BEAM DYNAMICS AND EXPERIMENT OF CPHS LINAC *

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Abstract

We present, in this paper, the present beam dynamics simulation results and experiments of the 3 MeV high current proton linac for the Compact Pulsed Hadron Source (CPHS) at Tsinghua University. The beam dynamics simulations of the recent status of the linac have been done, which helps the operation. Facility used for 2D beam profile measurement which is based on the CT algorithm with rotatable multi-wires, is under development. Some other experiments such as beam position measurement will also be introduced below.

INTRODUCTION

The Compact Pulsed Hadron Source (CPHS) project at Tsinghua University was launched in the year of 2009 [1], whose layout is shown in Figure 1. The final expected parameters of the CPHS linac are: beam energy to be 13 MeV, beam current to 50 mA, repetition rate to be 50 Hz and pulse length to be 500 µs.

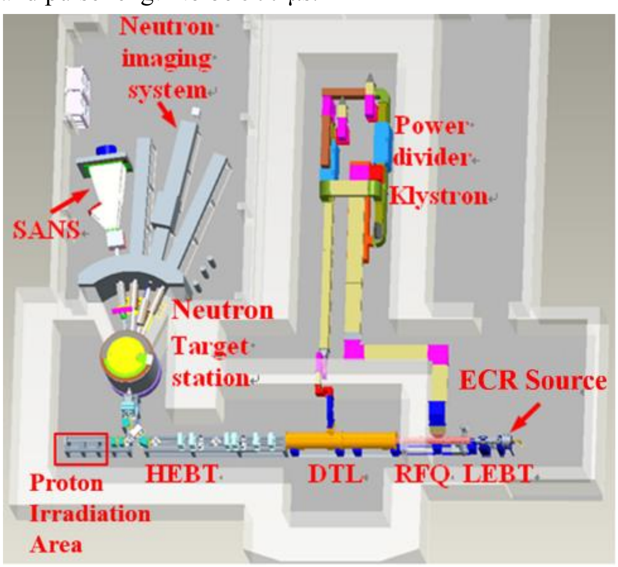

Figure 1: Layout of CPHS project.

So far, CPHS has achieved its mid-term objective: delivering the 3 MeV proton beam to bombard the Beryllium target [2]. Figure 2 shows the status of CPHS linac facility at Tsinghua University recently, which contains one ECR Ion Source (IS), one Low Energy Beam Transport line (LEBT), one 4-vane Radio Frequency Quadrupole (RFQ) accelerator, and one High Energy Beam Transport line (HEBT) [3].

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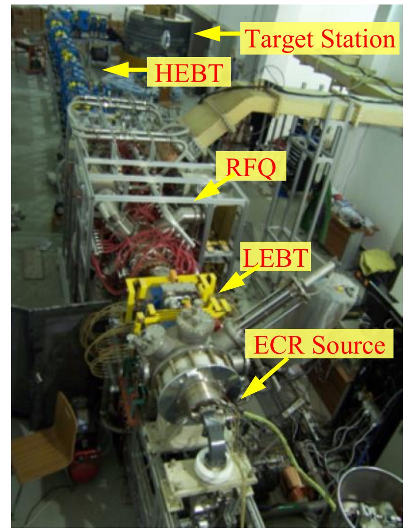

Figure 2: CPHS linac facility and the target station.

Figure 3 shows the operation status of the CPHS linac in 2014. The transmission rate of the RFQ is 70% recently, which is lower than the designed value of 97% and primary experimental value of 88% (with input peak current of 50mA at 50 µs /50 Hz). The reason may come from the unmatched beam from the LEBT, or the deformation of the RFQ cavity. Therefore, the linac will be inspected separately to solve the problem in the next stage.

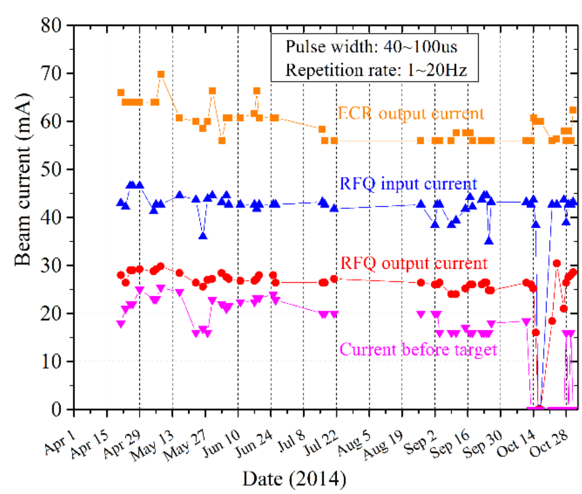

Figure 3: Operation history of the 3 MeV linac in 2014.

