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Seismic analysis of the ITER CVD diamond torus window unit

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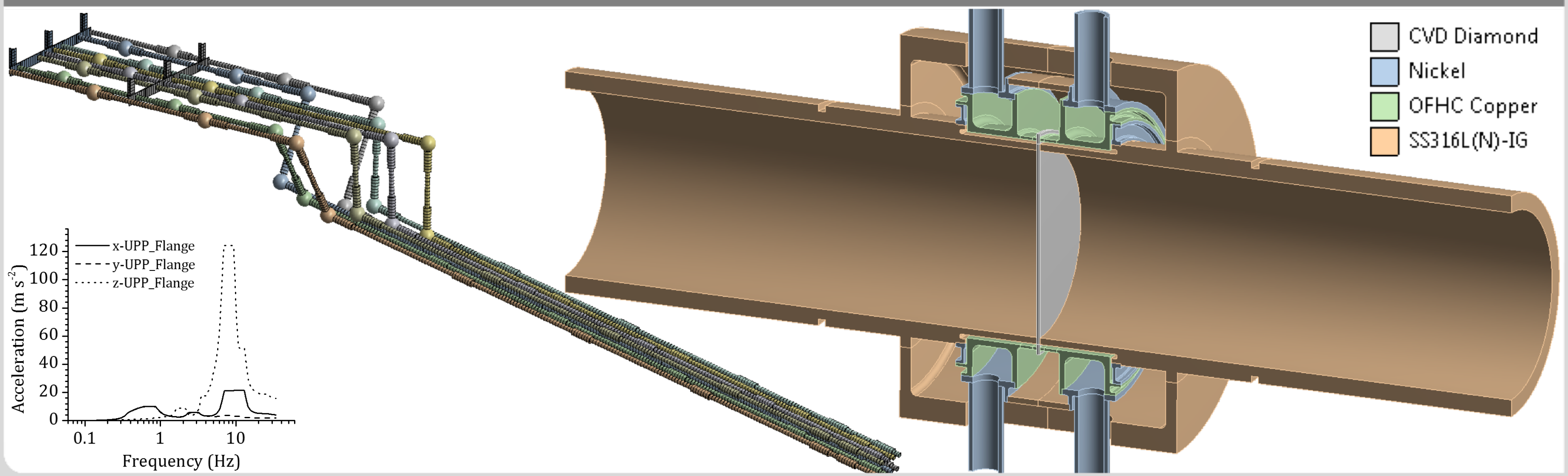
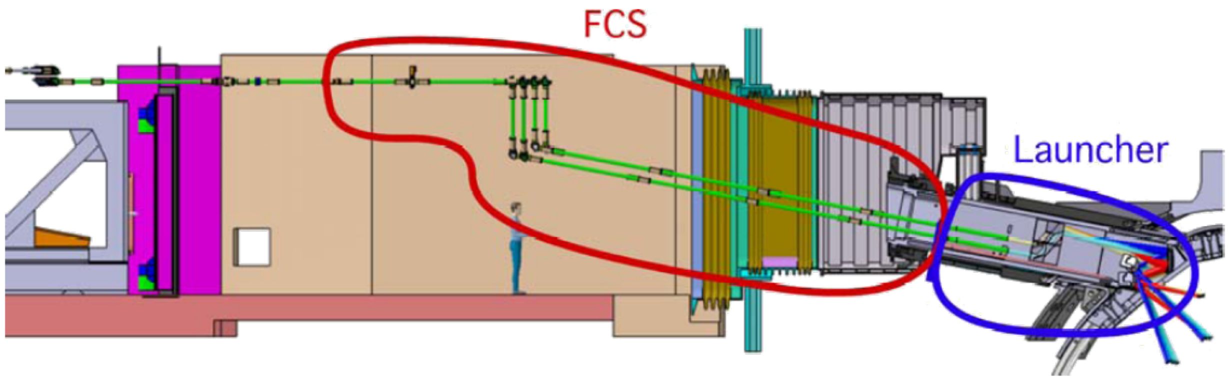


