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HOST:

A Setup for the Evaluation of Thermal Contact Resistance at Cryogenic Temperatures under Controlled Pressure Rates

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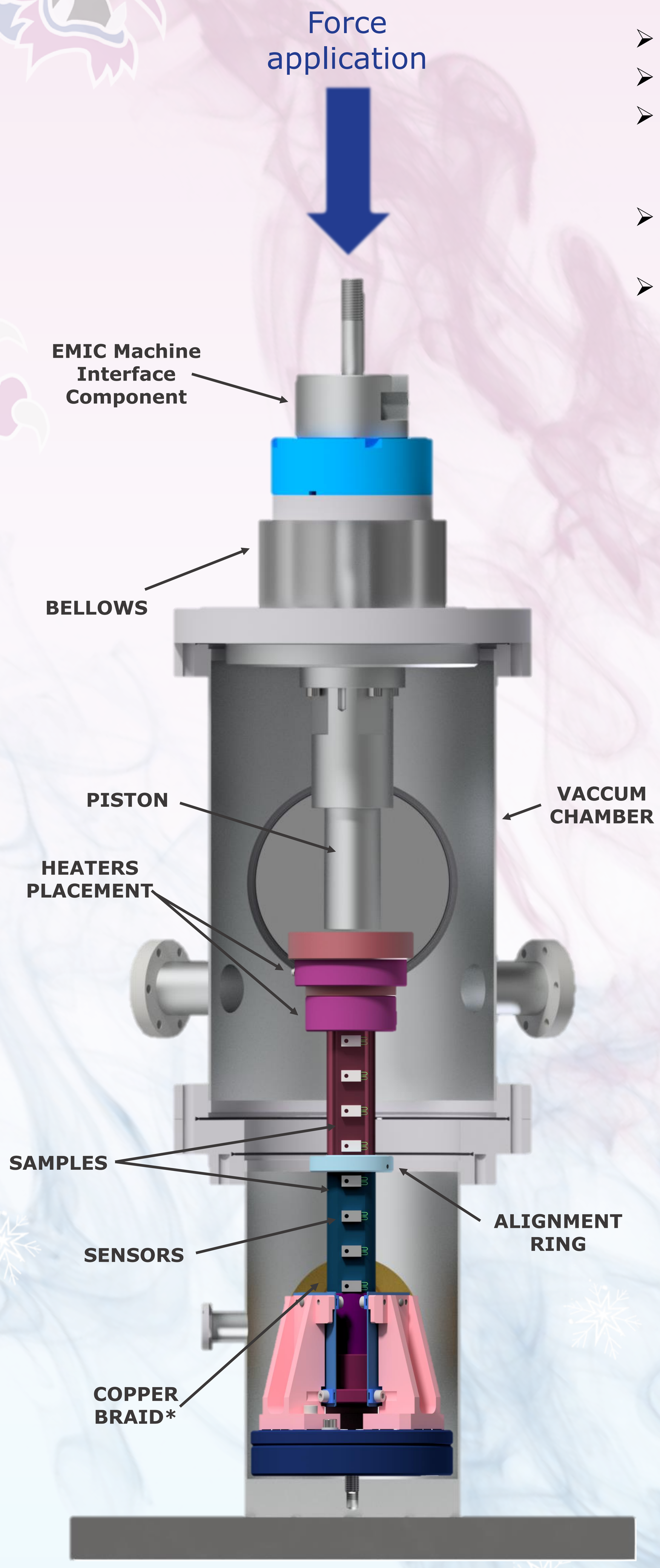
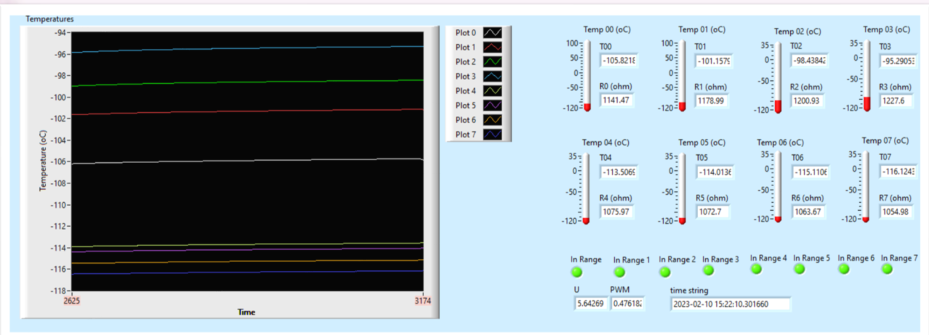
Project Concept & Design