In this paper, the beam dynamics simulation results of the recent status of the CPHS linac are presented. Experiments such as beam profile measurement and beam position measurement are introduced.

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BEAM DYNAMICS SIMULATION

The beam dynamics simulation mainly focus on the Low Energy Beam Transport line and 4-vane Radio Frequency Quadrupole accelerator, which are the main part of the CPHS linac. The simulation of the LEBT is taken by Trace3D [4], TRACK [5] and TraceWin [6], and the field of the solenoid is calculated by Possion/ Superfish [7], as shown in Figure 4 [8]. The distribution at the end of the LEBT is imported directly to the RFQ entrance, then the beam dynamics simulation is accomplished by Toutatis/ TraceWin [9].

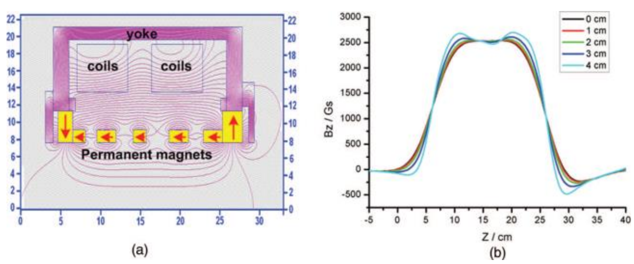

Figure 4: Solenoid and its field distribution in CPHS LEBT.

The beam information calculated by TraceWin at the LEBT entrance, RFQ entrance and RFQ end is shown respectively in Figure 5~Figure 7. These results show a nice beam in the RFQ. Figure 8 presents the beam envelop in the structures.

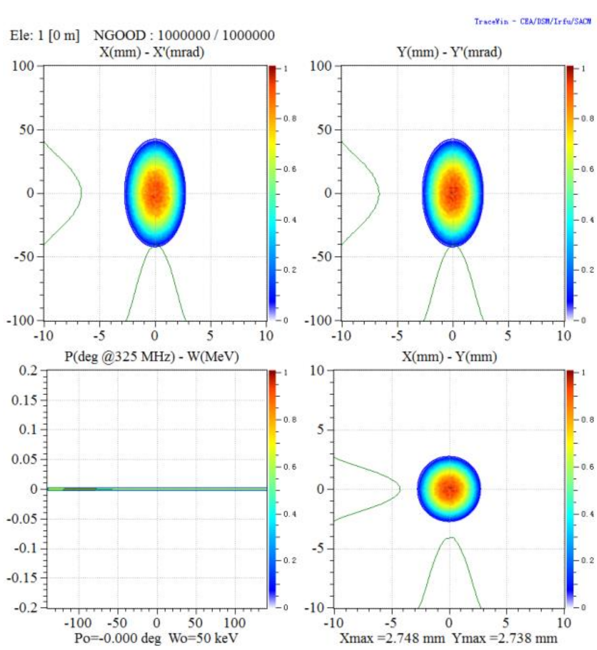

Figure 5: Beam information at the LEBT entrance.

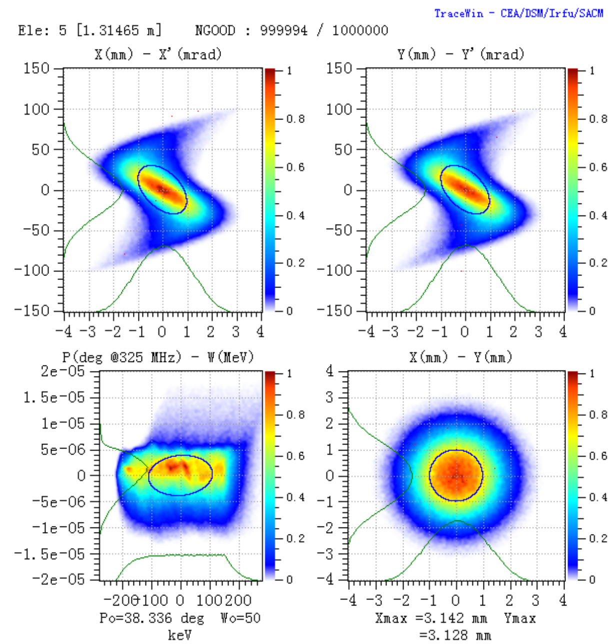

Figure 6: Beam information at the RFQ entrance.

