PROGRESS ON THE DESIGN AND CONSTRUCTION OF THE 100 MeV / 100 kW ELECTRON LINAC FOR THE NSC KIPT NEUTRON SOURCE

S. Pei#, Y. Chi, G. Pei, S. Wang, J. Cao, M. Hou, W. Liu, Z. Zhou, F. Zhao, R. Liu, X. Kong, J. Zhao, C. Deng, H. Song, J. Liu, J. Yue, Q. Yang, D. He, K. Lv, X. He, Q. Le, X. Li, L. Wang, X. Wang, H. Ma, H. Guo, B. Deng, J. Zhang, J. Zhao, C. Ma, IHEP, Beijing, China
A. Zelinsky, M. Ayzatskiy, V. Kushnir, V. Mytrochenko, I. Karnaukhov, KIPT, Kharkov, Ukraine
Y. Gohar, ANL, Illinois, USA

Abstract

IHEP in China is designing and constructing a 100 MeV / 100 kW electron linac for NSC KIPT, which will be used as the driver of a neutron source based on a subcritical assembly. Recently, the physical design has been finalized. The chicane scheme instead of the RF chopper one has been selected. The mechanical design is on-going and will be finished in the very near future. The injector part of the machine has been installed in the experimental hall #2 of IHEP and is being commissioned and tested. The progress on the machine design and construction are reported, initial testing and commissioning results of the injector are also presented.

INTRODUCTION

One 100 MeV / 100 kW electron linac in NSC KIPT is being constructed, which will be used to drive a neutron source based on a subcritical assembly. This neutron source is a joint project between ANL (USA) and NSC KIPT (Ukraine), and IHEP in China is responsible for the linac (including the transport line to the target) design and construction. Due to the high average beam power of 100 kW and the low beam loss of ~3 kW (including intended and unintended) along the entire linac, the whole machine is being designed and constructed elaborately. Table 1 shows the main parameters of the NSC KIPT linac.

Table 1: Main Parameters of the NSC KIPT Linac

Parameters	Values	Units
RF frequency	2856	MHz
Beam energy / power	100 / 100	MeV / kW
Beam current (max.)	0.6	A
Energy spread (p-to-p)	±4	%
Emittance	5×10^{-7}	m-rad
Beam pulse length	2.7	μs
RF pulse length	3	μs
Pulse repetition rate	625	Hz
Klystron	6×30MW / 50kW	Units
Accelerating structures	10×1.336m	Units
Gun high voltage	~120	kV
Nominal gun beam current	~1–1.2	A

The beam energy spread at the linac exit has been changed to ±4% for peak-to-peak rather than 1% for 1σ [1] [2]. This is determined by the energy spread acceptance of the beam transport line with 90° bending angle located at the linac end. With ±4% peak-to-peak energy spread, the beam power losses along the transport line can be reduced to less than 1 kW with ±0.2 mm alignment error, ±2° phasing jitter, ±0.15% modulator voltage jitter, ±0.5% gun high voltage jitter and ±1% RF pulse flatness.

Figure 1 shows the mechanical layout of the linac including the beam transport line. The klystron gallery is located at the downstairs of the accelerator tunnel.

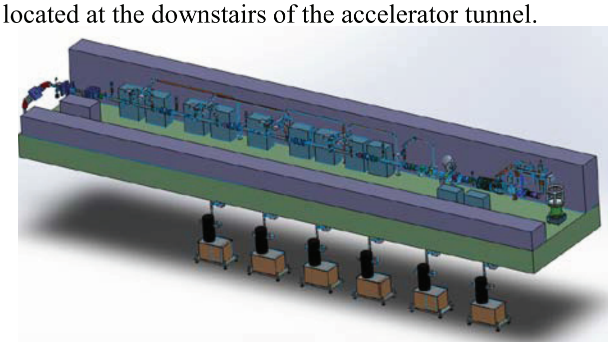

Figure 1: Mechanical layout of the linac including the beam transport line.

