Meeting on Tomography and Applications
Discrete Tomography, Neuroscience and Image Reconstruction 16th Edition
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Analysis, Design and Realization of a Furnace for in Situ Wettability Experiments at High Temperatures under X-Ray Microtomography

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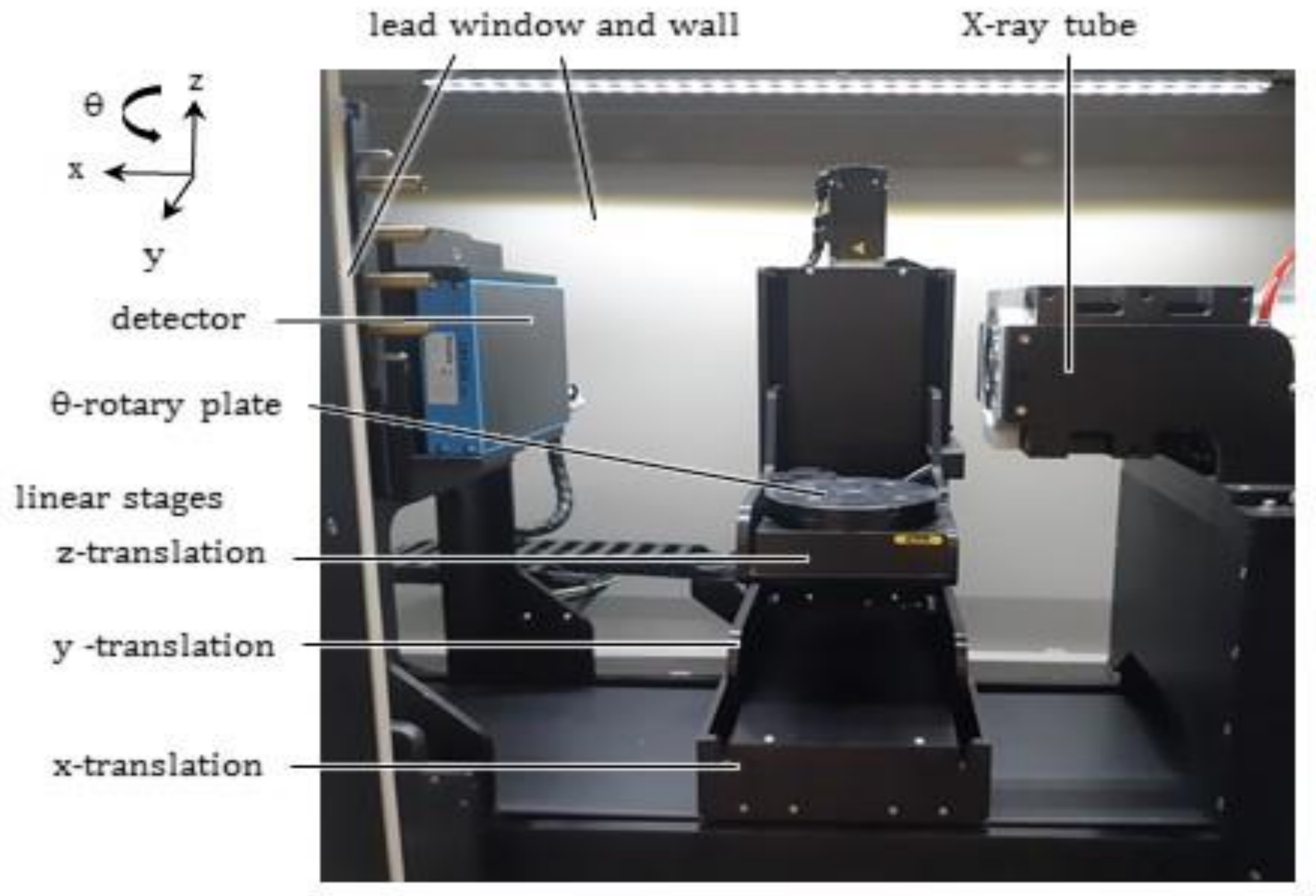
NSI X-ray microtomography cabinet at Politecnico di Milano



Tube Voltage 10-160 kV
current 0.05 mA-3 mA
Max power emission
80 W/10 W
Min focal spot size
0.5 micrometer

CMOS flat panel with
Gadox scintillator
1944 × 1536 pixels,
15 ×12 cm active area

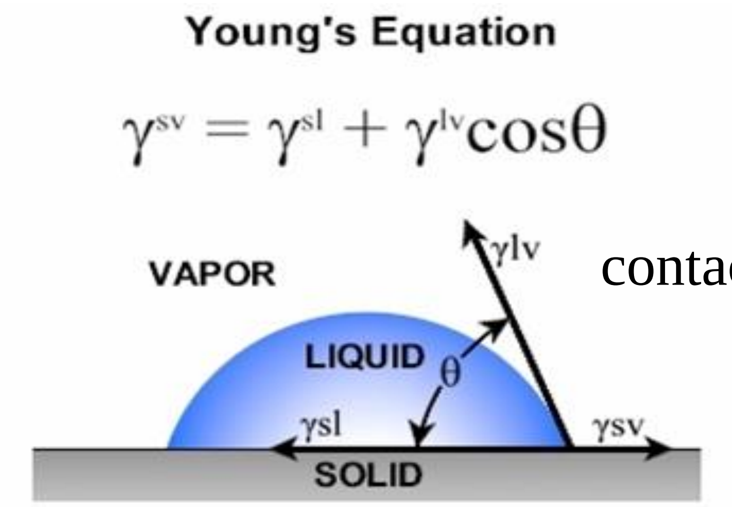
Cone beam magnification
up to × 65

Requirements for in situ sessile droplet at high temperatures

- In situ sessile drop (~3 mm)
- Inert atmosphere (Argon)
- Inner chamber Temperature range 500 –750 °C; effective insulation
- Suitable X-ray transmission
- High quality reconstruction

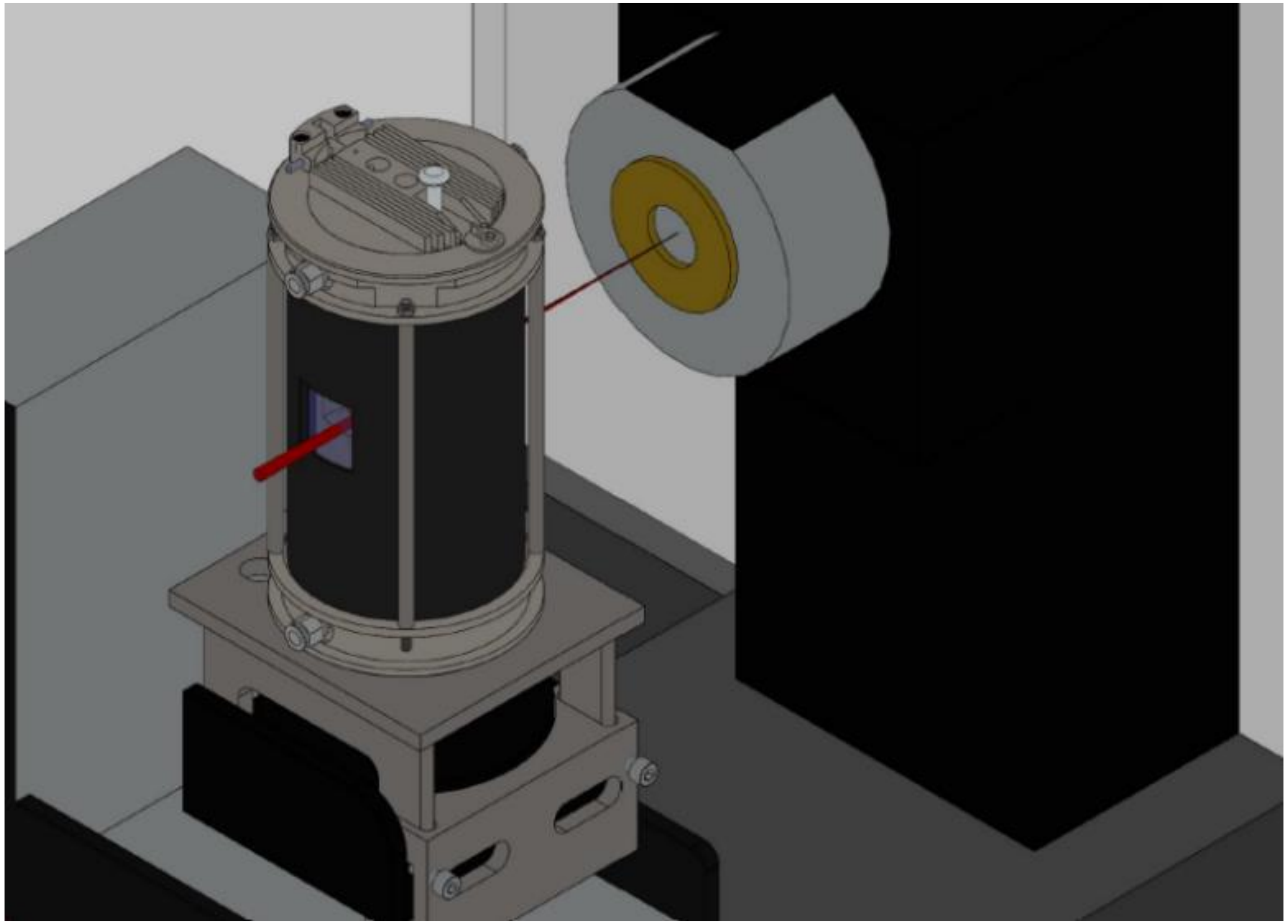
Challenges related to the set up constraints!

