Single-Cell Standing Wave Structures: Design

Valery Dolgashev, Sami Tantawi (SLAC)
Yasuo Higashi, Toshiyasu Higo (KEK)

X-band Structure Testing Workshop
KEK, Tsukuba, Japan, May 23-24, 2008

Outline

- Introduction
- Strategy
- Structures

Single Cell Accelerator Structures

Goals

- Study rf breakdown in practical accelerating structures: dependence on circuit parameters, materials, cell shapes and surface processing techniques

Difficulties

- Full scale structures are long, complex, and expensive

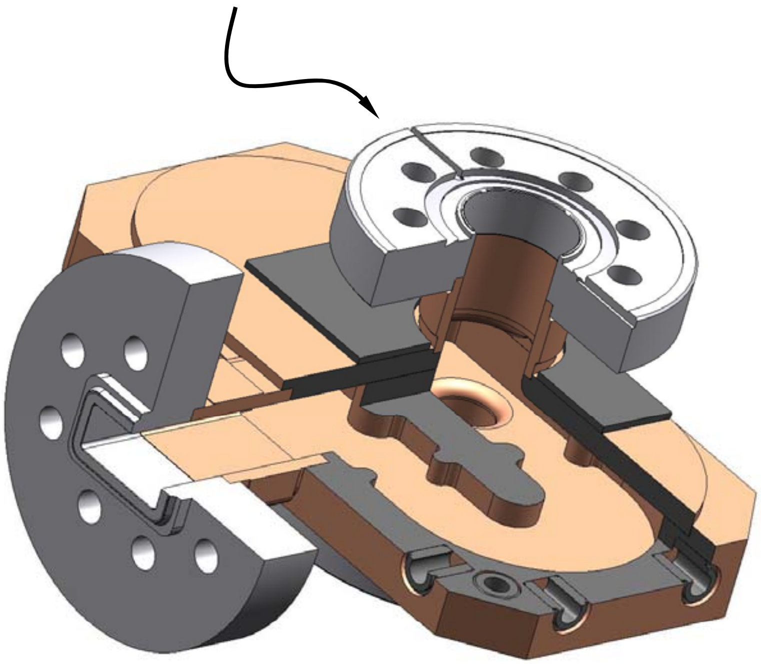
Solution

- *Single cell Traveling wave (TW)* and *single cell standing wave (SW)* structures with properties close to that of full scale structures
- **Reusable couplers**

We want to predict breakdown behavior for practical structures

Reusable coupler: TM_{01} Mode Launcher

Pearson's RF flange

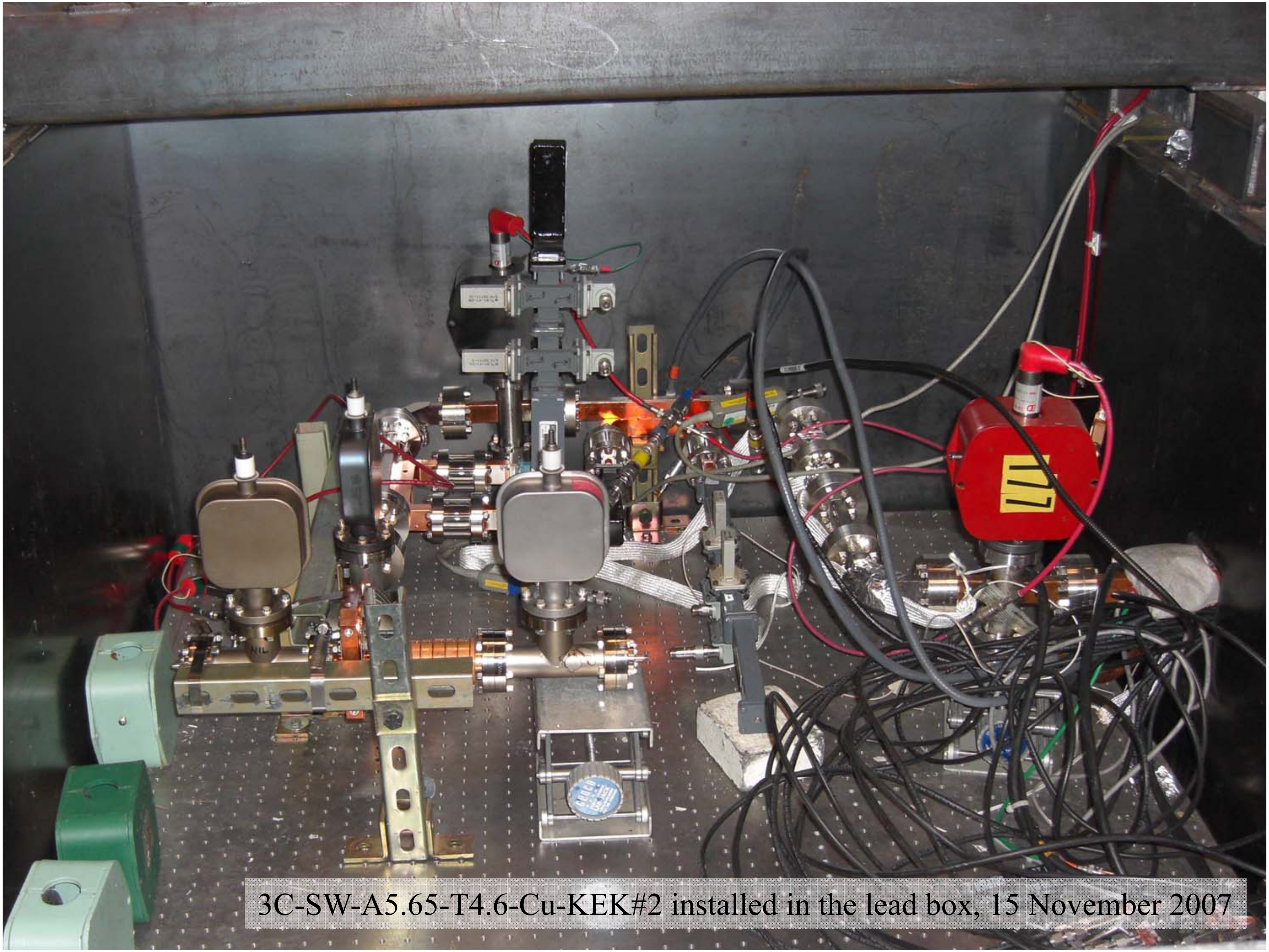


Cutaway view of the mode launcher

Two mode launchers

Surface electric fields in the mode launcher
E_{max}= 49 MV/m for 100 MW

S. Tantawi, C. Nantista



3C-SW-A5.65-T4.6-Cu-KEK#2 installed in the lead box, 15 November 2007

Strategy

Geometry
- Stored energy
- Electric field for same magnetic field
- Choke
- Choke WR90 coupler
- Shunt impedance, iris size, etc.
- …

Materials
- CuZr
- Molybdenum

…

Coatings
- TiN
- …

Some samples tested
- 1-C-SW-A5.65-T4.6-Cu
- 1-C-SW-A5.65-T4.6-Cu-TiN
- 3-C-SW-A5.65-T4.6-Cu
- 1-C-SW-A3.75-T2.6-Cu
- 1-C-SW-A3.75-T1.66-Cu

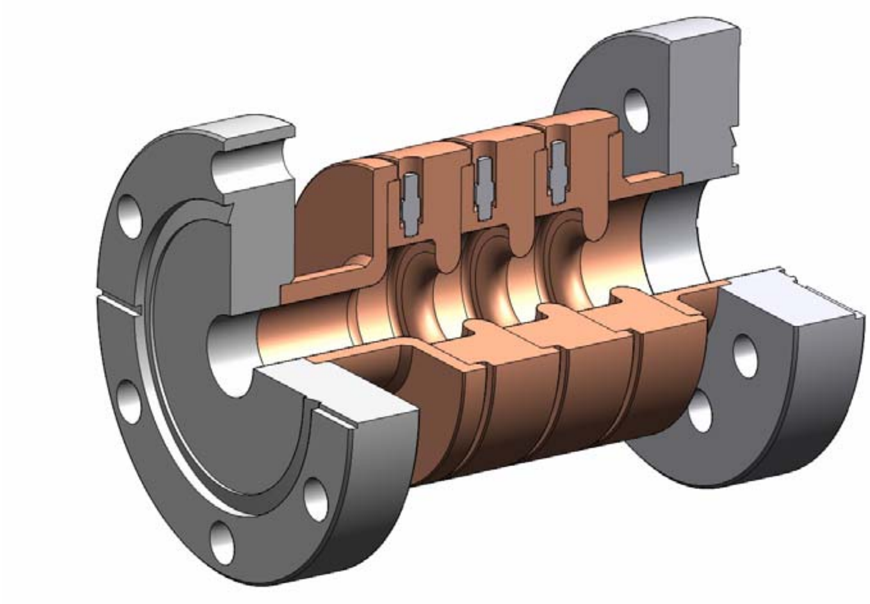
To be tested
- 1-C-SW-A5.65-T4.6-Cu-Choke
- 1-C-SW-A5.65-T4.6-Cu-PBG
- 1-C-SW-A2.75-T2.0-Cu
- 3-C-SW-A5.65-T4.6-Cu-WR90

