TEST AND COMMISSIONING RESULTS OF NSC KIPT 100 MeV/ 100kW ELECTRON LINEAR ACCELERATOR, SUBCRITICAL NEUTRON SOURCE DRIVER*

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Abstract

Neutron Source on the base of subcritical assembly has been constructed and is under commissioning in NSC KIPT, Kharkov, Ukraine. The source uses 100 MeV/ 100 kW electron linear accelerator as a driver. The accelerator was designed and manufactured in IHEP, Beijing, China. The accelerator has been assembled at NSC KIPT, all accelerator systems and components were tested and accelerator is under commissioning. Report describes the status of the NSC KIPT 100 MeV/ 100 kW electron linear accelerator. The results of the first tests are presented.

INTRODUCTION

100 MeV/100 kW electron linear accelerator [1, 2] is a driver of the ADS neutron source [3] that is under commissioning in NSC KIPT, Kharkov, Ukraine.

Table 1: Main KIPT Linac Parameters

Parameter	Value
RF frequency	2856 MHz
Beam energy	100 MeV
Beam current (max.)	0.6 A
Average beam power	100 kW
Energy spread (1σ)	1 %
Emittance (1σ)	5×10^{-7} m-rad
Beam pulse length	2.7 μs
RF pulse duration	3 μs
Pulse repetition rate (max)	625 Hz
Klystron power	30MW/50kW
Number of klystron	6
Number of ACC. structure	10
Length of ACC. structure	1.336 m
Gun voltage	~120 kV
Gun beam current (max)	2 A

The main accelerator parameters are shown in Table 1. The general layout of the KIPT neutron source facility is shown in Fig. 1. Taking into account the dependence of generated neutron flux on initial electron energy (see Fig. 2) and cross section of the electron interaction with the target materials, it is clear that chosen accelerator parameters are optimal in order to provide a neutron flux value of about 10^{14} neutron/s.

The accelerator design, manufacturing and system testing was started in February 2010 in IHEP, Beijing, China and basically was completed in February 2013. The assembling of the accelerator in NSC KIPT was started in May 2013. Now, all accelerator system are assembled and installed. The electron beam commissioning was started in October 2016.

ACCELERATOR LAYOUT AND SUBSYSTEMS

The layout of the NSC KIPT neutron source (Fig. 1) is typical for the state-of-art ADS with the accelerator at the second level of the facility and electron beam transportation system that provides vertical beam direction at a neutron generating target and uniform beam distribution at the surface of the target.

Because of nuclear safety reasons and quite high requirements to the electron beam parameters the accelerator-driver should satisfy several demands such as:

- to use traditional, safe and approved technological solutions.
- provide intensive electron beam with small beam sizes.
- provide low beam energy spread in order to minimize electron beam losses along the accelerator.
- provide uniform electron beam distribution at the surface of the neutron generating target.
- provide robust and intensive beam instrumentation system.

Considering all mentioned above NSC KIPT linear accelerator consists of the following subsystems:

1. A ~120 kV triode electron gun with beam current up to 2 A;
2. A 2856 MHz prebuncher;
3. A 2856 MHz travelling wave buncher;
4. Ten ~1.34 m 2856 MHz travelling wave-accelerating structures;
5. An electromagnetic chicane with a collimator to eliminate the electrons with large energy spread.
6. Electromagnetic focusing system (solenoids, quadtrupole) in certain drift spaces between the accelerating structures;

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7. The beam transport line and the beam scanning system with two bending magnets;
8. High power RF system with six klystrons and modulators;
9. Low-level RF control system;
10. Beam instrumentation system;
11. Vacuum system;
12. Support and alignment system;
13. Control system;
14. Facility cooling system.

