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Status Report on Accelerator and Neutron Activities of CPHS at Tsinghua University

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Abstract. The CPHS project that was launched in September 2009 at Tsinghua University has reached a first commissioning stage in conjunction with ongoing activities to fulfil the eventual design goal of a ~10^{13} n/s epithermal-to-cold neutron yield for education, instrumentation development, and industrial applications. The latest progress on the commissioning and applications of 3-MeV proton and neutron beam lines, and the design, fabrication, engineering of the 13MeV/16kW proton accelerator system and the solid methane moderator system will be reported. Two prototypes of neutron detectors, based on micro-channel plate and the boron-coated straw tube design, were under evaluation and development. The research progress on neutron optics and instrumentation will also be presented.

1. Status of CPHS facility

1.1 Commissioning and applications of 3-MeV CPHS

The Compact Pulsed Hadron Source (CPHS) [1][2][3][4] facility with 3MeV RFQ had operated for about 700 hours in 2016. The present main parameters together with the designed values of the proton beam are listed in Table 1. The applications are shown in Figure 1. About half of the operation was for testing of two prototypes of neutron detectors under development, quarter of that was for neutronics performance measurement and neutron imaging beam line evaluation, and the other quarter was for the proton beam measurement.

Table 1. Main parameters of proton beam bombarding the target

Parameter	Designed Value	Present Value
Beam Energy (MeV)	13	3
Peak Current (mA)	50	28
Beam Pulse Width (µs)	500	100
Repetition Rate (Hz)	50	20

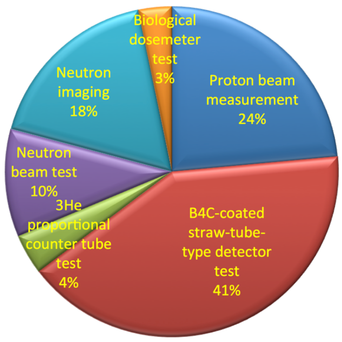

Figure 1. CPHS applications in 2016

1.2 Progress of upgrading to 13-MeV

The energy of the proton beam will be enhanced to the designed value of 13 MeV by the Drift Tube Linac (DTL) downstream the RFQ accelerator. The fabrication of the thirty-nine drift tubes and two

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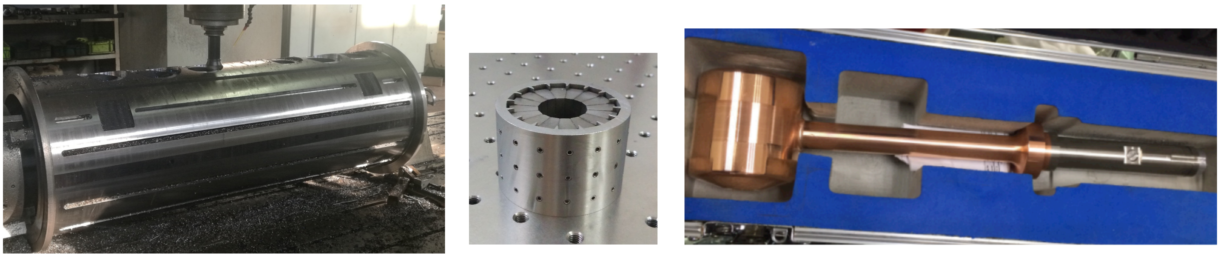
cavities will be completed in 2017. The experiments of alignment and tuning based on one test cavity and ten test tubes have been carried out to facilitate the final assembly and cold test.



(a) (b) (c)

Figure 2. (a) The DTL cavity being fabricated, (b) a mounted PMQ and (c) a qualified drift tube.

The engineering design of solid-methane moderator of CPHS was finished by CSNS target group in March 2017, and its fabrication is expected to be finished by the end of 2017.