- One-C-SW-A3.75-T2.6-CuZr
- One-C-SW-A5.65-T4.6-CuZr
- …

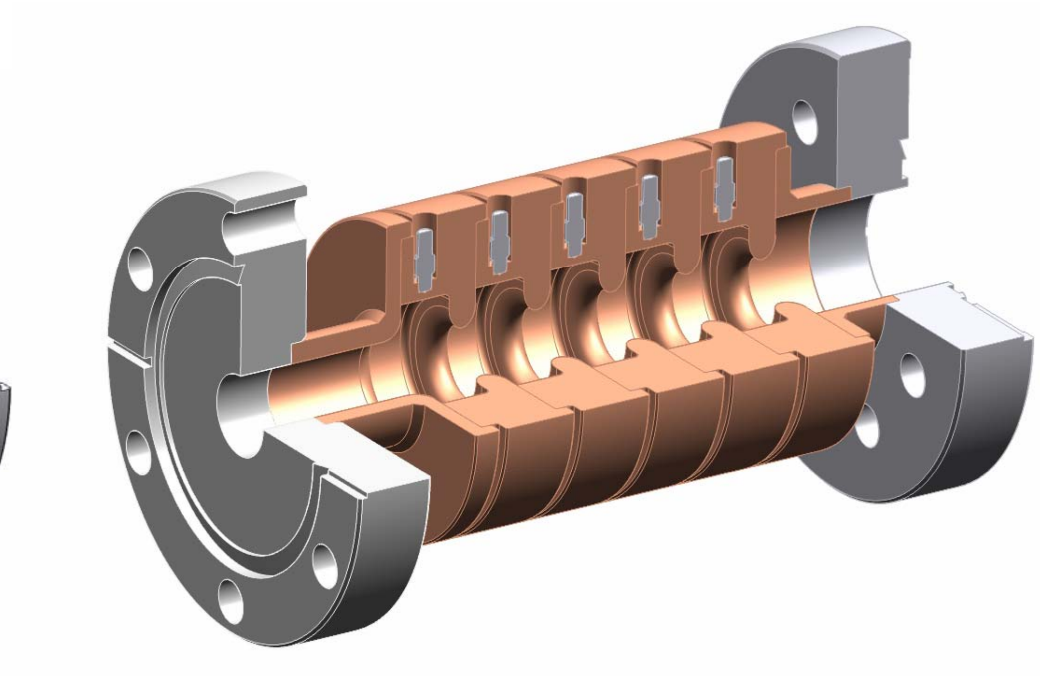
Parameters of periodic structures

Name	**A2.75-T2.0-Cu**	**A3.75-T1.66-Cu**	**A3.75-T1.66-Cu**	**A5.65-T4.6-Choke-Cu**	**A5.65-T4.6-Cu**	***T53VG3***
Stored Energy [J]	0.153	0.189	0.189	0.333	0.298	*0.09*
Q-value	8.59E+03	8.82E+03	8.56E+03	7.53E+03	8.38E+03	*6.77E+03*
Shunt Impedance [MOhm/m]	102.891	85.189	82.598	41.34	51.359	*91.772*
Max. Mag. Field [A/m]	2.90E+05	3.14E+05	3.25E+05	4.20E+05	4.18E+05	*2.75E+05*
Max. Electric Field [MV/m]	203.1	268.3	202.9	212	211.4	*217.5*
Losses in a cell [MW]	1.275	1.54	1.588	3.173	2.554	*0.953*
a [mm]	2.75	3.75	3.75	5.65	5.65	*3.885*
a/lambda	0.105	0.143	0.143	0.215	0.215	*0.148*
Hmax*Z0/Eacc	1.093	1.181	1.224	1.581	1.575	*1.035*
t [mm]	2	1.664	2.6	4.6	4.6	*1.66*
Iris ellipticity	1.385	0.998	1.692	1.478	1.478	*1*

