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Engineering aspects and technical systems of CLIC RF structures

G. Riddone
(*contribution from eng, design and fabrication team, and several collaborators*)

See also WG4- poster session

OUTLINE
° Engineering design
° Machining
° Alignment and bonding
° Assembly of CLIC RF structures
° Technical systems

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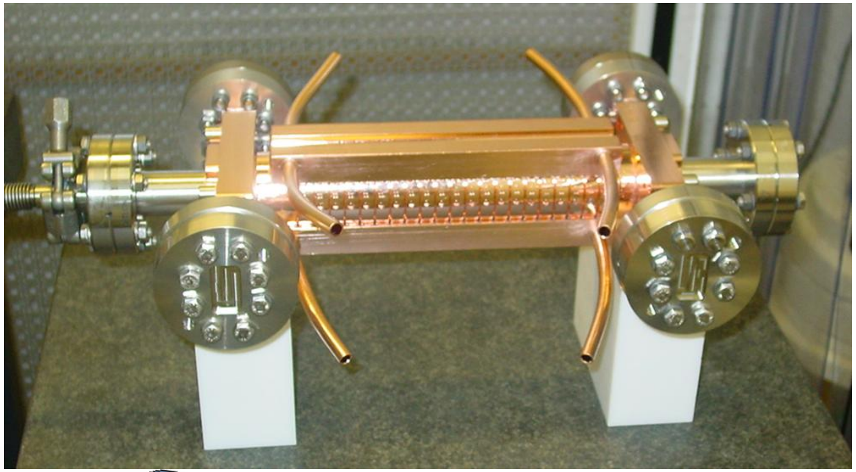
I will focus on the general eng. issues for ac. structures, and I will give some examples to show what has to be implemented for final CLIC accelerating structures

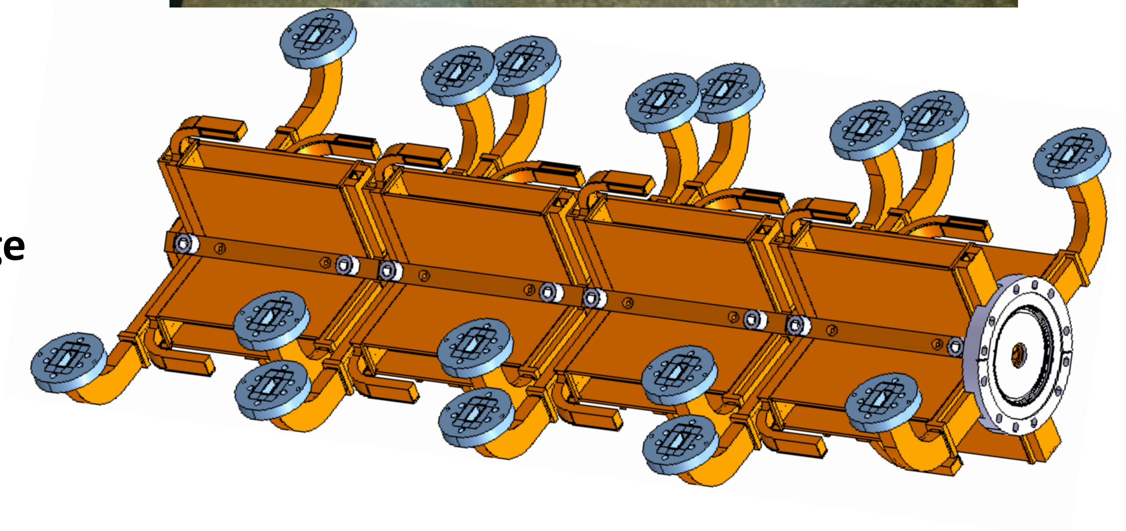
Test structures

Disks
Couplers
Cooling circuits



CLIC accelerating structures

Disks
Couplers
Cooling circuits **[~400 W average per structure]**
Vacuum manifolds (**10^{-9} mbar**)
Damping material
Superstructures (**2 to 4**)



ENGINEERING DESIGN

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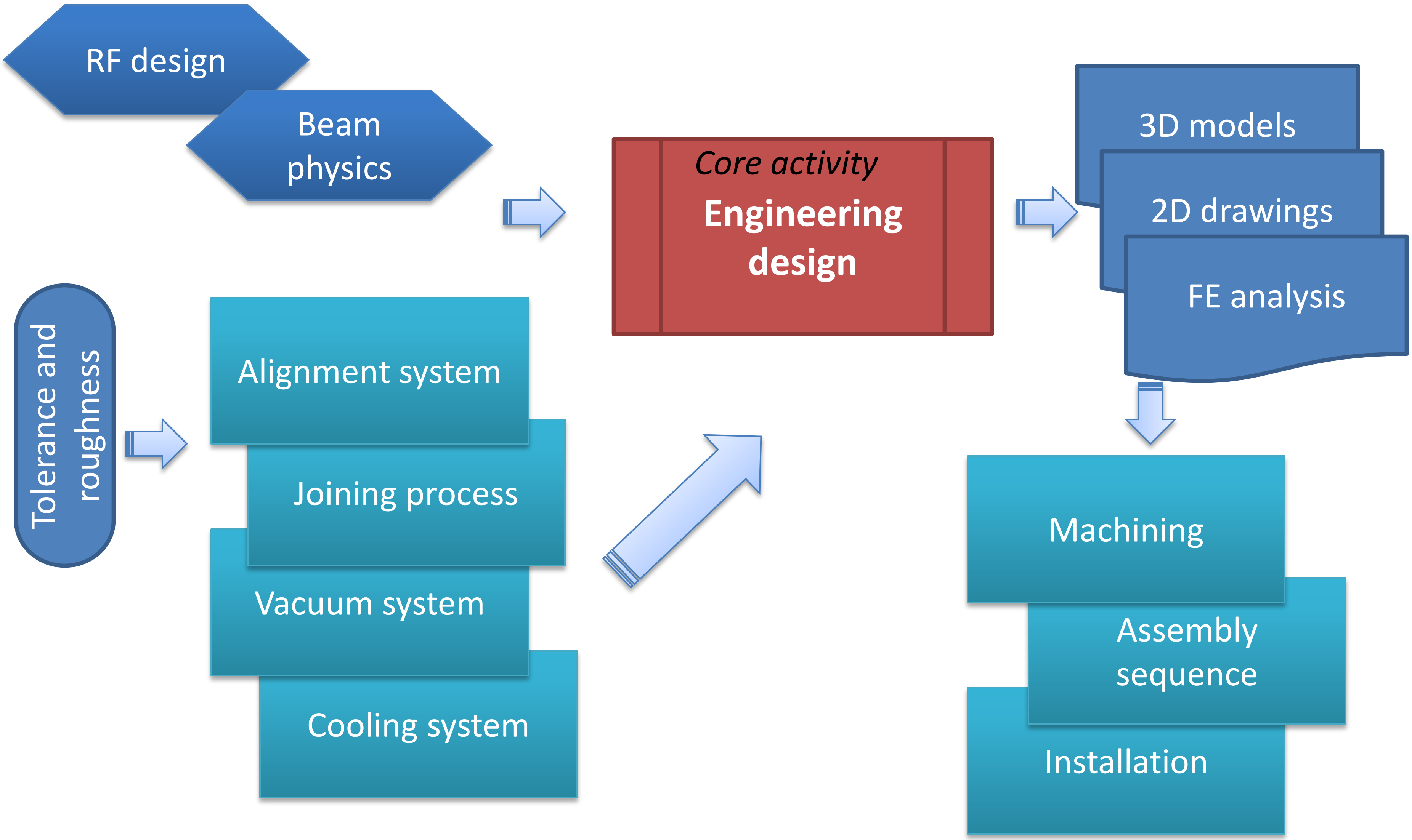
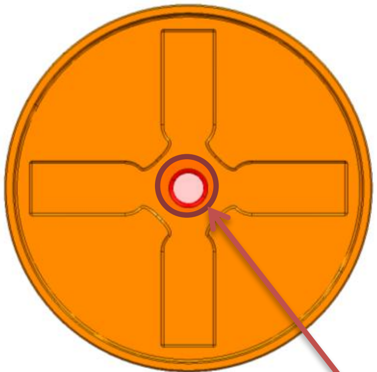
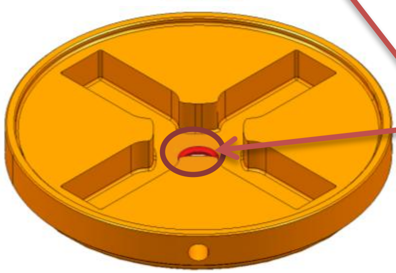


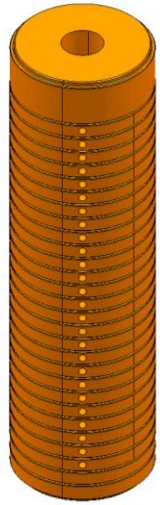
ENGINEERING DESIGN ISSUES (WAVEGUIDE DAMPED AS)

