# ***INTERNSHIP PROPOSAL***

Laboratory name: LPEM
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Internship location: ESPCI

Thesis possibility after internship: No
Funding: No

**Thermal Hall effect in Bismuth**

Thermal conductivity, like electrical conductivity is a tensor, which can have an off-diagonal component known as the thermal Hall effect. It refers to a longitudinal heat current generating a transverse temperature gradient in presence of a magnetic field perpendicular to both. Its existence in an insulator with no carriers of charge, known to give rise to a Hall signal because of a Lorentz force, was discovered a decade ago in a paramagnetic insulator [1]. Since then, a thermal Hall signal was detected in a variety of materials including those suspected to host Majorana fermions [2], and insulating cuprates [3], the parent compound of high-Tc superconductors. While the identity of heat carriers in these magnetic insulators has been controversial, its observation in non-magnetic insulators, such as strontium titanate [4] or black phosphorus [5], leaves little doubt that phonons can generate a thermal hall signal. Many theoretical scenarios have been proposed.

The goal of this internship will be to measure the thermal Hall conductivity of bismuth, an elemental semimetal, in which, we have already detected a thermal Hall signal. Bismuth hosts highly mobile carriers of charge (with a record mobility of $10^8$ $cm^2V^{-1}$ $s^{-1}$) [6]. Therefore, there is a large electronic contribution to the thermal Hall conductivity. In order to separate electronic and phononic components, thermal and electrical transport is to be explored in distinct configurations, by changing the mutual orientations of the crystalline axes and the magnetic field. You will learn how to measure electrical and thermal transport coefficients in a cryogenic environment, get hands on various low noise DC measurement, cryogenic, magnetic field manipulation.

[1] C. Strohm, *et al.* PRL **95**, 15 (2005): 155901
https://doi.org/10.1103/PhysRevLett.95.155901
[2] Y. Kasahara *et al.* Nature **559**, 227–231 (2018)
https://www.nature.com/articles/s41586-018-0274-0
[3] G. Grissonnanche *et al.* Nature **571**, 376–380 (2019)
https://www.nature.com/articles/s41586-019-1375-0
[4] X. Li *et al.*, Phys. Rev. Lett. 124, 105901 (2020)
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.124.105901
[5] X. Li *et al.* Nature Commun. 14: 1027 (2023)
https://www.nature.com/articles/s41467-023-36750-3
[6] A. Collaudin *et al.*, Phys. Rev. X 5, 021022 (2015)
https://journals.aps.org/prx/abstract/10.1103/PhysRevX.5.021022

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: NO Theoretical Physics: NO