Characterisation of additively manufactured synchrotron radiation absorber

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Overview

FCC-ee is a proposal for 92 km circumference twin ring which would generate a synchrotron radiation (SR) power of 50 MW/beam[1]. Design studies call for the SR fan to be intercepted every ~5m with localised absorbers[1]. Comparing to the continuous design (when the SRA channel is located all around the ring), this design is advantageous due to faster conditioning of the vacuum chambers and lower material and manufacturing costs[1]. Proposed design uses turbulent water flow to remove generated heat[2]. Additive manufacturing is a novel technology which enables us to achieve complex structures in shorter time and with lower material consumption, it's use is rapidly increasing within accelerator community[3]. The work currently done in I.FAST collaboration includes building prototypes, validating the design as well as manufacturing methods for use in the FCC-ee.

The Synchrotron Radiation Absorber

The thermal absorber was designed by M. Morrone, C. Garion, R. Kersevan, S. Rorison, P. Chiggiato of TE-VSC[2]. It inculdes an innovative inner twisted tape design which should create turbulent flow and increase the amount of thermal energy removed by the SRA[2]. The first prototypes procured are 95mm, in scale 1:1 to perform tests and prove green Laser Powder Bed Fusion (LPBF) additive manufacturing process technology is suitable for accelerators. The additive manufacturing (AM) technology is neccesary due to complex geometry, traditional methods are not suitable for this design.

The absorber sample was manufactured using LPBF technology out of pure copper powder by Fraunhofer IWS through I.FAST partnership (*Photos courtesy of Fraunhofer IWS*)

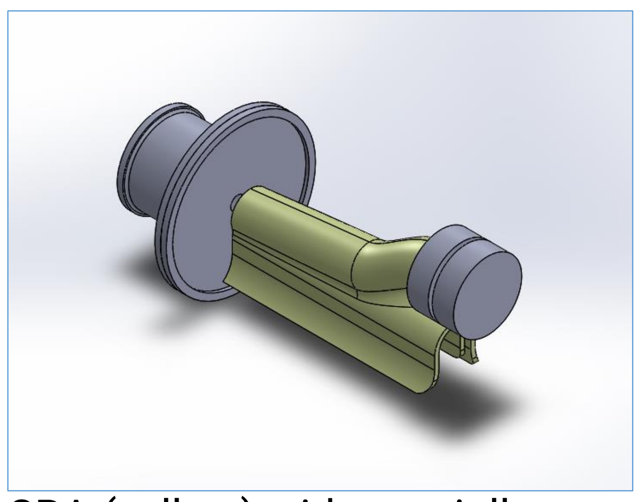
During visual inspection small deviations from the model can be observed, they are unlikely to interfere with final work in sample

Differences can be observed between laser and wire-cut finishes

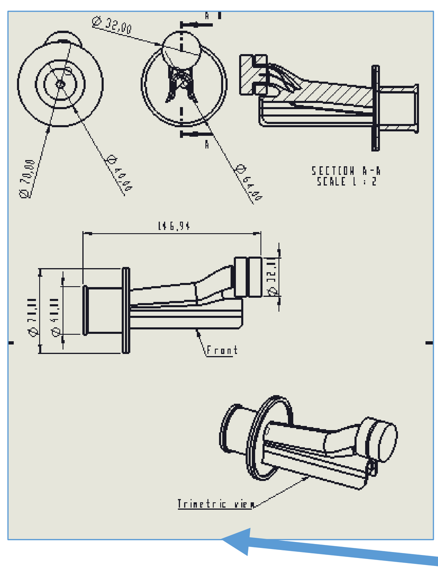
Helium leak tightness test setup

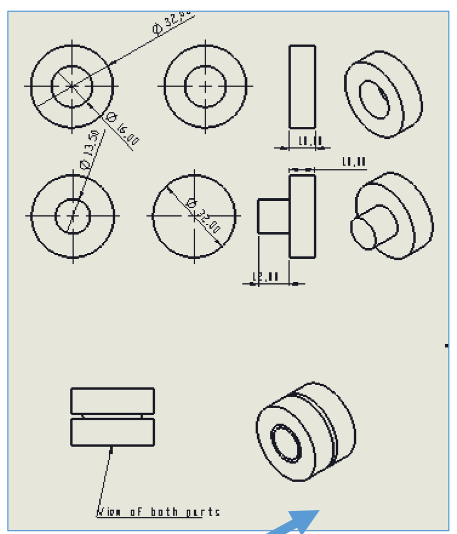
Helium (He) leak tightness test is necessary to validate the part and additive manufacturing method for ultra high vacuum (UHV) environment.