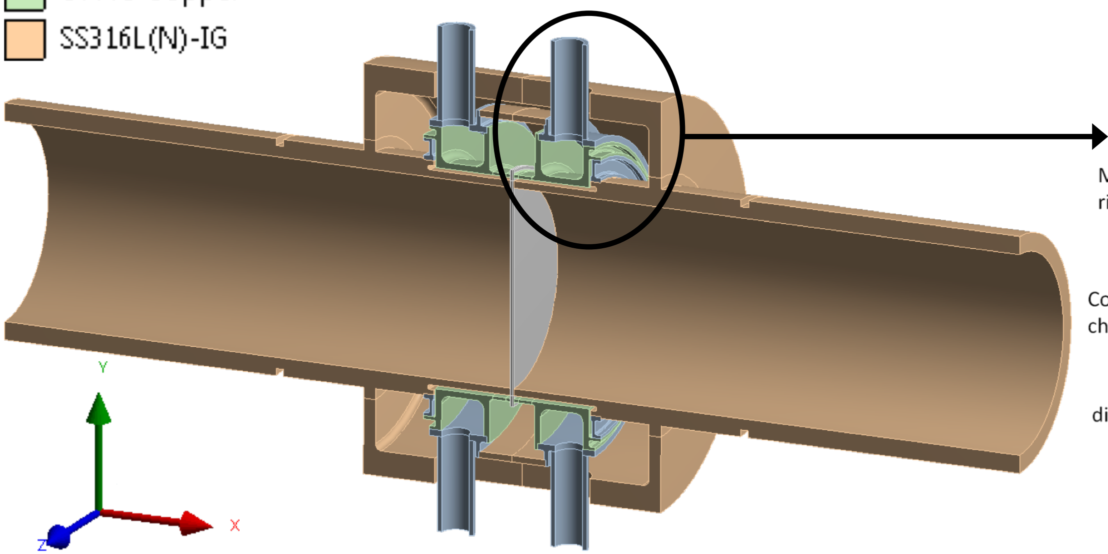
Outline

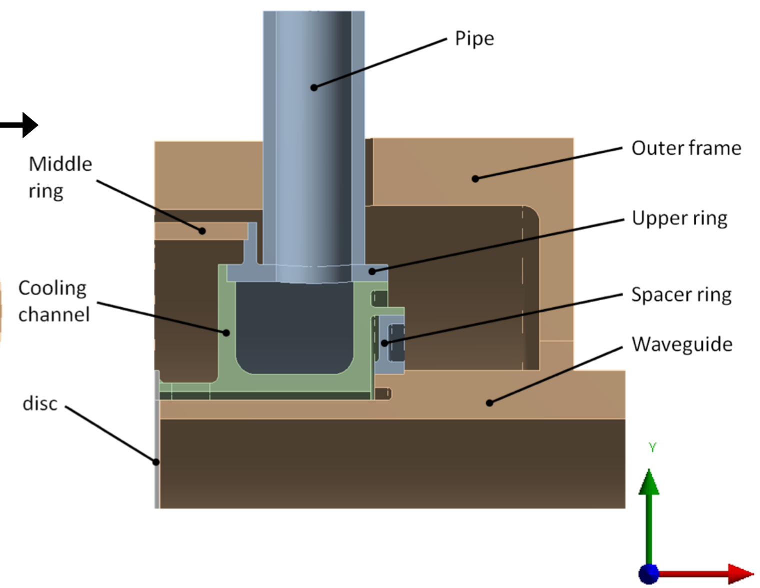
- What does a seismic event mean for the ITER diamond torus window unit?
- How does the seismic analysis of the unit using the beam element approach work?
- Results with reference to the new layout of the ex-vessel WGs (UL #13) and the ITER SL-2 seismic event.
- Impact of the SL-2 event on the unit design.
- Conclusions.

Design of the window unit



CVD Diamond
Nickel
OFHC Copper
SS316L(N)-IG





Meaning of a seismic event

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What does a seismic event mean for the window unit ?

Inertial effect (seismic vibration of the structure)

RS analysis is carried out by applying frequency spectra as input

Kinematic effect (relative displacement between the vessel and the building)

Structural analysis is carried out by applying relative displacement as input

The results (stresses and displacements) of these two different analyses are then summed up.

Beam element approach

RS analysis of the WGs by applying the **spectra** and using the beam elements

Forces and moments →

Structural analysis of the window unit using a detailed FEM model

+

Structural analysis of the WGs by applying the **relative displacement** and using the beam elements

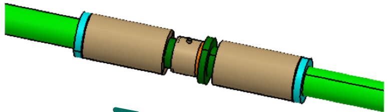
Forces and moments →

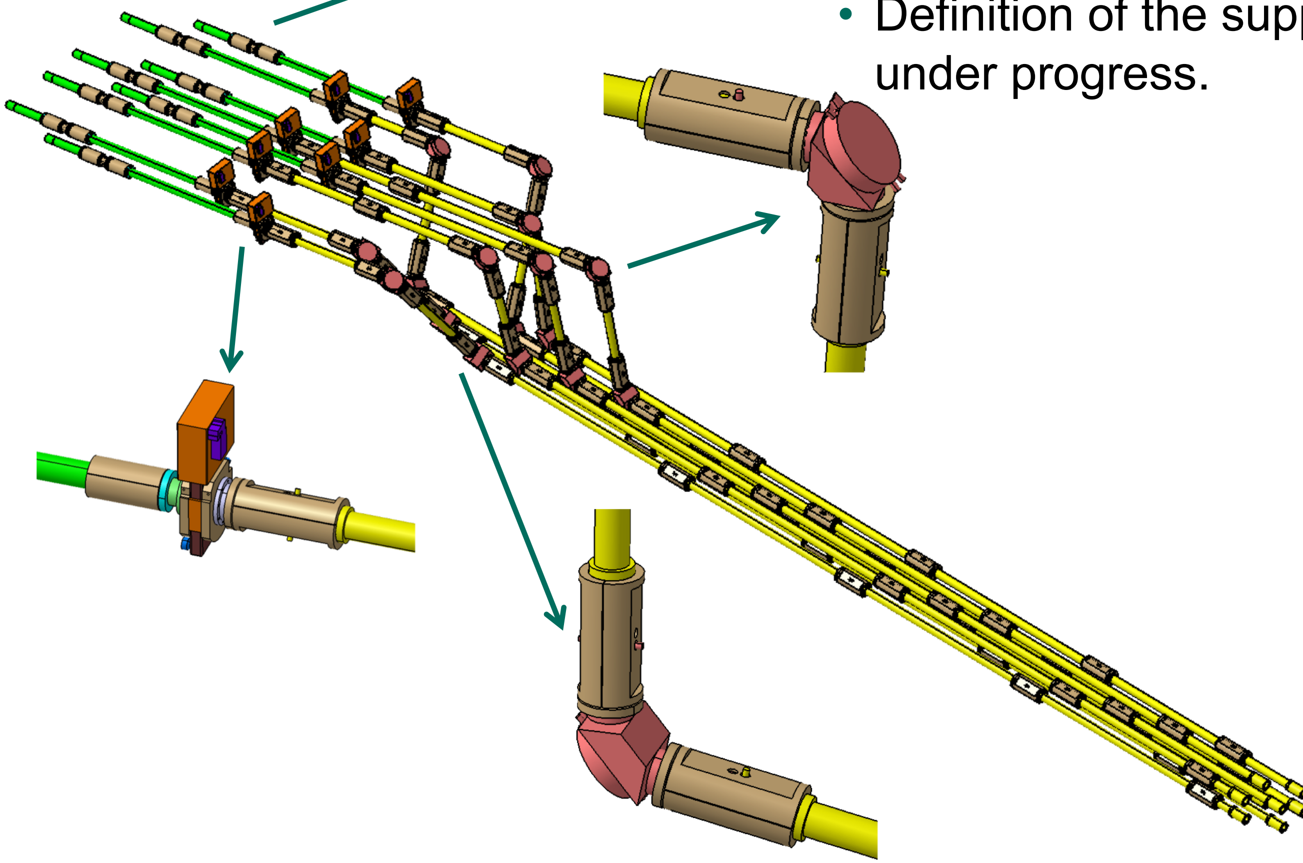
Structural analysis of the window unit using the detailed FEM model

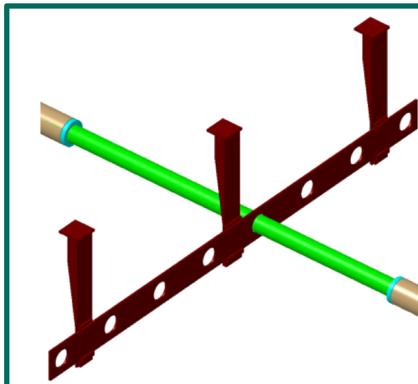
= **Total response in terms of stresses and displacements of the diamond window unit to the seismic event**

CATIA model of the ex-vessel WGs

- New layout of the ex-vessel WGs connected to the UL #13;
- Single and double Helicoflex^{TM} couplings;
- Definition of the supports configuration is under progress.

