IREN TEST FACILITY at JINR*

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Abstract

The **I**ntense **Re**sonance **N**eutron Source (IREN) is under construction at the Frank Laboratory of Neutron Physics (JINR) with the *200 MeV* electron linac (LUE-200) being created as a driver of IREN. The RF beam-off IREN Full-Scale LUE-200 Test Facility (FSTF) assembly is considered as a first needed stage of the Project. The main goals of the FSTF are getting a *35 MeV/m* acceleration gradient using the 5045 klystron and SLED system, as well as testing the RF high power of the linac units and systems. The other linac systems (beam diagnostics, target, etc.) are being tested on the operating *40 MeV* electron linac LUE-40. The FSTF scheme is presented and the examination program is discussed.

Introduction

A new time-of-flight, high resolution neutron spectrometer for investigations in the resonance neutron energy range, using the intense resonance neutron source (so called IREN) [1], is being created by the Frank Laboratory of Neutron Physics (JINR, Dubna).

The IREN designed parameters are:

- integral neutron yield is $\approx 1 \cdot 10^{15}$ *n/sec*;
- neutron pulse duration $\approx$ *400 nsec*;
- repetition rate *150 Hz*.

The IREN source consists of three parts: an S-band *200 MeV* driver electron linac, a photoneutron target as a converter, and a multiplying fissioning core. This scheme is not only a tribute to tradition [2] but also reflects our desire to have the advantage over other time-of-flight spectrometer, specifically over proton accelerator-based ones.

The LUE-200 traveling wave linac conception was designed by the Budker Institute of Nuclear Physics (BINP, Novosibirsk) [3,4] (see Table 1).

Table 1

Beam average power	*>10 kW*
Electron energy	*200 MeV*
Pulse current	*1.5 A*
Pulse duration	*250 ns*
Pulse repetition rate	*150 Hz*
Accelerating gradient	*>35 MeV/m*
Operation frequency	*2856 MHz*
Length	*10 m*

As calculations show, the efficiency of the energy transmission from the RF source to the beam $\approx$ *15%* can be reached. So, to obtain the required *10 kW* average power of the beam, it is necessary to provide approximately *70 kW* power from the RF source. The SLAC 5045 klystron satisfies this demand optimally. Two such klystrons with *150 Hz* repetition rate provide required power. Moreover, the 5045 klystron has a long life time *(≈ 40 000 hours*), and is supplied by the pulse transformer in an assembly.

The IREN project assumes the accelerator and the multiplying target will be positioned in the buildings of the now-oerating LUE-40 & IBR-30 JINR neutron source. The following strategy of the project realization has been accepted: dismantling of the operating IBR-30 installation will be begun only after receipt of a design value for the accelerating gradient of the IREN linac test-facility (see, Fig. 1).

IREN Full-Scale Test Facility

The main goals for creating IFSTF are:

- obtain the *35 MeV/m* accelerating gradient at a 150 Hz repetition rate;
- adaptation of the M-250 modulator for the 5045 klystron;
- accelerating sections RF of the processing and dark current studies;

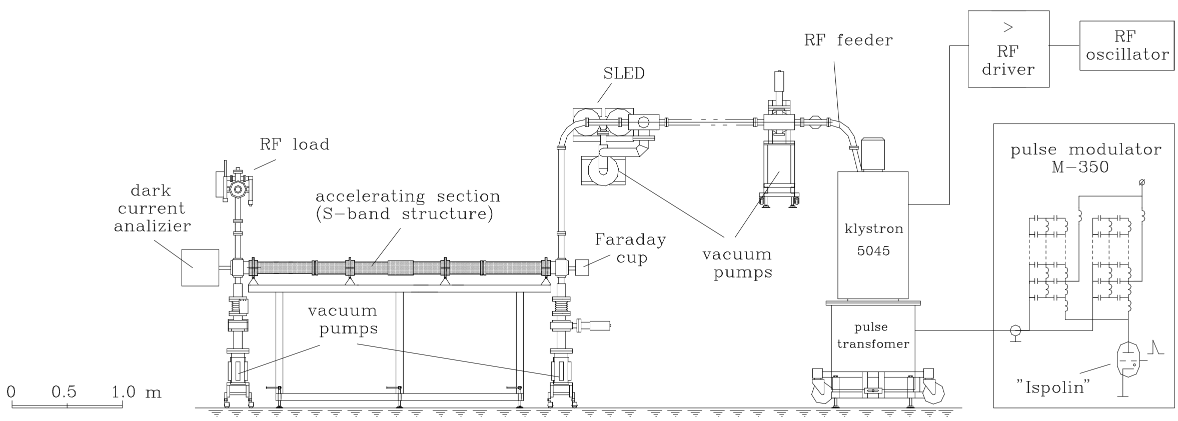

Fig. 1. The IREN Full-Scale Test Facility layout

- testing and certification of the LUE-200 equipment before its installation on the IREN facility.

