New directions in the study of optical properties of nanostructures with free electrons beams

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In the past 15 years, the use of free electron beams to study the optical properties of nanostructures has proved to be extremely efficient, especially due to the unrivalled spatial resolution attainable in an electron microscope.

Beyond this technical performance, new fields of investigation have been opened. The first relies on the quantitative interpretation of spatially resolved electron-based optical experiments – how close are they from optical experiments? The second field relies on the next experimental and conceptual challenges to be explored: How can we retrieve the missing information routinely gained in pure optical experiments but not with free electron beams – phase, non-linearity, lifetime measurements, etc …-?

In this presentation, I will present novel interpretations of plasmon mapping experiments in a scanning transmission electron microscope (STEM), both electron energy loss spectroscopy (EELS) and cathodoluminescence (CL), and how they relate to pure optical experimental quantities such as extinction and scattering cross-sections[1]. I will then show how, surprisingly, EELS can be employed to probe physical problems usually found in more fundamental fields of physics, like black holes gravitional waves generation[2]. I will then present experimental and theoretical results concerning the possibility to map the phase of plasmons with EELS[3]. I will then switch to the interest of using STEM-CL for various applications. Starting with applications of defects-related luminescent nanodiamonds to bio-imaging[4], I will then discuss the possibility to detect single photons emitters in CL[5], and finish by showing CL results proving the measurement of sub-nanosecond lifetimes with sub-15 nm in semiconducting heterostructures[6].

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[6] S. Meuret et al., *ACS Photonics* **3** 1157 (2016).