IREN STATUS: NEW ELECTRON LINAC DRIVEN INTENSE RESONANCE NEUTRON SOURCE *

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Abstract

Recently, JINR (Dubna) decided to erect a new accelerator driven intense resonance neutron spectrometer [1] Specifications in terms of output parameters are as follow. The integral neutron yield is approximately 10^{15} neutrons per second. The neutron pulse duration is approximately $400ns$. The repetition rate is $150Hz$. IREN source consists of a S-band linac, a multiplying target as a converter and a plutonium subcritical core. The present status of the S-band linac systems will be addressed.

I. Introduction

Frank Laboratory of Neutron Physics is erecting a new pulse neutron spectrometer. The neutron source consists of three parts: a $200MeV$, $10kW$, $250ns$ S-band linac, a photoneutron target and a plutonium subcritical core.

The intense resonance neutron source, (so called IREN) [1], is designed for investigations in the resonance neutron energy range. It would also provide good opportunities for experiments with fast ($E_n \leq 5MeV$) and thermal neutrons, specifically for thermal neutron measurements in condensed matter physics. The new source would complement the experimental possibilities of the stationary neutron sources of Grenoble, Gatchina, etc., at which experiments with thermal neutrons are carried out, (as they were in the study of parity violation effects in neutron interactions), and also of the pulsed neutron sources — GELINA, FAKEL, ORELA, LU-50 — operating with linear electron accelerators, which provide optimum conditions for investigating various averaged effects over fast neutron range.

An idea to use the combination of an electron accelerator as an injector and a reactor core as a neutron multiplication target is not only a tribute to tradition [1] but also reflects our desire to have the advantage over other time-of-flight, high resolution, neutron spectrometers, specifically over proton accelerator-based ones. This combination would allow:

- reduction of the requirements for electron accelerator parameters and thus have a safer operating machine;
- reduction (by an order of magnitude or even more) of the construction cost;
- have a much cheaper operating machine, both with respect to power consumption and the number of the maintenance staff;
- use of the entire infrastructure of the now existing spectrometer, including buildings, flight paths, experimental pavilions, part of the research instruments and the accelerator power supply system.

The IREN project is optimized for investigations with resonance neutrons and designed to have the parameters given in Table 1 (for comparison, the parameters of the existing IBR-30 booster are also indicated).

Table 1

Parameters	**IREN**	**IBR-30/ LUE-40**
Electron beam energy, MeV	200	40
Average beam power, kW	10	2.5
Electron pulse duration, ns	250	1600
Repetition rate, Hz	150	100
Beam current, A	1.5	0.3
Neutron multiplication gain	28	200
Integral neutron yield, n/sec	10×10^{15}	0.5×10^{15}
Fast neutron pulse duration, ns	400	4500

II. Layout of the System

A schematic layout of the IREN facility is given in fig. 1. The same IBR-30 and LUE-40 building will be used for the placement all IREN systems. The electron gun (1) delivers a pulsed electron beam. The beam here is accelerated up to 200 keV. After that the beam is driven downstairs to buncher and then to the first acceleration section (2). The beam is accelerated with a high gradient of $35MeV/m$. The second section (5) is placed in floor hole directly after first one. The final beam energy will be $\approx 200MeV$. The focusing system consists of two parts. The solenoidal field (8) is applied between the end of e-gun and the entrance of the second section. Four pairs of quads (9) guide the beam to the target (10). The convertor is a source of photoneutrons produced in the (γ, n)- reaction as a result of electron bremsshtralung of the accelerator beam. The converter is surrounded by a core with fuel elements. Converter and core are located in the reactor hall of the IBR-30 building. The core is made up of 124 plutonium fuel elements, similar in construction to the fuel elements of the IBR-30. Fuel elements are combined in groups forming fuel assemblies.

