INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: LOA
CNRS identification code:
Internship director'surname: Hamed Merdji
e-mail: Phone number: 0662711472
Web page:
Internship location: Ecole Polytechnique

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding:
Concours or research contract grant

Evidence of multipartite entanglement in semiconductor high harmonic generation

Quantum information science and imaging technologies reach some bottleneck due to limited scalability of non-classical sources. Future breakthroughs will rely on high production rate of various quantum states in scalable platforms. Generally, multipartite entanglement with N>2 suitable for quantum applications is difficult to achieve because of the low efficiency of the traditional schemes. Conventional quantum sources such as spontaneous parametric down conversion achieves production rates of 12 entangled photons at 0.27 mHz [Zho18] and 4.96 kHz for three entangled photons [Wan17]. The quantum nature of strong field processes occurring in high harmonic generation (HHG) has recently revealed the possibility of generating massively entangled quantum states [Tsa17,Lew21] that should come as a frequency comb of N entangled photons [Gor20]. To date, the quantum nature of the HHG emission has never been demonstrated experimentally. However, first experiments have started at LOA Laboratory in 2023 and recent measurements of the photon statistics indicate a non-classical behavior of the harmonic emission in standard semiconductors evidencing a bipartite two mode squeezing [The23]
Intrinsically, the HHG emission comes as a frequency comb and should exhibit N-partite entangled photons. Practically, the internship project will consist in extensively study the non-classical properties of the HHG process in a semiconductor for N>2. In the process, each emitted photon is a superposition of all frequencies in the spectrum, i.e., each photon is a comb so that each frequency component can be bunched and squeezed. The candidate will first develop and test entanglement and quantum correlations using the violation of Cauchy-Schwartz inequality. We will verify genuine multipartite entanglement of the photons in the time/frequency domain, by correspondingly measuring the longitudinal position as well as the frequency bandwidth. The approach will be further extended to verify multi-partite entanglement between even more optical modes. The Bell-like inequalities will therefore be generalized to witness entanglement between more than three mixed quantum states.

[Gor20] Gorlach, A. et al. Nat. Com. 11, 4598 (2020)
[Lew21] Lewenstein et al., Nature Phys. 17, 1104 (2021)
[Sha13] Shalm, L. K. et al., Nat. Phys. 9 (1), 19 (2013)
[The23] Theidel, D. et al. Submitted to Nature (in review)
[Tsa17] Tsatrafyllis, N., et al. Nat. Com. 8 (1) 15170 (2017)
[Wan17] Wang, H. et al., Nat. Phot. 11, 361 (2017)
[Zho18] Zhong, H. S. et al., Phys. Rev. Lett. 121, 250505 (2018)

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