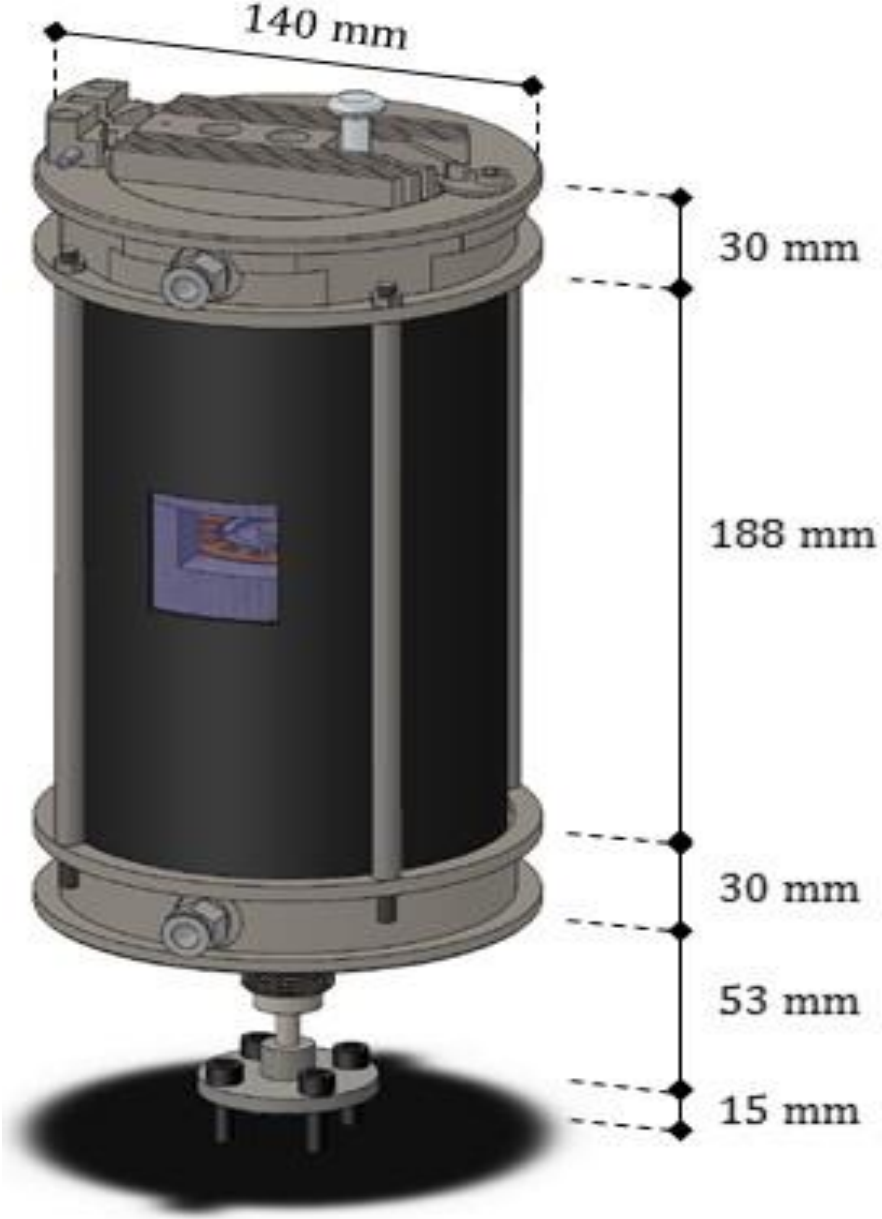
Sobczak, Asthana et al. 2010



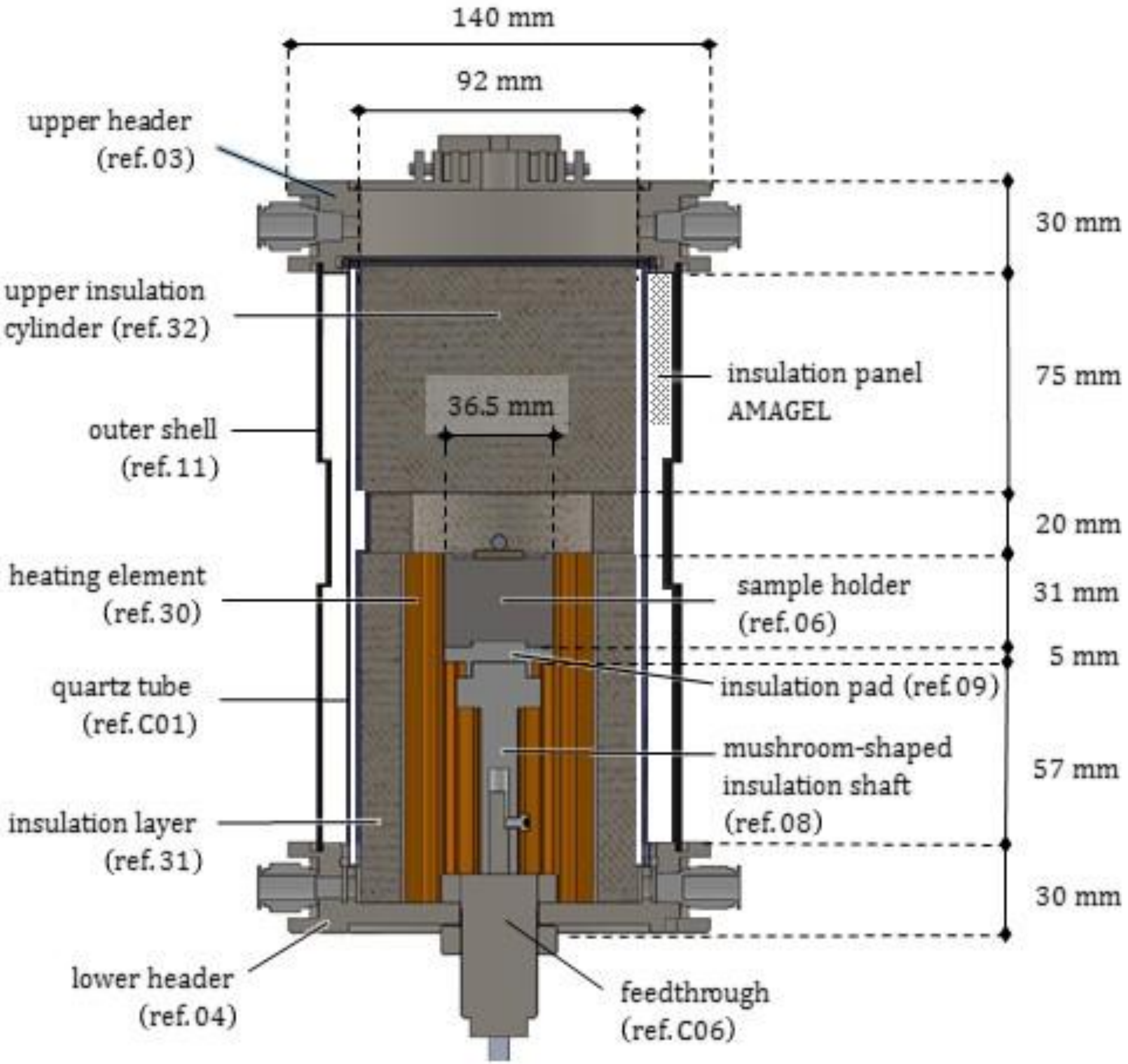
contact angle

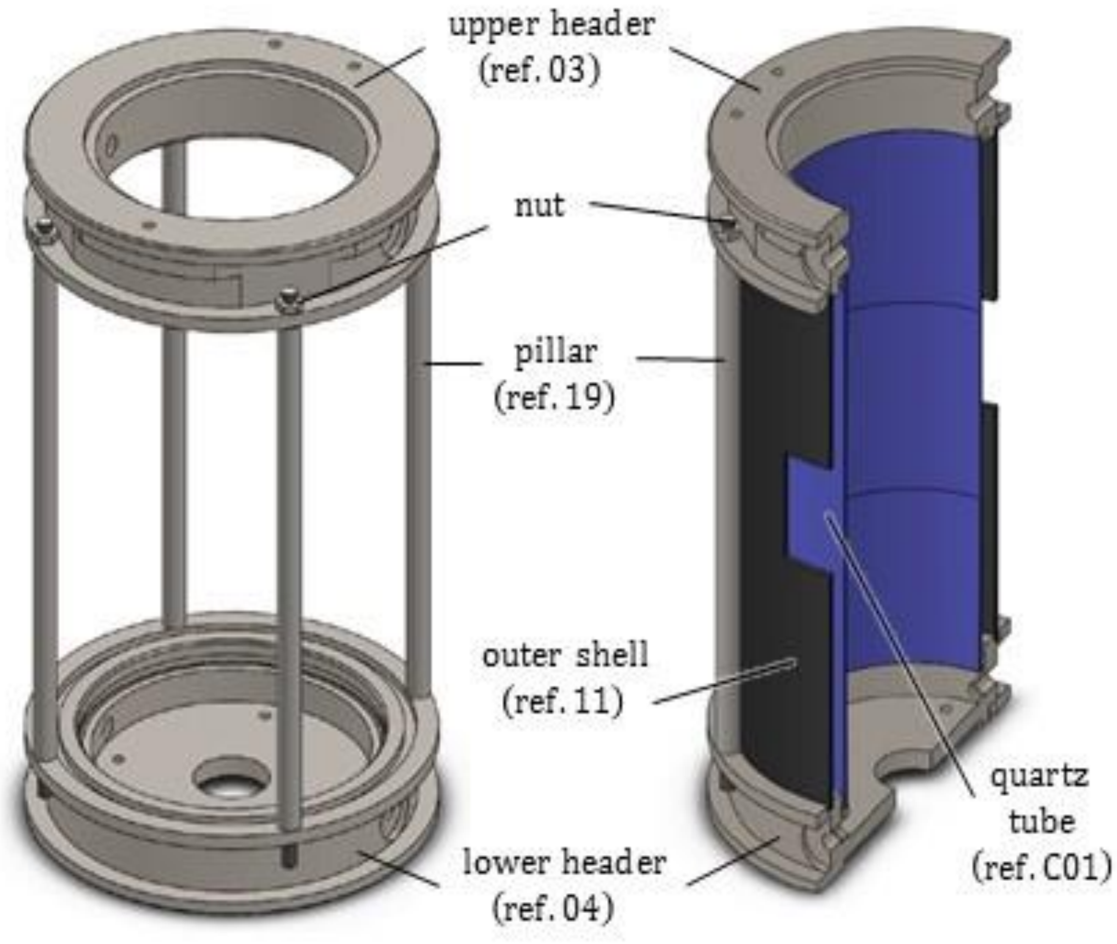
Furnace design and positioning in situ





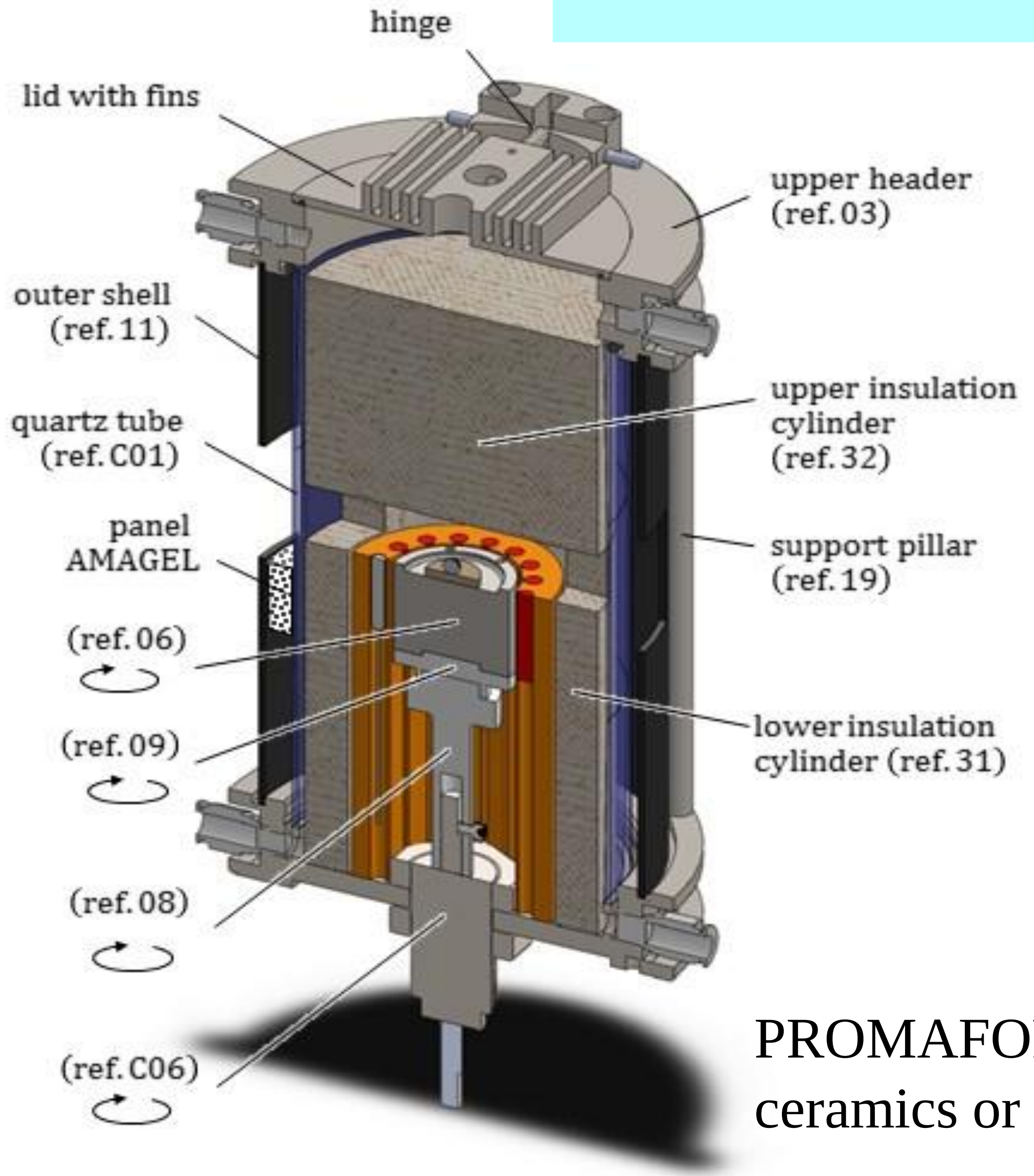
