ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO061

BEAM PARAMETERS MEASUREMENT OF C-BAND 6 MeV LINEAR ELECTRON ACCELERATOR*

D. S. Yurov[1], A. S. Alimov[1], A. N. Ermakov[1], V. V. Khankin[1], L. Yu. Ovchinnikova[1], N. V. Shvedunov[1], V. I. Shvedunov[1], A. S. Simonov, Laboratory of Electron Accelerators MSU Ltd., Moscow, Russia
[1]also at Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

Abstract

The new linear electron accelerator with beam energy varied in the range of 2-6 MeV with dual-energy option has been designed by Laboratory of Electron Accelerators MSU Ltd. Linac is based on compact high gradient standing wave C-band accelerating structure fed by multi-beam klystron and is used in the cargo inspection and cancer therapy complexes. In the report, we present the results of electron beam parameters measurements at special stand.

INTRODUCTION

We have developed an accelerating system based on C-band on-axis coupled bi-periodic standing wave accelerating structure (AS) connected to a three-electrodes electron gun [1] for electron accelerators designed for cargo inspection and radiation therapy systems. The above application areas require narrow energy spectrum of the beam and ability to control its energy in the range of 2-6 MeV. In order to measure beam parameters and select an optimal operating mode, a prototype of the accelerating system without the bremsstrahlung target has been built and installed on a special stand. The paper provides a description of the stand and gives the measurement results.

EXPERIMENTAL SETUP

Photo and layout of the stand are given in Fig. 1.

The accelerating system that includes an AS, electron gun, feeding waveguide with vacuum RF window and antenna installed in the coupler cell is connected to a vacuum chamber with a viewing window and a movable screen made of titanium foil mounted at 45^0-angle to the beam axis. The screen is intended to measure transverse charge distribution of accelerated beam by registering generated at foil transition radiation by the CCD camera. A spectrometer based on 45^0 magnet with Faraday cups (FC) located at 0^0 and 45^0 is installed at the output of the vacuum chamber. A slit collimator with the slit width of 3 mm is placed at the 45^0 FC input. 0^0 FC signal comes to an oscilloscope for measuring amplitude of pulsed current of accelerated beam, and 45^0 FC signal is measured with ADC through an integrating chain or sent to an oscilloscope as well. Power supply of the AS is provided by multi-beam klystron KIU-273 with operating frequency of 5712 MHz and maximum pulsed RF power of 3.5 MW [2].

