DESIGN OF COMPACT SYSTEM WITH WIDE ELECTRON BEAM FOR RADIATION TECHNOLOGIES

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1 INTRODUCTION

The development and translation of ecologically safe electron-beam technologies into industry and medicine to produce materials with improved characteristics and to sterilize medical devices, have demanded the application of relatively low-energy (100-200 keV) powerful electron beams.

In the recent years there has been observed extensive activity in these fields. To introduce widely the low-energy electron-beam technology, a demand arose for the production of high-quality sources of high-power electron beams. FSUE "RPC Istok" has developed a new class of devices, namely electron sealed-off guns generating electron beams with a high pulsed power and extracting them into atmosphere or a gas medium [1, 2]. There have been devised two kinds of sealed-off guns and the radiation systems on their basis.

2 SYSTEMS AND ELECTRON GUNS FOR IRRADIATION OF FIXED OBJECTS

The electron sealed-off gun (Fig.1) is a version of a direct-action accelerator, evacuated and hermitically sealed directly at the manufacturer's facility; it is further operated without vacuum pumps, much like in the case with a TV-tube.

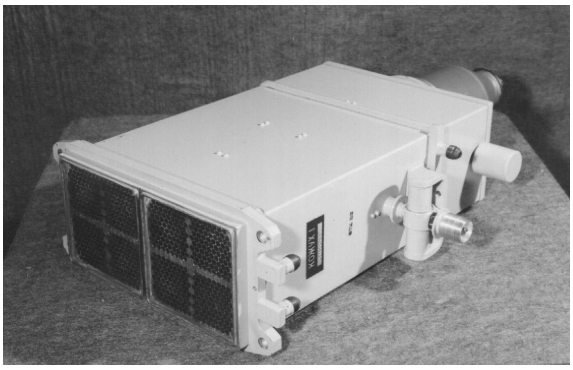

Fig.1. Electron gun with two round cathodes.

The electron beam is brought out through thin titanium foil, so the irradiation is performed instantaneously on a rather large area without using beam sweep devices. The gun is equipped with two round cathodes and special shaping electrodes providing diverging electron flows featuring uniform distribution of the electron flow density in the output unit region.

Table 1. Parameters of guns with round cathodes

Gun version	EG-1	EG-2	EG-3
Cathode diameter (mm)	5.7	11.4	24
Maximum pulse current from the cathodes (A)	6	15	80
Maximum voltage (kV)	200		
Radiation area (mm)	200 x 100		
Foil thickness in the output window (μm)	20		

The electron sealed-off gun, unlike the other electron guns, is compact, reliable, durable, and has a short time to be prepared and operated.

Based on guns EG-1 and EG-2, FSUE "MRTI RAN" and LLC "Biosterile technologies" have developed compact systems for electron-beam technologies PYXIS-1 and PYXIS-2 [3], at service in the 3M Company, St. Paul, USA (Fig. 2).

Fig. 2. PYXIS-1 system in operation.

The systems provide the irradiation of separate objects placed into the nitrogen-filled irradiation chamber. Low sizes of the systems are obtained due to the compactness of the electron-beam sealed-off gun as well as the high-voltage (200 kV) pulsed transformer designed by FSUE "MRTI RAN".

Table 2. Main parameters of the systems

System version	PYXIS-1	PYXIS-2
Type of gun	EG-1	EG-2
Accelerating voltage (kV)	100 –200	
Dose rate (kGy/s)	10	30
Pulse dose rate (kGy/s)	3 10^4	10^5
Pulse repetition rate (pps)	50-150	5-300
Pulse width (μs)	1	1
Radiation area (mm)	200×100	
System sizes (m)	0.7×0.7×2	
Water cooling	Autonomous	

The PYXIS-1 system is mounted in a radioelectronic cabinet. Besides The PYXIS-2 system contains the high-voltage power supply (0.7×0.7×1 m).

3 SYSTEMS ADN ELECTRON GUNS FOR IRRADIATION OF MOVING TAPES

FSUE "RPC Istok" in cooperation with LLC "Biosterile technologies" have developed the system to irradiate separate objects as well as a continuously moving tape 300 mm wide. Such a plant needs the use of an electron sealed-off gun providing a wide electron beam at the output.

The development of such a gun gives rise to a set of problems to be solved. The major issues are as follows:
- development of an electron optical system providing uniform distribution of the electron beam beyond the window;
- development of a reliable ribbon cathode at low filament current (5 A max), necessary to produce a compact pulsed transformer;
- development of an extended electron output window.

