Neuf-dix cell

Executive Summary Report

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Abbreviations List

An extensive list with the abbreviations used in this document can be found in NEUFDIX-LI-00229-QS [RD00].

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1. Introduction

Neuf-Dix stands for Non-Equilibrium Fluctuations during Diffusion in Complex Liquids and it aims at realising an experiment unit for the International Space Station (ISS) that allows investigating a variety of aspects related to diffusion processes:

- Non-equilibrium fluctuations in a complex mixture including a polymer.
- Glass transition in a ternary mixture including a polymer.
- Critical Casimir forces in equilibrium and out of equilibrium.
- Transient fluctuations in thermo-diffusion separation.
- Non-equilibrium fluctuations in dense colloidal suspensions.
- Diffusion aspects related to Biological samples.

The proposed experiment concept considers a fluid cell containing various samples, which are diagnosed by the optical tool 'Shadowgraphy', while a temperature gradient is applied onto the fluid cell in the direction of the optical beam.

Neuf-Dix will use the modular design concept as implemented in SODI, Transparent Alloys and COLIS and will consists of the following modules:

1. Image Processing Unit (IPU): The IPU connects Neuf-Dix with MSG. The IPU further distributes the required MSG resources to the other modules. The IPU acts as the brain of the Neuf-Dix experiment and houses a powerful computer, that fulfils a multitude of functions:
   - Communication to the outside world (through MSG)
   - Management of the experiment timeline and all experiment parameters
   - Storage and processing of all the acquired experiment data
   - Commanding all the controller units (peltier elements, magnetic stirrer, pump, motors, …)

   With respect to the SODI, Transparent Alloys and COLIS experiments, Neuf-Dix will not contain its own IPU but will reuse the COLIS IPU. This is because the COLIS IPU contains all functionalities and interfaces needed for Neuf-Dix.

2. Data Storage Unit (DSU). The DSU's are disk drives (rotational Hard Disk) used to store the raw and processed scientific data. The DSU's are plugged into the IPU and are easily replaceable. They can be returned to ground, if access to the acquired raw data is desired. If needed, additional DSU's can be uploaded together with Cell Modules.

3. Operating System Disk (OSD). The OSD is also a disk drive (rotational Hard Disk) that contains the operating system for the IPU computer. The operating system is always booted from the OSD and replacement is possible if needed.

4. Experiment Unit (EU). The EU contains all the optical and electrical sub-systems needed for the Neuf-Dix experiment. Its main function is the acquisition of the scientific data. Besides the optical sub-systems, "the Shadowgraph", it also houses all the driver electronics for the experiment hardware.

5. Cell Module (CM). The CM contains the actual experiment cells and can be inserted in a slot of the EU. The CM's main function is to provide two level of containments for the experiment liquid. It also contains all the necessary hardware for the successful conduction of the experiment.

2. Cell Module Design

In order to comply with the thermal requirements of the ESR [AD01], the cell module needs to be attached directly to the coldplate in order to dissipate the generated heat inside a cell stack. The cell module will provide two levels of containment in order to contain experiment liquids with THL 1.

An individual cell stack will measure approximately 65 x 76 x 96 mm (L x W x H) while the MSG coldplate measures 350 x 400 mm (L x W). This means that the cell module can be designed as an array containing a maximum of 5 cell stacks which will reduce the required crew time as more experiment liquids can be investigated with one integration cycle. Figure 1 shows the cell module with 5 cell stacks attached to the MSG coldplate.

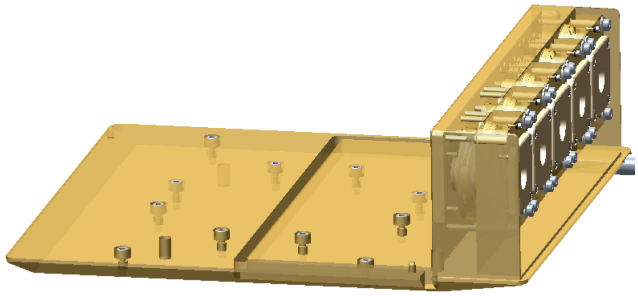

Figure 1: Cell module containing 5 cell stacks attached to the MSG coldplate

The sealed experiment liquid containment consists of the two sapphire windows which are separated by a PEEK spacer as indicated in Figure 2 in order to minimize the thermal contact between both windows. The sapphire windows will compress the O-ring and zirconium spacers will ensure that the design reaches the required parallelism.

In order to be able to fill the cell stack, the O-ring is pearsed with two needles. The needles will be glued to both the O-ring and the filling port of the PEEK spacer with Scotchweld 2216 to make sure it is leak tight. The diameter of the needles is 26G (0.4mm).

The performance of the containment is successfully tested with respect to the ability to fill the cell stack bubble free. This is fully described in the chemical compatibility test report where the BB cell were filled with the lowest and highest viscosity experimental liquids to verify a bubble free filling.