The method of measurement includes attaching the SRA to the leak detector (Leybold Phoenix 300i) with specially designed fittings, injecting He inside the channel and observing if the machine can detect traceable amount of He inside the vacuum chamber.

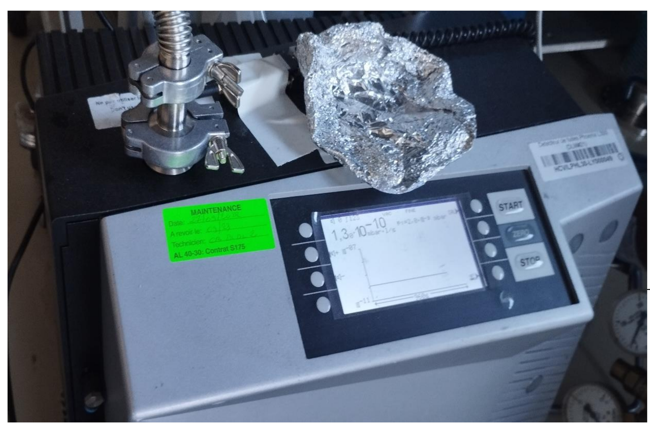


SRA (yellow) with specially designed tool (grey) for He leak test

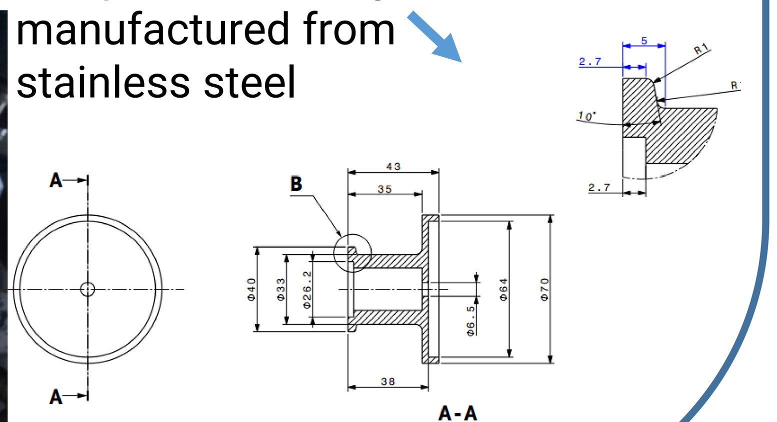




Leybold Phoenix 300i Leak detector with clamps and aluminium foil in sniffer mode

