THE ELECTRON GUN FOR LUE-200 (PROJECT IREN)
G.V. Trubnikov, V.A. Shvets
Joint Institute for Nuclear Research

INTRODUCTION

The pulsed source of resonance neutrons IREN, which is under construction in the LNPh JINR, consists of the linear electron accelerator and target (the converter with multiplying cover from fissile material) just as working up to 2001 neutron source IBR-30. That is traditional combination for JINR.

Pulsed neutron streams from a target are used for time-of-flight spectrometers of high resolution. The main purpose of new plant creation is the reduction of pulse duration under preservation of high average intensity of neutron streams. It is used to increase the spectrometer energy resolution. The integral neutron output will make \( \sim 9 \times 10^{14} \) n/s with neutron multiplication factor \( \sim 30 \) and neutron pulse duration 400 nanoseconds.

The plant will be placed in three floors of an LUE40 - IBR30 existing building. The accelerator will be placed in vertical position in two top floors and subcritical multiplying target will be placed in a ground floor.

ACCELERATOR LUE-200

The outline project and accelerator substantiation were developed in Budker Institute of Nuclear Physics (BINPh, Novosibirsk) [1,2].

The IREN design objectives on neutron stream define average capacity of the electron bunch \( \approx 10 \) kW, that determines electron energy about 200 MeV at pulse duration of 300 nanoseconds, value of an electron current in a pulse \( \approx 2.0 \) A and pulse frequency of 150 Hz.

The accelerating section produced by BINPh is used in the project. Sections of Stanford linear collider (SLAC) with energy increasing 35 MeV/m are prototypes for it.

The accelerator LUE-200 consists of electron gun, buncher, two accelerating sections, RF-power supplies - klystrons 5045 (SLAC) on 67 МВт, focusing system and other technological systems.

ELECTRON SOURCE

The electron source (electron gun) represents two-electrode system (the cathode - the anode) with the hollow earthed anode and isolated filament shielded cathode. The gilt tantalic wire netting of 0,1 mm thick and 2×2 mm² cell is located in the anode orifice. The pulse from thyratron modulator moves to cathode.

Design objectives of the electron beam produced by the gun are:
- electron energy - 200 keV,
- maximal beam current in a pulse-2.5-3.5 A,
- pulse duration of a beam current - 350 ns,
- the cross-section size of a beam - \( r = 4 \) mm,
- beam emittans (not more than)-\( \leq 0.01 \pi \) cm rad,
- energy dispersion - \( \leq 2 \) keV.

THEORETICAL (CALCULATED) PART

The electron source was developed on the basis of existing electron gun intended for a voltage of 300 kV [3].

The optimization task included requirements to a magnetic field of the cathode area and requirements to parameters of the electron beam, which sizes must not exceed aperture restrictions on the gun outlet, and also emittans minimization.

Magnetic field was formed with the help of the basic solenoid in the drift interval of the chamber. The field zeroing in cathode areas was made with the help of the antisolenoid and the magnetic shield.

For improvement of beam parameters netting was offered to use in anode. The net position was got out from requirements to the perveans. The initial geometry of cathode electrode has been chosen according to Pirs optics. Lengths and diameters of the solenoid and the antisolenoid were got out according to constructive restrictions.

Position of solenoids, thickness and form of the magnetic screen, form of the cathode electrode and net position in the anode orifice were optimized by means of computational modeling of electron dynamics with the help of program SAM.

The parameters and electron gun geometry were calculated with the help of software package SAM v3.0 (developed in Budker INPh the Siberian Branch of the Russian Academy of Science, M.Tiunov). This program allows to compute electrostatic and magnitostatic problems in axial symmetry systems.

Simulation procedure includes input of the real electron gun geometry (cathode, control electrode, wire net) and magnetic fields geometry (solenoid and antisolenoid) in axial symmetry and modeling of electron beam parameters at various characteristics of the cathode, electrodes and configurations of the electric and magnetic fields.

The following parameters for solenoids and magnetic shield have been chosen as a result of the optimization:

- The basic solenoid: length 10 cm, internal radius 5.75 cm, external radius 8.5 cm, 3850 A• turn, the maximal field 290 Gs, distance from the cathode up to the solenoid center 21.7 cm.
- The antisolenoid: length 3.8 cm, internal radius 8.8 cm, external radius 10.8 cm, 380 A• turn, the maximal field 40 Gs, distance from the cathode up to the solenoid center 12 cm.
The magnetic screen: thickness of 1 cm, internal diameter of 10 cm, external diameter of 29.2 cm, distance from the cathode 9.7 cm.