Low shunt impedance structures



1C-SW-A5.65-T4.6-Cu

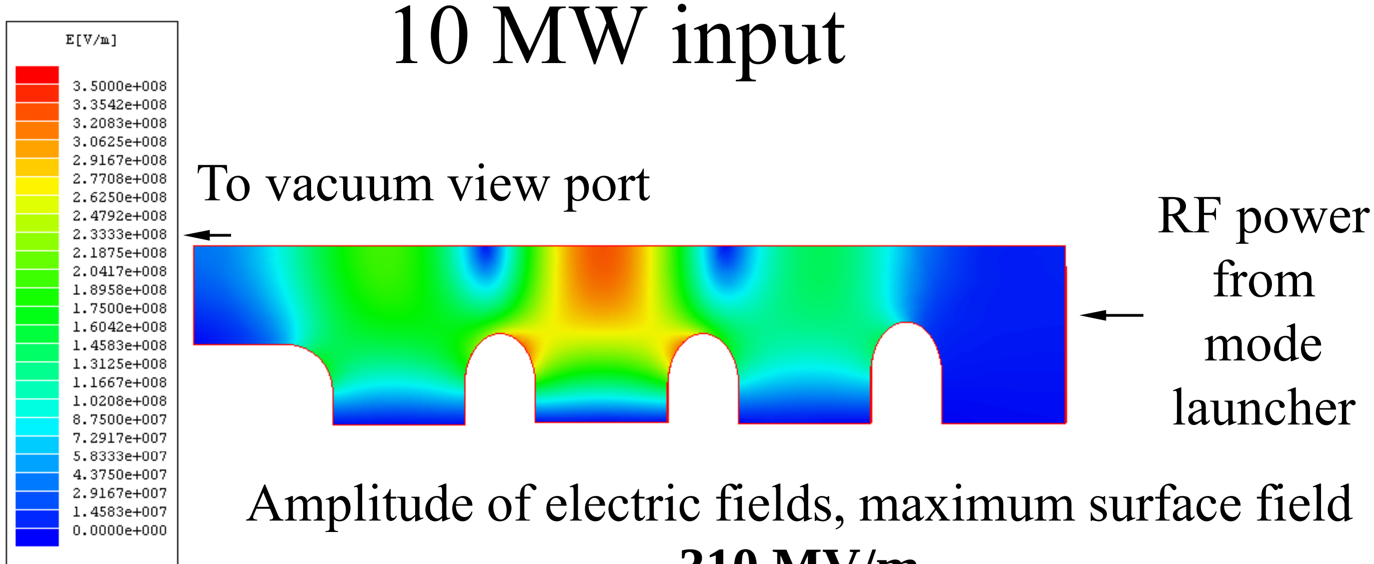


3C-SW-A5.65-T4.6-Cu

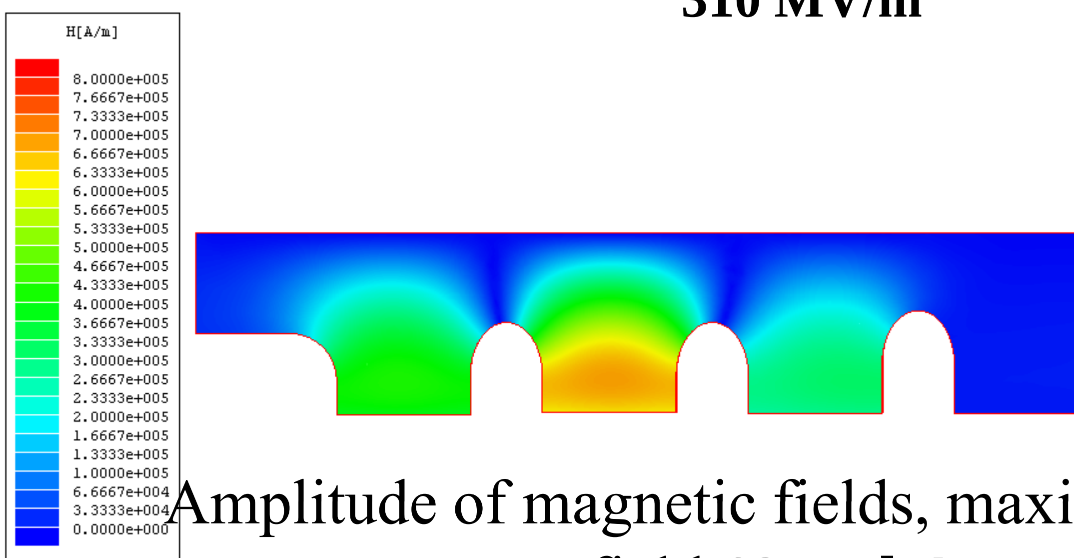
Solid Model: David Martin

Single-Cell-SW-A5.65-T4.6-Cu

10 MW input

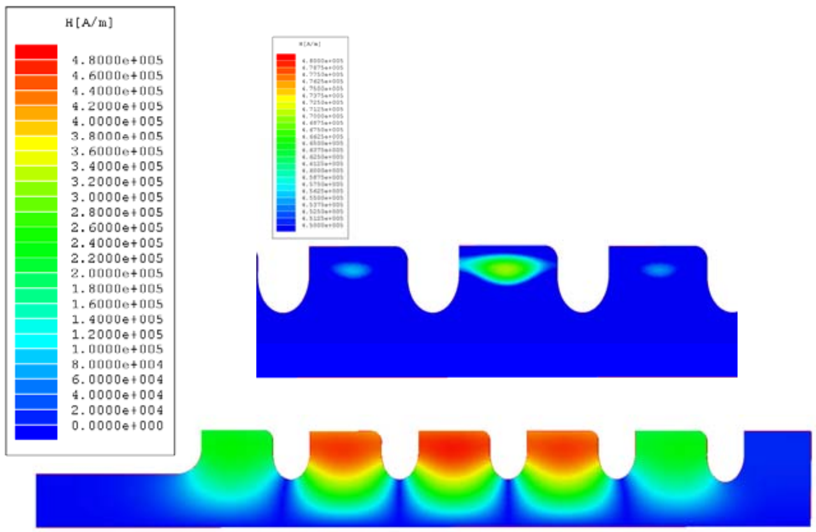


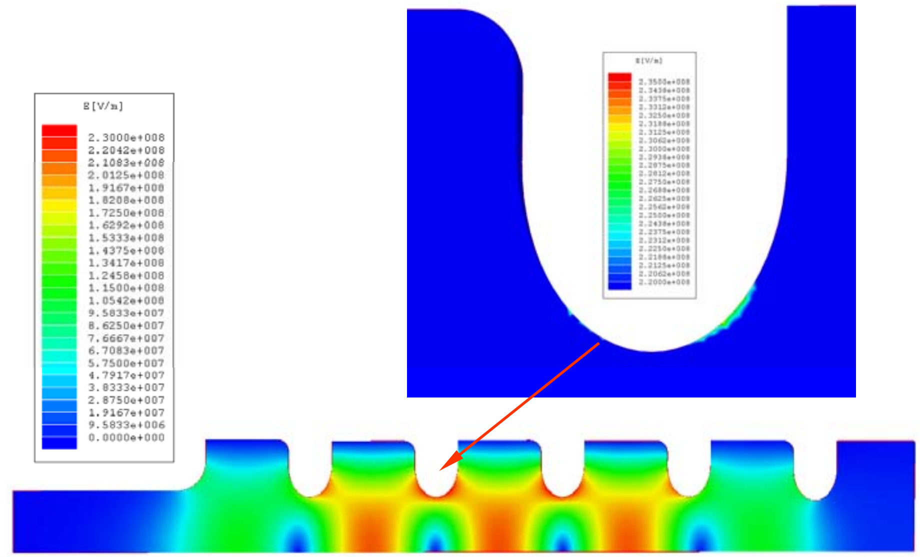
Amplitude of electric fields, maximum surface field **310 MV/m**



Amplitude of magnetic fields, maximum magnetic field **634.5 kA/m**

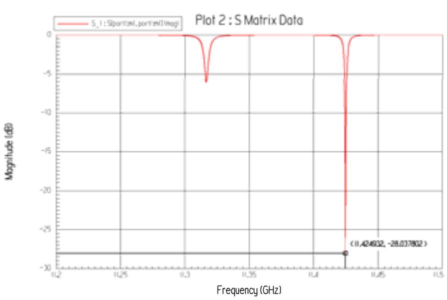
Three-Cell-SW-A5.65-T4.6-Cu,
10 MW input

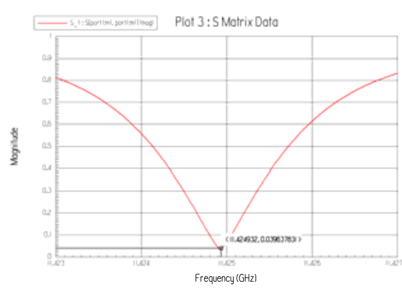


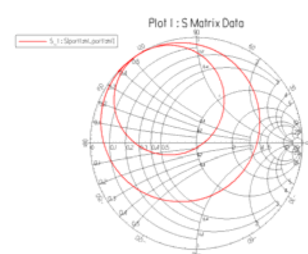


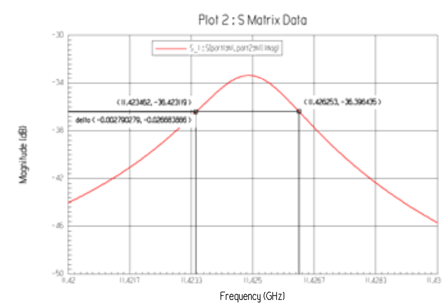
Maximum magnetic field **458 kA/m**
(SLANS 457 kA/m)

Maximum electric field **230 MV/m**
(SLANS 230 MV/m)









Resonance at 11.4249 GHz

(SLANS 11.424 GHz)

