Presentation of the funded projects in 2010 for the « Blanc International SIMI4 » Programme

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YEAR 2010

Project title	**COLORS** – Control of Optical LOcalized and Rare Structures
Abstract	In this project, we will develop control methods and strategies for the optical localized structures arising in nonlinear passive optical experiments such as shaping the patterns, switching between different coexisting structures, displacing them transversally, or else controlling rare intense events that can occur in spatiotemporal systems and that can have dramatic consequences. The research will imply to a large extend fundamental studies, both theoretical and experimental, on the nature of the structures under investigation and on the definition of their distinctive features. It will imply as well technological developments on the control of optical structures, such as controlling their dynamics by using convectively traveling regimes, increase or decrease the degree of interaction, shaping a single structure or clusters of them, studying the effects of inherent noise on their dynamics, controlling spatial extreme events. Therefore, we expect that the results of the project will also have an impact on future applications in the field of optical control and optical storage. We will setup two different types of experiments: optical passive cavity and optical feedback systems. At this purpose we will use nonlinear media that are of large transverse size such as photorefractive crystals, liquid crystal cell or light valves. We will study the conditions for optical bistability or multi-stability in both types of systems. In particular, the cavity configuration is very promising since it will provide a new mechanism for light localization in the presence of optical bistability between different light paths in the cavity. On the other side the feedback configuration presents a simpler configuration for the optical addressing. We will develop novel methods to manipulate the optical structures that arise from the spatial coupling resulting either from the feedback or the cavity configuration. The two main control methods will be based on: (1) A spatial beam shaping introduced by a spatial light modulator (SLM). By exploiting these performances we can impose specific intensity or phase profiles on the input beam. The optical addressing method by the SLM will permit to test such different experimental schemes as spatial periodic forcing, both one and two-dimensional, phase or intensity gradients,

space-time noise. On the other side, the spatial periodic forcing will be used to study front propagation and the behavior of localized structures. (2) Convective (or drifting) instabilities for achieving transverse motion control. These instabilities can be induced by e.g. a tilt of one mirror. The obtained traveling transverse will allow for motion of optical bits (solitons). Their interplay with noise will be in particular explored in view of studying the behavior of noise-sustained localized patterns. The characterization of the existence, stability features, dynamical evolution, interaction, and bifurcation diagram of localized complex states will allow us an adequate handling of complex localized states and glimpse novel potential applications. As mentioned before, we plan to study the statistics and properties of spatial localized intense events in different experimental configurations such as cavity and feedback systems. More specifically, we will explore their localization properties as well as the influence of the convective nature of the system in their statistical properties.

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Coordinator	Eric Louvergnaux - PhLAM eric.louvergneaux@univ-lille1.fr
ANR funding	312 047 €
Starting date and duration	March 2011 - 36 months
Reference	ANR-10-INTB-0402

Project title	**HighQ-Fermions** – Elementary excitations of highly correlated fermions at atomic wavevectors : Experiments and Theory
Abstract	One of the major goals of present physics is understanding the quantum properties of interacting many-body systems. In this proposal, we address for the first time the problem of the dynamics of correlated fermionic systems at elevated wave-vectors, in order to understand the nature and the interplay of incoherent (particle-hole) and coherent (plasmon, zero sound) excitations. The results apply to a large variety of systems: electrons in metals, quantum fluids, neutron stars. Liquid 3He is an excellent system for such studies, since its Fermi surface is spherical and a large range of densities (interactions) can be studied. In addition, two-dimensional 3He can be studied from the low density limit (Fermi gas) to a highly correlated Fermi liquid state. In this system, the interaction between incoherent particle-hole excitations and the collective zero sound mode can be tuned by changing the density. Under these optimal conditions, we shall investigate the excitations of a Fermi liquid in the high wave-vector sector of the spectrum. Advanced experimental techniques will be used to measure, by inelastic neutron scattering at very low temperatures, the dynamic structure factor of two- and three-dimensional liquid 3He. This magnitude provides all the necessay information on the elementary excitations of the system. Very low temperature nuclear magnetic resonance techniques will provide important additional information on other fundamental properties (effective mass, magnetic Landau parameters) as a function of density for bulk and adsorbed liquid 3He. The proposed experiments will be performed in Grenoble by experts in the field of quantum fluids, low temperature and neutron scattering physics and techniques (Institut Néel -CNRS, and INAC-CEA), using the best neutron and cryogenic instruments for that purpose. The Austrian partners are developing a microscopic theory that provides a new framework for understanding the dynamics of such strongly correlated Fermions. The theoretical description, based on the variational/equation of motion method, will be developed to a much higher level of accuracy than what has been achieved before, including in particular the important effects of exchanges, spin fluctuations, and a non-trivial single particle spectrum. The theory partner has a distinguished record in producing the most successful theories in liaison with the experiments. With the experiments and theory proposed here, developed in close collaboration, we expect to answer simple, yet

fundamental questions: What is the nature of the dynamics of a Fermi liquid? Do coherent excitations survive at elevated wave-vectors and energies in a Fermi liquid?

