THE NSC KIPT ELECTRON LINACS - R&D AND APPLICATION

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Abstract

The report contains the review of electron linac research and development activity at the National Science Center "Kharkov Institute of Physics and Technology". The main results on the research of electron sources (RF guns, secondary emission guns), injector systems, accelerating structures are presented. The report also presents descriptions of some applications of designed linacs.

1 INTRODUCTION

Characteristic of the Ukraine economy of today's period is the absence of stable situation on the radiation technology market. Considering this, it would be good advantage to develop, build and make use of accelerators with a broad range of parameters, capable to meet the market's demands. This ideology is fundamental in the activities of "Accelerator" R&D Production Establishment of the National Science Center "Kharkov Institute of Physics & Technology", the leading organization in the Ukraine in creation of electron linacs and applied technologies.

2 ELECTRON LINACS

There are six electron linear accelerators designed and fabricated at the "Accelerator" R&D Establishment besides the oldest linac in Europe LUE-2000. Main parameters of linacs are represented in Tab.1.

Tab.1 Basic Parameters of Lina

	EPOS	LU-10	KYT	KYT-20	LIC	LU-60
Energy range, MeV	10 -30	8-18	8-14	16-28	13-18	40-60
Operation energy , MeV	20	12	9	20	15	60
Frequency, MHz	2797.2	2797.2	2797.2	2797.2	2797.2	2797.2
Number of sections	2	1	1	2	1	1
DLW length, m	3.05	3.05	1.23	1.23	2.30	3.25
Number of klystrons	2	2	1	2	1	1
RF-pulse width, μs	5	4	5	5	2.2	1.5
RF-power input, MW	10	10	10	11	18	25
Current-pulse width, μs	4	3.5	4	4	1.5(0.007)	0.1
Normalised emittance (rms) π·mm·mrad	--	--	--	--	14	150
Repetition rate, pps	300	300	300	300	1-6.25	1-6.25
Average current, μA	1000	1000	800	1000	--	--
Maximum Bsf, Hz	3	3	3	3	--	--
Size of beam at the exit, cm	1 x 10	1 x 30	1 x 30	1 x 10	--	--

The linac EPOS [1] was built in 1999 on the base of the existing equipment. EPOS has been designed for radiation processing of various items, employing electron beams with energies up to 30 MeV. Since 1994 at the linac LU-10 [2] has been going research on radiation damage physics, radiation technologies and pharmaceuticals sterilization. The facility is equipped with metrologically licensed devices for energy spectrum measurements and monitoring of average and pulsed beam current. The accelerator KYT [3] has been operating in NSC KFTI since 1993 KYT, is meant for performing various radiation technological processes including sterilization of medical articles. The accelerator KYT-20 [4] is a high-power electron linac for irradiation applications. It is under testing now. The

linac consists of two accelerating structures with variable geometry and a compact injector.

All above mentioned technological linacs are equipped with extraction devices which consists of a scanning magnet and a special system with an air-cooled exit foil.

The accelerator LIC (Laser Injector Complex) [5] was developed and constructed for scientific researches. The universal RF gun of the linac can be used in both the thermionic (μs) and photoemission (ns) modes. During 1997-2001 the facility was used for studying the electron focusing in plasma by transverse components of wake-fields and coherent Smith – Purcell millimetres radiation. The linac LU-60 [6] was designed and established both as injector linac in a compact SR source and accelerating facility for scientific researches.

3 RESEARCH AND DEVELOPMENT

"Accelerator" R&D Production Establishment of NSC KIPT conducts different researches and developments in some fields of accelerator physics. The mains of them are studying properties of periodic electrodynamic systems and development different kinds of accelerator structures, electron guns and injector systems. Analytical and numerical methods of calculations and simulations are mastered and developed in the "Accelerator". The research of electron dynamics in accelerating and shaping systems of the linacs is successfully carrying out using both the well-known software (for example EGUN, SUPERFISH, PARMELA) and home made software.

3.1 Electron sources and injectors

During ten past years we carried out the investigation of RF electron sources with different types of cathode. The thermionic RF guns with various resonant system are theoretically and experimentally studied [6, 7, 8]. The typical beam characteristics of S-band thermionic RF guns are follows: the energy of 0.7-0.9 MeV, the pulse current of 1.5 A, phase bunch length less than 50°, the current pulse length of 0.7 - 1.5μs, normalized emittance (1 rms) is not more than 12 π·mm·mrad. The RF guns for the high current electron beam generation with nanosecond pulse length based on photocathode (11 A, 7 ns) and dielectric-metal cathode (4 A, 30 ns) have been designed and tested [9, 10]. Designed RF guns are used in research accelerators LIK, LU-60.