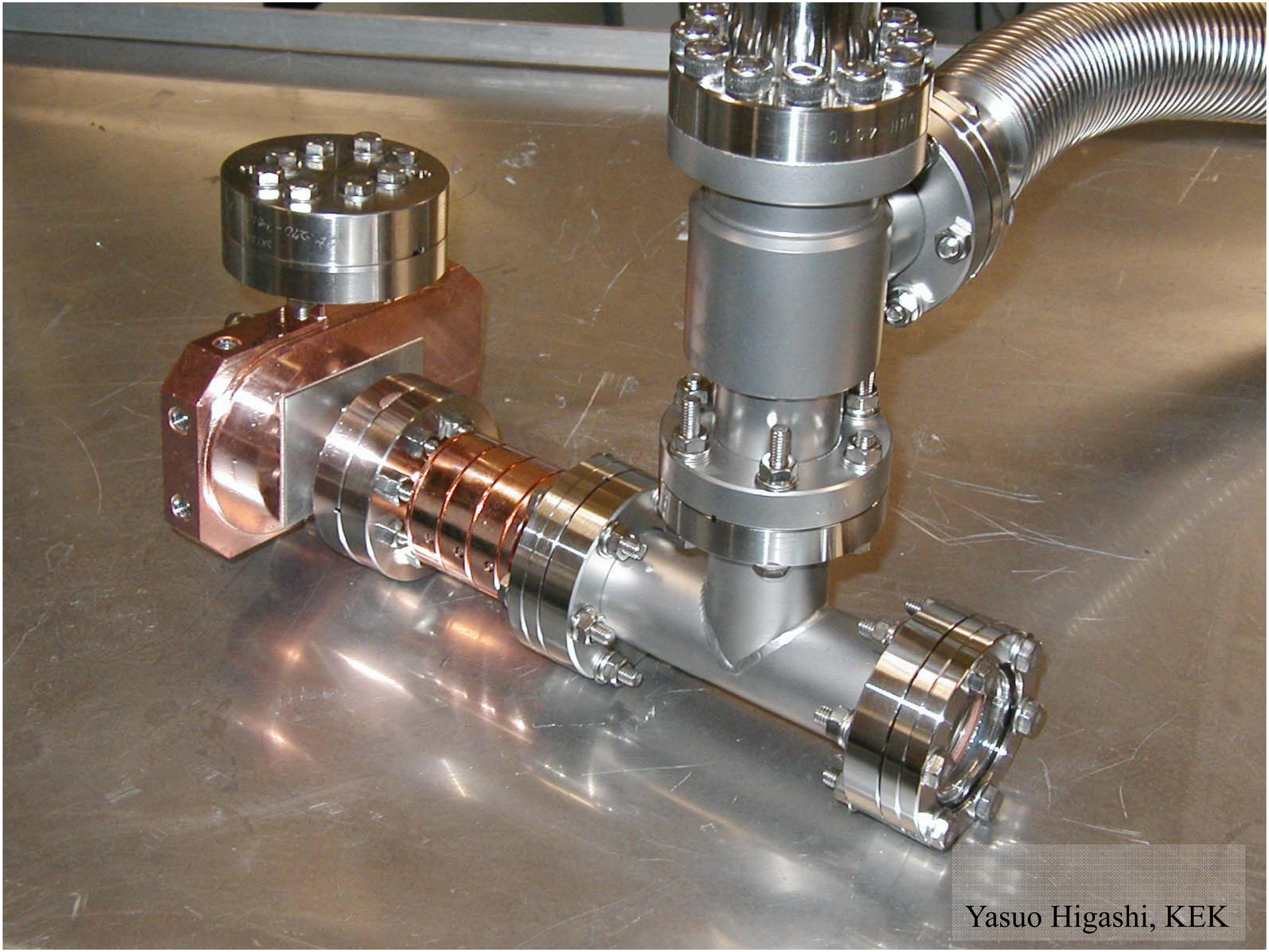
$\beta = 1.083$

(SLANS 1.075)

Over-coupled loaded Q $\quad \frac{11.4249}{0.00279027} = 4.095\times 10^3$

Unloaded Q $\quad 4.095(1 + 1.083)\cdot 10^3 = 8.53\times 10^3$
(SLANS 8.64e3)

V.A. Dolgashev, 2 March 2007


Yasuo Higashi, KEK

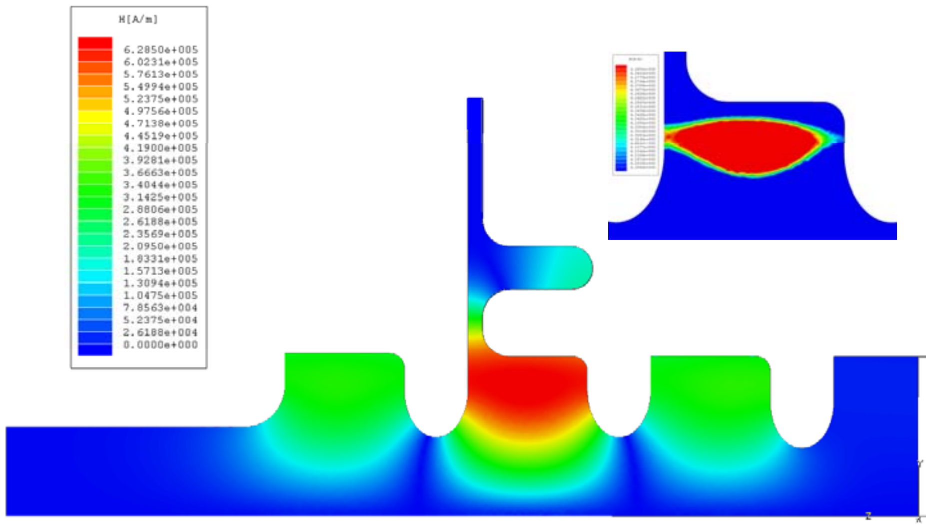

Yasuo Higashi, KEK

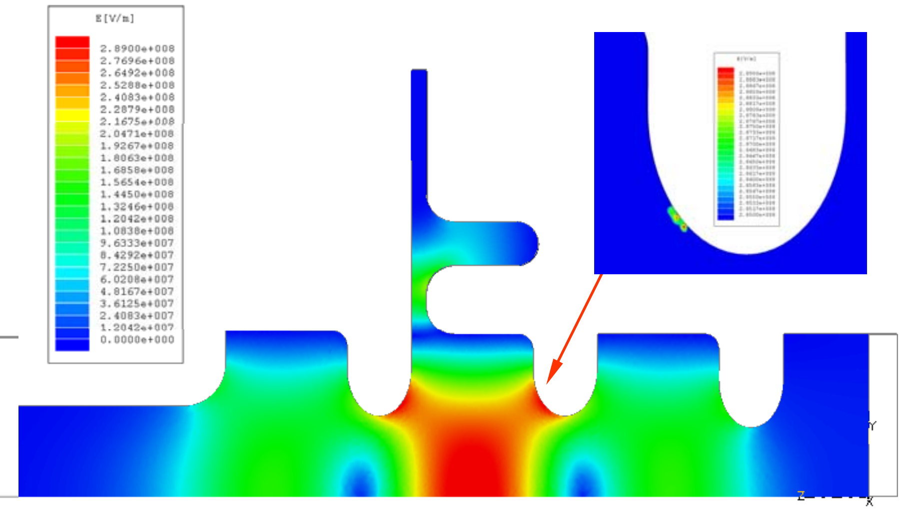
Manufacturing of 3-cell SW structure (3C-SW-A5.65-T4.6-Cu-KEK#1) at KEK,

Yasuo Higashi, KEK

1C-SW-A5.65-T4.6-Cu-Choke

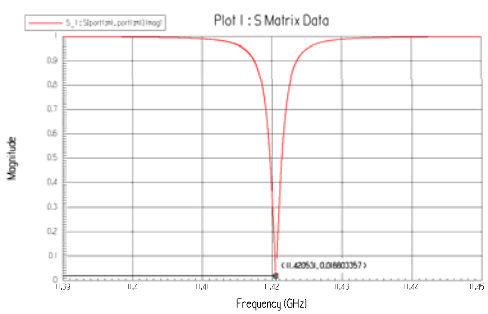
10 MW input

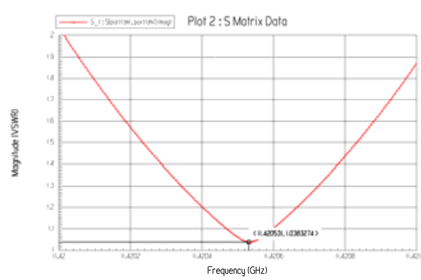


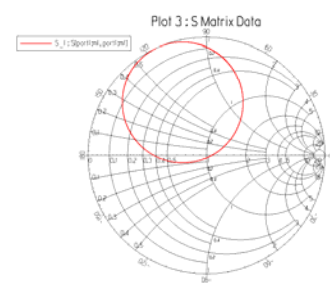


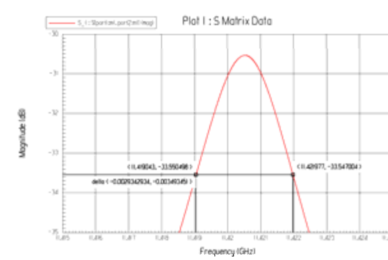
Maximum magnetic field 628.5 kA/m
(SLANS 627.5 kA/m)

