



ERASMUS MUNDUS



PHOTONICS - EUROPHOTONICS MASTER COURSE

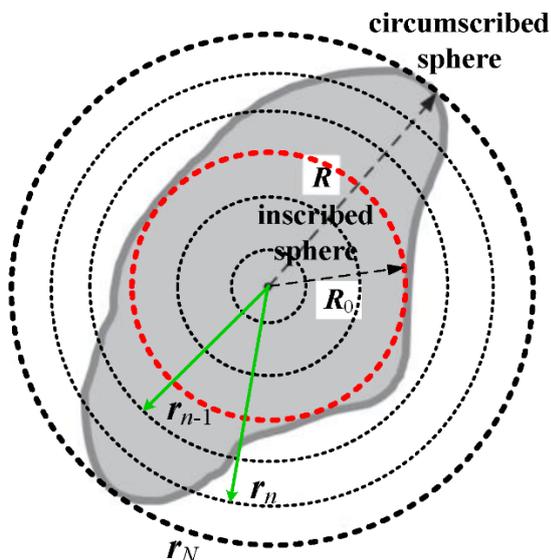
PROPOSAL FOR A MASTER THESIS

Dates: February 1st, 2025 – September 30th, 2025

Laboratory: Centre for Sensors, Instrumentation and systems Development (UPC-CD6)
City, Country: Terrassa, Spain

Title of the master thesis:

SOLVING MAXWELL'S EQUATIONS FOR COMPLEX PARTICLES GEOMETRIES



[Hu, S., Liu, L., Gao, T., & Zeng, Q. (2019). Design and Validation of the Invariant Imbedded T-Matrix Scattering Model for Atmospheric Particles with Arbitrary Shapes. *Applied Sciences*, 9(20), 4423.]

Name of the tutor of the master thesis: **Santiago Royo and Maria Ballesta**

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Summary of the subject (maximum 1 page):

Understanding how light interacts with complex media is essential for numerous applications in optical metrology, biomedical imaging, and material characterization. The fundamental description of light–matter interaction arises from Maxwell’s equations, which, for specific boundary conditions, yield exact analytical or numerical solutions that describe scattering, absorption, and polarization effects.

At CD6, we have been developing models of light propagation in turbid media, where scattering by micro- and nano-scale particles plays a critical role. Traditionally, Mie theory provides analytical solutions to Maxwell’s equations for spherical particles, allowing the study of their scattering and absorption properties. However, many real-world particles—such as biological cells, aerosols, or engineered nanostructures—deviate from perfect spherical symmetry.

To overcome these limitations, our research group has extended its modelling capabilities using the T-matrix method, which allows the analysis of spheroidal particles and other non-spherical geometries. This approach provides a more flexible framework to simulate realistic particle shapes while preserving the physical rigor of Maxwell’s equations.

The proposed master’s thesis will focus on deepening the mathematical understanding of Maxwell’s equations and their solutions for complex particle geometries, particularly through the T-matrix formalism. The student will explore the theoretical foundations, implement computational models, and analyze the applicability of these methods to various particle types beyond simple spheroids. The focus will be on four key areas:

- 1) **Technology background:** Reviewing Maxwell’s equations and their analytical solutions for electromagnetic scattering, with emphasis on Mie and T-matrix formalisms.
- 2) **State-of-the-Art Review:** Exploring current developments in light scattering models for non-spherical and irregular particles, identifying open challenges and existing computational approaches (T-matrix for Fortran).
- 3) **Mathematical modelling and implementation:** Deriving and implementing the T-matrix method for different particle geometries, understanding numerical stability and convergence aspects.
- 4) **Analysis and validation:** Comparing theoretical predictions with available reference data or experimental measurements, and evaluating the model’s applicability to diverse scattering problems.

This project aims to strengthen the theoretical and computational tools at CD6 for modelling light interaction in complex media, opening the door to more accurate simulations in optical metrology, biomedical optics, and nanophotonics.

Keywords: Maxwell’s equations, Mie theory, T-matrix, light scattering, complex particles, optical modelling, photonics, numerical methods

Additional information :

* Amount of the monthly allowance (if it is the case):

To be discussed depending on the value of candidate.

* Required skills:

Strong interest in theoretical and computational optics.

Solid background in electromagnetism, applied mathematics and numerical methods.

Programming skills (Python, Matlab, or C++ desirable).

Familiarity with numerical methods and scientific computing.

Self-motivated, analytical, and capable of autonomous work within a multidisciplinary team.

* Miscellaneous:

International team with several years of experience in the topic proposed.

Multidisciplinary environment with electronics and mechanics workshops, and specialists and technicians in metrology, optics, mechatronics, and electronics.

Access to high-performance computing resources and experienced technical support.

Possibility of joining the Centre for a PhD/Project Manager career in case of common interest.

Early incorporation welcome.