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BEAM COMMISSIONING OF A 325 MHz PROTON IH-DTL AT XiPAF*

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Abstract

The inter-digital H-mode drift tube linac (IH-DTL) is widely used as the main component of injectors for medical synchrotrons. This paper describes the beam commissioning of a compact 325 MHz IH-DTL with modified KONUS beam dynamics at Xi'an 200 MeV proton application facility (XiPAF). The IH-DTL is developed by Tsinghua University (THU). This IH-DTL accelerates the proton beam from 3 MeV to 7 MeV in 1.1 m. The average energy of the beam is 7.0 MeV with the energy spread range of −0.6 MeV to 0.3 MeV. The output transverse normalized RMS emittance of the beam is 0.58 (x)/0.58 (y) π mm·mrad with the input emittance of 0.43 (x)/0.37 (y) π mm·mrad. The beam test results show good agreement with the beam dynamics design.

INTRODUCTION

The inter-digital H-mode drift tube linac (IH-DTL) operates in mode TE_{111}. It has been carefully studied and applied in heavy-ion accelerators. The advantages of IH-DTLs are compact and power-saving. At Tsinghua University (THU), a 325 MHz IH-DTL with modified KONUS beam dynamics has been designed [1], fabricated [2]. The IH-DTL is beam tested at Xi'an 200 MeV proton application facility (XiPAF) [3]. This IH-DTL accelerates the H- beam from 3 MeV to 7 MeV in 1.1 m. The comparison of the effective shunt impedance between the cavity at THU and other IH-DTLs [4–8] is shown in Fig. 1. The effective shunt impedance decreases with the increase of the beam velocity and the RF frequency. The shunt impedance of the 325 MHz proton IH-DTL is lower than the heavy-ion ones. On the one hand, it's because the beam current of proton is higher and the beam velocity is higher. On the other hand, with the same bore radius, the ratio of bore radius to cavity radius of 325 MHz cavities is larger than that of 200 MHz ones, according to Ref. [9], the shunt impedance is lower.

In this paper, the results of the beam commissioning at XiPAF are given. Beam commissioning of the IH-DTL cavity is undertaken to verify the physical and mechanical design of the IH-DTL cavity. The beam energy, energy spread, emittance and long-hour stability are tested.

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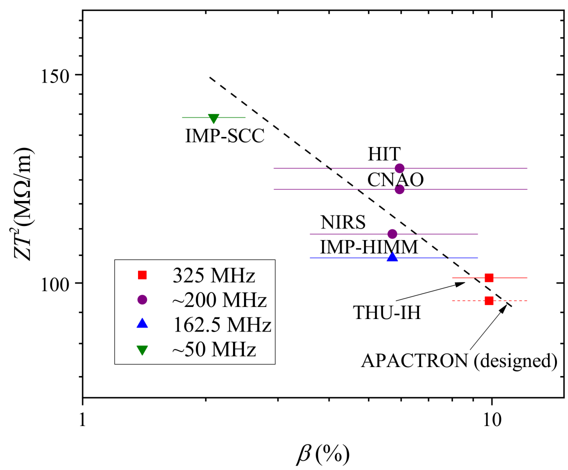

Figure 1: The comparison of the effective shunt impedance between the cavity at THU and other IH-DTLs.

PARAMETERS OF IH-DTL

To meet the multi-turn injection requirement for a typical medical synchrotron, a 325 MHz IH-DTL has been designed with a modified KONUS beam dynamics [1]. The IH-DTL is divided into three sections, namely, rebunching (-80°), 0° acceleration, and debunching (10°), which is slightly different from the conventional KONUS design. The -80° rebunching section eliminates the buncher between the IH-DTL and the RFQ. The positive phase design of the 10° debunching section helps to focus the beam and expand the beam phase. Thus the distance between the IH-DTL and the downstream debuncher can be shortened. This short IH-DTL tank has a length of 1.1 m with no focusing element inside. The main design parameters of this DTL are shown in Table 1. The IH-DTL cavity is shown in Fig. 2.