INJECTOR DESIGN AND TEST

To get a clean bunch without any satellite electrons in each RF period downstream the chicane system, the phases of all the RF structures (the prebuncher, the buncher and the 1st accelerating structure A0) and the solenoid field distribution in the injector are re-optimized. Finally one can obtain the phase and energy spectrums as shown in Fig. 2, which are appropriate for the beam collimation process with the chicane system to eliminate all particles with very large energy and phase spreads relative the reference particle located at the 0° phase. By this way, the beam power losses along the transport line can be minimized to the largest extent.

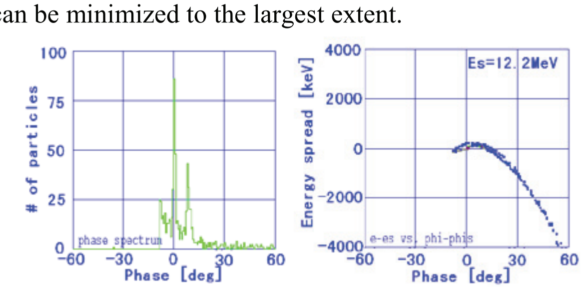

Figure 2: Phase and energy spectrums at the injector exit.

#peisl@mail.ihep.ac.cn

Fig. 3 shows the absolute energy spread distribution along the linac with all error and jitter effects considered.

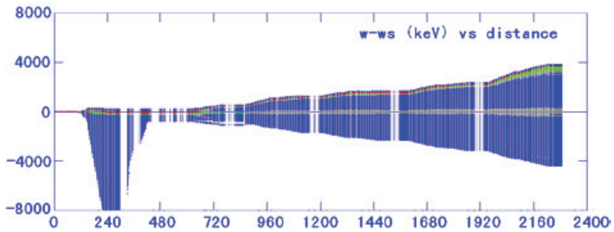

Figure 3: Absolute energy spread distribution along the linac with all error and jitter effects considered (unit: cm).

The injector part has been installed in the experimental hall #2 of IHEP, which is shown in Fig. 4. The commissioning and testing were started two months ago. For beam pulse length of 2.7 µs, the maximum current obtained at the injector exit is ~2 A, which is limited by the electron gun emission capability. No BBU effect in the injector was observed, which means the threshold current of the accelerating structure is higher than 2 A. Many effective measures are adopted in the linac design to cure the BBU effect as described in [1].

Figure 4: Injector testing facility installed in IHEP.

Fig. 5 shows the signals of BCT1 (gun exit) and ACCT1 (A0 exit, upstream the 37.5^{o} energy analyzing magnet used temporarily for injector test). Here the beam current indicated by the ACCT1 signal is ~770 mA. The bunching efficiency is not known yet because the BCT1 is not calibrated; however, the estimated value is ~70% according to the gun current calibration before installation. The waveforms' swing up and down along the pulse is because of the interference from the old grounding system of hall #2, which was constructed more than 20 years ago.

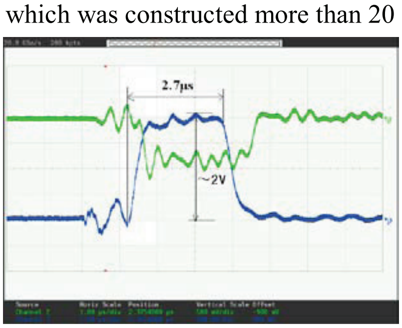

Figure 5: Signals of BCT1 and ACCT1.

Figure 6 shows the corresponding beam profile (downstream the analyzing magnet) at the energy and energy spread measurement line. It can be seen there is no high energy tails, but only low energy ones, which is consistent with the simulated energy spectrum in Fig. 2. The low energy tails will be collimated by the collimator located between the bending magnets CB2 and CB3 of the chicane system, and then a clean beam of ~600 mA without satellite electrons in each bunch can be obtained.

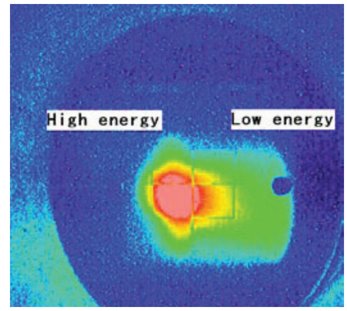

Figure 6: Beam profile at the energy measurement line.

