A 3D finite element analysis (FEA) model of a ceramic window. The model is rendered with a color gradient from blue on the left to red on the right, indicating stress or strain distribution. The shape is complex, with a large, rounded, bulbous section on the left and a more elongated, ring-like structure on the right. The surface is highly detailed, showing the mesh used for the simulation.

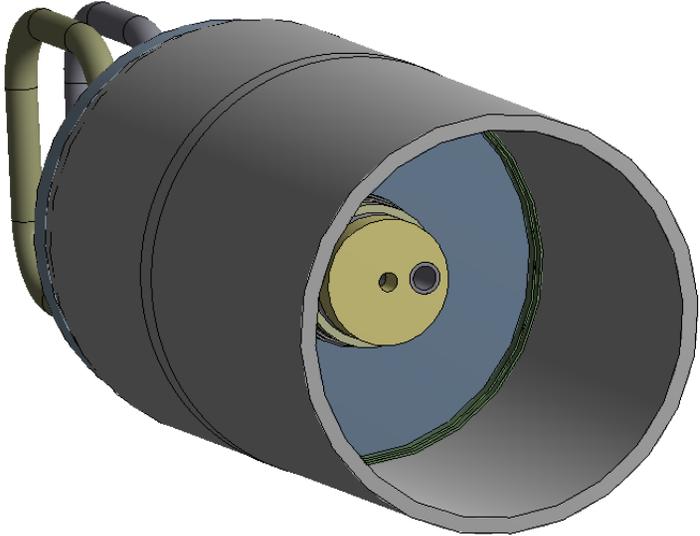
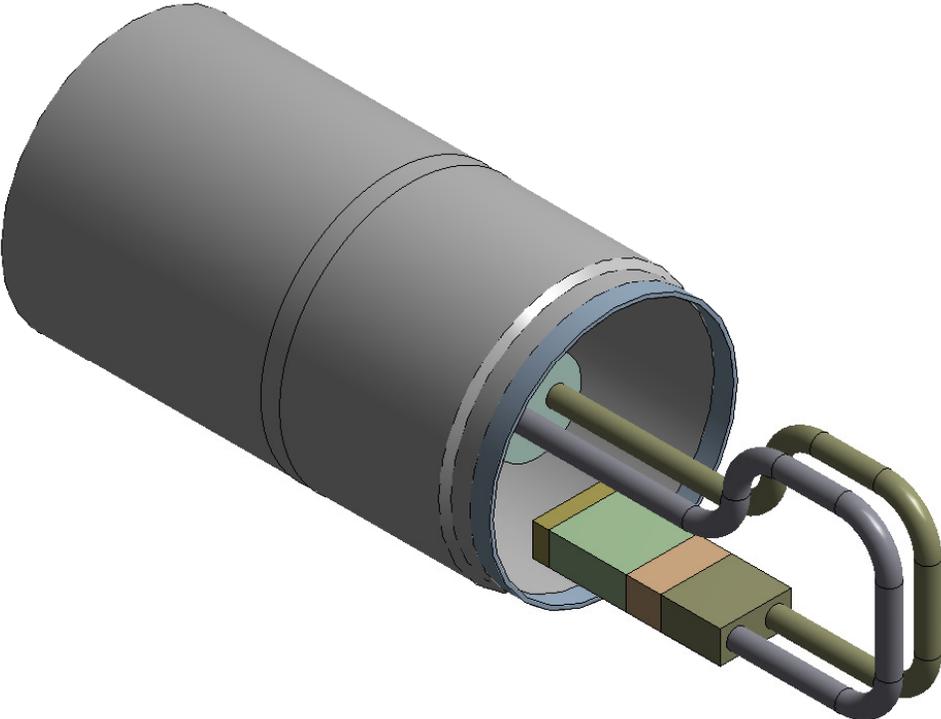
FEA of the Ceramic Window

