THE RF SYSTEM FOR RFQ-INJECTOR OF LINAC-20

V.G. Kuz'michev, A.V. Kozlov, Y.B. Stasevich, D.N. Seleznev, K.I. Dorohov, A.V. Kononov
FGBU "ITEP", Moscow, Russia
E-mail: victor.kuzmichev@itep.ru

The RF system of RFQ-injector being built in ITEP is presented. Two-channel RF system of RFQ-injector operates at 145 MHz in pulse mode. Parameters and test results of the channels operated on the dummy load are presented. The pulse output power of 400 kW was reached.

PACS: 29.20.Ej; 84.70.-p

INTRODUCTION

In the framework of the Nuclotron-M project the modernization of injection line is realized. It is planned to replace the 700 kV electrostatic injector of the DTL accelerator LU-20 by an RFQ accelerator. It enables to decrease the potential of the ion source high voltage platform down to 150 kV and as result to deliver on it the 35 kW electric power needed for the ion sources operation [1].

The RFQ accelerator, RF power and control systems are developed by ITEP. The amplifier units, similar to the ones utilized in many accelerating centers of Russia, based on the high-power generator triodes are developed for the RF drive system [2].

The RF system of the existing linear accelerator LU-20 operates in self-exciting oscillation mode. This issues additional requirements for dynamic phase synchronization between RFQ and DTL cavities. The synchronization is achieved by use of a high performance FPGA-based digital Low-level RF system (LLRF).

1. DESCRIPTION OF RF SYSTEM

Block diagram of the RF system is presented in Fig. 1. The RF system consists of two amplifying channels designed to feed the RFQ and the buncher installed inside the vacuum vessel of the DTL. RF channel for RFQ consists of a four-stage preamplifier and the output stage based on the high-power water-cooled triode GI-27AM.

The preamplifier consists of a 150 watt transistor amplifier, four stages based on GI-39B tubes, RF power splitter and combiner. To protect the transistor amplifier, at its output the ferrite circulator with low insertion losses is used.

Since the frequency separation between quadrupole and dipole modes is over 4 MHz, two RF coupler positioned symmetrically is designed for RF power delivering into RFQ resonator.

According simulation RF amplifier with a peak power of about 20 kW is required to supply the buncher. Therefore, the buncher drive channel with two stages based on GI- 39B tube and one transistor amplifier is constructed.

The RFQ cavity works at the same frequency as DTL and the stability of phase difference between the oscillations in these two cavities has to be kept within tolerance of one degree.

The synchronization of RF fields in the cavities realized by the master oscillator modules and the control phase unit developed in framework of the project.

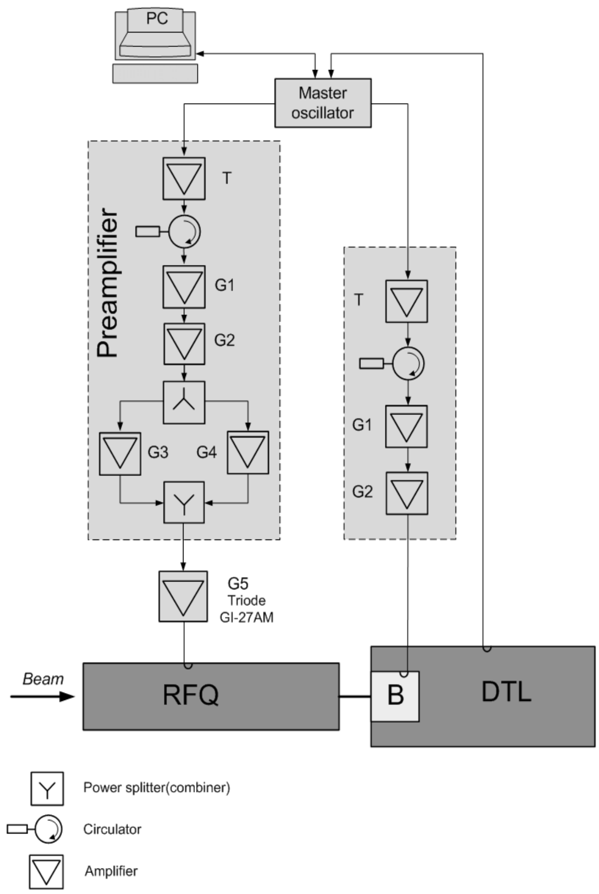

Fig. 1. Block-diagram of RF system: PC – computer, T – transistor amplifier; G1-G4 – generators with GI-39B tube; G5 – final stage; RFQ – accelerator; B – buncher; DTL – LINAC-20

2. MAIN PARAMETERS OF RF SYSTEM

First of all, tests the lamp amplifier stage GI-39B were carried out on. It was necessary to determine the power generated by single lamp on the operating frequency for 150 μs pulse duration. As result it was demonstrated that the lamp was able to produce power up to 30…35 kW, without exceeding the limits of the parameters specified in the data sheet for this product.