Furnace section and outer shell

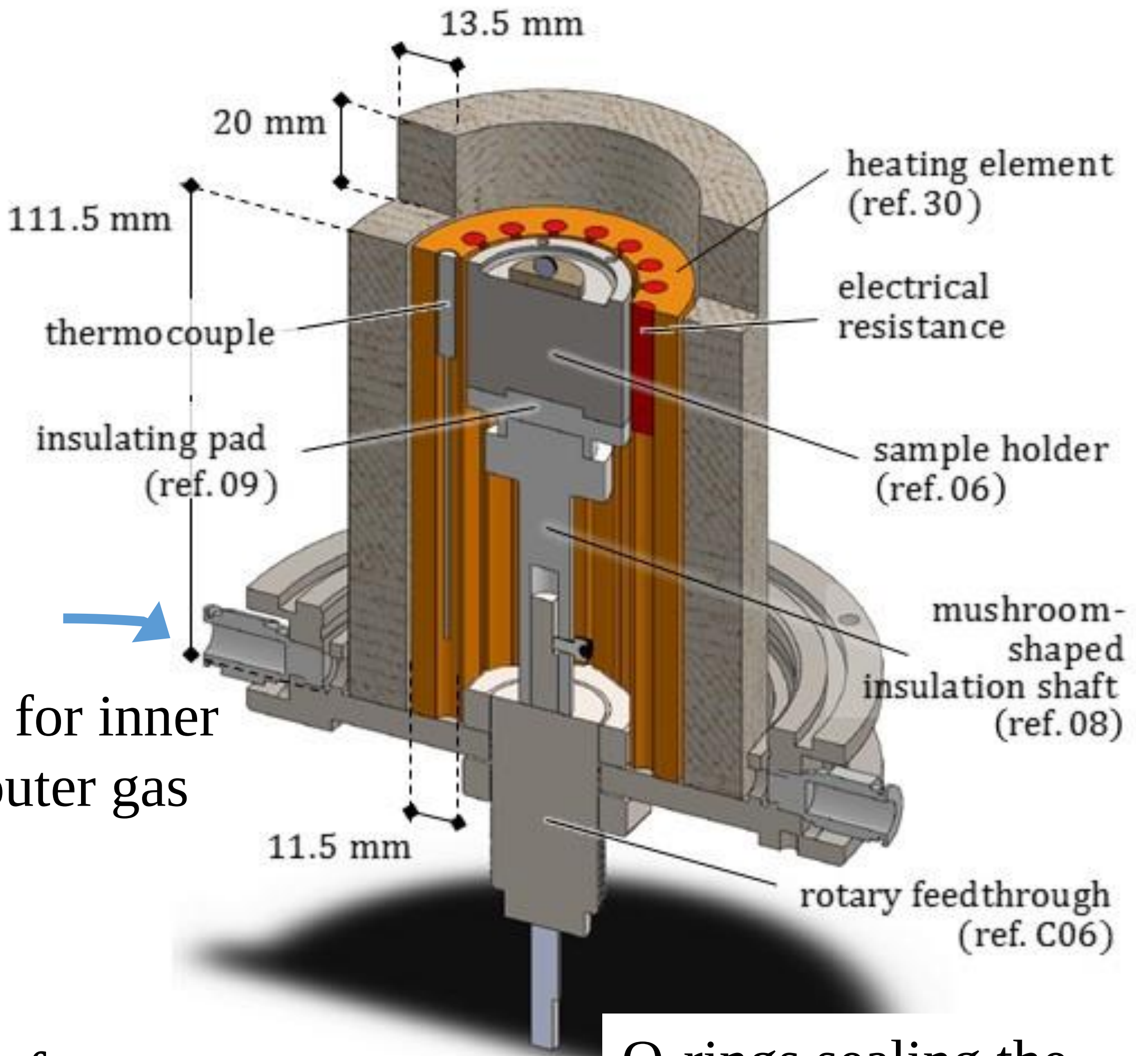




high purity fused silica (quartz glass), low X-ray attenuation, resistant to high temperatures, low thermal expansion

Axonometric views



