THE DESIGN OF A 2 M LONG COPPER LIGHT EXTRACTION VESSEL AT DIAMOND LIGHT SOURCE FOR THE DIAMOND-II UPGRADE

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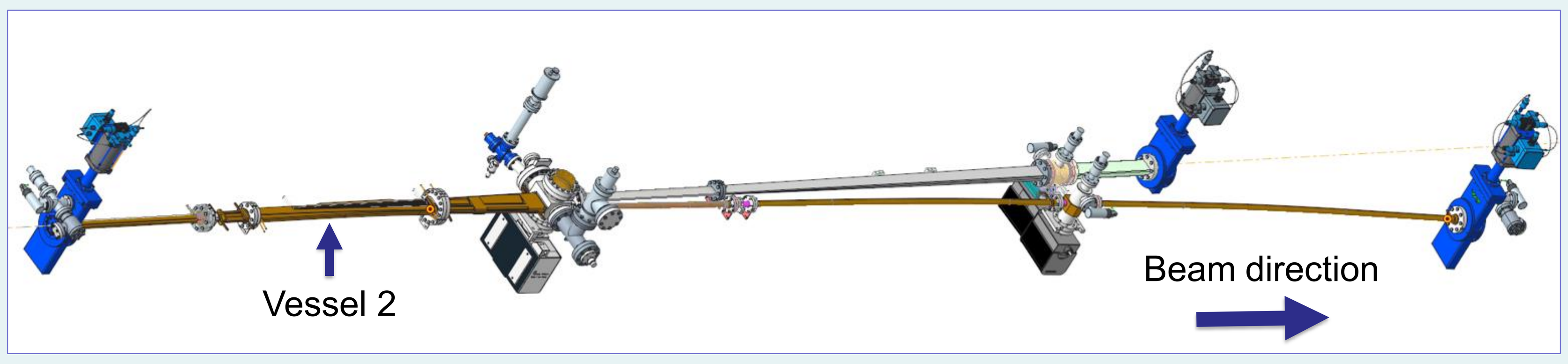
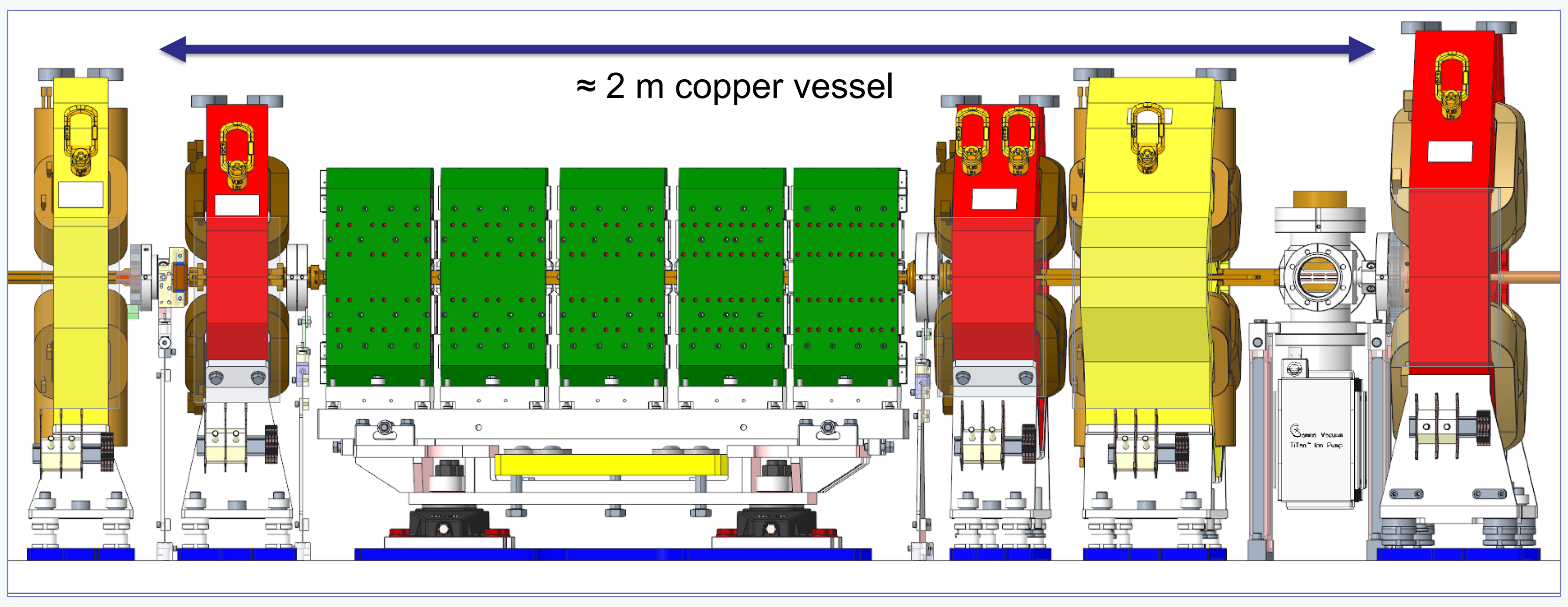
Abstract