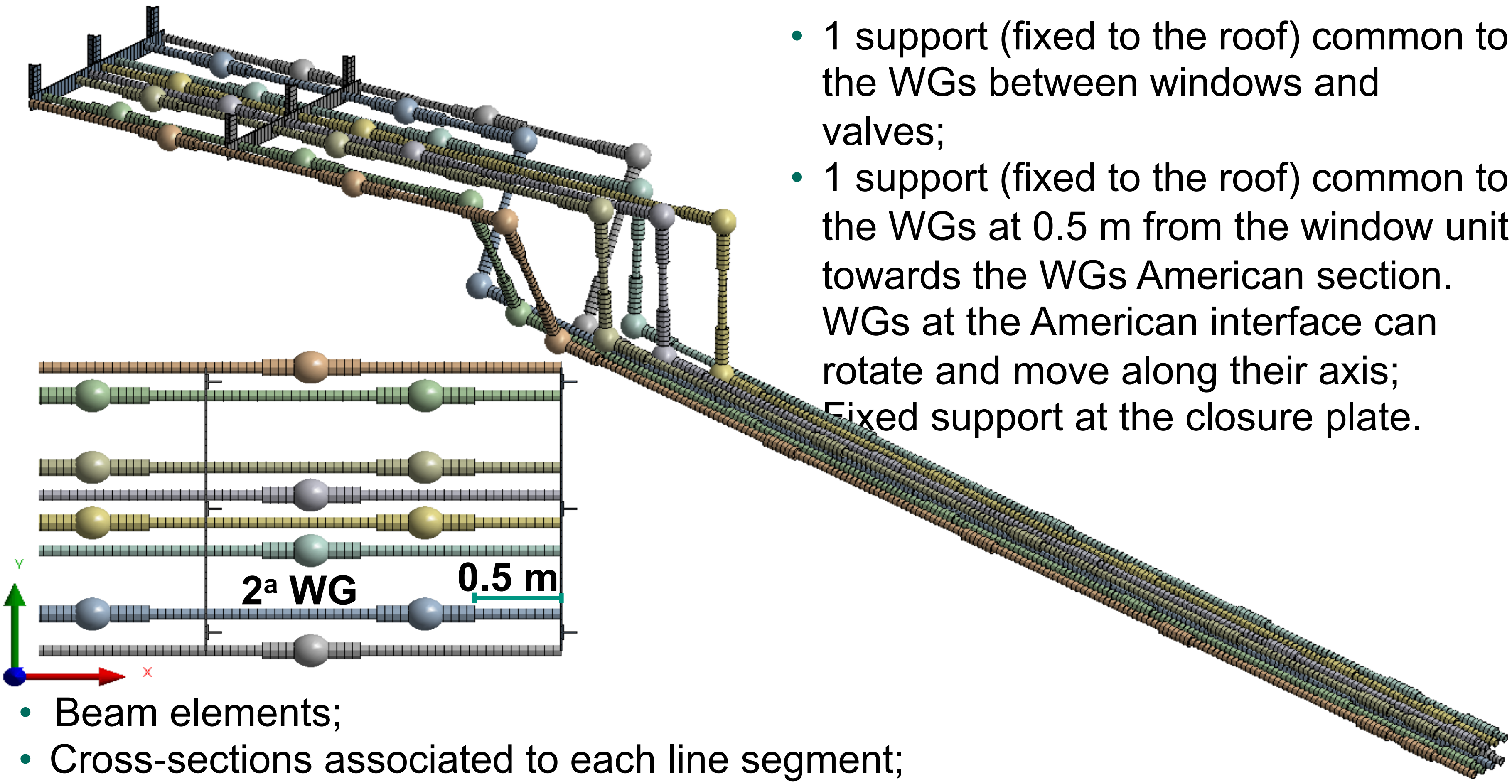




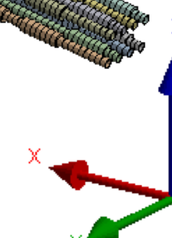


Support structure

Geometry and features

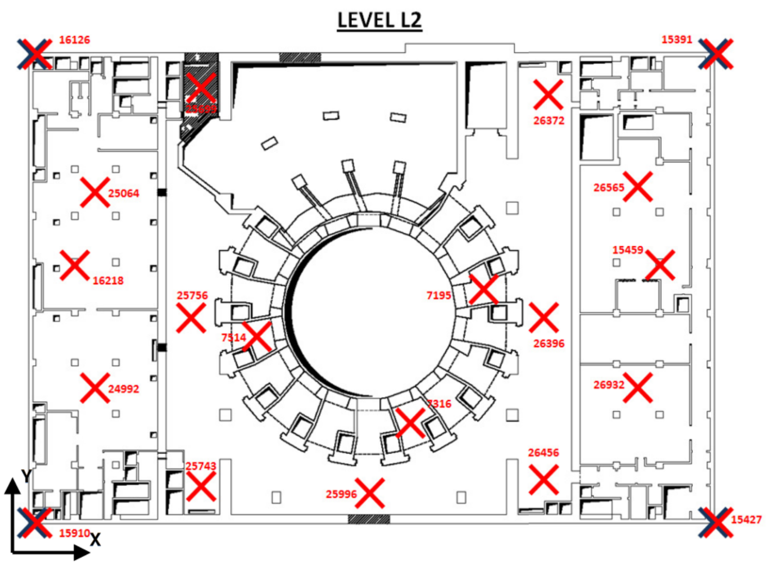


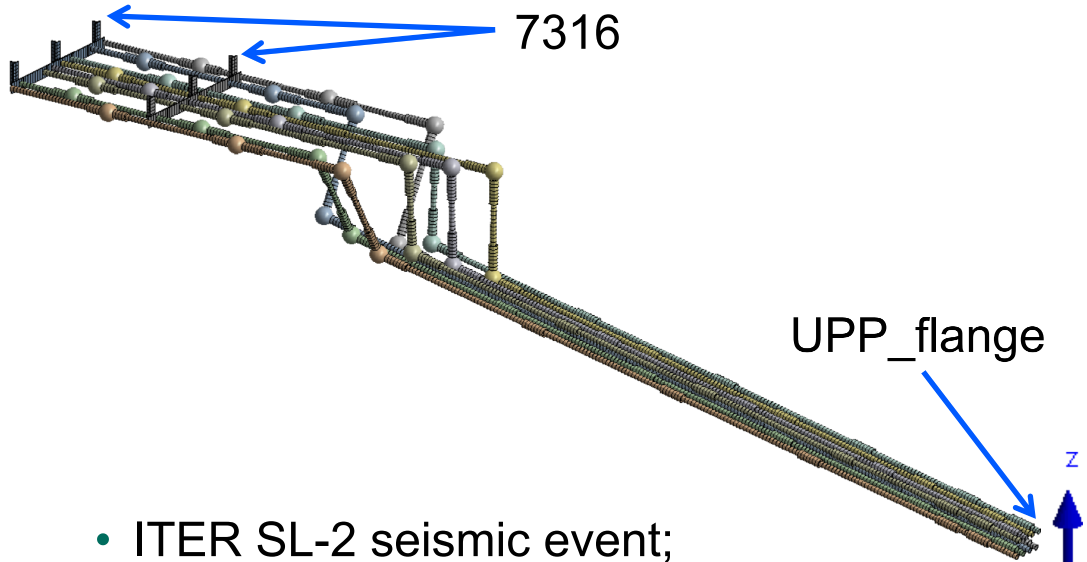
- 1 support (fixed to the roof) common to the WGs between windows and valves;
- 1 support (fixed to the roof) common to the WGs at 0.5 m from the window unit towards the WGs American section. WGs at the American interface can rotate and move along their axis; Fixed support at the closure plate.



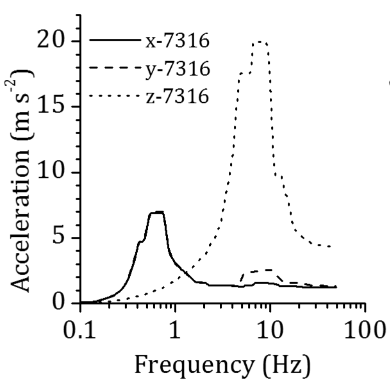
- Beam elements;