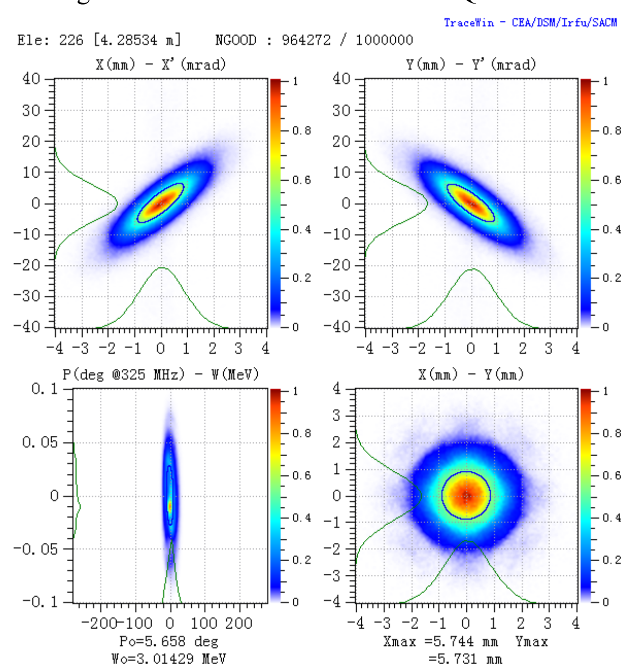

Figure 7: Beam information at the RFQ end.

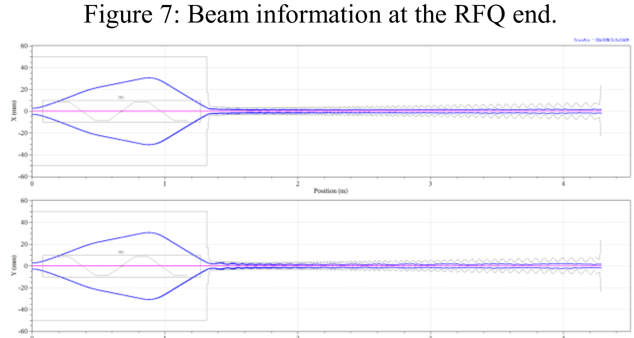

Figure 8: Beam envelop in the LEBT and RFQ.

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BEAM PROFILE MEASUREMENT

2D beam profile measurement is under development based on the Computed Tomography (CT) algorithm with rotatable multi-wires. Twenty carbon wires with the diameter of 30 μm are aligned and mounted on one stainless steel frame, as shown in Figure 9 and Figure 10.

The current signal is obtained from the Secondary Electron Emission [10] and then amplified by a set of electronics system. Then Total Variation Algebraic Reconstruction Techniques (TV-ART) CT Algorithm is used to rebuild the image of the beam profile.

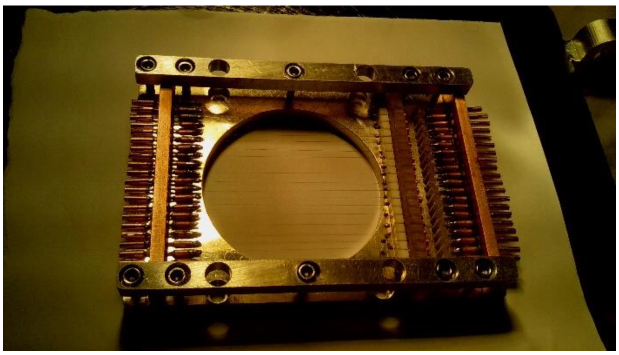

Figure 9: Rotatable multi-wires.

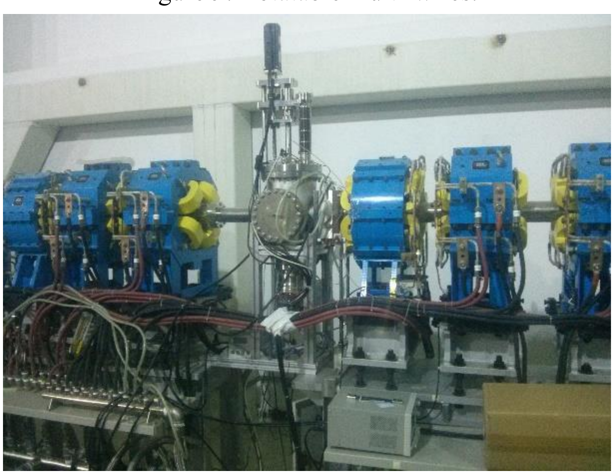

Figure 10: 2D beam profile measurement system.