RFQ Coupler design review

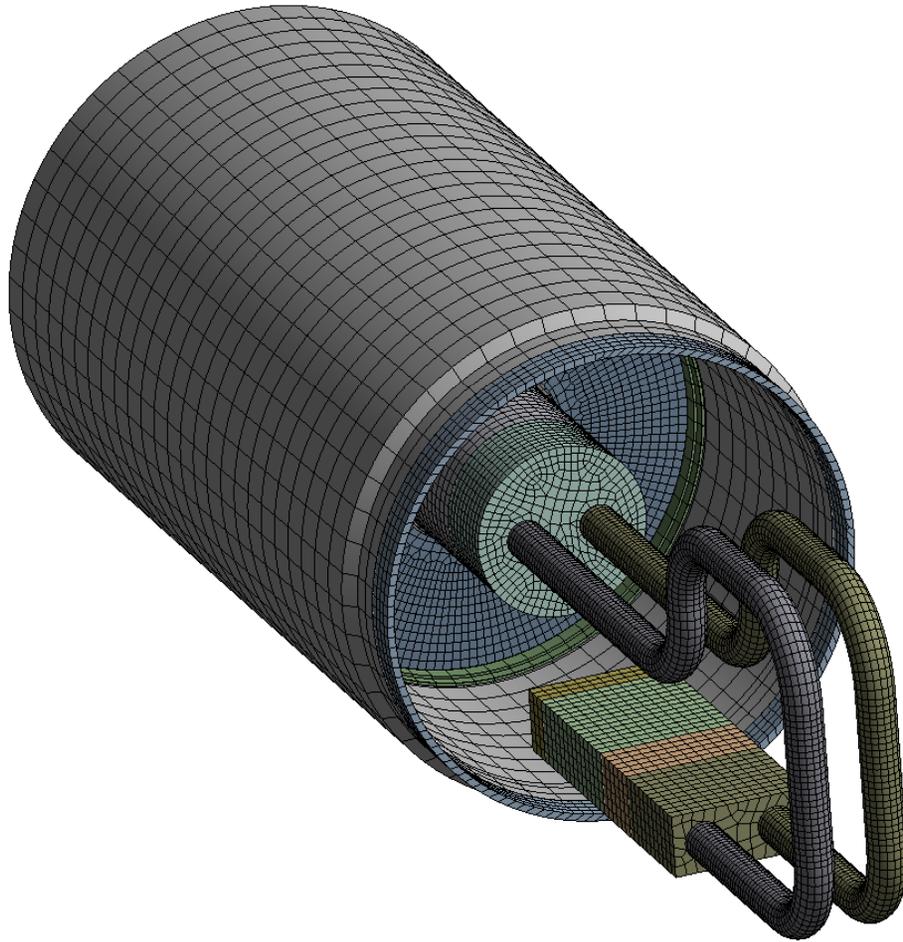
Prepared by Valeri Poloubotko

May 21, 2013

FEA Model of the Window Assembly



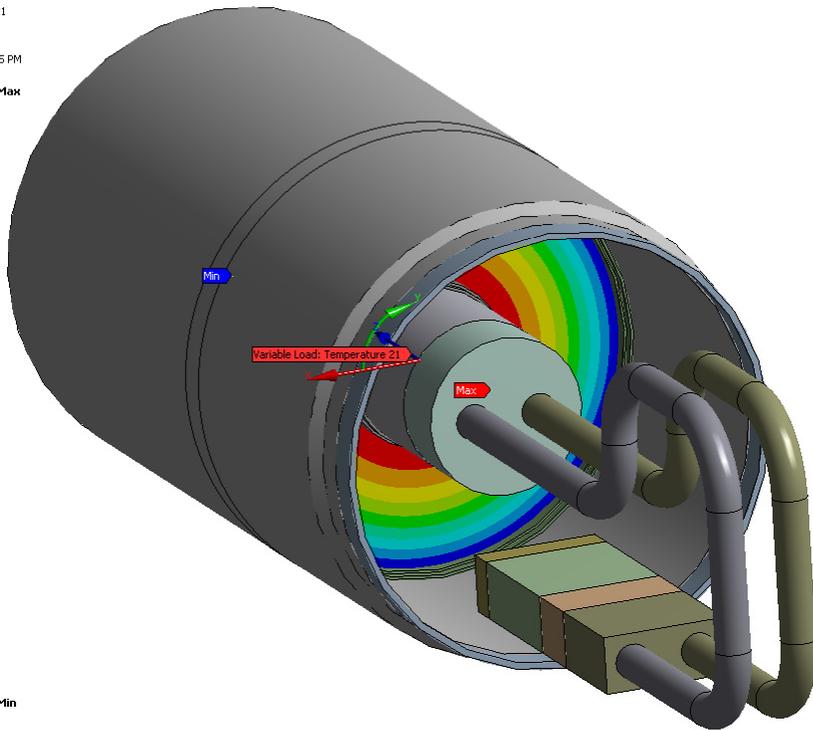
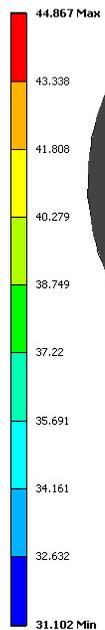
Meshing of the Window Assembly



Multizone meshing with individual body sizing

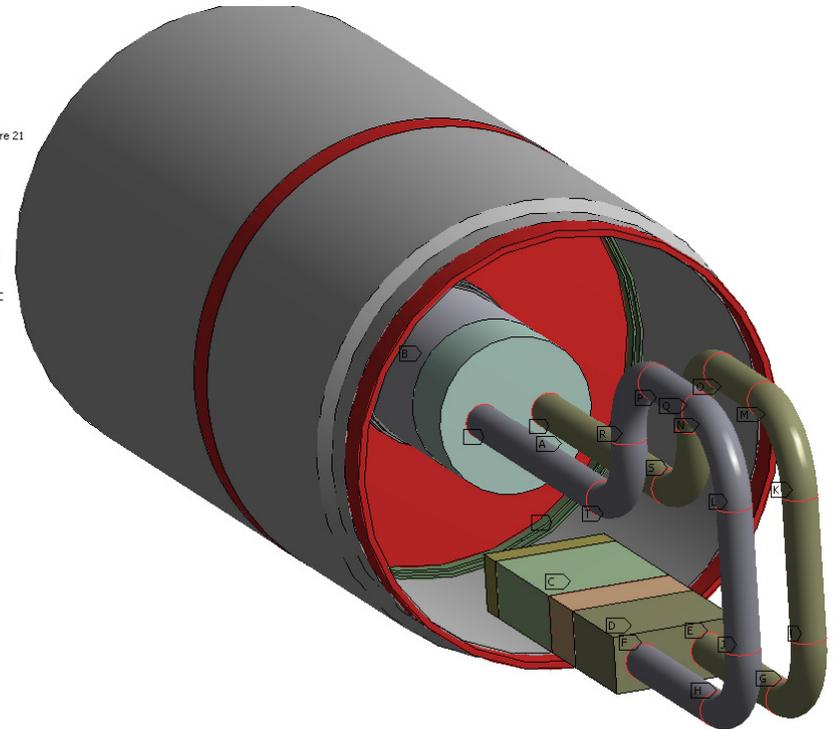
DOE of the Window Assembly

B: Steady-State Thermal
Temperature 21
Time: 1. s
Unit: °C
5/17/2013 1:55 PM



B: Steady-State Thermal
Steady-State Thermal
Time: 1. s
Items: 10 of 23 indicated
5/17/2013 1:57 PM

- A Temperature: 35. °C
- B Variable Load: Temperature 21
- C Temperature 3: 96.6 °C
- D Temperature 4: 96.5 °C
- E Temperature 5: 94.9 °C
- F Temperature 6: 95.8 °C
- G Temperature 7: 90.4 °C
- H Temperature 8: 103.4 °C
- I Temperature 9: 87.7 °C
- J Temperature 10: 103.6 °C

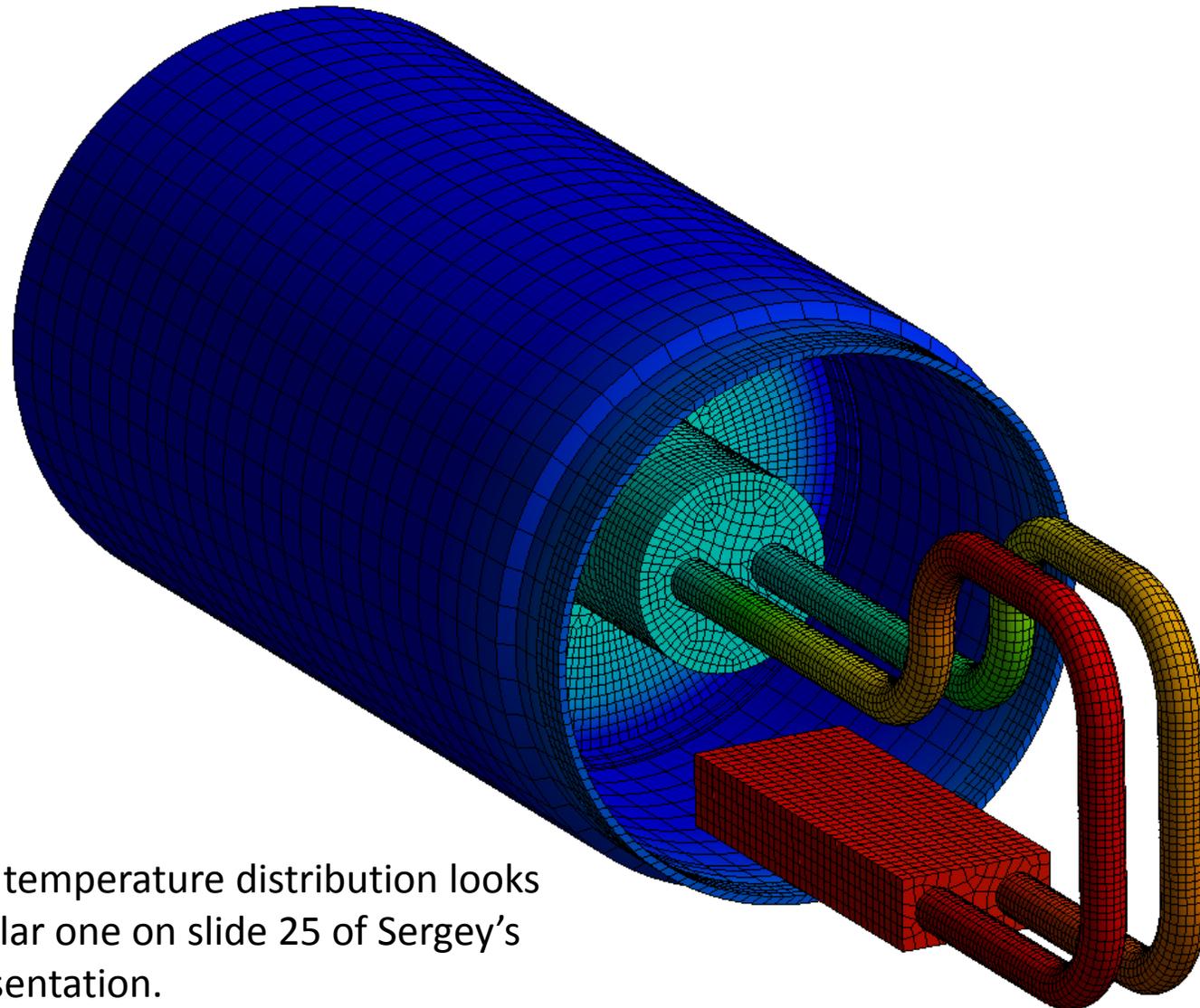
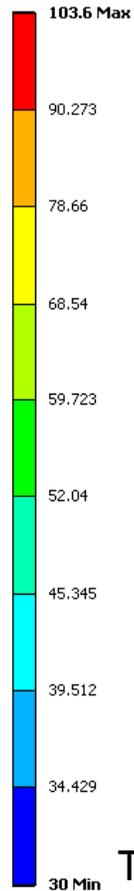


