# PhD position offer on

# *NANOELECTRONICS BY SCANNING PROBE MICROSCOPY*

**for students with a master degree obtained outside France**

in the research laboratories of the

**Institut Néel** [1]

**CNRS – Joseph Fourier University, Grenoble, France**

in close collaboration with the

**Louvain-la-Neuve University, Belgium**

in the frame of the RTRA[2] network

**« Nanoscience at the limit of Nanoelectronics »**

We propose an experimental study of the quantum physics that arises at low temperature in nano electronic devices by means of local measurements using scanning probe techniques.

**Research topic :**

The quantum nature of electrons is becoming central to the behavior of new classes of devices, such as resonant tunneling devices or low-dimensional semiconductor lasers, already on the market, but also to more challenging devices which are under investigation, such as single electron memories or quantum computers. The quantum world is therefore becoming the key for the future of nanoelectronics. On the other hand, electronic devices become so small that a single trapped charge or a single impurity in the device can dramatically affect its behavior. A precise understanding of how defects affect the proper working of nanodevices based on quantum phenomena will become essential for the development of nanoelectronics.

Most of the experimental studies consist of global measurements and the physics is understood by comparing these macroscopic measurements to theoretical models. During the last twenty years, several experimental tools have been developed to measure device properties locally, at the nanometer scale, as demonstrated by the scanning tunneling microscope (STM). However the new quantum devices, showing ballistic transport, phase coherence, and discrete charging at low temperature, are mainly based on semiconductor heterostructures where the electrons are separated from the surface by an insulating layer and cannot be probed by STM, sensitive only to surface electrons. To overcome that problem, a new technique was developed during the last few years called scanning gate microscopy (SGM). It uses a sharp tip, electrically polarized, to apply a local potential perturbation to the electrons located below the surface, while measuring the device conductance. Since the interaction is electrostatic, and not based on the tunnel effect, it extends through the insulating layer that separates the electrons of interest from the surface. Scanning this nanogate over the device thus provides conductance maps that feature real space signatures of nanoscale phenomena experienced by the electrons. In addition SGM microscopes also work as atomic force microscopes (AFM) in order to image the topography of the semiconductor nanostructures. This possibility of measuring forces makes it able to probe discrete charging phenomena by means of electrostatic force microscopy (EFM).

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[1] http://neel.cnrs.fr

[2] Réseau Thématique de Recherche Avancée, see : http://www.cnano-rhone-alpes.org/spip.php?article63

**PhD work subject :**

Our proposal for this PhD work is to study experimentally the coherent, ballistic, and charging effects that occur at low temperature in semiconducting nanodevices based on two-dimensional electron systems or ultra-thin silicon films. In particular, the research will focus on the spatial distribution of electronic wave functions in nanostructures, on the influence of charged defects, and on phase decoherence by magnetic impurities.

The PhD student will conduct SGM experiments (possibly combined with EFM experiments) using a microscope working at liquid helium temperature (4.2 K) and under magnetic field (11 T). This tool was developed recently in our laboratory and gave interesting results on ballistic quantum rings etched in InGaAs/InAlAs heterostructures (see references). Different kinds of samples will be investigated thanks to our collaboration with the IEMN in Lille which produces high quality III-V heterostructures and with the nanofabrication facilities available both in Louvain-la-Neuve and in Grenoble. The measurements will be interpreted in the light of numerical simulations carried out at the IMEP in Grenoble and also in Louvain-la-Neuve.

The envisaged experiments include the imaging of localization in periodic or random anti-dot lattices, the imaging of ballistic effects in confined nanostructures, the role of impurities on the ballistic transport in Silicon-On-Insulator ultra-thin devices, and the coherent transport in II-VI semi-magnetic nanostructures thanks to a collaboration with the Institute of Physics – Polish Academy of Sciences in Warsaw.

**References :**

- Imaging and controlling electron transport inside a quantum ring, B. Hackens, F. Martins, T. Ouisse, H. Sellier, [...] V. Bayot, S. Huant, Nature Physics 2, 826 (2006).
- Imaging electron wave functions inside open quantum rings, F. Martins, B. Hackens, M.G. Pala, T. Ouisse, H. Sellier, [...] V. Bayot, S. Huant, Phys. Rev. Lett. 99, 136807 (2007).

**Supervision and funding :**

This proposal is part of a RTRA project called "Scanning-Gate Nanoelectronics" coordinated by Dr. Serge Huant[3] and Prof. Hervé Courtois[4] at the Néel Institute. The PhD position is open from now and its duration is 3 years. The Institut Néel in Grenoble will be the host institution of the PhD student. The salary will be paid by the RTRA. The PhD student will benefit from the expertise of two supervisors :
- **Vincent Bayot** is professor at the Université Catholique de Louvain (UCL) in Belgium. He also holds a part-time RTRA chair position in Grenoble for 5 years. He is a specialist of thermodynamics and quantum transport in two-dimensional electron systems and semiconductor nanostructures made of III-V heterostructures and Silicon-On-Insulator.
- **Hermann Sellier** is associate professor at the Université Joseph Fourier and member of the Institut Néel. He conducted research activities on mesoscopic superconductivity and Coulomb blockade in nanodevices, and is now working on scanning probe experiments.

**Applications :**

The applicants must be highly ranked in their university degree which should have been obtained outside France. There is no nationality restriction. Applications should be sent to:
- Prof. **Vincent Bayot** (vincent.bayot@uclouvain.be) and to:
- Dr. **Hermann Sellier** (hermann.sellier@grenoble.cnrs.fr)
with a detailed CV, a letter of motivation, and at least one letter of recommendation by a former professor.

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