In the output stage a powerful generator tube GI-27AM is used. To obtain the required output power, at the input of the tube the power of about 50 kW is needed. The combination of two GI-39B triodes in parallel provides the necessary power level.

A simplified construction of the output stage is shown in Fig. 2. Detailed design of the generator is described in [3].

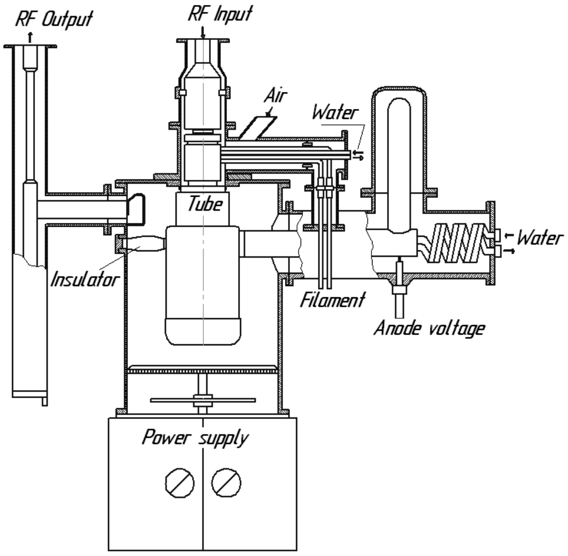

Fig. 2. Design of the final stage RF drive channel

Fig. 3 shows plots of the output RF power, the power consumption and the efficiency of the GI-27AM output stage versus anode voltage. The maximum value of the power gain is 8.5.

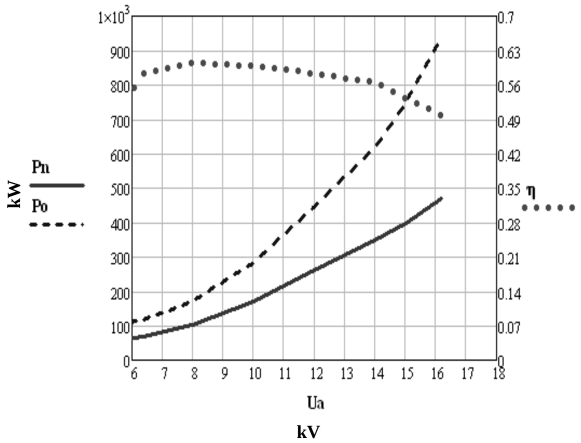

Fig. 3. Output power (Pn), consumption power (Po) and efficiency (η) versus anode voltage (Ua)

Two methods were used to measure the RF power at RF stages. In the first method, used power meter of absorbed power, which implements the method of peak voltmeter [4], in the second - directional coupler to set at the equivalent load. The difference in the measured power is within the error of the instrument.

The main parameters obtained for RF system given in Table 1.

Table 1

Main Parameters of RF system

Operating frequency	145.2 MHz
Pulse length	150 µs
Pulse repetition rate	1p/s
Peak power of RFQ drive channel	400 kW
Peak power of buncher drive channel	20 kW
Anode voltage on the final stage	15 kV

3. MODULATOR

A high-power voltage modulator was designed to supply the anode of RF tubes. The block diagram of the modulator is shown in Fig. 4.

A high-voltage power supply HCP700-6500 sets the voltage of the pulse-forming network in the range from hundreds volts to 6.5 kV with accuracy of 0.1%.

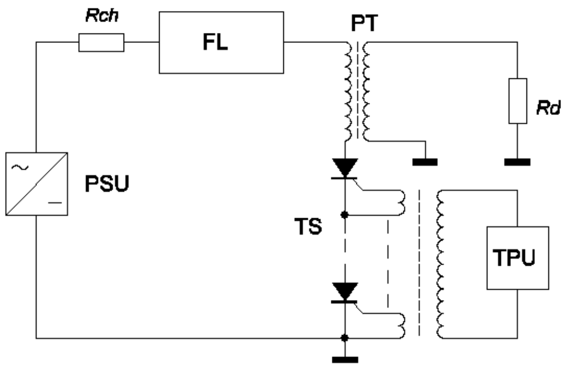

Fig. 4. Block diagram of modulator:
PSU – high-voltage power supply unit; FL – forming line; PT – pulse transformer; Rch – charging resistor; Rd – dummy load; TPU – trigger-pulse unit

A bank of 10 thyristor TB-143-400-12 in series forms a high voltage switch. All components of the modulator are placed in a metallic cabinet with dimensions of 1600×1800×600 cm. The parameters main obtained for modulator are given in Table 2.

