LINAC FOR THE COMPACT PULSED HADRON SOURCE PROJECT AT TSINGHUA UNIVERSITY BEIJING*

Xialing Guan #, X. W. Wang, C.K. Loong, C. Cheng, Q. Du , T. B. Du, Z. Feng , G. H. Li, J. Li, Y. He, W.Q. Guan, Ch. jiang, Q. Z. Xing, H. Y. Zhang, D. S. Zhang , S. X. Zheng, Department of Engineering Physics, Tsinghua University, Beijing 100084, China
James Billen , James Stovall, and Lloyd Young, USA

Abstract

A project of the Compact Pulsed Hadron Source (CPHS) led by the Department of Engineering Physics of Tsinghua University in Beijing, China has been reported in this paper. CPHS consists of a proton linac, a neutron target station (a Be target, moderators and reflector), and a small-angle neutron scattering instrument, a neutron imaging/radiology station, and a proton irradiation station.

INTRODUCTION

In 2010 June, Tsinghua University, in order to respond the increasing demand in China of accelerator-based neutron and proton experimental platforms for basic researches and technological developments, startup a project of building a Hadron Application and Technology Complex (HATC) which begins with a relatively small and moderate-power facility but later expandable. The initial phase of the HATC is called the Compact Pulsed Hadron Source (CPHS)[1]. The missions of CPHS are Education Student & staff training; Instrumentation and R&D; Neutron instrumentation tests; Limited-scale science discovery & applications with neutron imaging & scattering instruments. It will be completed as soon as possible in 3 years.

CPHS consists of a proton linac (13 MeV, 16 kW, peak current 50 mA, 0.5 ms pulse width at 50 Hz), a neutron target station, a small-angle neutron scattering instrument, a neutron imaging/radiology station and a proton irradiation station. Currently, progress of the project is under constructed. The initial phase of the CPHS construction is scheduled to complete in the end of 2012.

The accelerator part consists of a ECR ion source. LEBT section, a RFQ accelerator, a DTL linac and a HEBT. ECR ion source will give up to 60mA at 50keV proton beam with proton ration large than 85%, and 0.02 π cm mrad normalized emittance. A very short length of LEBT will be used to matching the beam from ion source to the RFQ entrance. An 3 meters long of RFQ machine can accelerate the proton to 3MeV. No MEBT will be requirement in this project. The Drift Tube Linac with permanent magnets focusing lens will accept the proton beam direct from RFQ. A 4.3 meters length of DTL with 43 cells will accelerate the beam up to 13MeV and the HEBT section will transport the proton beam from output of DTL to the target inside the target station centre with 3.5cmX3.5cm uniform distribution on the Be target. The main parameters of CPHS are listed in Table 1. Figure 1 shows the CPHS facility layout.

Table 1: CPHS Primary Design Parameters

Species	proton
Proton power on target （kW）	16
Proton energy （MeV）	13
Average beam current （ mA）	1.25
Pulse repetition rate （ Hz）	50
Protons per pulse	1.56×10^{14}
Pulse length （ms）	0.5
Peak beam current （ mA）	50
Target material	Be
Moderator type	H_2O (300K), CH_4 (20K)

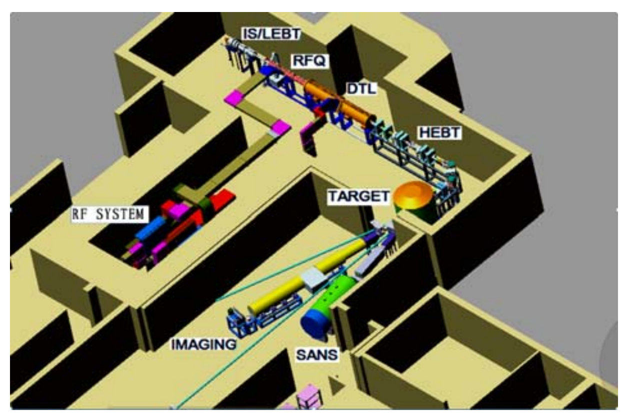

Figure 1: CPHS main facility layout.

ION SOURCE AND LOW ENERGY BEAM TRANSPORT

The proton beam is produced from the electron cyclotron resonance (ECR) proton source (2.45 GHz, 1.5 KW) and transported through the LEBT. The H_2 plasma is restricted by an axial magnetic field shaped by the source body of an all-permanent-magnet (NdFeB rings) design. The 50 keV pulsed beam of 0.5 ms length is extracted by a four-electrode system. The 1.3 m long LEBT consists of two solenoid lens, two steering magnets, and a cone

*Work supported by the “985 Project” of the Ministry of Education of China
#xialingguan@gmail.com

configuration optically matches to the RFQ with the Courant-Snyder parameters of α=1.354 and β=7.731 cm/rad[2].The design was assisted by Trace-3D and PBGUN simulations for a beam of 97% space-charge neutralization rate reaching the RFQ with 60 mA peak current and 0.2 μm rms normalized emittance. Figure 2 has shown CPHS ECR ion source and the LEBT.