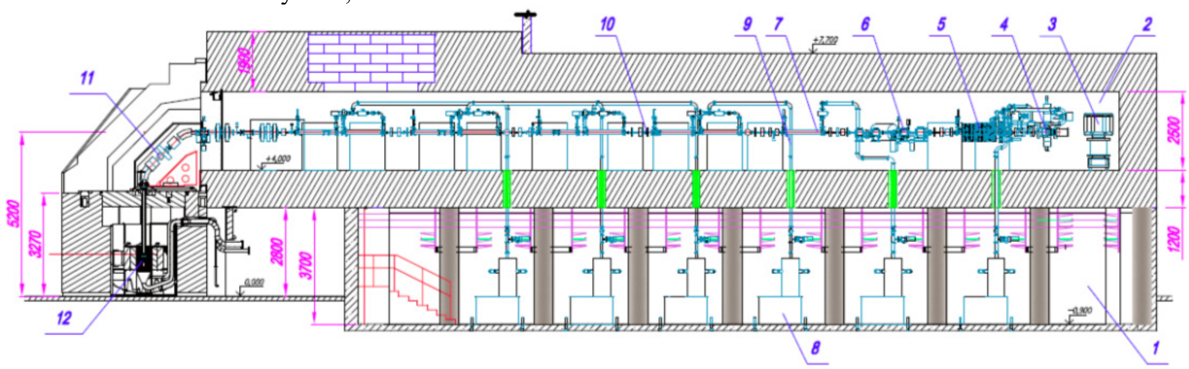

Figure 1: Layout of the accelerator and subcritical assembly systems: 1 is klystron gallery, 2 is accelerator tunnel, 3 is electron gun power supply, 4 is injector part of the accelerator, 5 is the first accelerating section, 6 is chicane, 7 is accelerating section, 8 is klystron, 9 is wave guide, 10 is quadrupole triplet, 11 is electron beam transportation channel, 12 is subcritical assembly.

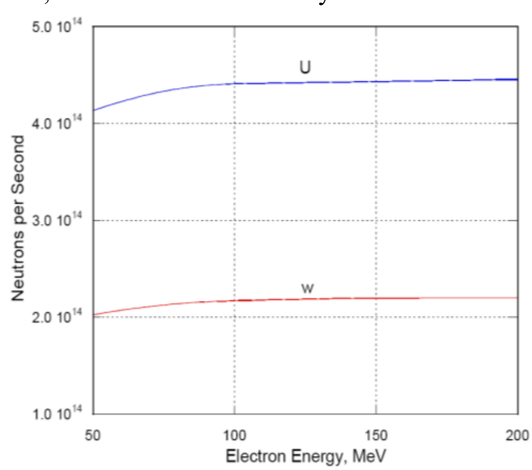

Figure 2: Neutron source flux vs electron energy for 100 kW electron beam power of natural uranium and tungsten target materials.

Figure 3: Testing of the transportation channel vacuum claps at vacuum bench.

ACCELERATOR SUBSYSTEMS ASSEMBLING AND TESTING

The assembling of the accelerator at NSC KIPT has been completed during May 2013 – June 2016. Simultaneously, the technological subsystem tests had been done.

Vacuum System

Vacuum system was assembled, tested and put in operation in accordance with original design [2]. Before installation at the accelerator the last vacuum clasp had been tested for the vacuum seal at separate bench (Fig. 3). Since then the vacuum system was operated without any failure and provides the value of the residual gas pressure of about 3×10^{-9} torr along accelerator and in the waveguide system.

Cooling System

Cooling system that consists of three different cooling loops: 30 C klystron gallery cooling loop, 30 C electromagnetic elements cooling loop (contaminated water), 40 C thermo-stabilization cooling loop was assembled, tested and put in operation in order to provide further accelerator RF conditioning and beam commissioning. During operation period, all cooling loops provide design temperature and tolerances. (30 C ± 1 C, 30 C ± 1 C, 40 C ± 0.2 C respectively).

Survey and Alignment

After assembling of the accelerator equipment in the accelerator tunnel and beam transportation channel the accelerator and facility coordinate system was formed.

The fiducialization of the accelerator electromagnetic elements was carried out and all accelerator elements in the tunnel were installed along accelerator axis with accuracy within 150 mkm. That accuracy meet the accelerator design requirement and provide the design beam losses value and positions.

Triode Electron Gun

Triode electron gun with EIMAC Y824 Tungsten matrix was installed and tested (Fig. 4). Results of beam tests showed the good agreement with design parameters and tests carried out in IHEP, Beijing, China [2]. Now the gun is in operation and is used during beam commissioning with current value of 0.5-0.8 A (Fig. 5).

