PROGRESS ON THE CONSTRUCTION OF THE 100 MEV / 100 KW ELECTRON LINAC FOR THE NSC KIPT NEUTRON SOURCE

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Abstract

IHEP, China is constructing a 100 MeV / 100 kW electron Linac for NSC KIPT, Ukraine. This Linac will be used as the driver of a neutron source based on a subcritical assembly. In 2012, the injector part of the Linac was pre-installed as a testing facility in the experimental hall #2 of IHEP. The injector beam and key hardware testing results were met the design goal. Recently, the injector testing facility was disassembled and all of the components for the whole Linac have been shipped to Ukraine from China by ocean shipping. The installation of the whole machine in KIPT will be started in June. The construction progress, injector beam and key hardware testing results are presented in this paper.

INTRODUCTION

The Kharkov Institute of Physics and Technology of National Science Centre (NSC KIPT, Kharkov, Ukraine) together with Argonne National Laboratory (ANL, USA) develops the project of a neutron source based on the subcritical assembly driven by an electron Linac with high average beam power [1].The main functions of the subcritical assembly are to support of the nuclear industry and the medical research. Reactor physics and material researches will be carried out. The goal is to create in Ukraine the experimental basis for neutron research based on safe intensive sources of neutrons.

Two main parts of the neutron source facility are an electron Linac and a beam transport line from the Linac to the target, both of which are constructed by IHEP, China. The Linac should be able to provide 100 MeV beam with average power of 100 kW. The beam line should be able to provide a beam transfer with minimum beam losses and form a homogeneous distribution of the particle density at the target. Construction of such an accelerator with high average beam power and low beam power losses is a technical challenging task, and all components of the machine have to be designed, fabricated, tested, assembled and commissioned elaborately [2-4].

In 2012, the injector testing facility was pre-installed in the experimental hall #2 of IHEP, and the beam and key hardware are tested with satisfying results. In the meantime, the performance of some hardware was also improved by modifying the initial design. Recently, the injector testing facility was disassembled and all of the components for the whole Linac have been shipped to KIPT from China by ocean shipping. In early June, the machine will be assembled in KIPT by IHEP team collaborated with KIPT team, hopefully the accelerator conditioning and commissioning will be started soon.

INJECTOR TESTING AND UPGRADE

Figure 1: Injector testing facility installed in IHEP.

Figure 1 shows the injector testing facility installed in IHEP in 2012. Initial beam testing showed that the beam current signals measured by BCT and ACCT can't reflect the true beam pulse shape because of the relatively longer rise/fall time [4]. In the meantime, due to the interference of the grounding system, the beam current waveforms' swing up and down along the whole beam pulse, the beam tuning and bunching efficiency estimation can only be done very roughly. Finally, by replacing the BCT and ACCT with FCT, improving the grounding system and the beam tuning, the beam transportation efficiency in the injector part was increased to ~90%. Fig. 2 shows the measured beam current signals with the nominal value of ~1.1 A at the electron gun exit. FCT1 and FCT2 are located at the exits of the gun and injector, respectively.

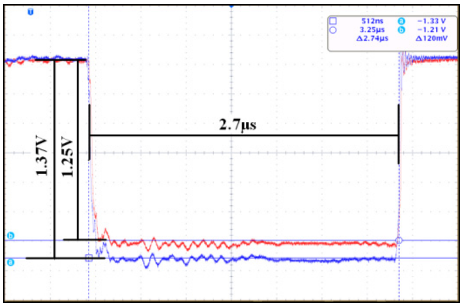

Figure 2: Measured FCT1 (blue) and FCT2 (red) signals.

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By measuring the beam profile following a dipole analyzing magnet located downstream of the injector, the 1σ beam energy spread at the injector exit were calculated to be ~2%. During the whole measurement process, the injector beam transportation efficiency was stabilized to be ~90%, and no clear high energy beam tails were found but only low energy tails, which means the electron beams provided by the injector are very appropriate for the beam collimation process with the following chicane system to eliminate all particles with very large energy and phase spreads. By this way, the beam power losses along the beam transport line can be well minimized. By optimizing the klystron drive waveform and applying feed-forward and feedback techniques, the beam loading compensation system was also tested. It is found that the injector's beam energy spread can be further decreased a little bit, which is expected and validates its functionality.

MAIN SYSTEMS AND COMPONENTS

The R&D of all the main accelerator systems was completed in early March, 2013. Later, all the auxiliary components are prepared and tested.

The electron gun with Y824 cathode assembly has been in steady turn-key operation during the whole injector testing period. The testing shows that >2A/3.0μs/120keV beam can be produced stably [5]. Maximum high voltage (HV) of 150 kV can be provided by the HV power station.