PREPARED BY A. SOLODKO

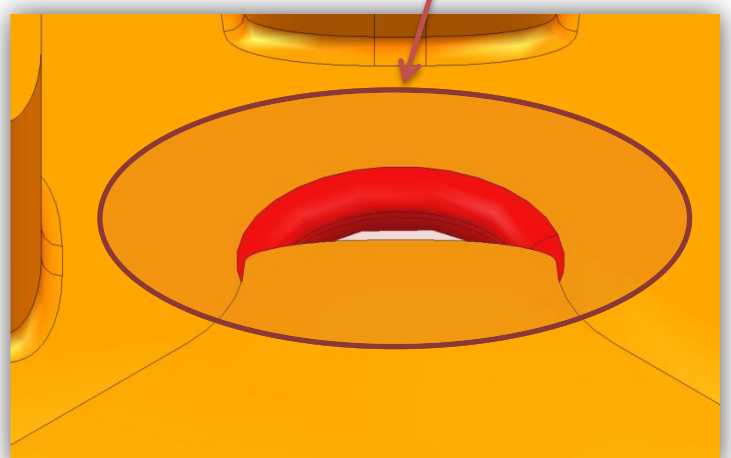
12WDSDVG1.8_R05

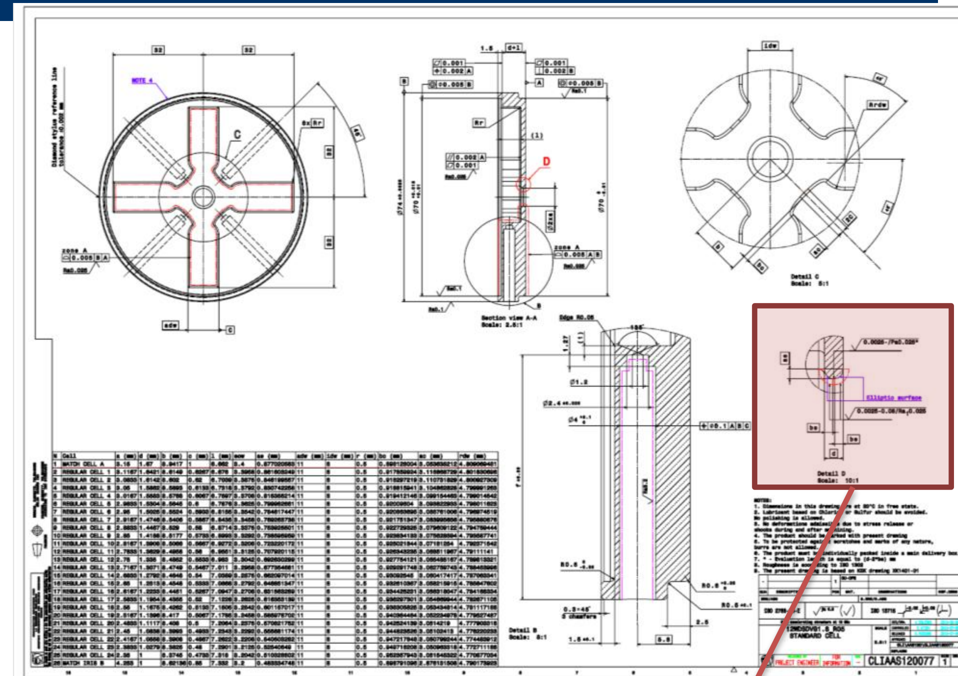






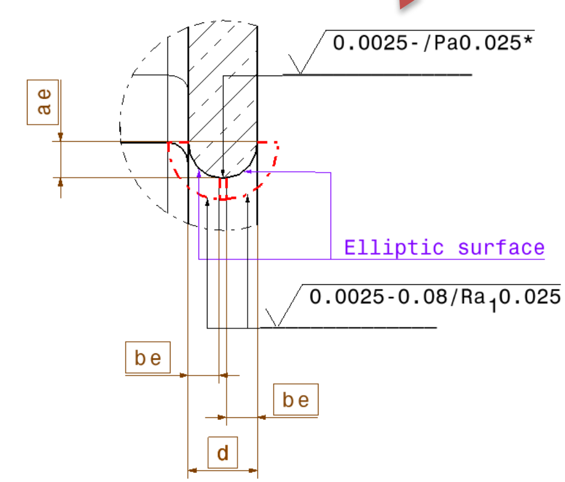
Iris





Geometrical tolerance of this zone

⌓	0.005	A	B
//	0.002	A	
▱	0.001		



* - Evaluation length is equal to (d-2*be) mm
Roughness is according to ISO 1302

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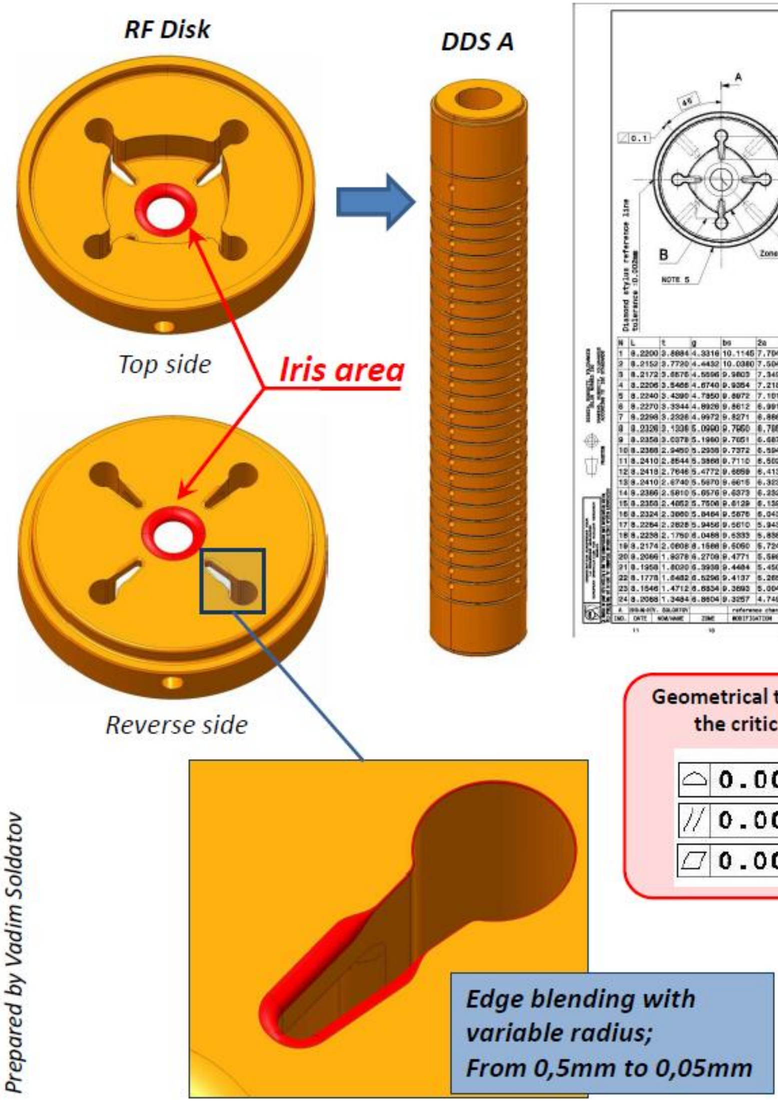
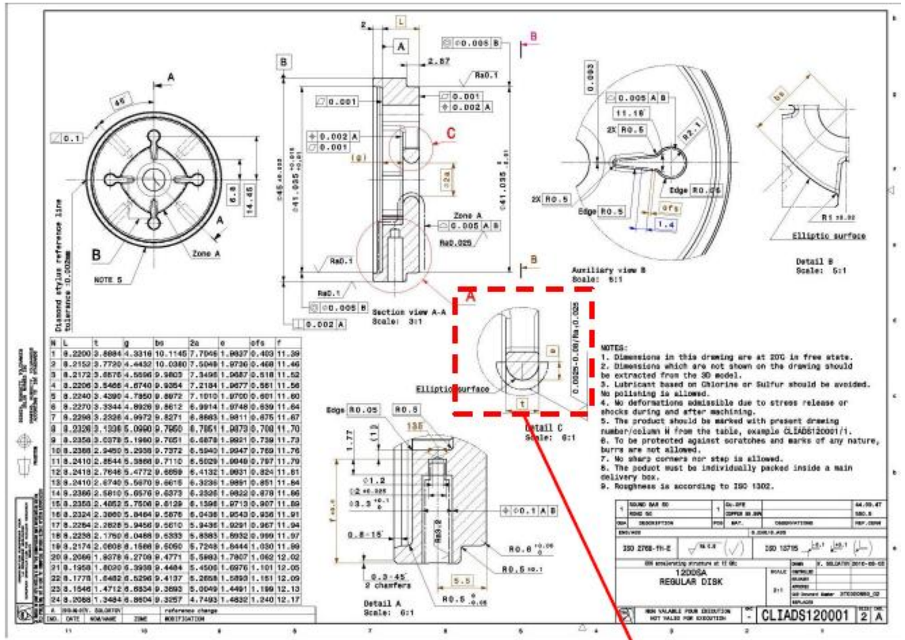
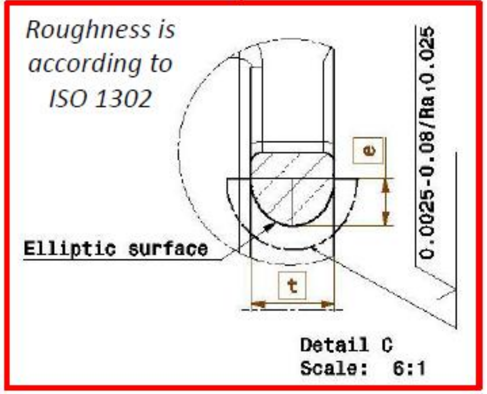




Geometrical tolerances of the critical zones

⌓	0.005	A	B
//	0.002	A	
⏥	0.001		



Prepared by Vadim Soldatov

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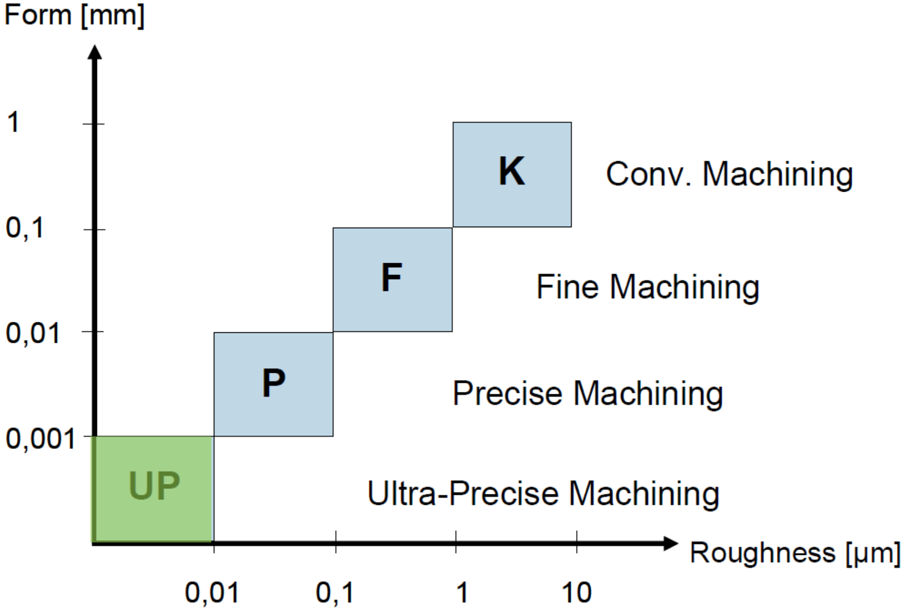
WHY WE NEED ULTRA-PRECISION MACHINING

Accelerating structures
- Milling and turning

PETS
- Milling



Diamond tool is required (about 7 tools per disks)

- Dimensional stability

-Maintenance of tolerances

- Less stresses

- Chips do not adhere to surface

- Expensive → well characterised

CLIC's needs:
shape accuracy ± 2.5 µm
roughness Ra 25 nm

At this level of tolerances: material stress-relief annealing is mandatory → Soft material →
- Special care clamping without damage
- Special requirements on 3D metrology (tactile): no indents!!

S. ATIEH

TYPICAL PROCEDURE OF UHP DISK MACHINING

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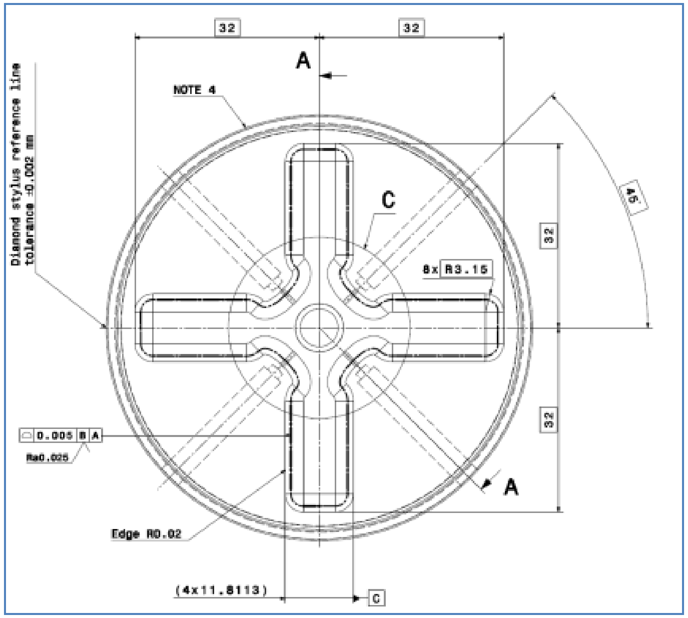
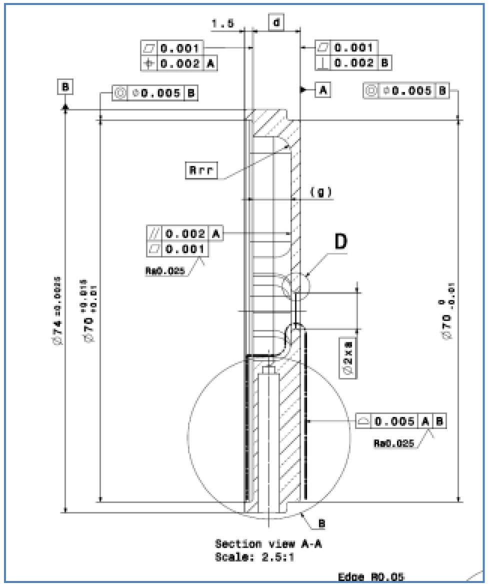
Pre-Fabrication:

Pre-turning + x100 µm
Pre-milling + x100 µm
Tuning holes
Stress relief ~180 °C (optional)
Finish turning + x10µm
Finish milling + x10µm
Stress relief ~245 °C



UHP-Machining:

Mounting of vacuum clamping adapter
UHP-turning of the support (diamond tools)
Alignment
UHP-turning ref. plan A
Alignment
UHP-turning opposite side
Wave guide UHP milling
Iris final turning (requested up to the nose)



