Final report of the exchange visit
STED Nanoscopy: Analysis of Metallic Nanoparticle Labels

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The purpose of this 6-day visit was establishing a scientific collaboration with the theoretical group led by Dr. Yonatan Sivan at Ben Gurion University of the Negev (Beersheba, Israel). This collaborative project has been set up to investigate the optical properties of metal nanostructures with potential applications in STED nanoscopy [1,2]. More specifically, this project aims to develop and combine two quasi-analytical tools for the theoretical description of plasmonic geometries under STED illumination. These devices will be designed to maximize the radiative enhancement experienced by nanoemitters located in their vicinity.

On the one hand, transformation optics will be employed to describe single three-dimensional nanoparticles. Lately, the applicant has developed strong expertise in this method, which has been successfully applied to the treatment of crescent-shaped spherical particles [3] and nanosphere dimers [4,5] under plane wave illumination. This collaboration aims at implementing more complex sources (such as dipole and STED excitations) into this framework.

On the other hand, Dr. Yonatan Sivan, together with Prof. David Bergman at Tel Aviv University, has made relevant advances on the eigenmode spectral expansion method [6]. This technique has made possible the quasi-analytical description of complex plasmon-assisted phenomena, such as plasmon amplification [7] or self-similar focusing [8]. This tool is especially suited for the investigation of the electromagnetic interaction between metallic nanostructures, which is a key feature for this collaboration. The eigenmode spectral expansion method will allow us to explore composite metallic systems as STED labels, in which the near-field coupling between different plasmonic resonances can be exploited.

Finally, the quasi-analytical results obtained with these theoretical methods will be tested against numerical simulations. In principle, due to its power and versatility, COMSOL Multiphysics will be the tool of choice for this purpose.

As explained above, the objective of this collaboration is the combination of transformation optics and eigenmode spectral expansion methods for the investigation of plasmonic nanoparticle designs as STED nanoscopy labels. This is the current task, once the capabilities and limitations of the two techniques have been discussed in detail during this scientific visit. The collaboration will continue in time, and it is expected that it will lead to high-impact publications in the medium term.

During this short visit, the applicant has also given two scientific seminars on his recent advances on the application of transformation optics for plasmonics: one in Tel-Aviv University (Monday 21st) and one in Ben-Gurion University (Wednesday 23rd).

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