Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: SPEC/CEA Saclay
CNRS identification code: UMR 3680
Internship director'surname: Preden Roulleau
e-mail: preden.roulleau@cea.fr Phone number: 0169087311
Web page: https://nanoelectronicsgroup.com/
Internship location: SPEC/ CEA Saclay

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: CEA

The Hong Ou Mandel experiment in graphene

Historically, the Hong Ou Mandel experiment has been performed to get time-domain information on the photon wave packets: it was a direct way to measure the time width of single photon wave packets. The lack of quadratic detectors to perform time auto-correlation at so low input level led them to consider the second order coherence $g_2(\tau) = |\langle\psi(x)|\psi(x-\tau)\rangle|^2$ by colliding the idler and signal photons generated by parametric down-conversion of a laser source on a beam splitter. Indeed, the interference of the two indistinguishable particles makes the particle detection statistics dependent on their wavefunction overlap. After N_0 experiments, the particle number fluctuation is $\Delta N^2 \propto 2(\frac{1}{4})(1 \mp |\langle\psi(x)|\psi(x-v_F\tau)\rangle|^2)$, where the plus sign holds for bosons, the minus sign holds for fermions, τ is the time delay between particles and v_F is their velocity. For non-overlapping states at large τ, the fluctuations of two particles independently partitioned is found. For zero delay (full overlap), the bosonic bunching doubles the noise whereas the fermionic exclusion makes it vanish. Hong–Ou–Mandel experiments are now standard in quantum optics. With the use of electronic beamsplitters in GaAs/AlGaAs, d.c. and a.c. voltage sources have shown anti-bunching [1,2].
Recently we have shown that it was possible to mimic these beam splitters in graphene and to obtain Mach Zehnder interferometers with record visibility of 70% [3]. Based on this, we propose an original Hong Ou Mandel geometry to probe for the first time the fermion statistics in graphene.
This proposal is part of the ERC starting grant COHEGRAPH (2016).

[1] J. Dubois, T. Jullien, F. Portier, P. Roche, A. Cavanna, Y. Jin, W. Wegscheider, P. Roulleau, & D. C.Glattli , Nature 502, 659-663 (2013)
[2] E. Bocquillon et al., Science 339, 1054 (2013)
[3] Quantum Hall valley splitters in graphene PN junction, M. Jo, P. Brasseur, A. Assouline, G. Fleury, H.S. Sim, W. Dumnernpanich, P. Roche, D.C. Glattli, N. Kumada, F.D. Parmentier, and P. Roulleau, submitted (2020)

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: YES Theoretical Physics: YES