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THE SIMULATION AND MANUFACTURE OF THE ROOM TEMPERATURE CH-DTL*

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Abstract

The room temperature Cross-bar H Type Drift Tube Linac (CH-DTL) is one of the candidate acceleration structures working in CW mode. In order to optimize the parameters, the 3 dimensional electromagnetic field of the CH-DTL cavity is simulated. The method of parameter sweeping with constraint variable is better than the method of parameter sweeping with only one variable during the optimization. In order to simplify the manufacture, the drift tube surface can be designed as spherical shape. The CH-DTL cavity has been manufactured and tested.

INTRODUCTION

An Accelerator Driven transmutation System (ADS) [1, 2], currently under development in China, will be used to reduce both the toxicity and half-life of the long-lived radioactive nuclear waste created in light-water reactors to a controllable level [3]. An industrial scale ADS will require an average beam current of≥10 mA. In 2010, the Institute of High Energy Physics (IHEP) and the Institute of Modern Physics (IMP) are both developing superconducting accelerating structures which would follow an RFQ [4].

Although low power consumption and a large aperture favor superconducting structures following a 2-3.5MeV RFQ, normal-conducting accelerating structures have some advantages [5, 6]. Normal-conducting structures in the energy range from 2 to a few tens of MeV are more compcter and can obtain high acceleration gradient than the superconducting ones and, when located downstream of the RFQ, they can serve as a beam filter to reduce the potential for beam loss at higher energies. The CH structure, initially proposed by IAP [7, 8], belongs to the π-mode family of accelerating structures and is typically characterized by high shunt impedance, low stored energy and stable geometry that is relatively easy to cool. This structure is evaluated as a potential candidate for CW operation. In this paper it is presented the results of geometry optimization of the CH structure using the method of parameter sweeping with constraint variable (PSCV) [9].

THE METHOD OF PARAMETER SWEEPING WITH CONSTRAINT VARIABLE

The parameters of a single cell are shown in Fig. 1. The outer drift tube radius (TR) and the radius of the drift tube aperture (HR) are fixed during the optimization. Typically a single parameter was swept while monitoring the cavity's RF properties. However, by changing the length of the drift tube, the resonant frequency changes. Our objective is to optimize the cavity geometry at a fixed frequency (325 MHz). If the frequency changes during the optimization, the optimized value of the swept parameter will differ from the value corresponding to the correct frequency as shown in Fig.2 and Table1. In Fig. 2 the radius of the drift-tube stem base (R2) was swept while fixing the cavity radius (CR). It can be seen that the effective shunt impedance decreases with increasing R2 while the resonant frequency increases from 321.7 to 333.5 MHz. It is convenient to use the cavity radius (CR) as a "constraint variable" to fix the resonant frequency to 325 MHz as shown in Table1. By doing so, it can be found that the maximum effective shunt impedance at the correct frequency occurs at R2=22. This method can be named after "parameter sweeping with constraint variables" (PSCV). Other parameters can be selected as constraint variables, but it is found that the resonant frequency is more sensitive to cavity radius than it is to other geometrical parameters.

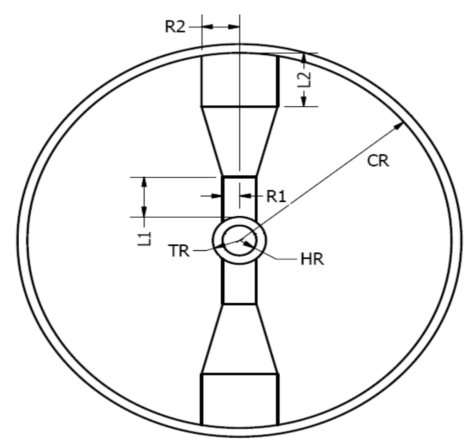

Figure 1: Geometry of a CH single cell.