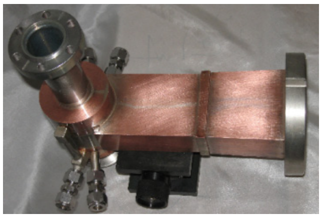

Figure 3: Pre-buncher.

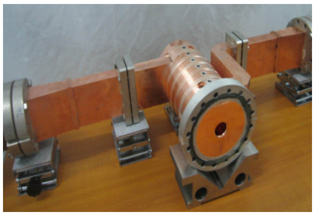

Figure 4: Buncher.

The pre-buncher is a single cell standing wave (SW) cavity, which is shown in Fig. 3. RF power is fed into the cavity by waveguide coupling with measured coupling factor β=~1.4. The buncher is a travelling wave (TW) constant impedance (CI) structure with $\beta=0.75$ of beam velocity. Initially, the buncher was designed to have only 4 cells. However, the adoption of water cooling jacket demands more longitudinal space (leading a longer buncher) to ease the installation. Finally, one 6-cell version was developed, which is shown in Fig. 4.

Ten TW constant gradient (CG) accelerating structures (A0–A9 along the Linac) with relatively bigger beam aperture have been developed and will be installed in the KIPT accelerator tunnel to boost the beam energy to 100 MeV. Figure 5 shows one structure in the RF cold testing lab. All of the 10 structures were tuned to have a cell-to-cell phase error $\leq\pm0.5^\circ$ and a cumulative one to the 1st cell $\leq\pm2^\circ$. The measured bandwidth, attenuation factor and filling time are ~5.5 MHz (VSWR≤1.2), ~0.155 Np and ~220 ns, respectively, which are consistent with the RF design [6]. To suppress the BBU effect, at the 2nd to 6th disks of each structure from A1–A9, 4 holes with diameters of 9 mm (A1, A4 and A7), 11 mm (A2, A5 and A8) and 13 mm (A3, A6 and A9) were drilled. Water cooling jacket is mounted along each structure after RF tuning in the lab and will be used to cool down the structure during machine operation with high average RF input power.

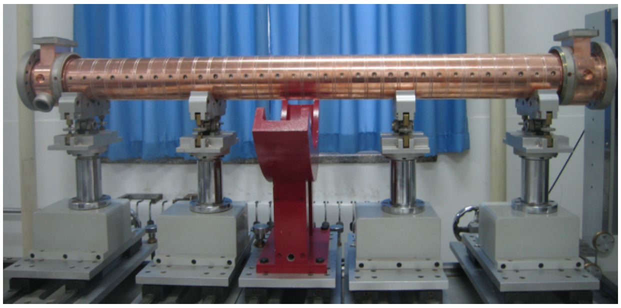

Figure 5: Accelerating structure in RF cold testing lab.

Six RF power units with each consisted by a Toshiba E37311 klystron and its modulator are applied in the KIPT Linac, the modulator is made in China. The 1st RF power unit used in the injector testing facility to energize the pre-buncher, the buncher and the 1st structure has been conditioned up to 500 Hz repetition rate with 3.2 μs pulse width (flat-top), and limited by the electrical capability of the experimental hall #2. Figure 6 shows the corresponding klystron output with 27 MW peak power.

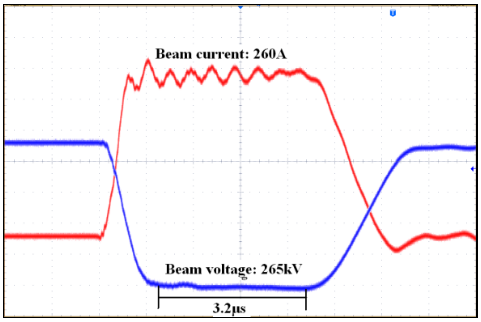

Figure 6: Klystron output at 500 Hz.

The beam instrumentation system is capable to measure the beam positions, intensities, profile, emittance, beam loss, beam energy and energy spread, etc.

In the KIPT Linac, 8 button type BPMs and BLMs are used to measure the beam orbit and beam losses; 3 PRs and 2 WSs are used to measure the beam profile; 5 FCTs instead of BCTs and ACCTs are used to measure the beam current and pulse shape. There are total two beam energy analyzing stations located at the exits of the injector and the Linac, respectively. The Strip Lame Screen (SLS, developed by KIPT) is used to measure the beam profile downstream the analyzing magnet, by which the beam energy and energy spread can be determined. Figure 7 shows the SLS assembly, which can withstand relatively higher average beam power, thus the beam energy can be measured at a relatively higher repetition rate. Quadruple scanning method is used to measure the beam emittance and TWISS parameters at the Linac exit, which is very helpful for the beam transport line tuning.