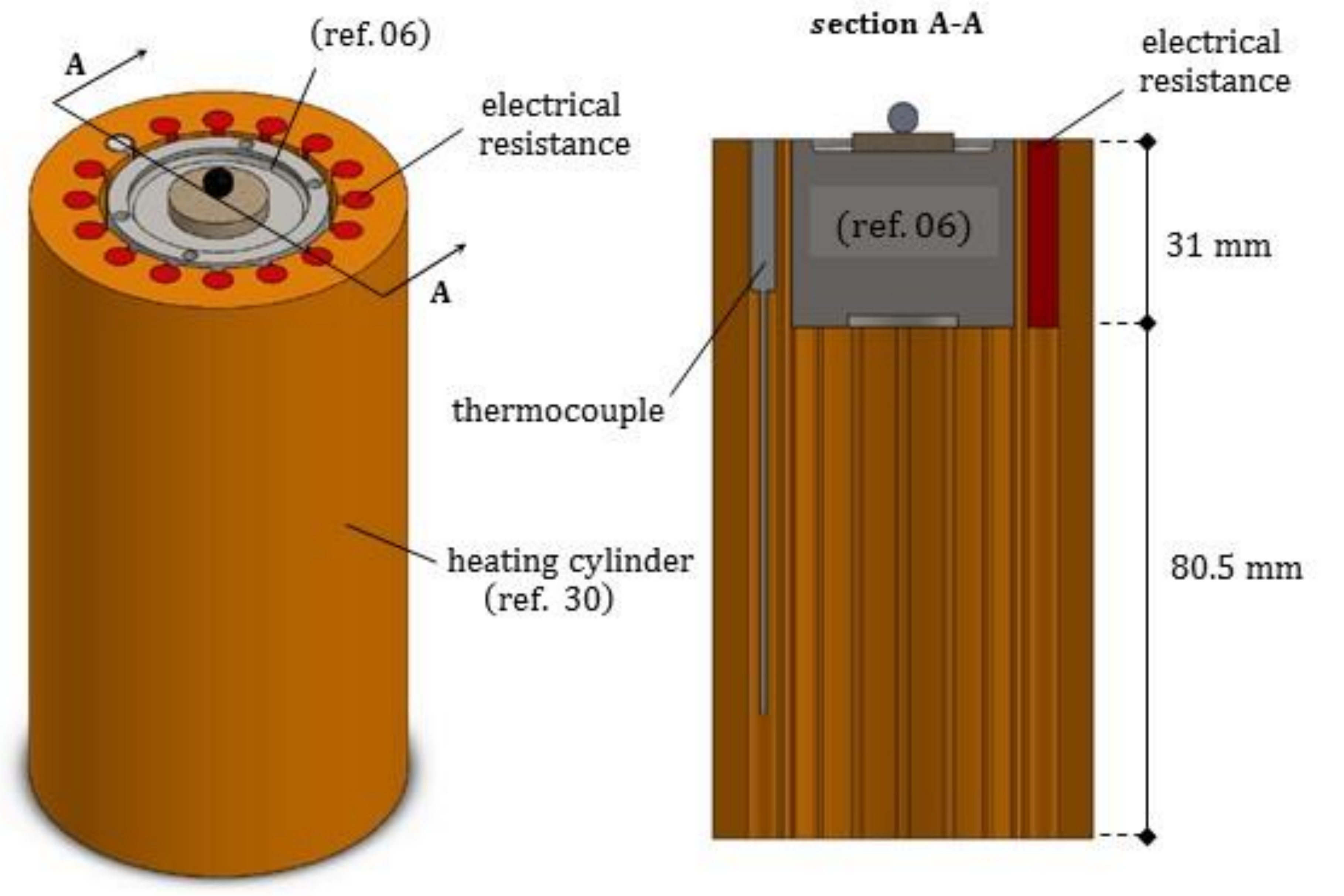


pipes for inner and outer gas flow

PROMAFORM® refractory ceramics or of bio-soluble fibers

O-rings sealing the quartz cylinder

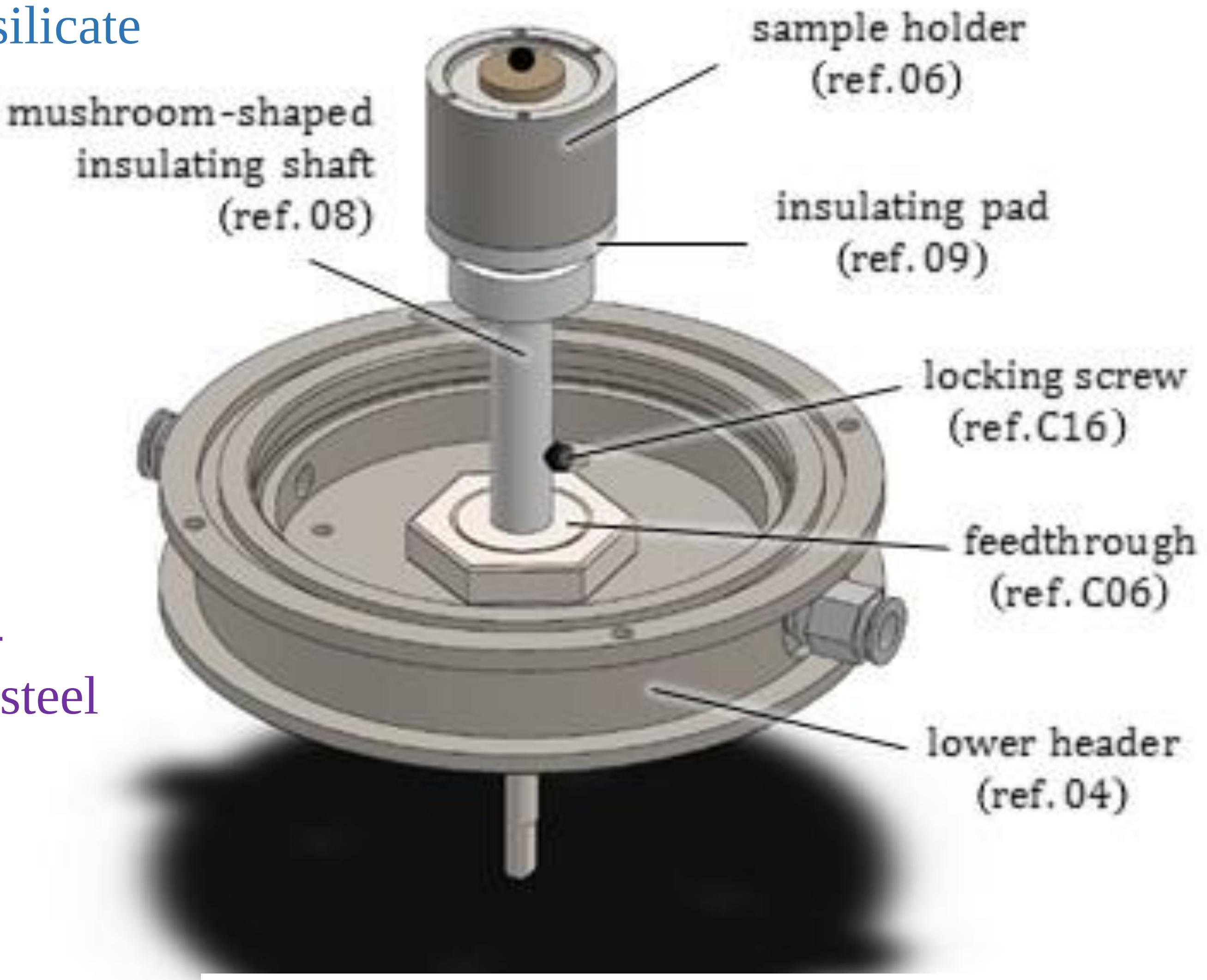
Ceramic heating element (42TE)