- Cross-sections associated to each line segment;
- Point masses take account for the components;
- Support structures: WGs can rotate and move along their axis;
- Aluminium and SS (ANSYS materials library).

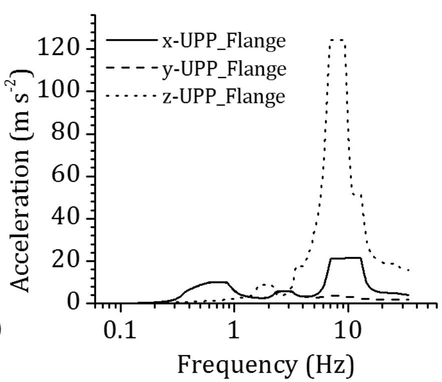
Inertial effect: RS analysis of the WGs



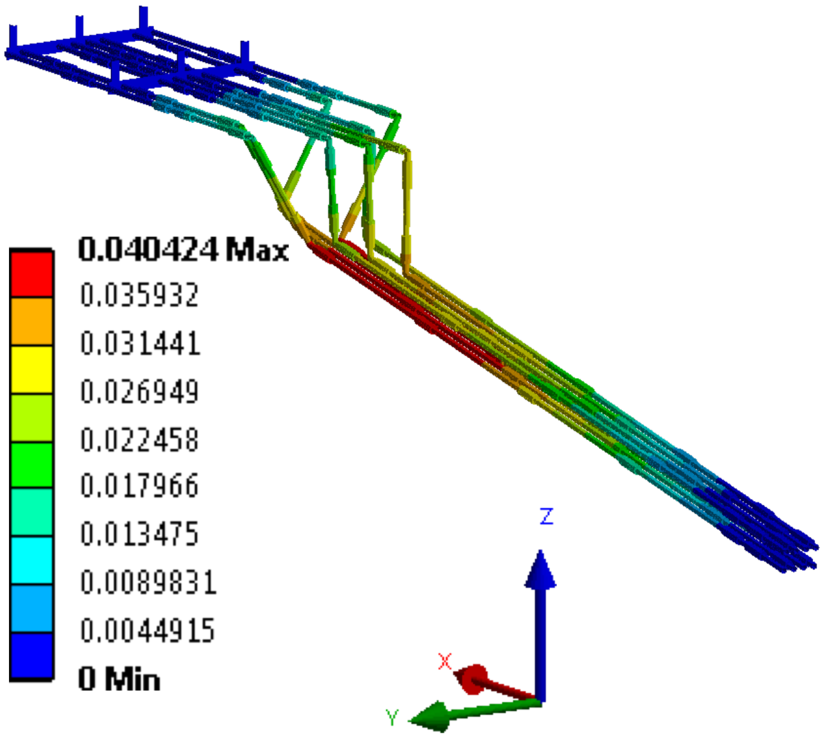


- ITER SL-2 seismic event;
- FRS applied simultaneously to the fixed supports in all directions;
- 147 natural vibration modes calculated in the modal analysis;
- Applied missing-mass correction method using the ZPA values;
- SRSS modes combination type;
- Positive results only.