Temperature load in the model
(slide 25 of Sergey's presentation)

Polynomial (of power 4) temperature distribution
in the ceramic window

Temperature Distribution in the Window Model

B: Steady-State Thermal
Temperature
Type: Temperature
Unit: °C
Time: 1
5/17/2013 2:11 PM



The temperature distribution looks similar one on slide 25 of Sergey's presentation.

Loads in the Structural Analysis

C: Static Structural

Static Structural

Time: 1. s

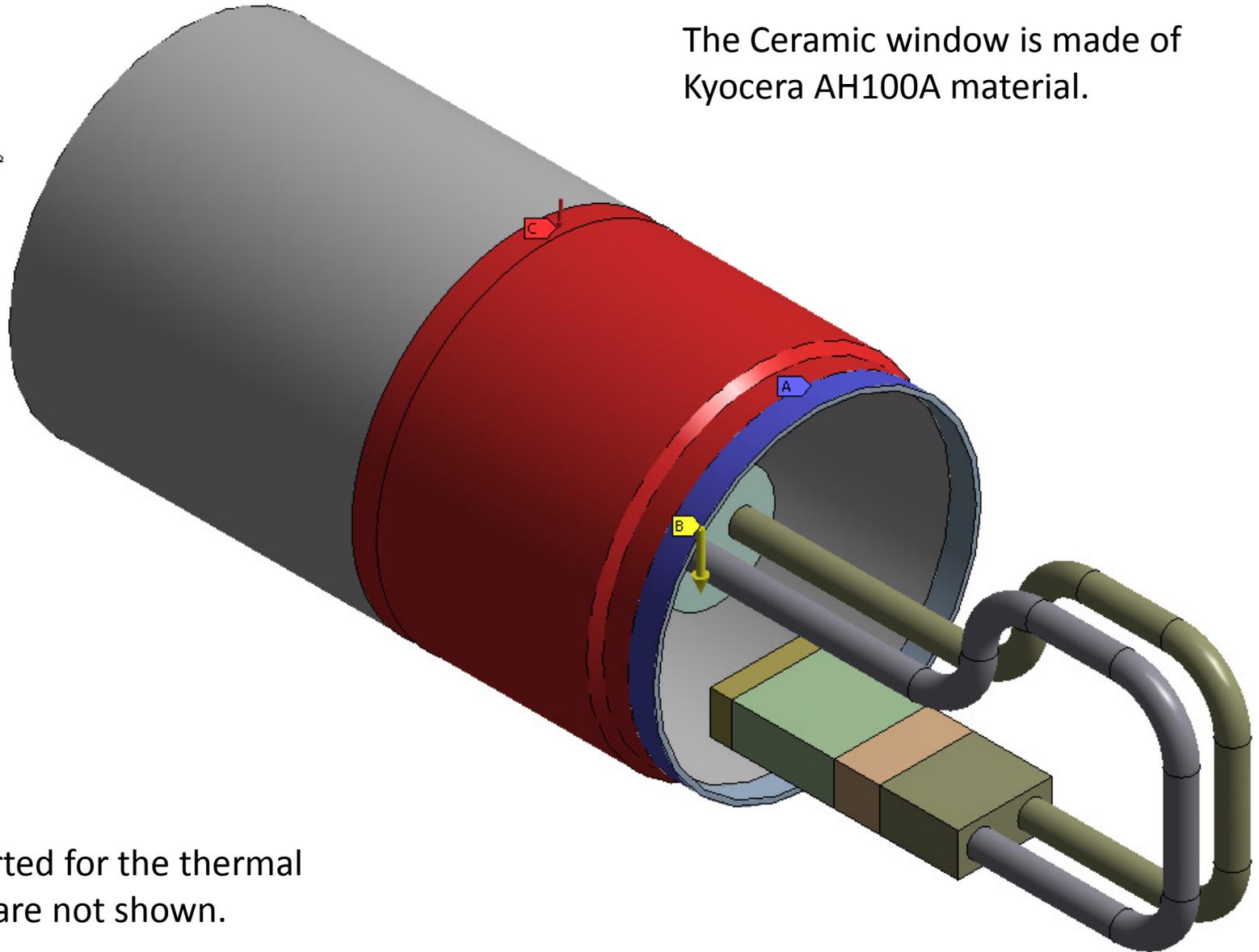
5/20/2013 10:00 AM

A Fixed Support

B Standard Earth Gravity: 9806.6 mm/s²

C Pressure: 0.10135 MPa

The Ceramic window is made of Kyocera AH100A material.



Remark: Imported for the thermal analysis loads are not shown.

