INR HIGH INTENSITY PROTON LINAC. STATUS AND PROSPECTS.

A. Feschenko, L.V. Kravchuk, V.L. Serov,
Institute For Nuclear Research, Moscow 117312, Russia

Abstract

The status and the prospects of High Intensity INR Linac are presented. The routine beam intensity is equal to 130 μA. The annual accelerator run duration is about 1600 hours. The main beam user facilities are multipurpose complex for neutron science, isotope production facility and proton therapy facility. The primary activities are accelerator maintenance, modernization of accelerator systems and beam transportation channels, increasing of accelerator reliability, improvement of beam parameters.

INTRODUCTION

The detail information on INR Linac has been given previously [1, 2, 3]. The current report repeats some basic information about the accelerator and describes the current status, prospects and latest activities.

INR Accelerator Complex is located in science city Troitsk (Moscow) 20 kilometers to the south-west from Moscow circular road. It includes the high-intensity proton Linac, Experimental Area with three neutron sources and Beam Therapy Complex as well as Isotope Production Facility (IPF).

In nineties INR accelerator was the second large high intensity and medium energy linac after LANSCE (former LAMPF) at LANL, Los Alamos, USA. Since that time two new linacs of this type with improved parameters have been put in operation (SNS and J-PARC) and several more ones are being constructed or designed now. This activity shows the urgency of the researches made at the accelerators of this type and confirms extreme topicality of the INR research complex.

LINEAR ACCELERATOR

General Description and Parameters

The simplified diagram of the accelerator is shown in Fig. 1. The accelerator consists of proton and H-minus injectors, low energy beam transport lines, 750 keV booster RFQ, 100 MeV drift tube linac (DTL) and 600 MeV coupled cavity linac (CCL, Disk and Washer accelerating structure). There are seven 198.2 MHz RF channels for five DTL tanks and RFQ cavity (including one spare channel) as well as thirty two 991 MHz RF channels for 27 CCL accelerating cavities and one matching cavity (including three spare channels and one channel for equipment tests). Design, obtained and currently available operational Linac parameters are summarized in Table 1.

The accelerator is in regular operation since 1993. 123 accelerator runs with total duration of 45000 hours have been carried out so far including 55 runs of total duration of 16000 hours within the last decade. The availability of the beam for the users is 80÷90 % of the total beam time.

Table 1: Main Accelerator Parameters

Parameter	Design	Obtained	November 2016
Particles	p, H-minus	p, H-minus	p
Energy, MeV	600	502	247
Pulse current, mA	50	16	15
Repetition rate, Hz	100	50	50
Pulse duration, μs	100	200	0.3÷200
Average current, μA	500	150	130

Resent Modifications

The main isotope produced at INR IPF is Sr-82 used for positron emission tomography. The efficiency of isotope production depends on proton beam intensity at the target. The limitation of beam intensity is set taking into account several effects. One of the effects is heating of the target including that within the beam pulse. To decrease the pulse heating the fast raster system has been developed, built and implemented in the beam line to IPF [4]. The system provides a circular scan with adjustable amplitude and the frequency of 5 kHz thus providing one turn of the beam on the target within the 200 μs beam pulse. Due to implementation of this system the tolerable beam intensity for 143 MeV beam has been increased from 100 μA to 130 μA.

In order to increase the beam intensity twice the efforts to increase the beam pulse repetition rate from 50 Hz to 100 Hz have been undertaken. Doubling of the repetition rate will also give the possibility to effectively split the beam between the IPF and the experimental area with the help of the pulsed magnet installed several years ago in the intermediate beam extraction area (160 MeV) providing the 50 Hz beam to each facility pulse by pulse [5]. Though the whole problem has not yet been solved several intermediate results have been obtained:

- The proton injector beam pulse repetition rate has been doubled and reliable operation of the injector has been achieved at 100 Hz [6].
- Accelerating system and RF power supply systems have been tested at 100 Hz.

When testing the RF power supply systems the effect of bi-periodicity of the RF pulses has been found. The effect was due to mains supply and was observed in both accelerator parts. The problem has been investigated and

ISBN 978-3-95450-181-6

generally solved [7]. However the task of replacement of the powerful modulator vacuum tubes by powerful RF tubes arose [8] and the problem of bi-periodicity will have to be newly investigated and solved in future for new vacuum tubes.

