

FABRICATION AND VALIDATION OF A NORMAL CONDUCTING RADIO FREQUENCY S-BAND DEFLECTING CAVITY FOR THE POHANG ACCELERATOR LABORATORY (PAL)

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Abstract

Radiabeam Technologies recently developed an S-Band normal-conducting Radio-Frequency (NCRF) deflecting cavity for the Pohang Accelerator Laboratory (PAL) in order to perform longitudinal characterization of the sub-picosecond ultra-relativistic electron beams. The device is optimized for the 135 MeV electron beam parameters. The 1m-long PAL deflector is designed to operate at 2.856 GHz and features short filling time and femtosecond resolution. RF design, fabrication, RF validation and tuning will be presented, as well as initial beam measurements.

INTRODUCTION

Some of the most compelling and demanding applications in high-energy electron beam-based physics, such as linear colliders [1], X-ray free-electron lasers [2], inverse Compton scattering (ICS) sources [3,4], and excitation of wakefields in plasma for future high energy physics accelerators [5,6] now require sub-picosecond pulses. Thus, improvement in resolution and capabilities of fast longitudinal diagnostics is needed.

RadiBeam has recently developed and delivered an S-Band Traveling wave Deflecting mode cavity to be utilized for direct longitudinal phase space measurements of compressed electron beams at the Pohang Accelerator Laboratory X-ray SASE-FEL [7]. The PAL deflector takes advantage of the well-established cell machining in S-Band as well as our version of the SLAC-modified procedure for surface preparation for high RF power operation.

RF/THERMAL DESIGN

The initial 3D surface model used for RF simulations with HFSS [8] is shown in Figure 1. It is a disc-loaded traveling-wave (TW) structure operating in the TM_{110} mode at 2.856 GHz. Two coupler cells allow the input and output of the RF power provided by a standard WR284 metallic waveguide. The main deflecting cells, stacked in between the couplers, have a pillbox-like shape, each with holes located perpendicular to the deflection plane for the separation of the two dipole-mode field polarizations.

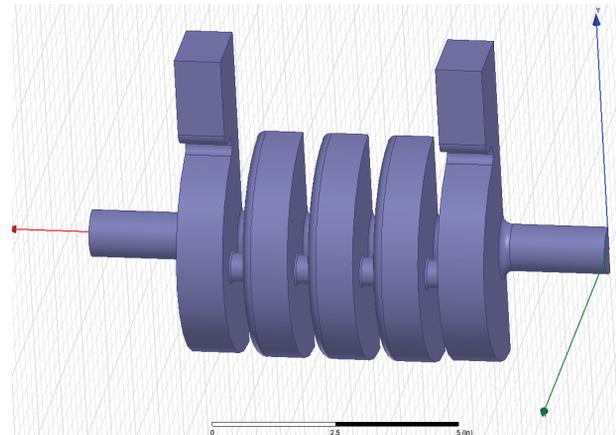


Figure 1: 3D surface model used for RF simulations in HFSS.

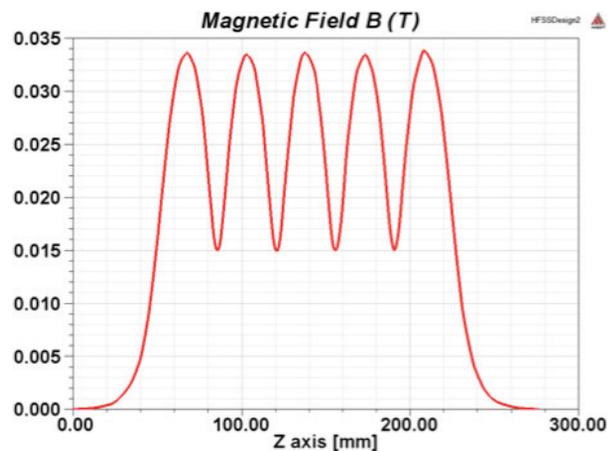


Figure 3: On-axis deflecting magnetic field profile.

