

PROJECT "IREN". CURRENT STATUS

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The pulsed source of Intense REsonance Neutrons (IREN), similar to the source-booster LUE-40-IBR-30 that operated at JINR till 2001, traditionally represents a combination of a driver – a linear electron accelerator LUE-200 – and of a target-converter. At the first stage of realization of the IREN project it is planned to use a non-multiplying target-converter with truncated pulse duration. An electron gun (a source of electrons) for LUE-200 was created and tested with the following parameters: beam current up to 5 A, electron energy up to 200 keV, repetition rate 50 Hz, pulse duration 400...500 ns.

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The electron gun represents a two-electrode system (cathode-anode) with the hollow earthed anode in whose aperture a grid of gilt tantalum wire, 0.1 mm thick, with a cell of $2 \times 2 \text{ mm}^2$ is located, and the isolated heated screened cathode to which comes the pulse voltage from a thyatron modulator.

The design parameters of the electron beam on the output of the electron gun: electron energy 200 keV, maximum beam current in a pulse (2.5...3.5) A, pulse duration 350 ns, transverse size of the beam $r = 4 \text{ mm}$, energy spread $\leq 2 \text{ keV}$, emittance $\leq 0.01 \pi \cdot \text{cm} \cdot \text{rad}$. Fig. 1 shows the geometry of the electron gun.

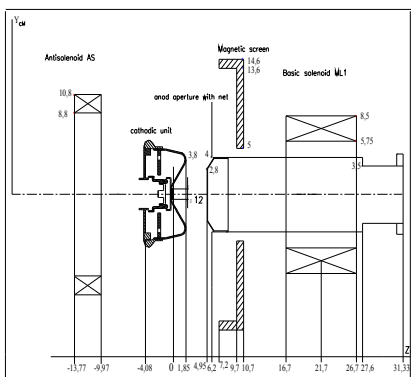


Fig. 1. Electron gun geometry

During optimization, the following parameters for the solenoids and magnetic screen have been chosen:

1. The main solenoid: length 10 cm, inside radius 5.75 cm, outside radius 8.5 cm, 3850 A×turns, maximum field 290 G, distance from the cathode to the solenoid centre – 21.7 cm.

2. The antisolenoid: length 3.8 cm, inside radius 8.8 cm, outside radius 10.8 cm, 380 A×turns, maximum field 40 G, distance from the cathode to the solenoid centre – 12 cm.

3. The magnetic screen: thickness 1 cm, inside diameter 10 cm, outside diameter 29.2 cm, distance from the cathode – 9.7 cm.

A negative voltage pulse with an amplitude of up to 200 kV is applied from the pulse raising transformer to the cathode of the electron gun successively through two isolators from air via oil to vacuum. The first isolator made of plexiglas, serving at the same time as a capacity for the transformer oil in which the second isola-

tor made of molybdenum glass is immersed, is connected to the earthed cooled case of the electron gun. A standard cathode unit from klystron KIU-12, processed at the manufacturing plant, is used as the second isolator "vacuum-oil". On its cathode leg, instead of the heater-cathode system of KIU-12, a block, developed and produced by us, which contains the heater-cathode unit of the Electron RF Lamp GS-34 with the cathode diameter of 12 mm and a removed grid electrode, was installed. According to Pierce optics, a new focusing pre-cathode electrode was also produced. The cathode leg, welded into a uniform block with the second isolator through which the negative pulse voltage and the heating voltage of the thermocathode is applied, is connected by flanges to the cathode case and together with the anode case forms the vacuum chamber of the electron gun.

On the surface of the second isolator, the anti-solenoid is placed at the cathode case of the gun in the oil cavity of the first isolator. It is intended, together with the ferromagnetic screen mounted outside the anode case of a special form, to reduce up to zero the magnetic field of the main solenoid ML1 in the cathode area. This focusing solenoid is installed directly after the ferromagnetic screen behind the anode aperture and serves, together with the first lens ML2 of the accelerator, for keeping the necessary transverse sizes of the beam in the transition area between the gun and the input of the accelerator.

At the calculated distance in the anode aperture (31 mm in this case), a grid unit is located. Such optics allows one to exclude the influence of the anode aperture in calculations and to use the plane diode model. The formation of an electron beam is done by the magnetic field of the ML1 solenoid whose centre lies at a distance of 217 mm from the cathode. The solenoid has a rectangular cross-section winding with the inside diameter of 115 mm and the outside diameter of 170 mm; the winding length is 100 mm. The ends of the solenoid case are cooled by water, which allows bringing the density of the excitation current up to 3.5 A/mm^2 and the magnetic field in the centre of the solenoid on the axis – up to 500 G. The steel magnetic screen, 10 mm thick, with the outside diameter of 292 mm and with an outer ring $L = 35 \text{ mm}$ installed, makes it possible to reduce the residual field of the solenoid in the cathode centre up to 5 G, and with the switched antisolenoid (~15% of the solenoid excitation current) the magnetic field in the cathode centre turns to zero. The beam emit-

tance thus decreases by ~20% in comparison with experiments when the antisolenoid was not powered and the magnetic screen was not installed.