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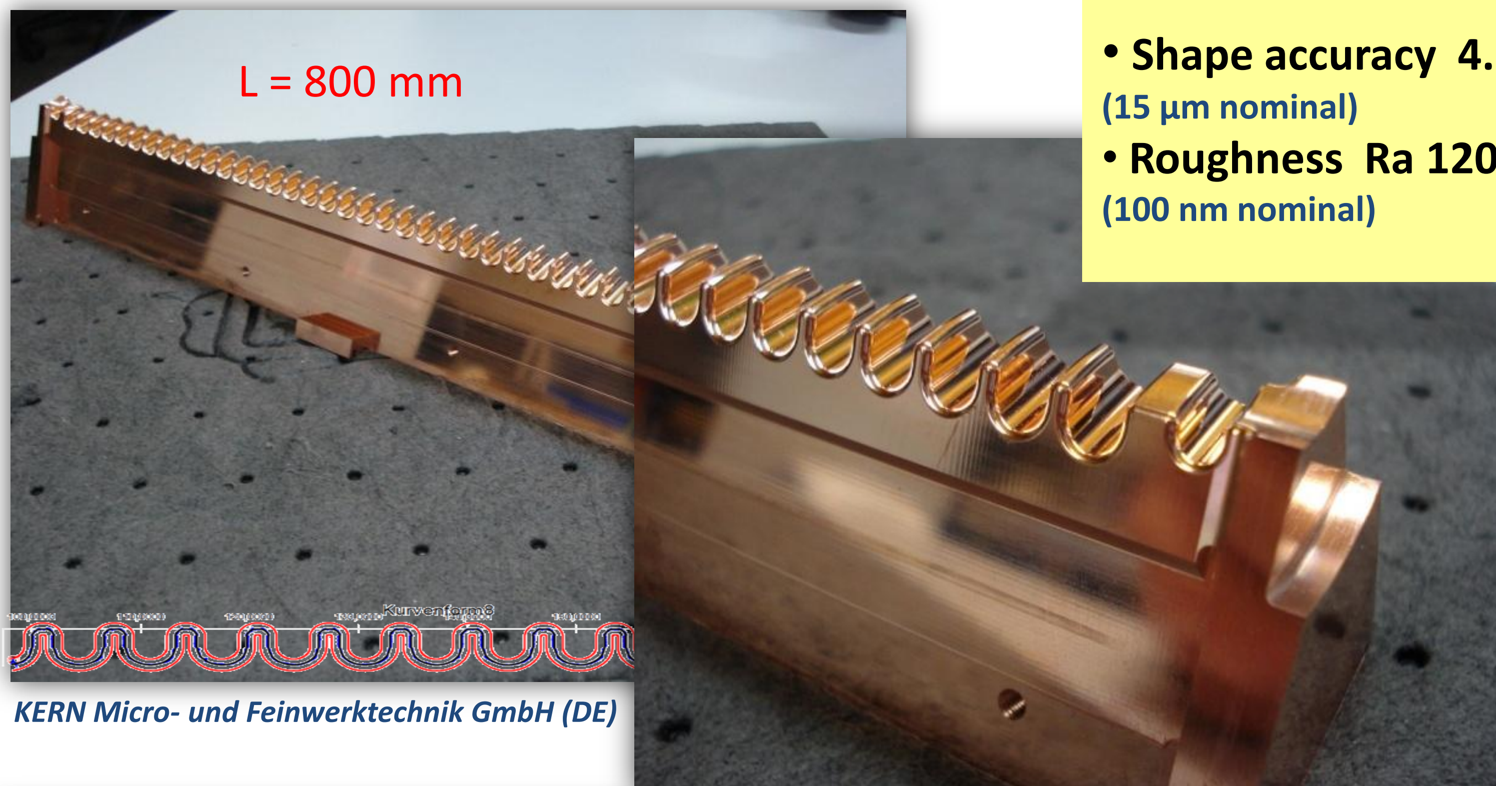
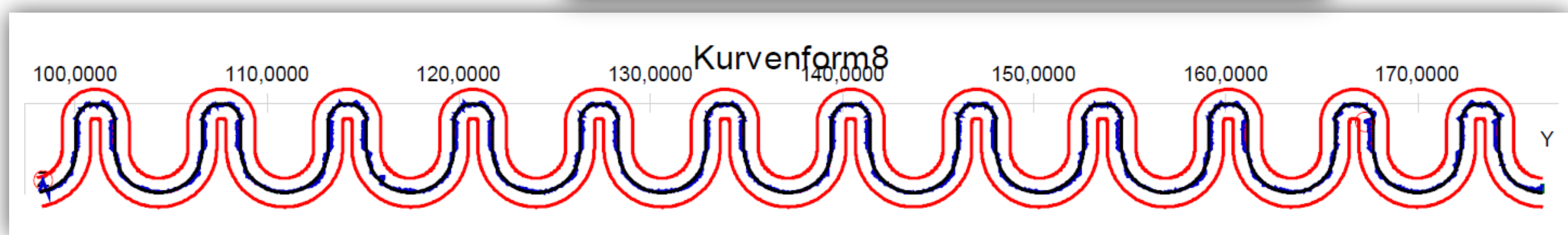


KERN Micro- und Feinwerktechnik GmbH (DE)

- **Shape accuracy 4.8 µm**
  (15 µm nominal)
- **Roughness Ra 120 -180 nm**
  (100 nm nominal)



DETUNED DAMPED DISK FROM VDL (TD24)

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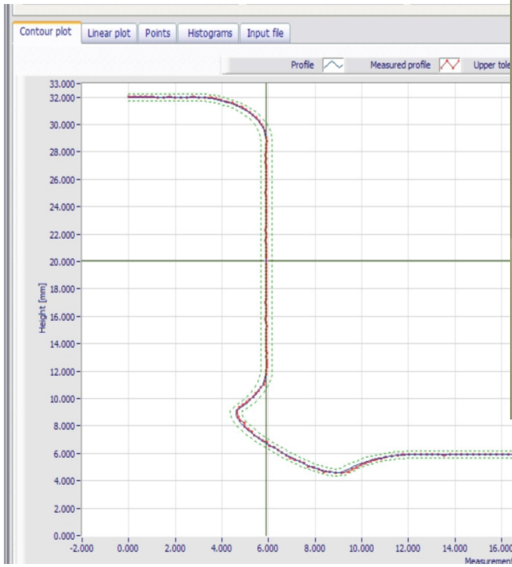
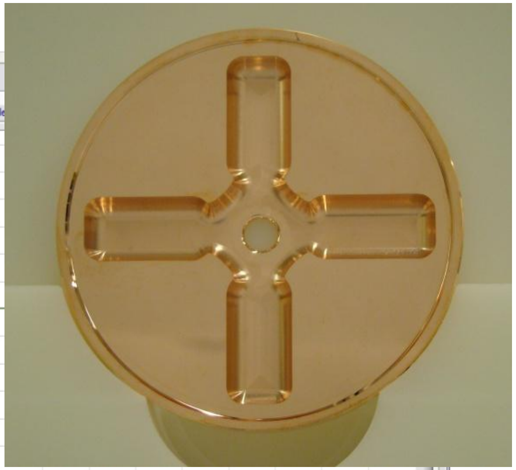
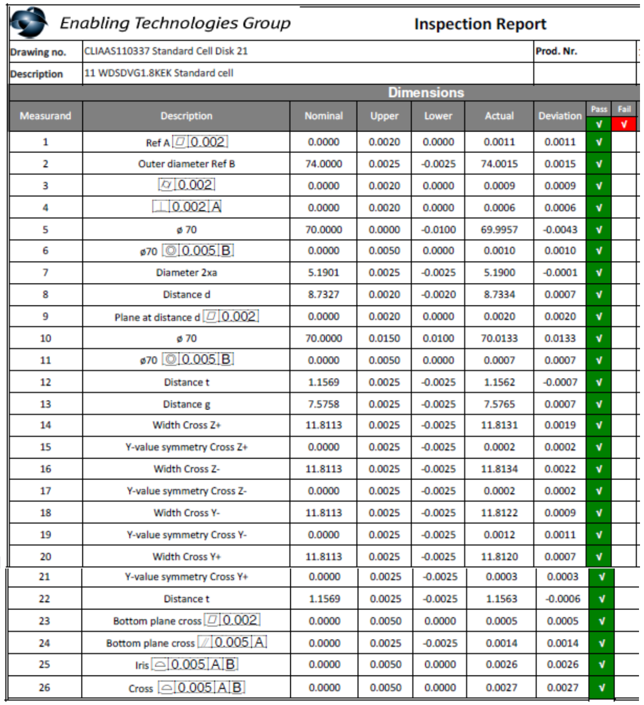






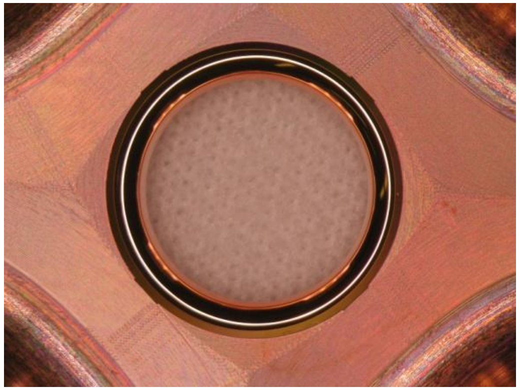
Enabling Technologies Group — Inspection Report

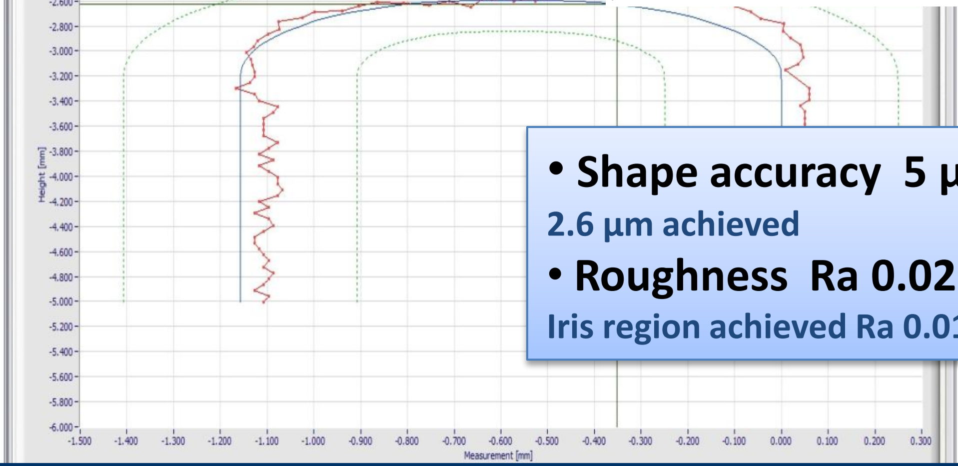
Drawing no.	CLIAAS110337 Standard Cell Disk 21	Prod. Nr.	
Description	11 WDSDVG1.8KEK Standard cell		

Dimensions

Measurand	Description	Nominal	Upper	Lower	Actual	Deviation	Pass √	Fail √
1	Ref A ⏥ 0.002	0.0000	0.0020	0.0000	0.0011	0.0011	√	
2	Outer diameter Ref B	74.0000	0.0025	-0.0025	74.0015	0.0015	√	
3	⌭ 0.002	0.0000	0.0020	0.0000	0.0009	0.0009	√	
4	⊥ 0.002 A	0.0000	0.0020	0.0000	0.0006	0.0006	√	
5	ø 70	70.0000	0.0000	-0.0100	69.9957	-0.0043	√	
6	ø70 ◎ 0.005 B	0.0000	0.0050	0.0000	0.0010	0.0010	√	
7	Diameter 2xa	5.1901	0.0025	-0.0025	5.1900	-0.0001	√	
8	Distance d	8.7327	0.0020	-0.0020	8.7334	0.0007	√	
9	Plane at distance d ⏥ 0.002	0.0000	0.0020	0.0000	0.0020	0.0020	√	
10	ø 70	70.0000	0.0150	0.0100	70.0133	0.0133	√	
11	ø70 ◎ 0.005 B	0.0000	0.0050	0.0000	0.0007	0.0007	√	
12	Distance t	1.1569	0.0025	-0.0025	1.1562	-0.0007	√	
13	Distance g	7.5758	0.0025	-0.0025	7.5765	0.0007	√	
14	Width Cross Z+	11.8113	0.0025	-0.0025	11.8131	0.0019	√	
15	Y-value symmetry Cross Z+	0.0000	0.0025	-0.0025	0.0002	0.0002	√	
16	Width Cross Z-	11.8113	0.0025	-0.0025	11.8134	0.0022	√	
17	Y-value symmetry Cross Z-	0.0000	0.0025	-0.0025	0.0002	0.0002	√	
18	Width Cross Y-	11.8113	0.0025	-0.0025	11.8122	0.0009	√	
19	Y-value symmetry Cross Y-	0.0000	0.0025	-0.0025	0.0012	0.0011	√	
20	Width Cross Y+	11.8113	0.0025	-0.0025	11.8120	0.0007	√	
21	Y-value symmetry Cross Y+	0.0000	0.0025	-0.0025	0.0003	0.0003	√	
22	Distance t	1.1569	0.0025	-0.0025	1.1563	-0.0006	√	
23	Bottom plane cross ⏥ 0.002	0.0000	0.0050	0.0000	0.0005	0.0005	√	
24	Bottom plane cross // 0.005 A	0.0000	0.0025	-0.0025	0.0014	0.0014	√	
25	Iris ⌓ 0.005 A B	0.0000	0.0050	0.0000	0.0026	0.0026	√	
26	Cross ⌓ 0.005 A B	0.0000	0.0050	0.0000	0.0027	0.0027	√	

