ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-WEPB10

STUDY ON A HOM TYPE BUNCHER*

L. Lu†, X. Xu, L. Shi, L. Sun, Institute of Modern Physcis (IMP), CAS, Lanzhou, China
C. Xing, T. He, L. Yang, University of CAS, Beijing, China

Abstract

Normally, drift tube linacs (DTL) are used following RFQ linacs for beam acceleration in middle and high beam energy region. The acceleration efficiency of DTLs is decreasing with beam energy increasing. Using resonated higher order mode (HOM) of cavity, DTL can achieve higher effective shunt impedance. We proposed a 325MHz DTL with TE_{115} mode. In this paper, the dynamics calculation and electromagnetic design of the HOM-DTL will be reported.

INTRODUCTION

Shown in Fig. 1, in the low energy region, the Interdigital-H (IH) type drift tube linacs (DTLs) have a higher shunt impedance and suitable accelerating structure for heavy ion acceleration, thus the DTLs operated in TE_{111} mode are normal used following the RFQ type linac [1–3]. However, in the medium and high energy region, the Alvarez type DTLs operated in TM_{010} mode are normally used although its shunt impedance reduces rapidly [4,5], shown in Fig. 2, because its shunt impedance is higher than the IH-DTLs in those energy regions.

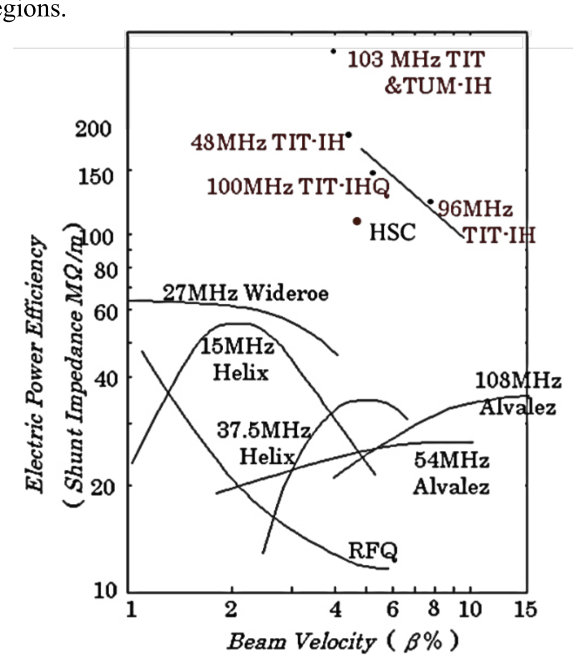

Figure 1: The shunt impedance of the low beta linacs.

Since the DTLs operated in TE_{11n} mode of the higher order mode have a property which is suitable to accelerate ions in medium and high energy region [6]. We proposed a 325MHz DTL operated in TE_{115} mode. Our proposed HOM-DTL is designed as a prototype buncher and its structure is shown in Fig. 3.

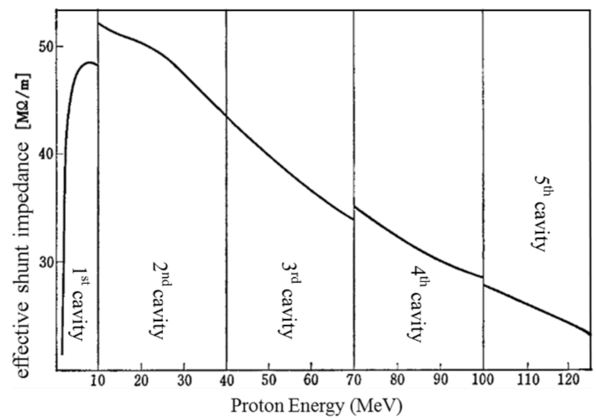

Figure 2: The shunt impedance changing of the Alvarez type DTLs in medium and high energy region.

