HIGHLY QUALIFIED PERSONNEL TRAINING

The HQP-program which follows is carefully coordinated with my 5-year Research Program (RP), see Research Program Form. For each HQP, I shortly describe the topic of the corresponding research project. Along the program, I plan to supervise: 5 honours students (Honours), 5 master students (MSc), 3 PhD students (PhD), 2 PostDocs (PDF).

Training Philosophy

As much as possible, I will adapt the level/depth of the research projects of the HQPs, to their mathematical and scientific background, interests, suitability to my research, feasibility, as well as future opportunities for these students. This last point is essential to give the students the best chances to pursue his/her studies or career in a field which is adapted to his/her competencies and interests. For the best students, I will challenge them on difficult and open theoretical problems, while I will give for weaker students the chance to develop more “practical skills”. In addition, at higher level (PhD, PostDoc), I will develop as much possible their intellectual independence. I do think that critical mind, and intellectual independence are essential skills that HPQs must acquire during their training.

Research Training Plan

I will train the students to be prepared to become independent and rigorous applied mathematicians and computational scientists. First, by the development of rigorous approach of research: extensive literature review, weekly group meetings, participation to workshops and conferences, and at some point publication process. As much as possible, I will organize for the most advanced students visits in my collaborators’s research group. In particular, HQPs involved in more “physics-oriented” projects, could also benefit from the expertise to my collaborators in Physics to help to consider more realistic problems, and derive accurate mathematical models. HQPs projects will be associated to very active research fields (Attosecond Science, computational PDEs, HPC, and even Quantum Information Theory), they could certainly have interesting opportunities in Academia, gouvernemental institutions, or even in Industry for those involved in most applied projects.

Honours students

- **Honours 1 [2018-19]:** Numerical approximation of fractional wave equations. This is an hot topic in numerical partial differential equations. Spectral and real space methods will be invistigated. This HQP-project is associated to Project I.a of the RP.
- **Honours 2 [2019-20]:** Numerical $C^*$-algebra. The purpose of the project will be an investigation of existing numerical $C^*$-algebra techniques for eigenvalue problems. This is HQP-project is associated to Project II.a of the RP.
- **Honours 3 [2020-21]:** Maxwell-Dirac modeling for relativistic filamentation. The purpose will be the reading of existing models in relativistic filamentation and nonlinear optics. This is HQP-project is associated to Project III.a of the RP.
- **Honours 4-5 [2021-23]:** Flexible: to be determined.

Master students

- **MSc 1 [2018-20]:** Convergence of Schwarz Waveform Relaxation (SWR) methods for nonlinear Schrödinger and approximation. Analysis of the rate of convergence of SWR methods using paradifferential calculus for nonlinear equations. This is HQP-project is associated to Project I.a of the RP.
- **MSc 2 [2019-21]:** Computational methods for the spectrum of the nonlinear Dirac. Derivation of balanced operator-based, normalized gradient flow, $C^*$-algebra-based,
and Feit-Fleck type methods. Computational methods and numerical analysis study. This is HQP-project is associated to Project II.a of the RP.

- **MSc 3 [2020-22]:** *Digital quantum algorithms for noised quantum wave equations.* Quantum algorithms for noised Schrödinger and Dirac equation. Brownian motion is included in the quantum wave equation to model error and decoherence effects. Algorithms for generation of quantum states are then derived for these equations. This is HQP-project is associated to Project IV of the RP.

- **MSc 4 [2021-23]:** *Mathematical methods for field-particle Schrödinger equation.* Exact nonperturbative computation of solution to Schrödinger equation with interaction potential. Spectral-theory-based methods for including the effect of the point and essential spectrum of the Schrödinger Hamiltonian. This is HQP-project is associated to Project III.a of the RP.

- **MSc 5 [2022-24]:** *Analysis of convergence of Schwarz Waveform methods for several (> 2) subdomains.* In this work we plan to study the convergence, and rate of convergence for an arbitrary number of subdomains, for the Schrödinger equation. In combination with multilevel methods, we also plan show how to accelerate the convergence of SWR methods. This is HQP-project is associated to Project I.b of the RP.

**PhD students**

- **PhD 1 [2018-22]:** *Analysis and implementation of domain decomposition methods for fractional and nonlinear Schrödinger and Dirac equations.* This is an important project which will require mathematical and numerical analysis, and computing skills. This is HQP-project is associated to Projects I and II and III of the RP.

- **PhD 2 [2019-23] Generalization of the mathematical methods pseudodifferential and paradifferential-based for evolution partial differential equations.* We plan to develop a general framework, and efficient computational methods. Although the target will primarily be quantum wave equations, we plan to develop technique going beyond this framework. This is HQP-project is associated to Project I of the RP.

- **PhD 3 [2019-23]:** Development of computational methods for nonperturbative nonlinear optics. We ultimately plan to develop a computational code for efficient laser-filamentation simulation, based on macroscopic nonperturbative models, which accurately include ionization effects. Laser-filamentation in weakly relativistic regime will also be addressed. This is HQP-project is associated to Project III.a of the RP.

**PostDocs**

- **PostDoc 1 [2018-20]:** *Computational and analysis for relativistic laser-material interaction (application to graphene).* Development of efficient IMEX-RK methods for the Dirac equation. Mathematical methods for optimizing the pair production process from laser-molecule/graphene interaction. Coupling with Maxwell’s equations will be considered. This is HQP-project is associated to Projects II and III.b of the RP.

- **PostDoc 2 [2020-22]:** *Domain decomposition methods for N-body Schrödinger equation.* Thanks to the expertise in quantum physics and domain decomposition methods, the plan is to develop highly scalable methods for N-body Schrödinger equation: computation of the spectrum of the Schrödinger Hamiltonian and time evolution of quantum particle subject to intense laser fields. This is HQP-project is associated to Project I of the RP.