In Diamond-II storage ring, there are 4 main types of arc girder vessel strings: MS, SM, ML and LM girder vessel strings. The most challenging case is the LM girder vessel 2 for I05 light extraction. The main challenges associated with the design of this vessel at that particular location are, firstly, the heat loads of I05 beamline upgrade involving the installation of a powerful and highly divergent APPLE-knot quasi-periodic insertion device. Second aspect is the requirement of a homogeneous NEG (non-evaporable getter) coating on the complex internal geometry of the vessel. Initially, an aluminium vessel with two copper absorbers and discrete ion pumps was considered but further studies have shown the concept was not capable of handling high heat loads making the aluminium vessel arrangement an unworkable solution. Therefore, it was decided to change the design concept from an aluminium vessel to a copper vessel. The main difference between two concepts is that the copper vessel has integrated absorbing surfaces instead of discrete absorbers. Due to the change, it was possible not only to reduce the power densities of the absorbing surfaces, but also it allows to move the active cooling directly on the high heat loaded areas. FEA analysis shows the peak temperature is reduced from 446°C to 71°C for the copper vessel as compared to the aluminium vessel discrete absorbers. The change from an aluminium vessel to a copper vessel will not only reduce the peak temperatures, but has the added benefits of improved vacuum performance, reduced beam impedance, reduced capital and operating cost, as well as reduced manufacturing risks due to splitting of vessels into three sub-vessels.

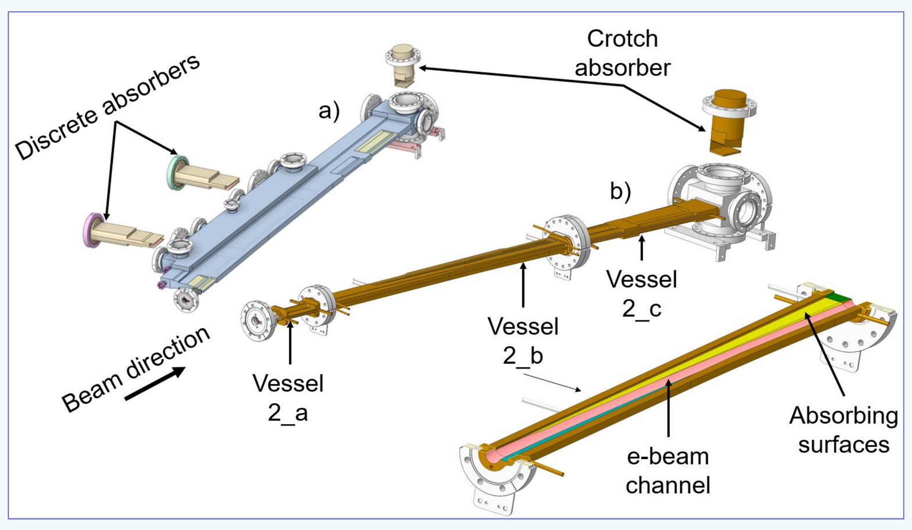
LM Girder Magnets and Vessels Arrangement