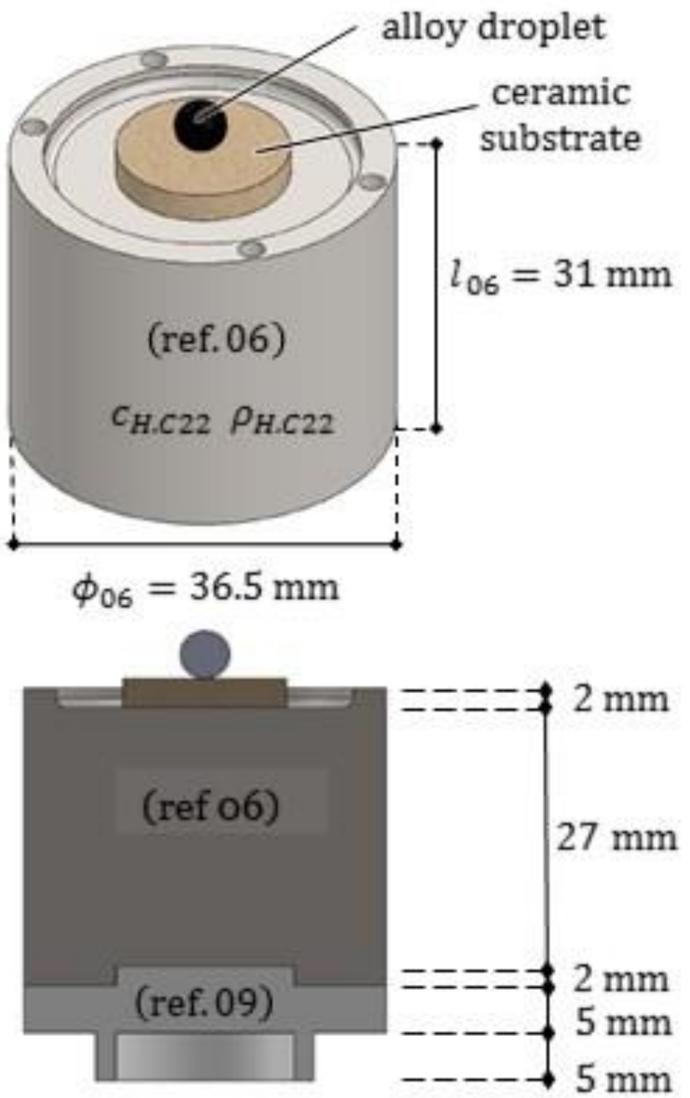


Rotating sample holder

ORVICAL 1500
calcium silicate

HASTELLOY C22 a nickel-chromium-molybdenum alloy

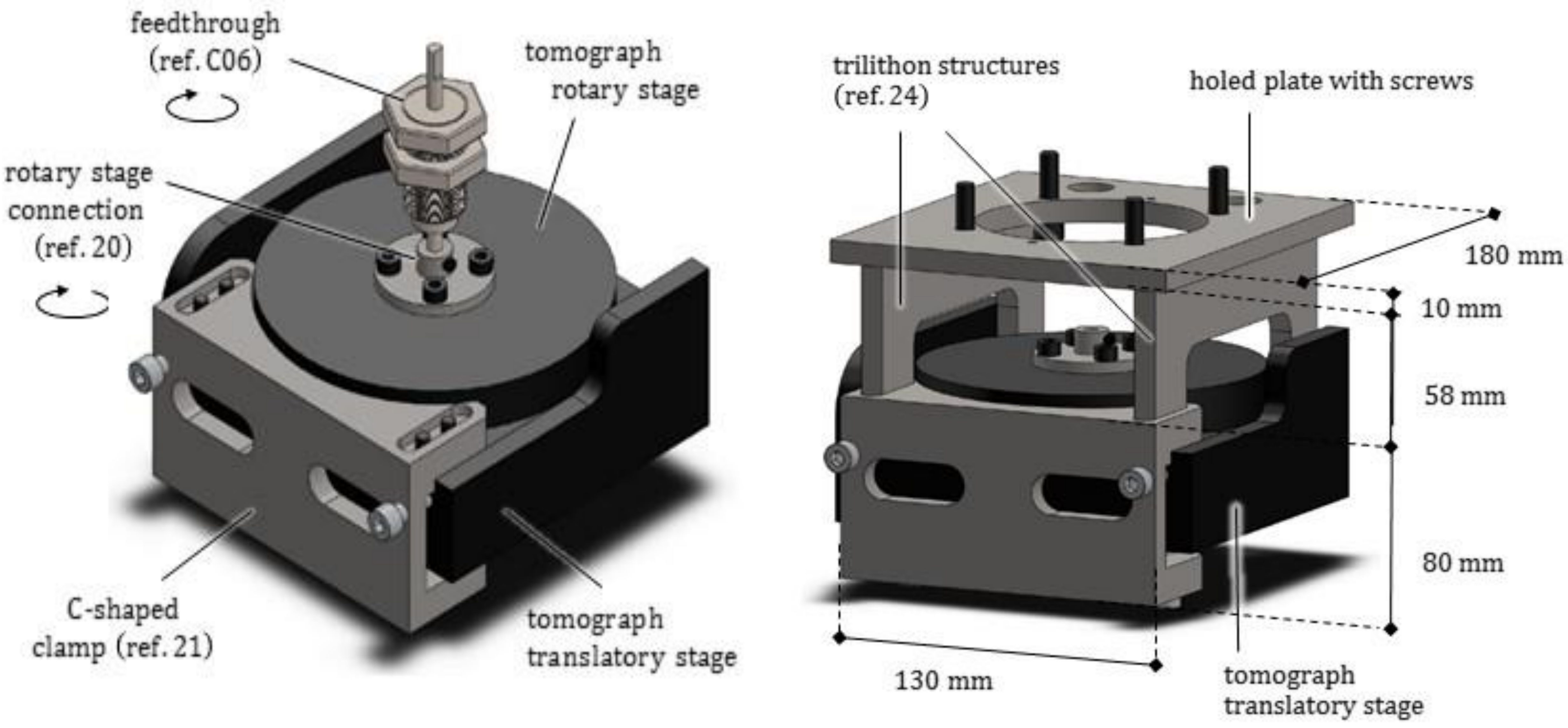


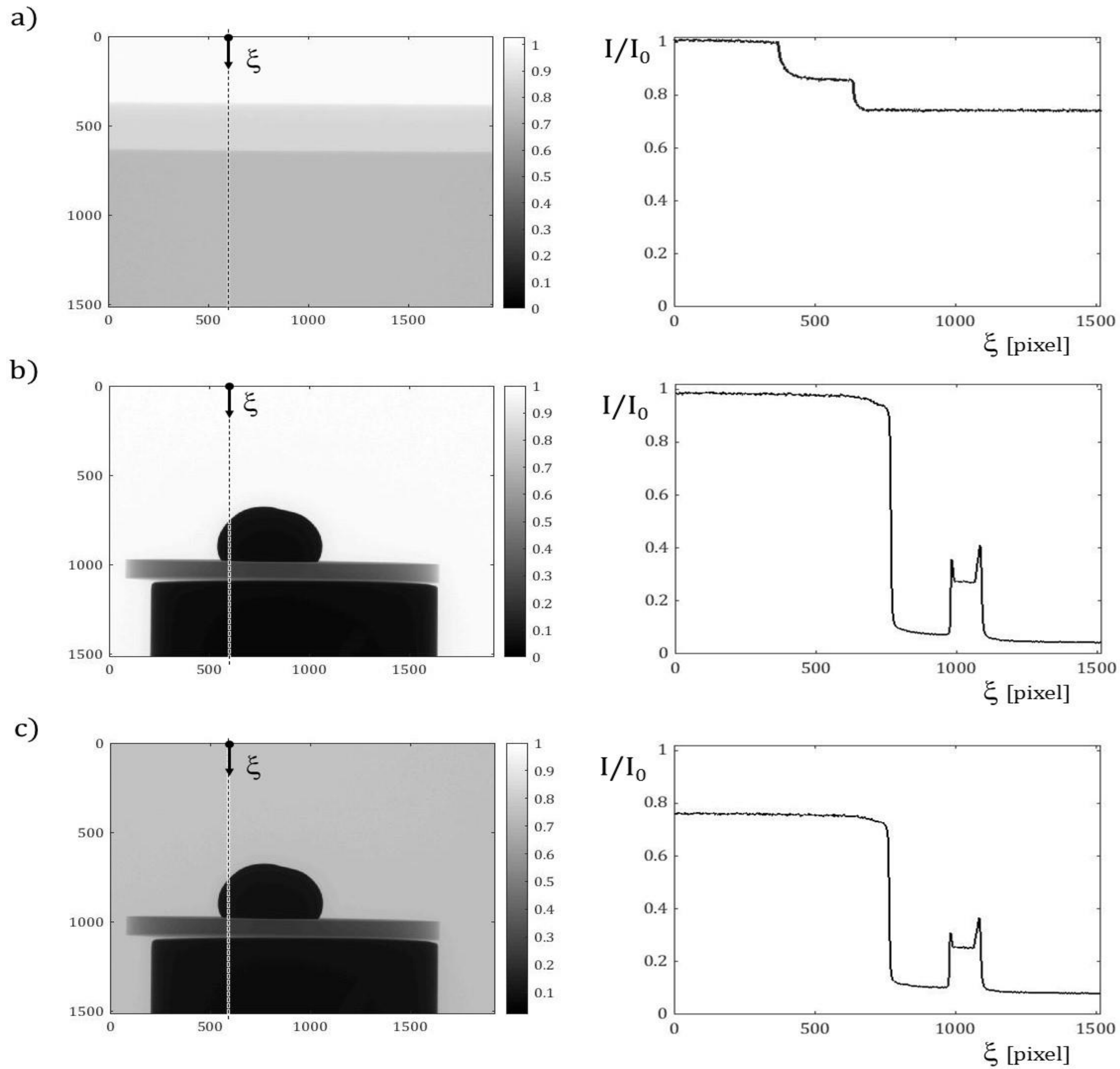


AISI 304
stainless steel

outgassing critical issue!

Anchor basis (carbon steel)





Transmission tests

