Heat flux sensors based on Nernst effects

Objectives:
The need to increase the efficiency in processes like thermal cycles, computing and energy storage and transportation has recently increased the focus on heat management, extending the field of interest to the reduced dimensions. In this framework, the design of thermal sensors based on new concepts towards higher versatility and reliability is of great interest for research and industry and has to be supported by metrological traceability. As a heat flux sensor, thermoelectric thermopiles represent an optimal choice in terms of sensitivity. However these devices are plagued but several drawbacks, as for example they are rigid structures, their sensing area has geometrical constrains and the miniaturization of devices is limited. A promising way to overcome these limitations is the realization of active sensing surfaces based on transverse thermoelectric effects [1], in particular the Nernst effect of metals and the anomalous Nernst effect (ANE) of ferromagnets [2]. Although the Nernst effect is smaller then the Seebeck effect, its geometry permits the realization of a sensor as a uniform surface, without the need of the two planes of junctions. The Nernst geometry, in which the thermoelectric voltage is perpendicular to the heat flux, simplifies the architecture of thermoelectric generators and therefore allows for higher integration towards the design of nanostructured devices and MEMS. A further advantage is the use of ANE materials, i.e. ferromagnets with a large remanence and a high coercivity such as MnBi [3,4].
Moreover, the possibility of using magnetic nano-particles and thin films as active elements allows the realization of flexible sensors, nano-structured devices and heat-sensitive coatings for sensors and energy harvesting devices.
The main objectives of the research on transverse thermoelectric effects are the optimization of the properties of materials for the preparation of devices, the experimental investigation of their transverse thermopower and the development of models related to the experimental findings.
These activities can support the investigation on more fundamental and exotic phenomena like the thermal counterpart of the quantum Hall effect that is expected to be found in Corbino geometry in a 2D electron gas (2DEG) [5].

[1] Boona, Stephen R., et al. Journal of Applied Physics 130.17 (2021): 171101
[2] Mizuguchi, Masaki, and Satoru Nakatsuji. "Energy-harvesting materials based on the anomalous Nernst effect." *Science and technology of advanced materials* 20.1 (2019): 262-275
[3] He, Bin, et al. "Large magnon-induced anomalous Nernst conductivity in single-crystal MnBi." *Joule* 5.11 (2021): 3057-3067
[4] Sola A., et al. AIP Advances 13, 035231 (2023); https://doi.org/10.1063/5.0135578
[5] Kavokin, A. V., et al. Proceedings of the National Academy of Sciences 117.6 (2020): 2846-2851

Skills and competencies for the development of the activity:
A scientific master is required (physics, engineering, material sciences) with a prevalence of experimental subjects. A good attitude for the experimental activities is required for this project, ranging from the preparation of materials to the development of specific measurement systems and code for data analysis. These skills have to contribute to the achievement of independence in the laboratory.