Proposal for an ESF Research Networking Programme – Call 2008

Section I:

Programme title:

Common perspectives for cold atoms, semiconductor polaritons and nanoscience

Programme acronym:

POLATOM

Name and full coordinates of principal applicant(s):

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Indication of which of the principal applicants is the contact person:

Georgios M. Kavoulakis and Richard Phillips

Keywords relating to the topic of the proposal:

Bose-Einstein condensates; microcavity polaritons; novel light emitters, entanglement, parametric scattering, cold atoms, nanoscience, quantum liquids, superfluidity and quantum transport, atomtronics

Abstract of the proposal:

The principal goal of the suggested Network is twofold. Firstly, to develop further the research fields of exciton/polariton condensates in semiconductor nanostructures, and that of cold atoms, promoting the collaboration between the scientists who work on these two fields. Secondly, to contribute to the development of technological applications, linking these two fields to nanotechnology. These areas have expanded dramatically in recent years, with remarkable achievements. The experimental developments in the field of cold atoms have made it possible to manipulate even single atoms, bringing future device design based on novel forms of matter within reach. The field of polaritons is at the forefront of condensed matter physics and is particularly rich in its interplay of theoretical predictions and their experimental realization.

The present Network combines a number of groups working at the front of the two fields of polaritons and of cold atoms in Europe, with a good balance between theory and experiment, and all the necessary prerequisites that will allow us to establish the goals of the Network. The combined knowledge of the groups which participate, as well as the scientists who will become involved in the Network activities, will definitely promote research in Europe in these highly interdisciplinary fields.

The goals will be met by the organization of annual workshops which will provide the main forum for information exchange. The workshops will include special pedagogical activities to aid development of postdoctoral scientists and research students. Delivery of results will be fostered by provision of bursaries for medium-term laboratory visits by researchers, in order to allow swapping of experimental and theoretical capabilities between project centres. Shorter discussion visits will also be funded to allow assessment and interpretation of results on a face-to-face basis.

Our Network fits very well with the goals and the philosophy of the ESF Networks. It also is well in line with other activities that either take place right now, or have just been completed.

Previous or concurrent applications to the ESF for any of the ESF instruments:
None

Section II:

Status of the relevant research field & scientific context:

Einstein predicted in the 1920s that an ideal gas of particles which obey Bose statistics may undergo a phase transition to a phase, where a macroscopic number of particles occupy a single, coherent quantum state. Apart from strongly-interacting systems, like e.g. liquid Helium, the experimental discovery of this phenomenon in more dilute systems had to wait many decades. In recent years, there has been a tremendous progress on achieving this phase transition in two different systems, namely in dilute vapours of atoms and in semiconductors. In the field of cold atoms Bose-Einstein condensation was realized in vapours of alkali-metal atoms in 1995 [Anderson et al., Phys. Rev. Lett. (1995); Davis et al., Phys. Rev. Lett. (1995); Bradley et al., Phys. Rev. Lett. (1995)]. These celebrated experiments clearly marked the beginning of a new era in quantum physics. In the field of polaritons, the research community is now convinced that the elusive goal of formation of condensates in semiconductors has been reached. At the recent Fourth International Conference on Spontaneous Coherence in Excitonic Systems, held in the summer of 2008 in Cambridge, for the first time at a major international meeting speakers were generally referring to “the condensate” as an achieved entity rather than an idea.

Part of the vitality of the field of cold atoms is due to the fact that the systems investigated are very clean, very dilute and very cold. The ability that we have to probe them optically has made possible measurements with a precision difficult to match in other systems. Often the characteristic length scales are comparable to the wavelength of light, and therefore spatial structures can be resolved optically at an unprecedented level of detail. In addition, most of the properties of these gases are tuneable externally. For example, one may control the density, the temperature, the external potential – and thus the effective dimensionality – and even the coupling strength between the atoms. Furthermore, the effective interaction between the atoms is in many cases well understood. It is thus possible to describe these gases using microscopic theories without any of the free parameters that often plague theories for conventional systems. Finally, many different species of atoms, each with a variety of internal states, may be used experimentally – a fact that has contributed to the richness of the field.