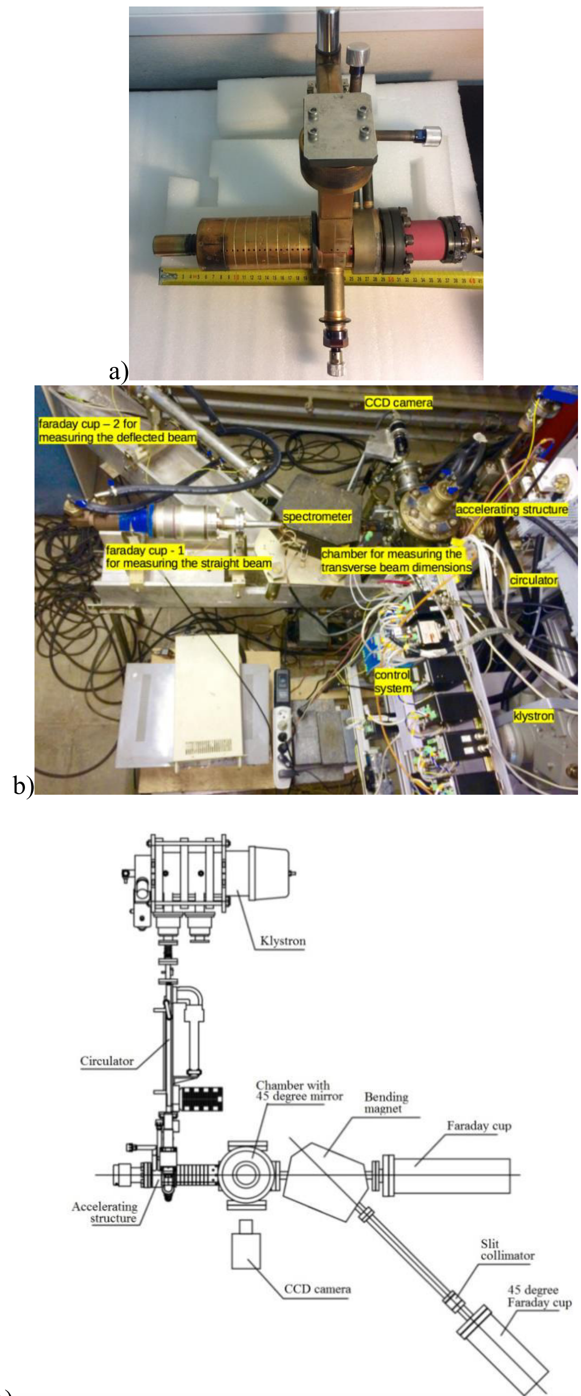


Figure 1: Photo of a) the accelerating system and b) the stand. c) Stand layout.

* Work supported in part by Grant of the Ministry of Education and Science of the Russian Federation #RFMEFI58217X0011

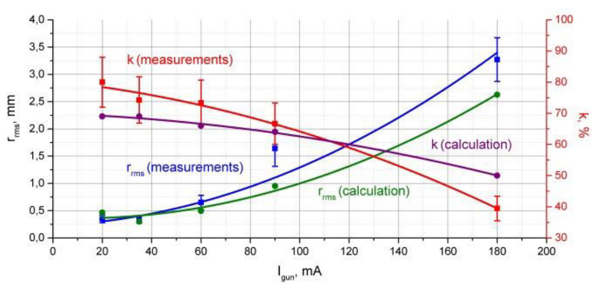
ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO061

DC high voltage controlled in the range of -10 ÷ -27 kV is applied to the cathode of the gun, the control electrode is fed by pulses with the amplitude set in the range of 0 ÷ +3 kV with respect to the cathode with controlled duration and delay relative to the RF field envelope pulse. Maximum pulsed gun current is 180 mA.

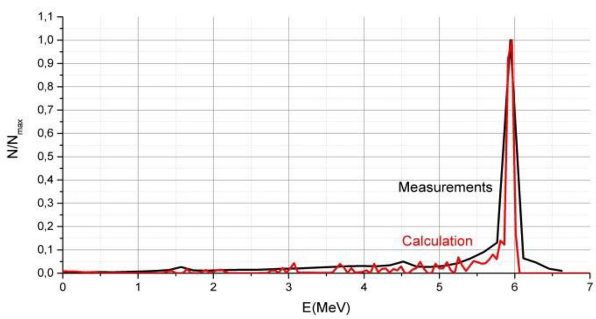
Average RF power loss in the AS walls is measured by the difference between input and output temperatures of the coolant and its flow rate with calorimeter Calec ST II. Pulsed RF power loss is calculated through duty cycle. Accelerating field level is additionally controlled with a RF detector, which receives signal from the antenna.

MEASUREMENT RESULTS

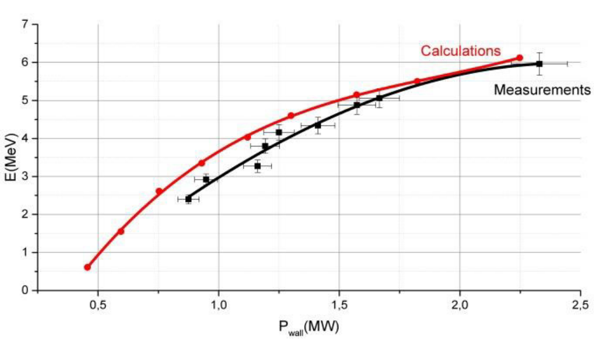
There were several series of beam parameter measurements conducted at the stand. Electron beam spectra, capture coefficient, RF power dissipated in the walls of the AS, as well as transverse charge distribution in the beam were measured as part of the first series.