III. Technical Aspects of the Electron Linac-Driven IREN Source

The linac project was designed in INP (Novosibirsk) by the A. Novokhatsky team [2]. A background of the design was the use of S-band SLAC 5045 klystrons. Both the injector of ϕ-factory

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[1] JINR has a old facility IBR-30, which was build more 30 years ago and still operated up to now

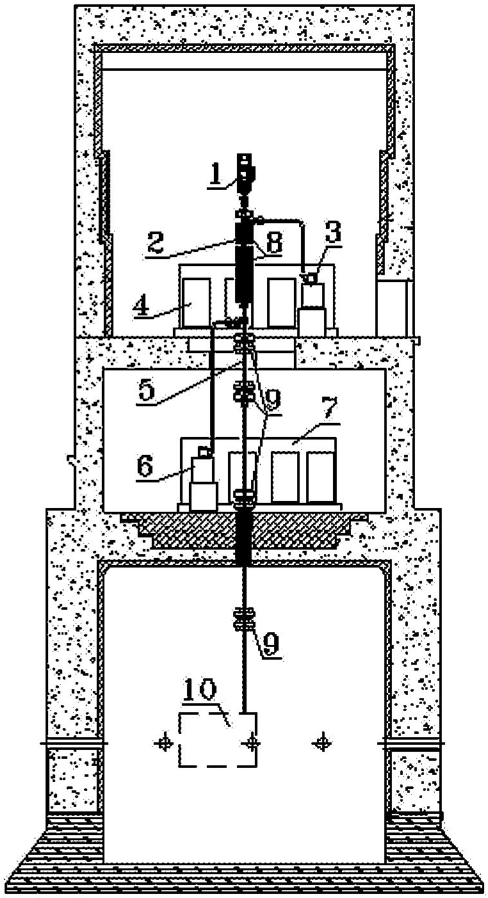

Figure. 1. Layout of the IREN facility

and the linac for IREN had been designed on the basis of the 5045 klystron used as high power pulse RF-sources.

A. The Electron Gun

A triode-type Koontz-like thermonic gun has been designed for a vertical placing. INP (Novosibirsk) will supply a cathode-grid node for the e-gun and a high voltage ceramic feedthrough while the rest of the e-gun nodes will be developed and manufactured at JINR. The electron gun consists of a high voltage DC power supply, a low voltage DC power supply for the grid driver, the grid driver itself, a high voltage insulator and a cathode assembly. The ceramic insulator in the gun is designed to withstand the maximum system voltage under normal atmospheric pressure. The cathode magnetic field on the cathode surface is zero. A vacuum pressure of about $10^{-9} Torr$ is provided by a pumping rate of about 60 liters per second.

The agreement regulating the working relationship between Frank Laboratory Neutron Physics and other JINR Laboratories for creation of the e-gun is at the final stage. The Contract with INP (Novosibirk) for manufacturing and shipping the high voltage feedthrough ($200kV$) and the cathode-grid unit has been prepared.

Table 2

Energy of electrons	$200keV$
Peak current	$10A$
Pulse width	$250ns$
Repetition rate	$150Hz$
Emittance less than	$0.01\pi \cdot cm \cdot rad$
Time jitter less than	$1ns$
Energy spread less than	$2keV$

B. Buncher, Accelerator Sections, SLED-cavities

These main linac elements will be designed, produced and shipped to JINR by INP (Novosibirsk) at the beginning of 1997.

The electron capture efficiency up to 55% in the energy range $\triangle E/E = 3\%$ can be reached with an initial current of $10A$. Parameters of the acceleration sections is shown in Table 3.

Table 3

Operation mode	$2\pi/3$
Operation frequency	$2856MHz$
Section length	$3030mm$
Number of accelerating cells in section	85
Period	$34.98mm$
Disk aperture radius	$25.6mm$
Cavity radius	$83.7mm$
Disk thickness	$6mm$
Overvoltage coefficient	1.7
Group velocity	0.02
Quality factor	$1.3 \cdot 10^4$
Shunt impedance on unit length	$53\text{M}\Omega/m$
Accelerating gradient	$40MeV/m$

In the first quarter of 1995, obligations for the Contract on design, manufacturing, assembling and tuning of the IREN linac accelerating system were drawn up. INP (Novosibirsk) as the head organization, will design and create the buncher, two accelerating sections and the SLED-cavities for two klystrons, and will also carry out adjustment of the nodes which are being created at JINR. The work is being carried out according to the Contract time schedules.

The work on design of the RF-feeder is being performed at the Moscow Engineering Physics Institute and at the power stacks of ”ISTOK” (Phryazino, Moscow region). This work is in the final stages: manufacturing of the feeder elements is almost complete and they could be shipped to JINR after ”cool” tests at the nominal power of the 5045 klystron.