With regards to semiconductors, the work of Weisbuch identified new prospects for monolithic semiconductor structures comprising a “microcavity” (MC) with embedded semiconductor material. The interaction of cavity modes in such a structure with the two-dimensional excitons – the elementary optical excitations in a direct-gap semiconductor quantum well – was shown to enter the “strong coupling” regime. Such a system shows a new spectrum of states, the coupled exciton-photon modes known as exciton polaritons. It was quickly realized that the special, tuneable, dispersion of the energy of these excitations with their in-plane k-vector gave access to new opportunities in physics. For appropriate detuning of the cavity mode from the exciton, the central part of the polariton dispersion first curves parabolically upward with increasing in-plane momentum, then turns over to become rather flat, ultimately corresponding to the shallow parabola of the (heavy) exciton. In high-quality samples this dispersion strongly restricts the phase space available for scattering of polaritons. This leads to a bottleneck for relaxation, which makes it hard to populate the lowest states by scattering down the band from the point where the exciton-like are stacked after initial relaxation. However, scattering in and scattering out are related, so the dispersion also protects the lowest polaritons from scattering, in a kind of k-space confinement. What is more, the ogee dispersion leads to another prospect in that a point can be identified on the curve which permits simultaneous scattering of one excitation up the curve, and one down, in a coherent process which satisfies energy and momentum conservation. Because the polaritons are bosons, there is an enhanced scattering probability into the final state if it is already occupied; very large populations were shown by Savvidis et al. [Phys. Rev. Lett. (2000)] to develop in appropriate circumstances. Convincing evidence for Bose-Einstein condensation in the ground polariton state was recently reported by Kasprzak et al. [Nature (2006)].The bosonic character of the polariton also underpins the proposal by Imamoglu and Yamamoto of the polariton laser, conceived as a route to inversionless lasing. Further novel properties of this system are associated with the Bogoliubov-like linear dispersion in the long-wavelength limit, which is the signature for superfluid behaviour. This has recently been shown in special conditions (Yamamoto), and opens many new opportunities.

Objectives and envisaged achievements:

The main goals of the present proposal include the following: 1) To develop links and to trigger collaborations between the two fields of polariton condensates and of cold atoms, 2) to support work on the key topics associated with the development of the field of polariton condensates – engineering strong coupling, fabricating samples with novel forms of light emission, establishing the next steps in electrical injection of polaritons, and investigating the physics of both Bose-Einstein condensed and other high-density systems, and 3) to develop links between cold atoms/polaritons and the field of nanotechnology. The field of nanotechnology, which is a very extensive, highly diverse, and multidisciplinary field, has been making impressive progress in fabricating and studying mesoscopic/nanoscale systems and devices. This has strong parallels to the field of polariton condensates and to cold atomic physics. It is clear that many of the key goals are now attainable, and a coordinated exchange of knowledge within Europe will have a very substantial impact.

With regards to the first goal, remarkably many of the fundamental problems that are studied within the fields of cold atoms and of excitons in semiconductors are essentially the same. Both result from the macroscopic occupancy of a single-particle state of the many-body Hamiltonian, which gives rise to fascinating phenomena. These include the class of problems that are associated with superfluidity (quantized vortex states, non-classical moment of inertia, collective effects – first, second sound, etc. – the Hess-Fairbank effect, the Josephosn effect, metastable persistent currents), nonlinear effects, coherence effects, etc.

Turning to the second goal of this Network, which is the development of the field of polariton condensates, the scientific targets include aspects of condensate formation (a problem that has been examined extensively in cold gases), studies of condensate properties, manipulation of polariton injection and exploitation of technical opportunities arising from all these. The present status of the field of Bose-Einstein condensation in semiconductors presents exciting targets which should be attainable in the lifetime of the Network. These centre on exploration of physical effects, but investigation of new material systems will also be an important source of innovation.