Window Ceramics



Properties*			Alumina											
			Porcelain	Steatite	Cordierite	Mullite	AD-85	AD-90	AD-94	AD-96	FG-995	AD-995	AD-998	
Units	Test					Nom. 85% Al ₂ O ₃	Nom. 90% Al ₂ O ₃	Nom. 94% Al ₂ O ₃	Nom. 96% Al ₂ O ₃	Nom. 98.5% Al ₂ O ₃	Nom. 99.5% Al ₂ O ₃	Min. 99.8% Al ₂ O ₃		
Density	gm/cc	ASTM-C20	2.40	2.78	2.05	2.80	3.42	3.60	3.70	3.72	3.80	3.90	3.92	
Crystal Size	Average	MICRONS	THIN-SECTION	–	–	–	10	6	4	12	6	6	6	
Water Absorption	%	ASTM-373	0	0	9.50	0	0	0	0	0	0	0	0	
Gas Permeability	–	–	0	0	–	0	0	0	0	0	0	0	0	
Color	–	–	WHITE	BEIGE	YELLOW	TAN	WHITE	WHITE	WHITE	WHITE	WHITE	IVORY	IVORY	
Flexural Strength (MOR)	20° C	MPa (psi x 10 ³)	ASTM-F417	130 (19)	140	55	170 (25)	296 (43)	338 (49)	352 (51)	358 (52)	375 (54)	379 (55)	375 (54)
Elastic Modulus	20° C	GPa (psi x 10 ⁶)	ASTM-C848	104 (15)	110	40	150 (22)	221 (32)	276 (40)	303 (44)	303 (44)	350 (51)	370 (54)	370 (54)
Poisson's Ratio	20° C	–	ASTM-C848	–	–	–	–	0.22	0.22	0.21	0.21	0.22	0.22	0.22
Compressive Strength	20° C	MPa (psi x 10 ³)	ASTM-C773	590 (86)	–	–	550 (80)	1930 (280)	2482 (360)	2103 (305)	2068 (300)	2500 (363)	2600 (377)	2500 (363)
Hardness		GPa (kg/mm ²)	KNOOP 1000 gm	5.9 (600)	–	–	7.4 (750)	9.4 (960)	10.4 (1058)	11.5 (1175)	11.5 (1175)	13.7 (1400)	14.1 (1440)	14.1 (1440)
		R45N	ROCKWELL 45 N	60	57	–	70	73	75	78	78	82	83	83
Tensile Strength	25° C	MPa (psi x 10 ³)	ACMA TEST #4	–	–	–	–	155 (22)	221 (32)	193 (28)	221 (32)	248 (36)	262 (38)	248 (36)
Fracture Toughness	K(I c)	Mpa m ^{1/2}	NOTCHED BEAM	2	–	–	2	3 - 4	3 - 4	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5
Thermal Conductivity	20° C	W/m K	ASTM-C408	5.0	2.5	1.6	3.5	16.0	16.7	22.4	24.7	27.5	30.0	30.0
Coefficient of Thermal Expansion	25-1000° C	1X 10 ⁻⁶ /°C	ASTM-C372	4.9	9	3.4	5.3	7.2	8.1	8.2	8.2	8.2	8.2	8.2
Specific Heat	100° C	J/kg*K	ASTM-E1269	–	–	–	950	920	920	880	880	880	880	880
Thermal Shock Resistance	Δ Tc	°C	●	–	100	350	300	300	250	250	250	200	200	200
Maximum Use Temperature		°C	NO-LOAD COND.	1400	1200	1200	1700	1400	1500	1700	1700	1700	1750	1750
Dielectric Strength	6.35mm	ac-kV/mm (ac V/mil)	ASTM-D116	–	–	–	9.8 (248)	9.4 (240)	8.3 (210)	8.3 (210)	8.3 (210)	8.7 (220)	8.7 (220)	8.7 (220)
Dielectric Constant	1 MHz	25° C	ASTM-D150	5.9	–	–	6.0	8.2	8.8	9.1	9	9.6	9.7	9.8
Dielectric Loss (tan delta)	1 MHz	25° C	ASTM-D150	0.0024	–	–	0.002	0.0009	0.0004	0.0004	0.0002	0.0002	0.0001	< 0.0001
Volume Resistivity	25° C	ohm-cm	ASTM-D1829	–	10 ¹³	10 ¹²	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴	> 10 ¹⁴
	500° C	ohm-cm	ASTM-D1829	–	10 ⁸	10 ⁶	4 x 10 ⁵	4 x 10 ⁸	4 x 10 ⁸	4 x 10 ⁹	4 x 10 ⁹	2 x 10 ¹⁰	2 x 10 ¹⁰	2 x 10 ¹⁰
	1000° C	ohm-cm	ASTM-D1829	–	–	–	–	–	5 x 10 ⁵	5 x 10 ⁵	1 x 10 ⁶	2 x 10 ⁶	2 x 10 ⁶	2 x 10 ⁷
Impingement	–	●	–	–	–	–	1.00	0.45	0.52	0.50	0.48	0.47	0.47	
Rubbing	–	●	–	–	–	–	1.00	0.36	–	0.60	–	–	–	

Window Ceramics

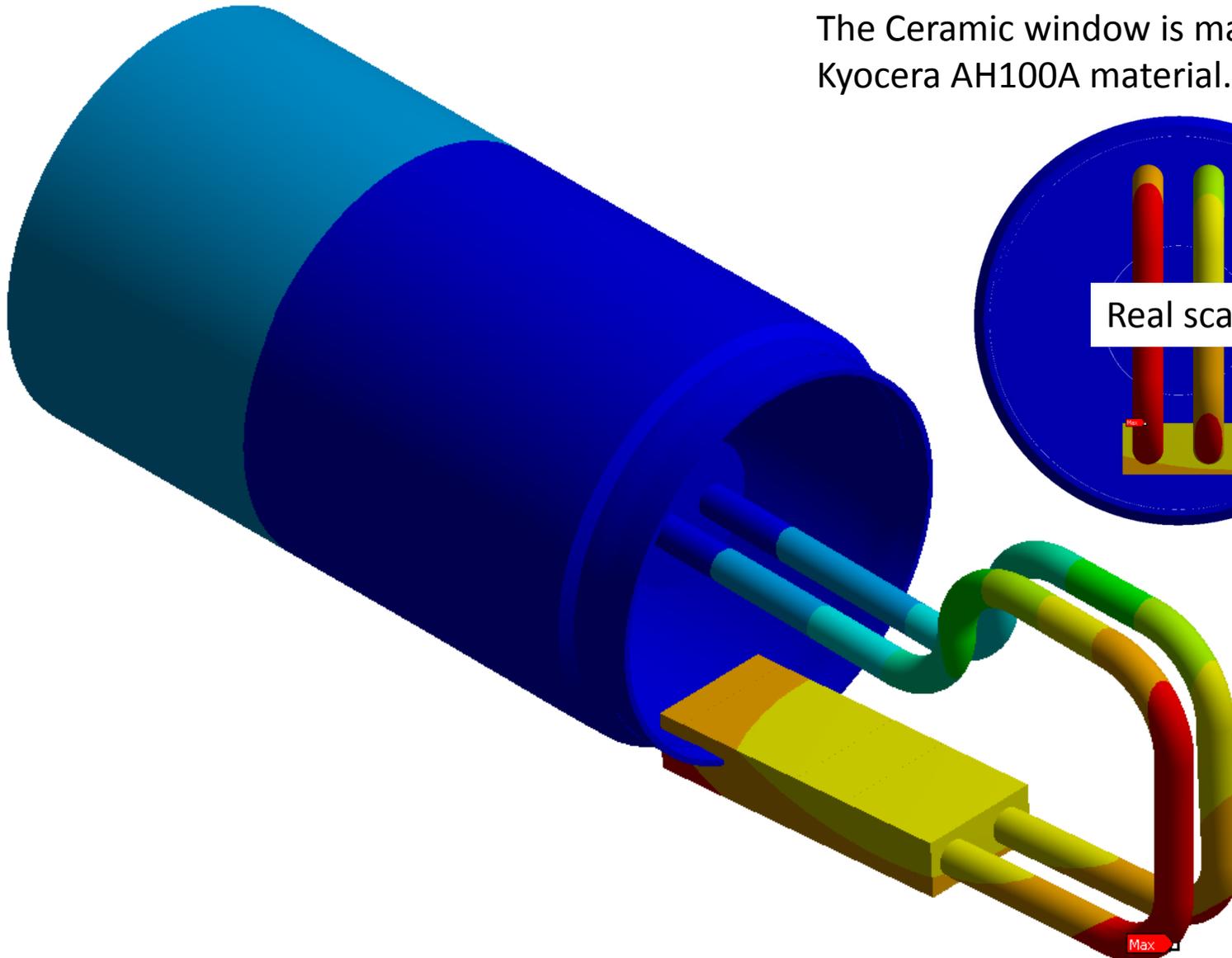
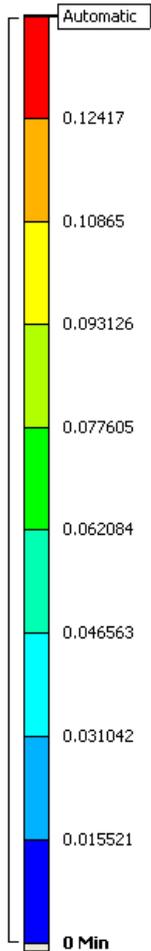
MATERIAL PROPERTIES for Antenna