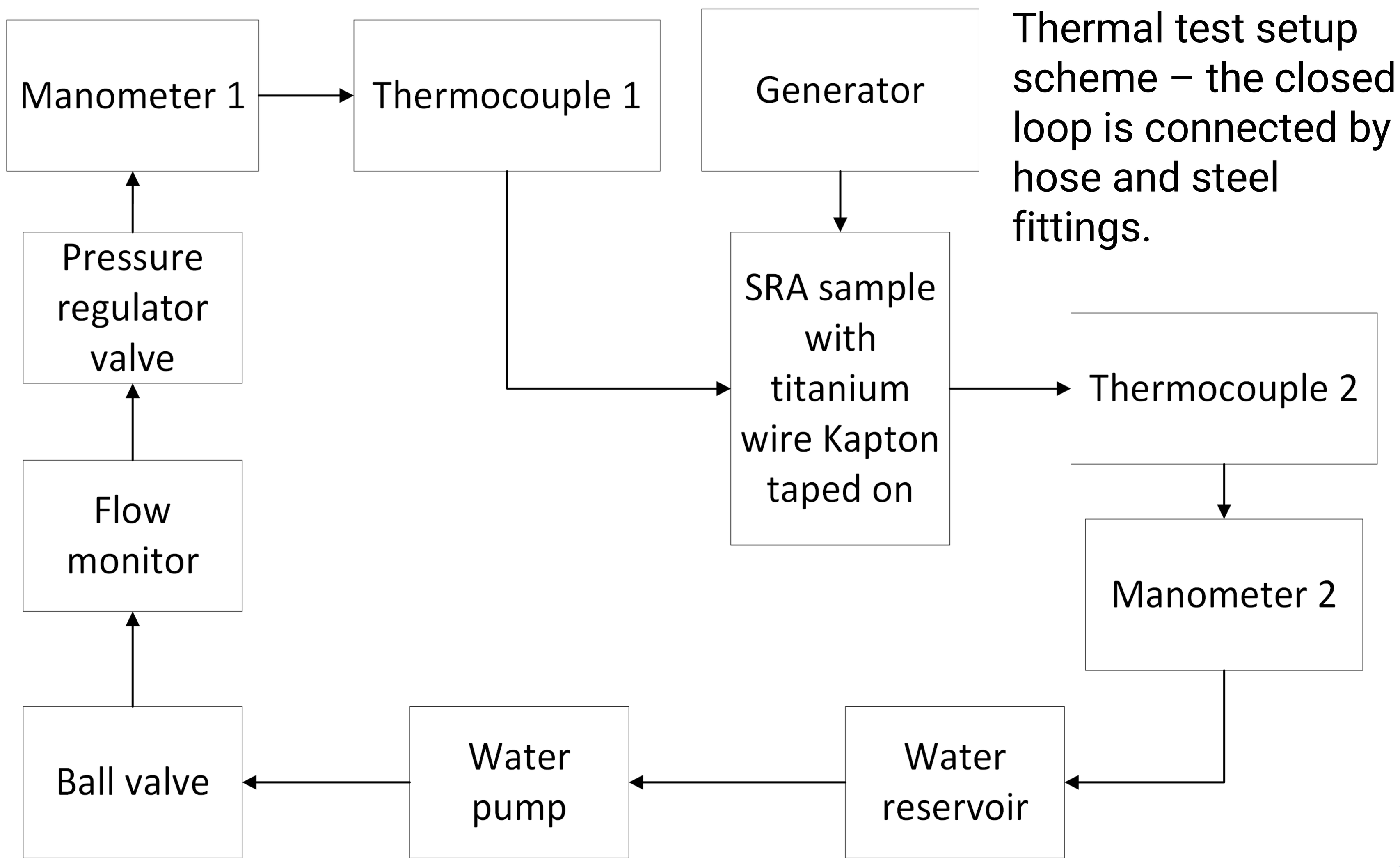


Blueprints of fittings to be manufactured from stainless steel



Heat transfer test setup

In order to test the thermal capabilities of the SRA, a heat transfer test is necessary. We will carefully monitor the water flow rate (approx. 5 m/s is expected), water pressure (no more than 3 bar) and temperature at inlet and outlet[2]. The predicted inlet temperature is 27 C°, while outlet temperature should not exceed 35 C°[2].

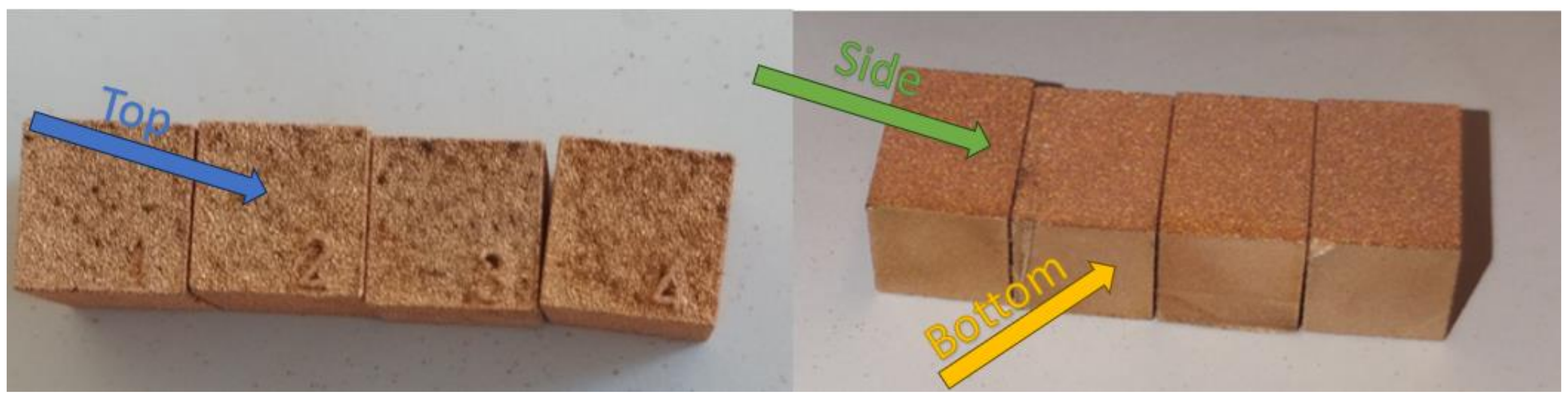


Thermal test setup scheme – the closed loop is connected by hose and steel fittings.

Further steps of investigation

To fully determine the suitability of design and manufacturing method for the needs of FCC-ee further tests are planned in the upcoming months (2023 07-08):

- 3D visual scan and additional computed tomography testing
- Tensile (stress/strain) testing samples prepared according to the E8 standard
- Outgassing test
- Density measurement
- Hardness testing
- Surface structure analysis using scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) methods



References:
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This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.