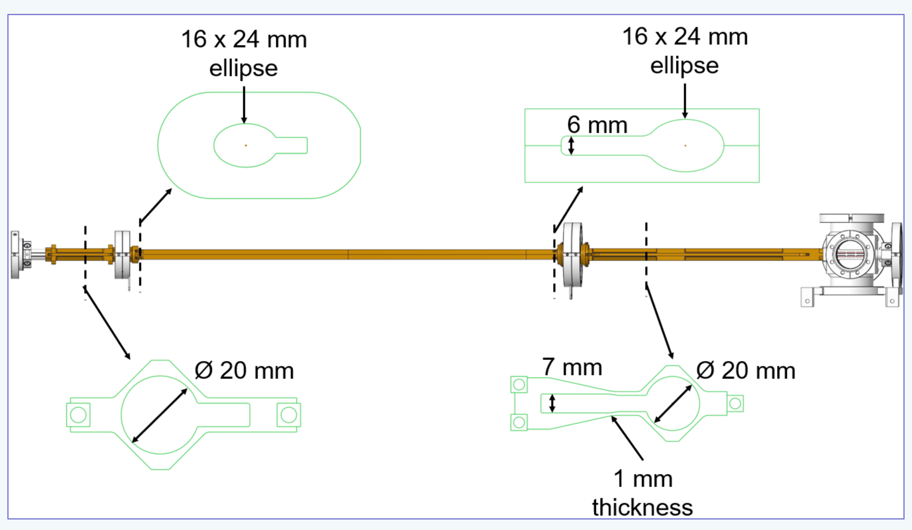




Design and Prototyping

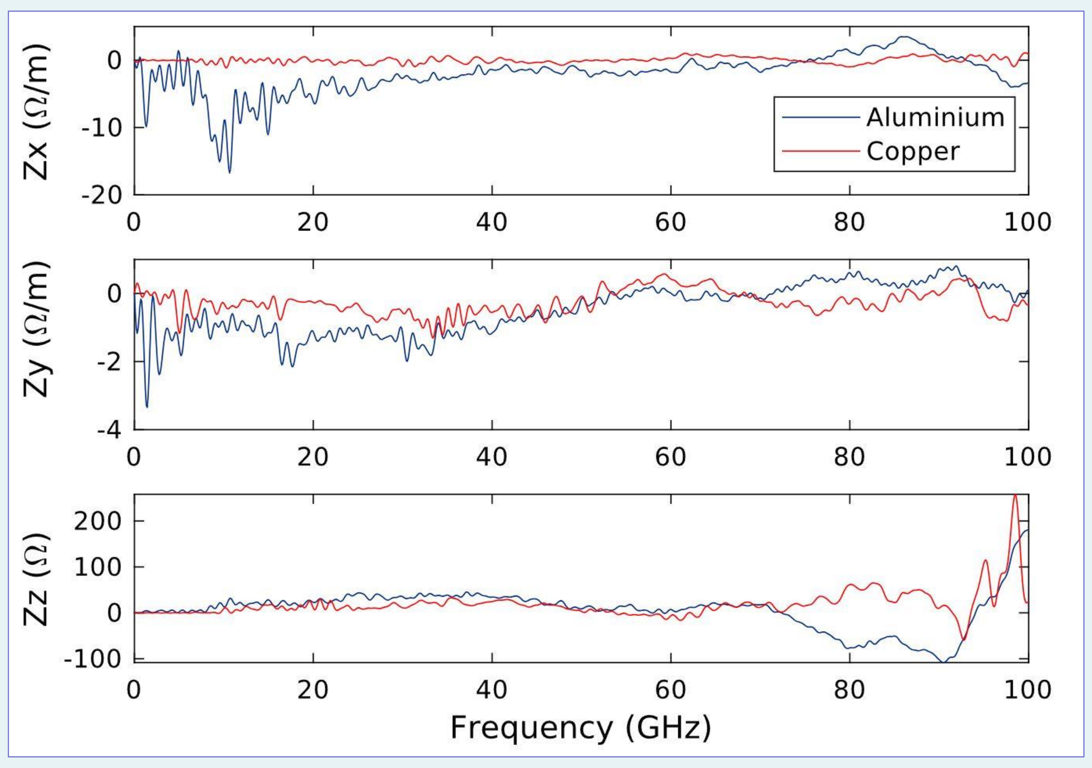
- Upstream flange bellows:+2 mm extension, -5 mm compression, and ±0.25 mm lateral offsets
- Two sets of beam position monitor (BPM) buttons at the entry and exit flanges
- The copper vessel design is comprised of 3 separate sub-vessels: vessel 2_a, 2_b, and 2_c, where **vessel 2_b** is the highest heat loaded section
- Min. internal height of the vessel is 6 mm (NEG coating limitation). Min. wall thickness is 1 mm
- Prototyping is divided into two directions: NEG trials and full prototype vessel manufacturing, both in progress





