Nonlinear Hall effects : towards efficient electrical rectification for THz detection

DIRECTEUR DE THESE : MATTHIEU BAILLEUL
IPCMS, 23 RUE DU LOESS, BP 43, 67034 STRASBOURG CEDEX, FRANCE
TEL : 03 88 10 70 08; E-MAIL : MATTHIEU.BAILLEUL@IPCMS.UNISTRA.FR

There is a lack of practical sources and detectors of radiation in the THz range (0.3-30 THz). It has hindered the development of the multiple applications of the THz wave including quality control, medical imaging, safety, and high-speed communication [1]. There is a clear need for efficient scheme for THz emission and detection.

The nonlinear Hall effect (NLHE) is a magnetotransport effect proportional to the second order of the electric field and is typically observed in systems with inversion symmetry breaking [2,3]. The (transverse) Hall voltage is current nonlinear as it varies with the square of the electrical current. Taking advantage of the current nonlinearity, it is possible to detect an alternating electromagnetic field using the electrical rectification, i.e., the process of turning an alternating current waveform into a direct current waveform. Recent theory works propose to use the NLHE for efficient THz detection at room temperature [4,5]. It is predicted that a large current responsivity and high sensitivity can be obtained in 2D materials with inversion symmetry breaking such as GeTe or WTe_2.

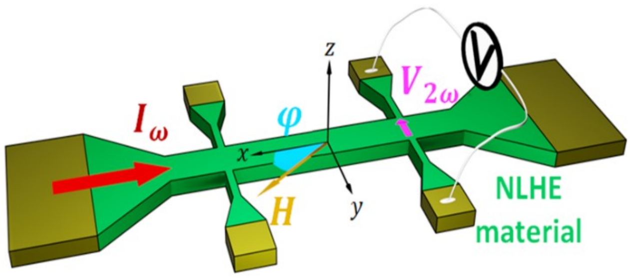

FIGURE 1 : SCHEMATIC REPRESENTATION OF THE MEASUREMENT OF THE NLHE IN A DOUBLE HALL BAR MICROSTRUCTURE.

The NLHE can be measured in double Hall bar microstructures as the one shown in figure 1. An AC current at the frequency ω, is injected in the Hall bar, the NLHE is detected as a second harmonic transverse voltage using lock-in detection (at low frequency) or as a DC rectified voltage. An external magnetic field can be applied to study the effect of the magnetic field or magnetization on the NLHE.

In this PhD thesis, we will study the potential of the nonreciprocal charge transport as Hall rectifiers. The proposed work will include devices microfabrication using cleanroom techniques and exfoliation of two-dimensional films with inversion symmetry breaking (STnano platform). The magnetotransport propertied of the microstructures will then be characterized using lock-in detection technique at low frequency. In a second step structures will be designed for the detection of the rectification in the GHz and THz frequency range. The work will be co-supervised by Dr. Matthieu Bailleul (HDR) and Dr. Paul Noël.

[1] Koenig, S. et al. Wireless sub-THz communication system with high data rate. Nature Photon **7**, 977 (2013)
[2] Ma, Q. et al. Observation of the nonlinear Hall effect under time-reversal-symmetric conditions. Nature **565**, 337 (2019)
[3] Du, Z. Z., Lu, H.-Z. & Xie, X. C. Nonlinear Hall effects. Nat Rev Phys **3**, 744 (2021)
[4] Isobe, H., Xu, S.-Y. & Fu, L. High-frequency rectification via chiral Bloch electrons. Science Advances **6**, eaay2497 (2020).
[5] Zhang, Y. & Fu, L. Terahertz detection based on nonlinear Hall effect without magnetic field. Proceedings of the National Academy of Sciences **118**, e2100736118 (2021).