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CELL DESIGN AND TEST FOR AN INDUCTION LINAC

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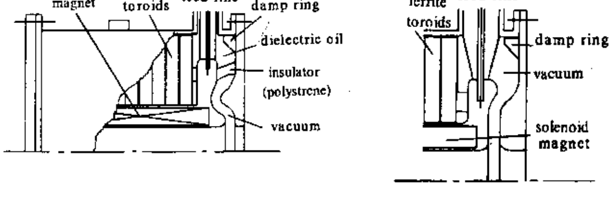
Abstract

The prototype cell design and test for an induction linac are presented. The two prototype cells, which are expected to operate at 250kV, are composed of a ferrite core immersed in oil (MODI) or in vacuum(MODII), an gap with curved stainless steel electrodes, a solenoid magnet with two dipole coils, and finally a insulator in MODI. The test results of the cells are introduced.

1 INTRODUCTION

An induction linac consists of an injector and a series of induction cells. Therefore, the final performance of the accelerator strongly depends on the cell feature. The Beam Break-up(BBU) instability due to the interaction between beam and cells and the corkscrew motion caused by misalignment and chromatic aberration of optical elements can also adversely effect the beam quality. The crucial issues considered in the cell design with emphasis on the measures taken for minimizing the transverse impedance and beam instability while optimizing the cell high-voltage stand-off are introduced briefly in this paper. The test results of the prototype cells are given.

Two prototype cells have been developed and are referred to as MODI and MODII shown in Fig. 1.



(a) MODI (b) gap region of MOD II

Figure 1: Schematic of the prototype cells

2 HIGH-VOLTAGE DESIGN AND TEST

The cross sectional area, A, of the induction cores is determined by the required voltage , U, pule duration, τ, and the magnetic flux swing, ΔB

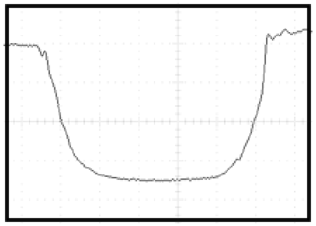
$$U\cdot\tau=\Delta B\cdot A \qquad (1)$$

11 home-made ferrite toroids with 237mm ID, 508mm OD, 25.4mm thick were used in MODI while 10 corner- radiused toroids with 254mm ID, 508mm OD, 25.4mm thick used in MODII to provide the accelerating pulse. The 148mm cell bore is a engineering compromise between the large bore needed to lower the transverse impedance and the small bore required to reduce the costs and to provide enough space for the solenoid magnet.

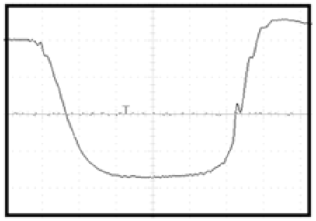
The designed maximum electric field stress was limited to 190kV/cm for Ocr18Ni9 stainless steel electrodes that form the accelerating gap. The electrodes were laser welded and grit blasted to ensure that 300kV voltage pulse can be sustained by the gap. The breakdown electric field of the insulator separating the oil-filled ferrite core from the vacuum portion of the cell in MODI was maximized by holding 42° angle between the insulator and the calculated electric potential line and carefully treating the "triple points "(vacuum, metal, and insulator interfaces). The insulator was also completely shielded from direct line-of-sight with the beam to prevent it charging and UV-induced breakdown in a way that reduces the MODI transverse impedance. The maximum electrical fields on the electrodes surface calculated by LWE2D and ELECAF2D are 185kV/cm (MODI) and 189kV/cm (MODII) and 70kV/cm in the insulator. Each cell is assembled as a ferrite loaded transmission line in favor of the pulse flattop, the impedance, R_f, and electrical length, T, of which are characterized by

$$R_f = \left[\left(\mu_r \mu_0 / \varepsilon_r \varepsilon_0 \right)^{1/2} / 2\pi \right] \ln\left(R_0 / R_i \right) \quad (2)$$