Beam impedance and Vacuum Simulations

Comparison of the real transverse and longitudinal impedances



Wakefields and impedance were calculated for the two vessel designs using CST Studio. A bunch length of 1 mm and wake length of 300 mm were used for the simulations. The copper vessel has significantly reduced impedance, especially at low frequencies in both transverse planes. This is especially important in the horizontal, where the aluminium design for this vessel was one of the most significant contributors to the total storage ring impedance.

Loss and kick factors for two designs

	kx V/pC/mm	ky V/pC/mm	kz V/pC
Aluminium	-0.1206	-0.0284	0.2378
Copper	-0.0021	-0.0063	0.0778

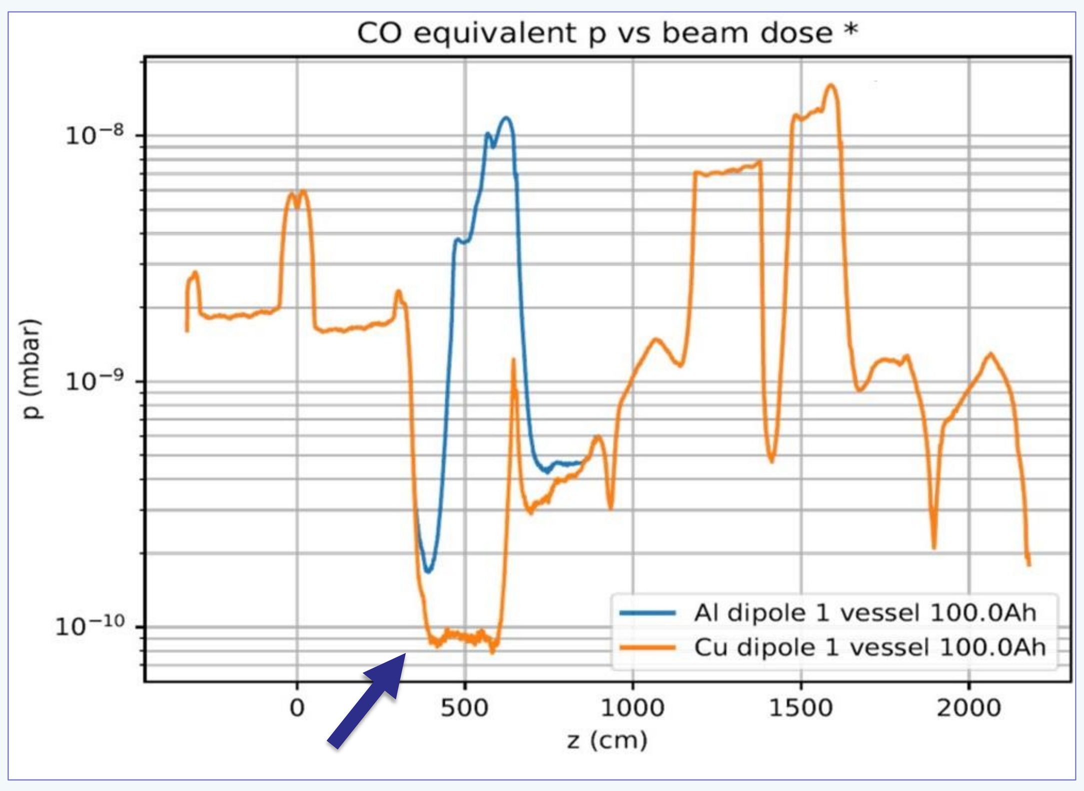
The horizontal kick factor is reduced by a factor of ≈ **60** for the copper design.