In order to evenly distribute the heat on the sapphire windows and compensate the difference in diameter between the peltier element and windows, a copper heat spreader is mounted in between the sapphire window and the peltier element. The heat spreaders are clamped on the windows using PEEK bolts in order to achieve a good thermal contact in between the heat spreader and the windows.

The copper heat spreaders are also used to measure and control the temperature set by the peltier elements. The cell stack contains 4 thermistors, mounted in each heat spreader for control and two thin film thermistors at the opposite side between the two sapphire windows to register the liquid container thermal gradient.

The peltier elements are wrapped around the experiment liquid containment. From the preliminary thermal analysis detailed in [RD46] is known that each peltier element needs to be able to deliver 10W of heating power. On top of that, the element should be radial around the optical clear aperture. The RH14-32-06 annular Peltier element from LAIRD was chosen. This element is capable of introducing 12.9W of heating power into the cell stack. It has an outer diameter of 55.12 mm and an inner diameter of 26.92mm which is well above the required clear optical aperture of 16mm. The peltier elements will be placed on top of the copper heat spreaders using DC340 thermal paste to improve the thermal contact.

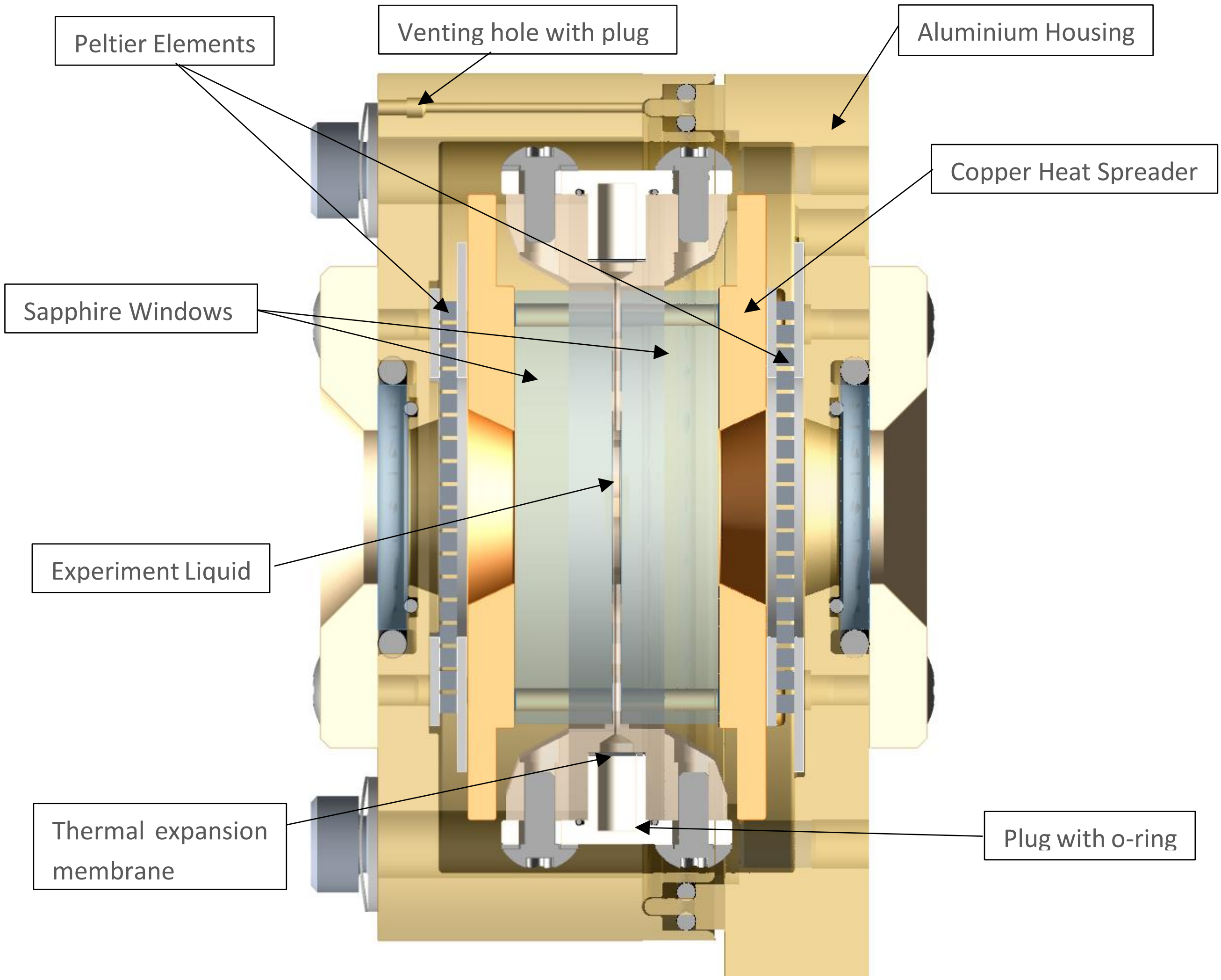

Figure 2: Cell module design section

Figure 3 shows the stack inside its housing. The housing is made of two Aluminium parts which are bolted together to provide the required pressure on the peltier elements in order to guarantee a good thermal contact in between the peltier elements and the copper heat spreader. DC340 thermal paste will be used to ensure a good thermal contact between the housing and peltier elements.

