Ecole Doctorale Carnot-Pasteur

Proposal of a PhD thesis

Subject : Optimal control of quantum systems: Maximizing the signal to noise ratio per unit time in spin systems

Laboratory : Laboratoire Interdisciplinaire Carnot de Bourgogne

Thesis advisor: Pr. D. Sugny

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Scientific domain: Quantum physics, quantum information, control theory

Description of the scientific project

This PhD project aims at applying innovative mathematical tools coming from optimal control theory to improve theoretical and experimental techniques in Nuclear Magnetic Resonance (NMR), in Electron Spin Resonance (ESR) and in NV centers. This approach will allow us to explore and to experimentally reach the physical limits of the corresponding spin dynamics in presence of typical experimental imperfections and limitations. A first objective will be to develop new optimal control algorithms able for an inhomogeneous ensemble of spins to maximize the signal to noise ratio per unit time of the system. A general problem is to generalize the Ernst angle solution used in NMR, which is only valid for a homogeneous spin ensemble. This work will be done in collaboration with the group of S. Glaser (TUM, Munich, Germany). This approach will find different applications in NMR and ESR where the sensitivity of the experiment is a crucial parameter. The student will focus on a specific experimental setup in ESR used by the group of P. Bertet (CEA, Paris Saclay), where an important goal is the maximization of the emitted signal of spins coupled to a microwave resonator. The student will take into account in the numerical computation specific constraints of this experimental setup. In the same direction, the student will also use optimal control techniques to design new CMPG sequences accounting for the coupling between the spins and the cavity. The same types of control techniques will also be used for manipulating NV ensembles in collaboration with the group of T. Debuisschert (Thalès, Paris). This will allow the improvement of the sensitivity of the corresponding experiments. For a more fundamental point of view, the ESR will investigate the numerical techniques used to design robust control fields with respect to experimental imperfections. A first objective will be to understand the efficiency of these methods and to prove the optimality (this concept will be to define rigorously) of the control fields. The ESR will mainly study spin systems but it is clear that the results of this project will not be restricted to the physical systems investigated and the techniques developed during the PhD could be applied to other physical systems with similar properties.

Required background of the candidate:
Master of physics, Numerical computations (Mathematica, Matlab)