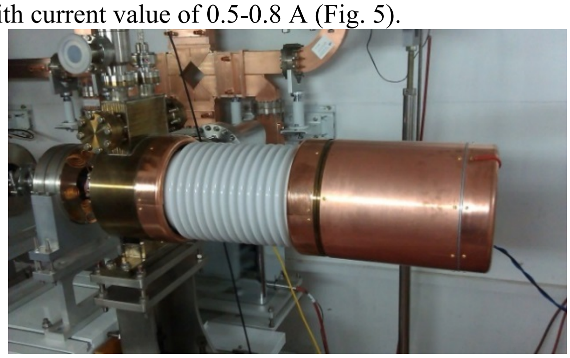

Figure 4: Triode electron gun of the NSC KIPT 100 MeV/100 kW linear accelerator.

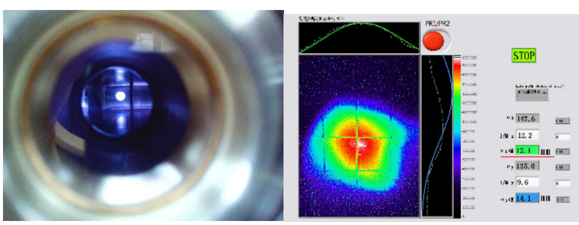

Figure 5: Electron beam at electron gun exit during injection section commissioning (0.5 A).

RF System and RF Conditioning

The RF system with 6 modulators and klystrons has been assembled installed and tested. In the middle of 2016 the RF conditioning of the waveguides and accelerating sections was started with low repetition rate values (5 Hz) and low value of high voltage (5-10 kV). At the moment the accelerator RF system can be operated with 400 Hz and maximum value of high voltage (40 kV). The RF conditioning is still in progress.

The equipment of the beam instrumentation, LLRF and control systems where installed and partly tested. The status of the systems allows to test accelerator injector and to start beam commissioning.

Injector Tests

The injector part of the accelerator was tested in IHEP [3] and after assembling in NSC KIPT. The beam parameters after electron gun and the first accelerating section and after electromagnetic chicane were measured. The electron beam with pulse current of about 0.6-0.8 A, with pulse duration of 2.7 µs, pulse front edges of about 10 ns was transported through the first accelerating section and electromagnetic chicane. The efficiency of the electron beam transportation through the injection section is about 80 %. The estimated beam energy spread after the injector section is about 10 %.

BEAM COMMISSIONING

The electron beam commissioning for the whole accelerator was started in March 2017. As a result of the first experiments the electron beam was delivered to the middle of the transportation channel where the last beam current monitor is installed. The last 45 degree bending magnet was switched off to avoid irradiation of the neutron generating target channel and facility core zone (Fig. 6). The beam commissioning is being carried out with low repetition rate of 2 Hz.

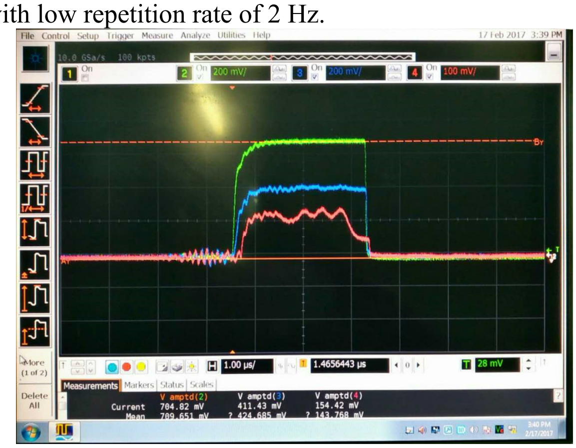

Figure 6: Profile of the electron beam along NSC KIPT 100 MeV/100 kW linear accelerator. Green – after electron gun, Blue – after the electromagnetic chicane, Red – after the first 45 degree transportation channel bending magnet.

CONCLUSION

100 MeV/100 kW electron linear accelerator for the NSC KIPT Neutron Source has been assembled and main accelerator technological systems were tested. The first beam commissioning results showed the correspondence of the realized technical solutions to the original design. The further accelerator adjustment will be done during 2017 year.

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