Table 2

Parameters of modulator

Pulse power	800 kW
Variation ranging of output voltage amplitude	0…18 kV
Pulse duration by base	150 µs
Amplitude pulse duration	70 µs
Pulse top drop	<1.5%
Amplitude instability	< 1%
Pulse repetition frequency	1 Hz
Supply voltage	220V±5%
Power consumption	2 kW

As a result, selection of the number of cells and the charging line inductances at its input managed to get a pulse from the modulator shown in Fig. 5.

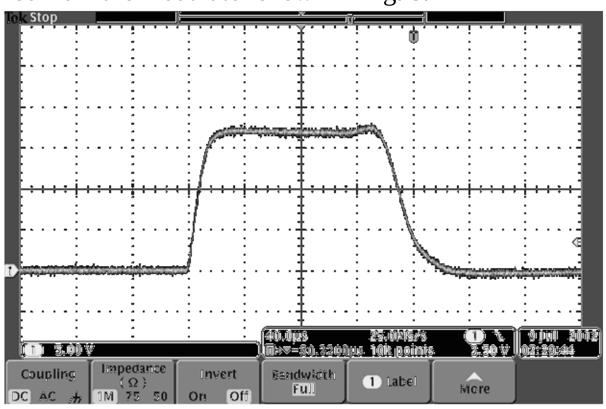

Fig. 5. High voltage pulse from modulator

CONCLUSIONS

The RFQ RF system shows the ability to generate of 400 kW of pulsed RF power on dummy loads. Required power and pulse duration are achieved.

Assembled and tested RF system is ready for further work with accelerator.

REFERENCES

1. A.A. Butenko, A.I. Govorov, D.E. Donets, et al. Modernization of the injection complex nuclotron // *Nuclei, Letters*. 2012, v. 9, №4-5, p. 654-665.
2. A.M. Raskopin, A.M. Kozodaev, V.G. Kuz'michev, V.G. Tsar`kov. The experience of the use GI-39B triode in the mode of increased average power // *XVIII Russian Conference on Charged Particle Accelerators. RUPAC- 2002*, October 1-4, Obninsk.
3. B.P. Murin, V.G. Kuhlman, L.G. Lomize, B.I. Polyakov, A.P. Fedotov. *Linear accelerators ions. V.2. Basic systems.* Oxford: Clarendon Press. 1978, 320 p.
4. M.I. Bil`ko, A.K. Tomashevski. *Measurement of power at microwave frequencies.* M.: “Radio and Communications”, 1986, 168 p.

Article received 22.10.2013

СИСТЕМА ВЧ-ПИТАНИЯ ДЛЯ RFQ-ИНЖЕКТОРА УСТАНОВКИ ЛУ-20

В.Г. Кузьмичев, А.В. Козлов, Ю.Б. Стасевич, Д.Н. Селезнев, К.И. Дорохов, А.В. Кононов

Представлена система ВЧ-питания ускорителя-инжектора с ПОКФ, разрабатываемого в ИТЭФ и предназначенного для замены электростатического форинжектора установки ЛУ-20. Система ВЧ-питания работает на частоте 145 МГц и состоит из двух усилительных каналов для возбуждения ускоряющей структуры и банчера. Приводятся параметры и результаты высокочастотных испытаний усилительных каналов при работе на эквивалент нагрузки. Канал возбуждения структуры с ПОКФ обеспечивает выходную мощность 400 кВт в импульсе.

СИСТЕМА ВЧ-ЖИВЛЕННЯ ДЛЯ RFQ-ІНЖЕКТОРА УСТАНОВКИ ЛУ-20

В.Г. Кузьмічов, А.В. Козлов, Ю.Б. Стасевич, Д.Н. Селезньов, К.І. Дорохов, А.В. Кононов

Представлена система ВЧ-живлення прискорювача-інжектора з ПОКФ, який розробляється в ІТЕФ і призначений для заміни електростатичного форінжектора установки ЛУ-20. Система ВЧ-живлення працює на частоті 145 МГц і складається з двох підсилюючих каналів для порушення прискорюючої структури і банчера. Наводяться параметри і результати високочастотних випробувань підсилюючих каналів при роботі на еквівалент навантаження. Канал збудження структури з ПОКФ забезпечує вихідну потужність 400 кВт в імпульсі.