● Growth of MCs with higher quality factor than those formerly studied; the key target is to increase the photon lifetime within the cavity in order to facilitate polariton cooling in the case of non-resonant injection. Experimental challenges here centre on improvements in growth control to give higher-quality MCs and reduce inhomogeneous broadening in embedded quantum wells.

● Planar MCs containing quantum dots. Here the challenge is to achieve sufficient density and field enhancement to permit shaped-pulse-driven condensate formation. Theoretical work has predicted new routes to BEC formation, potentially giving access to systems farther from equilibrium.

● Planar MCs containing bulk semiconductor. Condensation in this system is a key target because of the potential for yet higher-quality structures in which superfluid flow can be observed and utilized. Experimental challenges here also relate to growth, and to devising approaches to testing superfluid physics.

● Novel structures for polariton BEC. These have already been important in demonstrating 3-dimensional quantization of the polariton states. Key questions concerning mode competition remain to be investigated. Many avenues are open to produce lateral confinement. Approaches will include: pillar etching; patterning

structures after growth of the bottom distributed Bragg mirror (DBR) and cavity contents followed by regrowth; flip-chip methods to apply an independently-grown top DBR; lateral confinement using photonic crystal structures; microdisc structures. Confinement structures also open the prospect of studies of strongly interacting polariton states, which are of great interest to the theoretical arms of the Network.
A related issue is the growth and electro-optical studies of designed 0D, 1D and 2D heterostructures, designed for the polariton/exciton condensation physics at the Nanometer Structure Consortium at Lund University (Lars Samuelson). Nanowire rod-arrays should be able to produce some of the most ideal photonic microcavity structures.

● Polariton BEC at room temperature is a key target. Achievement of this goal has begun to look a realistic prospect in view of several recent results. It is expected that the attainment of a polariton BEC at room temperature would underpin a new generation of quantum devices. Likely to be a key aspect here is utilization of a wide range of material systems; this is well covered by the different growth centres included in the Network, and the excellent prospects for future enlargement as required.

● Development of real-space traps for exciton condensation phenomena. This area has been especially developed by the Network partners in the USA, and offers opportunities for testing many aspects of BEC and excitation relaxation theory. Again, this is one of the main issues of the field of cold gases of atoms.

● Exploitation of polariton lasing, for which the threshold is typically two orders of magnitude lower density than for photon lasing. The key steps for exploitation will be electrical injection and maintenance of strong coupling at room temperature. This should lead to a new form of light source emitting coherent radiation without the need for population inversion as in a photon laser. Recent results indicate that this is likely to be attainable during the life of the Network.

● Investigation of polaritonic effects in new materials will be a means of extending the scope of the future impact of polariton physics in technological applications, by increasing the range of options available for choice of material parameters which control key aspects of the polariton behaviour, such as dipole coupling strength.

● Theoretical work on polaritons has progressed in very close symbiosis with the experimental work, and this will cooperation will be enhanced in the Network. Particular targets include quantum-kinetic approaches to polariton condensation, using the particular expertise (Haug, Littlewood) of Keldysh Green functions as well as Boltzmann approaches (Savona). Further work by the Trento-BEC Centre (Carusotto) will be devoted to non-equilibrium effects in the transition to a coherent state. Further theoretical work will be carried out in the groups of Kavokin and Malpuech and Tejedor.

Finally, the third goal of this Network is to develop closer links between the field of cold atoms and of polariton condensates with nanotechnology. Actually, cold atomic gases in fact play an increasingly important role in nanoscience already today. Remarkably, phenomena such as Bose-Einstein condensation and coherent flow nowadays appear accessible for the micro- and nano-design of future quantum devices. The cross-fertilization between the research on cold atomic quantum gases and nanoscience applications, where future technological relevance is apparent, is at the core of this research Network. Below we list a number of specific examples where we expect collaborations within the Network to produce significant results.

