Study on Thermal Mechanical Design and Optimization Analysis for the ALBA Infrared Microspectroscopy Beamline (MIRAS) Extraction Mirror Based on Finite Element Analysis

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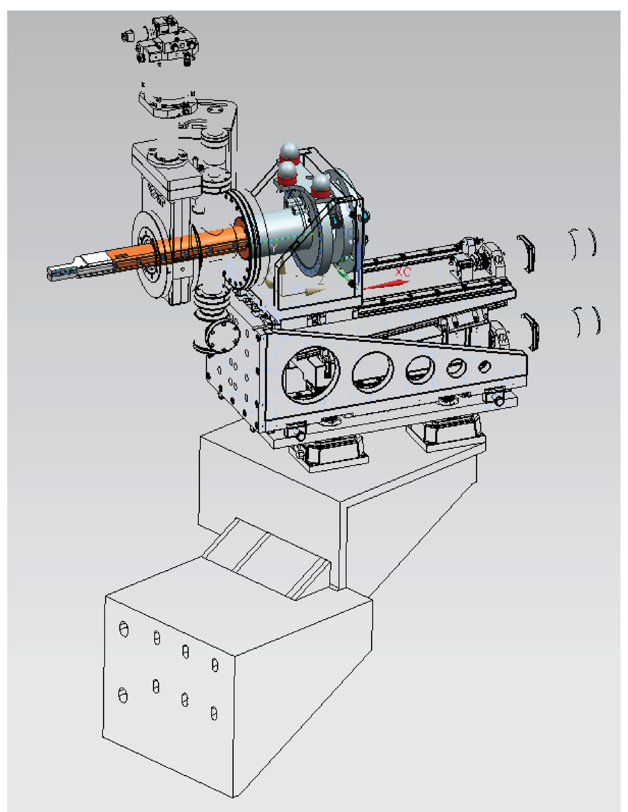
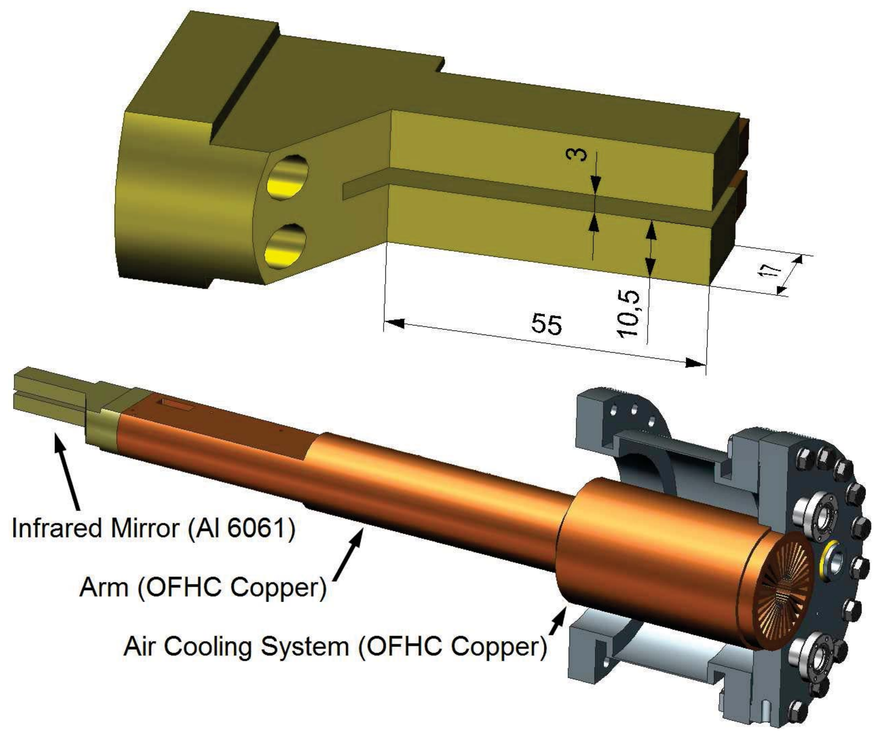
Abstract