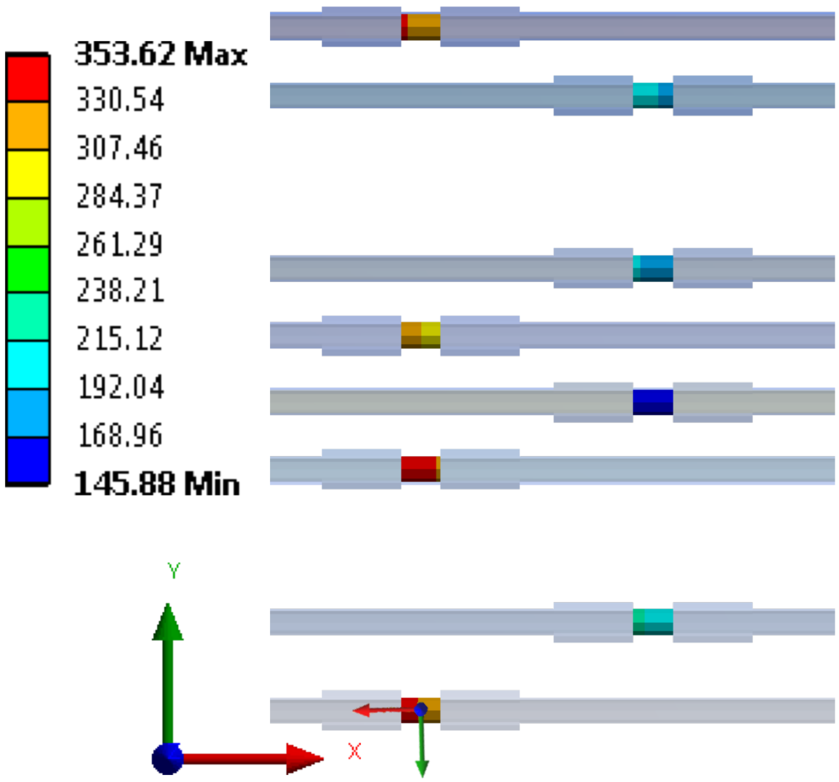




Inertial effect: results of the RS analysis

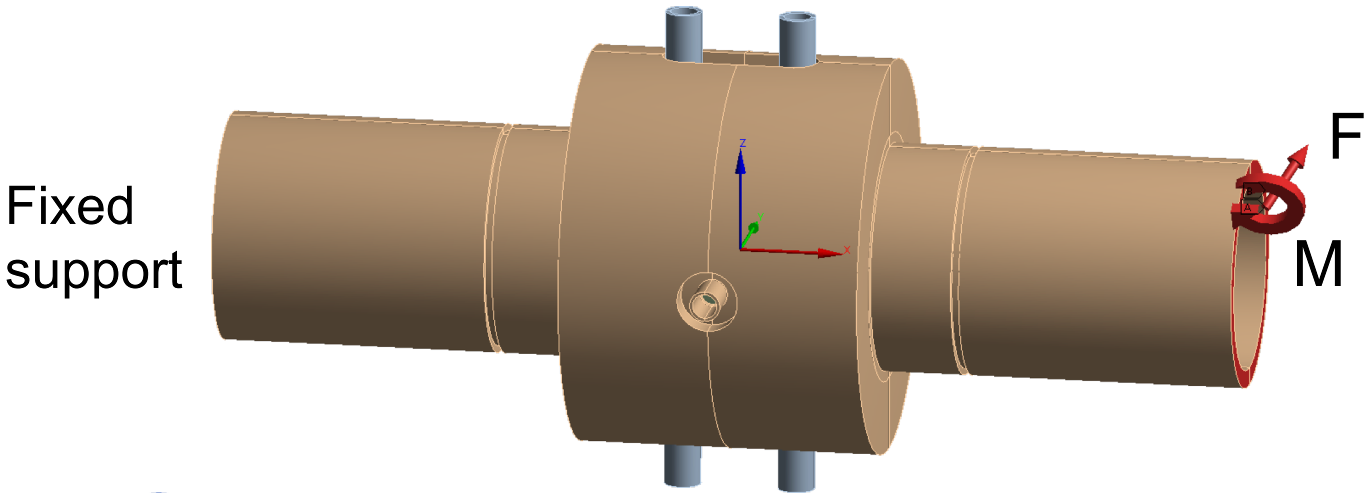


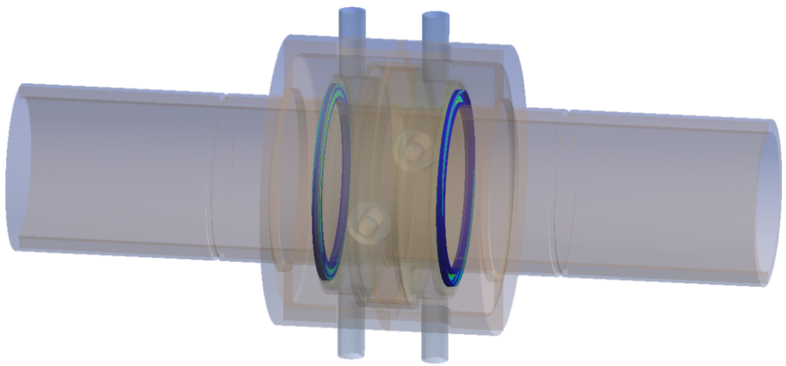
Displacements [m] of the WGs in the toroidal direction.



Horizontal bending [N m] acting on the window units.

Inertial effect: structural analysis of the unit

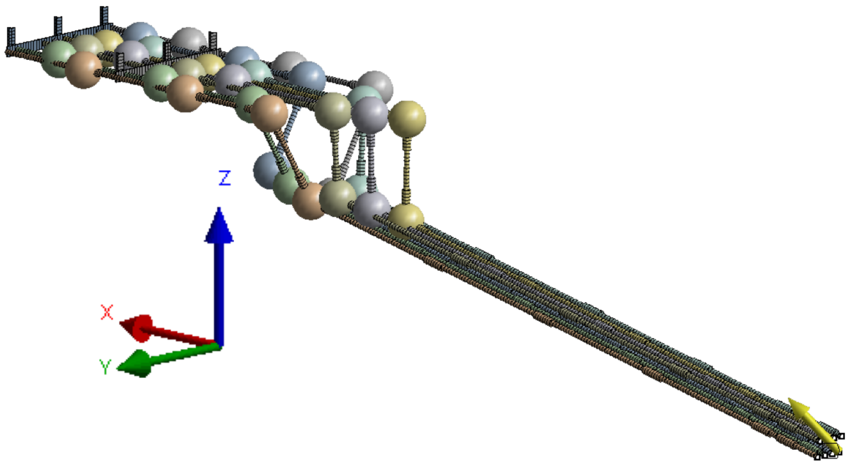




The maximum equivalent stress is in the nickel spacer rings and it amounts to **385** MPa.