The plot on the resulting on-axis deflecting magnetic field is given in Figure 2. The cell-to-cell phase shift is 120 degrees. The final full PAL deflector consists of an overall number (couplers plus main cells) of 28 cells. The main RF parameters for the L=1m long PAL deflector is listed in Table 1. The total deflecting voltage is equal to 8.5 MV, assuming an input RF power value of 10MW. Very good agreement was found between the simulated and the measured values.

Table 1: PAL Deflector RF Parameters

RF Parameter	Value
$2\pi/3$ -mode frequency f	2.856 GHz
Transverse Shunt Impedance r_T	28.7 M Ω /m
Unloaded Q	13,400
Attenuation α	0.15 m ⁻¹
Group Velocity v_g	0.014 c
Kick/\sqrtPower	2.7 MeV/ \sqrt MW
Length L	1 m

Thermal simulations were carried out with Ansys [9]. We only inserted a cooling channels system, very compact, for frequency/temperature stabilization. The result shown in Figure 3 refers to the case of an average RF power of 1kW. Due to the low temperature gradient (<3deg) across the structure, no internal channels were necessary.

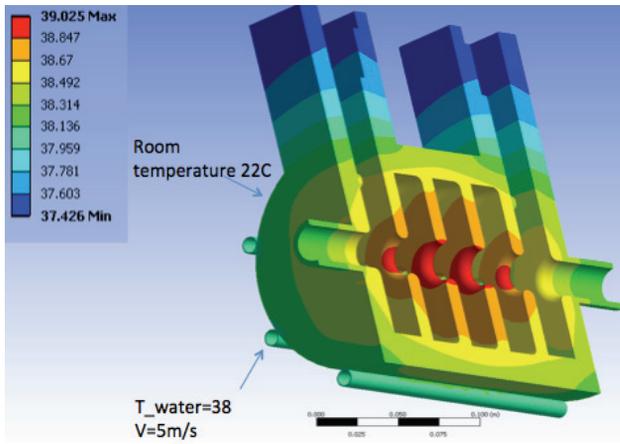


Figure 3: Thermal simulation of the PAL deflector model for 1kW average RF power.

THE PAL DEFLECTOR: TUNING AND INITIAL BEAM MEASUREMENTS



Figure 4: Picture of the PAL deflector after the final brazing and before installation.

The PAL deflector after final brazing and before installation is shown in Figure 4.

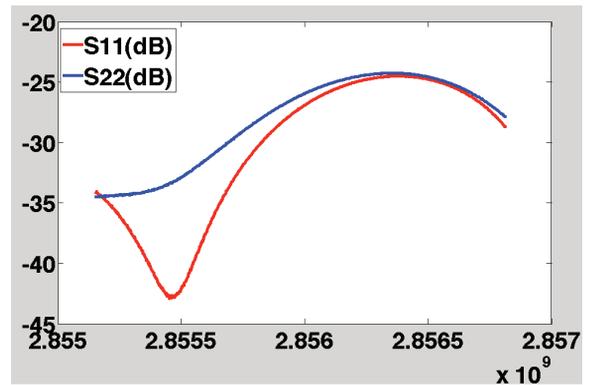


Figure 5: reflection coefficients at port1 and port2 (S11 and S22).

We measured the coupling coefficients at both ports, S11= -40dB (RF input port) and S22= -32dB with a SWR<1.05 for both ports.

The deflector cells were tuned to the spec ($\pm 2^\circ$), at 22C and under nitrogen flow, by using the nodal shift procedure (plunger method).

From bead-pull measurements, we obtained the “flower”-like manifold that is plotted in Figure 6 showing a perfectly tuned $2\pi/3$ operating mode.

