Preliminary study of proton Beam Transport in a 10 MeV Dielectric Wall Wall Accelerator

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Dielectric wall accelerator

- Dielectric wall accelerator (DWA) originated from the linear induction accelerator (DARHT, Dragon), which is based on the pulsed power technology.
- Concept of the modern DWA is proposed by G.J. Caporaso. The accelerating gradient of a proton DWA is expected to be 100 MV/m.
- Virtual traveling wave mode for any charged particle.
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Diagram:

- HGI tube
- Stacked solid-state pulse forming line
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DWA for proton therapy

DWA is the next generation accelerator system for intense modulated proton therapy (IMPT).

- The spot size, dose and energy (70 ~ 250 MeV) of the bunch can be varied from shot-to-shot
- No gantry, the accelerator can be rotated (<3 m)
- No neutron production

Therapy system proposed by LLNL
A DWA system for IMPT should be not only short but also light enough (no external focusing element)

1 MeV (20 MV/m) → 10 MeV (25 MV/m)

Development of the ion source and LEBT is performed by Institute of Heavy Ion Physics, Peking University
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DWA in CPAC (Y.J. Chen, RPIA2011)
Important DWA elements developed at IFP

Solid-state parallel-plate Blumlein

Simulation

Experiment
Important DWA elements developed at IFP

High gradient insulator (HGI)

High voltage breakdown mechanism of the HGI is still an open question

- Scaling law $\sim L^{-1/2}$
- Cathode triple junction initiated secondary electron avalanche
- Vacuum arcing
- Secondary electron emission from intermediate triple junction adjacent to the anode
Beam Injection

◆ Self-focusing of the bunch: accelerating field gradient at the entrance will provide a focusing force

◆ The envelops for injection beam of 40 keV, 20 mA were solved

◆ $E_z$ increases linearly from 0 to 25 MV/m at a distance of 5 cm

Beams with low injection energy are over-focused

$$E_r = -\frac{r}{2} \frac{\partial E_z}{\partial z}$$

$E_z$

$E_r$
Beam Transport Simulation

- 2-D axisymmetric particle-in-cell simulation for 40 keV, 20 mA, 1ns bunch
- Increase the acceptance of the DWA since any beam loss inside the HGI tube may cause surface flashover
- Emittance growth and energy spread are all acceptable since the beam line is too short

Phase 1: $r$ – focusing $z$ – decompressing
Phase 2: ……
Phase 3: $r$ – defocusing $z$ - compressing
Longitudinally bunching

$6 \times 10^{11}$ protons/min for IMPT

100 MV/m corresponds to the accelerating pulse width of 1 ns (FWHM)

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition rate (Hz)</td>
<td>10</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Bunch width (ns)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Peak Current (mA)</td>
<td>800</td>
<td>160</td>
<td>320</td>
</tr>
</tbody>
</table>

- Longitudinally bunching is required
- Bunching by applying head-to-tail velocity tilt
Thank you for your attention!