The FSTF includes the following systems:

- SLAC klystron 5045 and pulse transformer;
- accelerating section;
- pulse modulator M-350;
- SLED-cavities;
- RF oscillator and driver;
- RF feeder;
- RF control and diagnostics systems;
- vacuum system;
- other systems (protection, cooling, thermostat, timer, etc.).

Pulse Modulator M-350 for the 5045 Klystron

The 5045 klystron's modulator (it name, M-350) is based on the pulse modulator M-250 which is a unit of the OLIVIN *20 MW* (*20 kW*) klystron station for the Yerevan Physics Institute (YerPhI) injector linac [5]. OLIVIN stations were constructed and manufactured by the Russian Research and Industrial Institute of Powerful Radioconstruction (St. Petersburg). The M-350 is a pulse modulator with full discharging of the PFN and its resonant charging from a high-voltage power supply.

The parameters of the M-250 and the M-350 modulators are shown in Table 2.

Table 2

	M-250	*M-350*
Pulse power, *MW*	*65*	*150*
Tube voltage, *kV*	*50 - 250*	*50 - 350*
Output voltage of PFN, *kV*	*20*	*23.5*
Output pulse current, *kA*	*3.6*	*6.3*
Pulse flat top duration, *μsec*	*8.0*	*3.5*
Leading edge duration (from 0.1 to 0.9), *μsec*	*<1.5*	*<1.0*
Trailing edge duration (from 0.9 to 0.1), *μsec*	*<2.7*	*<1.8*
RF pulse flat top unevenness, %	*± 0.15*	*± 0.5*
Repetition rate, *Hz*	*100*	*150*
Forming line total capacity, *μF*	*1.05*	*0.7*
Forming line impedance, *Ohms*	*≈ 4*	*≈ 4*
Forming line voltage, *kV*	*40*	*47*
Supply line power, *kVA*	*150*	*200*

One can see that the charging voltage of the PFN for M-250 and for the M-350 differ not more than *20%*. Also, the values of the average charging current practically coincide. It allows us to use the charging circuit of the M-250 in the M-350 modulator after insignificant modification.

The pulse power on the M-350 load exceeds the similar parameter of the prototype by more than twice. The repetition rate of the pulses and average power in the load of the M-350 exceeds , by 1.5 times, the same parameters of the modulator M-250 at duration of the M-350 output pulse 2.3 times smaller than the duration of the M-250 pulse. The discharging circuit of the M-250 (forming device) should be greatly changed.

The PFN consists of two forming lines, which are charged from one source and discharge simultaneously on the joint load through the pulse transformer. The thyratron TGI1-5000/50 (Ispolin) was tested earlier at SLAC and is now used

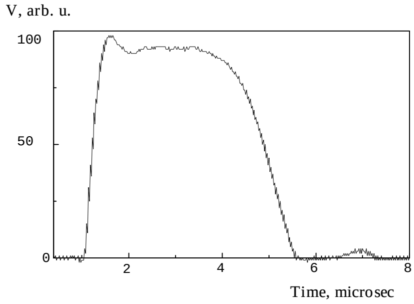

Fig. 2 The shape of the M-350 PFN voltage pulse. (preliminary result).

as the switcher of the M-350 (see. Fig. 2).

Accelerating section

The disk-loaded traveling-wave waveguide is used as an accelerating structure [3]. The damping time of the field in the section is the determining parameter for efficient transmission of the RF energy from the klystron to the beam.

The type of accelerating structure was chosen to maximize this parameter. The geometry of the accelerating cells is optimized for the maximum accelerating gradient necessary to obtain a high average beam power. The accelerating sections has been designed and is being manufactured by BINP.

FSTF RF Supplement System

The RF supplement system consists of:

- master oscillator;
- RF driver amplifier;
- power amplifier using SLAC 5045 klystron;
- SLED system;
- waveguide transmission line (RF feeder);
- RF diagnostics.

The digital controlled RF frequency syntesator with two output channels is used as a master-oscillator. The parameters of the master-oscillator are given in Table 3.

