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PROGRESS TOWARD NLC/GLC PROTOTYPE ACCELERATOR STRUCTURES*

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Abstract

The accelerator structure groups for NLC (Next Linear Collider) and GLC (Global Linear Colliders) have successfully collaborated on the research and development of a major series of advanced accelerator structures based on room-temperature technology at X-band frequency. The progress in design, simulation, microwave measurement and high gradient tests are summarized in this paper. The recent effort in design and fabrication of the accelerator structure prototype for the main linac is presented in detail including HOM (High Order Mode) suppression and design of HOM couplers and fundamental mode couplers, optimized accelerator cavities as well as plans for future structures.

HIGH GRADIENT TEST STRUCTURES

Since 2000, more then thirty structures with different length, aperture, phase advance and coupler design have been built and tested at the NLCTA. [1] Through the thorough comparison and analysis we have selected the following main accelerator parameters: 60 cm of length, 5π/6 phase advance /cell, low group velocity with optimal attenuation factor of 0.5-0.6 for optimal RF efficiency.

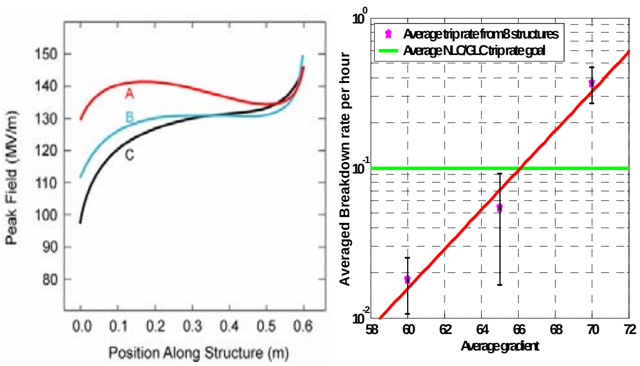

Figure 1. Maximum surface field for three types structures at unloaded gradient of 65 MV/m (left) and high power test results for eight structures (right).

The parameters of A (H60VG3S18), B (H60VG3S17) and C (H60VG4S17) are shown on Table 1. With reduced aperture a/λ=0.17, B and C have 10% higher RF efficiency than A. With asymmetric dipole mode detuning distribution, C has lowest surface field at the input end.

Table 1. Basic parameters for three typical structures.

Structure Type	H60VG3S18	H60VG3S17	H60VG4S17
Other Names	FXBs (2D), KX01 (2D)	FXCs	FXDs, KX02, H60VG4SL17
Length	62 cm	62 cm	62 cm
Number of Cells	53 cells + 2 Matching Cells	53 cells + 2 Matching Cells	53 cells + 2 Matching Cells
Iris Radius	< a/λ > =0.18	< a/λ > = 0.17	< a/λ > = 0.17
Phase Advance	5π/6 Per Cell	5π/6 Per Cell	5π/6 Per Cell
Group Velocity	3.27–1.24 % Speed of Light	3.56–0.78 % Speed of Light	4.50-0.82 % Speed of Light
Attenua-tion τ	0.533 0.508 (2D)	0.630	0.636
Filling Time	105 ns	116.5 ns	117.6 ns
Q_0 Value	~ 6640 ~ 6990 (2D)	~ 6670	~ 6660
Shunt Im-pedance	46.5-73.5 49.1-77.2 (2D) MΩ/m	54.7 – 68.8 MΩ/m	50.9 – 69.0 MΩ/m
Coupler Type	Mode Converter or Wave Guide Type	Waveguide Type	Wave Guide type
1st Band Dipole Mode Detuning	kdn/df Symmetric Gaussian Δf/f~10% (4.0σ)	kdn/df Symmetric Gaussian Δf/f~9.37% (3.94σ)	kdn/df Asymmetric $Sech^{1.5}$ with Δf/f~12.5% (5.1σ)
Es /Ea	2.06 - 1.90	2.04 -1.99	2.10 -1.97
Required Input Power	69 MW 63.2 MW (2D)	59 MW	58.2 MW
Unloaded Gradient	65 MV/m	65 MV/m	65 MV/m

The right plot of Fig. 1 show a summary of performance for the recent eight accelerator structures. The horizontal line is the goal line for GLC/NLC stable high power operation – less than 1 breakdown per 10 hours per 60 cm section at unloaded 65 MV/m gradient for 60 Hz RF pulses. The tilted line is a fit for average trip rates for

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different gradients. The factor of two lower trip rate has been successfully reached. [2]

DEVELOPMENT OF H60VG4SL17

Accelerator Design

As the first generation of full featured HDDS structures, four H60VG4SL17 type of structures are in the final assembly stage of fabrication. Figure 2 shows four HOM couplers in both input and output ends. Fundamental input/output couplers are waveguide type.

