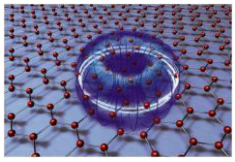
LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS



PhD student position

Quantum Hall effect in graphene for applications in fundamental metrology

Quantum Electrical Metrology Group

Laboratoire National de Métrologie et d'Essais (LNE)

Trappes – France

Funding: CIFRE-ANRT
Duration: 36 months
Location: Laboratoire National de Métrologie et d'Essais, LNE, Trappes (40 min away from Paris), France
Start date: End of 2018.

LNE, as a state-owned institute, attached to the French Ministry for the Economy, is the French National Metrology Institute and an internationally recognized testing laboratory. Notably, the institution steers the research in fundamental metrology by coordinating the French metrology laboratories at LNE, CNAM, CEA, Observatoire de Paris/CNRS.

In the department of Fundamental Electrical Metrology located in Trappes, the Quantum Metrology Group focuses on research for realizing the standards of the electrical units in the Système International (SI) based on solid-state quantum phenomena and for developing the associated instrumentation. The group is world leader in the application of the quantum Hall effect for the realisation of the electrical resistance standard, expert in the Josephson effect-based voltage standard, and pioneer of the development of an electrical current standard based on single-electron pumps. The group gathering 3 permanent researchers, 1 technician and typically 1 postdoc and 1-2 PhD students, is expert in low-noise, high-precision measurements of quantum electronic transport in quantum devices and nanostructures, down to low temperature (10 mK) and up to high magnetic field (20 T). The group also takes advantage of labs with controlled environment (temperature regulated within 0.1°C, humidity within 5%, electromagnetic shielding, anti-vibrating installations…), as required by high-precision metrological measurements.

The offered PhD student position is expected to mainly contribute to the research on the quantum Hall effect in graphene.

The main objective is the development of the quantum Hall resistance standard. The group has been conducting this application-oriented research in graphene for more than 10 years motivated by the prediction of the accurate Hall resistance quantization under relaxed experimental conditions in this material. Unprecedented performances were recently demonstrated at the lab in collaboration with CRHEA, C2N, L2C: in devices based on high quality graphene grown by hydrogen/propane CVD on SiC, the Hall resistance quantization has been observed with an excellent accuracy (below 1 ppb) in convenient experimental conditions (magnetic field of 3.5 T, temperature of 10 K or current of 0.5 mA) much simpler than those required by GaAs/AlGaAs heterostructures (Nature Commun., 6, 6806 (2015), Nature Nanotech. 10, 965 (2015)).

The next challenges to be tackled first concern devices made of CVD graphene on SiC: improving the stability and the control of the carrier density, exploring the limit of the Hall resistance quantization at low magnetic filed / low density, testing the quantization accuracy at record level (10^{-12}) by means of the quantum Wheatstone bridge technique, identifying the structural key control parameter for accurate and robust Hall quantization, and deepening the understanding of the underpinning physics. One major open question is whether graphene on SiC is the material of choice for achieving operation of the quantum Hall resistance standard at very low magnetic field (1 T). In this context, we also plan the investigation of high-mobility graphene interfaced with h-BN in collaboration with Néel Institut. Integration of the quantum Hall resistance standard in a cryogen-free cryomagnetic setup, while preserving ultra low-noise is another challenge for the group.

All these tasks are parts of the ANR GraphMet project, which has also the objectives to assess the potential of graphene for the Josephson voltage standard with S-G-S Josephson junctions (at Institut Néel and L2C) and for the single-electron current standard with quantum dots (at CEA/INAC), in view of the on-chip integration with the quantum Hall resistance standard. In the same way as the recent success of the group in the realization of an accurate programmable quantum current generator based on an ingenious combination of the quantum Hall resistance and Josephson voltage standards, such on-chip integration advances the achievement of a compact quantum multimeter, which would revolutionize the dissemination of the new "quantum" SI based on fundamental physical constants.

Besides, the group has the project to contribute to the development of an avalanche detector for single electrons or elementary excitations (*e.g.* levitons) based on the quantum Hall effect breakdown in graphene, in collaboration with CEA/SPEC.

Finally, the group pays close attention to the potential of the anomalous quantum Hall effect in magnetic topological insulator for realizing a quantum resistance standard operating at zero magnetic field and is open to any collaboration for achieving this objective.

The applicant will have a master's degree in condensed matter physics or nanoscience with personal tastes for experimental physics and instrumentation.

January 2018

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