Zeiss CMM, free state measurement





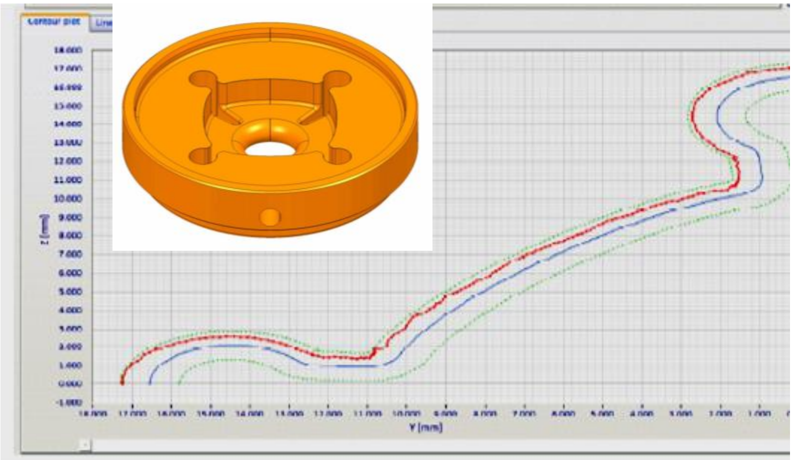
- **Shape accuracy 5 µm**

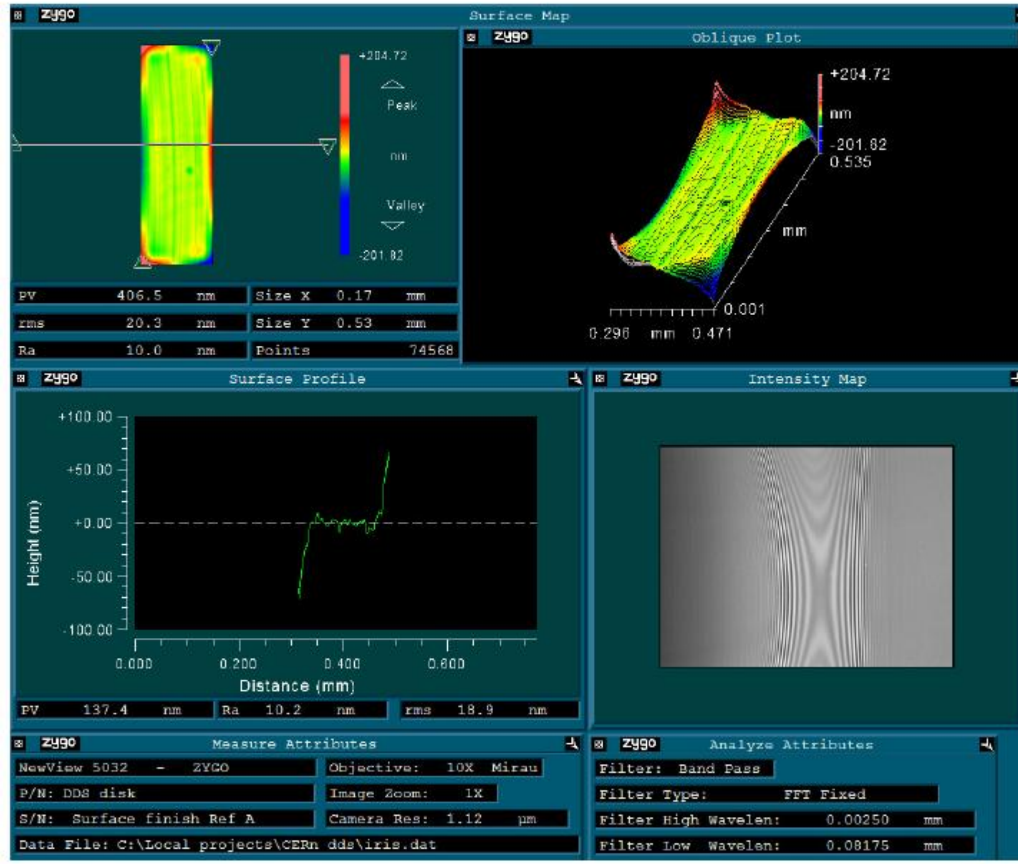
  2.6 µm achieved
- **Roughness Ra 0.025**

  Iris region achieved Ra 0.016

DETUNED DAMPED DISK FROM VDL (DDSA)

Zeiss CMM, free state measurement





Low-force probe: some disks show measuring indents (20 nm depth) after probing on the CMM ➔ local hardness of the material is not constant.

- **Shape accuracy 5 µm**

  1.7 µm achieved
- **Roughness Ra 0.025**

  Iris region achieved Ra 0.010

ALIGNMENT AND BONDING (T24@12 GHz)

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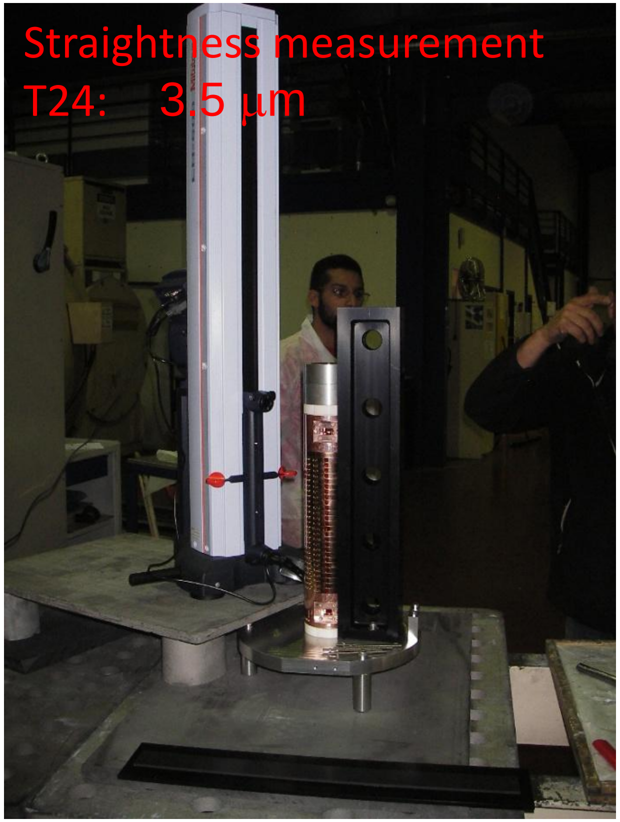
Reference on the external diameter:
- tolerance on external diameter: 12.5 μm
- tolerance on the ref. line: 1 μm

Alignment done on a V-shape vertical support in granite (accuracy of 1.5 μm)



DIFFUSION BONDING PARAMETERS AND CYCLE

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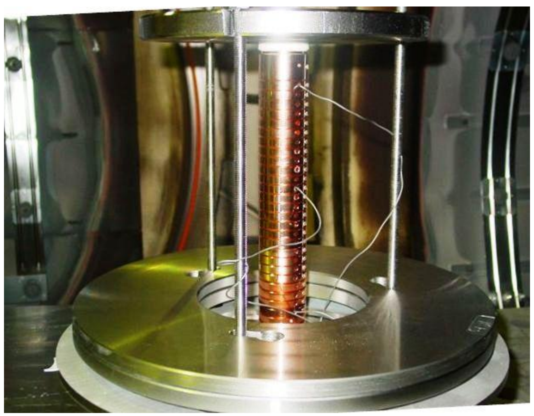
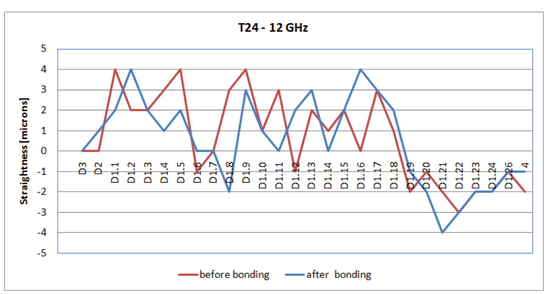
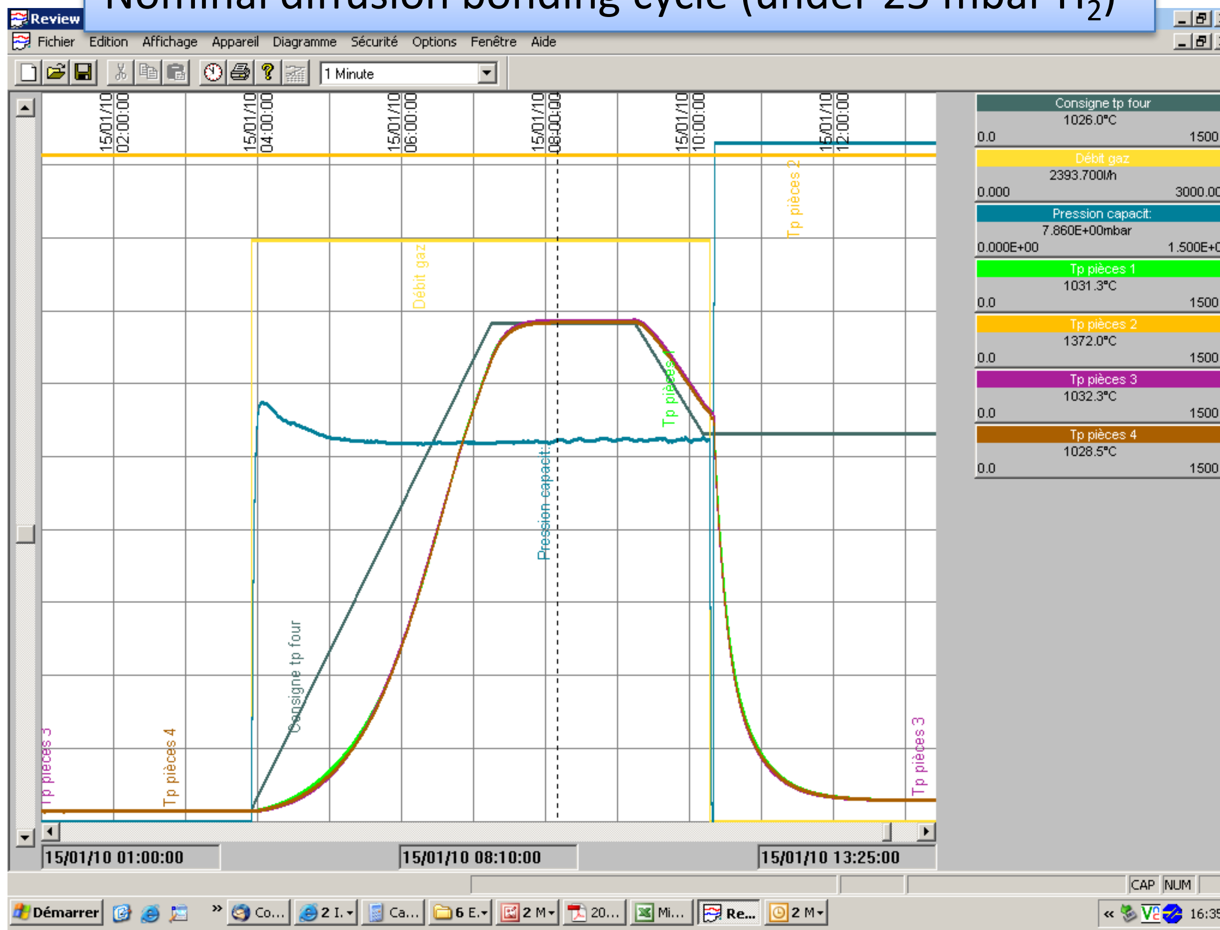
Temperature: up to 1040˚C
Pressure: 0.28 MPa
Holding time: 2 h