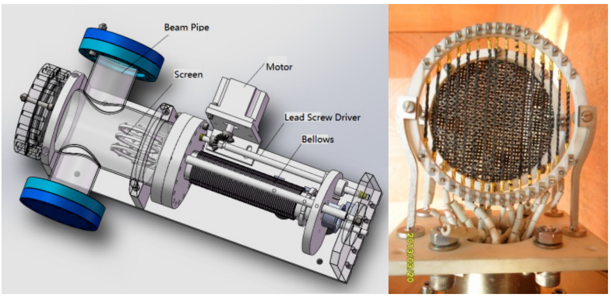

Figure 7: Strip Lame Screen assembly.

The LLRF system consist of 6 control units, the drive signal of each unit comes from the reference signal distributor. Feed forward is used to set up the drive waveform, while feedback for optimization of the drive phase, which comes from the beam phase measurement cavity. Initial testing shows the desired RF field shape and the optimized beam phase in the accelerating structure can be obtained. Figure 8 shows one typical control unit.

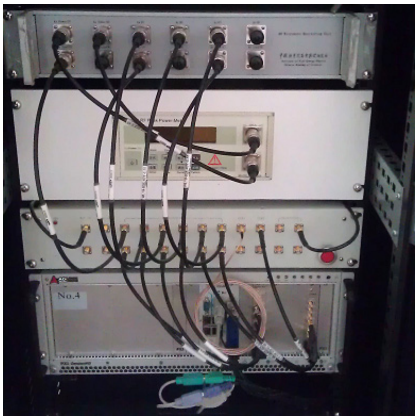

Figure 8: One typical control unit.

EPICS based control system with Channel Access communication protocol is developed by CSS. Online data storage and recovery is realized by Channel Archiver. Most of the components have been tested in the injector testing facility. Figure 9 shows the control architecture.

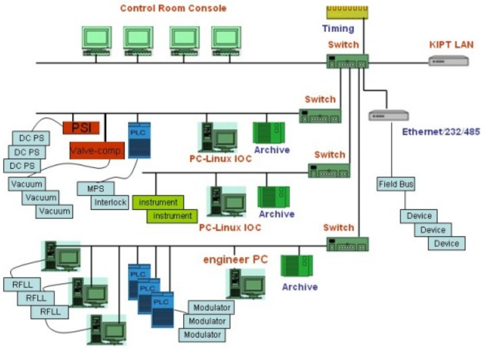

Figure 9: Newly updated control system architecture.

The Linac magnet system consist of 4 gun focusing lens, 22 solenoids, 6 triplets, 7 correctors and 4 chicane dipoles. The 1st chicane dipole was specially designed to have two functions [4]. One is for the nominal beam collimation process; another is to be used as an energy analyzing magnet (AM). For the beam transport line, there are 6 quadruples, 2 dipoles with 45° bending angle and 1 pair of scanning magnets (horizontal and vertical). By using the scanning magnets, homogenous beam intensity on the target can be formed in one scanning period. According to a repetition rate of 625 Hz, both horizontal and vertical scanning magnets need to run 25 steps in 1 second. Figure 10 shows the 1st chicane dipole and one of the scanning magnets in field measurement. The magnetic field of all magnets has been measured and meets the design requirement.

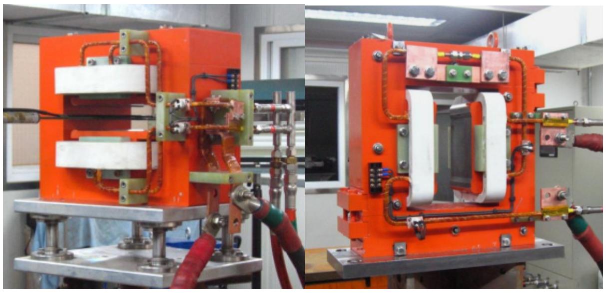

Figure 10: The 1st chicane dipole (left) and one of the scanning magnet (right).

The vacuum system assures the accelerator working at ultra high vacuum condition—better than $5.0\mathrm{x}10^{-8}$ mbar. All vacuum pumps were made in China. Injector testing shows the vacuum system can meet the design goal.

The water cooling system will be the 1st sub-system installed in the KIPT Linac. The prototype has been successfully tested in the injector testing facility.

SUMMARY

The construction of the 100 MeV / 100 kW electron Linac for the NSC KIPT neutron source is going on smoothly. Almost all of the main system and components were tested in the injector testing facility. The accelerator assembling in KIPT will be started in June, 2013.

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