Maximum electric field 289 MV/m
(SLANS 297.7 MV/m)









$$\frac{11.42053}{0.00293429} = 3.892\times 10^3$$

$$\frac{11.42053}{0.00293429}\cdot(1 + 1.03832) = 7.933\times 10^3$$

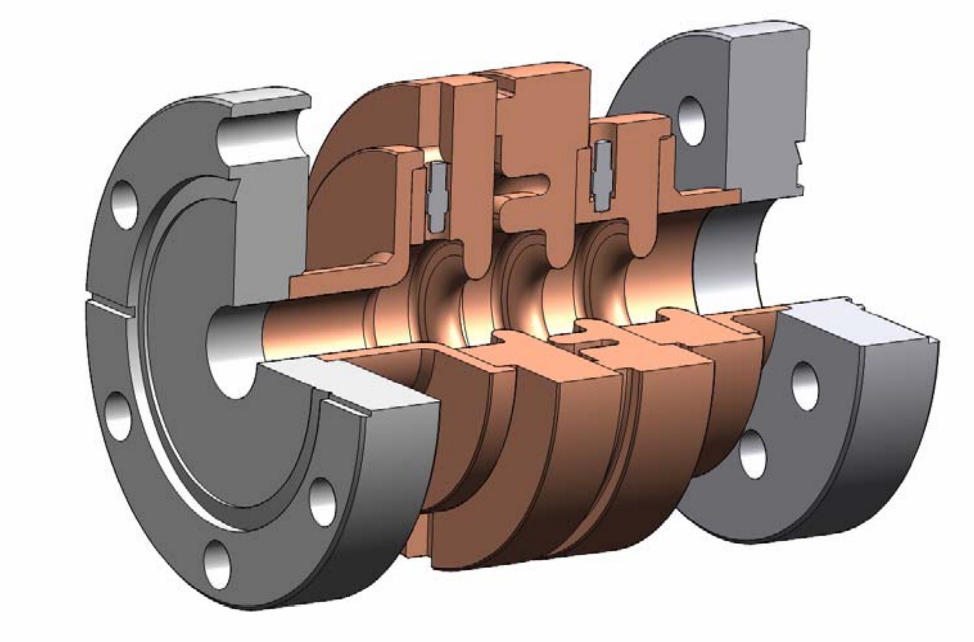
Resonance at 11.42053 GHz
(SLANS 11.424 GHz)

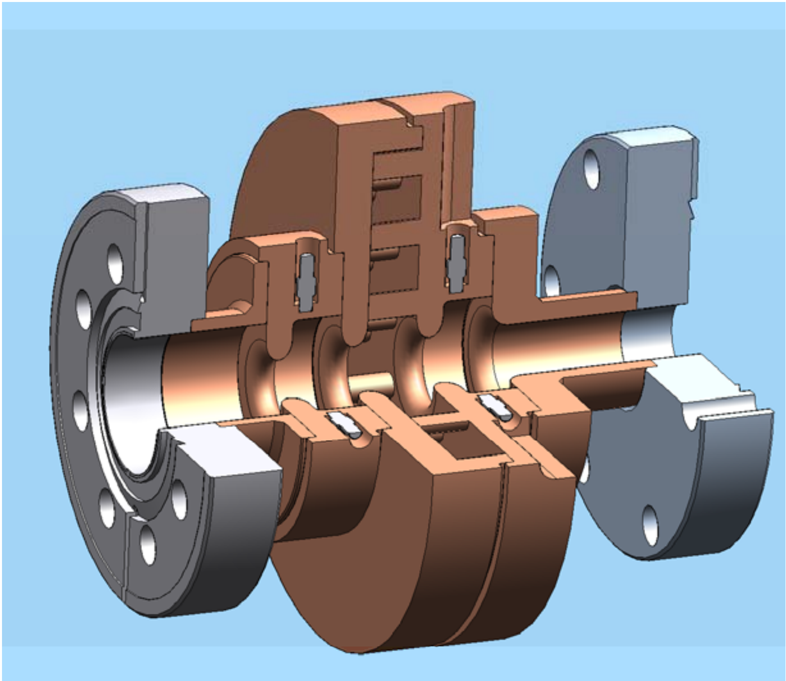
$\beta = 1.03832$
(SLANS 1.045)

Over-coupled loaded Q
Unloaded Q=7,933
(SLANS 7,933.5)

V.A. Dolgashev, 25 September 2007

Wakefield damping "ready" structures





Electrical design: Roark Marsh, MIT

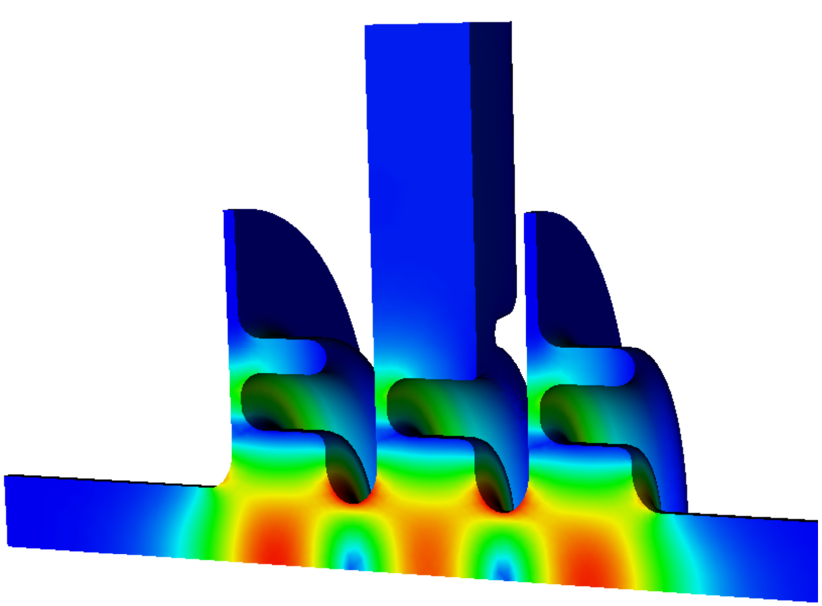
1C-SW-A5.65-T4.6-Cu-Choke **1C-SW-A5.65-T4.6-Cu-PBG**

Solid Model: David Martin

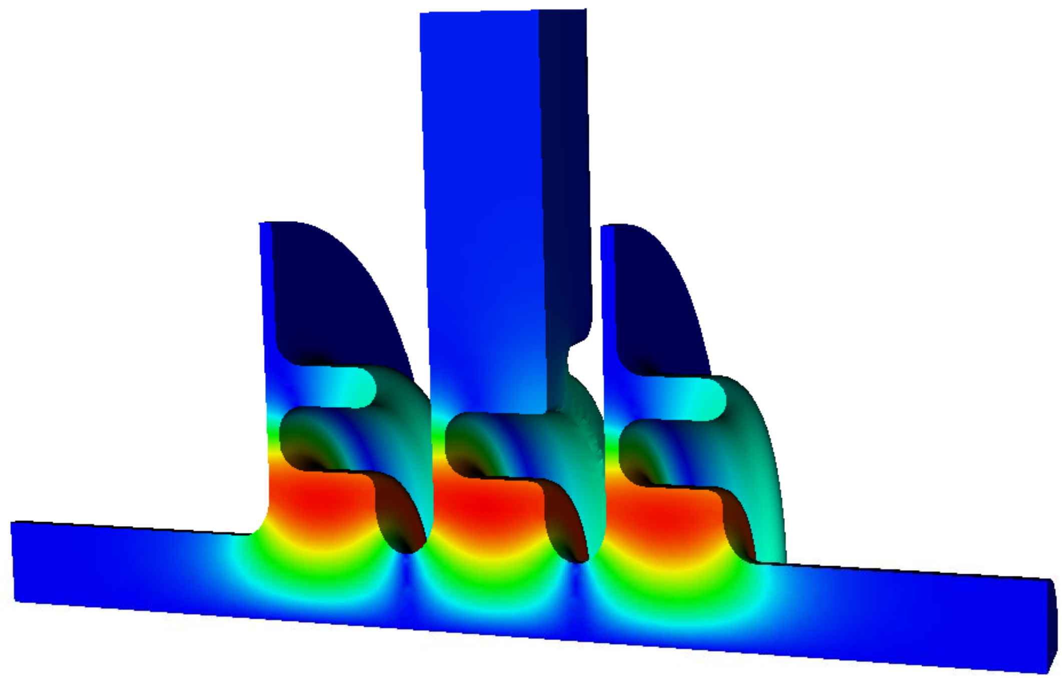
1C-SW-A5.65-T4.6-Cu-Choke-SLAC-#1 after bead-pull measurement