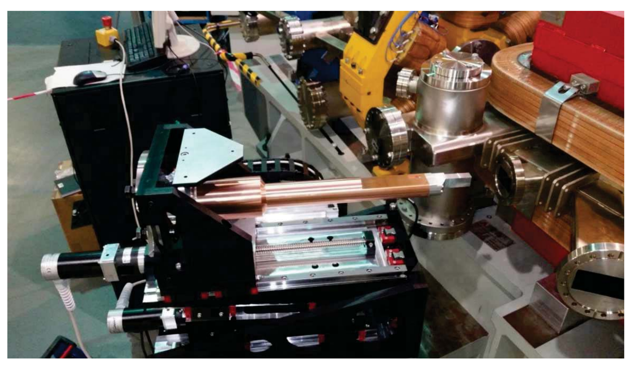
This paper reports design, modelling, simulation and optimization results for the ALBA MIRAS infrared radiation extraction mirror. Finite element analysis (FEA) was used to simulate the thermal mechanical behaviour of the device. With the aim to ensure a good thermal performance, conservative assumptions were applied: all of the incident Bending Magnet (BM) radiation is absorbed at the mirror surface, constant bending magnetic field and low thermal contact between the mirror Al 6061 and the OFHC copper arm. A novel solution has been implemented in order to provide an effective cooling by a natural convection on the in-air part of extraction mirror assembly. This has voided the necessity for a water cooling that often causes problems due to the associated vibrations. The power conditions were calculated by using SynRad+. The main ALBA Storage Ring design parameters are: 3 GeV, 400 mA and 1.42 T. According to these conditions, the mirror absorbs 15 W with a peak power density of 0.51 W/mm2. The peak temperature calculated was 63.2 ºC. The real measurements reported during the commissioning stage showed a good thermal performance, in agreement with the results predicted by FEA.

The ALBA Infrared Extraction Mirror

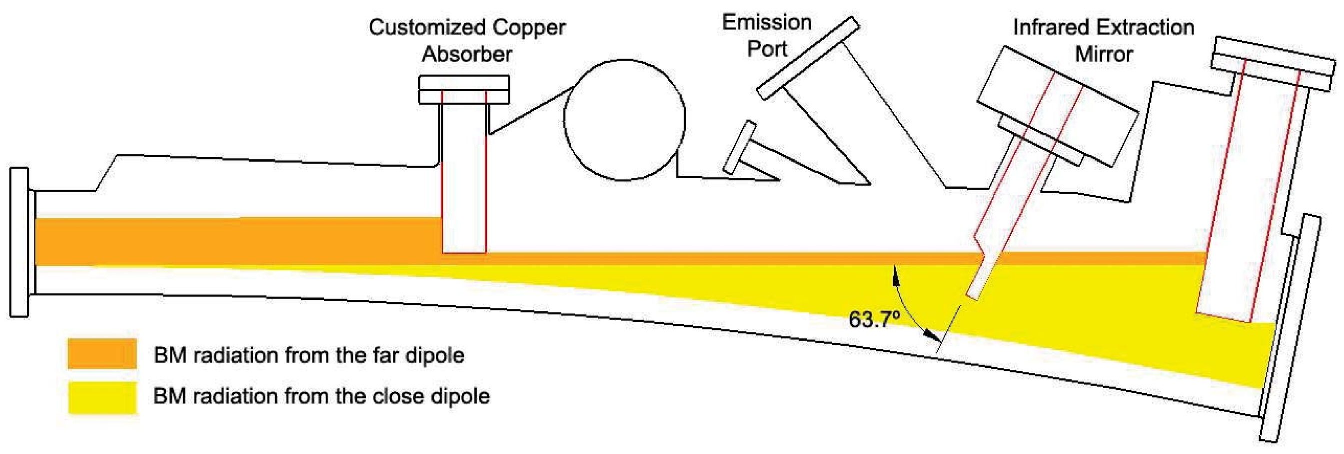
The ALBA infrared mirror is based on the slotted, non-cooled, type. The concept of the slotted mirror not only avoids interaction with the central high energy core of the dipole emissions, but also allows to realize a simple design that functions reliably without additional water cooling that often causes problems due to the associated vibrations .