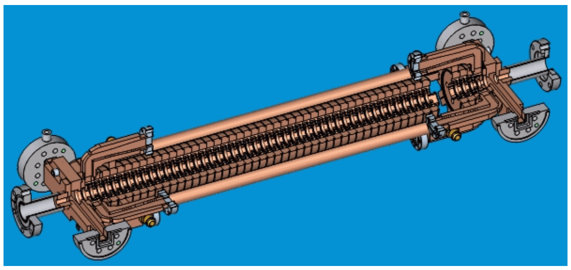


Figure 2: Cutaway view of H60VG4SL17 structure.

In order to reduce the field in the input end, the dipole mode detuned distribution becomes asymmetric. A $\mathrm{Sech}^{1.5}$ function distribution was adopted for better dipole mode suppression. The predicted wakefield is shown in Fig. 3.

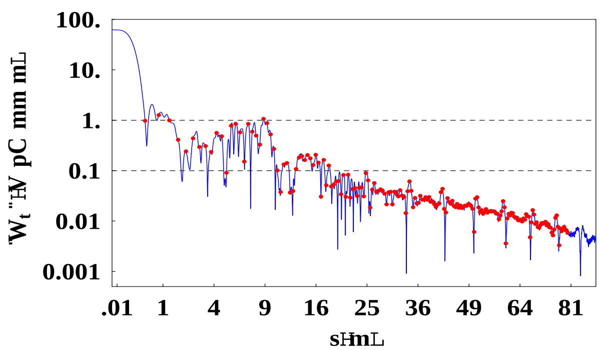


Figure 3: Envelope of simulated wakefield of two fold interleaved structures as function of the distance behind a driving bunch, dots show the location of trailing bunches.

Accelerator Cup Fabrication

Figure 1 shows one of accelerator cups for the latest structures, which are fabricated through a combination of precise milling and tuning. For KEK produced cups, final finish was done by single-diamond turning.

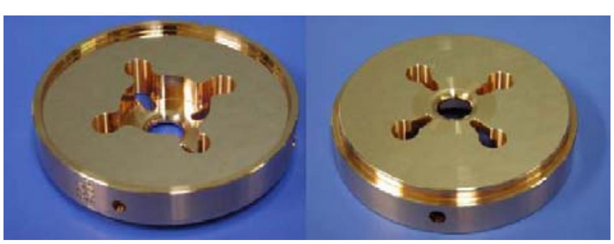


Figure 4: View from both sides of an accelerator cup.

The fundamental mode (TM01) frequencies and dipole mode (HEM) frequencies were measured by using a single cup microwave QC setup. The results for the first band of dipole mode were shown in Figure 1. The left plot shows the very smooth change for the frequencies corresponding to the cups of two interleaved structures A and B in the sequence of 3A, 3B, 4A, 4B, 5A, 5B and so on. Right plot shows the distribution of frequencies in comparison with accurately calculated theoretical values.

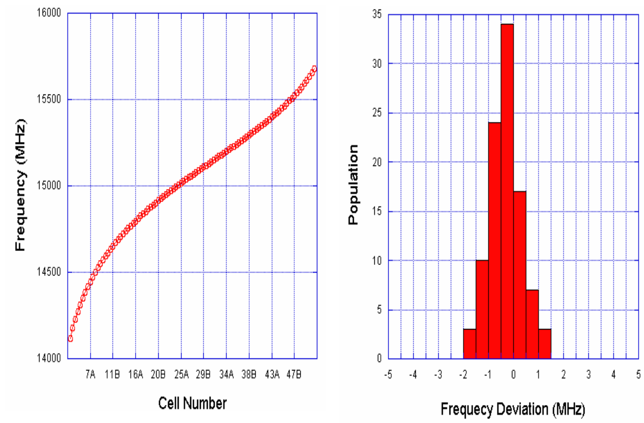


Figure 5: Measured dipole mode frequencies (left) and their tolerances.

HOM Coupler Design and Verification

HOM couplers are critical elements to connect each HOM manifold and corresponding WR62 load with good match. A scattering matrix computer code S3p was used to theoretically design the HOM couplers. Figure 6 shows a model with symmetric feeds and better than 0.1 of reflection coefficient within structure first dipole band has been reached with our design.

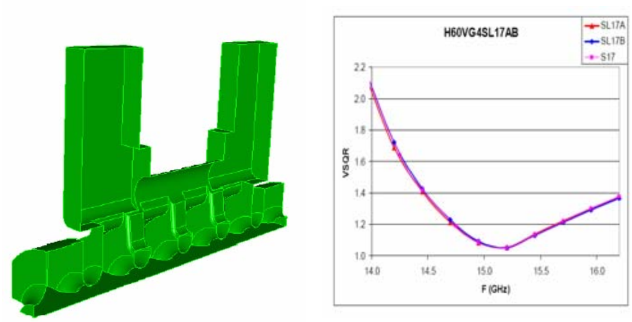


Figure 6: Simulation model for HOM coupler design (left) and match quality expressed by the VSWR in coupler pass region (right).

