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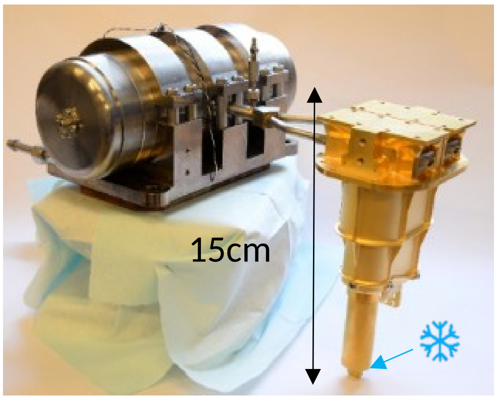
Offre de Thèse CNES/DSBT/CEA/LEGI

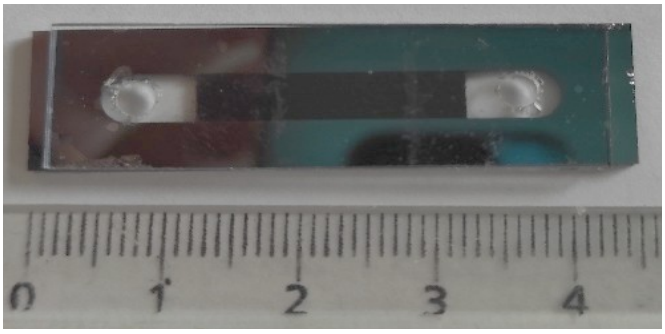
Study of the thermal performances of a reticular type regenerator

(Caractérisation des transferts thermiques dans un micro-régénérateur)

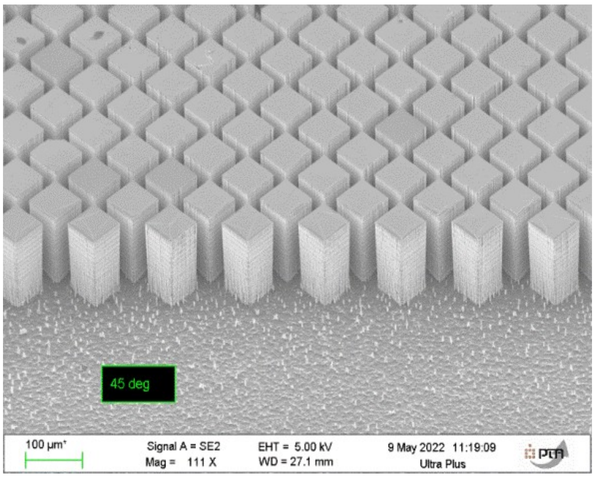
Conventional macro size pulse tube (15 cm)

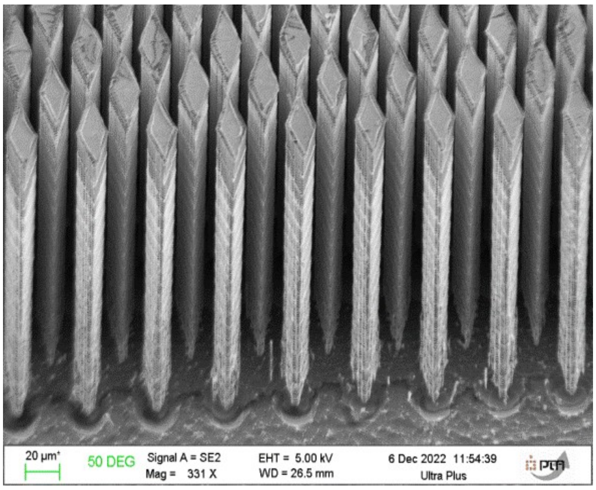


Mignaturized micro-regenerator (2 à 4 cm)



Examples of diamond-shaped cylinder array micro-regenerators produced by our team





Website to apply for the thesis project:

https://recrutement.cnes.fr/fr/annonce/2701775-24-339-study-of-the-thermal-performances-of-a-reticular-type-regenerator-38054-grenoble

Societal context:
Next-generation astrophysics or earth observation satellites use cryocoolers to cool detectors to cryogenic temperatures. These low temperatures make it possible to achieve unequaled sensitivities, particularly for observation in the infrared or X-ray domain. Devices intended for space missions must meet the following requirements: reliability, efficiency and reduced size and mass.

