CHOKE FOR STANDING WAVE STRUCTURES AND FLANGES*

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Abstract

SLAC participates in the U.S. High Gradient collaboration whose charter includes basic studies of rf breakdown properties in accelerating structures. These studies include experiments with different materials and construction methods for single cell standing wave accelerating structures. The most commonly used method of joining cells of such structures is the high temperature bonding and/or brazing in hydrogen and/or vacuum. These high temperature processes may not be suitable for some of the new materials that are under consideration. We propose to build structures from cells with an rf choke, taking the cell-to-cell junction out of the electromagnetic field region. These cells may be clamped together in a vacuum enclosure, the choke joint ensuring continuity of rf currents. Next, we propose a structure with a choke joint in a high gradient cell and a view port which may allow us microscopic, in-situ observation of the metal surface during high power tests. And third, we describe the design of a TM01 choke flange for these structures.

INTRODUCTION

We describe the design process and the parameters of three pieces of hardware utilizing an RF choke. We have designed and made a choke flange as a replacement for a flange whose rf current continuity depends on a metal-to-metal contact. We have also designed and are in the process of building two types of 11.424GHz, single-cell Standing Wave (SW) structures. The first is a structure that has a choke on the central high gradient cell as well as the adjacent matching cells. We call this structure the triple choke structure. The second is a structure which has two chokes on the central high-gradient cell and an extension beyond the choke used for attaching a view port and instrumentation for in-situ observation of breakdowns in the high electric and high magnetic region of the irises. We call this structure the full-cell choke structure. The purpose for a choke in both of these structures is to reduce the electromagnetic field gradients at the outer edges of the structure where the vacuum joint or viewing port will be placed. Figure 1 demonstrates all 3 of these devices.

DESIGN PROCESS

The design process involved using several modelling codes and optimization routines to meet the necessary design requirements.

Design Requirements

As a first requirement we aimed for minimizing the reflection in each of these components to less than 20 dB down at 11.424 GHz. For the choke flange we try to reach as wide a bandwidth as possible.

Secondly we imposed a requirement to reduce the electric and magnetic field near the vacuum joints of the structures to be as low as practically possible.

For the choke flange, we imposed the requirement to move the trapped modes at least 100 MHz (~klystron bandwidth) from the 11.424 GHz.

And finally for the structures we imposed the requirement that the peak electric field on the axis of the central cell should be double of that the adjacent cells and that the structure should be critically coupled or slightly overcooled (coupling coefficient >= 1).

Modelling Scenario

To design the choke flange, we first minimized the reflection at the coupler by adjusting the choke distance from the centreline, and the transmission to the artificial port at the outer diameter of the choke by adjusting the ratio of the distance from the centreline to the length of the choke. After we reached minimum reflection and transmission, we introduced a matching bump to cancel any residual reflection.

To design the standing wave structures we started with the model of an existing single choke structure which has been designed constructed and tested: iris radius a = 3.75mm and disk thickness t = 2.6mm [1, 2]. Then we added the same choke to the end cell and adjusted the end cell cavity diameter to bring the frequency back to 11.424GHz and repeated the process by adding a third choke to the coupler cell. We then adjusted the coupler iris to achieve slight over-coupling and balanced the electric field in each cell by adjusting its inner diameter, till the peak on-axis field in the central cell was exactly double that in the adjacent cells. Then we adjusted all 3 of the cell inner diameters to bring the frequency back to 11.424 GHz. We repeated the process of matching, field balancing and frequency tuning until the design requirements were satisfied.

THE STRUCTURES

Choke Flange

The choke flange was designed to replace the current flange where the vacuum joint is accomplished by crushing a copper gasket between knife edges. The rf joint is at a smaller radius and is accomplished by contacting "lips". As we change test structures, the rf joint deteriorates with multiple assembly/disassembly cycles.

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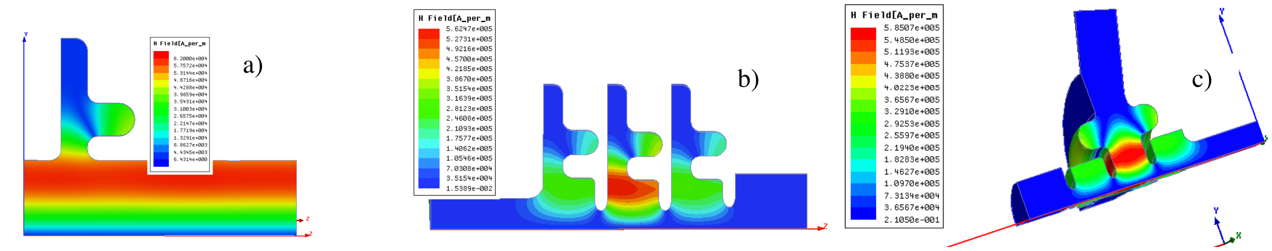

Figure 1. All three choke structures with the magnetic field magnitude calculated by HFSS: a) Choke flange, magnetic field normalized to 100 MW or transmitted power, b)Triple choke standing wave structure, c) full choke standing wave structure both normalized to 10 MW of rf power lost in the copper walls.