3-Cell structure with choke coupler and WR90 inputs

3C-SW-A5.65-T4.6-Cu-WR90



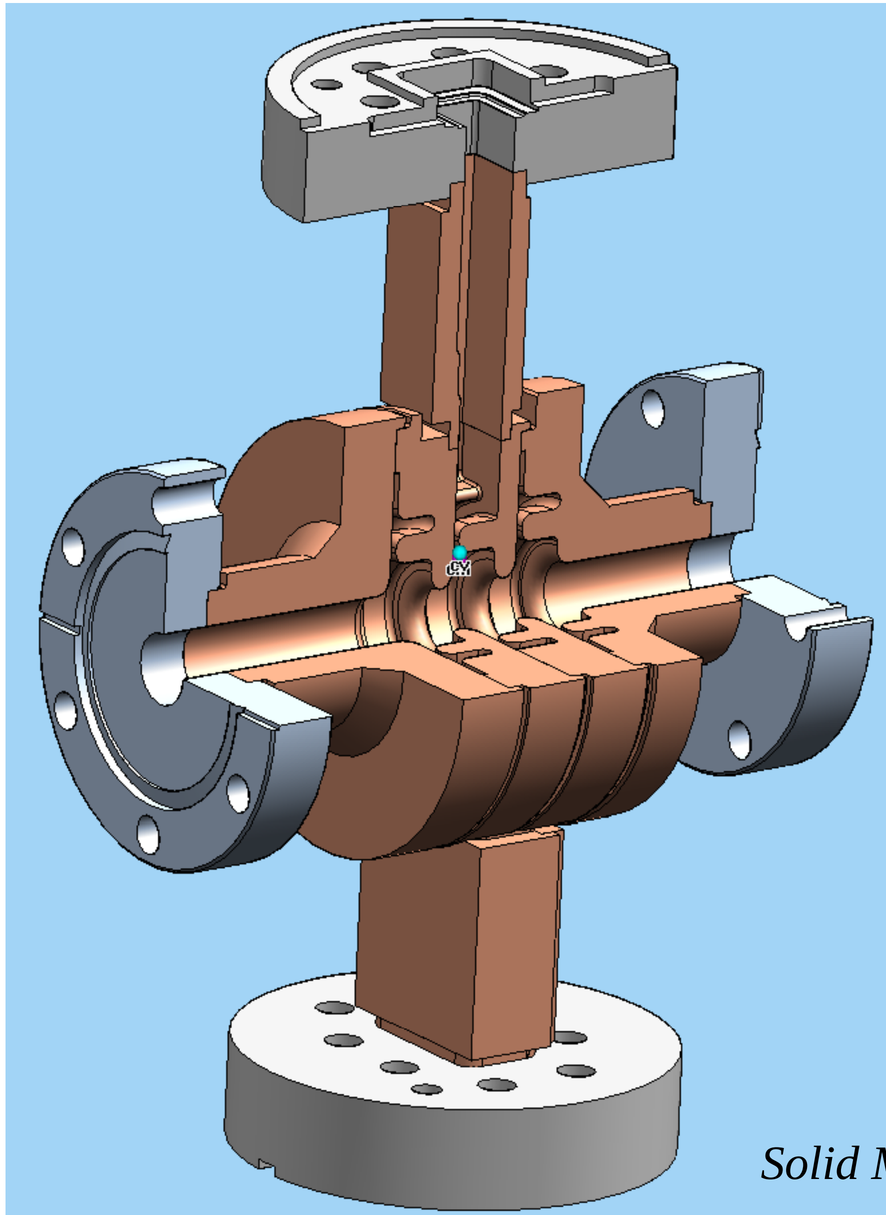
Surface electric fields



Surface magnetic fields

Electrical design: Z. Li, 8 November 2007

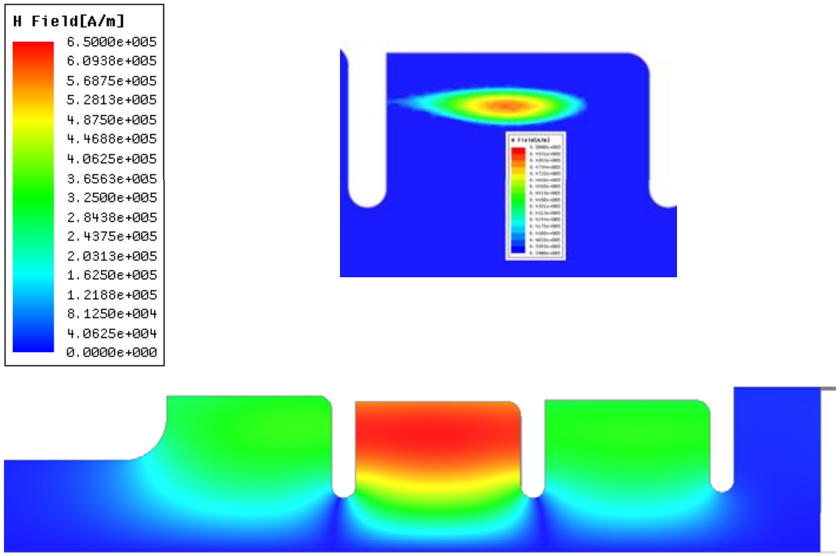
3-Cell structure with choke coupler and WR90 inputs
3C-SW-A5.65-T4.6-Cu-WR90



Solid Model: David Martin

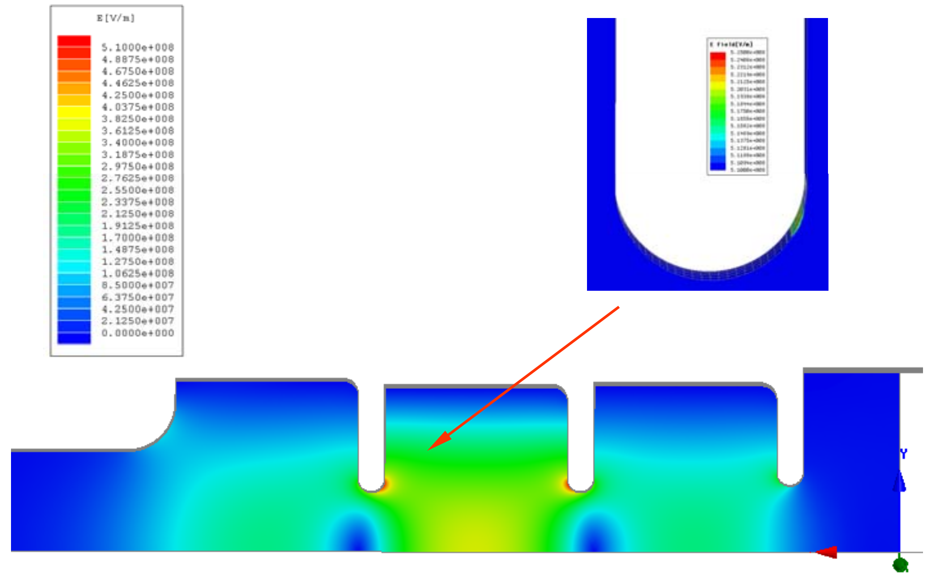
1C-SW-A3.75-T1.66-Cu

10 MW input



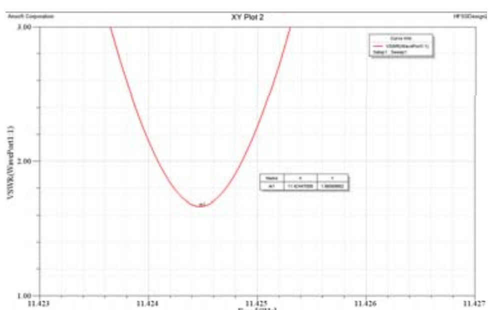
Maximum magnetic field 639 kA/m

(SLANS 642.37 kA/m)



Maximum electric field 525 MV/m

(SLANS 533.3087 MV/m)



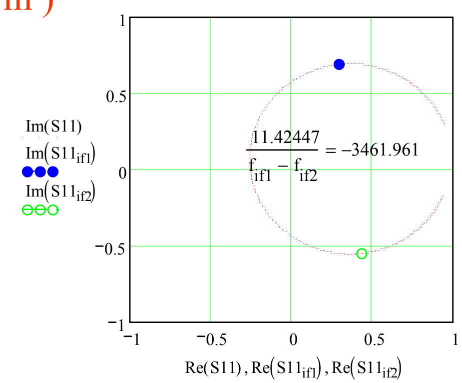
Resonance at 11.42447 GHz β = 1.666

(SLANS 11.423.91 GHz) (SLANS 1.788)

$$\frac{11.42447}{f_{if1} - f_{if2}} \cdot (1 + 1.666) = -9229.587$$

Unloaded Q=9.229 (Smith Chart)