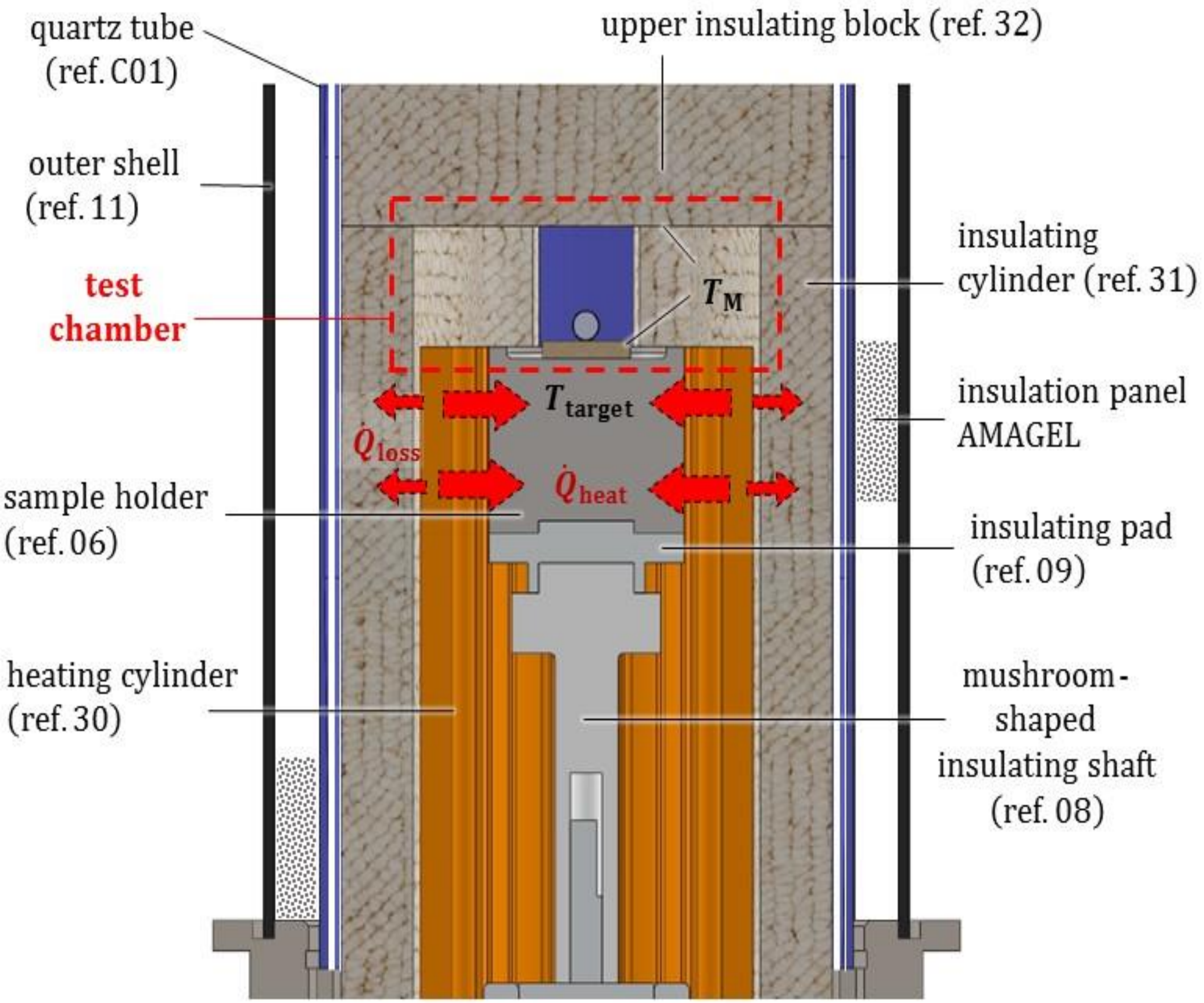
Ag solid droplet, 5 mm diameter; sapphire disc substrate

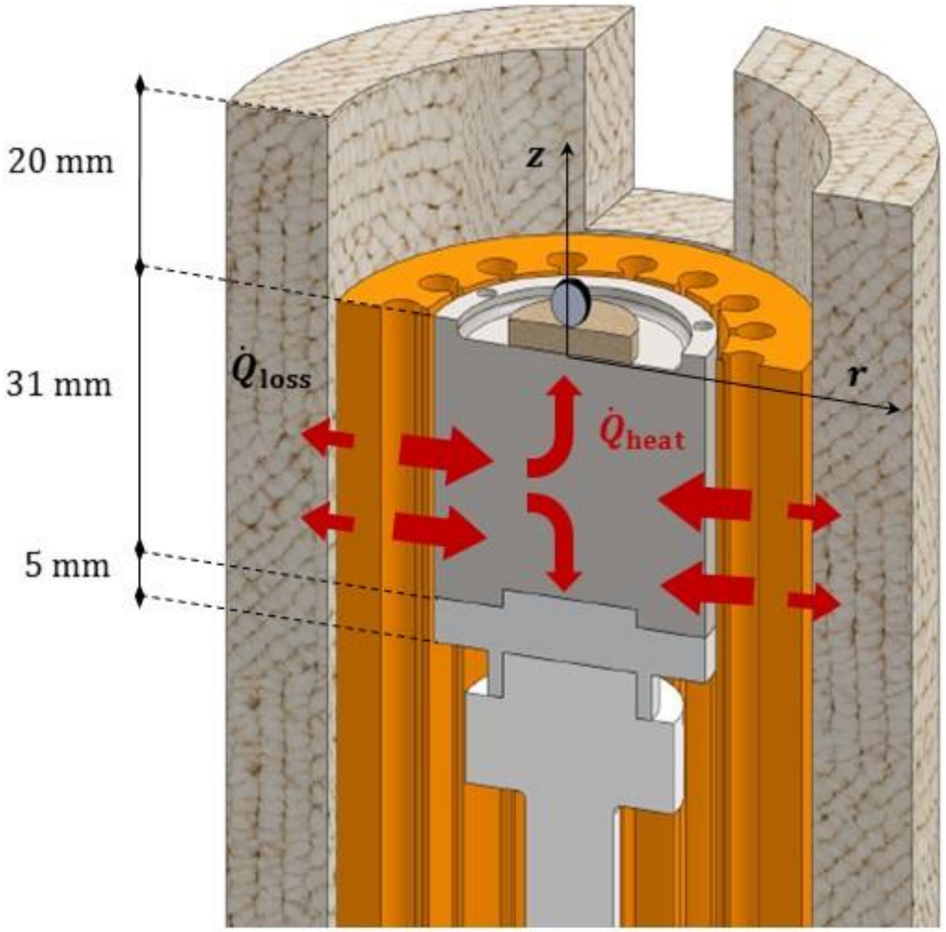
Beer-Lambert law

$$I(x) = I_0 \, e^{-\mu x}$$

Material	X-Ray Linear Attenuation Coefficient μ [cm^{-1}]
Fused quartz glass	0.684
Air (dry)	0.000254
Ar (Argon)	0.00109
Al_2O_3 (Alumina)	1.14
Ag (Silver)	92.1
Cu (Copper)	21.61

