École Doctorale SCIENCES ET INGÉNIERIE DES MATÉRIAUX, MÉCANIQUE, ÉNERGÉTIQUE

2020 Doctoral research projects for PhD recruitment
Institut P'

Application of Radiative Cooling to Thermoelectric and Thermophotovoltaic Generators

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3-year contract: 1768 € raw monthly salary (to be modified if complementary funding)

Key-words: Radiative Cooling, Thermoelectric Generator, Thermophotovoltaic Generator, Energy Conversion, Optimization.

Framework and objectives.

The main idea behind the concept of radiative cooling (RC) lies in a radiative heat removal from the surface of an object on earth directly into the outer space through the transparancy window of the atmosphere [8, 13 µm]. This phenomenon is very commun at the earth's surface and it can be illustrated by several natural processes. For example, dew or frost formation observed in the morning after long winter nights is a well-known manifestation of such a phenomenon. The pioneer work on RC goes back to the beginning of the 1970 and since then, several systems have been developed especially for night-time RC. In the last 7 years, such cooling method has known a growing interest, particularly for day-time applications due to its great potential in various domaines. A good RC of an object surface in day-time can be achieved through an optimized design of the radiative properties of such surface in a way that it can evacute more heat than what it receives.
On a large scale, RC can be one of the solutions to be envisioned to face the increasing demand in thermal housing comfort and also a way to tackle global warming. On a small scale, this technique could be very intersting to enhance the energetic performance of solid state energy conversion systems, such as thermoelectric generators (TEG) and thermophotovoltaic generators (TPVG). This later point constitutes the main subject of the proposed thesis.
A TEG is a device that converts an applied temperature difference between its two sides hot and cold into an electric potentiel difference. The conversion principle is based on Seebeck effect. As such, the TEG behaves as a battery allowing to provide an electric current in a closed circuit. The conversion efficiency of the TEG is low in comparison to other conventional thermodynamical energy conversion systems. Furthermore, it depends on the temperatures of the two sides hot and cold as well as on the thermoelctric figure of merit; a parameter that groups all the thermoelectric properties of the semiconductor (SC) material of the TEG device. The higher the thermoelectric figure of merit is, the higher the conversion efficiency of the TEG will be for a given temperature difference. An extensive number of studies have been conducted in the past in order to find the best thermoelectric material and therefore enhance the TEG efficiency. Several solutions have been developed and different materials were identified.

The working principle of the TPVG is similar to the photovoltaic (PV) generator, but with two major differences; (i) the heat source is not necessarly the sun and (ii) the PV cell SC material that converts the photonic energy into electricity has a longer wavelength energy gap. As for the TEG, the TPVG conversion efficiency is still low. Nevertheless, multiple solutions have been developed in the last years leading to a considerable augmentation such the utilization of wavelength radiative selective emitters. Multilayers systems and/or surface gratings allow theoretically, obtaining such thermal emission spectra.

Work program and means.

The commun feature of these two types of generators, as is the case for any energy conversion thermodynamical system, is the direct dependence of the efficiency on tempertaure. The study that we aim to realize consists in a detailed analysis of the benefit of RC in enhancing the energetic performance of TEG and TPVG. In the case of TEG, RC will be used to lower the temperature of the cold side while maintaining the temperature of the hot side, which will automatically increase the conversion efficiency. In the case of TPVG, the idea is to use RC to maintain the temperature of the PV cell at its optimal operation value, which will guarantee a better conversion efficiency as well.

Several parameters are to be considered in this study and the work will be both numerical and experimental. Through an optimization procedure, we aim theoretically, to find the best set of physical parameters that allow reaching the best energetic performance for a given configuration of the two types of generators. Once this set is obtained, the final goal will consist in designing an experimental demonstrator in order to prove the concept for both devices.

Applicant profile, prerequisites.

Master 2 or equivalent (engineering degree) with very good skils in condensed matter physics, electromagnetism, heat transfert especially radiation, numerical calculations and coding.