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(G*) Study of Annular Parallel Plate Waveguides for a Dielectric Wall Accelerator

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Introduction

Dielectric Wall Accelerators (DWAs), which coordinate high-gradient, nanosecond electric field pulses with particle bunch trajectory, may be suitable as compact accelerators for proton therapy. Parallel plate waveguides (PPWGs) have been proposed as a means of generating the electric field pulses. **This work is a study of annular PPWGs**, where electrical impulses applied at the outer radius propagate radially and produce electric fields at the inner radius (i.e. the beampipe). Radial propagation of the signal introduces distortions which must be quantified to 1) design upstream circuits that produce a suitable electrical impulse and 2) select the geometric and material properties of the PPWG. The design choices are made to produce a time-varying electric field at the beampipe that maintains longitudinal beam stability.

Methods

The electromagnetic fields of a PPWG were derived in cylindrical coordinates assuming radial propagation and axial symmetry. For TEM modes, the electric field is:
\begin{align}
\mathbf{E} &= \frac{\beta_s }{i\omega \varepsilon} \left[\kappa_1 J_0(\beta_s s) + \kappa_2 Y_0(\beta_s s)\right] \hat{z}; & \beta_s = \omega\sqrt{\varepsilon\mu},
\end{align}
where ω is frequency, ε is permittivity, μ is permeability, κ_1 and κ_2 are constants, J_0 and Y_0 are Bessel functions, and s is radial distance. By comparing field magnitude at the inner and outer radii, one obtains an expression for frequency-dependent amplification.

Various PPWG configurations were modelled in COMSOL Multiphysics and excited at the outer radius with a Gaussian pulse. The frequency response was measured by comparing the spectra of the input and output pulses. Numerical PPWG simulations with impedance-matched inner boundary conditions were compared to results obtained from the field equation.

Results & Conclusion

Agreement between theory and simulation indicates that at lower frequencies (<10GHz), ω, ε, μ, and radii all affect amplification, while at higher frequencies, amplification increases to a plateau determined exclusively by the two radii of the annulus. Plate separation has no effect on amplification for the studied TEM mode, but affects higher order mode activation. A mismatched impedance at the beampipe leads to deviation from theory. Future work will study physically realistic, time-dependent (due to particle transit) beampipe impedance. Additionally, experimental validation and collaboration with colleagues in beam physics and circuitry design will help to identify suitable PPWGs for use in DWAs.

Keyword-1

Accelerator Physics

Keyword-2

Waveguide design

Keyword-3

Proton Therapy

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