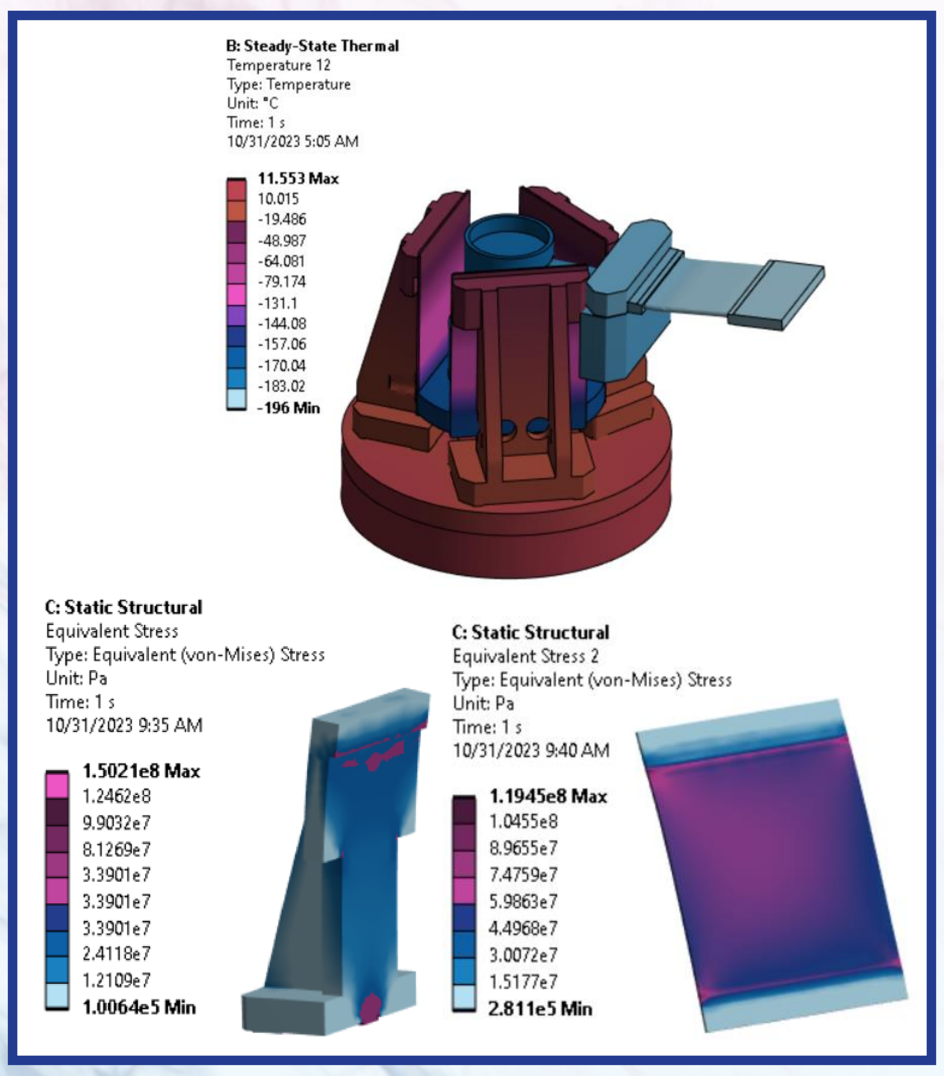


The setup with main components names.

- Project based in ASTM 5470;
- Load applied by EMIC Universal Test Machine;
- Temperature gradient controlled through a heater at the top and a LN2 flow cryostat connected to the bottom of the samples via copper braids;
- Temperature acquisition and heater actuation done from cRIO modules using a LabVIEW interface;
- Design modelled by FEA and Lumped-mass;



LabView interface to temperature acquisition and heaters control.



