Position Description

1. General Information

Name of the position	**Near-field effects in electromagnetism**
Foreseen date of enrolment	1 July 2024
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • Aix-Marseille Université (AMU) • The University of Sydney (USYD)
Research Host	Aix Marseille Université
PhD awarding institutions	Aix-Marseille Université & The University of Sydney
Locations	Primary: Marseille, France Secondary: Sydney, Australia
Supervisors	Stefan Enoch (CNRS, AMU) Redha Abdeddaim (AMU) Martijn de Sterke (USYD) Boris Kuhlmey (USYD) Alessandro Tuniz (USYD)
Group of discipline	Physics, Electrical Engineering

2. Research topics (only one of these projects will be funded)

Project 1: *Local density of States in Complex environments*
Spontaneous emission is a random process, somewhat like radioactive decay. Given a set of atoms in an excited state, it is known *how long* they stay there before relaxing to the ground state (on average) but predicting *which* atoms relax and which do not is impossible. The spontaneous emission *lifetime* is a bit like the radioactive half-life, but it subtly depends on the environment in which it is placed. For example, if an atom is placed in a cavity from which photons cannot escape then clearly the spontaneously emission is profoundly changed. We now know that the spontaneous emission lifetime is determined by the *Local Density of States*, i.e., the number of states available to photons as a function of position (for example, in the node of the electric field the Local Density of States is zero). Structuring the environment and thus the density of states has a wide range of applications, from increasing the brightness of LEDs and single-photon sources to no-threshold lasers and new near field physics. However, engineering the density of states is delicate, and simulations often don't match realistic experimental

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implementations: it is thus essential to measure changes in the radiative properties of atoms directly. This is very difficult since they are small, and their detailed environments are difficult to control with the required precision.

We have recently pioneered a technique to carry out equivalent experiments in the microwave and terahertz regions of the electromagnetic spectrum. Such experiments are much more controllable, making use of techniques that have been developed for these wavelength ranges.

The aim of this project is to design, simulate and then carry out microwave and/or terahertz experiments to characterise the Local Density of States in a number of complex environments that promise immediate applications for emission control, but also for discovering new physics, for example in waveguides and in band gaps of photonic crystals. The results will be applied to practical devices, for example scintillators for medical devices, antennas for MRI systems, or 6G photonic circuits.

Multiwave Imaging (MW) will provide a non-academic secondment and give concrete and valuable insights regarding impact development and creation. MW and Institut Fresnel are already research partners for more than 5 years and have co-supervised several PhD students in various topics including near field energy transfer and biomedical applications. Institute Fresnel and the University of Sydney also have a long-standing collaboration and have successfully co-supervised multiple PhD students. The secondment will also help the PhD student to develop a network of non-academic contacts, expanding their career opportunities.

Supervisors:

Stefan Enoch (CNRS, AMU); Redha Abdeddaim (AMU)

Martijn de Sterke (USYD); Boris Kuhlmey (USYD); Alessandro Tuniz (USYD)

Marc Dubois (MW)

Research Fields: Photonics, microwave physics, terahertz physics

Project 2: *Förster energy transfer*

Förster Resonant Energy Transfer (FRET) is a fundamental phenomenon that described the exchange of energy between two atoms (the "donor" and the "acceptor"). Initially one of the atoms is in the excited state and the other is in the ground state. In the final state this situation is reversed. FRET is important in many processes, such as photosynthesis and protein-protein interactions. In free space, FRET strongly depends on the distance of the donor and the acceptor: if they are far apart, the "FRET rate" is dominated by radiation and decreases as r^{-2}, but in the near field a much stronger contribution dropping as r^{-4} or r^{-6} depending on the orientation of the dipoles is dominant. The FRET rate also depends strongly on the environment, particularly if it has features that are comparable to the wavelength. The manipulation of FRET with the environment is in its infancy, but could lead to new applications ranging from higher density quantum computing or photonic chips all the way to new bio-imaging technologies. Doing systematic experiments on the FRET rate at optical wavelengths is very difficult because it requires submicrometer positioning in well-controlled environments. We have shown that such experiments can instead be carried out using microwaves and terahertz radiation with much better control.