Removing the metal-to-metal joint from the rf region should mitigate these problems. With the choke flange there is no metal-to-metal rf joint and the vacuum seam occurs out of the high gradient rf region.

We used the HFSS [3] code to design and optimize the choke flange. Figure 2 shows the key dimensions of the final design for a Cu flange.

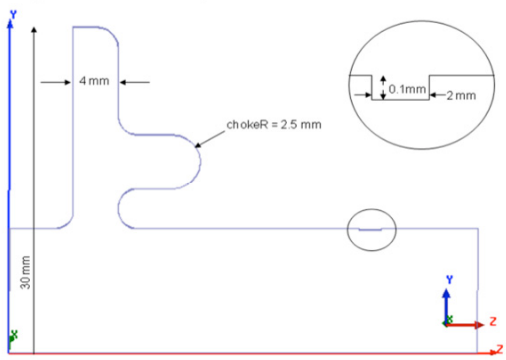

Figure 2. Choke flange geometry.

For the copper choke flange the reflection at 11.4236 GHz is 78 dB down and the bandwidth at 30 dB down is ~300MHz. We also checked for trapped dipole, quadrupole, and sextupole modes. They are all at least 2GHz away from 11.424GHz.

Given that this flange is also important for uses with various materials which we are studying, such as a new conducting ceramic called Cesic. We also simulated the response of the choke flange for Stainless Steel and Cesic materials. Cesic has a conductivity of 6000 Siemens/m, while Stainless Steel has a conductivity of 1.1 x 10^6 Siemens/m. Using the same exact geometry as for the Cu choke flange, the reflection at 11.424 GHz is well under 40 dB for all three material cases. Figure 4 demonstrates those results.

For 100MW input power, the electric and magnetic fields at the top of the flange are only 125kV/m and 225A/m. A stainless steel version of this flange has been constructed at SLAC and is ready for testing.

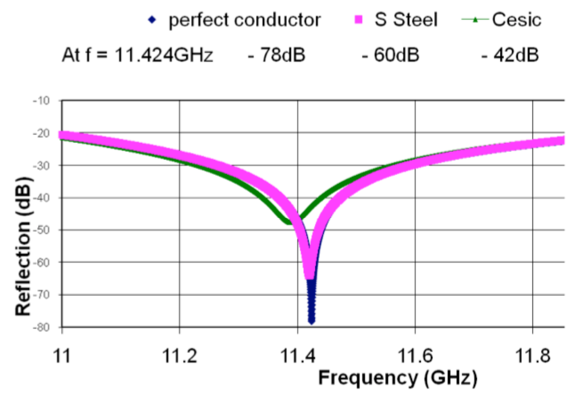

Figure 4. Choke flange frequency sweep for copper, stainless steel and Cesic materials.

Triple Choke Structure

The triple choke structure was designed in order to significantly reduce the electric and magnetic fields on the rf joint. A copper and molybdenum version of this structure will be constructed for high gradient rf tests.

We used the SUPERFISH [4] code to design and optimize the triple choke structure, and the HFSS code to verify the results and report the key parameters. Figure 5 shows the key dimensions and the electric equipotential lines of the final design for a copper triple choke structure.

The electric field in each cell is balanced such that the middle cell has twice as much peak field on axis as its adjacent cells, as shown on figure 6. The peak surface electric field in the middle cell for 10MW rf power loss is 327MV/m, while at the top of the structure, above the choke, the electric and magnetic fields are 37kV/m and 40A/m respectively. The reflection at resonance is -30 dB. The structure has Qo = 8660 and Qe = 7771. It is over-coupled with a coupling coefficient of 1.11.

This same structure was optimized to build from molybdenum as well. Its cell sizes vary from the copper structure by less than 1μ m and the coupler aperture is larger by approximately 300 μ m.

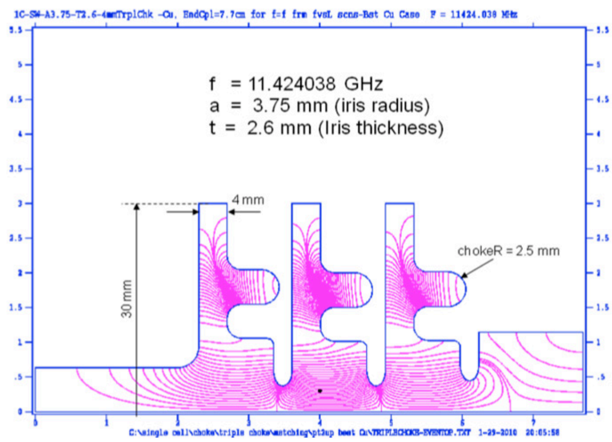

Figure 5. SUPRFISH plot of Cu triple choke structure.