Partners	Institut Néel Institut Nanosciences et Cryogénie/Service de Physique Statistique, Magnétisme et Supraconductivité Insitute for Theorical Physics –Johannes Kepler University, partenaire étranger (Autriche)
Coordinator	Henri Godfrin – Institut Néel henri.godfrin@grenoble.cnrs.fr
ANR funding	405 318 €
Starting date and duration	March 2011 - 36 months
Reference	ANR-10-INTB-0403

Project title	**ProQuP** – Paires d'atomes corrélés pour la physique quantique
Abstract	Two partners are involved in this project, both being pioneering groups in quantum atom optics and one-dimensional quantum gases: the laboratoire Charles Fabry de l'Institut d'Optique (Institut d'Optique, CNRS, Université Paris Sud 11) through the setups « metastable helium » et « atom chip », and the Atominstitut der Österreichischen Universitäten (Vienna University of Technology) through one setup on « atom chip ». Strongly correlated states are at the heart of the project. These states are expected to increase the sensitivity in atomic interferometry and are central to understand 1D physics. The project could be split in three main parts. The first one deals with the search of an efficient process of twin atomic beams. Their quantum properties will be studied through two-body correlation function, an asset of the two partners since both have developed state of the art single atom detectors. Two-mode source will be particularly studied. The second part is linked to 1D physics. In particular the integrability of such atomic systems will be studied et their two-body correlation function during time-of-flight and in-situ will be measured. This last point will be achieved by a new method based on tomography. The third part concerns a transfer of technology. The Austrian partner will help the French partner to build a single atom, time-resolved, light-sheet detector similar to the one developed in Austria.
Partners	Laboratoire Charles Fabry de l'Institut d'Optique Technische Universität Wien, partenaire étranger (Autriche)
Coordinator	Denis Boiron - LCFIO denis.boiron@institutoptique.fr
ANR funding	280 800 €
Starting date and duration	March 2011 - 36 months
Reference	ANR-2010-INTB-0404

Project title	**QuanTherm** – Thermoelectricity of quanum matter
Abstract	There has been a recent surge in the quest for useful thermoelectric materials partly motivated by the environment-friendliness of thermoelectric refrigerators and generators. In fundamental research on electron organization in solids, thermoelectricity has emerged as a very sensitive, even if poorly understood, probe, in particular in presence of strong electron correlation. Quantum criticality arises when a macroscopic phase of matter undergoes a continuous transformation at zero temperature. Studies of Seebeck and Nernst coefficients in a number of correlated-electron systems have opened a new window to this issue. Recent studies have found that the breakdown of the Landau Fermi liquid picture is accompanied by an unusual thermoelectric response. A main aim of this proposal is to study the thermoelectric signatures of quantum criticality in a wide range of systems including both heavy-electron materials and stacks of grapheme. Topological insulators, band insulators with particular symmetry properties arising from spin-orbit interaction have recently attracted a tremendous amount of theoretical attention and inspired an increasing number of experiments. All three hitherto identified families of topological insulators happen to be good thermoelectric materials and the origin of their large Seebeck coefficient in these systems is still far from established. We intend to put under scrutiny the thermoelectric response of these systems and explore the possible existence of Kondo topological insulators, which are also thermoelectrically interesting materials. Recently, Nernst effect has emerged as a probe of quantum oscillations with unrivalled sensitivity. We intend to use this probe in both graphite and bismuth to provide fresh input for a problem many-decades old yet unsettled: the fate of the three-dimensional gas of electrons pushed beyond the quantum limit. The large Nernst coefficient of these semimetals suggests that the Nernst route towards useful thermoelectricity deserves a more extensive exploration. The two partners, among a handful of groups on the international scene exploring the thermoelectric response of correlated electrons in extreme conditions, propose to initiate a new collaboration. The core of the project is to recruit two postdoctoral researchers, one based in Vienna and one based in Paris, carrying out a set of high-resolution thermoelectric measurements in the two laboratories and in high-field facilities. The results are expected to provide experimental input for a deeper theoretical understanding of thermoelectric phenomena.

Partners	Laboratoire Photons Et Matière-Ecole Supérieure de Physique et de Chimie Industrielle Technische Universität Wien, partenaire étranger (Autriche)
Coordinator	Kamran Behnia - LPEM-ESPCI kamran.behnia@gmail.com
ANR funding	259 409 €
Starting date and duration	February 2011 - 36 months
Reference	ANR-2010-INTB-0401