Load	Type of load	Maxima values
F_x [N]	Axial force	171
F_y [N]	Horizontal shear	228
F_z [N]	Vertical shear	263
M_x [N m]	Axial torque	0.292
M_y [N m]	Horizontal bending	354
M_z [N m]	Vertical bending	224

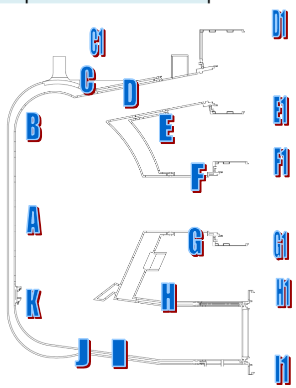
Kinematic effect: structural analysis of the WGs



- 1 support (fixed to the roof) common to the WGs between windows and valves;
- 1 support (fixed to the roof) common to the WGs at 0.5 m from the window unit towards the WGs American section. WGs at the American interface can rotate and move along their axis;
- Imposed displacement (VV_D point used) at the closure plate.

Max loads on windows	WGs RS analysis (FRS)	WGs structural analysis (rel. displ.)
F_x [N]	171	0.000116
F_y [N]	228	0.828919
F_z [N]	263	-2.485697
M_x [N m]	0.292	0
M_y [N m]	354	-1.901505
M_z [N m]	224	0.903168

	VV relative displacement to Bioshield		
	Urad max [mm]	Utor max [mm]	Uvert max [mm]
VV_D	4.77	4.72	7.25