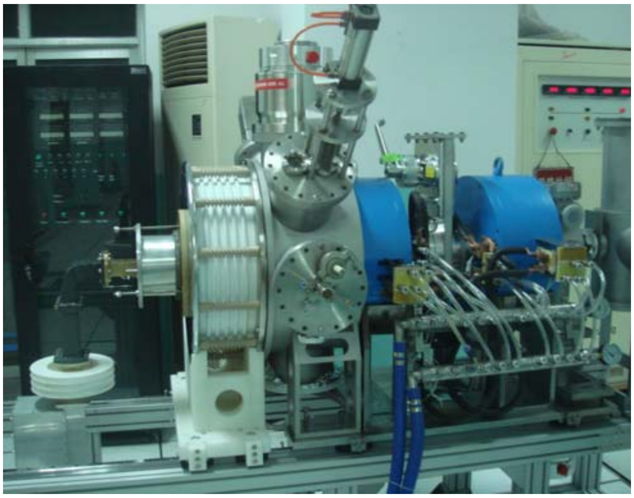

Figure 2: CPHS ECR ion source and the LEBT.

RADIO FREQUENCY QUADRUPOLE (RFQ)

The RFQ cavity cross-section is the "conventional" triangular shape with a significant longitudinal variation in the width of the vane skirt[3].

The transmission rate given by the PARMTEQM codes is 97.2%. The transverse emittance increases by ~20% when the beam reaches the RFQ exit. Mechanically, the 3-m long RFQ of the 3 MeV, 50 mA peak-current RFQ is separated into three sections of 1 m each to facilitate machining and brazing. Figure 3 shows the one of 3 RFQ sections after brazing at the Kelin Co. Ltd. in Shanghai .

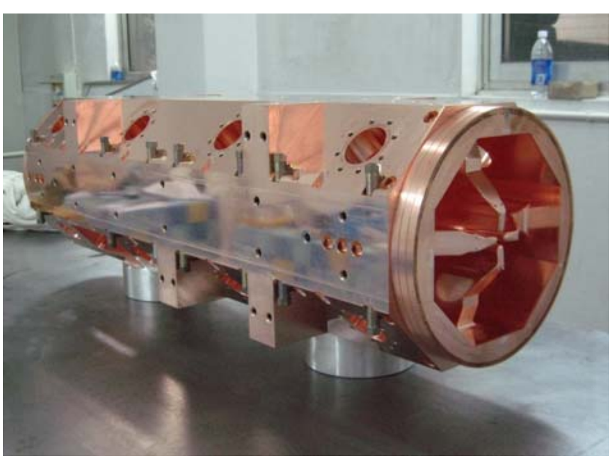

Figure 3: The one of 3 RFQ sections after brazing.

Quadrupole and dipole components after tuning which shows that the resulting fields are in excellent agreement with the design (<1% and ± 1%) which just likes that shown in figure 4.

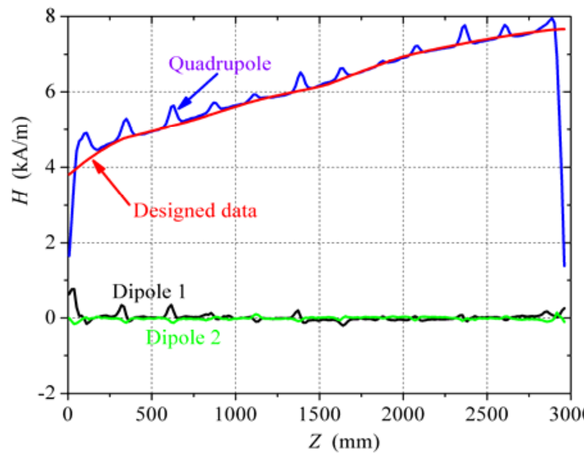

Figure 4: Quadrupole and dipole components after tuning.

DRIFT-TUBE LINAC (DTL)

No middle energy beam transport will be adopted. The beam focusing in exit of RFQ and the entrance of DTL have a matching design for the transverse and longitudinal. The physical design of the 13 MeV, 50 mA peak-current DTL was revised in late 2009[4]. The 4.4-m long DTL cavity in a FD lattice consists of two sections of totally 40 cells. Permanent-magnet quadrupoles (PMQs) are used for the transverse focusing at the constant gradient (84.6 T/m). The average accelerating field varies from 2.2 to 3.8 MV/m with the maximum surface field up to 1.6 Kilpatrick. Presently, the full cross-section prototype is under development at Tsinghua university. The parameters of the DTL linac as shown in table 2. Figure 5 shows the manufactured and brazing single DTL cavity.