1.3 Beryllium target burned

The 1.2mm-thick beryllium target had been mounted with a 2mm-thick aluminium plate of high thermal conductivity and good mechanical property to avoid being broken. The aluminum was attached to the beryllium with thermal conductive adhesive. However, the neutron flux since 2016 was found to be only 18% of the simulation results. We found the target was cracked and burned after taking it out, which is shown in Figure 3. The main reason of cracking is the hydrogen deposition in target. To avoid cracking, we have designed a new beryllium target of 1.1mm backing vanadium proposed by Yamagata [5] and brazing by Ag-Cu.

Figure 3. cracked beryllium target.

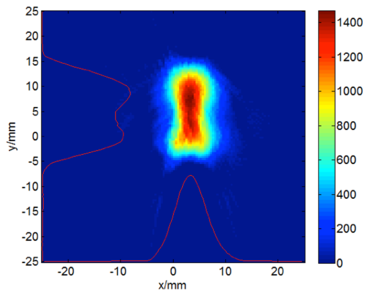


Figure 4. 2D profile of the proton beam.

1.4 Development of 2D Profile Measurement

2D profile measurement of the proton beam is under development by rotatable multi-wires based on CT algorithm, 20 carbon wires with the diameter of 30 μm are aligned and mounted on one board. With the position step of 0.1 mm and angle step of 5°, the 2D profile was acquired at the position of about six meters downstream the RFQ accelerator, as shown in Figure 4. The dynamic range of the measurement can reach ~10^4 in one-dimensional and ~10^2 in two-dimensional.

2. Development of neutron detectors

2.1 Boron coated tube array

An 800 mm × 800 mm array detector based on the 8mm-diameter boron coated tubes are expected to be built for CPHS-SANS instrument. A prototype module consisting of 64 tubes which stacked into 8 rows and 8 columns was developed as shown in Figure 5(a). Each tube is 800 mm in length and 8mm in diameter. A multiplex readout system was developed to decode the neutron hitting positions [6]. Its performance was studied on CPHS test beamline. The module was moved along its axis for 9 different positions. Position resolution for each tube of the prototype module were all measured, the average spatial resolution of 8mm × 8mm × 5.7mm was achieved and the worst axial resolution was 7.7 mm, which could still meet the CPHS-SANS' requirement.

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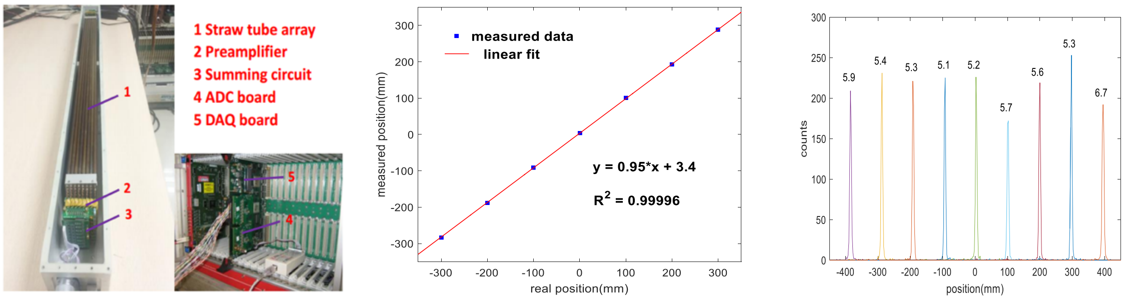


(a) (b) (c)

Figure 5. (a) Prototype module, (b) position linearity and (c) resolution of a single tube

2.2 Boron-lined honeycomb

A new detector design, as shown in figure 6(a) and proposed by Yang[7][8][9], removes the necessity of placing thousands of anode wires inside the boron lined gaseous detector, by introducing an electric field to drive the charged particles ionized electrons out to the electron multiplier, which is adjacent to the boron lined honeycomb structure. The boron lined honeycomb structure then only play the role of "neutron convertor", but not the role of "electron multiplication". The electron multiplier, which is used to replace the large number of anode wires, will collect the migrated electrons leaving from the honeycomb convertor and multiply them to form the neutron signals.