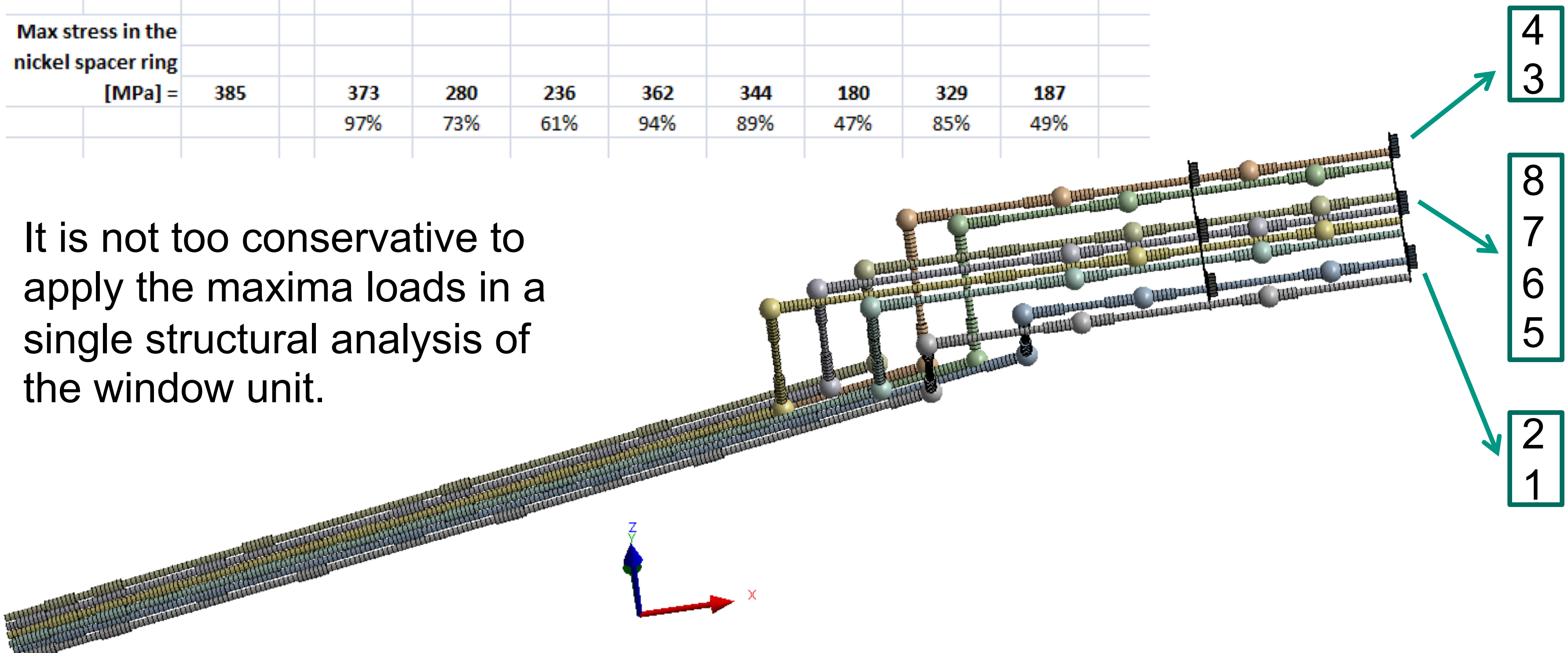


Seismic loads on all the windows

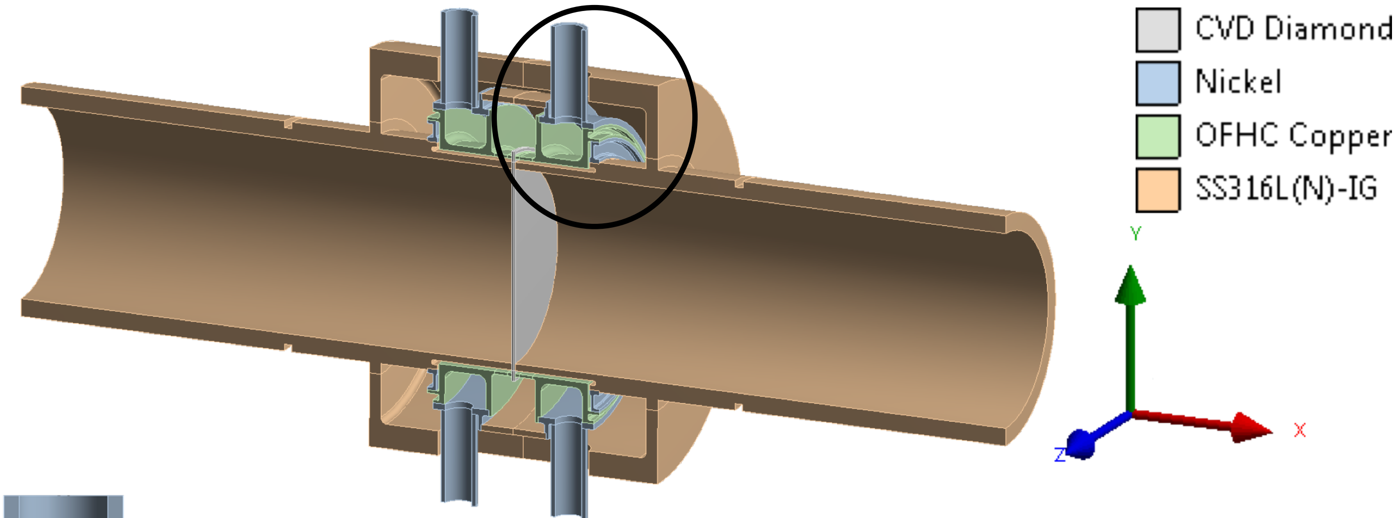
	Max loads	Unit in WG1	Unit in WG2	Unit in WG3	Unit in WG4	Unit in WG5	Unit in WG6	Unit in WG7	Unit in WG8
Fx [N]	171.11	86.97	171.11	82.87	86.35	110.03	94.00	102.80	94.56
Fy [N]	228.00	151.88	228.00	173.55	142.44	99.34	121.13	113.27	96.20
Fz [N]	263.34	226.32	263.34	247.39	224.20	232.25	194.83	208.48	231.33
Mx [N m]	0.2915	0.1899	0.2915	0.2301	0.2271	0.0680	0.0469	0.0525	0.0751
My [N m]	353.62	341.26	223.68	209.48	334.84	353.62	167.17	318.86	196.62
Mz [N m]	224.20	224.20	193.99	147.22	213.07	147.16	102.22	169.54	81.27
Max stress in the nickel spacer ring [MPa] =	385	373	280	236	362	344	180	329	187
		97%	73%	61%	94%	89%	47%	85%	49%

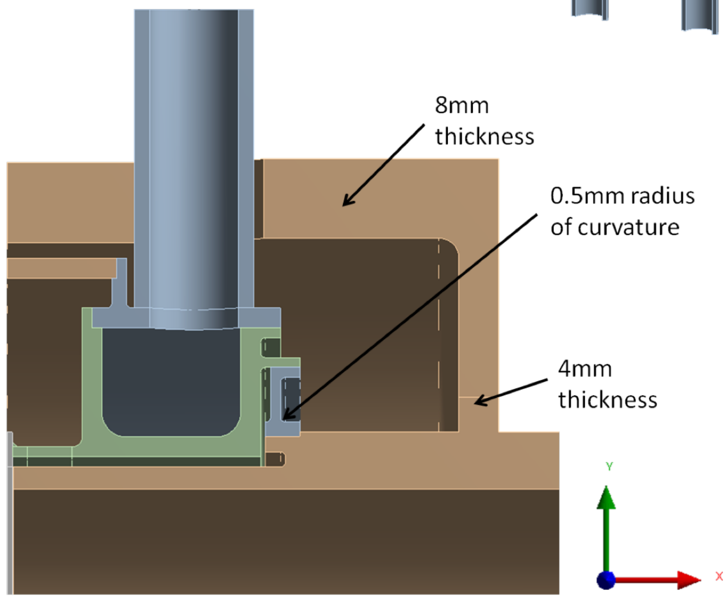
For each load type:
red= the highest value
green= the lowest value

It is not too conservative to apply the maxima loads in a single structural analysis of the window unit.



How to manage the high equivalent stress generated in the current design?

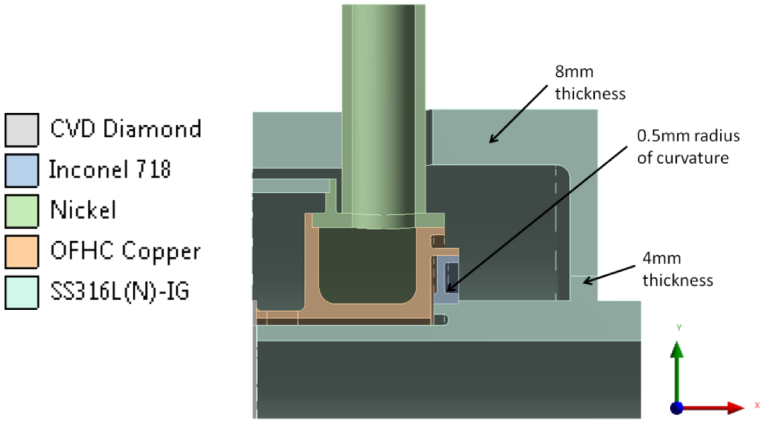




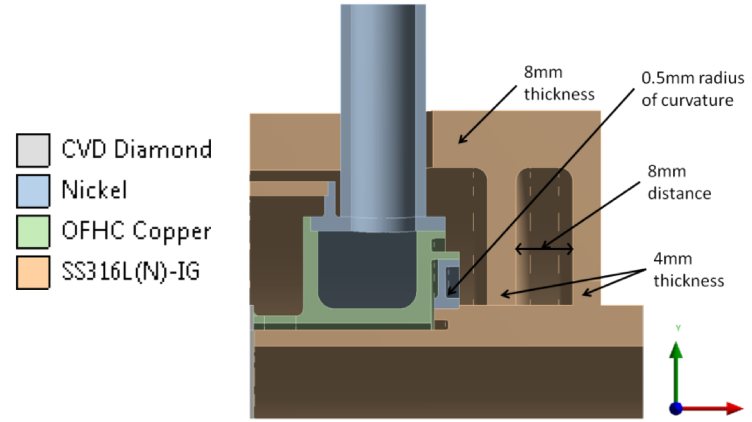
Possible solutions:

- Inconel 718 instead of nickel in the spacer ring;
- Stiffer outer frame and different radius of curvature in the spacer ring.