(SLANS 9,182.93)

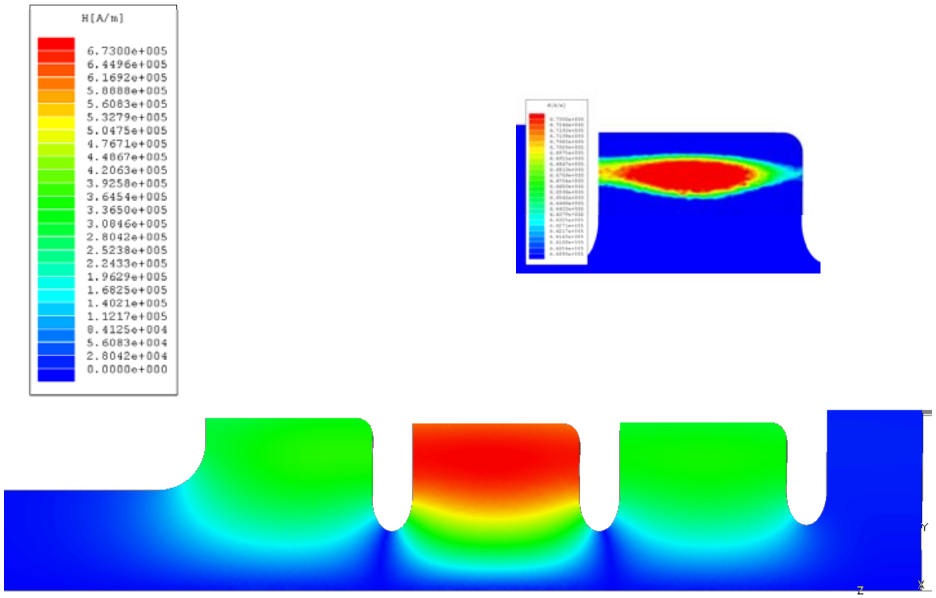


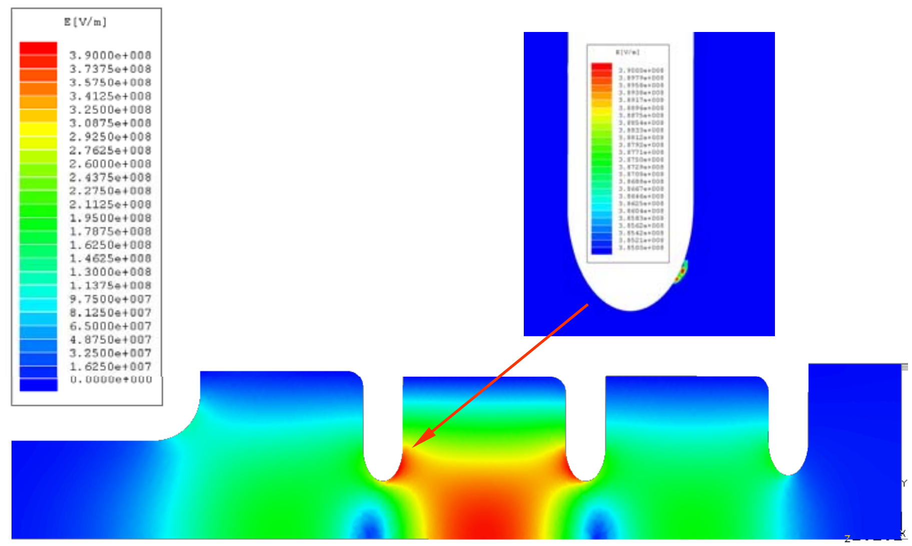
Over-coupled loaded Q

V.A. Dolgashev, 12 November 2007

1C-SW-A3.75-T2.6-Cu

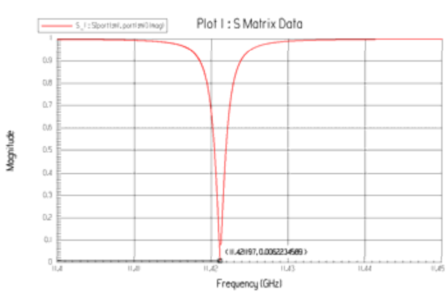
10 MW input

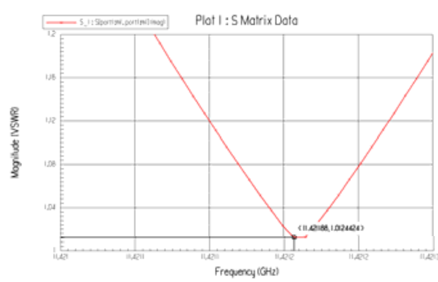


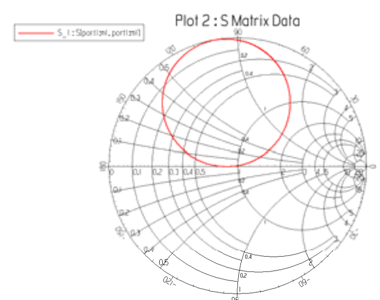


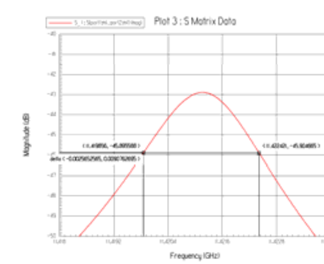
Maximum magnetic field 672 kA/m
(SLANS 668.0 kA/m)

Maximum electric field 390 MV/m
(SLANS 398.9 MV/m)









Resonance at 11.4212 GHz

(SLANS 11.4241 GHz)

$\beta = 0.988$

(SLANS 1.032356)

Under-coupled loaded Q

$$\frac{11.4212}{0.00256526} = 4.452\times 10^{3}$$

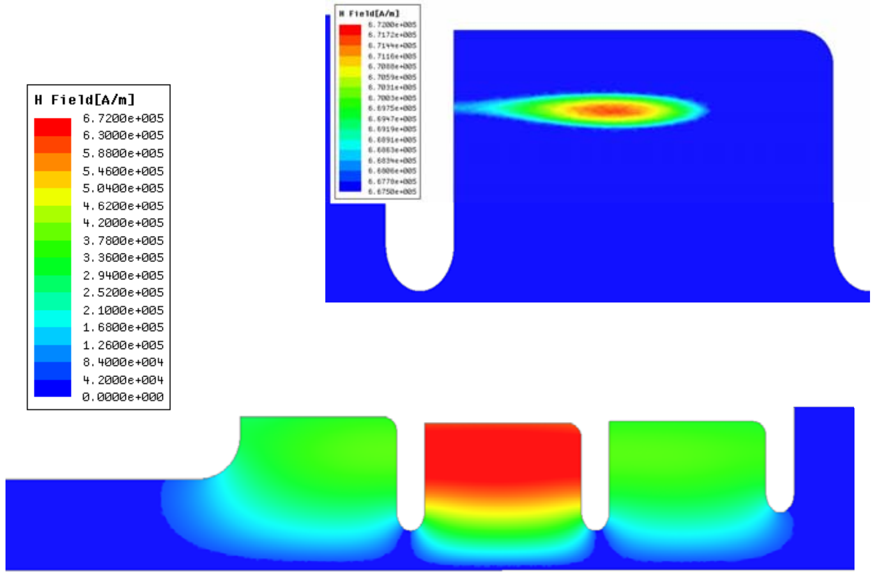
Unloaded Q=8,849.8
(SLANS 8,912.5)