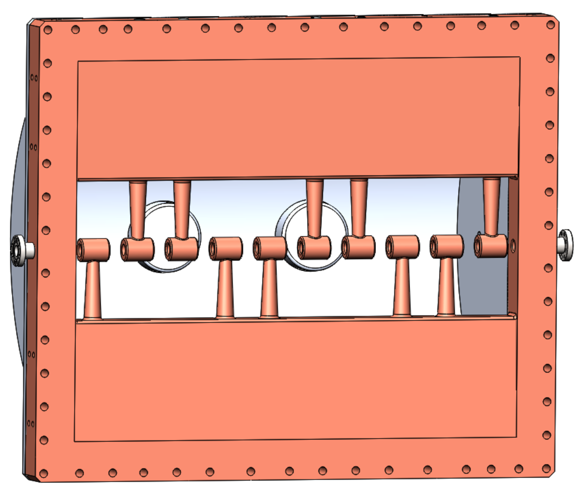

Figure 3: The inner structure of proposed HOM-DTL.

ELECTROMAGNETIC DESIGN

The frequency of proposed HOM-DTL is 325MHz which is 4th harmonic of the frequency of 81.25MHz. This HOM-DTL is a prototype research for future heavy ion buncher. The estimated peak voltage is rather high as several mega-voltages (MV). The Microwave Studio (MWS) code and ANSYS code are used to calculate the cavity electromagnetic simulation and mechanical simulation [7,8].

As shown in Fig. 3, the HOM-DTL has normal DTs and ridges that is same to the normal type IH-DTLs with TE_{111} mode and Alvarez type DTLs with TM_{010} mode,

†luliang@impcas.ac.cn
*Work supported by the NSFC under Grant No. 11427904, No. 11475232 and No. 11535016.

ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-WEPB10

however, the resonated frequency of cavity can be tuned to TE_{115} mode by configuring directions of the stems. Shown in Fig. 4 and Fig. 5, the biggest feature of the HOM-DTL is that the axial accelerating e fields of gaps are quite flat, even in the two end gaps. The flat e field distribution makes the field tuning of cavity very easy. The proposed HOM-DTL adopts 10 stems and 11 gaps, and the total length is 1m. Shown in the table 1, when the Kilpatrick factor adopts 1.5, the simulated total voltage of the HOM-DTL is 1.93MV, and the shunt impedance of the HOM-DTL is calculated as 91.8 MΩ /m that is better than other structure linacs in same beam beta region shown in Fig. 1 and normal DTLs shown in Fig. 2. That indicates the 325MHz HOM-DTLs have a better power efficiency in the medium energy region.

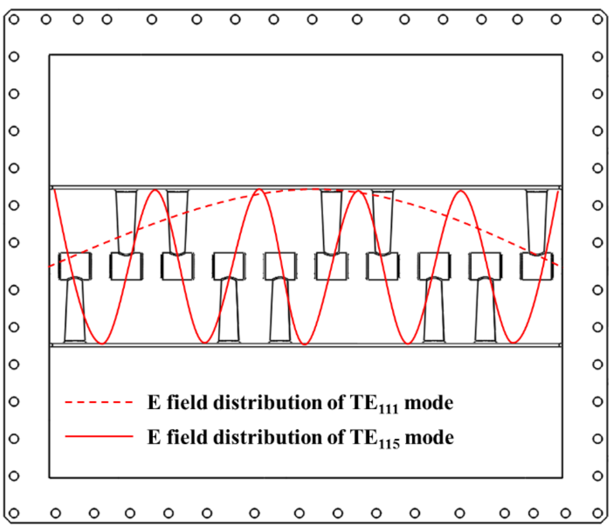

Figure 4: RF property of TE_{115} mode (solid line) in the HOM-DTL. Dot line shows RF property in IH-DTLs.

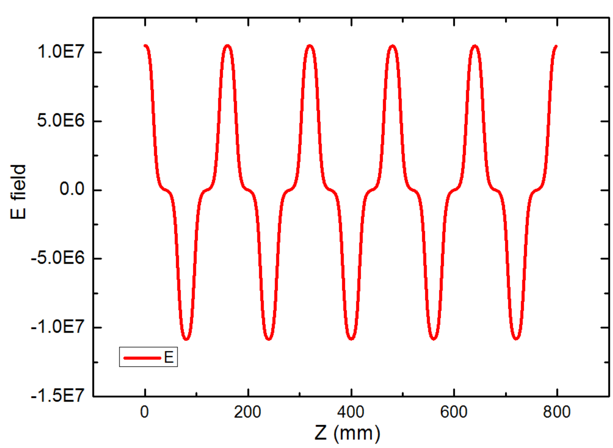

Figure 5: Flat e field distribution of TE_{115} mode in the HOM-DTL.