ITEMS	UNIT	CUSTOMER' s REQUEST	PROPOSED CERAMIC MATERIAL	
KYOCERA MATERIAL No.	--	--	A479B	AH100A
APPLICATION	--	--	RF EQUIPMENT	HIGH VOLTAGE
METALLIZATION	--	Mo/Mn + Ni Plating	Mo/Mn+ Ni Plating Ag-Cu-Ti + Ni Plating	Ag-Cu-Ti +Ni Plating
BRAZING ATMOSPHERE	--	NO REQUEST	N2/H2 VACUUM	VACUUM
BRAZING MATERIAL	--	NO REQUEST	Ag-Cu / Cu / Au-Cu	Ag-Cu
Al2O3 PURITY	%	99.5MIN.	99.8	97
SEE Coefficient (Max.)	—	NO REQUEST	11.5	5.7
FLEXUAL STRENGTH	MPa	NO REQUEST	300	359
YOUNG'S MODULUS	GPa	NO REQUEST	370	386
POISSON'S RATIO	—	NO REQUEST	0.23	0.25
VOLUME RESISTIVITY	Ohm*cm	NO REQUEST	>10 ¹⁴	>10 ¹⁴
DIELECTRIC CONSTANT (1MHz)	—	9.8 +0.2/-0.4	9.9	10.9
Tan Delta (@1MHz)	(×10 ⁻⁴)	<10 ⁻⁴ at R.oom Temperature	0.4 (@8GHz) circular cavity	2X (10GHz)
CTE	×10 ⁶ /deg C	NO REQUEST	7	7.4
THERMAL CONDUCTIVITY	W/(mK)	NO REQUEST	29	24

The Model Deformation

C: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
5/20/2013 9:49 AM

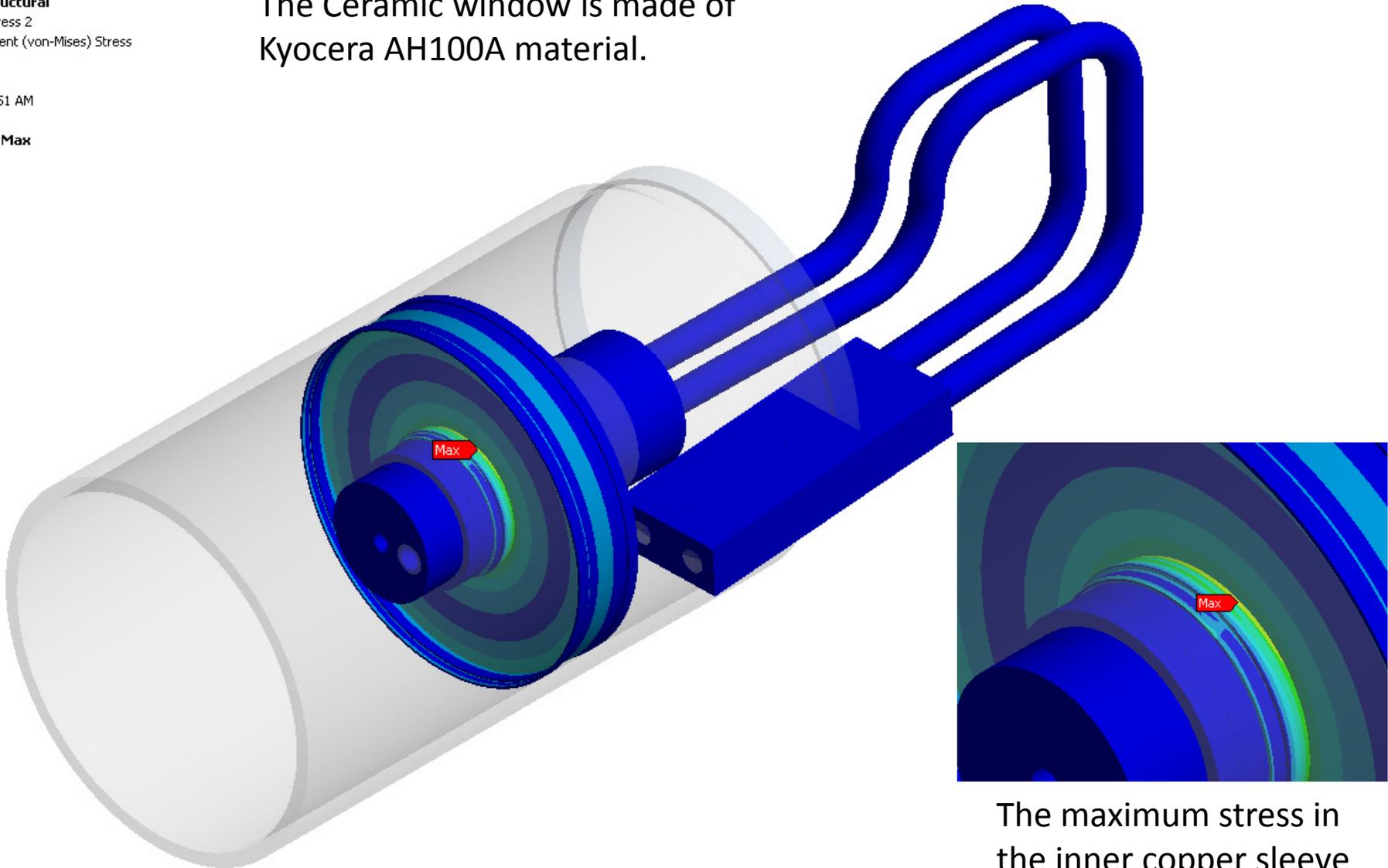
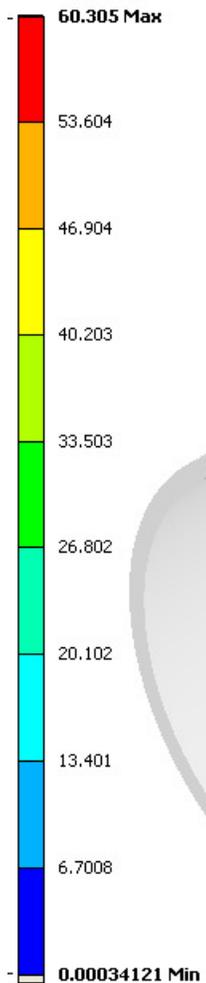


The Ceramic window is made of
Kyocera AH100A material.

Equivalent Stress in the Model

C: Static Structural
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
5/20/2013 9:51 AM

The Ceramic window is made of
Kyocera AH100A material.