The lower housing is directly connected to the MSG coldplate to ensure a direct thermal connection between the cell stack and the coldplate in order to remove the heat generated by the peltier elements. The two housing parts are connected to each other as well in order to recuperate part of the generated heat of the cooling peltier to the heating peltier.

Neuf-Dix aims at investigated experiment liquids with a THL=1. This means that the cell module needs to provide two levels of containment. Since the containment of the experiment liquid is considered as a functional level of containment only, the housing itself needs to provide the additional two safety levels.

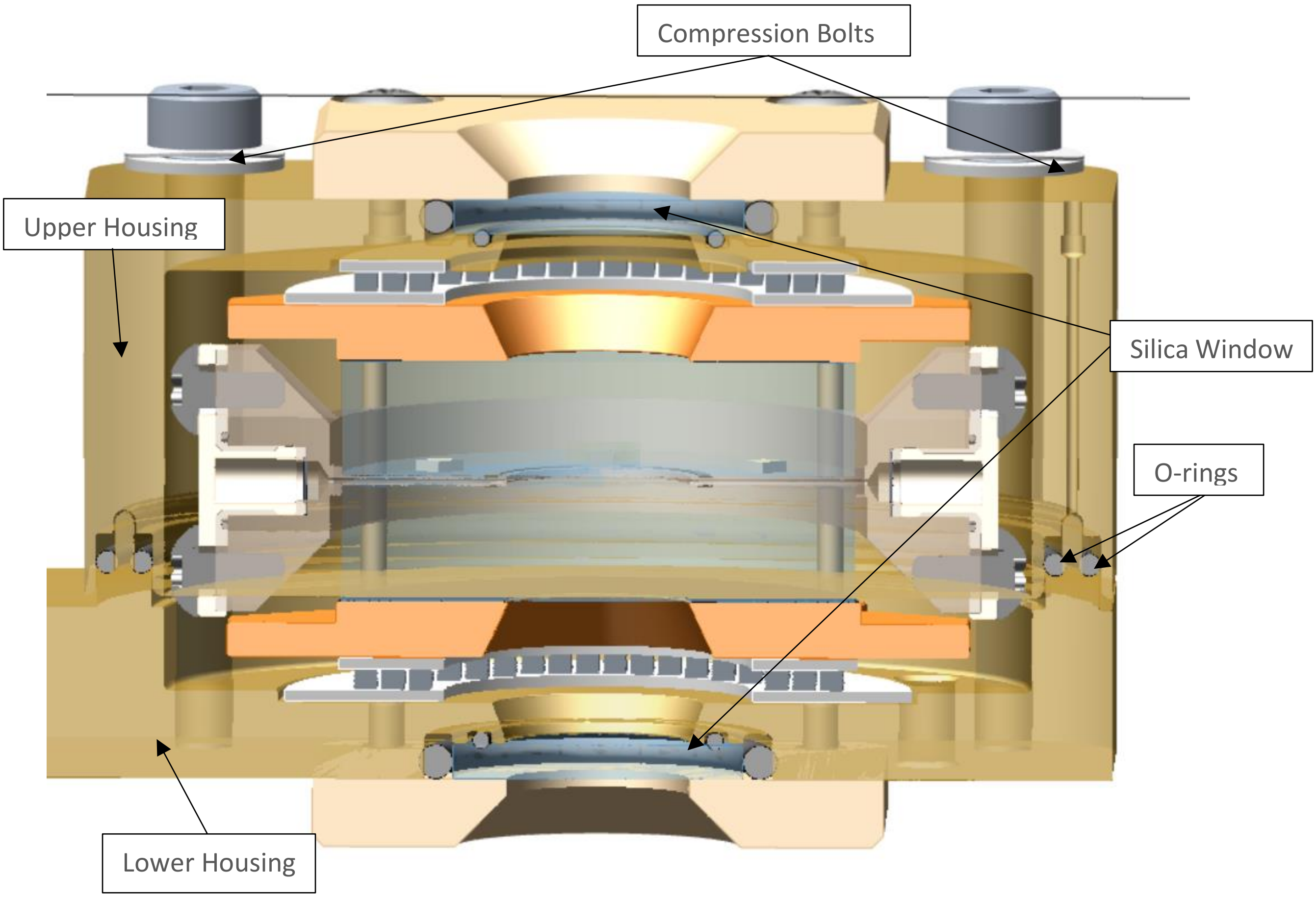

Figure 3: Cell module housing

In order to provide two levels of containment, the two parts of the housing contain two O-rings. The type of elastomer the O-rings will be made of will be decided corresponding to the experiment liquid to be used in the cell stack.

