STATUS OF 1 MEV 25 KW CW ELECTRON ACCELERATOR

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Abstract

Status of 1 MeV 25 kW continuous wave (CW) linear electron accelerator for radiation technologies which is under construction at SINP MSU is described. Driven by 50 kW CW klystron on-axis coupled standing wave accelerating structure was optimized, manufactured and tuned. The results of accelerating structure measurements and tuning are presented. RF system, high voltage, vacuum and control systems of the accelerator are described.

INTRODUCTION

Industrial CW linear electron accelerator with beam energy 1.0 MeV and maximum beam power 25 kW is under construction at SINP MSU using as a prototype the two-section accelerator with 1.2 MeV energy and 50 kW maximum beam power [1]. Accelerator general view is shown in Fig. 1, main parameters are listed in Table 1.

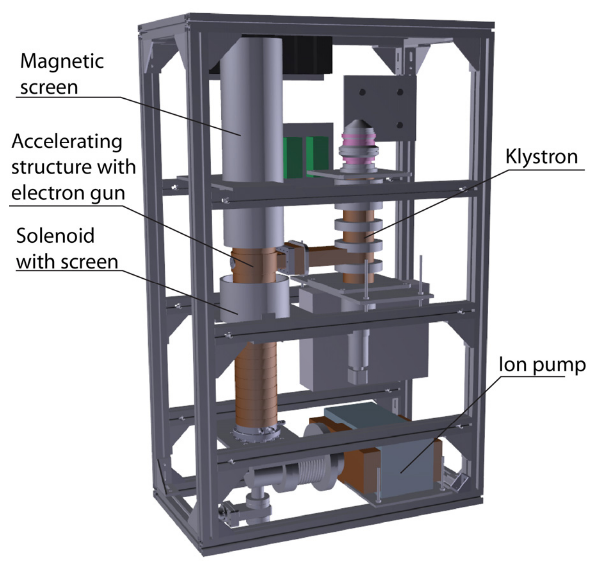

Figure 1: Accelerator general view.

Advantages of the proposed accelerator are its compactness and low weight which allows to use local radiation shielding and to incorporate the accelerator into operating material production lines which need radiation processing. The accelerator power supply system has no voltages exceeding 15 kV therefore operates without high voltage discharges.

The accelerator will be used at SINP MSU for the following purposes [2]:

- Electronics radiation stability testing.
- Solar batteries radiation degradation testing.
- Obtaining new data on variations of mechanical properties, surface structure, phase composition and microstructure of model and construction materials for nuclear reactors and nanostructure objects.
- Investigations of radiation resistance of optical materials with bremsstrahlung beam.
- Investigations of radiochemical processes.

Table 1: Project parameters of the accelerator

Beam energy	1,0 MeV
Beam current	0 - 25 mA
Maximum beam power	25 kW
Gun /Klystron high voltage	15 kV
Operating frequency	2450 MHz
Klystron power	50 kW
Electric power consumption	~75 kW
Efficiency	~33%
Dimensions	500x900x1400 mm3

ELECTRON GUN

15-keV electron gun with two intermediate anodes providing current regulation from 0 to 250 mA has been designed and manufactured (Fig. 2). The electron gun is joined directly to the input accelerating section flange without any drift space, standing alone pre-bunching cavity, and focusing elements between the gun and the accelerating section.

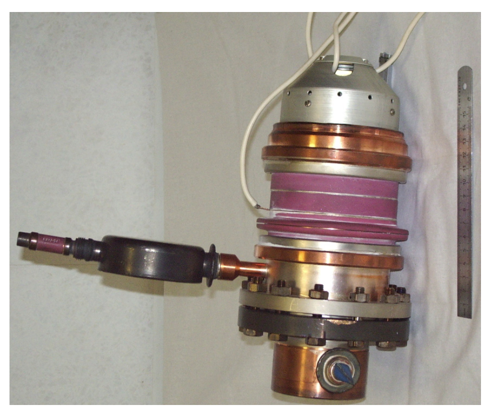

Figure 2: Electron gun after manufacturing.

ACCELERATING STRUCTURE

The accelerating structure is a standing wave bi-periodic on-axis coupled structure. As it is described in [3,4] the first accelerating cell acts as a buncher cavity while the second cell increases the beam energy to level sufficient for further acceleration in low strength field inherent to CW operation. This approach permits to get

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more than 50% capture efficiency at only 15 keV injection energy.

The optimization of the accelerating structure was performed simultaneously with the computations of the beam dynamics following the iteration procedure.

Sectional view of accelerating structure is shown at Fig. 3. It includes 18 accelerating cells and 17 coupling cells. The 10th accelerating cell is used as an RF power coupler, it also carries an antenna, which provides RF signal proportional to the level of accelerating field.