CHICANE SYSTEM DESIGN

The chicane system is located downstream the injector but upstream the 2nd accelerating structure A1. There are 4 bends in the chicane system， mechanical layout of which is shown in Fig. 7. The bending magnets CB1 and CB4 are sectors, while CB2 and CB3 are rectangles. The 1st bending magnet CB1 was specially designed to have two functions. One is for the nominal beam collimation process with a bending angle of 10^{o}; another is to be used as an energy analyzing magnet (AM) with 45^{o} bending angle for measuring the beam energy and energy spread of the electron beam at the injector exit, then the RF phases seen by the beam in the prebuncher, the buncher and the 1st accelerating structure A0 can be optimized in real operation. The vacuum chambers for CB1, AM and CB2 are integrated together for saving space. Similarly, the chambers for CB3 and CB4 are also integrated.

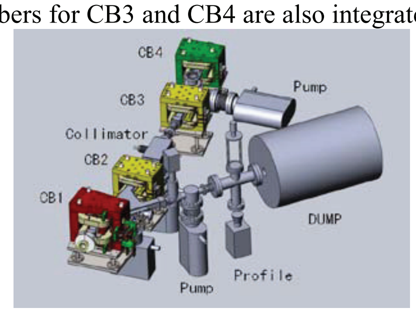

Figure 7: Layout of the Chicane system.

MAIN SYSTEMS AND COMPONENTS

Based on the decision to adopt the chicane scheme instead of the RF chopper one because of technology difficulty caused by the high beam current, construction and commissioning of all main systems are on-going.

The electron gun with Y824 cathode assembly has been in normal operation with high voltage (HV) of 120 kV (conditioned to 135 kV) for couples of months in the injector testing facility. The emitted current exceeded the design requirement of 2A. Fig. 8 shows the gun system setup in the tunnel.

ISBN 978-3-95450-122-9

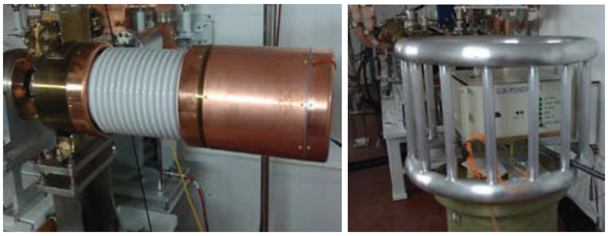

Figure 8: The electron main body and the HV station.

Figure 9 shows the modulator and the Toshiba E37311 klystron. ~400 Hz rep. rate (less than the design goal of 625 Hz) with 3μs RF pulse width has been reached because of the electrical capability of the experimental hall. Higher rate to 625 Hz will be conditioned after the electrical network upgrade. Fig. 10 shows the klystron output at 100 Hz. 30 MW peak power has been obtained.

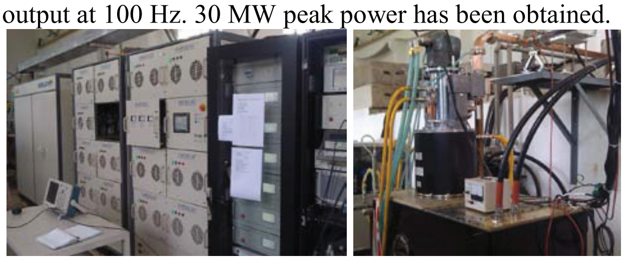

Figure 9: The modulator and Toshiba E37311 klystron.

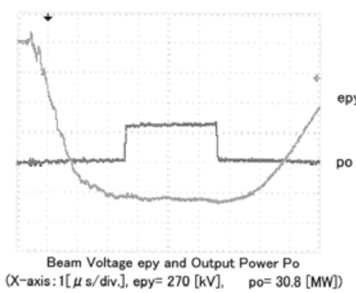

Figure 10: The klystron output at 100 Hz.