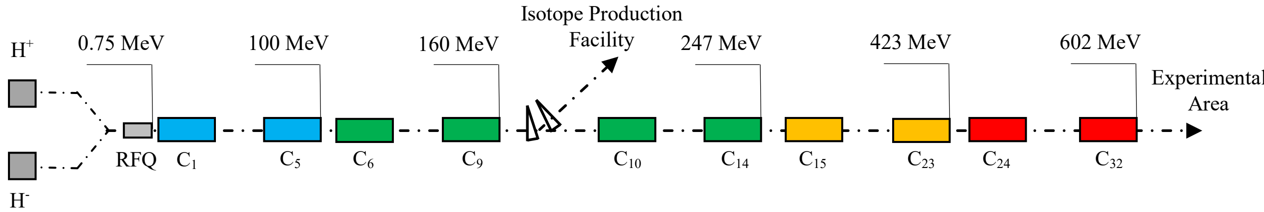

Figure 1: Simplified diagram of the accelerator ($C_1 \div C_{32}$ – accelerating cavities). The sectors of the accelerator are marked with different colors (five sectors totally).

The tests of the accelerating system with 100 Hz repetition rate revealed a catastrophic problem with the first CCL Disc and Washer cavity (100÷113 MeV). Number of RF breakdowns in the cavity increases drastically which makes practically impossible its operation at 100 Hz with the required pulse duration of more than 200 µs. The activity to develop the new cavity based on the novel Cut Disk Structure has started [9].

As mentioned above the accelerator includes the intermediate extraction area where the Isotope Production Facility is located. The IPF is a stationary installation and is foreseen to work with high intensity beam. However the tasks to irradiate different items with low intensity beams arise regularly. Recently a decision to build an irradiation channel for low intensity beams (up to 1 µA) with the energies from 100 MeV up to maximum possible energy has been done and the construction has started at the exit of the accelerator.

EXPERIMENTAL AREA

Experimental Area is shown in Fig. 2. All the equipment of experimental area is foreseen to work with the beam of 600 MeV but now the power supply system is restricted and enables to work with the energies up to 300 MeV. At present the following facilities are in operation: Spallation neutron source IN-06 with a number of multipurpose instruments, 100-ton spectrometer LNS-100 on slowing down in lead, RADEX facility (a modified beam stop) with neutron guides and stations for time-of-flight spectrometry, Beam Therapy Complex.

Initially the main beam for the Experimental Area was foreseen to be H-minus. Splitting of the primary beam into several ones by stripping and further separation in vertical plane was intended. The separated beams were planned to supply to different experimental installations simultaneously. As the beams appeared to be displaced with respect to each other their further transportation was not an easy task as no one beam moved along the axis of the magnetic system. Moreover optimum position of the magnetic elements was not at the same level and they were displaced vertically. In this configuration transportation of even one high intensity beam was not an easy task.

After restructuring in 2014 the transportation channels of the experimental area from the accelerator exit to the experimental facilities have been passed to the accelerator division. After careful analysis of the current status of the channels, available possibilities and the realistic tasks a decision to abandon the multi beam mode with simultaneous beam transportation to several experimental installations has been done. All the electromagnetic equipment has been realigned and installed on one level thus enabling to simplify beam tuning, to reduce requirement to beam parameters, to decrease beam losses and to improve reliability.

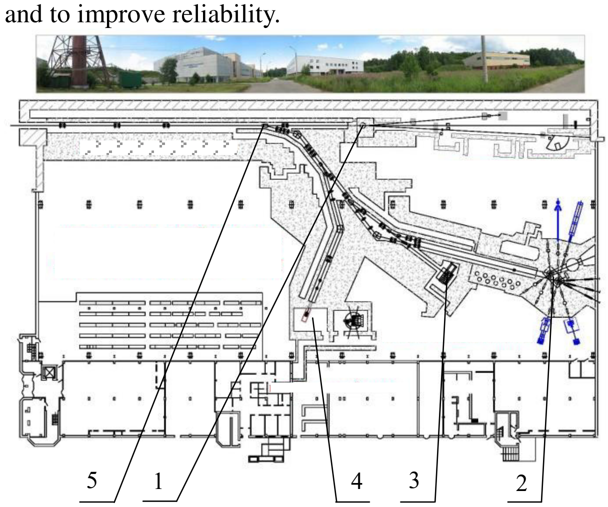

Figure 2: Experimental Area (1 - RADEX facility, 2 - Spallation neutron source IN-06, 3 - LNS-100 spectrometer, 4 – Beam Therapy Complex, 5 – beam separation area).