New infrastructure to guarantee uniform load





Nominal diffusion bonding cycle (under 25 mbar H_2)



Straightness measurement after diffusion bonding: variation of 1 μm before and after bonding

DIFFUSION BONDING SIMULATION (1/2)

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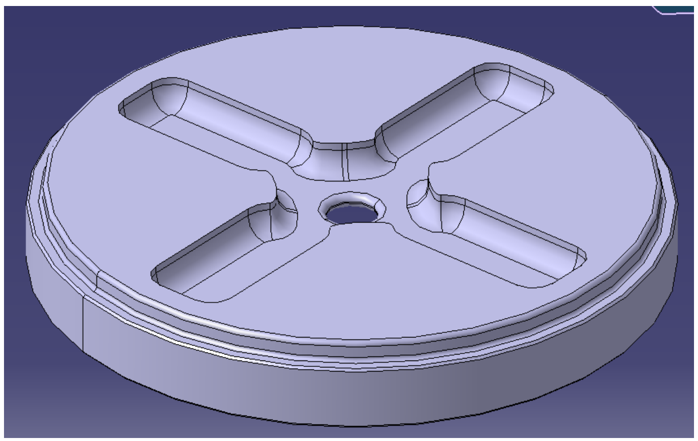
We wanted to study:
- Pressure distribution and deformation under bonding load [0.4 MPa, symmetrical disks]
- Stresses during bonding (transient – very heavy simulation)[TD24]

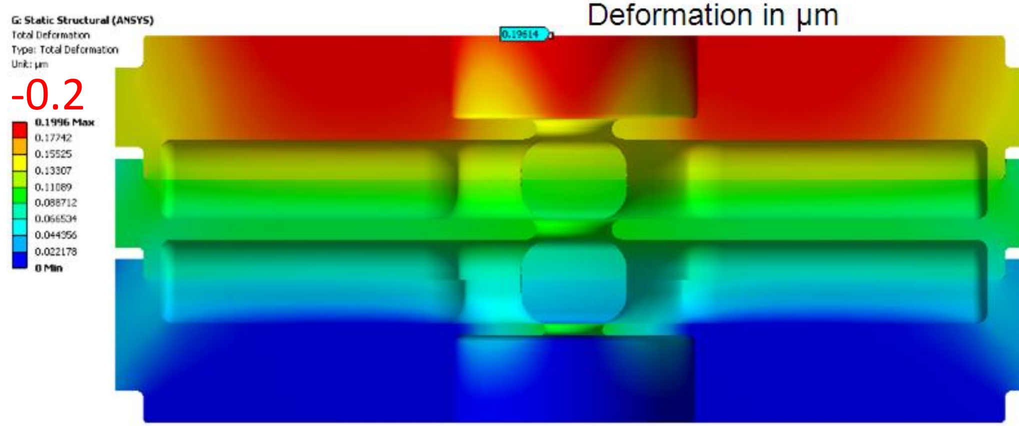
Pressure distribution and deformation under bonding load

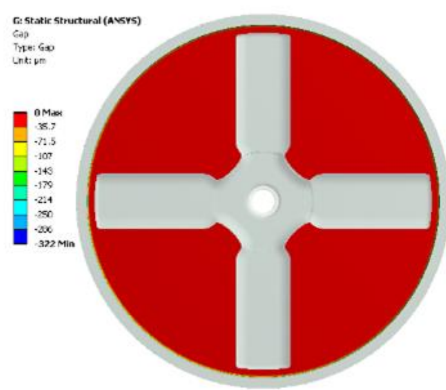


Linear static model
Frictionless contact, no sticking

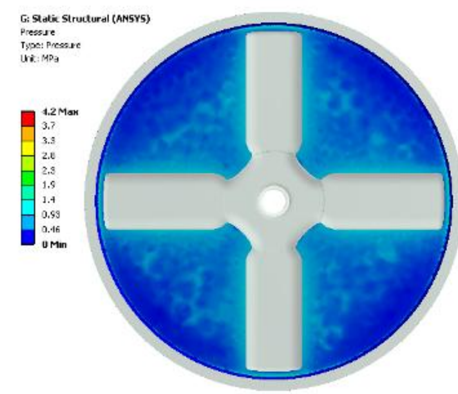
J. HUOPANA

Deformation in µm





Gap given µm



Pressure in MPa

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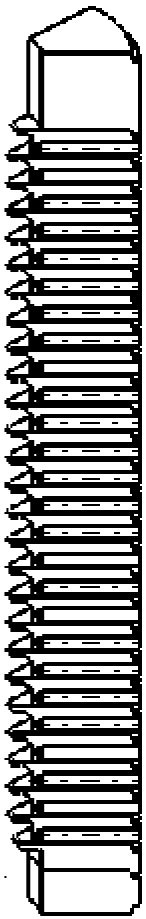
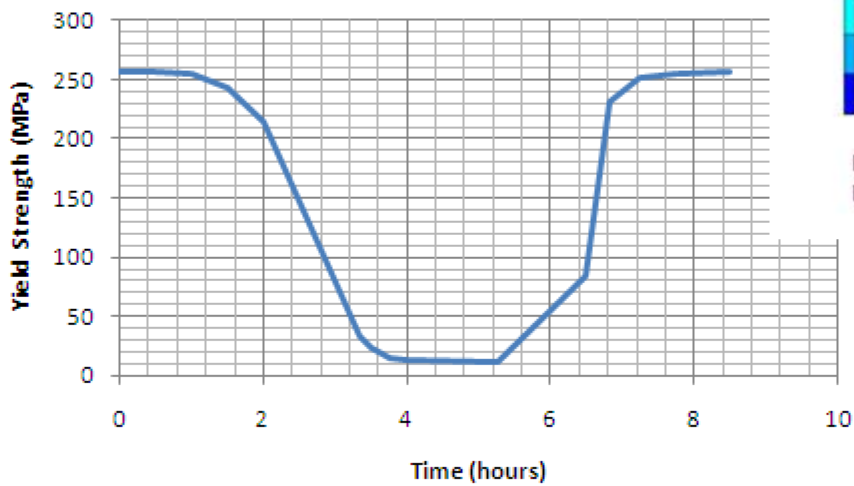
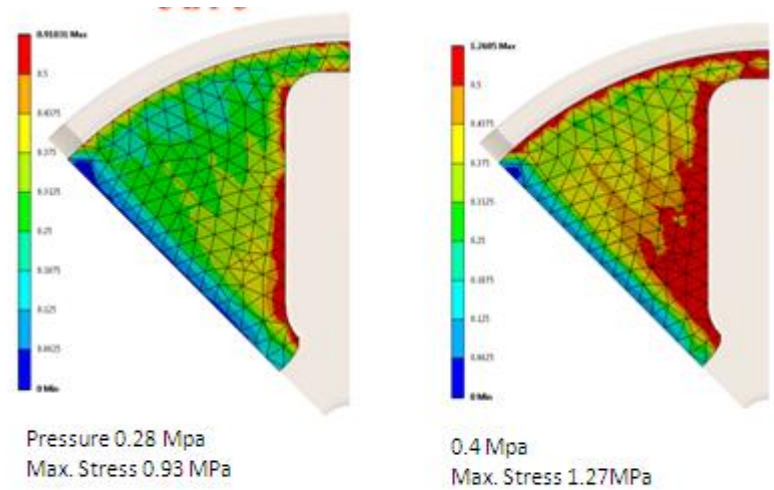
1/8 TD24

Stresses during bonding (0.28 MPa and 0.4 MPa)



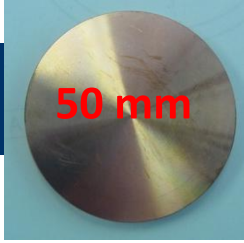
Max Stress 0.93 MPa (0.28 MPa)
1.27 MPa (0.4 MPa)
Min. yield strength **11.7 MPa**
Min. young's modulus 5.8 GPa





J. HUOPANA, T. BERG

DIFFUSION BONDING INVESTIGATION



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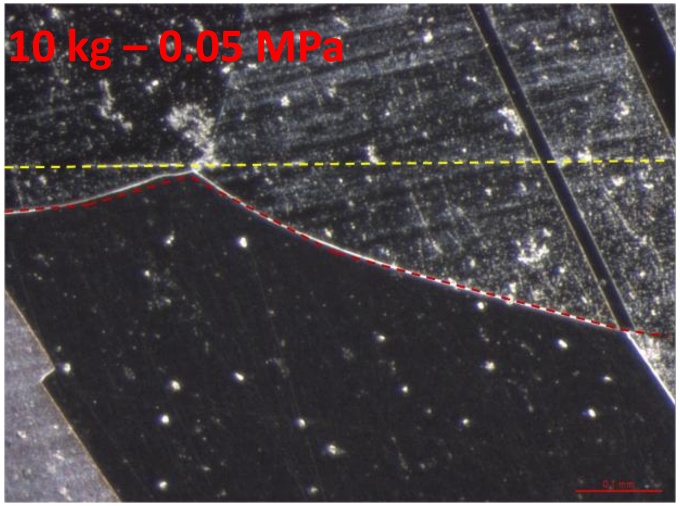
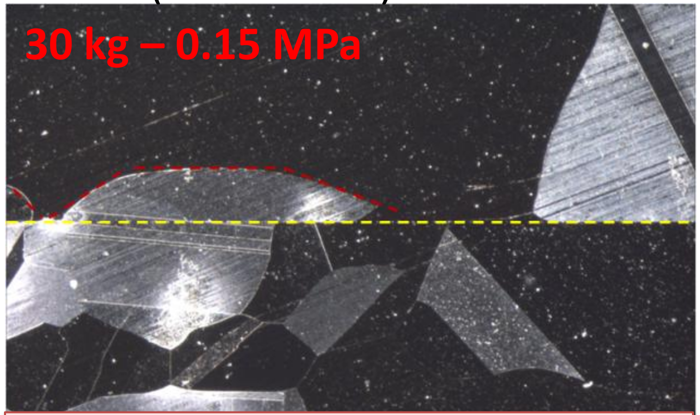
S. LEBET

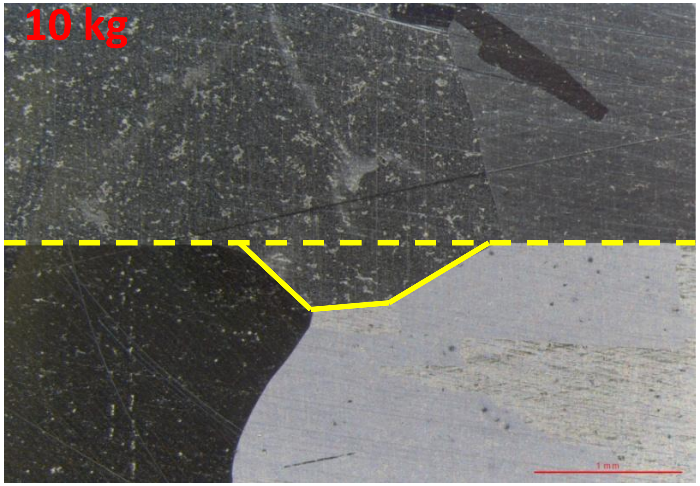
We want to understand the influence of different pressure loads and machining types on joining process (first results)