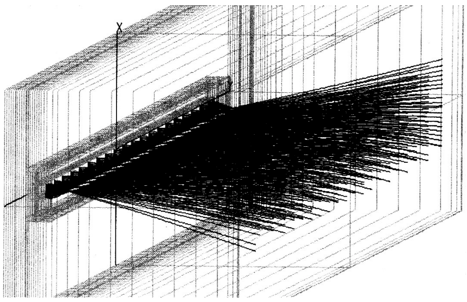

Fig. 3. Electron beam in a half of the gun with a ribbon cathode

Figure 3 shows the calculated distribution of the electron beam. A ribbon cathode having an emitting area of 320×6 mm and a shaping electrode produces a diverging electron beam (320×40 mm) in the output window region.

The extended ribbon cathode is manufactured as a set of eight interconnected simple ribbon cathode 40 mm long each. The total cathode filament power is 200 W.

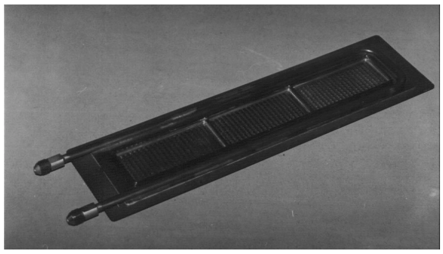

Fig. 4. Output window of the gun with a ribbon cathode.

The electron output window (Fig. 4) consists of three parts, and a package interconnected by argon arc welding. Each of the window contains the copper grate and 20 μm titanium foil. The window is cooled with water; the cooling lines are located in the window periphery.

There has been engineered a construction, and manufactured a test prototype of the electron sealed-off gun (Fig. 5). Its tests are now under way.

Fig. 5. Electron gun with a ribbon cathode.

Table 3. Parameters of the gun with a ribbon cathode

Cathode dimensions (mm)	320×6
Max. pulse current from the cathode (A)	25
Maximum voltage (kV)	200
Radiation area (mm)	300×40

Design of a high-voltage pulse transformer has been developed. The transformer consists of a number of identical modules interconnected in series, thus producing a secondary high-voltage winding. The transformer is coupled with the electron gun via a short coaxial feeder, forming a common structure, i.e. a radiation source. The transformer and the feeder are filled with transformer oil so that the outer side of the electron gun insulator is immersed in oil.

Now the design of TAPIS radiation system has been developed using the electron gun with a ribbon cathode. It includes the processing cabinet and the power supply cabinet.

The processing cabinet contains the electron gun, the high-voltage pulse transformer, the transport mechanism for the tape, the autonomous water cooling system, and the radiation shielding (Fig. 6).

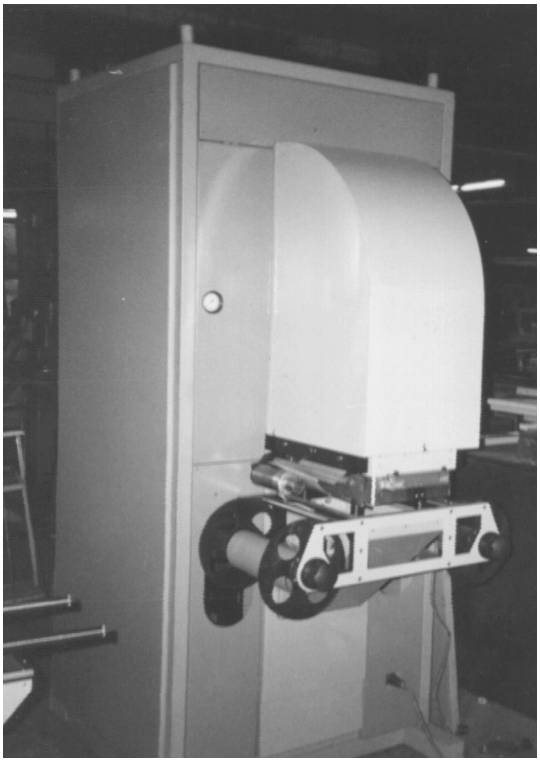

Fig. 6. Processing cabinet of the TAPIS system.

Table 4. Main parameters of the TAPIS system

Accelerating voltage (kV)	100 – 200
Dose rate (kGy/s)	60
Pulse dose rate (kGy/s)	2.6×10^5
Pulse repetition rate (pps)	5 – 150
Pulse width (μs)	1.5
Width of tape (mm)	300
Speed of tape (mm/s)	20 – 200
Power supply cabinet sizes (m)	0.7×0.7×2
Processing cabinet sizes (m)	1×1.2×1.2
Water cooling	Autonomous

4 CONCLUSION

As a result of the work, design of a compact system for radiation processing of products and materials has been developed. The system provides two modes of irradiation, i.e. irradiation of continuously moving tapes and fixed samples. The irradiation is performed in a hermetically sealed chamber filled by nitrogen.

This ecologically pure system includes the radiation protection, autonomous water cooling system and automated PC-control. It can be placed in any production or clinical room.

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