Monte-Carlo dynamic simulations were carried out for the two vessel designs using Synrad and Molflow. Firstly, Synrad was used to model the synchrotron radiation photons incident on the vessel wall including reflections. Molflow was then used to calculate the pressure distribution along the electron beam path, taking into account photon stimulated desorption. This was carried out for the 4 main residual gases (CO, H_2, CO_2 and CH_4) and for a range of beam conditioning doses in Ampere.hours.

Design target of average pressure is 10^{-9} mbar or lower

The pressure in LM vessel 2 is reduced from 10^{-8} mbar to 10^{-10} mbar after 100 A.h with an electron beam current of 300 mA.

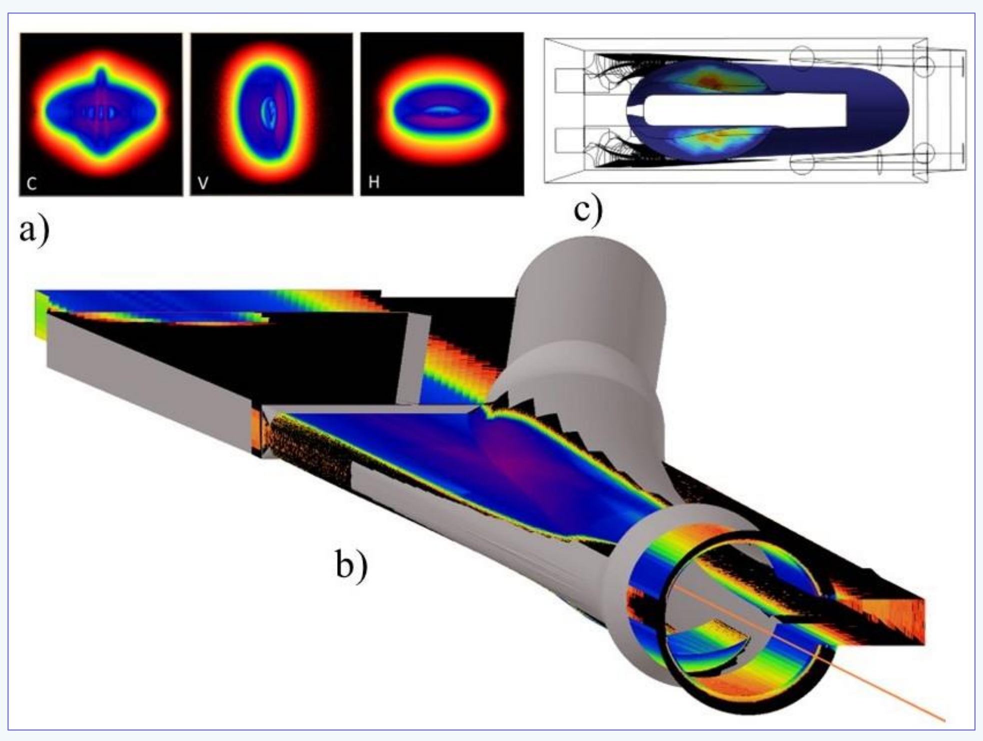
Calculated pressure vs. distance curve along the entire machine cell



