X-Band Dipole Mode Deflecting Cavity for the UCLA†† Neptune Beamline

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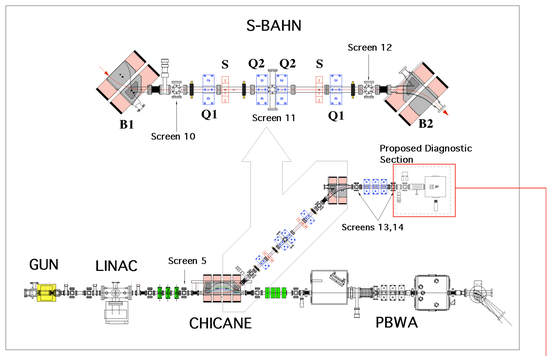
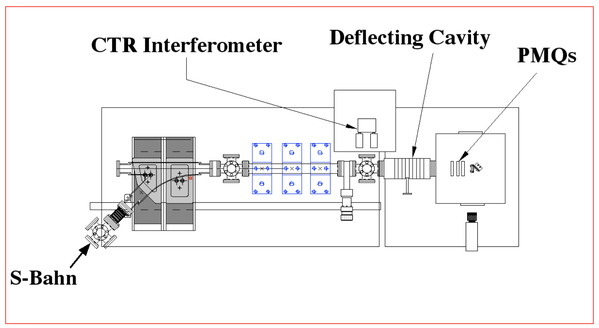
Abstract

We report progress on the design and construction of a nine-cell cavity operating in a TM_{110}-like dipole mode for use as a temporal diagnostic of the 14 MeV, 300 pC electron bunches generated at the UCLA Neptune Laboratory linear accelerator, with an anticipated temporal resolution of 50 fs at a peak input power of 50 kW. The cavity is a center-fed standing-wave π-mode structure, operating at 9.6 GHz, and incorporating a knife-edge and gasket assembly which minimizes the need for brazing or welding. Results of initial RF testing of the prototype cavity are discussed and compared with simulation results obtained using the commercial code HFSS.

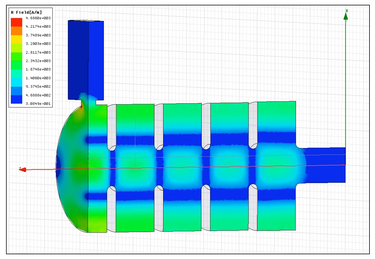
UCLA Neptune Beamline



Proposed Diagnostics Section



Simulated H-Field Magnitude Plot (HFSS 9.0)



- Cavity designed using HFSS 9.0 and MAFIA.
- Central coupler designed for coupling β=1.
- 9 Cells = 9 modes in pass band
- 4 modes are suppressed by choice of central coupler

Cavity Design Parameters

Parameter	Value	Units
Number of Cells	9	
Material	Copper	
π-Mode Freq	9.59616	GHz
Shunt Impedance	6.1	MΩ
Deflecting Voltage	552	kV
Quality Factor	9080	
Cell Radius	18.25	mm
Cell-to-Cell Distance	15.62	mm
Iris diameter	10	mm
Beam pipe diameter	10	mm
VSWR	1.0	

E-Beam Parameter Goals

Parameter	Initial	Final
Energy	14 MeV	14 MeV
Charge	200 pC	200 pC
X-Emittance	5 μm	10 μm
RMS Bunch Length	2.5 ps	1.6 ps
RMS Energy Spread	1.8%	1.8 %

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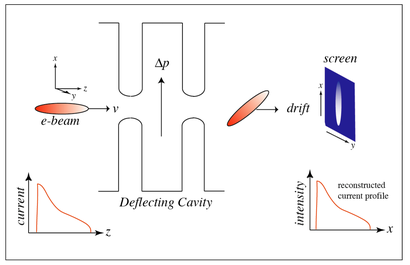
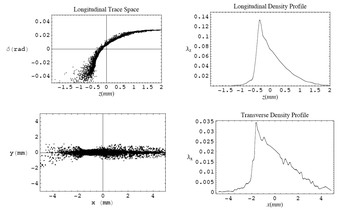
Deflecting Cavity as Longitudinal Profile Diagnostic



- At zero crossing of RF, deflection is linear in z-position
- Head (Tail) of beam is deflected in +x (-x) direction.
- Amount of deflection is proportional to frequency, deflecting voltage, and drift length.
- With sufficient deflecting voltage, time profile of beam at cavity entrance can be reconstructed from the transverse profile on downstream profile monitor.

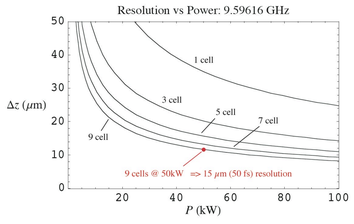


Initial Current Profile

Reconstruction from Downstream Transverse Beam Profile

- Above results produced using ELEGANT tracking code.
- Simulated cavity voltage: 609 kV
- Corresponding estimated RF power: 50 kW

Estimated Temporal Resolution



$$\Delta t = \Delta x \frac{U/e}{L\pi f V_0}$$

$\Delta x \sim 30\,\mu m$

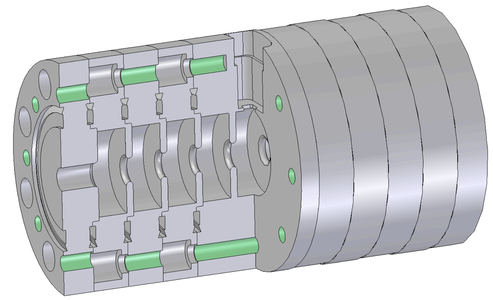
$L = 0.5m$

$f = 9.6GHz$

$V_0 = 552kV$

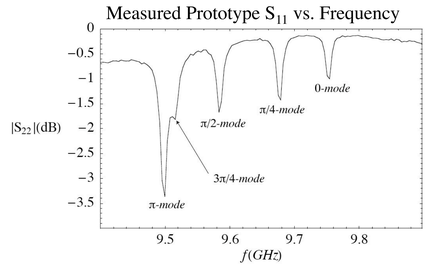
$U = 14MeV$

Steel Prototype Cavity Results



- Stainless Steel 316 prototype.
- Modular design with knife-edge vacuum seals between segments.
- Easily assembled/disassembled for tuning.

Measured Prototype S_{11} vs. Frequency



Mode	Measured	Simulation
f_π	9.4959 GHz	9.4910 GHz
$f_{3\pi/4}$	9.5132 GHz	9.5070 GHz
Separation	17.3 MHz	16.0 MHz

- Operating mode is the π-mode.
- Backward wave device (i.e. $f_\pi < f_0$)
- Only 5 modes in pass band (4 modes suppressed by central coupler).
- Overlap of first 2 modes due to poor conductivity of steel.
- Expect improved mode separation when prototype is electrolytically coated with copper.
- Final cavity design will be constructed of copper.