Table 3

Frequency range	*2851.0 ÷ 2860.0 MHz*
Output power (each channel)	*40 ÷ 600 mW*
Phase shift (ch. 2 vs ch.1)	*± 180°*
Discrete value of the phase shift	*± 1°*
Phase switching transition time	*≤ 15 ns*

The pulse preamplifier, which is part of the OLIVIN station, is used as a RF driver.

To get the high accelerating gradient (*35 MeVm*), a SLED system of RF pulse compression is assumed to be used.

It consists of a *3 dB* coupler, two high-Q cavities and a fast 180^o phase shifter. Accurate calculations taking into account the real shape of RF pulse from 5045 klystron shows that for $\tau = 0.5\mu s$, the optimal magnitude of cavity coupling is *5.5*. The SLED system is constructed and being manufactured by the Budker Institute of Nuclear Physics. The parameters of the SLED system are: RF power multiplication coefficient - *3.8*; RF pulse duration shortening factor - *6.5;* SLED transformation efficiency - *0.5*.

There is an opportunity to measure the level and phase of the incident and reflected waves before the input of the section, in the excitation line of the klystron, as well as on its output, in the drive line of the buncher, and on the output of the section. These signals will be used for the control and maintenance of the RF system's given operating mode. The reference phase line will be stipulated for the control of the phase instability measurement and for protection of the klystron, accelerating section, and SLED cavities, as well as of the waveguide line.

Vacuum system

In development of the vacuum system, the following main requirements have been taken into account:

- the average presure must be $\leq 5{\cdot}10^{-9}$ *Torr* in the accelerating section, RF feeder and SLED cavities;
- the system must be degassed at $250\ ^oC$.

The vacuum system is developed by JINR. Part of the vacuum equipment is being designed and manufactured by VAKUUM PRAHA Company.

FSTF Program

The main purpose of the M-350 modulator's test is to obtain of the necessary parameters for the high-voltage pulse on the load according to the technical requirements, which were given in Table 2, as well as the repeatability of these parameters from pulse to pulse, and the reproducibility of the operation modes and operational reliability of the modulator, including the protection system.

The PFN of the M-350 modulator (as well as of the M-250) is being created using the IMK-100-0.05 type capacitotrs, which should operate close to its technical limits. At the initial stage of the creation of the M-350 modulator the specified capacities will be tested and selected according to the following criteria:

- charging voltage up to *100 kV;*
- discharging depth up to *40%;*
- repetition rate up to *200 Hz;*
- discharging pulse duration up to $3\ \mu s$.

The next necessary stage will be the certification of the klystron equivalent for the M-350 and confirmation of the correctness of the technical decisions accepted during the development of the modulator, in particular, the study of the thermal mode of IMK-100-0.05 capacities.

The traditional cycle of the so-called "cold" RF measurements on a low level of RF power should be carried out for the accelerating sections and SLED cavities, as well as for the units of the RF feeder before their installation on the FSTF. The accelerating gradient of the disk-loaded waveguide will be measured by the spectrum of the electron dark current using the magnet analyzer in an energy interval up to *100 MeV* [6]. A significant information on the parameters and operation modes of the linear accelerator can be received by phase measurements in the RF system. First of all, we mean this gives us an opportunity to fix the initial stage of the multipactions in the section or in the SLED cavities. For this purpose, the IFSTF will be equipped with the devices for high ($< 0.5^o$) resolution measurement of phase shifts.

The klystron's RF test includes reception of the nominal output parameters according to its certification, and the measurement of the RF pulse envelope, as well as the sensitivity of the amplitude and phase of the output signal to small deviations of the operation mode parameters**.** The fast (from pulse to pulse) protection and feedback subsystems of the IREN RF system will be also tested.

The other IREN systems (control, electron and neutron beams diagnostics, target, etc.) are being tested on the operating *40 MeV* electron linac LUE-40 and pulse IBR-30 booster-reactor [1]. Test studies of the instrumentation system prototype have begun here. The general parameters of the facility (RF-power signals, e-beam current, e-beam profile, thermal neutron signal, etc.) can be measured for a definite time interval and stored for subsequent analysis in on-line experiments.

Conclusion

Thus, the S-band linac's FSTF is being built at JINR. The reception of the *35 MeV/m* accelerating gradient at the *150 Hz* repetition frequency is the major problem of that facility. The received results will be used in the ditect process of constructing IREN. At the same time a modern experimental base for research in the area of accelerating technology will also be created.

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