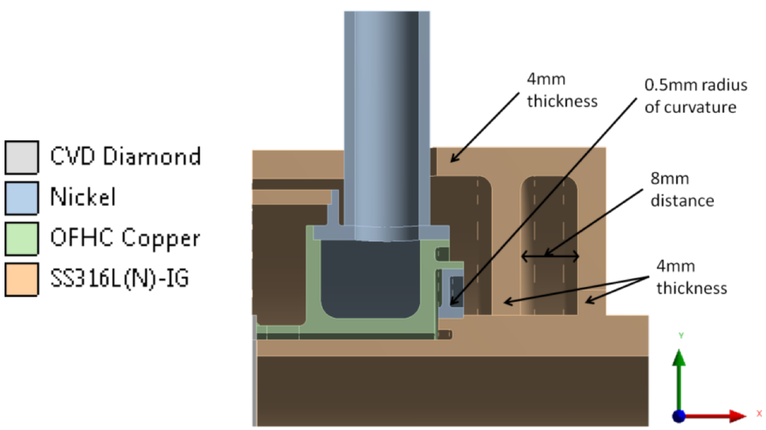
Investigated design options



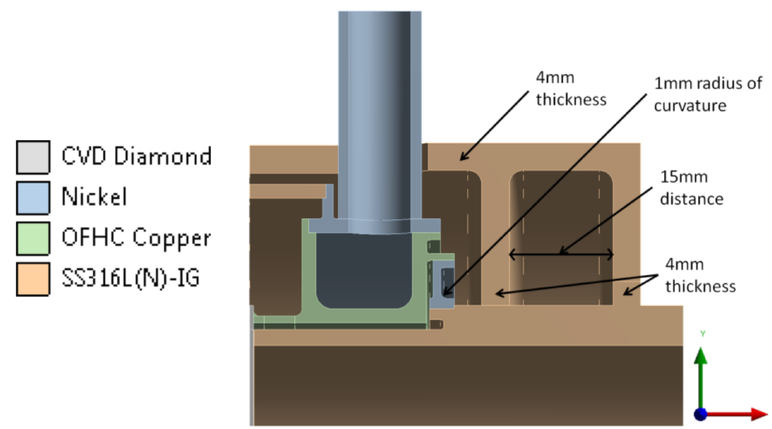
Max equiv. stress = 385 MPa



Max equiv. stress = 168 MPa

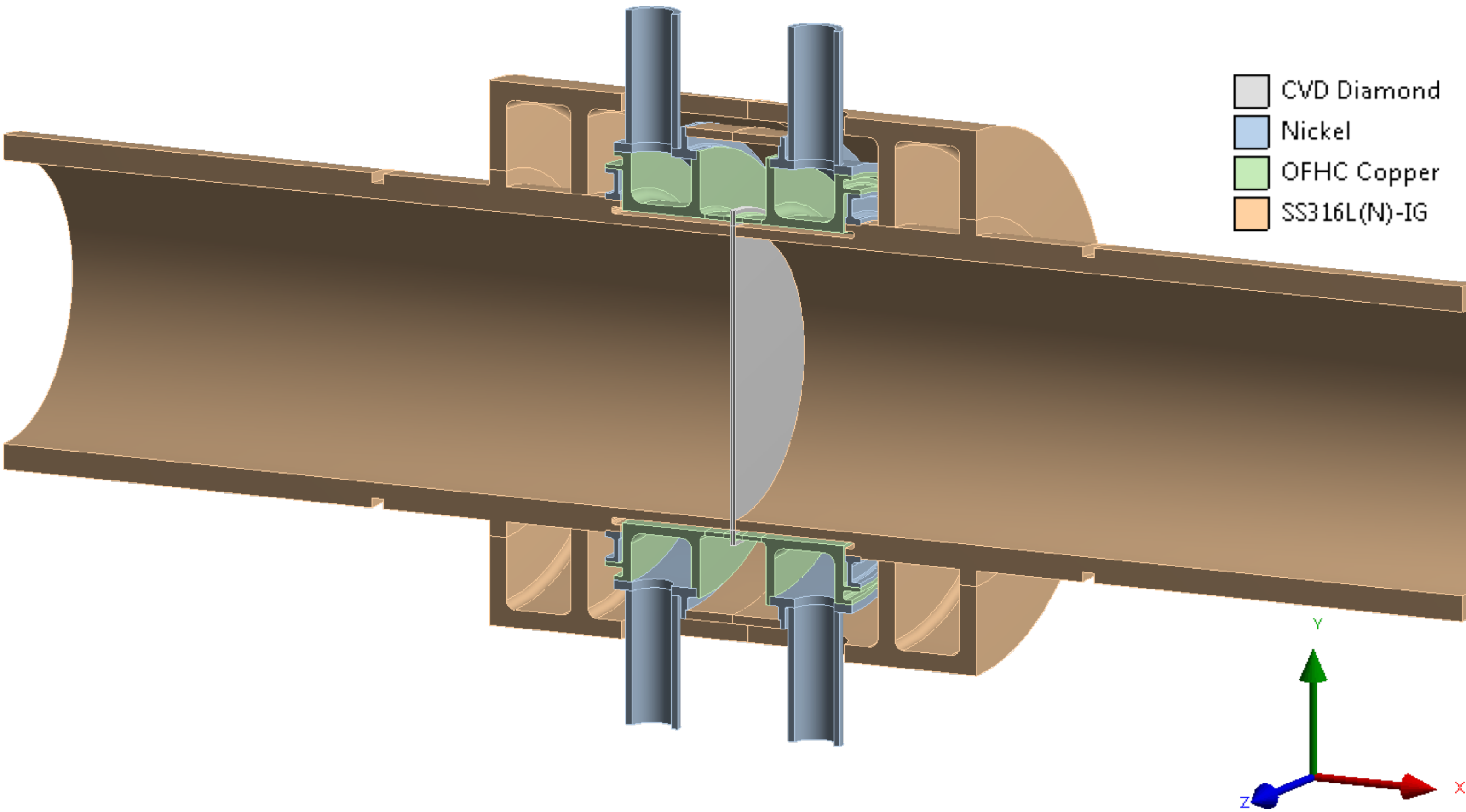


Max equiv. stress = 179 MPa



Max equiv. stress = 156 MPa

Proposed new design of the window unit



Conclusions and outlook

- The ITER torus window unit has the most stringent ITER safety and vacuum classifications. A seismic analysis of the unit is thus required.
- The seismic analysis was carried out with the beam element approach. The severe ITER SL-2 seismic event was considered and a preliminary supports configuration of the 8 ex-vessel WGs (connected to the UL#13) was assumed.
- The seismic analysis led to a different design of the unit. The maximum equivalent stress in the nickel spacer rings can be decreased to 156 MPa with a stiffer outer frame surrounding the unit.
- Next step is to investigate the behaviour of the window unit by applying cyclic seismic loads.