Heating mechanism

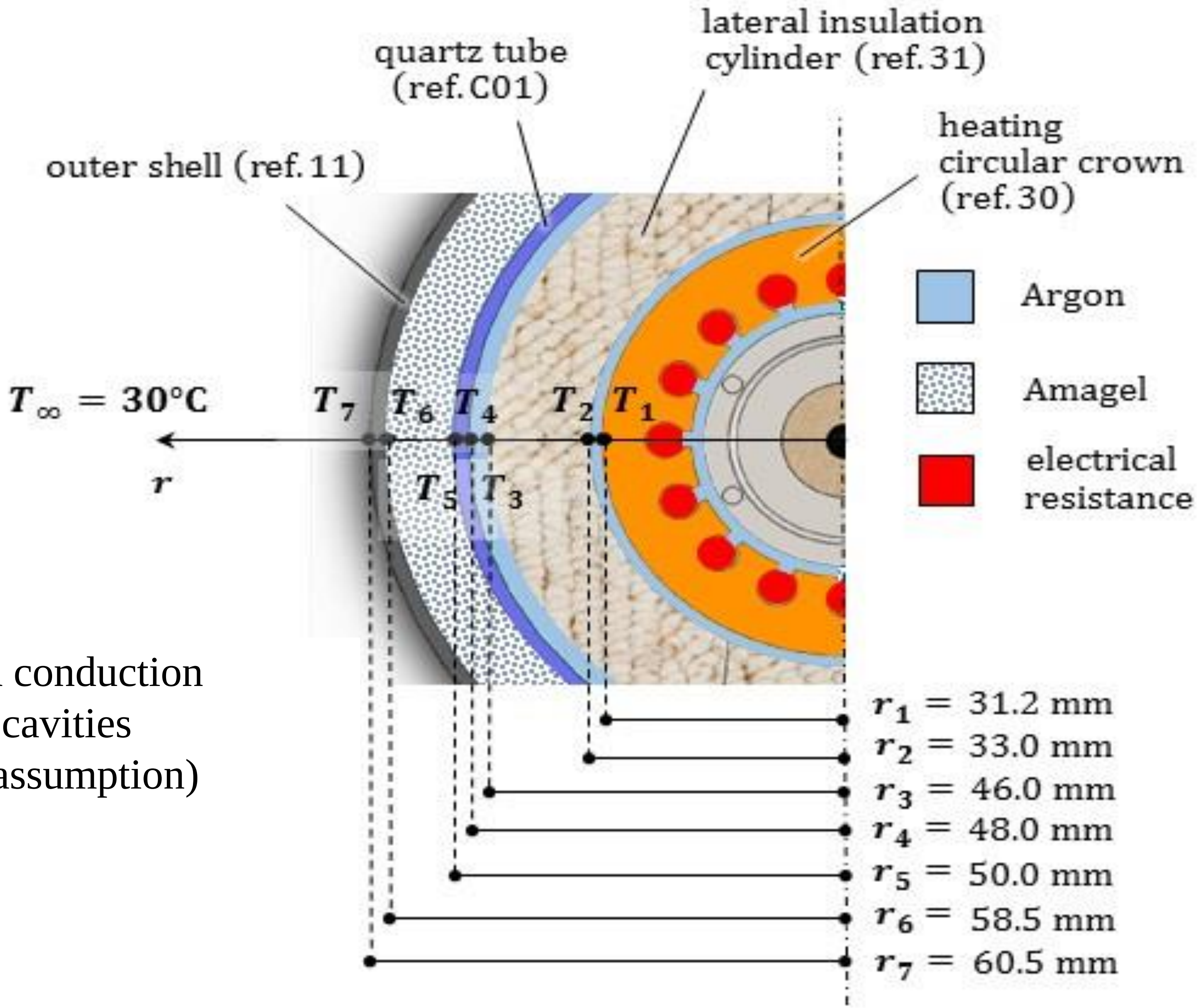




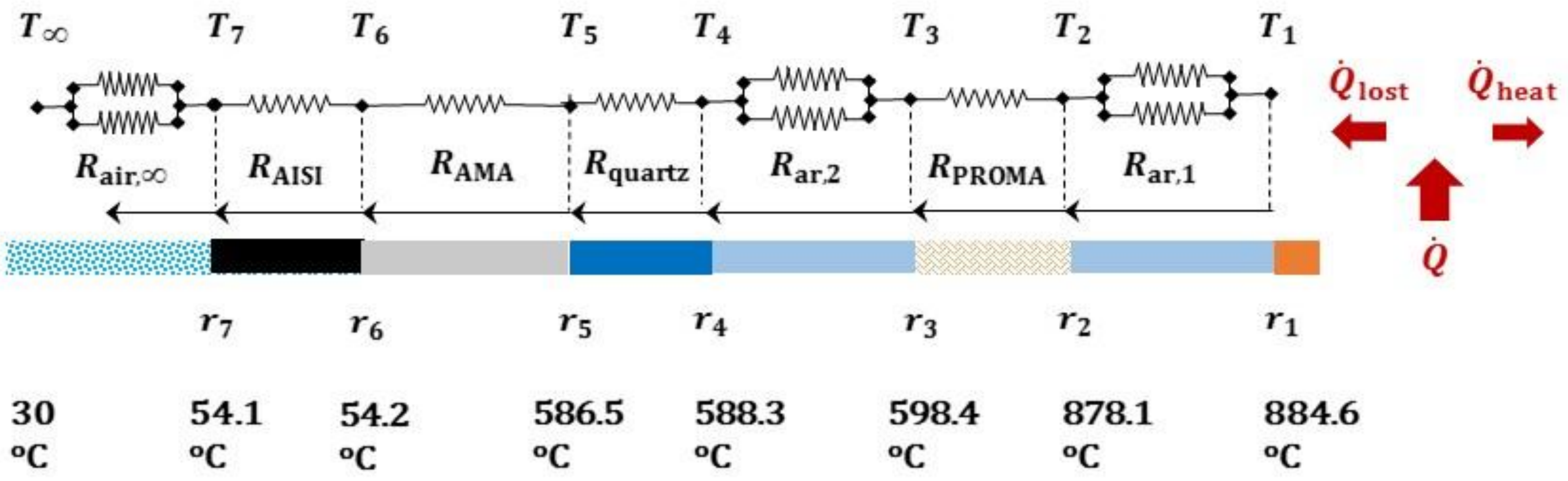
Radial heat transfer approximation

(free or forced) convection over the outer shell

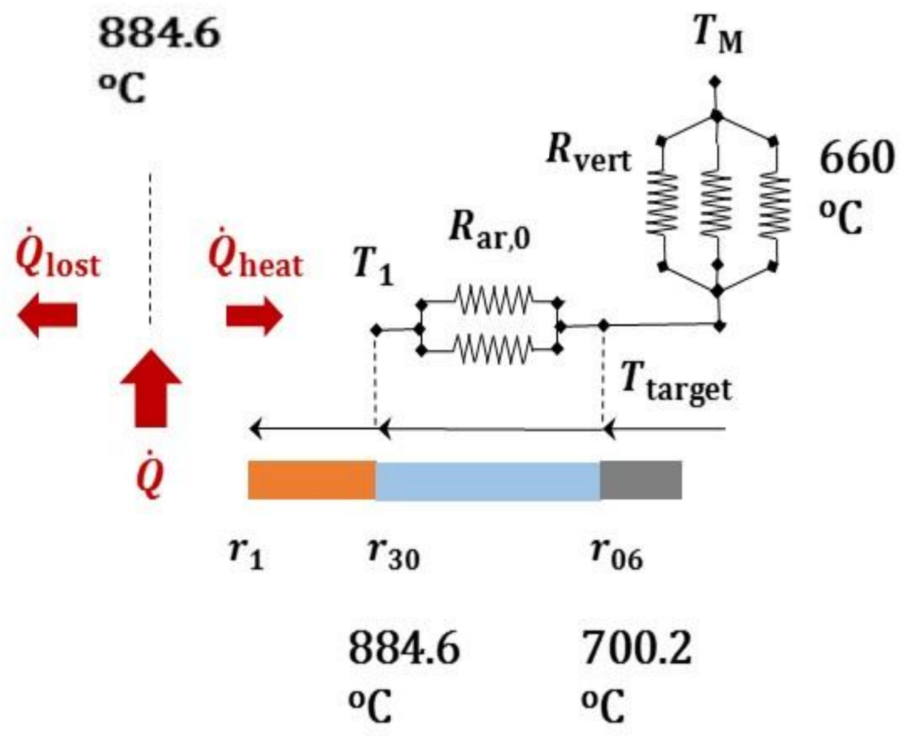
radiation and conduction within small cavities (quiescence assumption)