● A major goal in the field of cold atoms, as well as in nanotechnology, is to engineer and coherently control single quantum-mechanical degrees of freedom using atomic traps, atoms in optical lattices, single-electron transistors, and quantum dots. This overlap has the potential for fruitful interdisciplinary collaborations in the future. Remarkably, systems consisting of a Bose-Einstein condensate on a chip coupled to micro- and nanomechanical resonators (Treutlein et al., Phys. Rev. Lett., 2007) are already being investigated experimentally. Such experiments would push the boundary of quantum mechanics further into the macroscopic world. This is one example of how the remarkable degree to which one can manipulate cold atoms nowadays, combined with their macroscopic quantum-mechanical properties, give experimentalists unique opportunities to design revolutionary nanoscale devices.

● In another intriguing combination of nanoscience and cold atomic physics, one could use the effect of persistent flow in a Bose-Einstein condensate of atoms to design devices with dissipationless flow, leading to numerous fascinating applications. Nonlinear effects, which may also give rise to solitary waves that propagate over large distances with no change in the shape of the atom pulses, may turn out to be useful in nanodevices. Coherence effects may allow one to perform precision measurements via interference phenomena and come up with useful applications in nanotechnology. The effectively reduced dimensionality that one may easily achieve nowadays via appropriate manipulation of the electromagnetic fields that confine the atoms, may also allow one to investigate novel effects, which are sensitive to the dimensionality of the system. The effect of disorder (introduced either by design, or because of unavoidable irregularities) on the coherent transport properties, combined with the engineering of interaction (short-ranged versus long-ranged; attractive versus repulsive) may give rise to interesting phenomena. The fact that one may control the atom number to a high precision can be used to investigate the cross-over between microscopic and thermodynamic behavior, with obvious relevance to the design of nanoscale devices. Presently, experimental groups are embarking on a project with the aim at studying exactly such small atomic systems. Precursors of phase transitions (which are real phase transition in the thermodynamic limit of large particle number) and novel states of matter may also appear in the systems that we have in mind, which would require the study of both static, as well as dynamic processes. A goal of the Network is to galvanize significant research progress in the topics above.

● The scientific community has the ability now to examine a tuneable system of paired fermionic atoms, which may prove to be extremely important in our understanding of e.g., high-temperature superconductivity. This system, coupled with solid-state devices, may also have very important applications, in devices like the SQUID.

● The field of “atomtronics” opens up an entirely new and fascinating research horizon. Atomtronic applications set focus on atom analogues of electronic materials, devices and circuits, as well as on creating non-classical devices, which are difficult or impossible to design using conventional electronics. The design of an atomtronic diode with a strongly-asymmetric current-voltage curve exploits the existence of superfluid and insulating regimes in the phase diagram analogue of a bipolar junction transistor (Seaman et al., Phys. Rev. A, 2007). Of particular interest is also the extension of Coulomb blockade phenomena in nanostructured semiconductors to interaction blockade in cold atomic quantum gases (Capelle et al., Phys. Rev. Lett., 2007; Cheinet et al., Phys. Rev. Lett., 2008), as well as related questions on quantum information.

Remarkably, a key point in the above ideas is that Bose-Einstein condensates are characterized by macroscopic coherence with very low thermal noise, which means that atomtronics holds a significant advantage over conventional electronics for achieving non-classical devices. A major goal of the Network is to advance our understanding and applications of this important fact, which holds the potential to revolutionize the design of nano-scale devices and quantum computing.

Facilities and expertise which would be accessible by the Programme:

Austria, Vienna: Confined atoms at ultralow temperatures, mesoscopic-many body quantum systems, strongly correlated low dimensional systems, coherence and decoherence, applications of quantum degenerate systems, magnetic field sensors, quantum information and quantum simulation, quantum interconnect, quantum memory, atomchips, and matter wave optics.

Denmark, Lyngby: Ultrafast spectroscopy, excitons, polaritons, photonic crystals.

Denmark, The Niels Bohr Institute and the Niels Bohr Academy: Theory of BEC, solitons and solitary waves, microscopic many-body theory, random matrix theory, strongly interacting Fermi systems, superfluidity, dipolar atomic gases, nuclear physics.