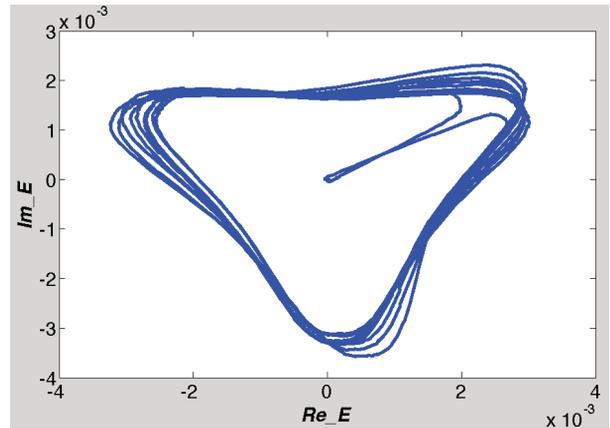


Figure 6: Polar plot of the on-axis electric field.

The bead-pull measurement (off-axis) of the electric field profile after final tuning is given in Figure 7.

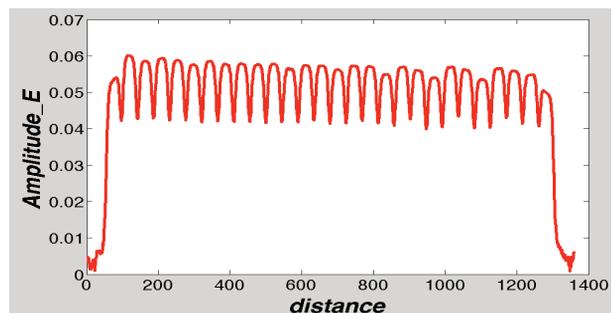
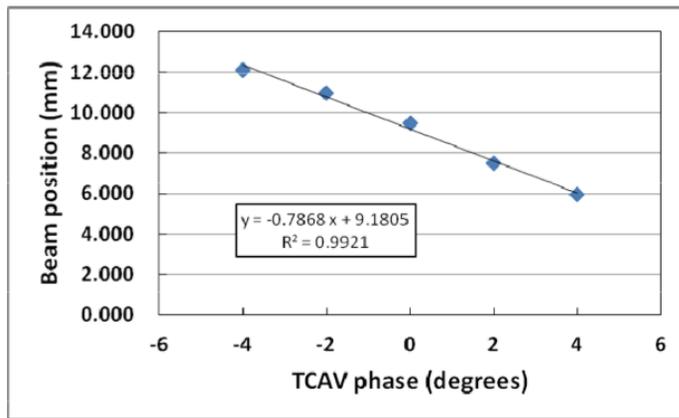
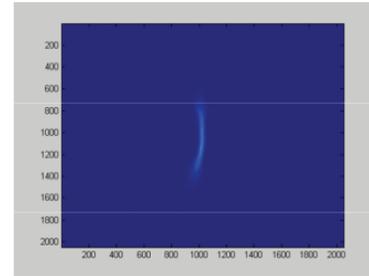


Figure 7: Off-axis electric field measurement (bead-pull).



parameter	value
Laser inj. ph.	35 °
Beam energy	85.6 MeV
Beam charge	200 pC
TCAV RF power	0.137 MW



TCAV phase (degrees)	CM in Y (pixel)	beam position in Y (mm)	beam size in Y (μm)	
4	716	5.943	1268.55	
2	901.2	7.480	1267.40	(rms bunch length)
0	1139.7	9.460	1238.08	~ 1.53 ps
-2	1317.9	10.939	1226.97	~ 0.456 mm
-4	1455.6	12.081	1262.24	~ 1.57 degS

Figure 8: Low-power initial beam diagnostics at PAL by using the deflector delivered by RadiaBeam.

The S-Band deflector was delivered to PAL in May 2013. After RF conditioning, initial beam length measurements were performed in August (see Figure 8). Only a fraction of MW of RF power was required at the moment for the resolution of their 200pC, 85.6 MeV beam.

CONCLUSIONS

RadiaBeam Technologies has successfully completed design, fabrication, brazing and validation of an S-Band deflector for the Pohang Accelerator Laboratory (PAL) X-FEL. Upon delivery to PAL and EF conditioning, promising and satisfactory initial beam length measurements were carried out.

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