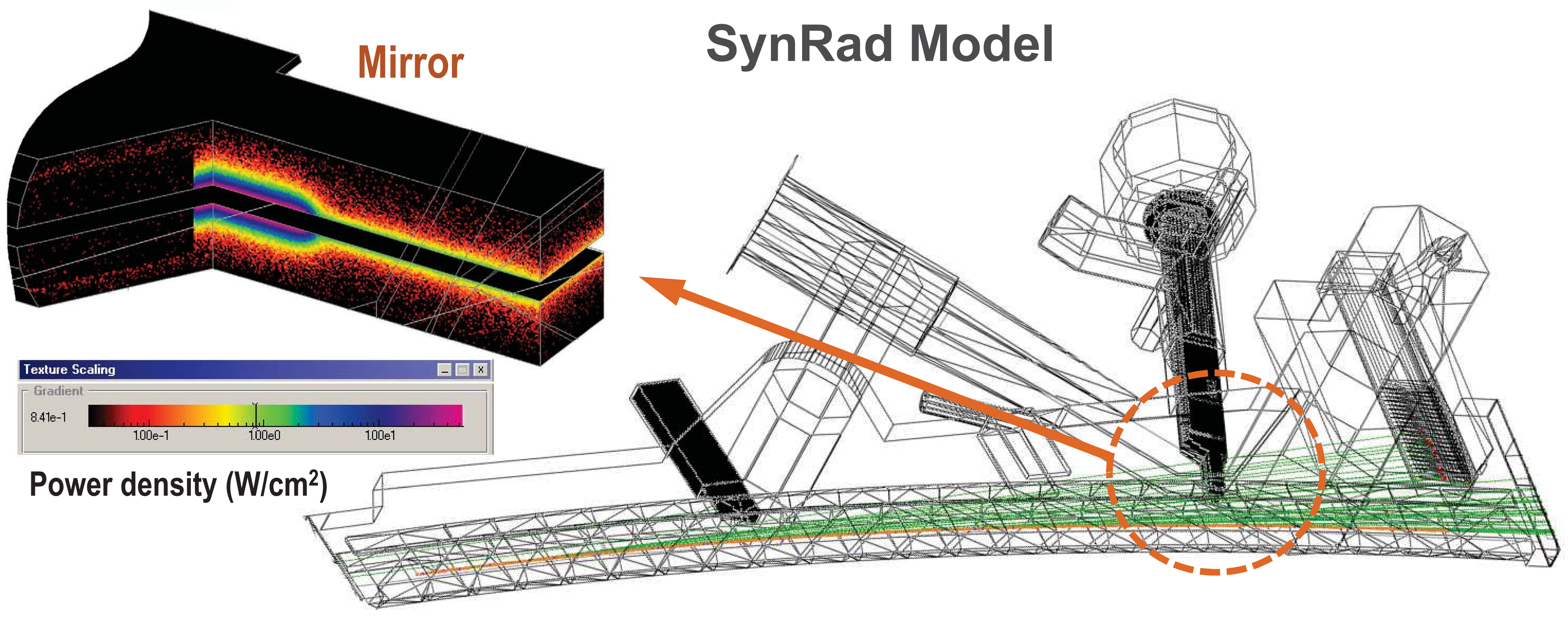




Ray Tracing and Power Deposition

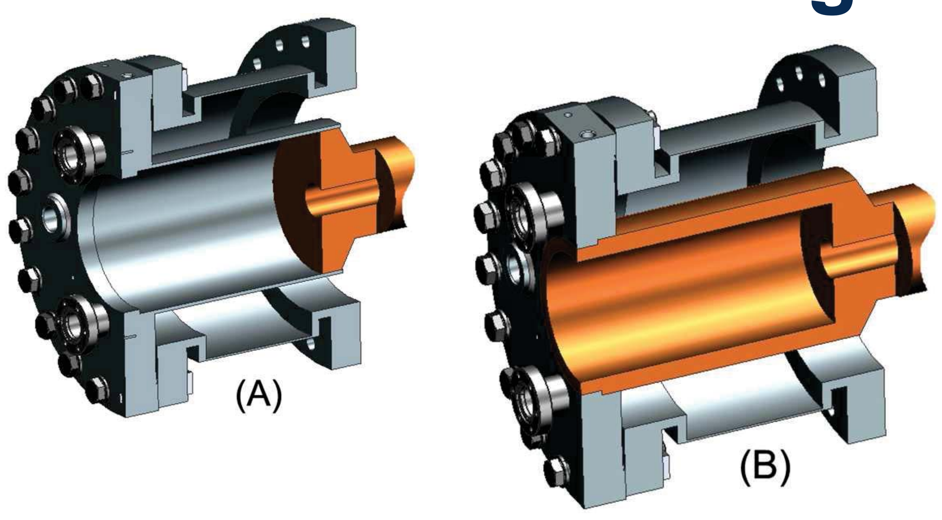


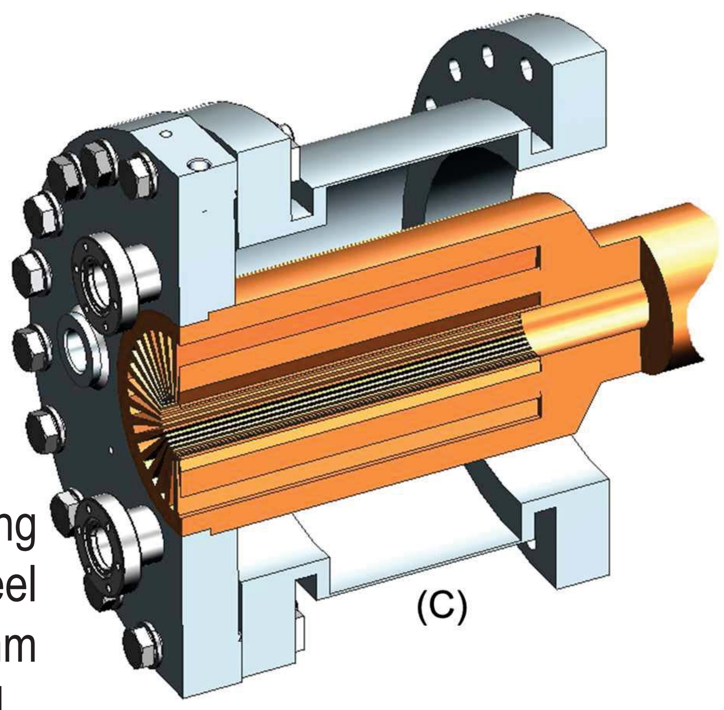
Ray tracing for MIRAS dipole chamber. The orange fan is the BM radiation coming from the far dipole chamber and the yellow zone is the radiation from the close dipole.