Finland, Jyväskylä: Quantum transport in nanosctructures, many-particle theory of fermions and bosons in confined systems, generalized Hubbard models for electrons and fermionic atoms in one and two-dimensional lattices.

France, Clermont Ferrand: Theory of BEC, polaritons, excitons, electrical injection, spin.
France, Grenoble: cw and high time-resolution optical spectroscopy. Materials; Low-dimensional strongly interacting quantum gases, superfluidity of confined Fermi and Bose gases on a ring, macroscopic quantum coherence and the Josephson effect in quantum gases, effects of disorder and interactions in quantum gases.
France, Paris: Quantum many-body systems, including quantum fluids and solids, ultracold atomic gases, and phase transitions and quantum phases; Theory of BEC, polaritons, excitons. Various spectroscopies.
France, Valbonne: Experimental cold atom, including coherent transport in disordered media, e.g., coherent backscattering and Anderson localization, random lasers, mechanical effects of light on cold atoms, and plasma physics with neutral cold atoms, e.g., fluid equations and non linear dynamics.
Germany, Berlin: SAW devices on microcavities.
Germany, Bremen: II-VI and nitride growth and fabrication.
Germany, Frankfurt: Theory of BEC, polaritons, excitons.
Germany, Hamburg: Finite systems, spin dynamics in quantum dots, nanowires and ultracold spinor condensates, transport through confined quantum systems far from equilibrium, low dimensional semiconductors, strongly correlated states at high magnetic fields; bosonic and fermionic ultracold quantum gases, mixtures of quantum gases, physics of solitons in BEC, strongly correlated quantum gases, Bragg spectroscopy on optical lattices, and nonlinear effects in BEC.
Germany, Heidelberg: Experimental investigations of ultracold few-fermion systems with tuneable interactions, clusters, or quantum dots; BEC-BCS crossover and strongly interacting Fermi gases; multicomponent Fermi gases.
Germany, München: Hybrid quantum systems composed of ultracold atoms coupled to micro- and nanostructured solid-state systems; atom chips; ultracold atoms coupled to mechanical resonators; coherent manipulation of atoms with miniaturized microwave circuits on atom chips; the physics of mesoscopic BECs composed of several tens of atoms; spin squeezing and entanglement of BECs, and quantum information processing on atom chips.
Germany, Stuttgart: Dipolar quantum gases, in applied atom optics, e.g., atom lithography, high power atom lasers, in ultracold Rydberg gases, in quantum critical phenomena, in ultracold chemistry/molecular physics, in quantum information processing using Rydberg atoms, in electromagnetically induced transparency, and in laser cooling.
Greece, Athens: Eliashberg theory of superconductivity, unconventional superconductors, high-Tc materials, heavy fermion superconductors and organic superconductors.
Greece, Heraklion: Electrical polariton injection, various spectroscopies; Confined atoms at ultralow temperatures, nonlinear effects and solitary waves, superfluidity of confined and finite systems, excitons in semiconductors.
Italy, Modena: Low-temperature physics of fermions in the few-body limit. Physics of nanostructures and related computational approaches, including configuration interaction calculations.
Italy, Trento: Confined bosons and fermions at ultralow temperatures, nonlinear effects and solitary waves, superfluidity of confined and finite systems. Theory of polaritons.
Netherlans, Eindhoven: Few-body interactions in ultracold gases, Feshbach resonances, BCS-BEC crossover and the coherent atom-molecule oscillations in a BEC.
Spain, Barcelona: Atoms in optical lattices, and in particular ultracold disordered gases, ultracold spinor gases, ultracold dipolar gases, ultracold gases in artificial gauge fields, ultracold gases in optical cavities, quantum information and ultracold gases, ultracold frustrated cold gases, and nonostructuring on the single atom level.
Spain, Madrid: High time- and spatial-resolution optical spectroscopy; theory.
Switzerland, Lausanne: cw and high time-resolution optical spectroscopy.
Interferometry, theory, materials: GaAs- and GaN-based.