PROSPECTS

Due to several reasons the design parameters of the linac have never been obtained. Meanwhile some accelerator systems including vacuum system, focusing system, control, diagnostics and conventional facilities work practically in the design mode. At present the accelerator regularly works with the energy of 209 MeV. The available amount of klystrons enables to accelerate the beam up to 247 MeV with minor efforts. It is quite realistic to obtain the energy of 300÷350 MeV but

ISBN 978-3-95450-181-6

essential efforts and expenditures are needed. Increasing the beam intensity above 130÷150 mA requires doubling of the beam pulse repetition rate up to 100 Hz. To solve this task the first accelerating cavity of the high energy part of accelerator must be replaced by a new one and the RF power supply system of the low energy part must be modernized.

Building the irradiation channel at the exit of the accelerator is also considered as a promising improvement enlarging the accelerator functionality.

However the most promising task being discussed and negotiated with international Thorium Energy Committee (iThEC) is an ADS experiment based on INR linac and spallation neutron source IN-06. According to iThEC, INR facility is the most suitable place in the world where the demonstration ADS experiment can be performed at a relatively modest cost and on a relatively short time scale. The subcritical ADS core can be installed in the second compartment of the spallation source which is empty now. The formulated requirements to the accelerator beam do not seem unattainable: proton beam energy 247÷350 MeV, beam intensity up to 250 μA, beam power 25÷90 kW. With these characteristics, it will be possible to study ADS properties up to a thermal power of 2.5 MW, varying the neutron multiplication factor k_s up to 0.98. For the minimum required beam power of 25 kW the thermal power of 1 MW can be obtained with k_s=0.972.To supply the beam to the second compartment of the neutron source the beam line with the length of near 40 m must be built. The main electromagnetic equipment for this line is in hands.

CONCLUSION

The scientific facility based on 600 MeV Proton Linac is in operation at the Institute for Nuclear Research. Permanent modernization of the accelerator and the Experimental Area enables not to only maintain the complex in operational state but also to improve beam parameters and complex capabilities. The existing experimental facilities are the basis for variety of both basic and applied researches.

ACKNOWLEDGMENT

The authors acknowledge the personnel of accelerator division for their contribution to the work.

REFERENCES

[1] L.V.Kravchuk. INR proton Linac operation and applications. Nucl. Instr. and Meth. A 562, (2006), 932-934.

[2] L.V.Kravchuk. Operation and Research Activities at the INR accelerator complex. Proc. of RUPAC2008, pp.137-140.

[3] A.Feschenko et al. Multipurpose Research Complex based on the INR High Intensity Proton Linac. Proc. of RUPAC2012, pp.90-94.

[4] O.Volodkevich et al. Use of Fast Magnetic Beam Raster System for INR Isotope Production Facility. Proc. of RUPAC2014, pp.426-428.

[5] N.I.Brusova et al. Beam Pulse Separation System of INR Linac, Proc. of RUPAC2012, pp.451-452.

[6] E.S.Nilulin et al. INR RAS Proton Injector 100 Hz PRR Operation Mode. Proc. of RUPAC2014, pp.306-308.

[7] A.N.Drugakov et al. Investigation of INR Linac DTL RF System Operation at 100 Hz Repetition Rate, Proc. of RUPAC2012, pp.296-298.

[8] A.Kvasha et al. Development of the INR Linear Accelerator DTL RF System, THXSH0, these proceedings.

[9] I.Rybakov et al. Proposal of the Accelerating Structure for the First Cavity of the Main Part of INR Linac, TUPSA004, these proceedings.

ISBN 978-3-95450-181-6