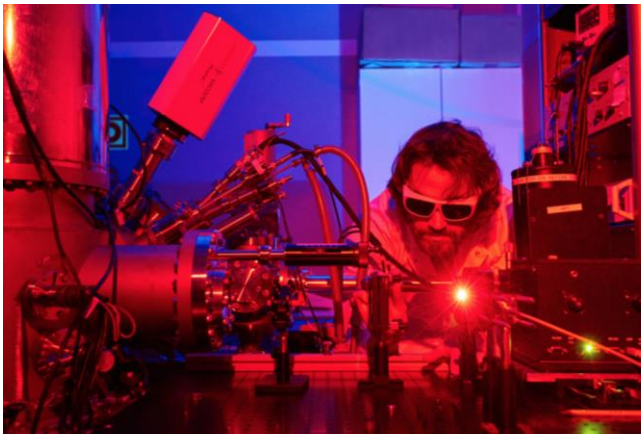
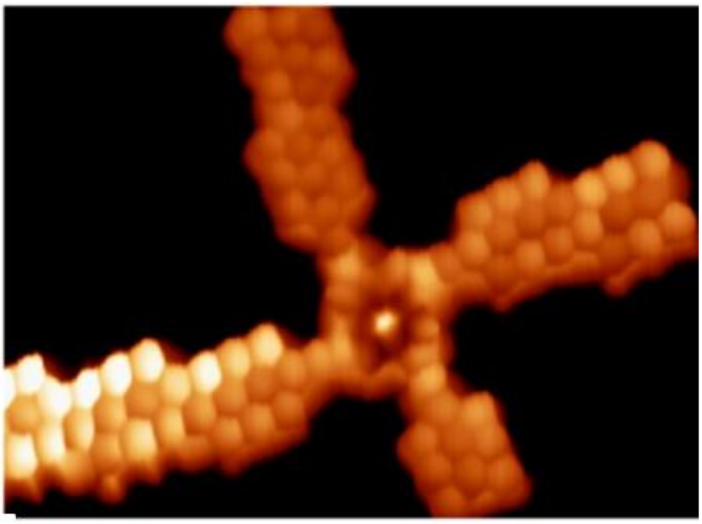
FINAL PUBLISHABLE SUMMARY

The interaction of light with structures much smaller than its wavelength, i.e. far below the diffraction limit, is enhanced by the effect that electromagnetic fields cause in the charge of the object. The excitation of plasmons enhances and focuses the light in the proximity of the nanostructure, mediating the energy exchange between photons and electrons. As the size of metal nanostructures and optoelectronic nanodevices approaches atomic scale dimensions, quantization effects in their electronic and plasmon structure gain increasing relevance in light scattering. Understanding the coupling of photons with electrons in the presence of quantum effects is crucial for improving the functionality of optoelectronic nanodevices like light emitting diodes or for the performance of nanoparticles in fields like medicine, or catalysis.



In this research project, we study the quantum limits of light emission and scattering by metallic and molecular nanowires of nanometer sizes. The goal is to prove that atomic or molecular nanowires of atomic sizes behave as optical antennas due to the quantization of their plasmon structure. This would mean that excitation of plasmon resonances can enhance the coupling between photons and electronic transitions in the nanowire. Since this research project bridges the fields of atomic-scale spectroscopy and nanooptics, a novel experimental approach is proposed. The fellow combined a low temperature scanning tunnelling and force microscopies with a light excitation and detection set-up, to resolve at the atomic scale both electronic structure and light scattering/emission by the atomic-sized antennas in response to optical/electron excitations. Specifically, he constructed an optical table coupled to our low-temperature STM via a set of mirrors and lenses. The system has been tested successfully by detection of plasmonic light emitted form a gold tip.



This setup was applied to investigate the light emission from graphene nanoribbons. These systems are ideal 1D semiconductors, atomically thin, and constructed almost defect free on the surface of a metal. As the electronic structure of the nanoribbons depends strongly on their width, so will their optical properties. They work dealt in a second step with the preparation of graphene nanoribbons with novel functionality. These ribbons are constructed employing organic precursors, which then covalently assemble into the final structures. We expanded the existing toolbox available by combining different precursors and succeeded in producing interesting systems for optoelectronic, such as quantum dots embedded in the ribbon, or ribbons covalently contacting optically active components such as porphyrin molecules All these are ideal systems for optoelectronic devices.

The relevance of optoelectronics is inferred from the multitude of industrial sectors where this field is increasingly found at the centre of innovation. These sectors include information, communication, imaging, lighting, displays, manufacturing, life sciences and health care, as well as safety and security. In these areas, the development of new materials improves the performance and efficiency of the device components, while reducing their cost and energy. This research field facilitated the integration of the fellow in nanoGUNE, a research institute combining latest generation of research tools with a diverse expertise of groups working in various aspects of nanoscience. In particular, the fellow expanded his low-temperature surface science know-how to nanofabrication and optics methods through in-house collaboration and reached a stable position as Ikerbasque Research Professor in the Host institution.