The housing also contains two silica windows which will be contained in two additional O-rings. The glass itself is designed for minimum risk and will provide the two levels of containment.

3. Test achievements

3.1 THERMAL TEST

In order to verify the system capability to maintain the set temperature for a certain duration as well as to keep the system homogeneous during this period, steady state verification measurements were performed for a longer duration in worst case conditions. T_{set} was defined as the set temperature around which the maximal thermal gradient of 20°C was evenly spread. These tests indicated that the cells were stable within 4mK and have a set point temperature stability better than 1mK/h which complies with requirements: SYS-550, SYS-560 and SYS-580. The same results were obtained during a thermal cycle test of the environment. For the response, the time needed to achieve the required thermal gradient was within requirements for a nominal environment, but exceeded the time needed with 1-3% for worst case conditions. It is expected that these conditions will not be present during the execution of the experiment (coldplate at 30°C).

3.2 CHEMICAL COMPATIBILITY TESTS

The sealing compatibility tests for the O-ring design are on-going. Currently only a potential incompatibility between kalrez and Ludox and decalin with viton is shown. No safety issue arises as the Viton seal is showing acceptable results for sealing the Ludox experimental liquid and the decalin liquid is removed from the potential liquids due to THL=2. A potential outcome of the test would be that a Viton seal shall be used for Ludox containing cell stacks.

The submerged compatibility tests are started on 26-27/02/2019. Till this moment, the tests are running successfully. A preliminary visual inspection is performed after 24 hours without any concerns. From the performed literature survey, no issues are expected during the following tests. With respect to the most critical experimental liquid (L6) two additional tests are added in order to have a back-up material available for the needles used in the BB design with known compatibility issues for higher concentrations. At the moment the tests are running successful.

3.3 SCIENCE TEST CAMPAIGN

A science campaign with the breadboard cell and the optics from the Neuf-Dix project was held on February 20-22, 2019. The results of the test campaign was presented in a dedicated Science Test report, with following major conclusions regarding the performance of the cell and optics.

Technical tests	1.1 Toluene	Radial temperature gradient	PASS (must be complemented with the results of thermal modelling of the cell)
		Thermal performances of the cell	PASS
Scientific tests	2.1 Binary mixture	Amplitude of signal generated by non-equilibrium fluctuations.	PASS
		Effect of the strobing of light sources	FAIL
	3.1 Ternary mixture	Evaluation of the amplitude of signal generated by non-equilibrium fluctuations.	PASS
	4.1 Concentrated ternary mixture. Filling	Verification that the cell can be filled even by using a highly viscous concentrated polymer solution	PASS
	4.2 Concentrated ternary mixture. Fluctuations	Evaluation of the amplitude of signal generated by non-equilibrium fluctuations.	PASS

The effect of the strobing of the light sources has been further evaluated in the Neuf-Dix experiment unit project, and new results were delivered to the science team for further evaluation.

4. Final Conclusions

The current design is in line with a level of detail for PDR as final design within phase A/B of the overall Neuf-Dix project. Although as already indicated in the conceptual trade-offer, the preferred design using an exchangeable cell module causes some incompatibilities with other requirements as summarised below.

- Cell windows of diamond (sys-485): The required window size cannot be procured and there is chosen together with PI for sapphire windows cut along the C-axis instead.
  - Sapphire windows has been used during science campaign and tested. It has been agreed during the science workshop that Sapphire C-axis cut is acceptable. The test results show good performance. It is proposed to remove this requirement from the ESR
- The transmitted wave-front distortion λ/10 (sys-490) is stated to be difficult to achieve for the current design as discussed with PI during the science campaign (NEUFDIX-MOM-00319-QS). Best achievable distortion by manufacturer is λ/4
  - Requirement was based on diamond windows, which have been replaced by Sapphire c-cut windows and tested during the science campaign. It is proposed to remove this requirement from the ESR
- An alignment accuracy of the thermal gradient with the optical axes of 30 arcsec (sys-545) is found technical unrealistic for an exchangeable CM as preferred in the current design as discussed with PI during the science campaign (NEUFDIX-MOM-00319-QS)
  - The current design has been selected on future cost estimates for a replaceable cell. The current concept has been tested during the science campaign. During a QS-ESA-PI joint-telecon, this was discussed and agreed to update the ESR towards the highest achievable alignment possible with a replaceable cell module.