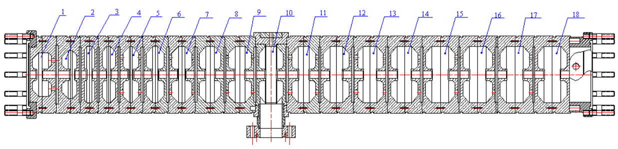

Figure 3: Sectional view of accelerating structure.

The accelerating gradient of 1 MeV/m corresponds to an RF power dissipated in the walls of the structure of ~1.07 kW per cell. The calculated distribution of accelerating field on the axis of the structure is shown at Fig 4. Fig. 5 shows calculated spectrum of accelerated beam for the RF wall losses level ~17 kW.

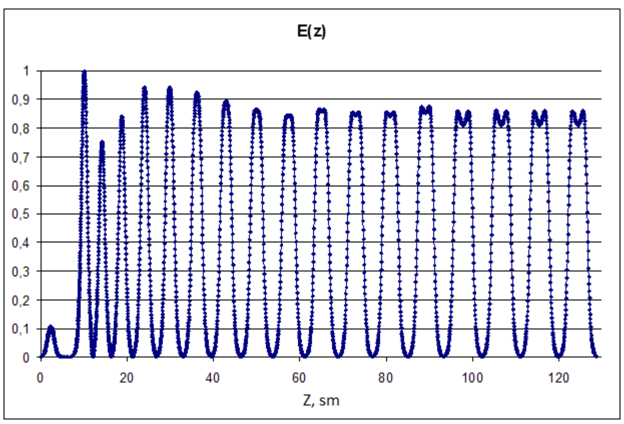

Figure 4: Calculated distribution of accelerating field on the axis of the structure.

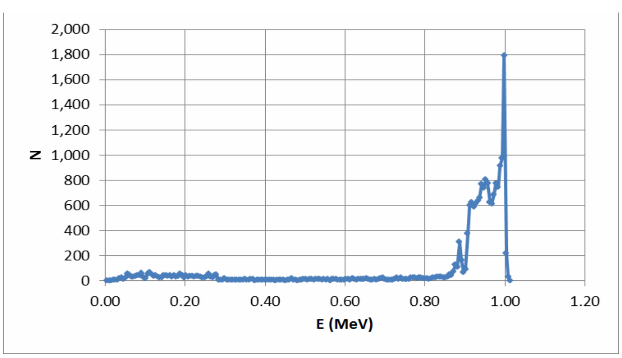

Figure 5: Calculated spectrum of accelerated beam.

On the basis of the calculations half-cells of the accelerating structure have been manufactured. The electrodynamics characteristics of the accelerating cells were measured after manufacturing, after that it was tuned [5] and brazed. The distribution of the accelerating field on the axis of the brazed structure and the photo of the structure equipped with focusing solenoid and steering coils are shown at Figs. 6 and 7, respectively.

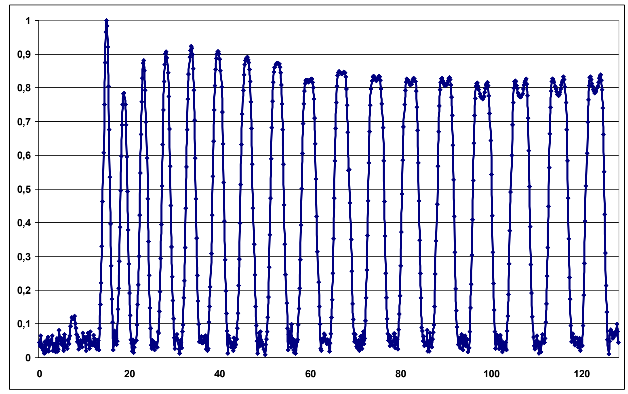

Figure 6: Distribution of the accelerating field on the axis of the structure after tuning and brazing.

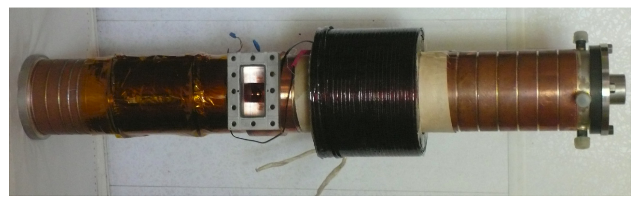

Figure 7: The photo of the accelerating structure.

RF SYSTEM

Our RF system shown in Fig. 8 uses self-excitation in a positive klystron–accelerating structure feedback loop, which makes it possible to operate accelerator without master oscillator, isolating circulator between the klystron and the accelerating structure, and without control of structure resonance frequency.