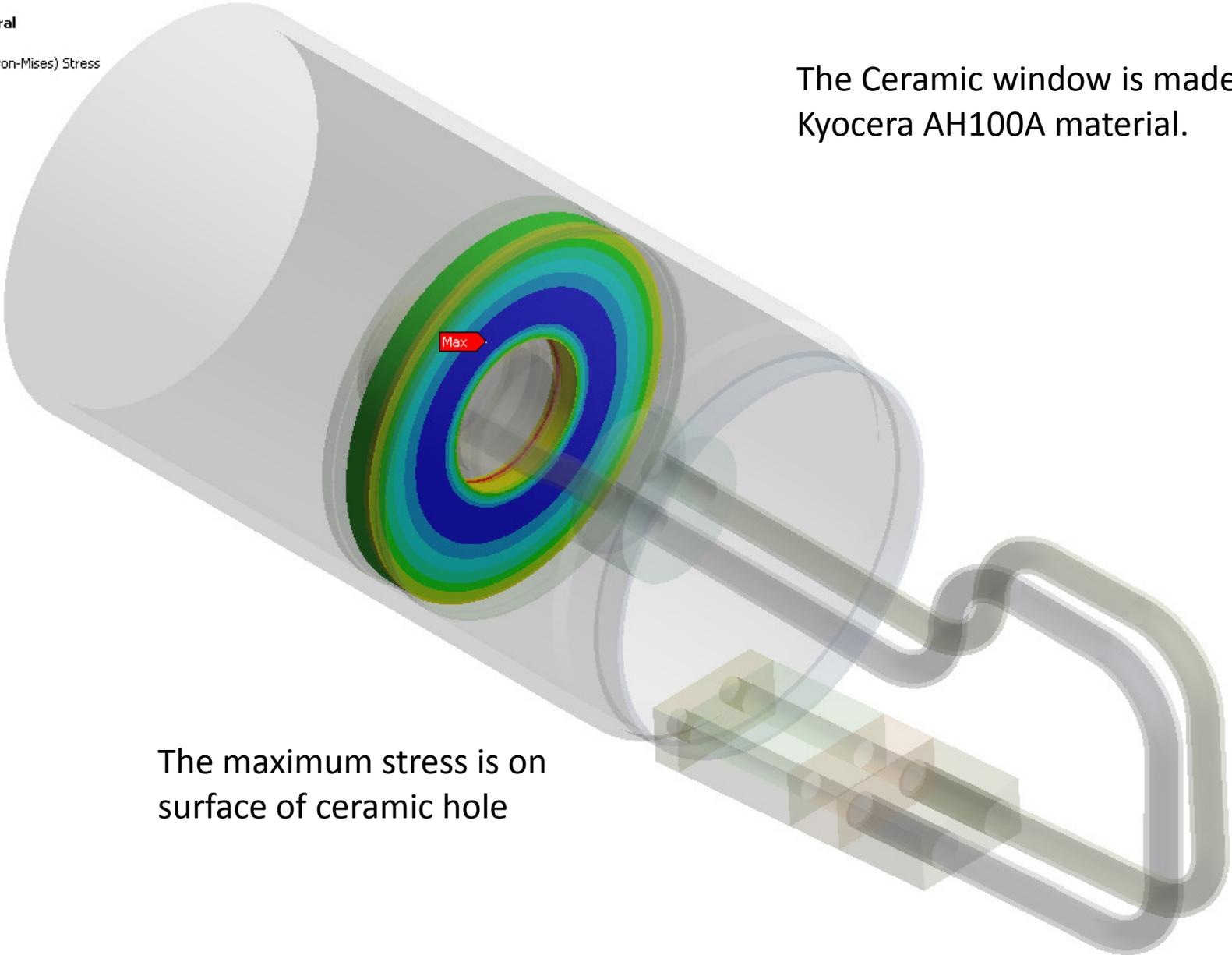
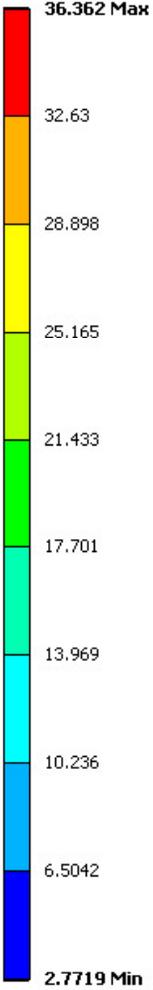


The maximum stress in
the inner copper sleeve

Equivalent Stress in the Ceramic Window

C: Static Structural
Equivalent Stress 3
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
5/20/2013 9:54 AM

The Ceramic window is made of Kyocera AH100A material.



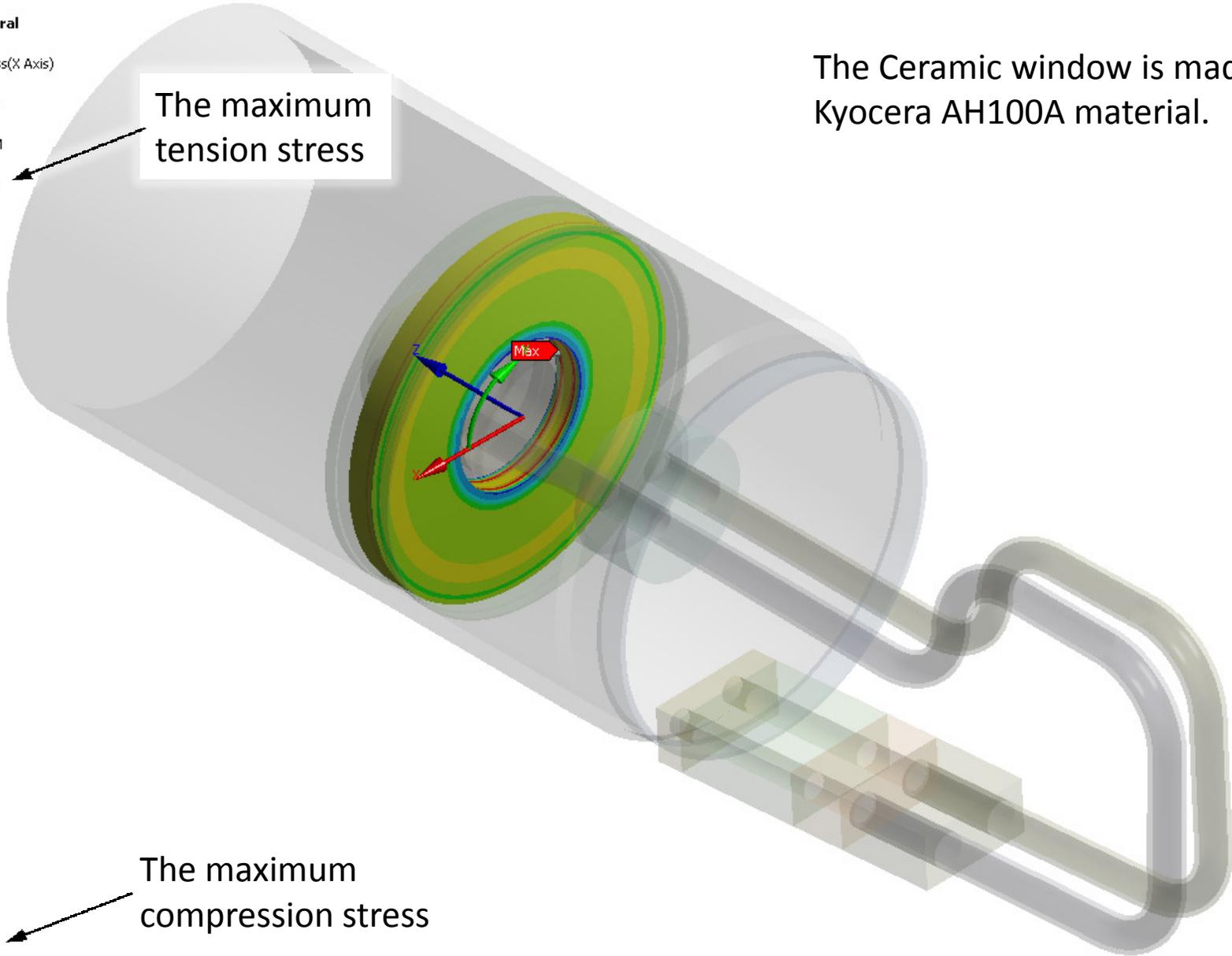
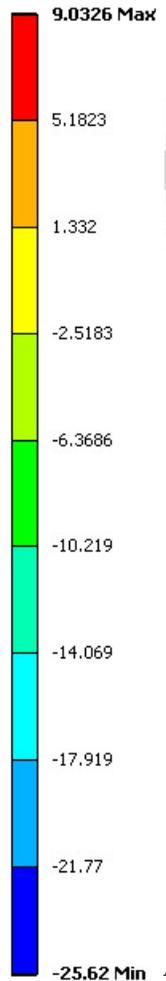
The maximum stress is on surface of ceramic hole