As a result of experimental tests, the steady mode 175 kV 5 A 50 Hz has been reached at the on-top pulse duration of the order of 0.5 μ s. The diameter of the beam, which was emitted to the atmosphere through a 80 micron-thick titanium foil, thus constituted ~5 mm (the maximum focused beam at the excitation current of the solenoid ML1 is equal to 3.1 A).

At present, the manufacturing of the new pulse transformer (PT) for the pulse modulator of the electron source is being completed. It is mounted in a rectangular tank of 800×800×500 mm made of stainless steel and filled by transformer oil. The core of the PT is made of two oval magnetic circuits from the pulse transformer of KIU-12. The primary and secondary windings are executed by a wire with fluoroplastic insulation on plexiglas frames. The transformation ratio of the PT is equal to 6.25. The forming line of the modulator (in this case double – DFL) for feeding the new pulse transformer has 2×8 links consisting of (400...450) pF condensers and of solenoids with adjustable inductance of $L_{mid} \approx 5.5 \mu$ H.

A source of RF-power No.1 for klystron 5045 is being mounted on the permanent site of the IREN facility. The in-house installation of modulator No.1 with the forming line on condensers K75-35 24 nF and on solenoids with the adjustable inductance nominal value of 1.6 μ H, produced at JINR's LPP, has been completed. Also installed was the high-voltage power supply system of the OLIVIN station, produced at RIPR, St. Petersburg. Complex adjustment of the high-voltage source (modulator No.1) for the loading equivalent is planned for October–November 2005.

Tests have been carried out at high level of the RF-power of the SLED multiplication system and elements of the RF feed buncher system and of the first section of the accelerator (the directional coupler, the phase shifter and the power regulator).

For effective acceleration of the rather short pulse current, the optimal mode is the mode of reserved energy in the accelerating sections, which is realized also in the ac-

celerating structure on a running wave if the SLED multiplication system, produced at BINP, Novosibirsk, is used.

The system of RF-power multiplication consists of two high-quality cylindrical resonators, excited on H_{015} wave, and of a 3-dB bridge. Measurements of the parameters of the RF-power multiplication system were done at the low level of input power. The scheme of the measurements is shown in Fig.2.

A signal with frequency $f = 2856$ MHz from the driving generator was coming to the input of the pulse power amplifier through the 3-dB coaxial bridge. This bridge halved the power between the amplifier input and the power meter. The power meter was necessary to control the RF-power coming to the input of the pulse amplifier to avoid burning it. For starting the modulator of the pulse power amplifier and for starting the pulse generator G5-15, from which the signal was given for shifting the fluctuation phase of the driving generator to 180°, the pulse generator G5-54 was used. A measuring directional coupler was installed on the input of the power multiplication system to control the falling and reflected waves. The same coupler was installed on the output of this system before the matched load to control the output signal.

A RF-power signal with pulse duration of 3.5 μ s was given on the input of the power multiplication system. After 2.0 μ s the phase shifter of the driving generator to 180° was switched for 0.5 μ s. In terms of the amplitude of the output signal the value of the multiplication ratio was approximately 4.

After “cold” measurements on a full-scale RF stand, tests of the power multiplication system were performed at a high-level power.

It is seen on the oscillogram (Fig. 3) that the amplitude of the signal on the output of the power multiplication system is 2 times greater than the amplitude of the input signal, and since $P \sim I_{det}^2$, as we work in the linear part of the detector performance, the power multiplication ratio is about 4. During checking of the power multiplication system, thermostabilization of the resonators was not conducted (the working temperature of resonators should be stabilized), nor was checked the tuning of the resonators for the frequency of 2856 MHz.

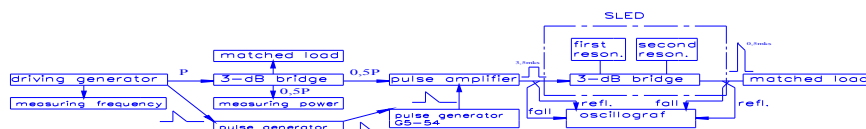


Fig.2. The scheme of measurements at low-level power

The results of testing meet the requirements for the power multiplication system stipulated by the project. The final adjustment of the power multiplication system will be made during its installation at the permanent site within the system of RF-power supply of the accelerator LUE-200.

From the output of the first klystron, the RF-power of about 60 MW moves along the rectangular vacuum

waveguide with a cross-section of 72×34 mm to the input of the directional coupler where it is divided into two parts. Its greater part is applied to the input of the SLED power multiplication system and then to the first accelerating section.

