ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO060

LINACS FOR INDUSTRY, CARGO INSPECTION AND MEDICINE DESIGNED BY MOSCOW UNIVERSITY*

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Abstract

The report presents the results of development of applied linear electron accelerators with an energy of up to 10 MeV, performed by the Laboratory of Electron Accelerators MSU. We describe linear accelerators for mobile, stationary and train cargo inspection systems with interlaced energies and pulse repetition rate up to 2 kHz, accelerators for radiography, a sterilization accelerator with beam parameters that are adjustable over a wide range, and an accelerator for a radiotherapy complex.

INTRODUCTION

Laboratory of Electron Accelerators MSU Ltd. (LEA MSU) was established on the base of Skobeltsyn Institute of Nuclear Physics Lomonosov Moscow State University (SINP MSU) in 2013. Within five years we have designed six different types of linear accelerators for security, industry and medicine and supplied customers with more than 20 units. The customer of accelerators for security systems is the co-founder of the LEA MSU - Scantronic Systems LLC, which developed a number of cargo inspection systems, including stationary, train and mobile [1]. LEA MSU closely cooperates with the JSC "SPE" Toriy" [2] - enterprise that produces the powerful vacuum RF devices. We use in our accelerators the multi-beam klystrons, accelerating structures and electron guns manufactured by "Toriy" and carry out joint deliveries of accelerators. Our accelerators operate in S-band (2856 MHz) and C-band (5712 MHz). Examples of klystrons and sealed accelerating systems are shown in Figs. 1-2.

The accelerators designed by LEA MSU are equipped with a control system based on specialized controllers - each controller is responsible for a separate accelerator system [3]. The control system allows remote monitoring of the accelerator operation while saving the accelerator regime and beam parameters on the server. The control system allows changing the parameters of the accelerated beam within wide limits in accordance with the requirements of the technological process.

An important part of the RF system of our accelerators is a fast digital AFC system, permitting to reach stable beam energy and dose rate for a time of less than 1 s after start.

* Work supported in part by Ministry of Education and Science of Russia Grant # RFMEFI58217X0011
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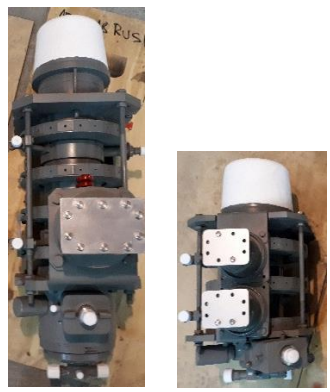

Figure 1: S-band (left) KIU-168 and C-band KIU-271 klystrons [2].

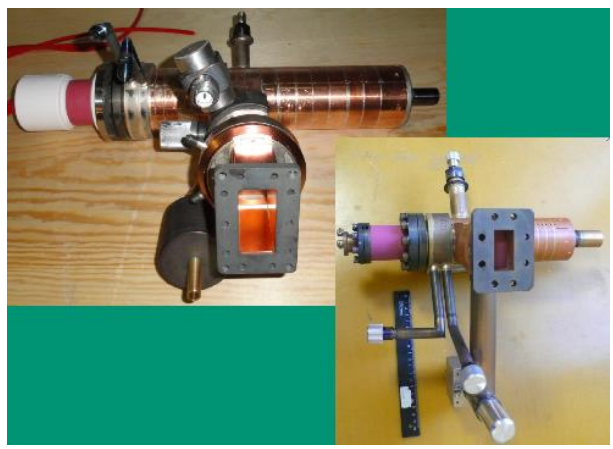

Figure 2: S-band (upper) and C-band accelerating systems.

Preliminary information about LEA MSU accelerators was given in [4-5].

CARGO INSPECTION

We have designed and manufacture accelerators for three types of cargo inspection systems: stationary, train and mobile. All these accelerators operate in interlaced energies mode with beam energy switching between 3.5 and 6 MeV. The beam spot size at the placed in vacuum, liquid cooled bremsstrahlung target is less than 1.5 mm for low energy and less than 1 mm for high. Accelerators are equipped with a local radiation shielding with a narrow gap collimator. Pulse to pulse beam energy stability is about 0.6 % rms. Some additional parameters are given in Table 1, accelerators photo are in Fig. 3. High repetition rate

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of train system accelerator permits to inspect trains at velocity 70 km/h.

Table 1: Parameters of Accelerators for Cargo Inspection

Parameter	Stationary	Train	Mobile
Rep. rate, Hz	2×200	2×1000	2×200
Dose rate, Gy/min	4	6	0.2
Radiation leakage	2×10^{-5}	2×10^{-5}	10^{-6}
Frequency, MHz	2856	2856	5712

(a)

(b)

(c)

Figure 3: Accelerators for cargo inspection systems, (a) stationary (with modulator), (b) train and (c) mobile.

RADIOGRAPHY

Accelerators for radiography are simplified versions of the accelerator for a stationary cargo inspection system, they are produced with three maximum beam energies: 6 MeV, 8 MeV and 10 MeV. The maximum dose rate at energy of 10 MeV is 40 Gy/min. The energy of the accelerated beam for each version of the accelerator can be reduced in wide range, down to 50% of the nominal value to ensure the best image quality depending on the thickness of the object under inspection. Accelerator for radiography in operation is shown in Fig. 4.