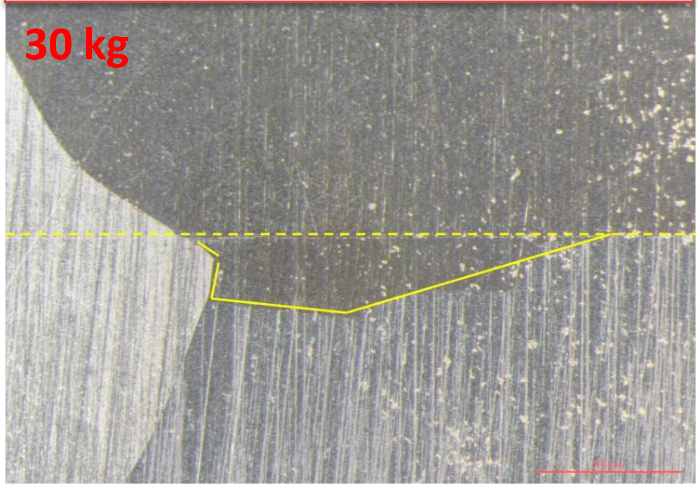
Conventional tool



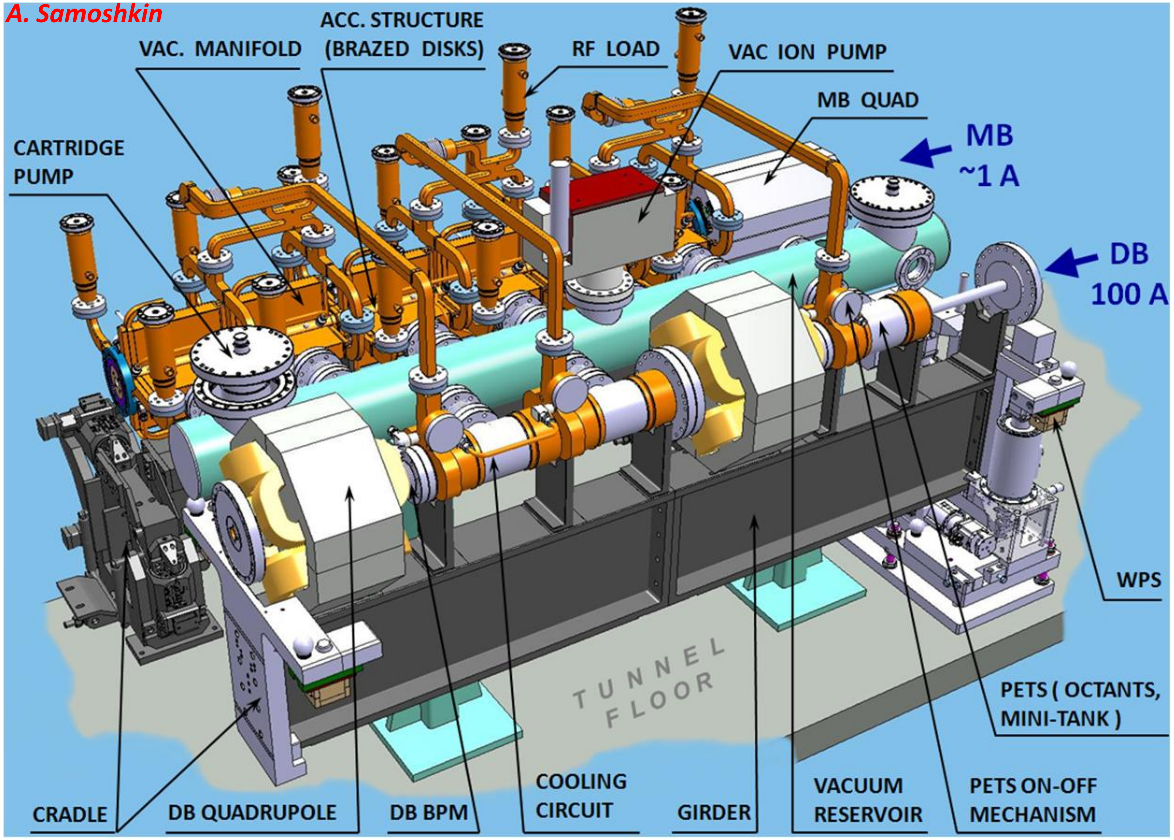
Deformation of few tens of um on the ext. dia.



Diamond tool



CLIC TWO-BEAM MODULES



Up to 8 accelerating structures and 4 PETS in a two-beam module
Design takes into account CLIC requirements and integration with other technical systems

ASSEMBLY OF ACCELERATING STRUCTURES (1/2)

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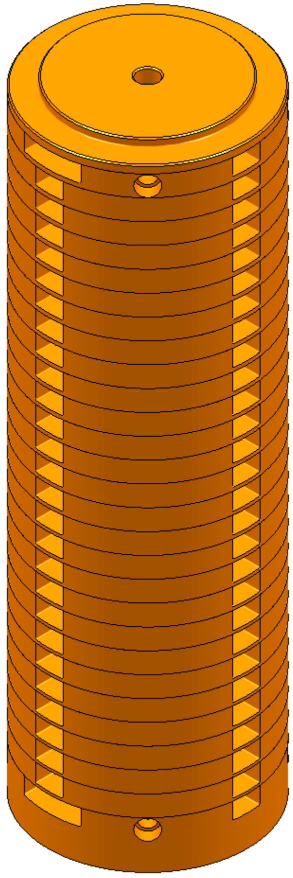
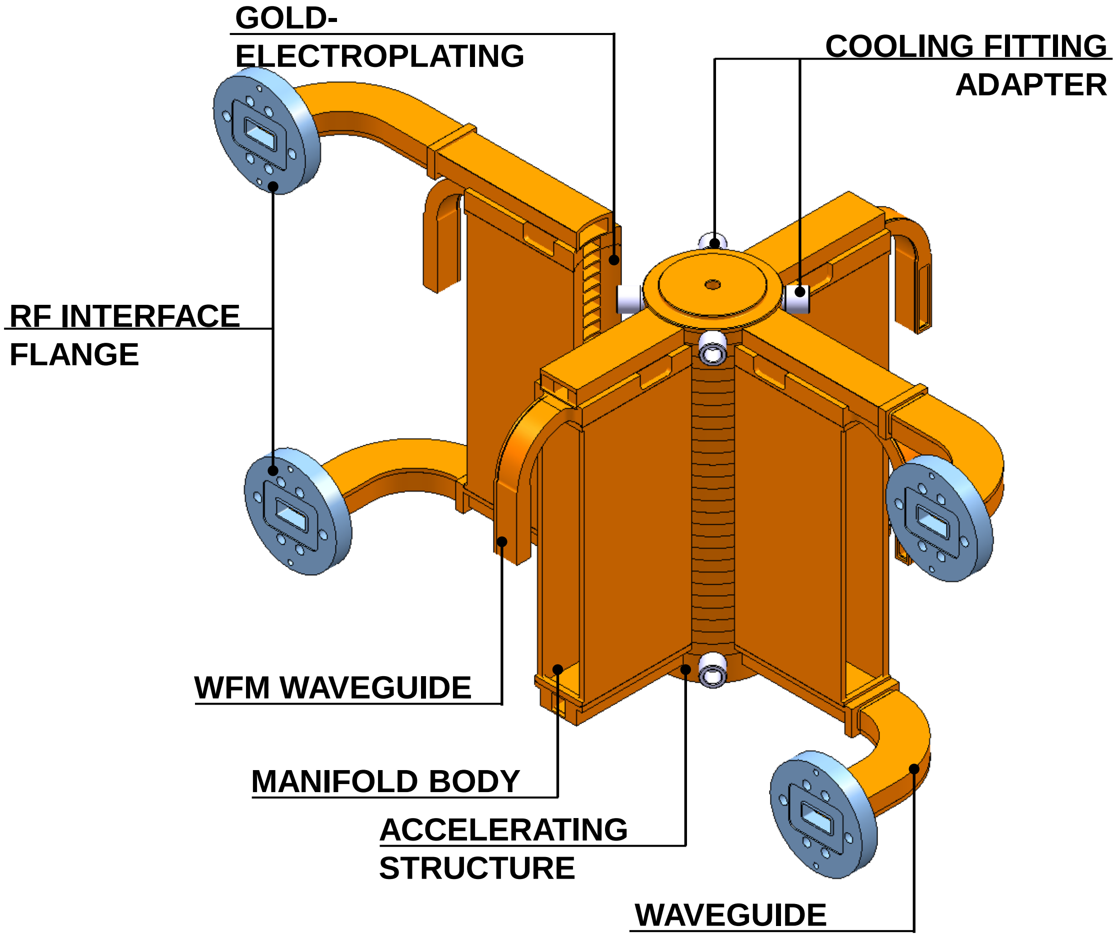
1. Diffusion bonding of high precision disk stack



D. GUDKOV, A. SOLODKO

2. Brazing of the manifolds by means of Gold-electroplating (validation tests needed)
3. Brazing of cooling fitting adapters



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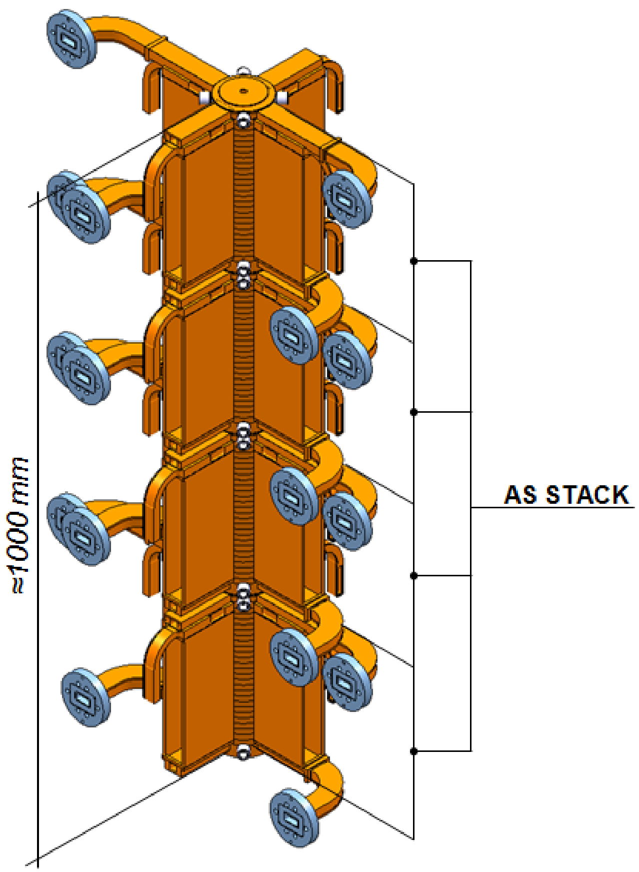
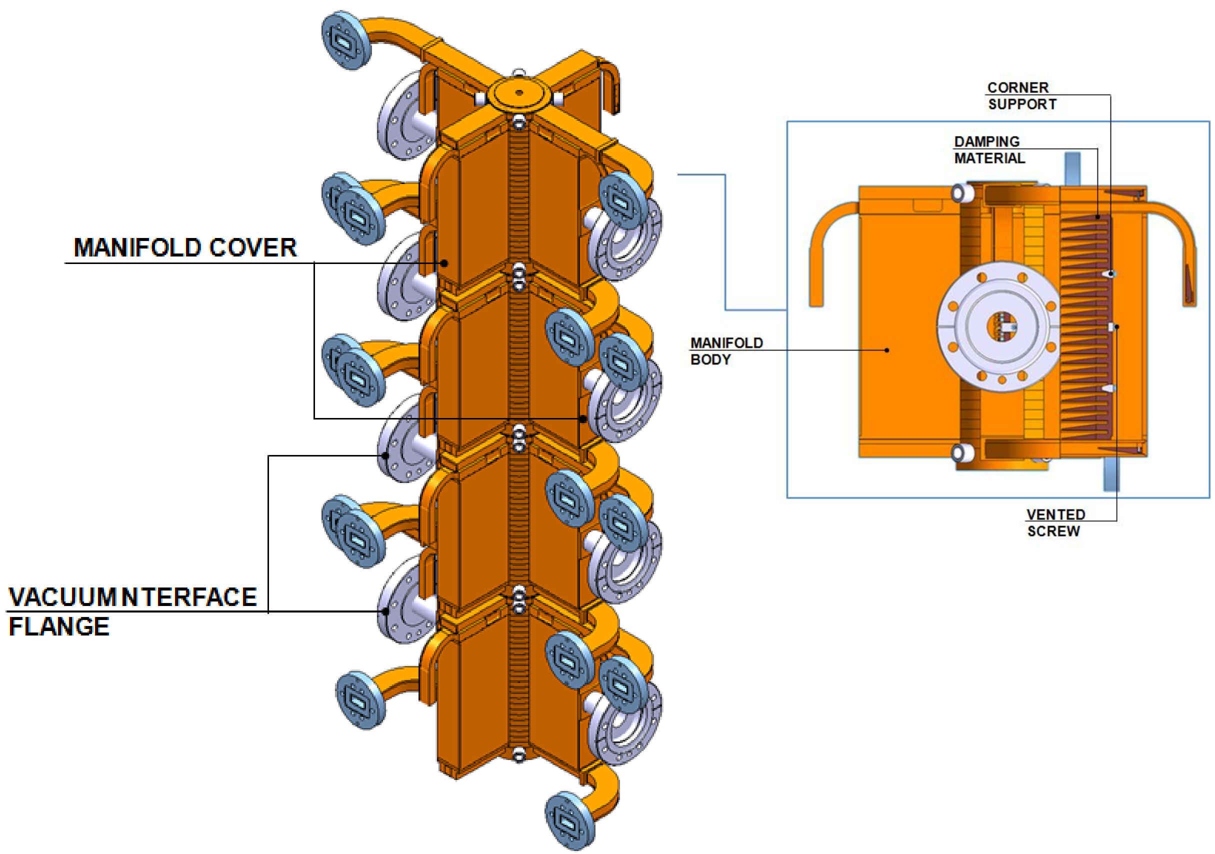
4. Brazing of prepared accelerating structure stack **(superstructure)**