Table 2: The Main Parameters of DTL

Extraction energy (MeV)	13
Peak current (mA)	50
RF frequency (MHz)	325
RF peak power (MW)	1.2
Emittance norm. rms (um)	0.2
Average current (mA)	1.25
RF duty factor (%)	3
Synchronous phase (degree)	-30 to -24
Accelerating field (MV/m)	2.2 to 3.8
Focusing magnet type	PMQ
Quad gradient (kG/cm)	8.46
Cell number	40
Length(m)	4.4

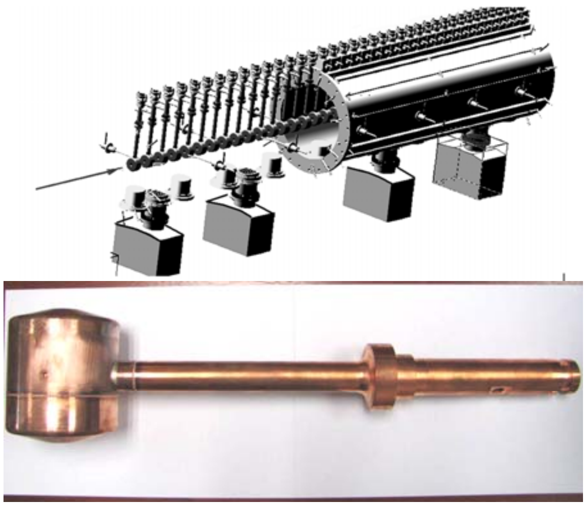

Figure 5: The manufactured and brazing single DTL cavity (down).The DTL of 40 cells and 4.4 m long has been divided into two section(up).

RADIO-FREQUENCY SYSTEM

Both RFQ and DTL share a single RF power source that consists of the signal generator at 325 MHz, amplifier, klystron, high voltage power supply, pulsed modulator, crowbar protection, RF transmission, and control and interlock systems. The RF transmission consists of a power divider with a ratio of near 1:2, an isolating attenuator, an isolating phase shifter, and waveguides. The 2.1 MW peak power from the klystron is split accordingly. The isolating attenuator consists of a 4-port circulator, a Y-junction, a high power load and a sliding short. It can be adjustable for amplitudes from 100 to 80% to meet the 0.6 MW power need of the RFQ. The output of the phase shifter can be adjusted for a range of +/- 45°. Figure 6 shows the block diagram of RF transmission system [5].

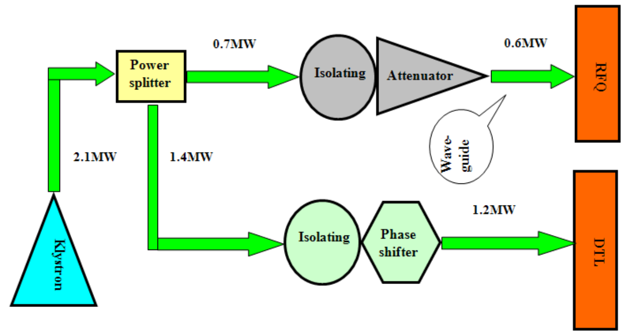

Figure 6: Block diagram of RF transmission subsystem.

THE HIGH ENERGY BEAM TRANSPORT (HEBT)

The CPHS high energy beam transport line (HEBT) is designed to deliver a circular shaped (3.5cm×3.5cm) on Be-target, 13MeV proton beam at pulse current 50mA with relatively uniform density （10%）using three octupole magnets for nonlinear focusing in both transverse directions. In fig.7, we show the results of physical design simulation of HEBT beam-line with the effects of space-charge, incorporating nonlinear focusing from three octupole magnets.

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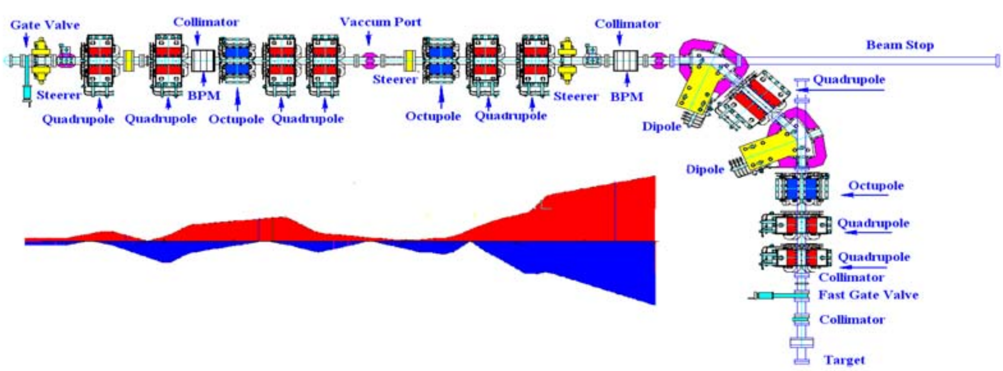

Figure 7: The layout of HEBT.

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