

# IMPROVED ELECTRON BEAM SOURCES FOR COMPACT LINEAR ACCELERATORS

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## Abstract

The design and main parameters of electron beam sources for accelerators are described. Two designs of cathode assemblies for RF electron injectors were developed. For increasing lifetime of the sources lanthanum hexaboride single crystal emitters are used. Indirect heated disc cathodes with diameter 4-6 mm and thickness 1,5 mm ensure beam current up to 10 A and small surface erosion rate under ion bombardment. The latter parameter is 3-4 times smaller than for lanthanum hexaboride polycrystal emitters. The described electron sources will be used for compact linear accelerators.

## Introduction

For linear accelerators which are used in applied fields it is especially important reliability and stability performance of all systems incorporated, including injector. A number of electron sources designs are used in compact electron linacs. The most critical element of the injector is the emitter, which in considerable degree defines the performance characteristics of the whole beam generating system. As a rule, thermionic cathodes emitters are used in applied electron linacs. Wire emitters are simple, but they have low operation time and stability, considerable beam emittance. Disc and bar cathodes require more complicated assembly design, but ensure high stability and electron brightness, large operation period without taking apart. Good beam formation is also very important in many fields. The most exact beam parameter describing transverse beam dynamics is beam brightness at gun output. It was shown in [1, 2] using analysis of beams parameters at the output of many linacs, that one of the most important factors defining the transverse formation quality is a beam brightness at the injector output, which normalized value is maximum in the injector and decreases during the beam acceleration. Taking into consideration these conclusions it is very important for high output linac beam brightness to obtain minimal value of transverse emittance in the electron source, which is defined by many factors including stability of emission characteristics, cathode position, etc. The purpose of this work was to develop the designs of electron sources for compact electron linacs of 3 and 10 GHz range with improved performance characteristics of the output beam. As they will be used in industry, special attention was paid to the reliability of the design, reproducibility of the emitter position after emitter changing, convenience in handle.

## Description of the design

As it was shown earlier, the solid emitters are preferable for obtaining high quality electron beam and this type was chosen for the electron sources developed. The cathode material is lanthanum hexaboride, which combines high emission current density, considerable resistance to active gases poisoning and ion bombardment, low evaporation rate. This material is also very advantageous in case of linac injector because of periodic air exposures during taking apart. The cathode diameters were chosen in the range of 4-8 mm and the indirect heating method with electron bombardment from auxiliary cathode was used. As a result of a number of both theoretical and experimental investigations the cathode assembly design was developed (see fig.1).

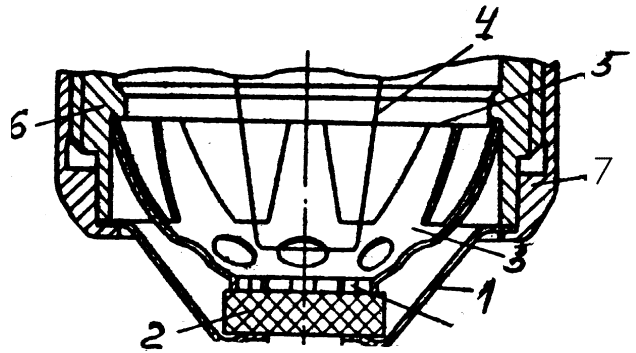


Fig.1. Scheme of the cathode assembly.

It consist of a hollow cone-shaped cathode holder I, a lanthanum hexaboride cathode pill 2, a hollow cone-shaped component 3 for pressing the pill 2 to the holder I and a ribbon heater 4, which produces an electron flow to bombard the cathode 2. Because of the cathode material is sufficiently fragile, it is necessary to ensure elastic pressing of cathode pill to the holder during the whole working period. During the heating and cooling of cathode and other components termodeformations in component 3 lead to gradual deformation of its elastic elements. Original feature of proposed cathode assembly is execution of this component 3 with the projections 5 at the larger side of the cone. These elements are placed in the region of low temperature and thus the influence of nonelastic deformations in these projections can be considerably decreased. Another important difference of this cathode assembly is an auxiliary cathode - heater 4.It made of a refractory metal strip, which is supplied by cuts in emitter part alternately spaced from both sides. In this