Because an existing mainl coppery frame (copper-colored part in the Fig. 3) was adopted for simulations and fabrications of the 325MHz HOM-DTL, the optimization of the RF structure design is limited. In our opinion, the shunt impedance could be increased 1.5 times of the calculated 91.8 MΩ/m.

Table 1: The Simulated Parameters of the HOM-DTL

Items	Value
Frequency / MHz	325.008
Gap No.	11
DT No.	10
Cavity diameter / mm	660
Beam bore / mm	20
DT diameter / mm	40
β (particle energy)	0.173
Inner length / mm	800
Total voltage / MV	1.93 @ 1.5 Kp.
Dissipated power / kW	50.6 @ 1.5 Kp.
Q value	9167
Shunt impedance / MΩ /m	91.8

The RF properties of proposed HOM-DTL are confirmed by MWS, shown in Fig. 6, according to the resonated TE_{11n} order, the frequency shows an uptrend and the Q value shows a downtrend. The downward Q indicates that the RF mode is more higher, the higher RF power is needed. Based on our calculations, the ridges have a big effect on the cavity RF property. The height of the ridges is more higher, meanwhile the stems are more longer, the Q value is more higher. The TE_{114} is 308.223MHz, the desired resonated RF mode is 325MHz which is totally separated from the neighbor mode.

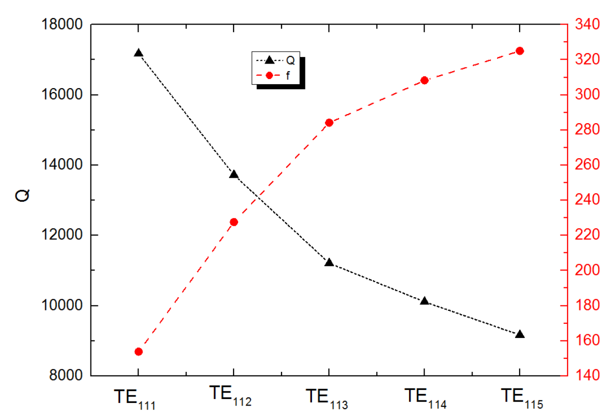

Figure 6: Resonated RF mode and Q values of calculated HOM-DTL. According to the TE_{11n} order, the Q shows a downtrend and the frequency shows uptrend.

And same with the normal IH-DTLs, the hottest part of the HOM-DTL is the stem [9]. Shown in Fig. 7, the surface current concentrates in the stems. Though we are limited by budgets, and the HOM-DTL will be carried out low power test and aimed to test the shaping method without alignment. However, the cooling designs of stems should be considered for possibilities of future use. According to the ANSYS calculations, with 10 water

ISBN: 978-3-95450-203-5 doi:10.18429/JACoW-HIAT2018-WEPB10

routes for stem cooling and 10% duty, the maximum deformation is occurred in the cavity (between two tuners) and the maximum temperature is about 40^0C and locates in the first tube.

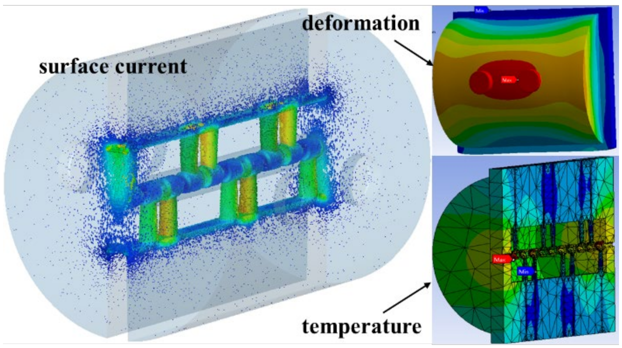

Figure 7: Images of surface current (left part) and multi-physics analysis. The intensity increases as the color changes from blue to yellow and to red.