Figure 4: Accelerators for radiography in operation.

STERILIZATION

The first accelerator for sterilization produced by the LEA MSU and JSC "SPE" Toriy" was installed in the pilot complex of antimicrobial product processing [6] in the Kaluga region (Russia) – Fig. 5. Its main parameters are given in Table 2. An important feature of the accelerator is the possibility of adjusting the parameters of accelerated beam and scanning system according to parameter of the product to be treated [7].

Table 2: Parameters of Accelerator for Sterilization

Parameter	Value
Beam energy, regulated, MeV	5 - 10
Pulsed beam current, mA	400
Average beam power, regulated, kW	5-15
Klystron pulsed power, max, MW	6
Klystron average power, max, kW	25
Operating frequency, MHz	2856
Wall plug efficiency	20%
Beam scanning width, regulated, cm	40-60

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Figure 5: Accelerators for sterilization.

MEDICINE

LEA MSU is developing an electron accelerator for the radiotherapy complex, which is designed by JSC "Scientific Research Institute of Technical Physics and Automation", Moscow, Russia [8]. The accelerator provides a beam energy of 6 MeV at a dose rate of 10 Gy/min in the therapeutic mode and 2.5 MeV energy in the portal image acquisition mode. To have a compact design the accelerator is operating at 5712 MHz. The results of the beam dynamics calculations are presented in [9], experiments on measuring electron beam parameters are described in [10]. At present, the design of the accelerator is being completed-its design is shown in Fig. 6. Tests of the accelerator and its transfer for installation in gantry are planned for December 2018.

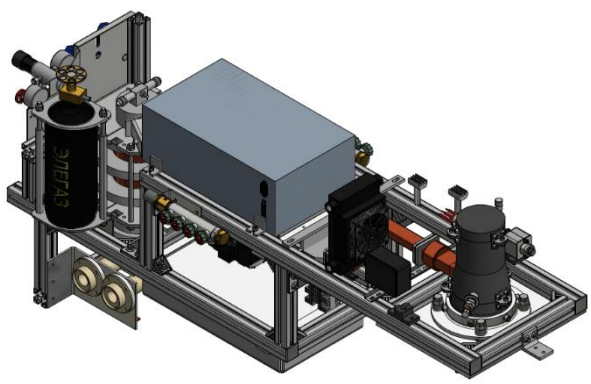

Figure 6: Accelerators for medicine.

CONCLUSION

During last 5 years the LEA MSU has designed and supplied to customers 25 accelerators, including 5 for radiography, 19 for X-ray inspection systems, 1 for sterilization. Accelerator for medicine is under construction. Contracts for ten more machines have been signed. Design of accelerators is based on the results of fundamental research conducted in previous years at Skobeltsyn Institute of Nuclear Physics Lomonosov Moscow State University.

ACKNOWLEDGEMENTS

The authors are grateful to professor B.S. Ishkhanov, academician of the RAS V.P. Smirnov, A.V. Nalivaev and Dr. S.A. Ogorodnikov for supporting this work.

REFERENCES

[1] http://www.scantronicsystems.com

[2] http://www.toriy.ru

[3] A.N. Ermakov, A.N. Kamanin, V.G. Sayapin, I.V. Shvedunov, V.I. Shvedunov and D.S. Yurov,, "Control Systems for Radiography and Cargo Inspection RF Accelerators", in *Proc. of RuPAC2014*, Obninsk, Kaluga Region, Russia, pp. 410-412.

[4] A.N. Ermakov, A.S. Alimov, B.S. Ishkhanov et al, "Main Parameters and Operational Experience with New Generation of Electron Accelerators for Radiography and Cargo Inspection", *in Proc. of RuPAC2014*, Obninsk, Kaluga Region, Russia, pp. 143-145.

[5] A.N. Ermakov, V.V. Khankin, A.S. Alimov et al, "Commissioning of High Efficiency Standing Wave Linac for Industrial Applications", in *Proceedings of RuPAC2016*, St. Petersburg, Russia, pp. 99-101

[6] http://www.tecleor.com

[7] V.V. Khankin, A.S. Alimov, A.N. Ermakov, A.N. Kamanin, A.S. Kurilik, N.I. Pakhomov, N.V. Shvedunov, V.I. Shvedunov, D.S. Yurov, I.V. Shvedunov, A.S. Simonov, "Linear Electron Accelerator for Radiation Technologies with Beam Parameters Varied in a Wide Range", presented at the 29th Linear Accelerator Conference, LINC18, Beijing, China on 16-21 September 2018, paper MOPO62, this conference.

[8] http://www.niitfa.ru

[9] 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 Conference, LINC18, Beijing, China on 16-21 September 2018, paper MOPO59, this conference.

[10] D.S. Yurov, L.Yu. Ovchinnikova, A.S. Alimov, A.N. Ermakov, V.V. Khankin, N.V. Shvedunov, V.I. Shvedunov, A.S. Simonov "Beam parameters measurement of C-band 6 MeV linear electron accelerator", presented at the 29th Linear Accelerator Conference, LINC18, Beijing, China on 16-21 September 2018, paper MOPO61, this conference.