Ray Tracing and Finite Element Analysis

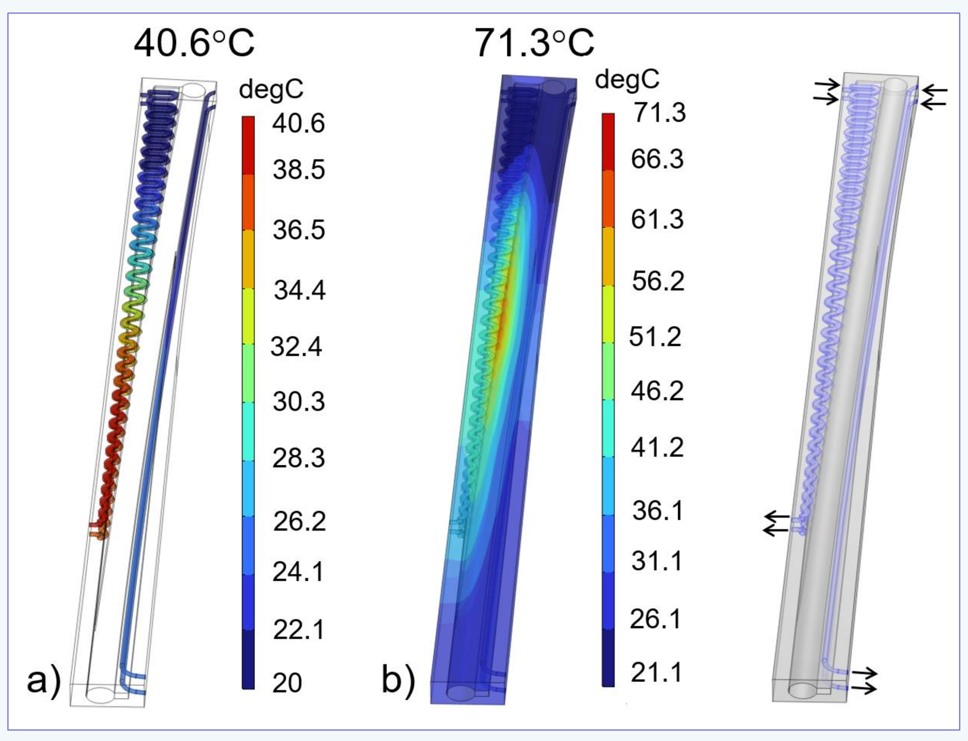
Simulation procedure

a) I05 APPLE-knot Quasi-periodic ID power density, 3 polarisation modes with a period of 140 mm and 10 eV minimum electron energy
b) Ray tracing onto vacuum vessel, circular mode
c) Projected wall power density in ANSYS