Radial Stress in the Ceramic Window

C: Static Structural
Normal Stress
Type: Normal Stress(X Axis)
Unit: MPa
Coordinate System
Time: 1
5/20/2013 9:56 AM

The maximum tension stress

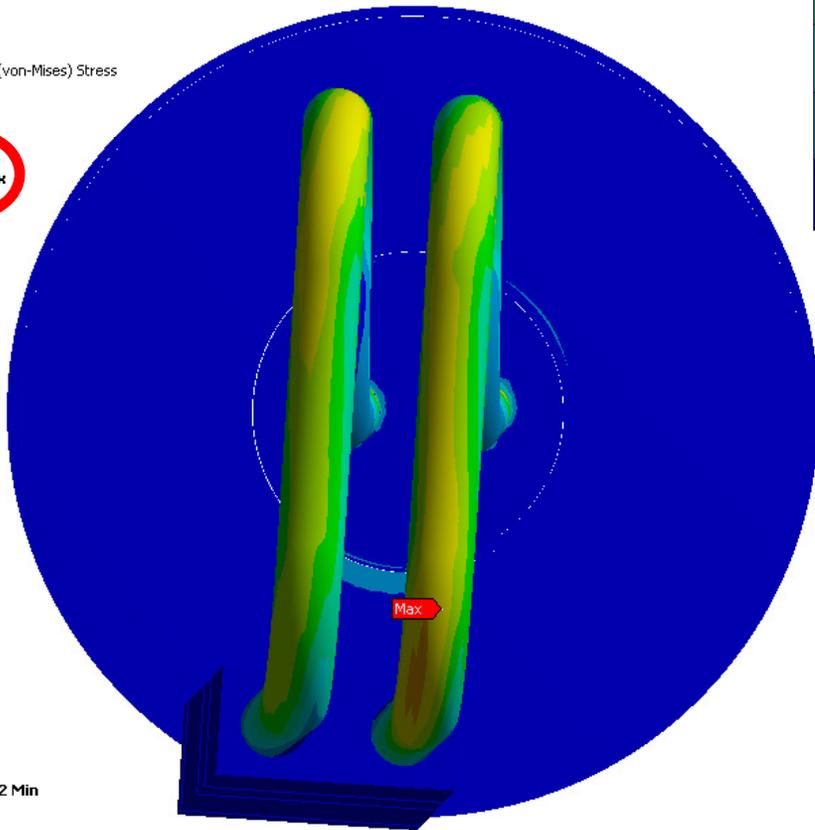
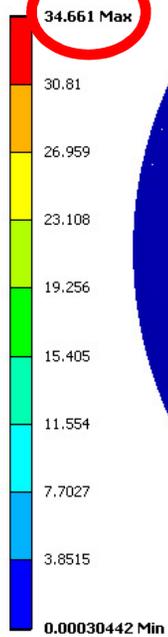
The Ceramic window is made of Kyocera AH100A material.



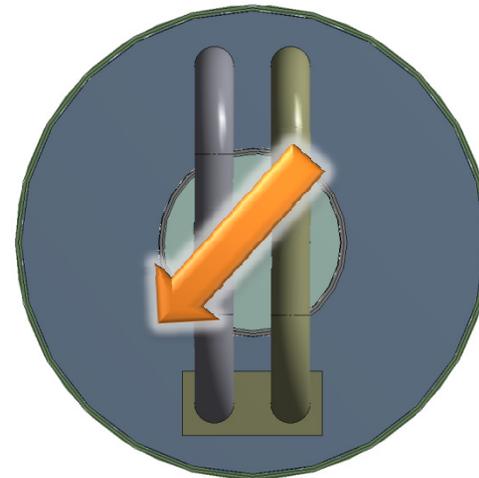
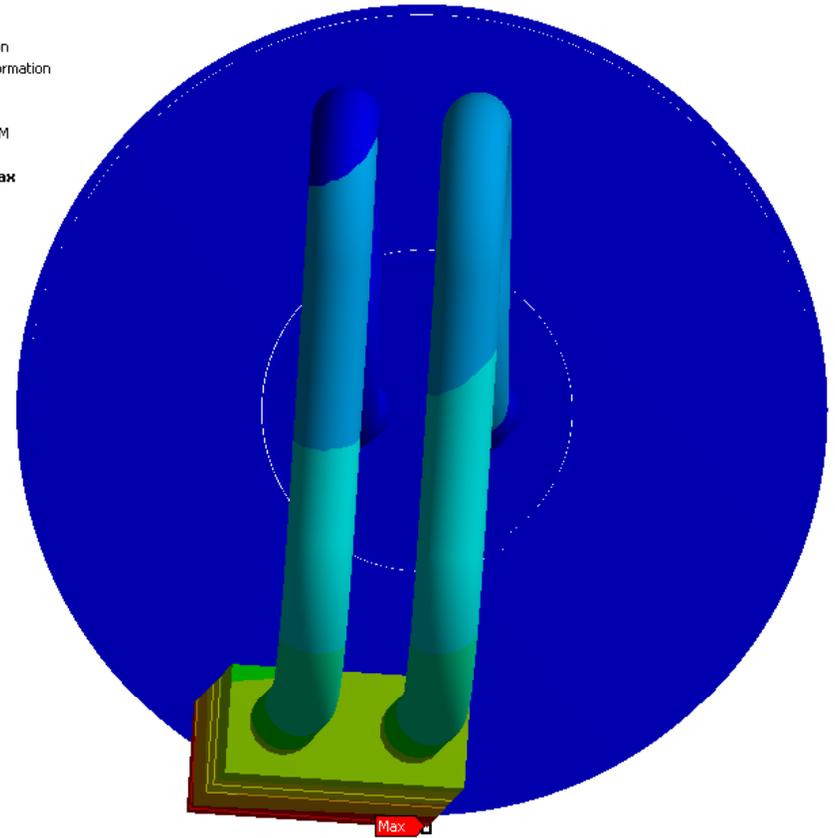
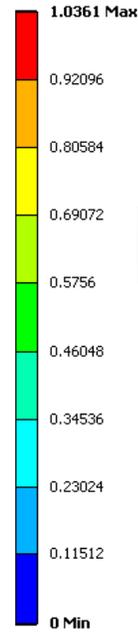
Coupler Transportation

The Ceramic window is made of
Kyocera AH100A material.