BEAM COMMISSIONING

Beam commissioning of the IH-DTL cavity is undertaken to verify the physical and mechanical design of the IH-DTL cavity. The IH-DTL cavity is installed on the beamline

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Table 1: Main Parameters of DTL

Parameter	Value
Ion type	Proton
RF Frequency	325 MHz
Input beam energy	3 MeV
Output beam energy	7 MeV
Input peak current	15 mA
Tank length	1.1 m

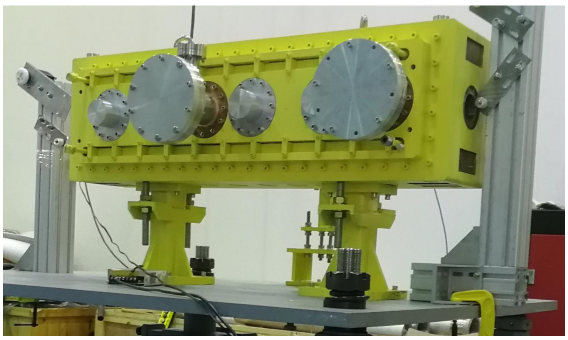

Figure 2: IH-DTL cavity.

of the H^- linac injector of XiPAF, downstream the RFQ accelerator.

Temporary Beamline

The injector of XiPAF consists of an H^- ECR source, an LEBT, an RFQ, and an Alvarez-type DTL. For the beam commissioning of the IH-DTL, the Alvarez-type DTL is replaced by the IH-DTL. The temporary beamline is shown in Fig. 3. The temporary beamline downstream the RFQ consists of a beam matching section (BMS), the IH-DTL, and the test beamline.

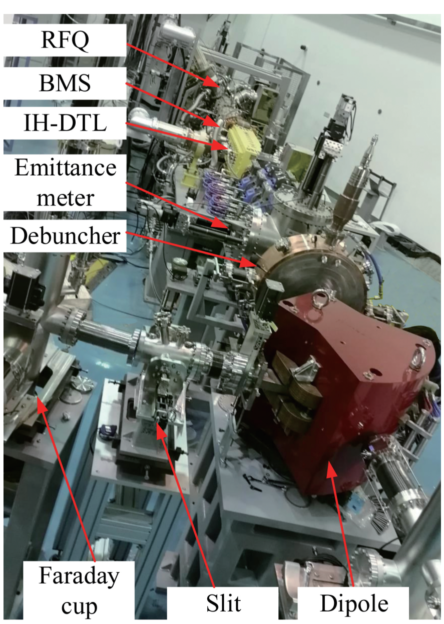

Figure 3: Temporary beamline.

Operating Point

The operating point of the IH-DTL, including the RF power and the RF phase, needs to be determined. The approximate RF power is given by the tunning result. The RF phase is scanned to find a rough range compared with the simulated transmission result. Finally, the operating point is given by a refined scan of the RF phase under three different input power [10].

Energy Measurement

The output beam energy at the exit of the IH-DTL is measured by the TOF method using the BPMs and one dipole magnet. At the operation point, the average energy measured of the BPMs at the exit of IH-DTL is 7.0 MeV, and the error of the measured energy is within ± 0.2 MeV.

At the operating point, the average energy of the beam at the IH-DTL exit can be obtained as 6.96 MeV using the dipole magnet [2]. The result is in good agreement with the TOF method. The measurement and analysis results of the energy spread are demonstrated in Fig. 4. The density of the average energy has been normalized to 1. It can be seen from Fig. 4 that with the decrease of the slit width, the measurement error is also reduced. When the width of the slit is 1.4 mm, the measured energy spread is in good agreement with the simulation results.

Emittance Measurement

The transverse emittance at the exit of the IH-DTL is measured with the emittance meter. The measurement results show that the normalized RMS emittance at the exit of the IH-DTL is 0.58 (x)/0.58 (y) π mm·mrad, while the normalized RMS emittance at the exit of the RFQ is 0.43 (x)/0.37 (y) π mm·mrad [2]. The measured phase spaces at the exit of the IH-DTL are given in Fig. 5.