$$\frac{11.4212}{0.00256526}\cdot(1 + 0.98771) = 8.8498\times 10^{3}$$

V.A. Dolgashev, 25 September 2007

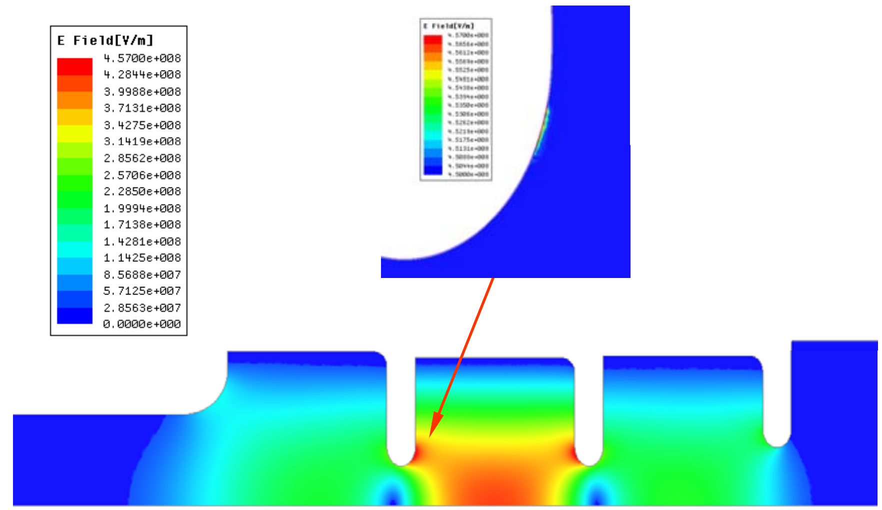
1C-SW-A2.75-T2.0-Cu

10 MW input



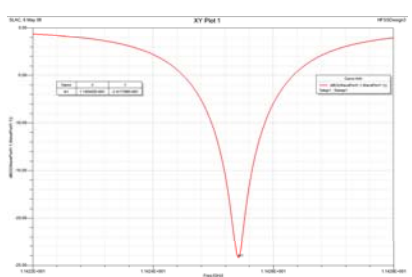
Maximum magnetic field 667.5 kA/m

(SLANS 666.8 kA/m)



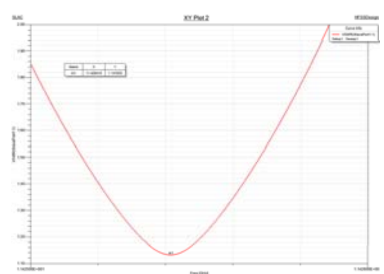
Maximum electric field 457 MV/m

(SLANS 456.3 MV/m)



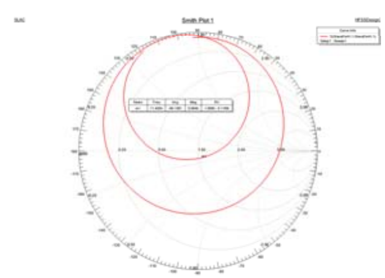
Resonance at 11.42542 GHz

(SLANS 11.42398 GHz)



β = 1.131

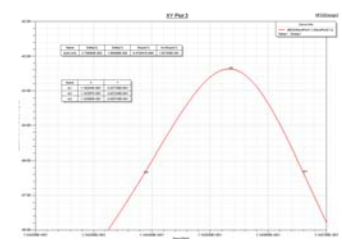
(SLANS 1.164)



Over-coupled loaded Q

Unloaded Q=8,919

(SLANS 8,9594)

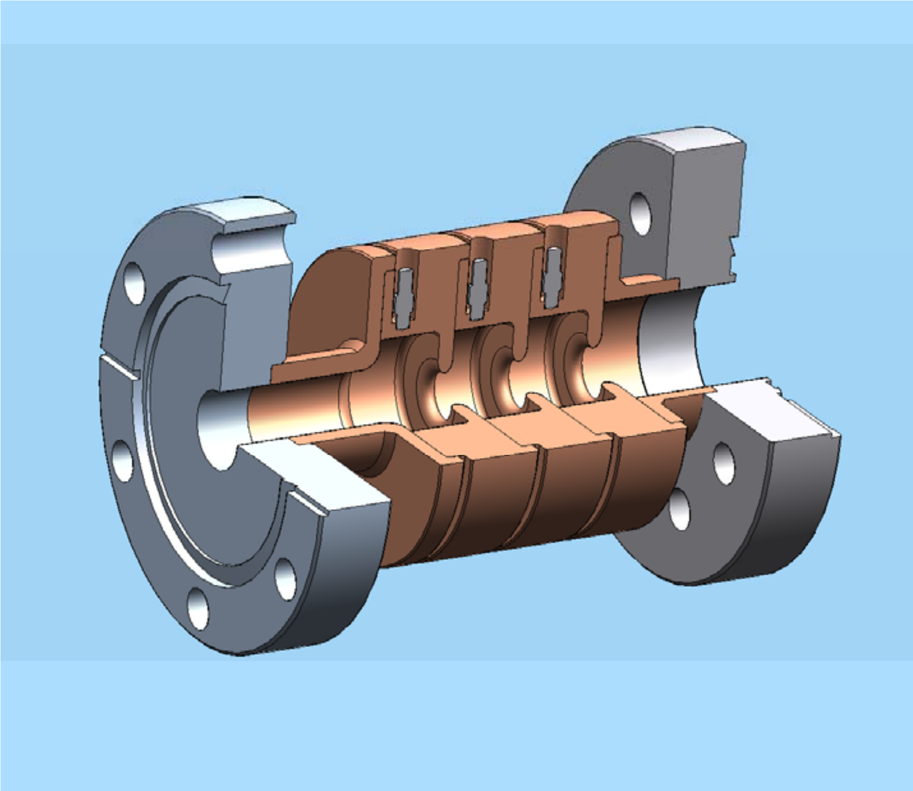


$$\frac{11.42542\,\text{GHz}}{2.73\,\text{MHz}} = 4.185\times 10^3$$

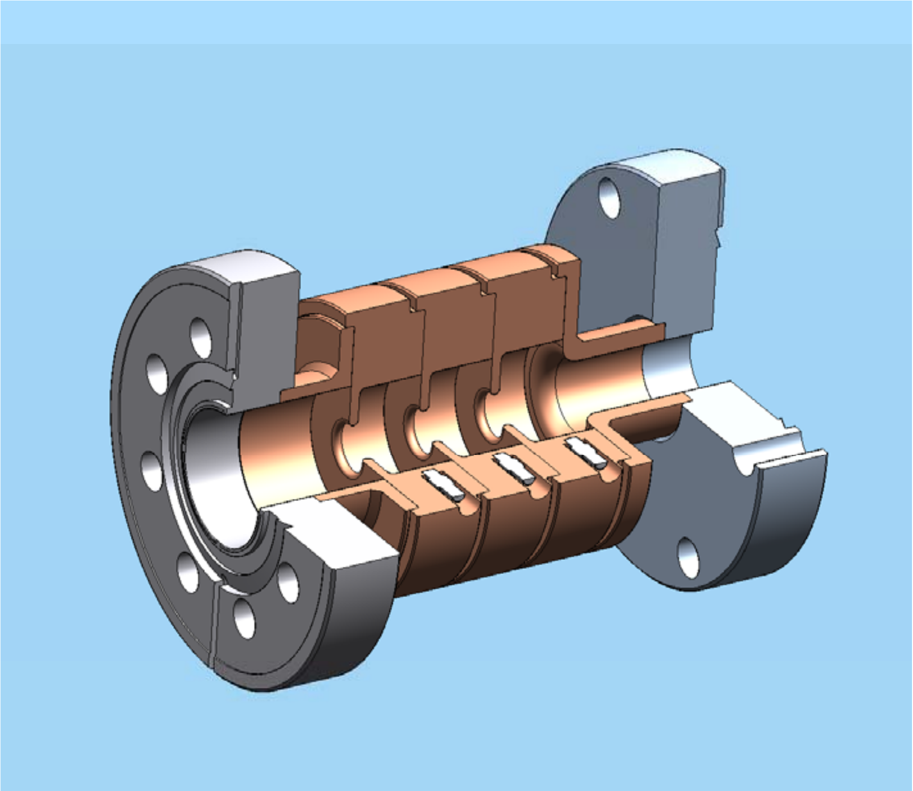
$$\frac{11.42542\,\text{GHz}}{2.73\,\text{MHz}}(1 + 1.131) = 8.919\times 10^3$$

V.A. Dolgashev, 6 May 2008

High shunt impedance structures



1C-SW-A3.75-T2.6-Cu



1C-SW-A3.75-T1.66-Cu

Solid Model: David Martin

Summary

We designed a set of single cell standing wave structures. We attempted to cover range parameters need for high-gradient, heavy wake-field loaded accelerator. These structures being built at KEK, SLAC and Frascati and high-power tested at SLAC. As we learn results of the high power tests, we design new structures.