MeV with total power of 2.4 MW, accelerated beam current is 100-300 mA. These values depend on the beam loading effect. The durations of the beam pulse were changed from 2.5 ns to 5 µs. With RF control the beam capture was achieved 100%. The diameter of cross section of the beam profile was about 3 mm. The beam loading effect is studying.

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