12-Hour Stability

The main purpose of the stability test is to observe the influence of long-time environmental changes on the beam quality of the IH-DTL. So we need to do a stability test to verify its stability in a long time. The stability test was carried out for 12 hours. The results of the stability test are shown in Fig. 6, and only one breakdown occurs at 05:00. The beam current at the exit of the IH-DTL is above 1.5 mA during the 12-hour test. It can be observed that the current at the exit of the DTL is relatively stable around 1.56 mA.

CONCLUSION

This paper gives a summary of the beam commissioning of the IH-DTL. The beam test result of IH-DTL is given in Table 2. The experimental performance of the IH-DTL cavity verifies the design methodology including the beam dynamics and cavity design. The application of the IH-DTL with KONUS - beam dynamics is expanded to proton accelerators with beam tested.

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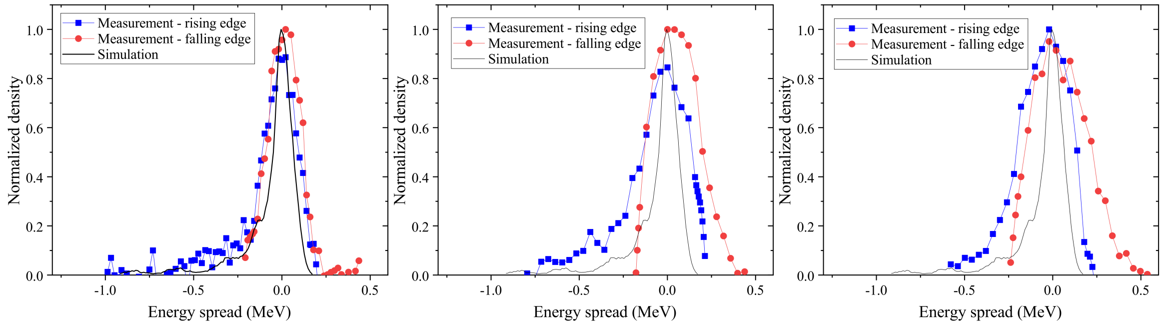

Figure 4: Energy spread measurements: 1.4 mm slit (left); 2 mm slit (middle); 4 mm slit (right).

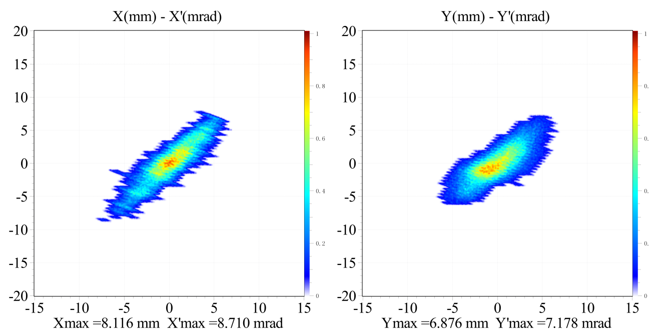

Figure 5: Measured phase spaces at the exit of the IH-DTL: $x - x'$ (left); $y - y'$ (right).

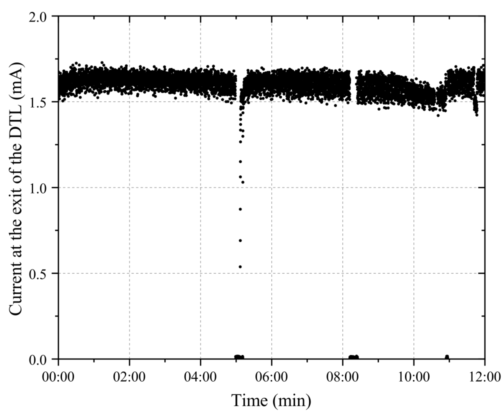

Figure 6: 12-hour stability of the IH-DTL: current at the exit of the DTL.

Table 2: Beam Test Result of IH-DTL

Parameter	Value
Ion type	H^-
Input beam energy	3.0 MeV
Output beam energy	7.0 MeV
Peak current	≥1.5 mA
Input Norm. RMS transverse emittance	0.43(x)/0.37(y) π mm·mrad
Output Norm. RMS transverse emittance	0.58(x)/0.58(y) π mm·mrad

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