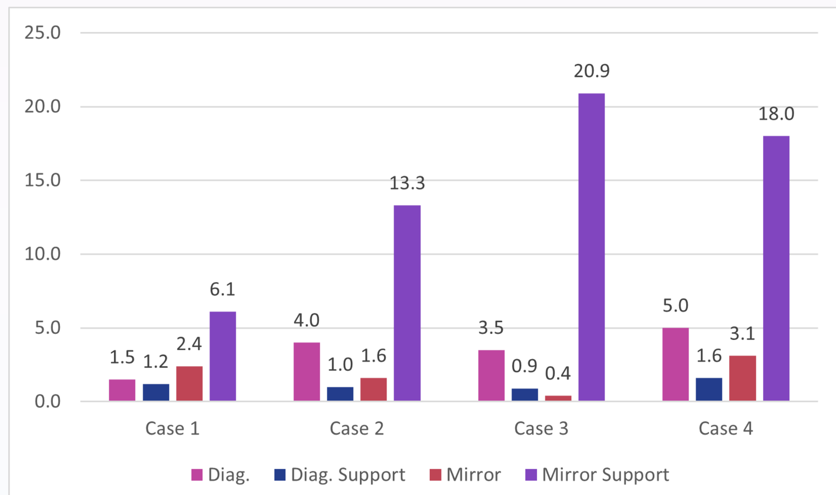
Top: Thermal simulation of setup support;
Bottom: static structural simulations of individual parts

Abstract

The design of optical elements compasses different development areas, such as optics, structures, dynamics, thermal, and control. Thermal designs of mirrors aim to minimize deformations, whose usual requirements are around 5 nm RMS and slope errors in the order of 150 nrad RMS.
One of the main sources of uncertainties in thermal designs is the inconsistency in values of thermal contact resistances (TCR) found in the literature. A device based on the ASTM D5470 standard was proposed and designed to measure the TCR among materials commonly used in mirror systems. Precision engineering design tools were used to deal with the challenges related to the operation at cryogenic temperatures (145 K) and under several pressures rates (1~13 MPa) whilst ensuring the alignment between the specimens. We observed using indium as Thermal Interface Material reduced the TCR in 10~42,2% for SS316/Cu contacts, and 31~81% for Al/Cu. Upon analyzing the measurements, we identified some areas for improvements in the equipment, such as mitigating radiation and improving the heat flow in the cold part of the system that were implemented for the upgraded version.