It is possible to generate the following magnetic field configuration in the gun working area:

![Magnetic Field Configuration](image)

**Fig. 1: Distribution of a magnetic field in cathode area**

The form of the cathode electrode was selected by means of form transformation of the initial Pirs electrode with the help of the conjugate curves.

Special emphasis was given to the relative position of the cathode emitting surface and the cathode electrode. Edge electrons cause deterioration of angular dispersion. As a result of modeling the following geometry (fig. 2) has been chosen.

**Fig. 2: Geometry of electron gun**

The form of the cathode electrode was selected by means of form transformation of the initial Pirs electrode with the help of the conjugate curves.

The cathode stem, welded in one block with the second isolator through which the negative voltage pulse and the termocathode filament voltage moves, is connected to the cathode case by flanges. Together with the anodic case it forms the vacuum chamber of the electron gun.

This focusing solenoid is installed directly after the ferromagnetic shield behind an anode orifice. Together with the first accelerator lens ML2 it serves for keeping necessary cross-section sizes of a bunch in the transition region between the gun and the accelerator input.

In the anode orifice at calculated distance (in this case it is 31 mm) the net unit is placed. Such optics allows to exclude influence of the anodic orifice calculations and to use model of the p-n junction diode. Electron bunch forming is carried out by a magnetic field of solenoid ML1 which center is on distance of 217 mm from the cathode. The solenoid has a rectangular cross-section winding with internal diameter 170 mm and external diameter 170 mm; winding extension is 100 mm. Butts of the solenoid case are cooled by water. That allows to bring the density of the excitation current up to 3,5 A/mm², and the magnetic field in the solenoid center on the axis up to 500 Gs.

The steel magnetic shield of 10 mm thickness with external diameter of 292 mm and installed external ring L = 35 mm allows to reduce the residual solenoid field in the center of the cathode to 5 Gs. If the antisolenoid is turned on (~ 15 % of the excitation current of the solenoid) the magnetic field in the center of cathode turns into zero.

On these conditions beam emittans decreases ~ for 20 % in comparison with experiments when the antisolenoid was not powered and the magnetic shield was not installed.

**PULSE MODULATOR**

The modulator for the supply of the pulse transformer of the electron gun LUE-200 together with the equipment (so-called pulsed system) represents thyatron generator with full discharge of the artificial
form line FL (a line with concentrated parameters) on inductive load (that is pulse transformer EP) [4].

The thyratron modulator includes:

1) an artificial forming line with concentrated parameters,
2) the switchboard - pulse discharge thyratron TGI1-2500/50,
3) a system for charge of a forming line,
4) a system for charging voltage stabilization,
5) power supply systems, control system.

EXPERIMENTAL RESULTS

After adjustment of modulator forming line on resistive load $R_n=300$ Ohm a pulse transformer with an equivalent of a beam loading and power supply systems of electron gun has been connected to its output.

The equivalent load is placed in a special water-cooled case filled with transformer oil. Output pulse voltage has been regenerated after long training with gradual increase of the high voltage and pulse recurrence rate on a transformer loading of about 200 kV 50 Hz.

The forming line of the modulator was reconstructed in appropriate way to equivalent output resistance "equivalent of loading || electron beam ".

In this experiment the loading equivalent carried out the role of a ballast resistor in order to prevent breakdowns in the gun vacuum system in case of cathode emission absence. As a result of two-week training the steady mode 175 kV 5 A 25 Hz has been achieved at pulse duration on top about 0,5 μs.

The diameter of the beam which has been let out in the atmosphere through a 80 microns titanic foil, was ~ 5 mm (maximally focused bunch at a solenoid ML1 excitation current equal to 3,1 A). To increase group rate to 50 Hz the current of the focusing solenoid was reduced to 1,5 A in order to prevent membrane thermal burn-through.

The beam diameter has increased up to 1 cm. The steady operating mode of the electron source has been fixed during several tens of shifts. The further growth of a voltage and frequency is now limited to opportunities of the charging system.

REFERENCES