In order to examine the accuracy of the electrical design and mechanical fabrication for those HOM couplers, a cold test assembly of H60VG4SL17B output end HOM coupler was tested. By sequentially changing the number of cups between back-to-back HOM couplers at certain frequency, the amplitude of reflection coefficient within dipole mode pass band can be mapped out. The consistency between measurement and theory gave us the confidence to fabricate such complicated elements.

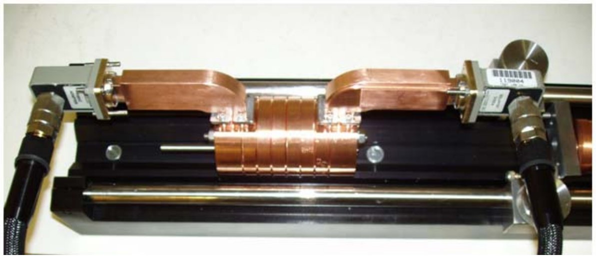


Figure 7: Microwave measurement for a HOM coupler test assembly.

NEXT PROTOTYPE STRUCTURES

Optimization of Accelerator Disks

To improve the shunt impedance of the structures by 10 to 15%, a structure incorporating rounded cells is being studied and test cups are being machined. The main technical challenge is to machine round-edged pie-shape slots along curved cavity wall. High speed ball milling is the first option. The second choice is to mill with a shaped tool in a 5-axis milling machine, then a so called "leek-head" cavity shape design is needed in order to allow the tool to cut the curved slot edges near the cavity outer wall. Fig. 8 shows accelerator cups schematically.

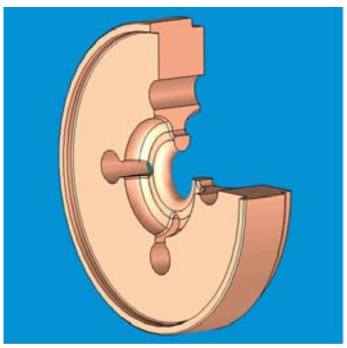


Figure 8: Cutaway view of a proposed full rounded symmetric accelerator cups.

Fundamental Coupler

We plan to adapt a compact design (shown in Figure 9), which was used in early RDDS1 structure for both input/output fundamental couplers. Trapped modes need to be studied very carefully as was done for H60VG4S17 structures. [3]

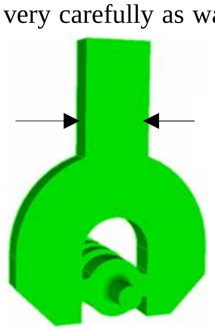
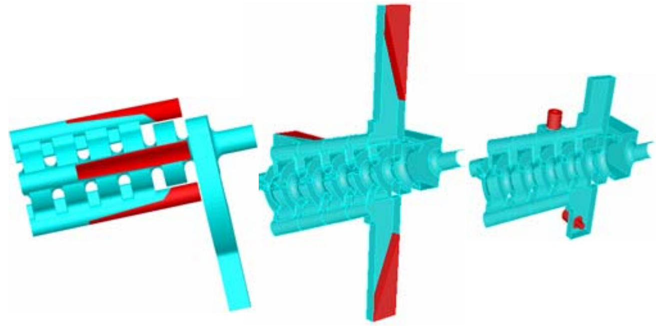


Figure 9: Compact fundamental couplers

HOM Coupler and load

In present design, the HOM modes are transmitted through a mitered WR62 bend to an external load and pick-up assembly. In order to reduce the complexity and fabrication cost, there are three proposed and designed configurations for HOM coupler ports as showed in Fig. 10. Design A is so called in-line load type, where microwave absorbers are located inside of manifolds. The technical challenges are good broad band HOM matching and low absorption for fundamental mode power. Design B is to braze transverse WR62 loads directly on HOM port. Design C is to use waveguide to coax adapter terminated by a coax load.



(A) (B) (C)

Figure 10: Three types of HOM coupler design

Wire measurement

A wire-based structure experimental method [4] is being developed to quickly and inexpensively analyze the wakefield suppression properties of accelerator structures. Using a 300-micron thick brass wire, measurements of the structure S-parameters are made to compute the impedances for the monopole band and higher dipole mode bands. The test results for a standing-wave structure, a short traveling-wave structure, and the RDDS1 structure (see Fig. 11) show a reasonable agreement with computer simulations.

Figure 11: Wire measurement set-up with the RDDS1 structure.

REFERENCES

[1] J. Wang and T. Higo, ICFA Beam Dynamics Newsletter No. 32, SLAC-PUB-10370.
[2] S. Doebert, WE101, this conference.
[3] R. M. Jones et al., MOP40, this conference.
[4] N. Baboi, et al., MOP64, this conference.