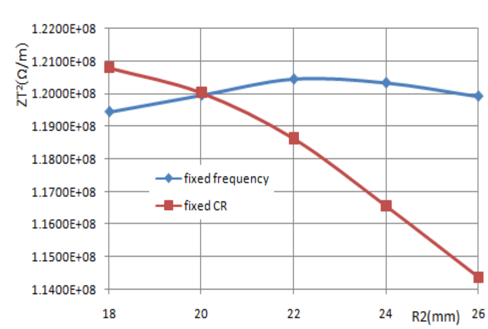

Figure 2: Shunt impedance as a function of outer stem radius using two methods of parameter sweeping.

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Table 1: Comparison of Parameter Sweeping with and without a Constraint Variable

Fixed frequency			
R2(mm)	CR(mm)	f(MHz)	$ZT^2(\Omega/m)$
18	140.9	324.69	1.1945E+08
20	142	324.9	1.1996E+08
22	143.1	324.52	1.2045E+08
24	144.2	324.18	1.2033E+08
26	145.2	324.06	1.1992E+08
Fixed cavity radius			
R2(mm)	CR(mm)	f(MHz)	$ZT^2(\Omega/m)$
18	142	321.7	1.2080E+08
20	142	324.9	1.2004E+08
22	142	327.9	1.1864E+08
24	142	330.8	1.1656E+08
26	142	333.5	1.1438E+08

SPHERICAL DRIFT TUBE

The drift tube in CH-DTL is typically much smaller than drift tubes in a conventional DTL, and the small drift tubes have much smaller capacitance resulting in a higher shunt impedance, but they are so small they are difficult to manufacture with integral cooling channels. Traditional drift tubes are nominally cylindrical as shown in Fig. 3. By modifying the design to have a spherically shaped drift tube, the stem and drift tube can be manufactured (turned) in one step without welding or brazing. In Fig. 4 it can be seen that axis of revolution for the stem is coaxial with that of the drift tube. The effective shunt impedance of the spherical drift tube is only slightly lower than that of the cylindrical drift tube (<1%) as shown in Fig. 5.

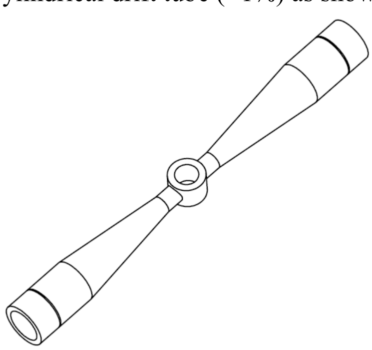

Figure 3: Cylindrical drift tube.

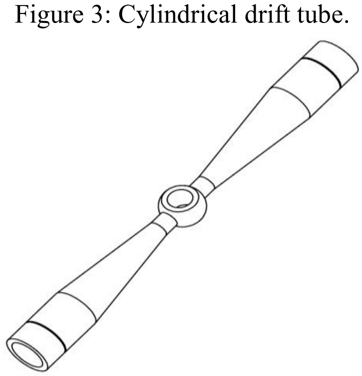

Figure 4: Spherical drift tube.

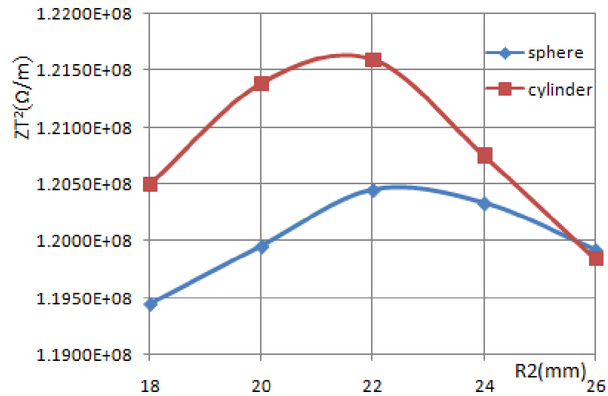

Figure 5: Shunt impedance for two different drift tube shapes as a function of the stem-base radius.