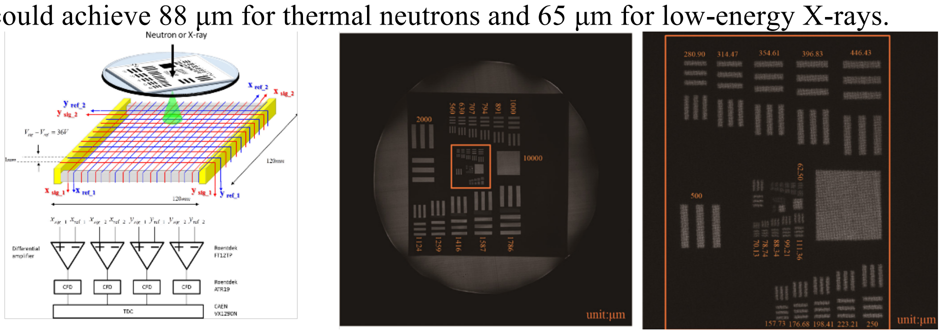
As shown in figure 6(c), this design can achieve the detection efficiency of more than 40%@25.3meV. A typical size of the detector cell is 10 cm ×10 cm ×10 cm, and many of the detector cells can be used to form a detector array to measure the neutrons scattered from the sample in the neutron scattering.

(a) (b) (c)

Figure 6. (a) The design of boron lined gaseous detector, (b) the honeycomb neutron convertor, coated with $0.9 mg/cm^2$ of ^{nat}B nano-powder and (c) The simulated detection efficiency of the detector.

2.3 Large area ^{n}MCP for neutron imaging

A large area (106 mm in diameter) neutron sensitive micro-channel plate (^{n}MCP) detector has been developed in Tsinghua[10][11][12][13], as shown in Figure 7. By doping 3 mole% of $^{nat}Gd_2O_3$, the ordinary MCP becomes neutron sensitive. The measured detection efficiency is 34%@25.3meV, and the spatial resolution could achieve 88 μm for thermal neutrons and 65 μm for low-energy X-rays.



(a) (b)

Figure 7. (a) The neutron sensitive micro-channel plate; (b) The spatial resolution of the ^{n}MCP

3. Neutron optics for CPHS-SANS

3.1 Research on neutron focusing mirrors for SANS

Aiming at enabling a more practical SANS instrument, neutron focusing mirrors, as one of the potential devices to increase neutron flux, have been proposed [14][15]. A geometry of ellipsoid-shaped conical mirrors, which employs simple cones to take place of precisely curved ellipsoid, have been applied to the design of CPHS-SANS [16]. A geometrical design has been made for the test mirror as shown in Figure 8, which is a two-shell ellipsoid-shaped conical geometry with a magnification 0.6 and will be coated with m=2 supermirror. The radii of the two shells are about 42 mm and 39 mm respectively and each shell contains 4 segments with a length of 49 mm. Tongji University in China, which has the experience on X-ray telescopes [17], is fabricating the mirror.

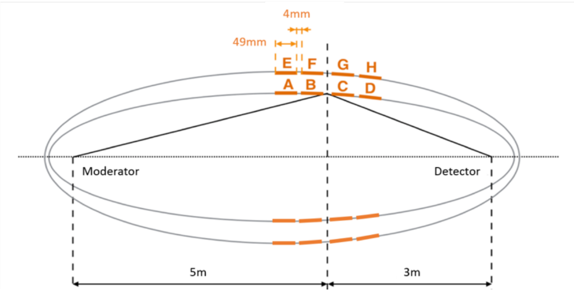


Figure 8. Schematic drawing of a two-shell ellipsoid-shaped conical mirror for test

3.2 Multi-pinhole design

There is a trade-off between flux and resolution in conventional pinhole system. Multi-pinhole collimator was proposed to increase the flux at sample while maintaining the *Q*-resolution [18]. McStas package was used to simulate and signal to noise ratio was also analyzed.

Acknowledge

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