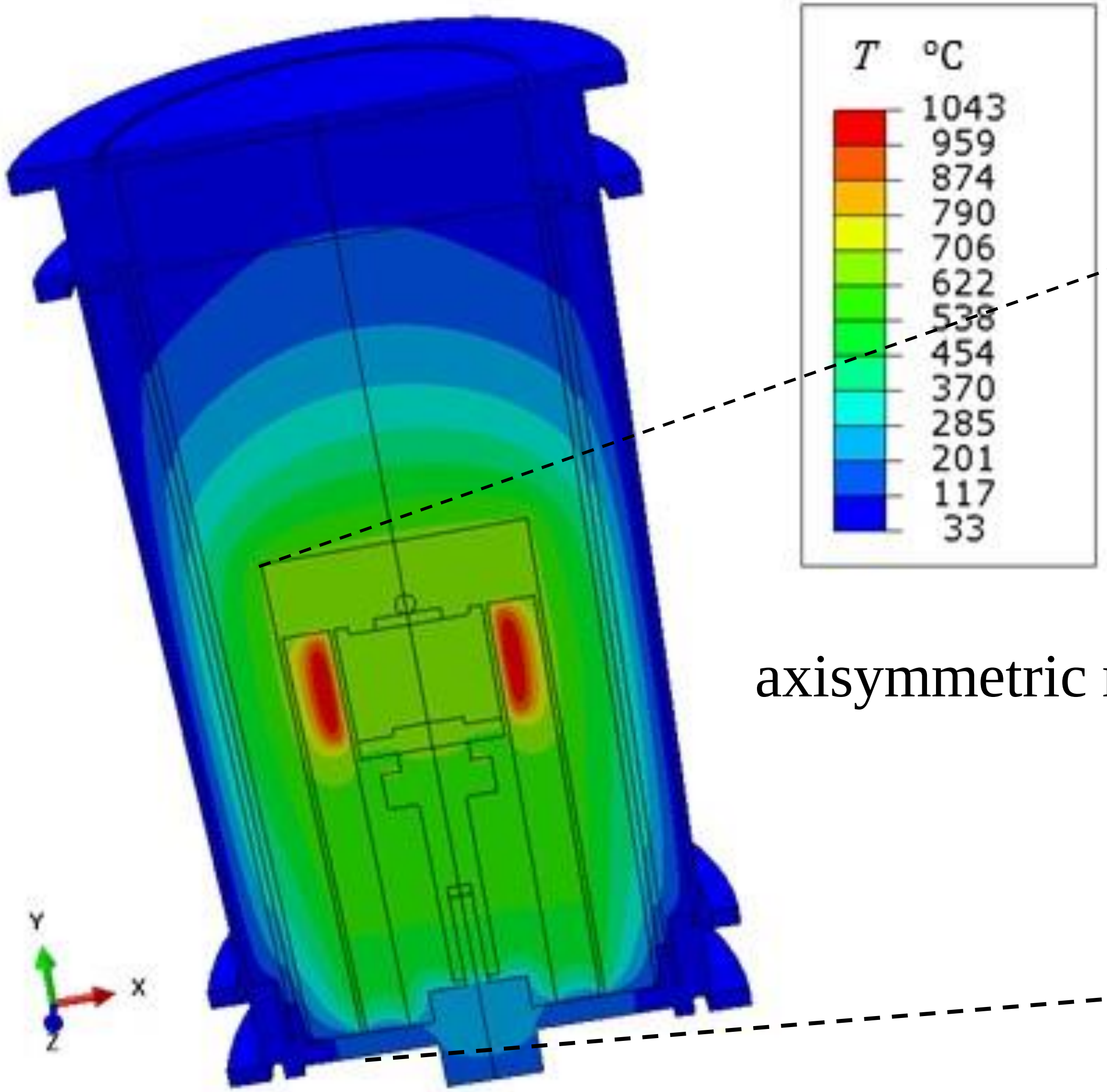
Thermal resistance network for steady state temperatures



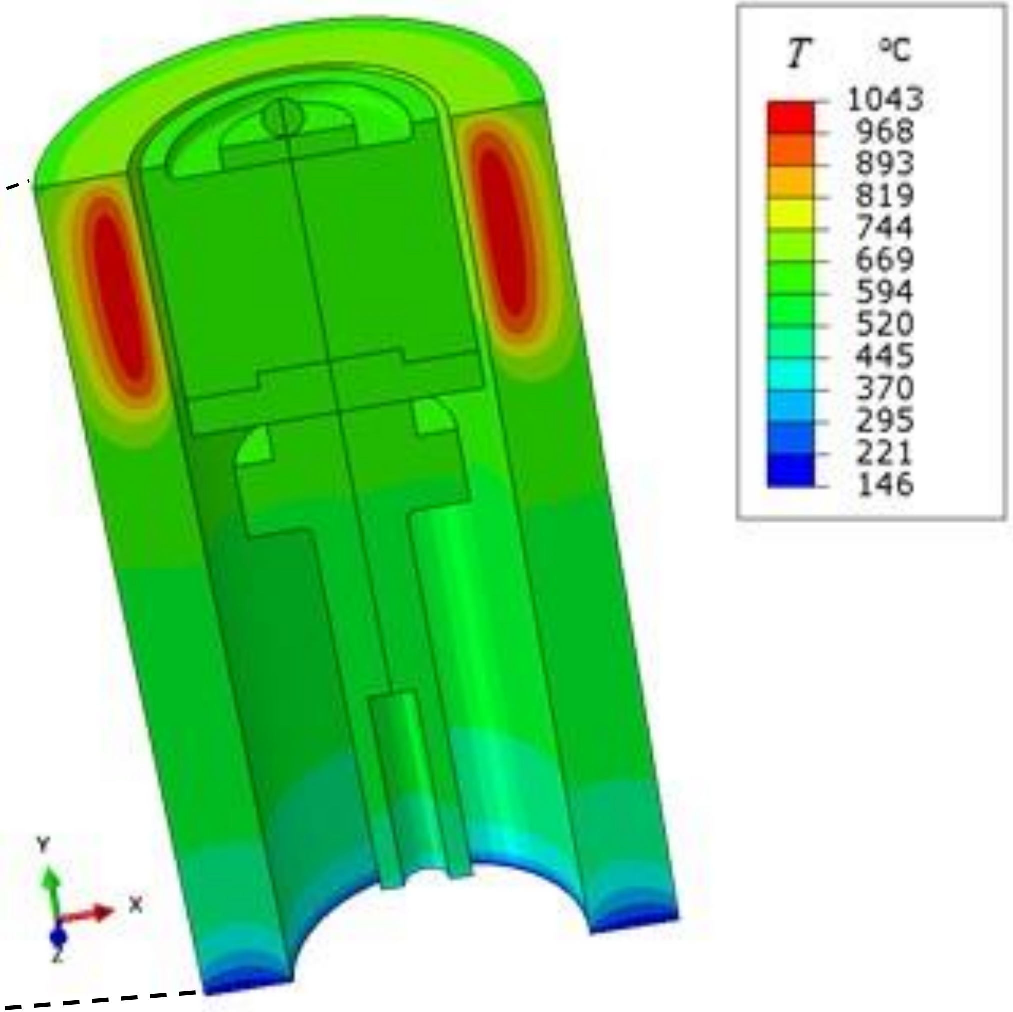
$$\dot{Q}_{lost} = \frac{T_1 - T_\infty}{R_{tot,ins}}; \quad \dot{Q}_{heat} = \frac{T_M - T_1}{R_{tot,heat}}; \quad \dot{Q} = \dot{Q}_{lost} - \dot{Q}_{heat};$$



Steady state finite element analysis by Abaqus®



axisymmetric model



no convection inside the inner cavities,
requiring CFD simulations!

Closing remarks and future prospects

Prototype was realized after an accurate design, selection of materials and technological solutions, under a limited budget.
(Fedele et al. J. Imaging **2021**, 7, 240)

Several issues still need be addressed by a wide experimental campaign:

(i) thermal insulation and inert gas atmosphere

(ii) stability of the rotating droplet

(iii) accuracy of 3D reconstruction of the droplet

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