5. Installation of damping material
6. Welding (EBW) of manifold covers





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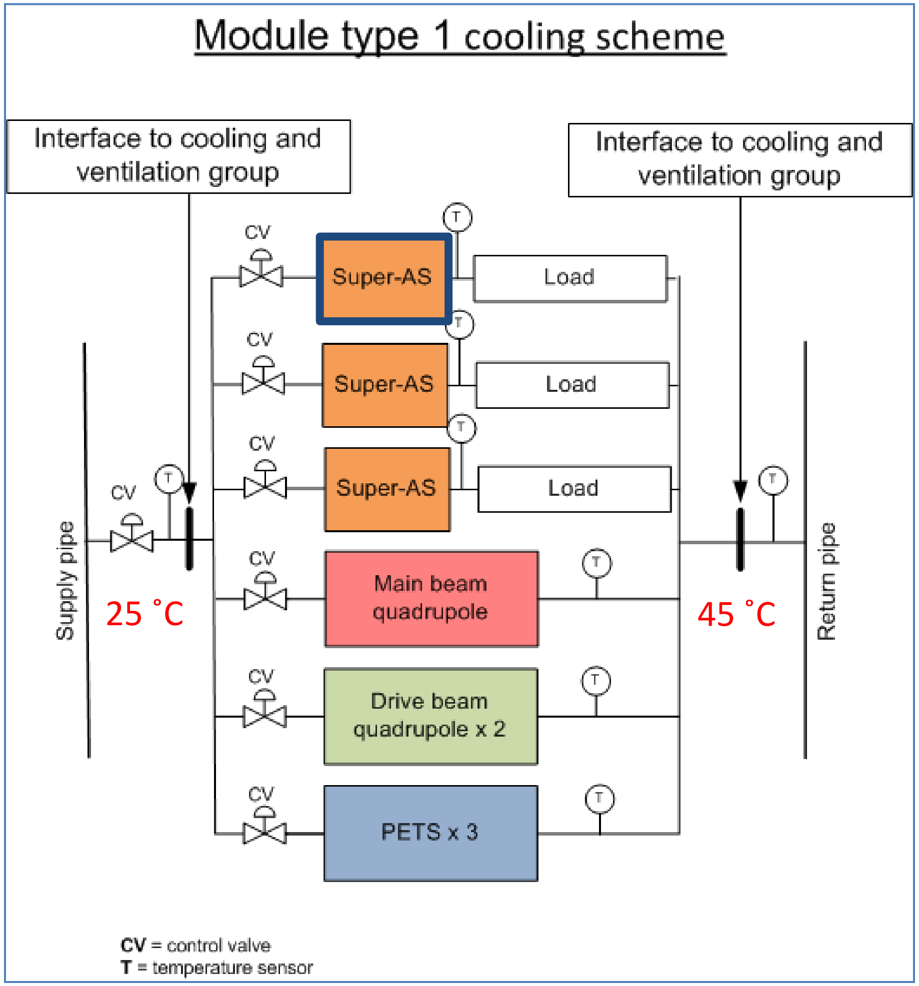

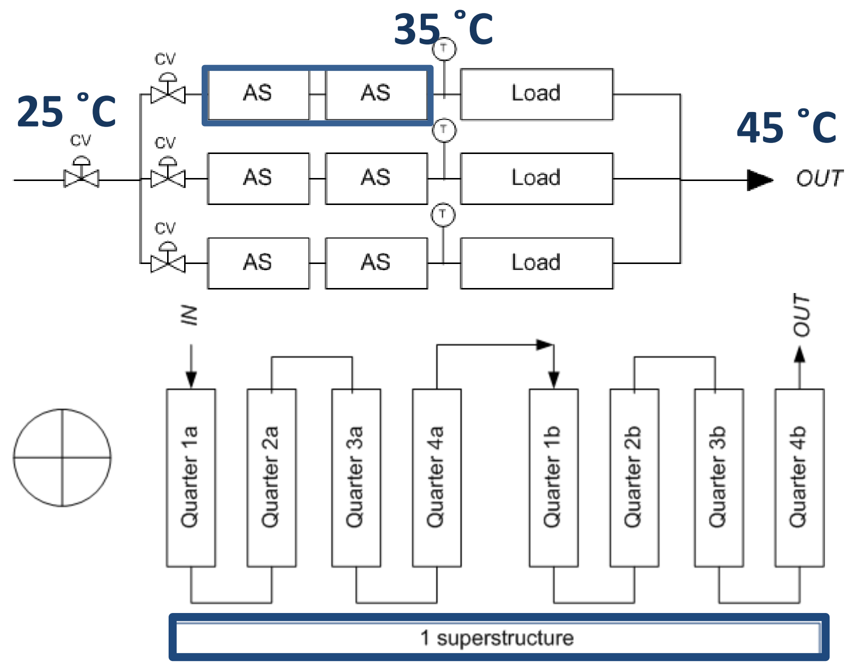

Twater_in = 25 ˚C [2 ˚C]

Re = 5800 (d = 7 mm)

h = 3750 $W/m^2/K$

V= 70 l/h [per AC. STR.]

V = ~350 l/h [per MODULE]

V = 3500 m/h [per LINAC]

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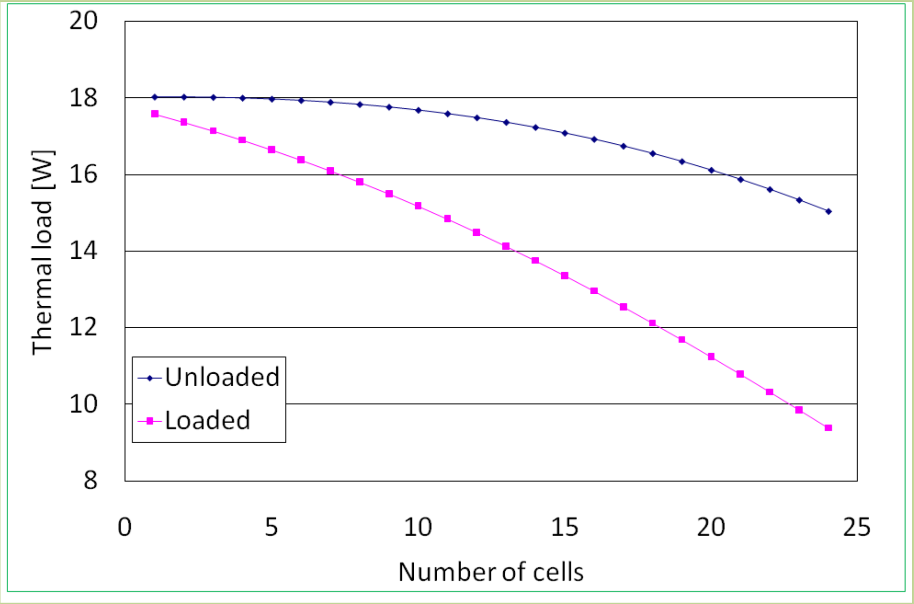
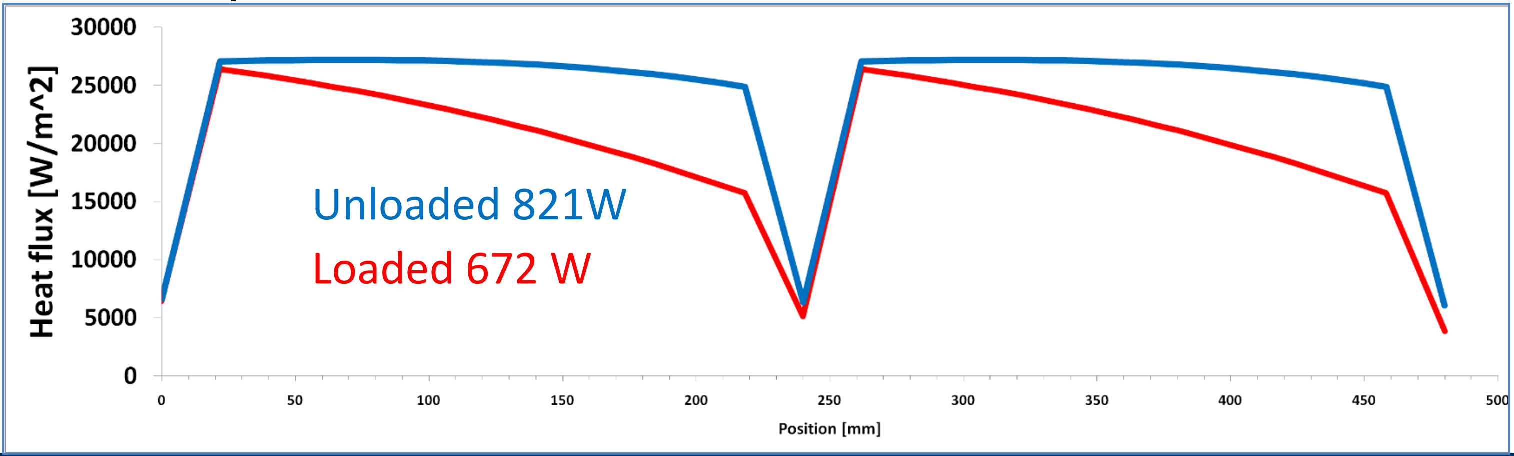
Accelerating structure EDMS 964717

- Thermal load is **not** constant through an accelerating structure
- Considered unloaded conditions and loaded conditions

Cell-by-cell heat dissipation



Distribution of heat flux over 480 mm: superstructure



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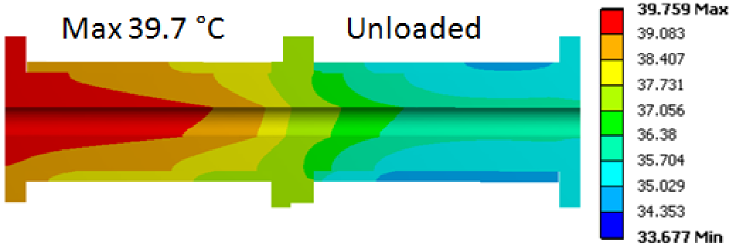
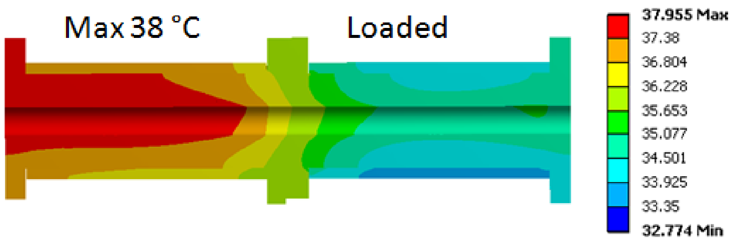
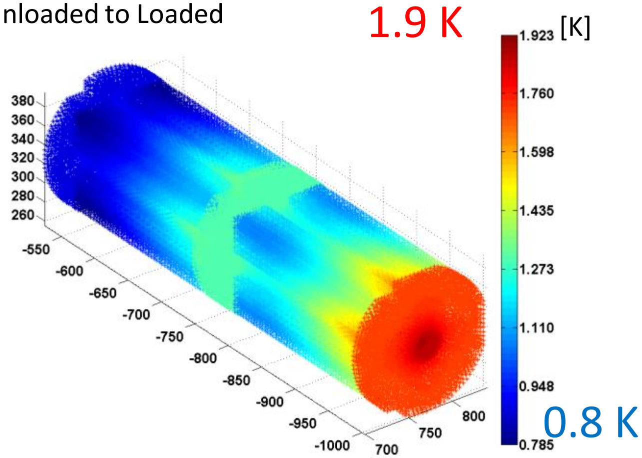
Thermal and structural analysis