Sweden, Lund: Experimental and theoretical activities in quantum engineering, hosted by the Nanometer Structure Consortium, which is one of the main actors in the field of nanoscience today. Cutting-edge fabrication and characterization facilities. Development of nanotechnology for truly one-dimensional electron systems with gate-controlled doping. Computational many-body physics and its applications to finite fermion and boson systems. Nanostructured quantum systems, trapped atomic Fermi gases and Bose-Einstein condensation.
Sweden, NORDITA: Ultracold atoms in optical lattices, Bose-Einstein condensation, non-linear dynamics of Bose-Einstein condensates, rotational properties of superfluids, and degenerate fermionic atoms.
Sweden, Umeå: Confined atoms at ultralow temperatures, superfluidity of confined and finite systems, quantum phase transitions, optical lattices, disorder; Brownian motors and ratchet effects, fluctuations, non-equilibrium systems, laser cooling from a fundamental point of view.
UK, Cambridge: Theory of BEC, polaritons, excitons. cw and high time-resolution optical spectroscopy materials. Coherent light-matter interactions and coherent spin dynamics in nanoscale semiconductor structures, strong-correlation physics in atomic gases.
UK, Cardiff: High time-resolution optical spectroscopy.
UK, Sheffield: Theory of BEC, polaritons, excitons. cw and high time-resolution optical spectroscopy, materials.
UK, Southampton: Theory of BEC, polaritons, excitons. cw and high time-resolution optical spectroscopy.

Expected benefit from European collaboration in this area:

The interplay between nanostructure physics and research on cold atoms/polariton condensates will pave the way for novel developments in applications and device technologies. Importantly, it will also give us the opportunity for a deeper view into the properties of quantum matter.

The previous record of achievement through European collaboration in the study microcavity polaritons is exemplary, and led to many previous ground-breaking advances in polariton physics, including the first accepted observation of condensation in this system. Three of the six Principal Applicants have worked together previously in a similar context in running the highly successful EQUONT Euroconference series, and will develop the format from this prior experience.

Our proposed Network fits very well with the key objectives of the ESF Networks, such as the creation of interdisciplinary fora, the sharing of knowledge and expertise among the different research leaders in the field, and the development of new techniques. Naturally the training of young scientists is a very important aspect of this Networking activity, which will be given strong priority.

Presently, many research teams in the European countries are at the forefront of research, competing well with the leading groups in the United States, Japan, and Australia. Creating a core of scientists working on cold atoms, polariton condensates, and nanoscience within Europe is certainly vital, if European research in this area aims to take the lead, and to be well prepared to meet the future technological challenges.

While several groups have already performed very interesting studies in the spirit of the above ideas, this effort of combining the two fields of cold atoms and polaritons, as well bringing them closer to nanotechnology has yet a long way to go. To achieve this goal, one should get a good knowledge of the basic problems that appear in these fields, and bring together the leading experts from both of these research areas – an effort that is at the heart of this Network.

There is a very strong training value associated with the core activities of the proposed Network. The regular scientific meetings will provide not only a forum for presentation of papers, but also sessions of a pedagogic character at which young researchers learn new approaches and swap ideas. The various activities that will be organized will give junior scientists the chance to interact with the leading European research groups in the field, and to build up contacts with a truly European perspective for the future. The initiative will largely contribute to the training of the students, who will also have the chance to meet the senior scientists working on the research areas of the Network, and to establish themselves in the field. The Network will have an extensive link to the already existing Graduate Schools that various members of the Network are coordinating, or are involved in. This increased interaction of the various Graduate Schools will be particularly beneficial for the large number of Ph.D. students Europe-wide who are currently engaged in both research fields.

The Workshops will be supplemented by short-to-medium-term exchange visits between laboratories; via these exchanges techniques will be disseminated through the community, and the individual skills of the participants enhanced. Such visits will frequently also be associated with transfer of specially-grown and characterised specimens which will be studied in the host laboratory using techniques not available to the originator. In this manner the level of scientific output will be enhanced throughout the community. The presence of leading theoretical groups in the Network will add greatly to the assessment and understanding of experimental results, and hence make a substantial contribution to the future impact of the work. It is expected that the exchange visits between theorists and experimentalists will further enhance the design of future experiments, and give theorists access to unpublished experimental results.