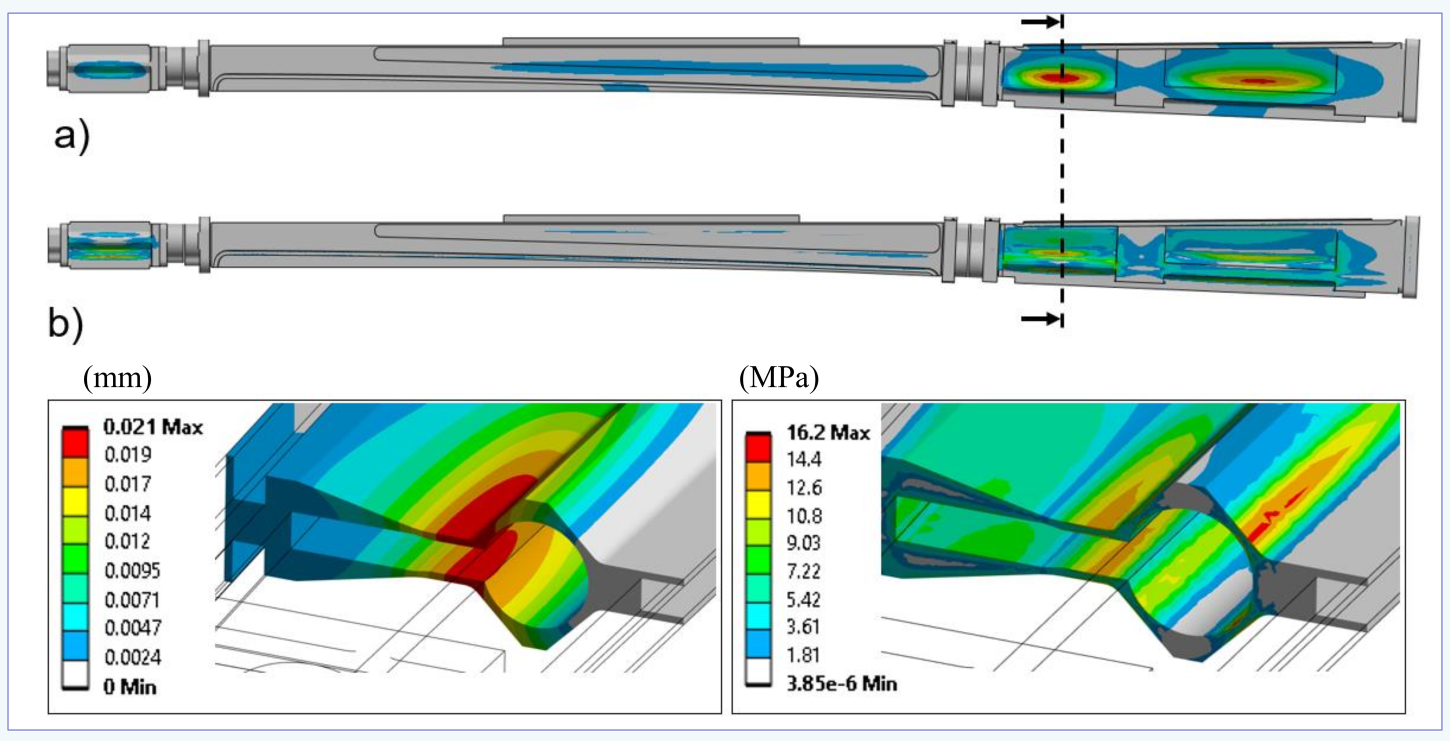
COMSOL Simulations

Max. vessel wall temperature for the circular mode is **71°C** (446°C for Al. vessel) for a total heat load of **7 kW** and peak (absorbed) wall power density of 4 W/mm²
a) Coolant temperature, b) vessel body temperature



ANSYS Simulations

Static structural FEA analysis have been performed to identify maximum deformations and stresses due to atmospheric pressure loading of copper vessel around the thin-walled regions.
a) maximum deflection 21 µm, b) maximum von-Mises stresses 16 MPa



Conclusion

A workable solution of LM girder vessel 2 was developed for Diamond-II storage ring, which is capable of handling the heat load of a new APPLE-knot insertion device. Peak temperatures of the copper vessel have been reduced from 446°C to 71°C compared to the previous concept. The beam impedance and average vacuum pressure around vessel 2 was significantly improved. NEG coating trails and the full prototype vessel manufacturing has already been commenced. The intention is to implement the light extraction copper vacuum vessel of the LM girder onto the remaining MS, SM and ML girder designs. The intention is to implement the same concept of the copper vessel onto the MS, SM and ML girder designs.

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