a)



b)



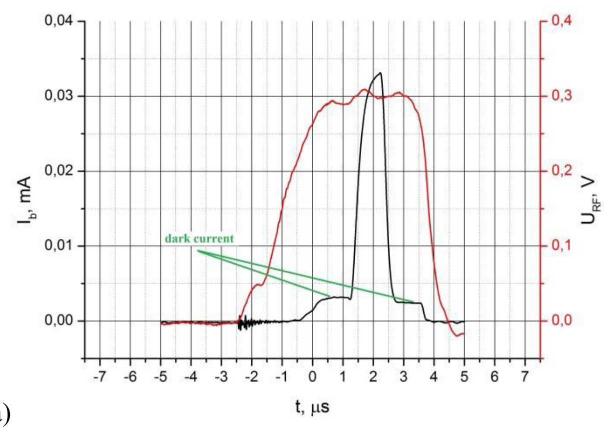
c)

Figure 2: a) Measured and calculated dependencies of rms beam radius (blue and green) and capture coefficient (red and purple) on gun current at the accelerated beam energy of 6 MeV. Measured (black) and calculated (red) b) beam spectra at gun current of 20 mA and accelerated beam energy of 6 MeV, c) dependencies of beam energy on pulsed RF power loss in the AS walls.

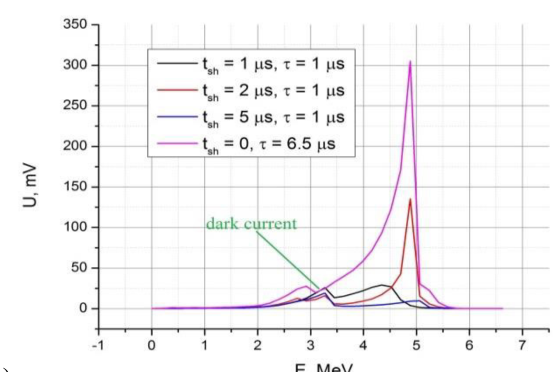
The measurements were conducted for various gun currents and different accelerating field levels that correspond to the maximum electron energy from 2 to 6 MeV. At that, width of the accelerating field envelope was 4.4 μs, and the pulse of the gun current completely overlapped the pulse of the envelope of the accelerating field.

Figure 2 shows dependencies of rms beam radius and capture coefficient on gun current at the accelerated beam energy of 6 MeV (a), beam spectrum at gun current of 20 mA and pulsed RF power loss in the walls of 2.5 MW (b), as well as dependence of beam energy on pulsed RF power loss in the AS walls as compared to calculated data (c). As one can see, calculated results agree rather well with measurement results.

In the second series of experiments, measurements were conducted for a fixed level of klystron pulsed power and for different duration of electron gun pulse and its delay relative to pulse of accelerating field envelope (Fig. 3). The graphs clearly show the dark current contribution.



a)



b)

Figure 3: a) Pulse of accelerating field envelope (red) and accelerated beam current pulse at 0^0 FC (black) at gun current pulse duration of 1 μs and its delay with regard to the front edge of RF pulse of 3 μs. b) Measured spectra for different duration of the gun current pulse τ and its different delays with regard to the front edge of RF pulse t_{sh}.

ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO061

MEASURING SPECTRA AT SHORT TIME INTERVALS

The shape of measured accelerated beam spectra (Figs. 2, 3), besides the specific characteristics of beam dynamics in the AS and energy resolution of the spectrometer, is also determined by the following factors. At short width and amplitude of the gun current pulse one can notice contribution of dark currents: faint spectral peaks seen at Figs. 3b and 2b, as well as the base of dark current at a pulse at the 0^0 FC shown in Fig. 3a. For the pulse of gun current that fully overlaps with the pulse of accelerating field envelope, contribution from the electrons accelerated at the pulse front to the spectral width becomes noticeable.