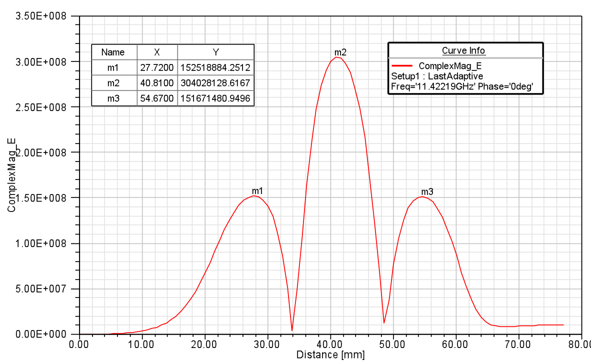

Figure 6. Cu Triple choke structure on-axis E-field.

Full Choke Structure

The full choke structure was designed to reduce the electric and magnetic fields at the outer radius of the middle cell so that we can construct a view port on the cell without perturbing the fields. The goal is to view the high electric and high magnetic field regions in the cell between and during rf pulses using various instruments.

We used the 2D Finite Element code SUPERLANS [5] to design and optimize the full choke structure without a view port. Then we used that geometry in HFSS and added two view ports. The view ports are 180 degrees apart, and tilted by 15 degrees from the normal to the cell surface to permit maximum view of the irises, where the maximum surface fields occur. Figure 7 shows a solid model of this structure.

As in the triple choke structure, the peak electric field on axis is twice as high in the middle cell as in the adjacent cells. The resonant frequency is 11.4216 GHz, reflection at resonance is -30.5dB, Qo = 12412, Qe = 11938 and the coupling coefficient is 1.07. Table 1 summarises the key parameters for the triple choke and full choke structures.

SUMMARY

The three choke structures were successfully designed. They are in the process of being built at SLAC, KEK, and Frascati for high power tests.

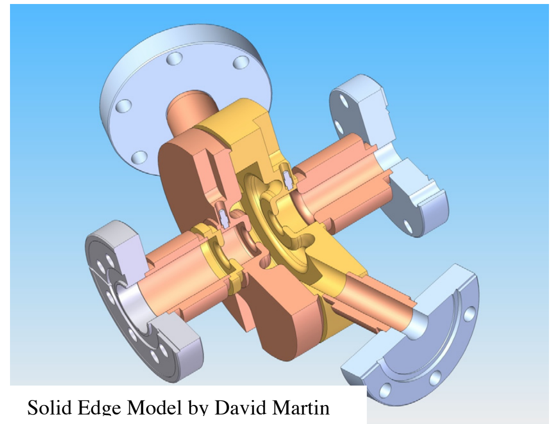

Figure 7. Full choke structure.

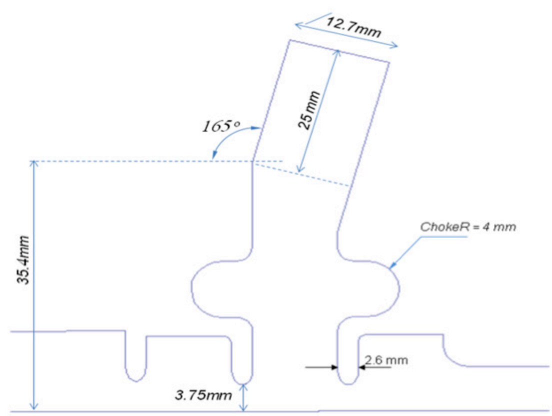

Figure 8. Triple choke structure key dimensions.

Table 1. Parameters of the trip and full choke structures normalized to 10MW power loss.

	Triple Choke	Full Choke
Stored energy [J]	1.676	1.731
Qo	8660	12416
Emax [MV/m]	327	342
Hmax [MA/m]	0.562	0.585

REFERENCES

[1] V. Dolgashev, S.G. Tantawi, C. Nantista, Y. Higashi, and T. Higo, in Proc. of IEEE PAC 2005, Knoxville, Tennessee (2005), pp. 595-599. slac-pub-11707

[2] V. Dolgashev, S.G. Tantawi, Y. Higashi, and T. Higo, in Proc. of EPAC 2008, Genoa, Italy (2008), pp. 742-744.

[3] HFSS, http://www.ansoft.com/products/hf/hfss/

[4] K. Halbach and R. F. Holsinger, in Proc. of IEEE PAC 1976, pp 213-222

[5] D.G. Myakishev and V.P. Yakovlev, in Proc. of IEEE PAC 1991, San Francisco, Ca (1991), pp. 3002-3004.