case the cathode heating is more uniform and the undesirable influence of magnetic field connected with heating current can be minimized. These improvements developed lead to increase of cathode working life and improvement of beam formation quality. Both in technological electron beam guns and electron injectors the most frequent reason for gun to be out of work is a damage of strip or wire heater. To eliminate this deficiency we suggested the following manner and arrangement for above cathode assembly. A screen made of refractory metal is situated between the heater 4 and the cathode 2. Power supplies produce electric fields in the spaces heater-screen and screen-cathode, which accelerate electrons towards the screen. The heating of this screen to high temperature is provided by electron bombardment from the heater 4. Screen heated to high temperature radiates the heat flow towards the cathode 2 and heats it. After the cathode reaches his working temperature it begins to emit electrons from both sides. One electron flow ensures main beam and the electrons from opposite side are accelerated towards the screen and bombard it. From this moment the heater 4 can be switched off because the heating of the screen is provided by electron bombardment from cathode 2, which in turn is heated by the radiance from the screen. In this device the heater 4 is used in short periods of turning on only and the working period of the whole cathode assembly increases many times.

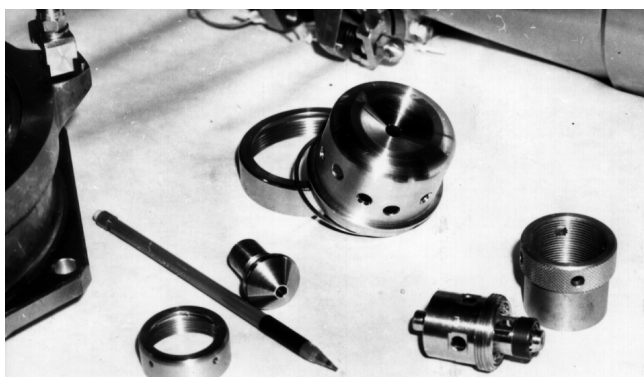


Fig.2. Overall view of the cathode assembly (in the right bottom corner).

This manner ensures more uniform heating of the cathode and avoids erosion of the cathode surface by electron bombardment in usual methods. The cathode assembly, designed with using these solutions, is shown in fig.2.

Another important problem of electron beam guns design is stable and reliable operation of high-voltage electric isolator assembly. We developed several reliable high-voltage as semblies with alumina ceramics isolators. They ensure stable work with voltages up to the 100-120 kV and lead-in four different voltages in vacuum part of a gun. All of above designs were tested, applied in industry and showed good results.

### Performance characteristics

A number of electron guns for technology and linacs were developed on the basis of above design solutions. The main parts of the electron gun is shown in fig. 3.



Fig.3. The main parts of electron gun high voltage assembly.

Accelerating voltage can vary from 20-30 kV up to 100 kV. Continuous beam current is controlled from several mA up to I A by variation of grid voltage within 0-5 kV. Power consumption of cathode assembly is equal 50-60 W. It allows gun to operate without compulsory water cooling for four and more hours. The heat released by cathode assembly is transferred to the gun components via liquid dielectric-castor oil or special silicon oil. In the latter case it is possible for gun to operate for about ten hours without turning off. This design is very advantageous in case of portable linac or if electron gun is to move inside technological vacuum chamber. Vacuum conditions under which the electron gun has capacity for work are extended to 0.1 Pa, however the working period of cathode assembly sharply decreases. It equals tens hours under such high pressure. In high vacuum (less 0.001 Pa) the working period is equal hundreds hours. Comparison of operation period of lanthanum hexaboride emitters of various technological production was carried out. The above value for single crystal cathodes is considerably higher than for polycrystal ones ( in 3-4 times).