The frequency tuning is being designed using four tuners. Both sides of the main frame have two tuners, and the tuners are uniform distribution in the beam direction. The diameter of tuners is 60mm, and the preset inserting length of the tuners is 35mm. According to our simulations, the adjustment region of frequency is ±1.56MHz which is enough for frequency tuning.

FABRICATION

The HOM-DTL is being fabricated in manufacturing company. Shown in Fig. 8, although the main frame is being shaped from a block copper by using a numerical-controlled machine tool, the cavity wall is being bent from an aluminum sheet because of the budget limitation. The stand supports the main frame directly by using two stainless holders. And two tuner-supports fixes the four tuners. The tuners are also made from aluminum material.

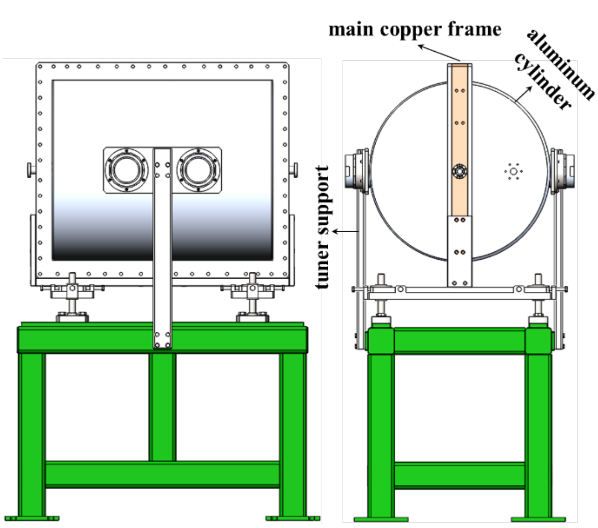

Figure 8: Assembly image of the HOM-DTL. The main frame is made from oxygen-free copper material. The other cavity parts (walls and the tuners) are being made from aluminium material.

SUMMARY AND FUTURE PLAN

A HOM structure cavity driven by TE_{115} RF mode was calculated and simulated for high energy beam bunching. Its shunt impedance is higher than IH-DTLs and Alvarez type DTLs in medium energy acceleration. Along the 800mm axis, the designed 325MHz HOM-DTL buncher could induce 1.93MV with flat e field distribution along the axis. Its shunt impedance is 91.8 MΩ/m with a safe Kp factor of 1.5. The core part of the HOM-DTL is being shaped from a block copper, and other parts are being fabricated from aluminium material.

The fabrication and assembly will be finished by the end of this October. Our team will carry out a low power test for measuring the RF properties such as resonated frequency and e field distribution. Also, we are applying a national natural science foundation of China for future copper fabrication of the cavity wall.

ACKNOWLEDGEMENT

Return to our researcher, the authors would like to convey thanks to Prof. Dacheng ZHANG for fruitful discussions and comments on the cavity designs.

REFERENCES

[1] T. Ito, L. Lu, et al., Nucl. Instrum. Methods Phys. Res. B 261, 2007, p.17-20.
[2] L. Lu, T. Hattori, et al., Nucl. Instrum. Methods Phys. Res. A 688, 2012, p.11-21.
[3] L. Lu, T. Hattori, H.Y. Zhao et al., High Power Test of An Injector Linac For Cancer Therapy Facilities, Phys. Rev. ST Accel. Beams 18, 111002, 2015, p.1-8.
[4] L.W.Alvarez, Phys. Rev., 70, 799, 1946.
[5] M. Heilmann, X. Du, P. Gerhard, L. Groening, M. Kaiser, et al., Design Study for A Prototype Alvarez-Cavity for the Upgraded Unilac, *in proceedings of IPAC2017*, Copenhagen, Denmark, 2017, pp.2205-2207.
[6] N. Hayashizaki, T. Hattori, IH Linac with Higher Order Modes, *in proceeding of EPAC08*, Genoa, Italy, 2008, pp.3419-3421.
[7] http://www.cst.com
[8] https://www.ansys.com/
[9] L. Lu, L. P. Sun, T. He, L. Yang, W. Ma, et al., Research on A Two-Beam Type Drift Tube Linac, *in proceeding of LINAC2016*, Michigan State University, East Lansing, Michigan, USA, 2016, pp.989-991.