OPTIMIZING THE MULTI-CELL CAVITY

The multi-cell CH-DTL cavity model includes four drift tubes and five gaps as shown in Fig.6. In addition to the parameters optimized above, the multi-cell cavity contains two additional geometrical features requiring optimization. These include the length and radius of the end cups (EL and ER). ER is first swept to find that the effective shunt impedance is inversely proportional to ER as shown in Fig. 7.

As the end cup length (EL) increase, it can be seen that the effective shunt impedance decreases rapidly due to the power dissipated in the end regions where no acceleration occurs as shown in Fig. 8.

CAVITY MANUFACTURE AND LOW POWER RF MEASUREMENT

The stem, the cavity wall and drift tube is made of the oxygen free copper, and the flange is made of the stainless steel with copperized inside as shown in Fig. 9. The network analyzers is used for the low power RF measurement, and the Q value is about 7194.

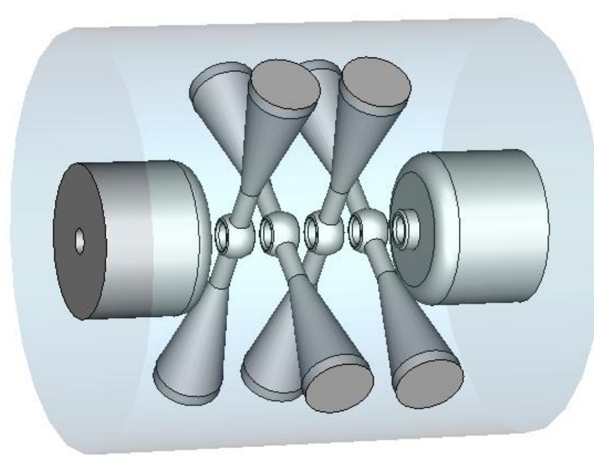

Figure 6: 3-D geometry of the 5-cell CH-DTL cavity model.

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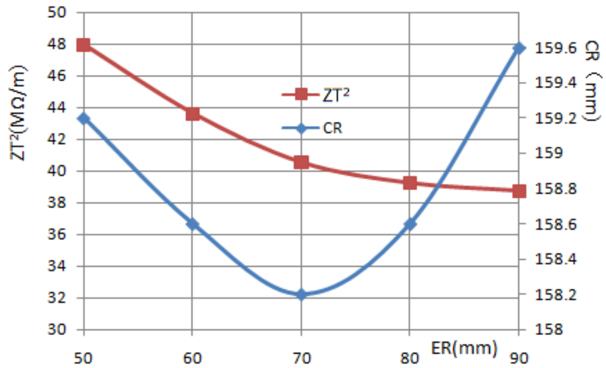

Figure 7: Shunt impedance and cavity radius at a fixed frequency as a function of ER for a 5-cell cavity without end cups.

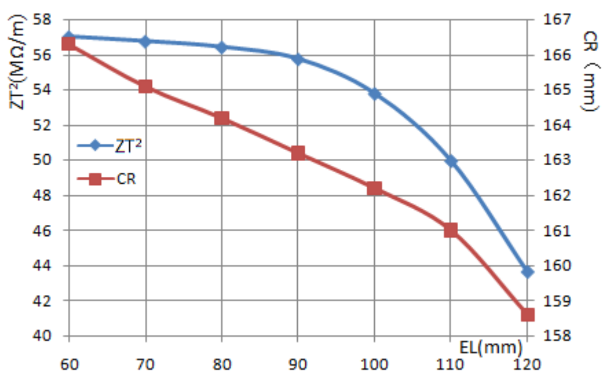

Figure 8: Shunt impedance and cavity radius at a fixed frequency as a function of EL for a 5-cell cavity with end cups.

Figure 9: The inside view of the manufactured cavity.

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