Surface power density distribution using the SynRad+ computer code.

Air Cooling Optimization



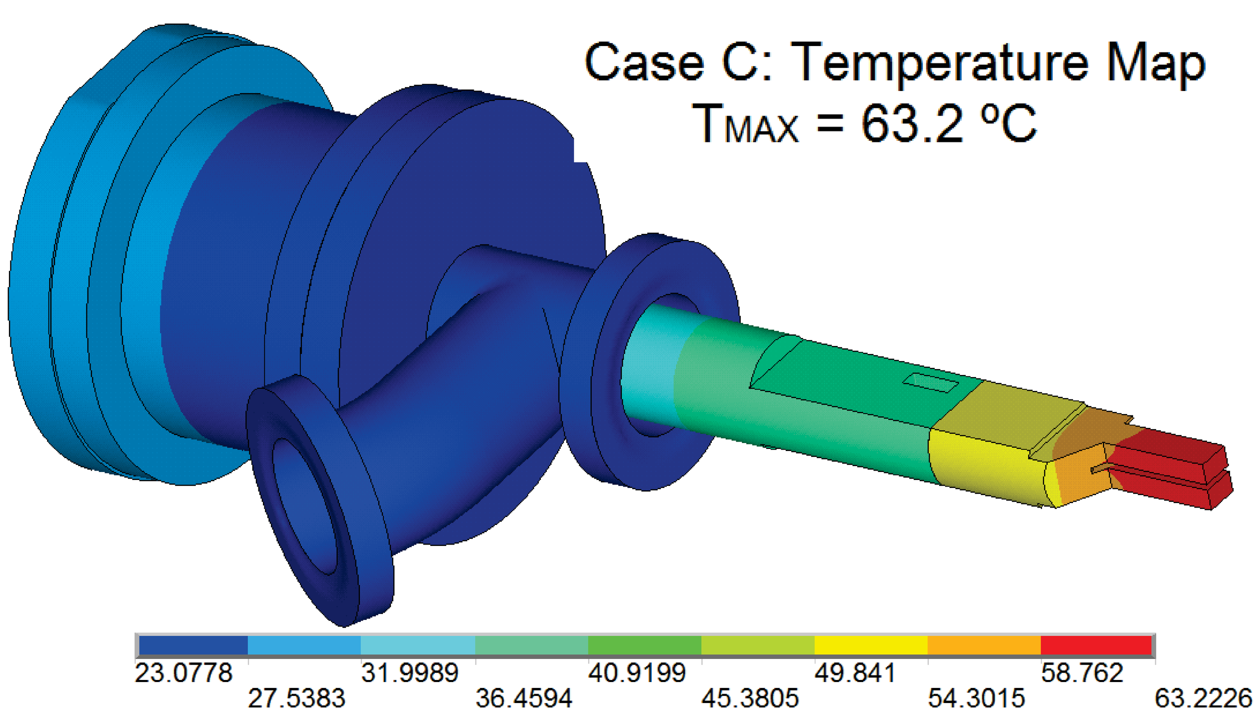


In order to enhance the heat dissipation on the air cooling system, three geometries are studied: A) Stainless steel cylinder, 2 mm wall thickness, B) Copper cylinder, 10 mm wall thickness, and C) Case B with internal fins attached.