Physical processes during generation of hollow electron beams in magnetron guns with secondary–emission cold metallic cathodes have been investigated since 1993 [11, 12]. The hollow electron beams of 5 MW (the beam current ~50…100 A) pulse power were produced in a single gun and in a system of guns. The magnetic field was reached ~3000 G, the beam inner diameter was approximately equal to the cathode diameter and the wall beam thickness was 1 - 2 mm].

The compact injector (total length is 20 cm) for a technological high power S-band linac has been designed, fabricated and tested. The injector consists of low voltage (≈ 25 kV) diode electron gun, prebuncher and beam current monitor. It produces the electron beam with energy more than 600 keV, pulse current up to 1.5 A. These injectors are used in the technological linacs KYT and KUT-20. The new SW S-band injector integrated with TW accelerating structure (phase velocity equal to the velocity of light) has been also designed. During past years we designed electron source and two different injector systems for compact K-band linac.

3.2 RF - Structures

Methods of fabrication and tuning of piecewise-homogeneous accelerating structures (PHAS) have been developed in KIPT recently [13]. The PHAS type section having high accelerating gradient up 20 MeV/m was designed and used in the linac LU-60. The main problem for PHAS tuning is the choice of transition cell parameters. Novel mathematics models of coupled pillboxes and disc-loaded waveguides [14] and tuning techniques were developed to solve this problem. According to this techniques the four inhomogeneous accelerating structures with 2π/3 operating mode have been developed and manufactured. New modifications of disc-loaded waveguides having (-2π/3) phase shift per cell were designed for the acceleration of short-pulse high current electron beams [5, 15]. The operating mode in such structures is the first spatial harmonic. The fundamental harmonic is no synchronous and provides radial RF focusing of a beam. This structure is used in the accelerator LIC. To create the small-sized linear electron accelerator with energy up to 5 MeV the technology of manufacturing and tuning technique of an accelerating X and K band structure is under development.

4 APPLICATION

Electron linacs of NSC KIPT are used for research of radiation effects in reactor materials, plasma-beam interactions, gamma-activation analysis of the ore samples, as well as sterilization of single-use medical products, modification of polymers and semiconductors, isotope production for nuclear medicine etc.

4.1 Radiation facilities & metrological maintenance

Analytical methods and technologies using electron (or bremsstrahlung) irradiation demand continuous monitoring of the radiation parameters. To provide a certification of the accelerators and technologies as well as a metrological maintenance of the radiation treatments a number of the standard and technological measurement channels have been developed [16]. Most of them were investigated by means of computer analysis using code GEANT.

4.2 Isotope production

Taking into account a continuous growth of the medical isotope utilization, an elaboration of the secure methods for their production is a problem of extreme importance. The application of electron accelerators is proposed as some opportunity to solve this problem [17, 18].

Technetium-99m. The method of production based on photonuclear reactions under braking photons of high-current electron accelerator provides a sufficient yield of the ^{99}Mo without generation of large amount of the waste.

Isotopes for PET. It was shown in our investigation that on electron linac (25 MeV, 20 kW) one can produce the ^{11}C, ^{13}N, ^{15}O and ^{18}F isotopes with the specific activity $1.9\cdot10^{7}$; $1.67\cdot10^{6}$; $2.5\cdot10^{6}$; and $1.7\cdot10^{6}$ Bq/g·μA (beam current) respectively.

4.3 Gamma-activation method

It is known that γ-activation analysis is used for express measurement of the Au concentration in ore samples. We have shown the possibility of its application in the analysis of rare and noble metals as well as in biophysics [19].

It seems to be one more promising linac application for characterization of radioactive waste of wrecked Chernobil 4-th unit. So, the waste activation with high-energy braking photons enables the transformation of the β-active isotope (^{90}Sr) into γ–active one (^{89}Sr) and makes easier its identification. A practically nonactive ^{238}U can be transformed also into γ-active ^{237}U using ^{238}U(γ,n)^{237}U reaction (i.e. determined by means of γ-activation analysis). On the other hand the problem of reliable disposal of the long-lived waste is of particular importance as well. The appropriate methods for production of the radionuclide-tracers and operative determination of their diffusion coefficients into geological barriers under different doses of the bremsstrahlung are elaborated.

4.4 Electron radiation processing and radiation test

The industrial facility for sterilization based on LU-10 linac was put into operation. The productivity of the facility is up to 15 tons per operating day (for absorbed dose value up to 25 kGy). A radiation modification of semiconductors enables to improve their time parameters. More than 10^5 units of various thyristor and silicon plates were treated on LU-10.

The radiation facilities of the NSC KIPT enable to test different materials, devices and construction elements within a wide range of radiation parameters and dose values. A number of fission reactor elements and materials, ceramics, magnetic [20], concrete and granite samples as well as semiconductor detectors of γ-radiation were tested.

5 CONCLUTION

As one can see from the presented results, “Accelerator” R&D Production Establishment KIPT is a dynamic developing department which plays an important role at the Ukrainian market of radiation technologies.

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