THE COMPACT PULSED HADRON SOURCE STATUS*

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Abstract

The Compact Pulsed Hadron Source (CPHS) at the Tsinghua University in Beijing, China has been reported in this paper. CPHS consists of a proton linac, a neutron target station, and a small-angle neutron scattering instrument, a neutron imaging/radiology station, and a proton irradiation station. The proton linac accelerator part is composed of a ECR ion source, LEBT section, a RFQ accelerator, a DTL linac and a HEBT. Up to now, the IS/LEBT and the RFQ have ready. The first phase of the CPHS construction is scheduled to complete 3MeV proton beam on the target in the end of 2012.

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. The initial phase of the CPHS construction is scheduled to complete in the end of 2012.

The accelerator 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 πcm mrad normalized rms-emittance. A very short length of LEBT(less than 1.3m) will be used to matching the beam from ion source to the RFQ entrance. A 3 meters long of RFQ 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 Be target inside with 3.5cmX3.5cm uniform distribution. The main parameters of CPHS are listed in Table 1. Figure 1 shows the CPHS facility layout.

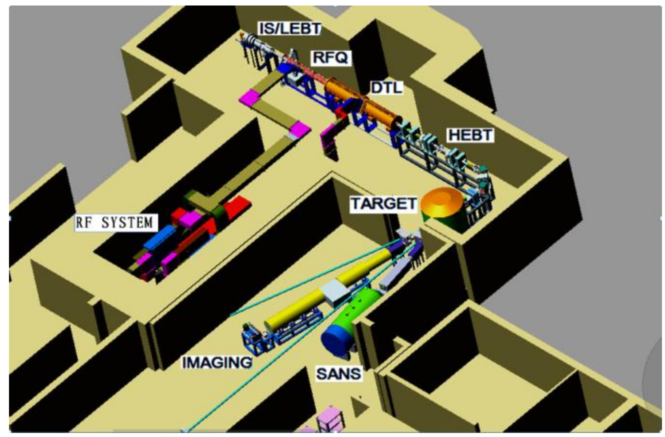

Figure 1: CPHS main facility layout.

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	$1.56\text{x}10^{14}$
Pulse length（ms）	0.5
Peak beam current（ mA）	50
Target material	Be
Moderator type	H_2O (300K), CH_4 (20K)

IS & LEBT

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

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of two solenoid lens, two steering magnets, and a cone 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 pi μm rms normalized emittance. Figure 2 has shown CPHS ECR ion source and the LEBT.

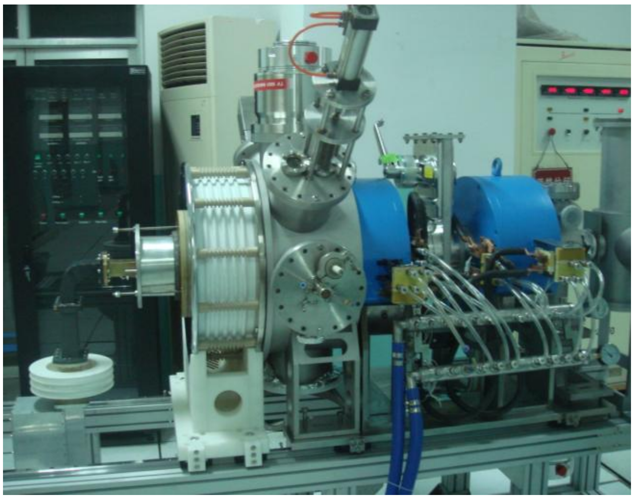

Figure 2: CPHS ECR ion source and the LEBT.

RFQ & DTL

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

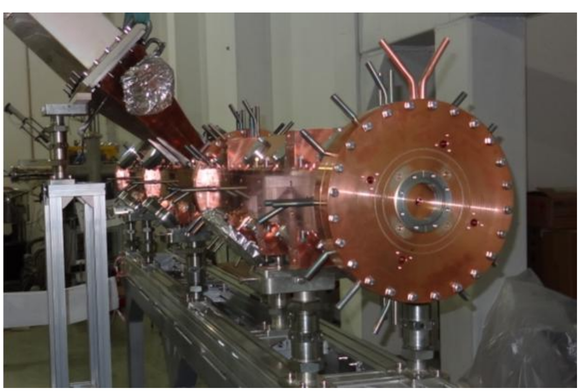

Figure 3: The RFQ photo in site.