FEA Results

Case C: Temperature Map

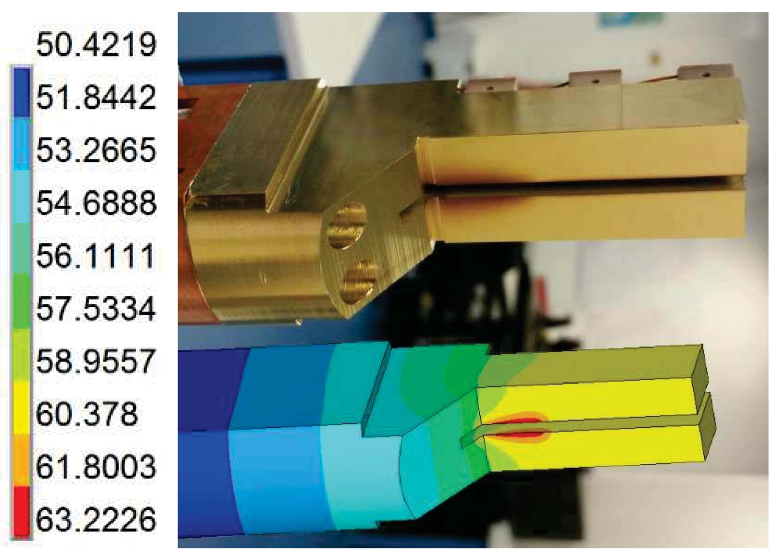
T_{MAX} = 63.2 ºC



Type	T_{MAX} (ºC)
Case A	125.6
Case B	76.6
Case C	63.2

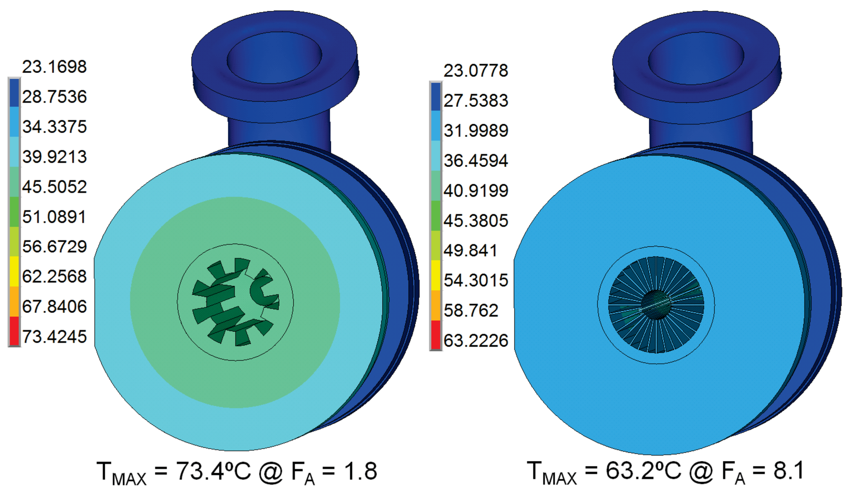
Temperature map on the mirror for case C. The peak temperature reached is 63.2 ºC. Figure shows the temperature distribution for the complete Infrared Extraction Mirror.

FEA Results



Case C. Included a real photo captured during the commissioning stage. The carbonized zone in the mirror matches the observed BM power deposition calculated by SynRad+. The local temperature measured in the body above the slot was 25.5 ºC with 130 mA. The FEA model predicts a range < 32 ºC.

Effect of fin surface on the temperature. This effect is studied by means of the variable F_A: ratio between the total fin surface and the case without fins.



F_A	T_{MAX} (ºC)
1.0	76.6
3.0	70.1
5.0	66.5
8.1	63.2

Conclusions

The measurements reported during the commissioning stage showed a good thermal performance of the mirror, and the results are in agreement with the conservative results predicted by FEA.

The case C has been found the most appropriate geometry in terms of maximum heat dissipation. This model has been designed and implemented for ALBA.

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