C. Modulators for the 5045 klystrons

The average modulator power consumption is $\approx 130 - 140kW$. Several units of the Russian M-250 modulator had been designed and manufactured for the updating of the ErPhI injector before the Russia industry collapsed. According to the Agreement between JINR and Armenia, there is a possibility to use different nodes of M-250's for the IREN source.

The main parameters of the M-250 and the modulator which is necessary to achieve (it was named as M-350) are shown in Table 5

Table 5

Parameter	M-250	M-350
Pulse power, MW	65	150
Tube voltage, kV	50-250	50-350
Output voltage of PFL, kV	20	23.5
Output pulse current, kA	3.6	6.3
Flat top pulse duration, μsec	8.0	3.5
Top flat unevenness, %	± 0.15	± 0.5
Repetition rate, Hz	100	150

The relatively high average power consumption ($\approx 150kW$) by the modulator of the 5045 klystron and the absence (in Russia) of a modulator scheme realization regarding such power have demanded the technical design project of a full scale, stand modulator. This project has been completed for the time being. The high power stand has been set up at the Frank Laboratory and a high power supply has been already created for the 5045 klystron modulator. Strategy for the creation of the 5045 klystron modulator based on Russian standards has been determined by the collaborators of JINR (Dubna), ErPhI (Armenia) and the Russian Institute of Powerful Radioconstruction (St. Petersburg). The scheme of the M-250 Russian modulator will be the basis for the design of the new M-350 modulator for the 5045 klystron (SLAC). It should be noted that several M-250 modulators were manufactured for the OLIVIN acceleration station and stocked at ErPhI. The basic technical decisions for the redesign scheme and equipment composition of the new M-350 modulator have been determined.

Two types of Russian thyratrons were shipped to SLAC (Stanford University) for the purpose of complex high power tests in order to study the possibility of using such thyratrons in the 5045 klystron modulator. For the time being, the first one has already been assembled on the high voltage stand and its tests have been begun. An item for pulse amplitude stabilization of the 5045 klystron modulator has been considered - that it be supplied from the industry network directly. A technical solution was suggested which does not demand the creation of a special highly stable supply. In this case, the suggestion provides for stability of the voltage amplitude in the tube when the modulator is supplied from the industry network used at JINR. It was shown that this task could be fulfilled with the least amount of engineering and industrial effort if the new technical decisions and the OLIVIN station elements could be used.

The relationships between the collaborators on decisions of the questions connected with the new modulator creation have been drawn up. The Armenian government has agreed to ship the part of the OLIVIN station equipment needed to arrange a full scale klystron stand at JINR as Armenia's share of the payment for the JINR budget. Right now this equipment is being prepared for transportation from ErPhI to JINR.

D. Focusing System

The technical specifications for the acceleration focusing system design has been coordinated with INP (Novosibirsk) and accepted by the Laboratory of Nuclear Problems team of JINR. The estimation of tolerances for the focusing system elements is being done according to the time schedule. The work on the construction of these elements has begun. A variant of the separate short focusing solenoids is being designed to reduce the amount of power value consumed from the network. Simultaneously, modelling of the hardware for the power supply system is being carried out.

E. General Layout of the Linac in Existing FLNP Building #43

Fixation of the main acceleration elements relative to the existing linac pavilion has been done. The engineering study of two new M-350 modulator placements at 9.5 m altitude has led to a high equipment concentration and increased demands for the production of an air cautioning system. As an alternative variant, placement of the modulator equipment on two building floors is being considered: the first klystron and its facility being housed at 15.6 m altitude and the second one housed accordingly at an altitude of 9.5 m.

F. Control System Design

Test stand studies of the instrumentation system prototype have begun on the IBR-30 and LUE-40 facilities. The system for measuring the general facility parameters (e-beam current, thermal neutron signal, RF power signals, etc.) can be measured for a definite time interval and stored for subsequent analysis in on-line experiments. A study of the influence of different machine operation modes on the neutron flow parameters is being performed.

IV. Acknowledgement

The JINR IREN linac team thank Mrs. A. Schaeffer for her help in preparing this report.

References

[1] IREN Project, Frank Lab of Neutron Physics, JINR, Dubna, 1994.

[2] Linear Accelerator for Intense Resonance Neutron Sourse (IREN), A. Novokhatski, et al., in Proceedings of the 2nd Workshop on JINR Tau-Charm Factory, p.197, D1,9,13-93-459, Dubna 1994.