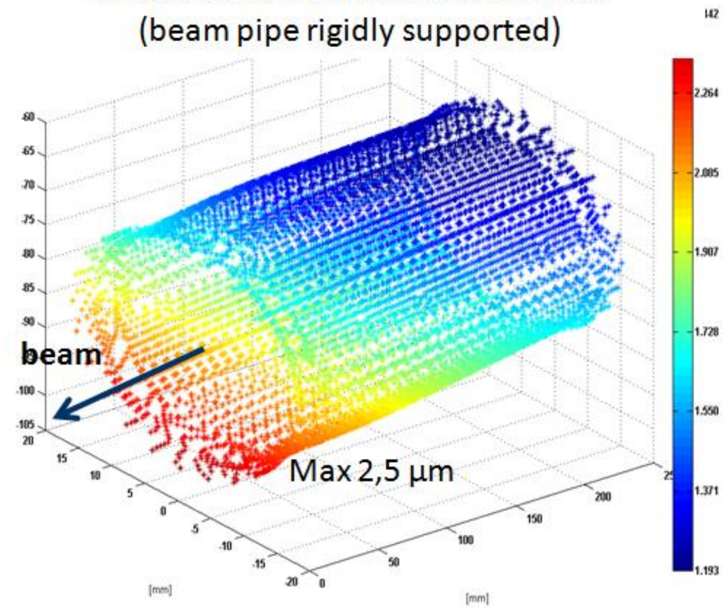




Temperature difference
Unloaded to Loaded



Beam pipe deformation:
unloaded to loaded structural effect
(beam pipe rigidly supported)

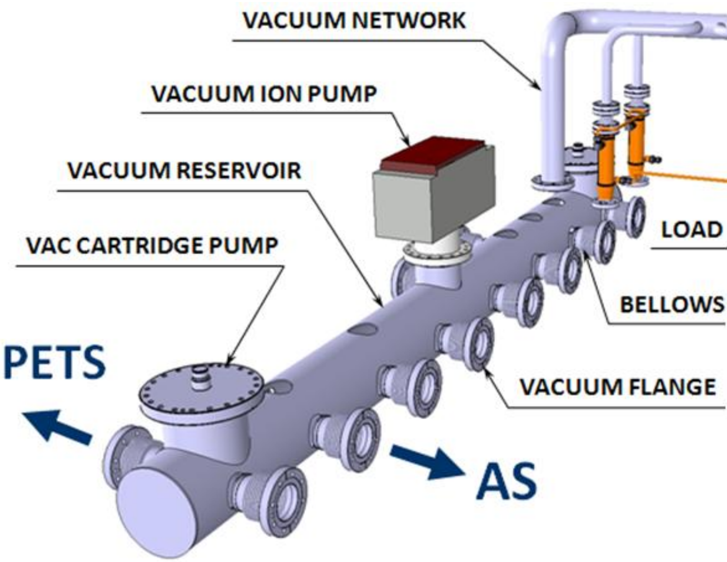


Minimized by adjusting the mass-flow rate

R. NOUSIAINEN, R. RAATIKAINEN

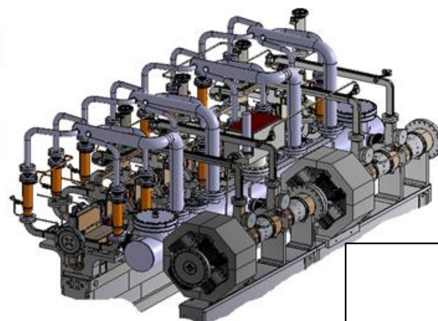
VACUUM ISSUES

C. GARION, A. SAMOSHKIN, D. GUDKOV

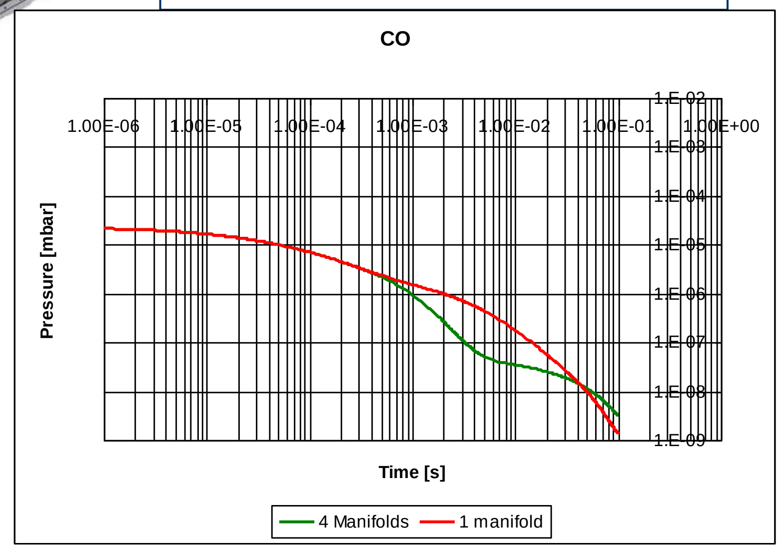


✓4 manifolds around the accelerating structures linked to a common reservoir

- ✓Pumping speed for 1 accelerating structure= 300 l/s
- ✓ 4 manifolds 30 mm x 30 mm (equivalent)



Recovery after breakdown



✓ simulation did not show not a “big” difference between 1 or 4 manifolds

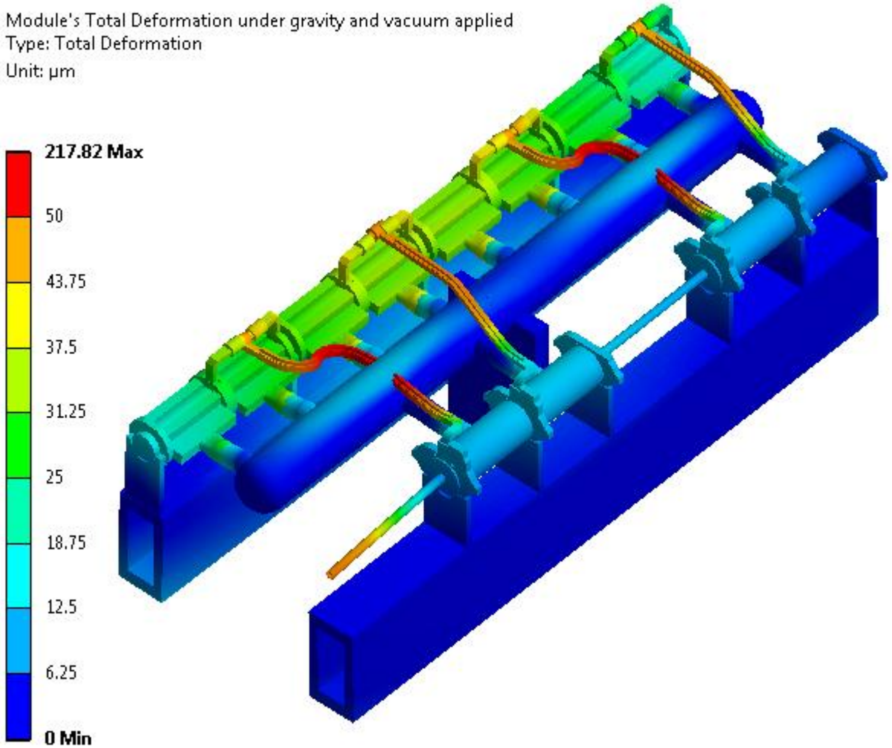
✓Depending on the species, the local pressure does not exceed the range 10^{-8}-10^{-7} mbar after 20 ms.

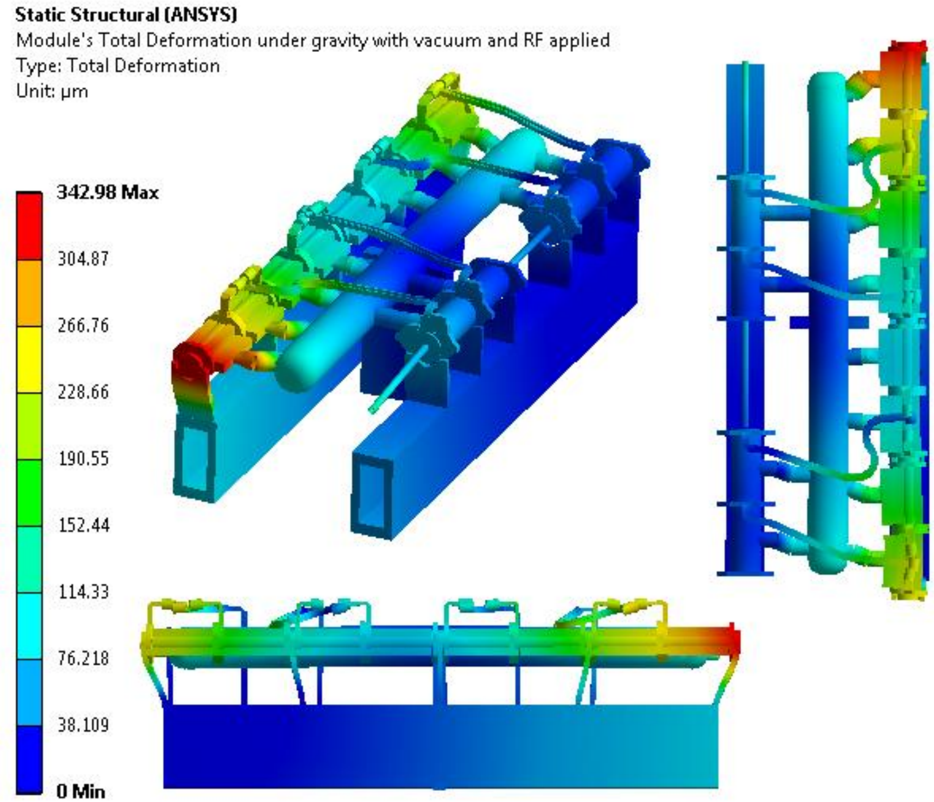
✓ Only 1 manifold could be needed (to be confirmed with the prototype modules)

THERMO-MECHANICAL MODEL

R. NOUSIAINEN (input from technical experts)

Structural analysis





Gravity + Vacuum

Gravity + Vacuum + RF (unloaded)

Lateral deformation and wave guide deformation to be confirmed with the prototype modules (if not acceptable from RF, the four connected super structures will be decoupled).

CONCLUSIONS AND FUTURE STEPS

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- Production of 100 MV/m RF accelerating structures is very challenging: several engineering issues are being addressed before CDR
- Mechanical design shall take into account all requirements on RF, beam physics, machining, assembly, installation and operation
- Micro-precision tolerances imply dedicated machining procedures
- CLIC structures integrate all features and technical systems: additional eng. issues are to be addressed
- Industrialization studies started in collaboration with companies
  - Review of design aiming at:
    - Reduction of types of tooling
    - Confirmation of tolerances requirements: review of regions with stringent and relaxed tolerances
    - Confirmation of roughness requirements in the different regions
  - Optimization of design for chosen assembly/joining methods

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EXTRA SLIDES

DDSA, prototype disks

Just for Roger

DDSA, prototype disks