

Numerical study of heat transfer between electrocaloric ceramics plates and an oscillating fluid

The present proposal of a M2R internship is part of **Chilling with electrocaloric ceramics**, an ANR project jointly proposed by CETHIL¹, ELYTMAX², LGEF³ and LIST laboratories. CETHIL and LGEF are hosted by INSA-Lyon, ELYTMAX is an International Research laboratory based mainly at Tohoku University, and LIST is a Luxembourg laboratory.

The present M2R internship is proposed by CETHIL laboratory and will be realized in CETHIL laboratory and supervised by Shihe Xin (shihe.xin@insa-lyon.fr) and followed closely by Hervé Pabiou (herve.pabiou@insa-lyon.fr) and Gaël Sebald (gael.sebald@insa-lyon.fr).

General context:

We are interested in **developing electrocaloric cooling devices** by making use of electrocaloric effect of certain materials. Applying an electric field to an electrocaloric material results in polarization in one direction and depolarization in another direction: polarization generates a heat source in the material and heats the material up and depolarization produces a heat well and cools it down (see Figure 1). The temperature difference created can be used for chilling and this can be achieved through a regenerative system (Figure 2): the electrocaloric material at high temperature due to polarization heats up hot fluid moving right and is cooled down; depolarization cools it down further and cold fluid moving left heats it up; the cycling allows to establish a temperature difference in the fluid and chill the left side of the system.

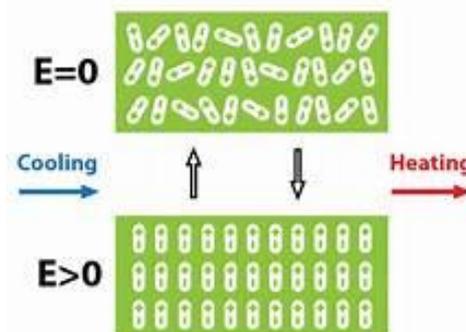


Figure 1: Illustration of **electrocaloric effect in ferroelectric materials**. Application of an electric field implies heating and its removal results in cooling. Picture from [Electrocaloric Effect | CaloriCool](#).

¹ CETHIL (CNRS/INSA Lyon//Université Claude Bernard Lyon 1) : <https://cethyl.insa-lyon.fr/en>

² ELYTMAX (CNRS/INSA Lyon/Centrale Lyon/Université Claude Bernard Lyon 1/Tohoku University) : <https://www.elyt-lab.com/fr/content/elytmax-irl-3757>

³ LGEF (INSA Lyon): <https://lgef.insa-lyon.fr/en>

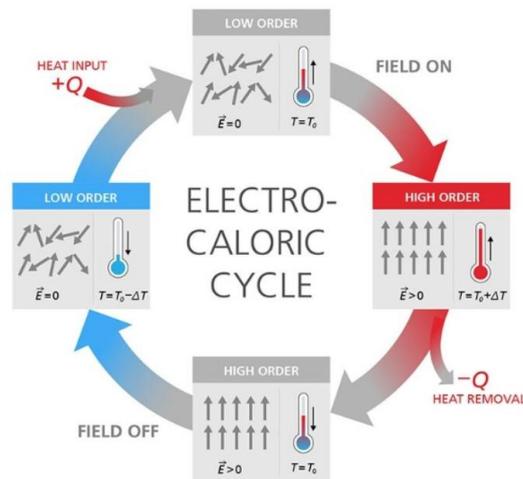


Figure 2: **Principle of the regenerative system..** At first step, an electric field is applied and the electrocaloric material heated up transfers heat to one fluid reservoir. At second step, the electric field is removed and the electrocaloric material cooled down absorbs heat from another fluid reservoir. This process leads to a temperature span between the two fluid reservoirs. Picture from [Electrocaloric materials & systems - Fraunhofer IPM](#)

The cooling process using caloric materials is based on **heat transfer** between electrocaloric materials in plates and the working fluid in a periodic regime. The process efficiency and the cooling power depend heavily on the enhancement of heat transfer between the electrocaloric material and the fluid. To improve the performance of the refrigeration system, the key question that needs to be answered is: how can heat exchange between the electrothermal plate and the fluid be improved, given that there is a trade-off between improving heat exchange in the transverse direction and maintaining low heat exchange in the longitudinal direction, which adversely affects the temperature range of the device? Furthermore, due to the periodic regime, this system also addresses the complex issue of modelling heat exchange in an unsteady configuration.

Internship:

To answer the questions, we intent to start with a M2R internship which is focused on numerical study of parallel plate configuration in periodic regime by improving the 1D modeling and preparing the development of 2D numerical modeling. A literature review should also be performed on heat transfer enhancement in periodic regime.

Perspective:

Based on the results obtained during the internship, the following step of the project is the heat transfer enhancement between the plates and the fluid in periodic regime by using both numerical and experimental approaches. The presence of obstacles on the plate surface will be considered: numerical simulations will allow to find efficient structures and experimental tests will be realized to validate the concept and the numerical results in terms of velocity and temperature fields. These developments will constitute the core of a double degree PhD thesis of INSA Lyon and Tohoku University. The candidate doing the present M2R internship will be encouraged to apply for the thesis and details of the application will be advertised later.

Note: The PhD thesis will be realized at CETHIL laboratory in Villeurbanne and ELyTMaX laboratory in Sendai (Tohoku University, Japan). Half of the PhD duration should be spent in Japan.