Scientific context:

Pulsed tube cryocoolers (PTC) are suitable for space applications due to their reliability and low level of induced mechanical vibrations. The oscillator is the most bulky element of a PTC. It has been shown that a reduction in its size necessarily leads to an increase in work frequency (Lopes et al. 2012).

The PTC heart consists of a regenerator. It is a porous medium which alternately absorbs and release the sensible heat of a gas which oscillates in its interior. When designing a regenerator, in order to obtain the best performance, we mainly seek to reduce pressure losses and maximize heat exchanges between the gas and the solid matrix composing the porous medium.

Today, regenerators are classically made up of a random stack of fibers, metallic fabrics or metallic spheres. The flow in this type of porous media depends on the average compactness of the network, the average size of the pores. Under these architectures, the operating frequency is between 30 and 50 Hz. Several researchers have observed a degradation in the efficiency of PTC at high frequencies with this type of technical solution (Ju et al 1998; Nam and Jeong 2003; Zhao and Cheng 1996). Authors maintain that this loss of performance may be the result of an amplification of mechanical losses by effects of compressibility of the gas in oscillating regime. Other work has shown that the internal structure of the regenerator plays a decisive role in limiting the loss of efficiency of the regenerator, in particular a reduction in its diameter hydraulic is more favorable to an increase in frequency. In this sense, Lopes et al (2012) and Vanapalli (2007a) succeeded in manufacturing PTCs which work at frequencies above 100 Hz using a regenerator in metallic fabrics of very fine wires -below 25 um-. Unfortunately, this type of architecture has a very limited level of miniaturization and let very little opportunity for geometric optimization. For several years, in order to overcome these limits imposed by conventional structures, several research teams are working on the development of a new generation of regenerators innovative solutions based on perfect control of the geometry of the network composing the porous medium.

Consortium:

This project will involve two members of the DSBT: Manuel Medrano Munoz (Assistant professor) who is responsible for this area of research and provides skills in nano/micro manufacturing, regenerator technology; Nicolas Luchier (CEA/HDR senior researcher) which brings its expertise in numerical simulation. This project will involve also two members of the LEGI: Damien Colombet (Assistant professor) and Frédéric Ayela (Professor) who brings complementary skills in nano/micro manufacturing, microfluidic flows, heat transfer, metrology and numerical simulation. The coordination of this project will be facilitated by the fact that all the permanent actors involved in this project have already collaborated together on two theses in this topic (A. Sochinskii and B. Bataille).

Scientific program and project structuring:

This work will focus on the thermal aspects of a stationary and oscillating flow inside a reticular type regenerator. This will happen by following the main steps below:

1/Preliminary experimental study of the thermal performances of the micro-regenerator in steady state with water as working fluid and comparison to simulations performed by A. Soshinskii. The spatial distribution of heat in the sample will be evaluated using a thermal camera (access to the 2D temperature field on one side of the exchanger), which is difficult to achieve in cryogenic conditions because thermal radiation is lower.

2/ Preliminary numerical study of the thermal in oscillating regime will be carried out by simulating the behavior of around thirty patterns either by a finite volume simulation method, or by a more simplified 1D or system approach.

Those two last steps will help prepare the rest of the study to get closer to real operating conditions.

3/ Manufacture of new samples compatible with a study in oscillating flow, with reduction of non-useful mass (reduction of the exchanger envelope, maximization of the surface area exchange), switching to the use of soldered connectors on silicon chip to eliminate the sample holder (process developed by CERN and used by LEGI).

4/ Experimental study of the thermal performances of micro-regenerators in

cryogenic conditions in stationary regime then in oscillating regime: experiments carried out under vacuum in a cryostat already present at DSBT/CEA

Contact: For more Information about the topics and the co-financial partner please contact

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