The aim of this project is to design, simulate and carry out microwave and/or terahertz experiments to characterise the FRET rate a number of complex environments, for example in near waveguides and in band gaps of photonic crystals and to understand the results using simulations.

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Research Fields: Photonics, microwave physics, terahertz physics

Project 3: *Investigation of terahertz waveguides by near-field probing*

Integrated photonic devices are a poised to be a key driving building block of several 21st century technologies, e.g., quantum information and intelligent hardware, and rely on efficiently guiding light in a compact and controlled environment via dense networks of waveguides. Though the best-known example of these are optical fibres, recent years have seen an increased interest in short-range chip-based waveguides that harness exotic phenomena to provide additional degrees of freedom for controlling light. We have recently discovered a novel method to characterise exotic waveguides using a near-field emitter and receiver. The near-field effects allow for the full control over the excitation of the waveguide modes, which can then be picked up by the receiver. Scanning the receiver and taking the spatial Fourier transform then gives the allowed wavenumbers of the modes as a function of frequency. Although this is conceptually straightforward for simple planar waveguides, the investigation of much more interesting for waveguides with structure such as photonic crystal waveguides. It will also be possible to investigate more exotic structures in this way, for example those with Weyl points or Dirac points which can occur in topological materials, the subject of the 2016 Physics Nobel prize, materials in which the light flow is confined to the edges of a material, rather than to the bulk.

In this project you will carry out experiments to characterise the modes of waveguides and compare with numerical simulations and with theoretical results.

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Supervisors:

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Martijn de Sterke (USYD); Boris Kuhlmey (USYD); Alessandro Tuniz (USYD)
Marc Dubois (MW)

Research Fields: Applied Physics, Photonics, Electromagnetic waves

3. Employment Benefits and Conditions

Aix-Marseille Université offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months).

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of 28,764 EUR. Of this amount, the estimated net salary to be perceived by the Researcher is 1,926 EUR per month (before the deduction of tax at source). However, the definite amount to be received by the Researcher is subject to national tax legislation.

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Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be invited to join the Marie Curie Alumni Association.
- Access to all the necessary facilities and laboratories at Institut Fresnel (Aix-Marseille Université) and The University of Sydney.
- Tuition fee waiver at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for 12 months in Australia.
- 25 days paid holiday leave.
- Contractual doctoral students are subject to the same sick leave rights as other contractual employees of the State Civil Service, namely: the contractual agent in activity benefits, on presentation of a medical certificate, during twelve consecutive months if its use is continuous or during a period including three hundred days of effective services if its use is discontinuous, of sick leave within the following limits
  - After 4 months of service: 1 month on full pay and 1 month on half pay;
  - After 2 years of service: 2 months on full pay and 2 months on half pay;
  - After 3 years of service: 3 months on full pay and 3 months on half pay.
- Parental leave: if the employee has at least 1 year's seniority at the date of the child's birth, he/she is entitled to parental leave at his/her request (after maternity leave for the mother or paternity leave for the father). This leave ends at the latest when the child is 3 years old. The leave is granted for renewable periods of 2 to 6 months. He/She must apply for it at least 2 months before the start of the parental leave.

4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

Applicants must hold a Master's or equivalent degree performed at a high academic standard, and which includes a substantial component of original research.

Applicants must also prove English language proficiency (see: https://www.sydney.edu.au/study/how-to-apply/international-students/english-language-requirements.html).

More information on Aix-Marseille Université's requirements

Applicants holding a Master's degree outside the Bologna process or a degree equivalent to a Master's degree must submit an application for a Master's Degree for validation to the doctoral school secretariat prior to their enrolment.

Important: as Institut Fresnel (Aix-Marseille Université) is subjected to ZRR (Zone à Régime Restrictif) regulation, hiring choices must be approved by the Haut Fonctionnaire Securité Défense (HFSD).

Visit the website: https://college-doctoral.univ-amu.fr/en

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More information on the University of Sydney's requirements

Meeting the minimum requirements for eligibility, does not guarantee admission. Admission remains at the discretion of the Associate Dean (Higher Degree by Research) for each faculty.

For more information on admission requirements, please visit the University of Sydney's Apply for postgraduate research page: https://www.sydney.edu.au/study/how-to-apply/postgraduate-research.html

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