The primary experiment shows that wire current near the beam centre is 0.3 mA (while the estimated value is 0.4 mA). The beam is unstable day by day at the measurement position. Figure 11 shows one of the 1D distribution measured by the wires, in which the "halo" can be seen clearly.

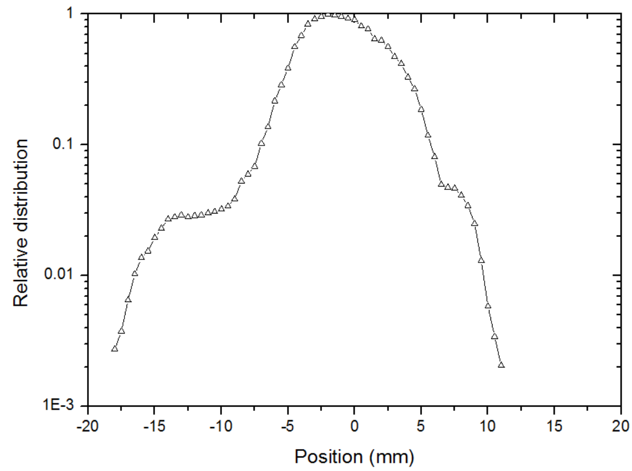

Figure 11: 1D distribution measured by the wires.

Figure 12 shows the rebuilding result with data of five directions. Streak artifacts can be seen in the image. When the angular sampling increase to 17, the image become quite well, as shown in Figure 13. To avoid the thermal emission of the wire, the pulse width is decreased to 40 μs while the beam profile measurement.

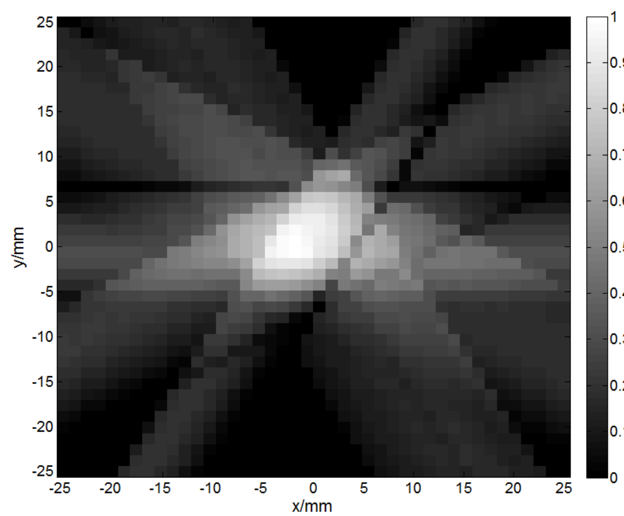

Figure 12: Rebuilding image of five directions.

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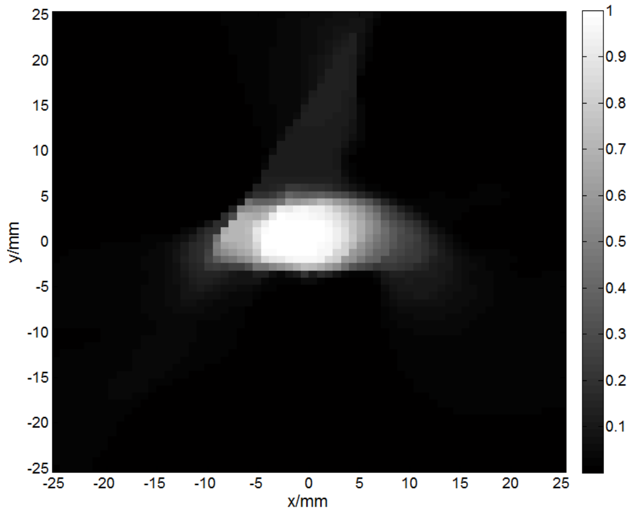

Figure 13: Rebuilding image of 17 directions.

The following challenging work on the electronics system is to measure the current which is less than 1 nA near the beam edge.