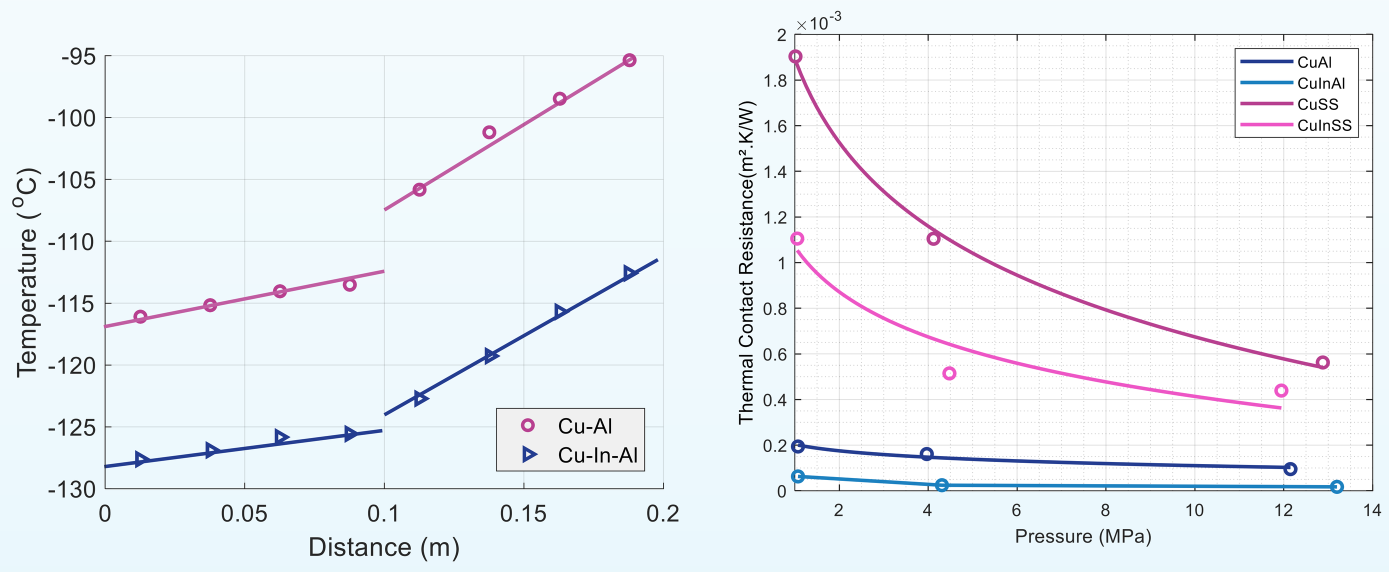
Motivation

Currently, our thermal designs are based on contact resistance values from a literature that does not represent exactly the operating scenarios, resulting on some discrepancies.



Temperature variations between real system and lumped-mass model for first mirror of CARNAUBA beamline in 4 different conditions.

Discussion



- Sensor position vs temperature curves were generated for each set of samples.
- From these curves, the Thermal Conductance Resistance was calculated using the Fourier equation (thermal conduction).
- The data points were calculated under steady-state conditions.
- Results were compared for different pressures and in the presence or absence of interface material (indium).
- For these initial analyses, effects of radiation and heat leakage to the external environment neglected.

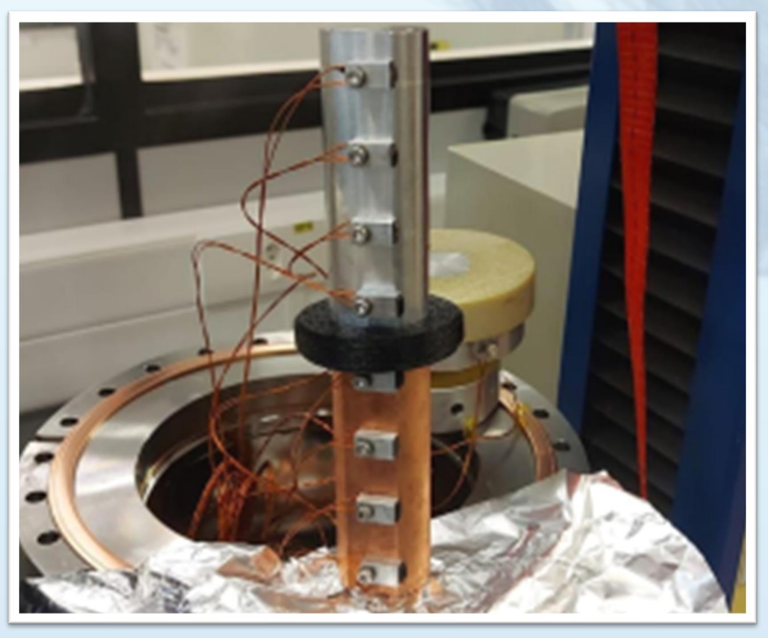
Experiments

Initial sets of samples:
- Cu-In-Al
- Cu-Al
- Cu-SS
- Cu-In-SS

Load range: 0-13 MPa

Environment: 1E-7 mbar

Cryogenic temperatures



Al6061 and Cu OF samples installed in the setup.

Setup placed inside of the EMIC to start the experiment.

Conclusion

A setup for the evaluation of thermal contact resistance (TCR) at cryogenic temperatures was proposed. Preliminary studies led to the conclusion that using indium as Thermal Interface Material reduced the TCR in 10~42% for SS316/Cu contacts, and 31~81% for Al/Cu. We have ongoing plans for equipment enhancements, such as the introduction of a radiation shield, further investigations into contacts with varying surface roughness, and the application of mathematical analysis to refine result accuracy. Our work expects to advance the understanding of TCR and contribute to more effective thermal designs for optical instruments.

CNPEM Brazilian Center for Research in Energy and Materials

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