D: Multi-G
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 5
5/3/2013 2:45 PM



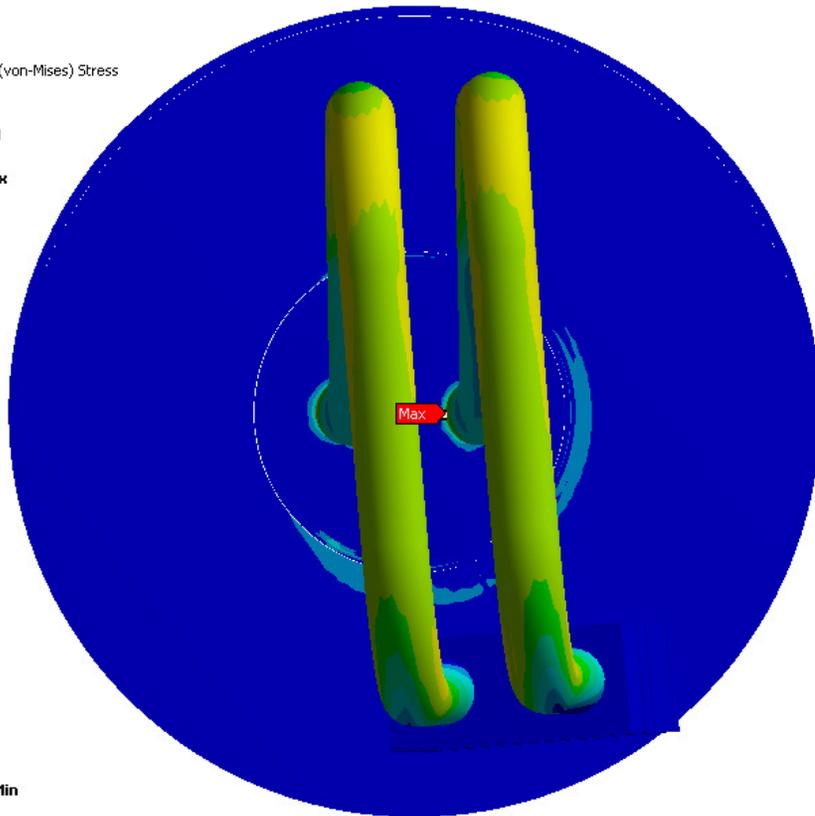
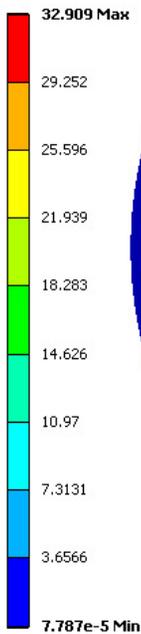
D: Multi-G
Total Deformation
Type: Total Deformation
Unit: mm
Time: 5
5/3/2013 2:45 PM



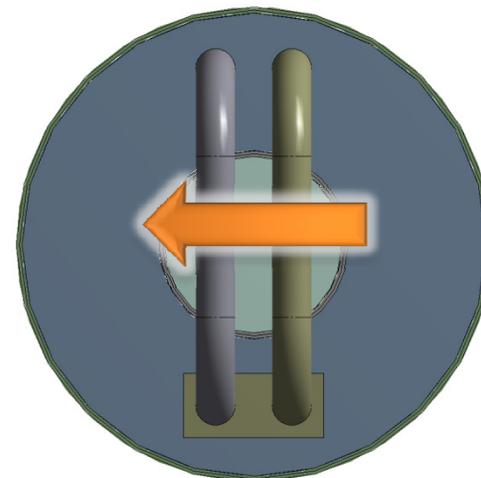
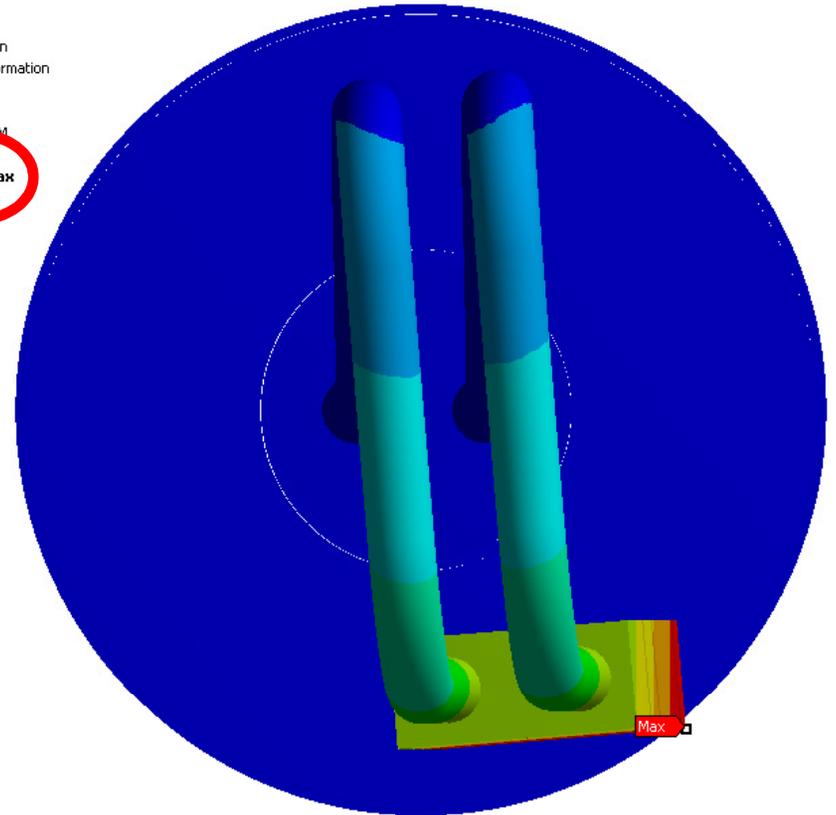
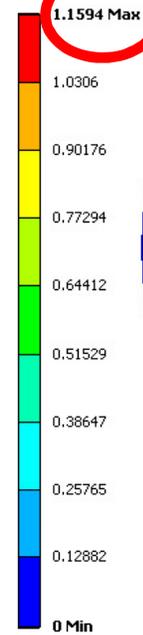
Coupler Transportation

The Ceramic window is made of
Kyocera AH100A material.

D: Multi-G
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 6
5/3/2013 2:41 PM



D: Multi-G
Total Deformation
Type: Total Deformation
Unit: mm
Time: 6
5/3/2013 2:41 PM



10G load



Thank you

Prepared by Valeri Poloubotko

May 21, 2013