The line of the RF feed buncher includes the directional coupler, the power regulator, the phase shifter,

vacuum windows, small-power waveguide loads, and the measuring directional coupler.

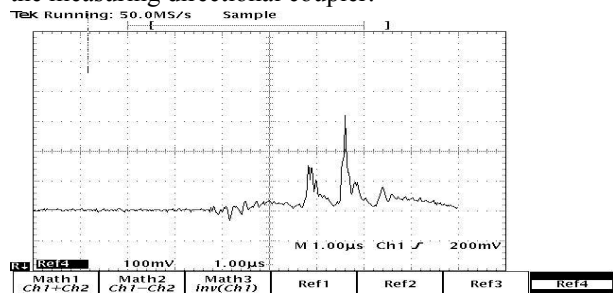


Fig.3. The oscillogram of the signal at the output of the power multiplication system

By means of the directional coupler, some of the power from the output of the first klystron divides into the line of the feed buncher. The amplitude and the phase of fluctuations coming to the buncher are set and regulated with the help of the power regulator and the phase shifter.

As power regulator we use an adjustable coupler which was executed based on two waveguide bridges and an adjustable phase shifter with phase changing from 0 up to 180°. This power regulator has the following advantages: the absorbed power dissipates in external loading, which allows one to provide the working capacity of the phase shifter at sufficiently high levels of power (in fact it is limited by the electric strength of the wave guide); the value of the voltage standing wave ratio from the input of the power regulator does not depend on the coupled attenuations, the power regulator provides a rather large range of regulation of attenuations (from 0 to 20-25 dB).

The directional waveguide coupler is intended for branching some of the output power of the first klystron for the feed buncher. The directional coupler represents a two-hole coupler with connection along a narrow wall which provides a higher electric strength. The calculated transition attenuation of the coupler is close to 17 dB.

The block diagram of measurements of the phase shifter parameters consisted of a measuring generator, an uncoupling attenuator, a measuring line and of the phase shifter. Changes of the phase were measured by the measuring line on the moving of the voltage unit in the line. The results of these measurements are shown in Fig.4.

It is seen from the results of measurements that at moving the piston of the phase shifter the phase.

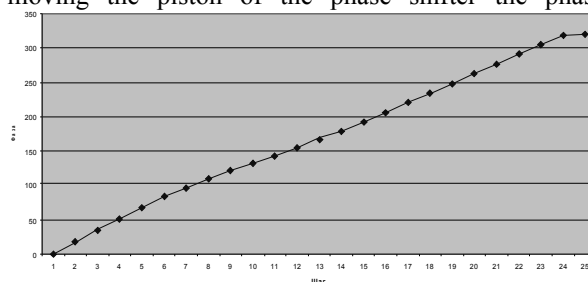


Fig.4. The results of phase measurements variation from 0 up to 320°

The block diagram of measurements of the power regulator parameters consisted of the driving generator, a frequency meter, the pulse power amplifier, the power regulator and of the power meter. From the power amplifier the signal was given to the input of the power regulator and was measured on the output by the power meter. The results of these measurements are presented in Fig.5.

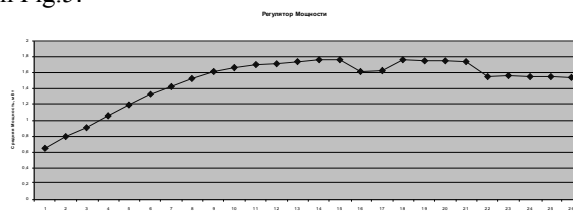


Fig.5. The results of measurements of the power regulator parameters

ПРОЕКТ "ИРЕН". СТАТУС, СОСТОЯНИЕ

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Интенсивный импульсный источник резонансных нейтронов ИРЕН представляет собой традиционную комбинацию из драйвера – линейного ускорителя электронов ЛУЭ-200 и мишени-конвертера. На первой стадии выполнения проекта ИРЕН запланировано использовать неумножающую мишень-конвертер с ограниченной продолжительностью импульса. Создана и испытана электронная пушка (источник электронов) для ЛУЭ-200 с параметрами: ток пучка до 5 А, энергия электронов до 200 кэВ, частота повторения импульсов 50 Гц, длительность импульса электронов 400...500 нс.

ПРОЕКТ "ИРЕН". СТАТУС, СТАН

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Інтенсивне імпульсне джерело резонансних нейтронів ІРЕН являє собою традиційну комбінацію із драйвера лінійного прискорювача електронів ЛПЕ-200 і мішені-конвертера. На першій стадії виконання проекту ІРЕН заплановано використати непримножуючу мішень-конвертер з обмеженою тривалістю імпульсу. Створена і випробувана електронна гармата (джерело електронів) для ЛПЕ-200 з параметрами: струм пучка до 5 А, енергія електронів до 200 кеВ, частота повторення імпульсів 50 Гц, тривалість імпульсу електронів 400...500 нс.