BEAM POSITION MEASUREMENT

The CPHS beam position measurement system is formed by several button-type BPMs and a hadron phase & position processor- Libera Single Pass H.

The button-type BPM, which have one button in each of the four directions, is showed in Figure 14 and Figure 15.

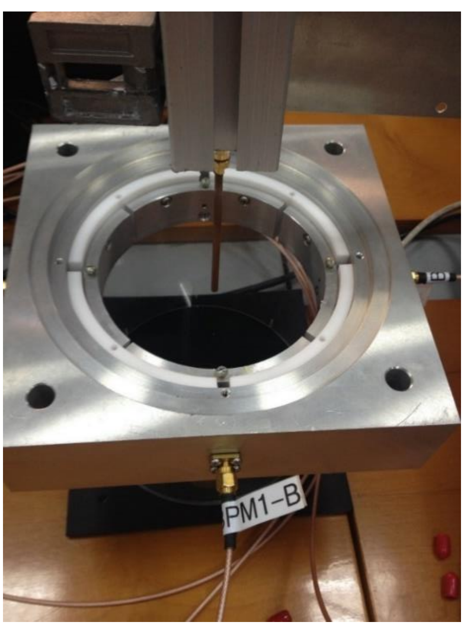

Figure 14: The button-type BPM in test.

Figure 15: The button-type BPM on the beam line.

The output signals from the four ports of the BPMs are imported into Libera through a 20 dB amplifier. IQ sample signals can be obtained by using the method of undersampling and digital orthorhombic demodulation. These signals are used to calculate the amplitude and phase. The value of the particle energy can be obtained from the phase information of two BPMs. Figure 16 and Figure 17 respectively show the transverse position signal and the longitudinal phase signal displayed in Libera, from which we can conclude that the beam center is 2 mm above the beam channel and 2 mm on the right of the beam channel.

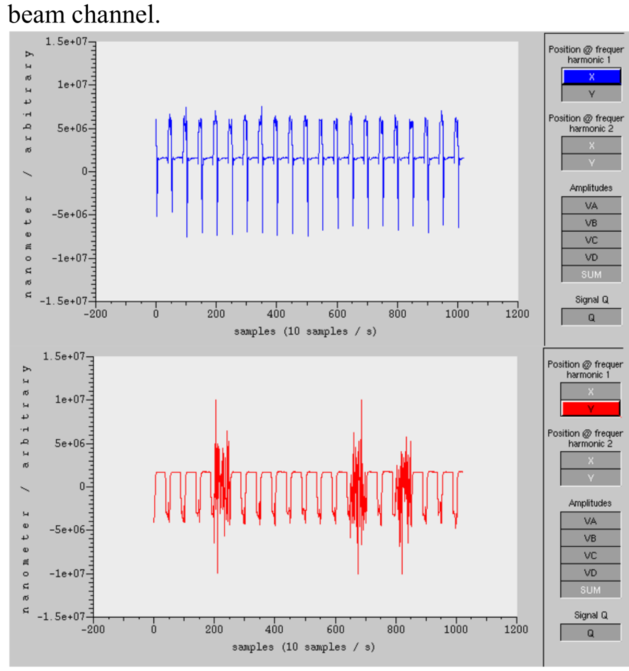

Figure 16: The transverse position signal displayed in Libera.

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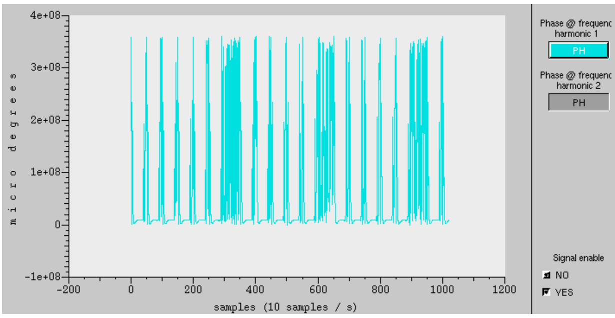

Figure 17: The longitudinal phase signal displayed in Libera.

At present, the measurement resolution of transverse position is 180 μm and the measurement resolution of phase is 0.6 degree.

CONCLUSION

The operation notes and beam dynamic results show that there are some problems to be solved. The experiments on the linac are proceeding quite well. The next stage of CPHS linac is the transformation of the low-energy part including Ion source, LEBT and RFQ and the upgrade of the whole linac system.

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