Most of the beam instrumentation devices are being fabricated and tested. Fig. 11 shows the ACCT with electromagnetic shielding and the BPM.

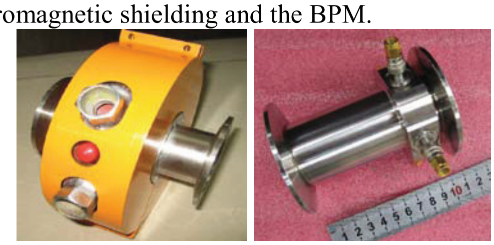

Figure 11: ACCT and BPM

The 1st accelerating structure A0 has been installed in the injector testing facility and is running well at couples of Hz rep. frequency. In the near future, it will be tested to run at 625 Hz with the nominal input power. If the result is positive, another 9 structure will be fabricated.

The LLRF system is being tested in this month. As shown in Fig. 12, the klystron drive waveform is optimized to obtain the desired pulse shape with minimized fluctuation. The testing of the firmware for digital signal processing including feed-forward and feedback control algorithms has been finished.

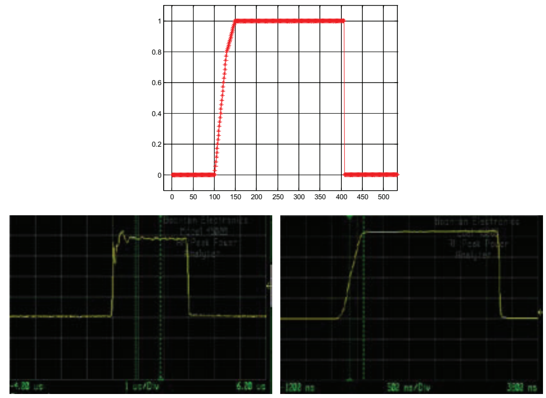

Figure 12: The klystron drive (upper), amplifier output before (lower left) and after (lower right) optimization.

The control system is based on EPICS, which includes all front-end controller, driver and operator screen as shown in Fig. 13. Currently, the design has been finished; most components are in the purchasing and tuning stage. The injector control system is being in operation stably.

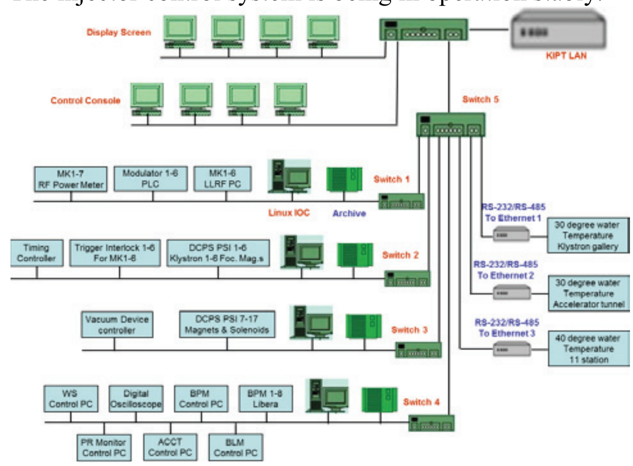

Figure 13: The control system architecture.

The water cooling system is designed to be composed by 3 subsystems: 1) first loop of 30 (max.) $\pm 1^{\circ}$C for the tunnel devices; 2) first loop of 30 (max.) $\pm 1^{\circ}$C for the klystrons gallery devices; 3) 40$\pm$0.2°C constant temperature system for the accelerator. The prototype is in well operation for the injector testing facility.

SUMMARY

The design and construction scheme of the 100 MeV / 100 kW linac for NSC KIPT neutron source has been finalized. The injector testing facility is being in operation to test the related systems / components. Currently, the testing results are acceptable. However, further work still need to be done to improve the machine performance including test of the beam loading compensation online.

REFERENCES

[1] S. Pei et al., MOPS033, Proceedings of IPAC2011, San Sebastian, Spain.
[2] Y. Chi et al., TUPC034, Proceedings of IPAC2011, San Sebastian, Spain.