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. Three sections fabrication has finished at the Kelin Co. Ltd. in Shanghai (Fig. 3). 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. Figure 4 shows the quadrupole and dipole components after tuning which shows that the resulting fields are in excellent agreement with the design (<1% and ± 1%). Figure 5 shows the frequency spectrum of the RFQ after tuning.

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.

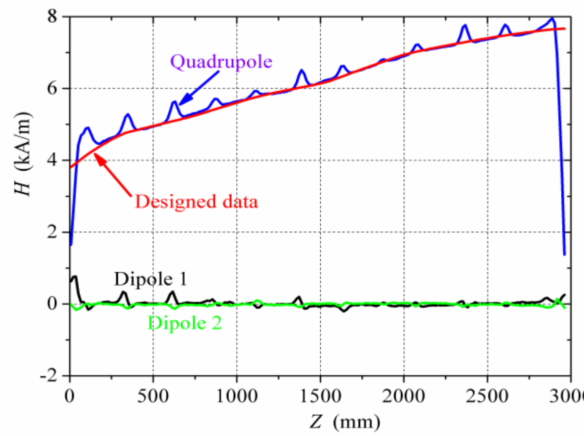

Figure 4: Quadrupole and dipole components after tuning.

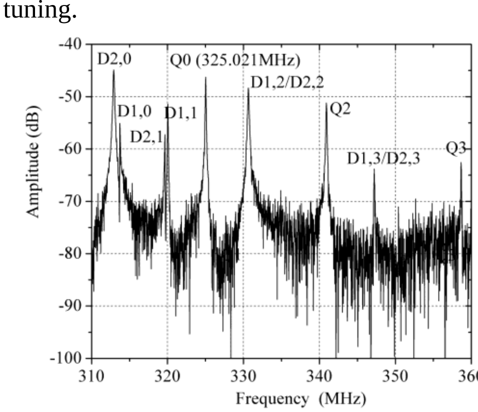

Figure 5: The frequency spectrum of the RFQ after tuning.

Table 2: The 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

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 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].

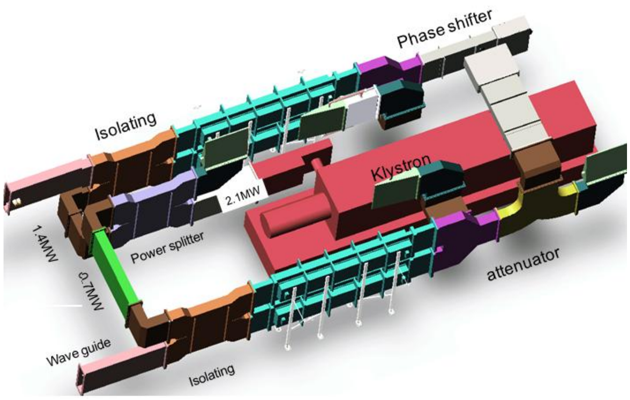

Figure 6: Block diagram of RF transmission subsystem.

HEBT & TMR

The CPHS high energy beam transport line (HEBT) is designed to deliver a square shaped (3.5cm×3.5cm) on Be-target, 13MeV proton beam at pulse current 50mA with relatively uniform density (10%) using two octupole magnets for nonlinear focusing in both transverse directions. In Fig. 7, we show the picture of the CPHS facilities including the ion source, the LEBT, the RFQ, and the high energy beam transportation, which was installed at Tsinghua university site.

The target station consists of the target, moderator, reflector (TMR) as shown in Fig. 8. The Be target is 63.5mm in diameter and 1.2mm in thickness. The moderator includes the moderator cell, cryogenic refrigerator, the vacuum vessels for thermal isolation and PT415 to provide the cryogenic environment. The solid methane, 20K, size 110*110*18 mm. Reflector is light water, 300K. The target station TMR in under construction.

Figure 7: The picture of the CPHS facilities.

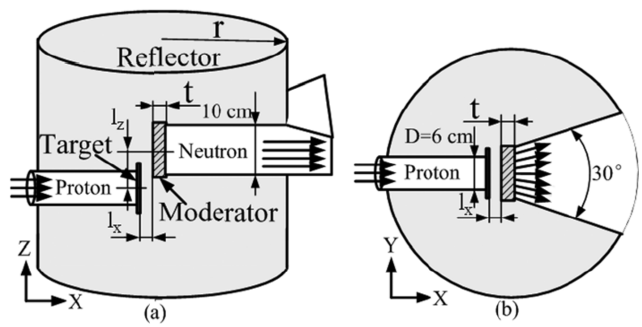

Figure 8: The TMR assembly.

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