$$T = l \left(\mu_r \varepsilon_r \right)^{1/2} / c \quad (3)$$

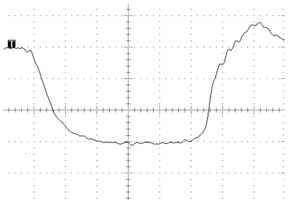


(a) 252kV with flattop74ns,144kV/div,25ns/div

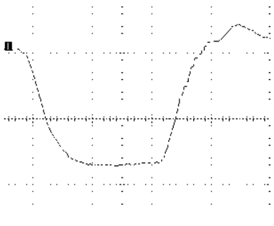


(b) 300kV with flattop70ns,160kV/div,25ns/div

Figure 2: MODⅠ accelerating voltage pulses



(a) 250kV with flattop 62ns,84kv/div,20ns/div



(b) 300kV with flattop 58ns, 85kV/div, 20ns/div

Figure3: MODⅡ accelerating voltage pulses

where l is the length of the ferrite core. ε_r , μ_r and ε_0 , μ_0 are the permittivity and permeability of the ferrite core and free space respectively. c is the speed of light in vacuum. R_0 , R_i are the outer and inner radii of the ferrite toroids. The auto-reset circuit of the core and the conducting ceramic resistors provide adequate and stabilized reset current for the core and compensate the fluctuations in accelerating pulse caused by the variations of cell impedance and beam current[1]. The accelerating pulses measured are shown in Fig.2,3.

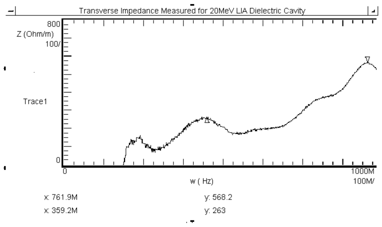
3 CELL TRANSVERSE IMPEDANCE

The beam instability arising from the high-frequency transverse oscillations degrades the beam brightness and time-integrated beam spot size at the final focus of the accelerator. Theoretic analysis have shown that the transverse impedance of the cells can be reduced by using insulator material, the dielectric constant of which is near to that of oil used in MODI, placing the insulator close to the cell bore, slanting the insulator at approximately the Brewster angle to enhance the *rf* waves to the ferrite, exposing the ferrite to the cell to absorb the *rf* waves , putting a piece of ferrite at the cell corner to damp the cell modes. The curved gap in MODI was designed to form a section of coaxial transmission line inserted between the cell structure and the accelerating region to cut off the cell TM110 mode[2], thereforeto reduce the transverse impedance of this mode. To further lower the transverse impedance , a conducting ceramic ring is being fabricated to replace the nylon insulator.

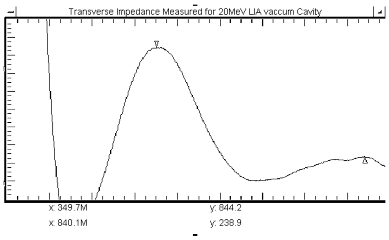
The cell transverse impedance measured by biwire method[3] are shown in Fig. 4. It shows that the transverse impedance corresponding to TM110 in MODI is lower than that in MODII. The value shown in Fig. 4. will be reduced by about 20% at operation, because of the core bias.

4 ALIGNMENT

The chromatic aberration of the focusing elements and misalignmentof the accelerator may result in transverse oscillation of the beam centroid referred to as corkscrew motion. Special care was taken in the cell design and fabrication to control the mechanical tolerance. The magnet are positioned with respect to the bore to ensure that the magnetic alignment is as good as mechanical. The quadrufilar windings, the iron field-smoothing ring, and the corrective coils are used to improve the magnetic alignment.

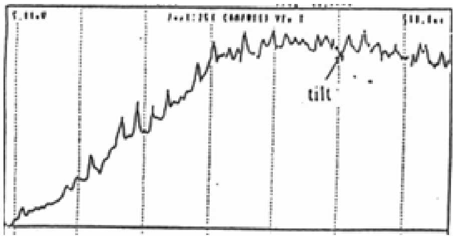


(a) MOD I

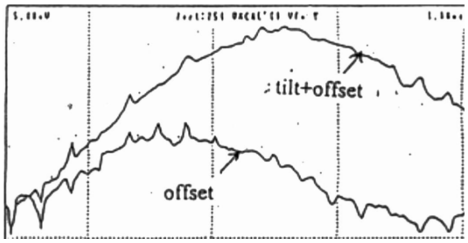


(b) MOD II

Figure 4: The cell transverse impedance



(a) tilt



(b) tilt and offset

Figure 5: Signals of magnetic tilt and offset

The pulsed taut-wire[4] measurements show the offset and tilt of the magnetic axis from the mechanical axis are 0.2mm and 1.0mrad respectively(Fig. 5).

5 CONCLUSION

Both of the two prototype cells exhibited good properties for constructing electron-beam induction linac. Compared to MODII, the MODI is even better.

6 ACKNOWLEDGEMENTS

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