Electron beam formation is carried out by both electrostatic optical system and electromagnetic focusing lens. They provide convergent beam at the gun output with crossover diameter less 1 mm and beam currents up to I A. High power density permits to carry out such technological processes as electron beam welding of thick metal components. These guns were used in aviation industry for welding and thermoprocessing of various components. The gun with 60 kV and I A beam ensures joining of steel details with thickness up to 100 mm and

aluminium alloy components with thickness up to 300 mm.

Electron technological guns are supplied with fast electromagnetic deflecting systems of ring-shaped type, which provides scanning of electron beam over large area. Such devices were used for surface hardening of various important components, for example working surface of ball-bearings for oil industry. Electron beam processing forms surface layer of

1-2 mm thickness with high hardness up to 62 HRC which increases working period of ball-bearings to 50% and more. Electron injector for 10 MeV travelling wave linac was developed. Energy of electrons at the gun output 40 kV, beam current 2 A, pulse length duration 4 mcs. The assembly drawing of this injector is shown in fig. 4.

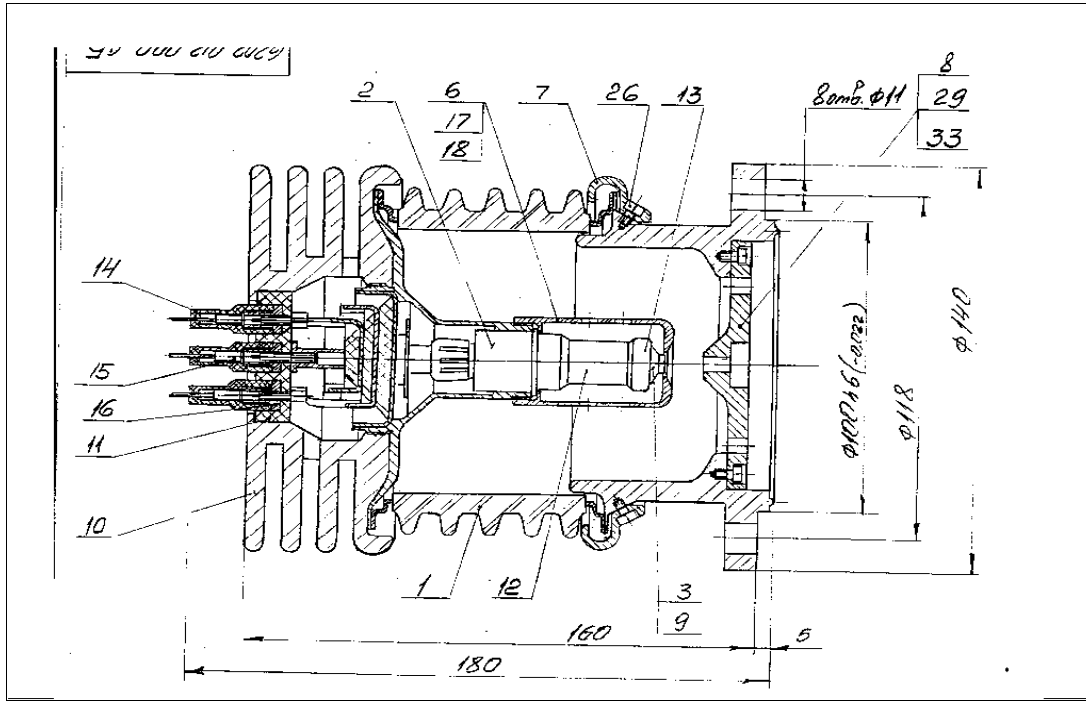


Fig.4. Assembly drawing of electron source for linac.

The gun design includes the same cathode assembly and high-voltage isolator. This injector is now assembling and will be tested. The guns described can be used in various fields of physics and industry. The authors are ready to fruitful cooperation with organizations interested.

#### References

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- [2] V.A. Polyakov, "High Brightness Beam Dynamics in Linear Electron Accelerators", Moscow Engineering Physics Institute, Moscow, Russia, Ph.D. Dissertation, 1982.