To minimize these factors we have used a method that allows one to obtain beam spectrum at a specific moment of the pulse of accelerating field envelope averaged over the time interval of 50-100 ns. For that purpose, oscillograms of beam current from 45^0 FC for various values of spectrometer magnet current were measured. An example of such pulse is shown in Fig. 4 (blue curve) for magnet current corresponding to the energy of 4.93 MeV.

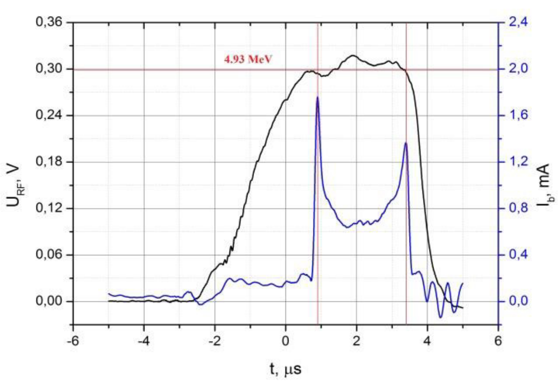


Figure 4: Pulse of accelerating field envelope (black) and current pulse at the 45^0 FC at the spectrometer magnet current corresponding to the beam energy of 4.93 MeV.

When magnet coils current approaches the value corresponding to the maximum beam energy, “rabbit ears” of the current pulse in Fig. 4 converge and ultimately merge into one peak. By measuring 45^0 FC current pulse amplitude depending on magnet coils current for a given time t_0, one can obtain beam spectrum for the point on the accelerating field envelope corresponding to the moment t_0. The spectrum obtained in this way for the moment of time $t_0 = 2$ µs (in Fig. 4) is shown in Fig. 5 by the black curve as compared to the calculated data (red curve) and as compared to the spectrum (blue curve) measured in a conventional way, with the gun current pulse that fully overlaps with the accelerating field envelope pulse. Width of the spectrum measured in accordance with the method described turns out to be much closer to the calculated spectrum width.

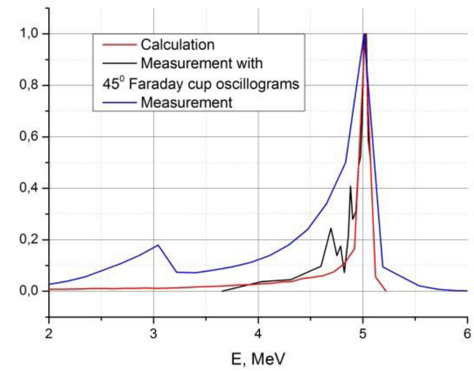


Figure 5: Accelerated beam spectra: red line – calculated, black line – measured with the help of the method described in this section, blue line – measured in a conventional way.

CONCLUSION

We have carried out beam parameter measurements for the newly developed electron accelerator based on C-band AS at a stand specifically built for this purpose. Electron beam with energy controlled in the range of 2-6 MeV and characteristics that are well correlated with calculated results has been obtained. Study of various accelerator operating modes has shown that dark currents and fronts of accelerating field envelope pulse have great influence on spectrum shape. To minimize contribution of these factors it is necessary that the electron gun current pulse would span the top of the accelerating field envelop to the maximum extent possible not capturing the edges. In addition, we have developed a new spectrum measurement method that allows one to take measurements for the selected moment of the accelerating field envelope in the short time interval of 50-100 ns.

REFERENCES

[1] L. Yu. Ovchinnikova, V. I. Shvedunov, “Design of C-band electron linear accelerator for a complex of radiation therapy”, presented at the 29th Linear Accelerator Conf. (LINAC’18), Beijing, China, Sep. 2018, paper MOPO059, this conference.

[2] www.toriy.ru