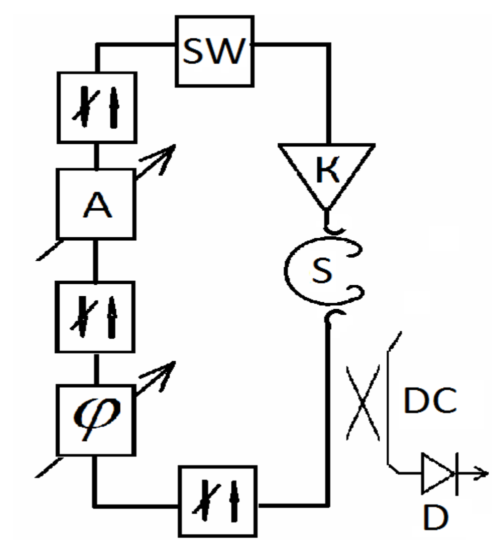

Figure 8: Block diagram of the RF system.

The phase shift and attenuation in the feedback loop, as well as monitoring of the accelerating field level, are controlled by low power RF unit. The signal from an RF

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probe of the section S goes through a controlled attenuator A and a phase shifter φ to the klystron coaxial input. Due to a high loaded Q of the section, which is 6000–7000, self-excited oscillations are produced near the section's resonance frequency. The phase shifter and attenuator are used to select the conditions for self-excited oscillations and regulate their amplitude and frequency within given margins. The signal from the diode D via the directional coupler DC is used by control system to stabilize the accelerating field amplitude. The accelerator operation safety is provided by RF switch SW, which allows to cut the positive feedback loop in case of low coolant consumption, vacuum degradation, opening of the doors of acceleration chamber or switching key in the safety lock.

The operation of the RF unit is managed by the RF unit controller and interlocking controller.

To feed accelerating structure a low voltage multi-beam klystron with periodic permanent magnet focusing system KU-399A with field reverses developed at FSUE "Toriy", Moscow, Russia [6], is used. Klystron photo is shown in Fig. 9.

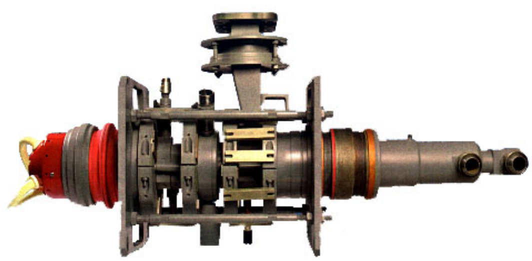

Figure 9: CW multi-beam klystron KU-399A.

VACUUM SYSTEM

Operating vacuum of the electron gun is 10^{-5} Pa, while in the accelerating structure it could be 5×10^{-4} Pa. Pumping of the acceleration structure and electron gun from atmosphere is produced by rotary vacuum pump.. High vacuum pumping is provided by 100 l/s ion pump which is installed at the exit of the accelerating structure and by separate 5 L/s ion pump, mounted at the electron gun. The accelerating structure and the klystron are separated by the klystron's vacuum window. The irradiation chamber is separated from the accelerator by the vacuum valve. Vacuum is measured by universal digital vacuum meter and the resulted value is transmitted to the control system.

HIGH VOLTAGE SYSTEM

Injection energy is chosen to be 15 keV, coinciding with the klystron high voltage, 15 kV, which allows to use common power supply for the electron gun and the klystron. To power the klystron and the electron gun, high-voltage power supply was designed. It provides high voltage to the cathode, filament voltage of the cathode heater, voltage of the control electrode, high voltage of the klystron's ion pump. It also provides 15 kV high voltage to the electron gun and allows to supply and regulate the voltages of electron gun control electrodes, as well as filament current of the gun cathode heater. The photo of the power supply is shown at Fig. 10.

Figure 10: High-voltage power supply.

CURRENT ACTIVITY PROGRESS

At the moment the accelerator is being assembled, the accelerator control system development is at the final stage

REFERENCES

[1] A. S. Alimov et al., "A Continuous-Wave Linear Accelerator with an Output Electron Energy of 600 keV, Average Beam Current of 50 mA", PTE #5 (2002) 114.

[2] A. S. Alimov, B.S. Ishkanov, V.I. Shvedunov, "Compact Linear Electron Accelerator for Radiation Technologies", MSU Herald, Series 3: Physics, Astronomy #4 (2008), p. 28-31.

[3] A.S. Alimov et al., "Method for accelerating electrons in a linear accelerator and an accelerating structure for carrying out said method". US Patent 8,148,923 B2. Apr. 3, 2012.

[4] A.S. Alimov et al., "Low-injection energy continuous linear electron accelerator". US Patent 8,169,166. May 1, 2012.

[5] A.S. Alimov, B.S. Ishkanov, V.I. Shvedunov, "Method of Measurements and Tuning of Accelerating Structures", PTE #4 (2008), p. 1-9.

[6] I.A. Frejdovich, P.V. Nevsky, V.P. Sakharov et al., "Proceedings of IVEC-IVESC 2006", Report N13.5.

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