European context

● Marie Curie Initial Training Networks (FP7-PEOPLE-ITN-2008) “Clermont4”: dealing with the physics of semiconductor microcavities. It is limited to a small number of participants (10): University of Rome II, CNRS, Universite Paris VI, University of Sheffield, University of Southampton, University of Cambridge, Durham University, Universidad Autónoma de Madrid, Foundation for Research and Technology – Hellas, Ecole Polytechnique Fédérale de Lausanne, Laboratories for Photonic and Nanostructures (Marcoussis, France).

● Stephanie Reimann and Lars Samuelson are directing the Linnaeus Center of Excellence “Nanoscience and Quantum Engineering” at Lund University. Extensive interaction with this center and the associated Graduate School is foreseen within this new initiative on the European level, and with no doubt will create a very interdisciplinary and interactive research forum for all Ph.D. students associated to the proposed ESF Network.

● One of the participants of our Network, Robin Kaiser, is the coordinator of the International Cold Atom Network (INTERCAN), which aims at the promotion of European Research and Education in the domain of Ultracold Dilute Atomic Systems and their Applications. It provides a European platform for information exchange and collaboration for some 300 senior physicists and 250 Ph.D. students in the European Union. INTERCAN aims to define the European Research Space for the field of cold atoms at large.

● One of the participants of our Network, Tilman Pfau, is the coordinator of a local excellence center of the German research foundation "SFB/TRR 21: Control of quantum correlations in tailored matter: Common perspectives of mesoscopic systems and quantum gases."

● Another Network that has formed within the Scandinavian countries (“NordForsk”), which is led by Stephanie Reimann, with the title “Coherent Quantum Gases - From Cold Atoms to Condensed Matter” (01.11.2007 – 30.10.2010), has similar interests as the present one.

● Finally, our Network is closely related to the Eurocores program “*Cold Quantum Matter*” (EuroQUAM).

Proposed activities:

The two main components of the proposal are annual workshops, and personnel exchanges between scientists inside *and* outside this Network. Workshops are proposed annually.

As a first step, we will form a steering committee, which will consist of the principal applicants, plus a representative from each country that participates in the Network.

This committee will get together once per year, and its duty will be to discuss and plan the future activities, and also review the past activities within the Network.

Special attention will be paid by the committee to the advertisement of the activities associated with the Network. It will also make sure that the results that are announced in the conferences are available online on a website.

The planned annual activities include:

- A workshop annually with expected attendance (supported by the Network) of up to 80 people. These will span 4 days typically, at venues chosen so that local organization can be undertaken by a member of the Steering Committee, or one of the Principal Applicants. Emphasis will be placed on the Workshop format with explicit inclusion of programme features to assist beginning researchers.
- Funds are budgeted annually for short exchange visits averaging 3 days, for 50 people. This will allow reciprocal visits between most of the centres, and will provide a resource to help introduce new contacts to the Network.
- Longer-term research visits averaging one month are also budgeted, with up to 15 bursaries for these per annum. This will allow extended work by researchers visiting host laboratories within the Network to permit exchange of experimental facilities and expertise, and also allow more substantial theoretical projects to be undertaken collaboratively.

Key targets and milestones:

* Investigate the links between the physics of cold atoms and the physics of polaritons in semiconductors
* Develop further the field of atomtronics, also experimentally
* Develop technological applications taking advantage of the superfluid properties of cold atoms, in connection also with the high tunability of these systems
* Investigate the possible combination of solid-state devices with cold atoms
* Develop the methods of engineering of atoms
* Investigate the pairing mechanisms between fermionic atoms, in connection with high-temperature superconductivity
* Perform high-precision measurements with cold atoms
* Study room temperature Bose-Einstein condensation of polaritons
* Study the dynamics of polariton condensation
* Polariton condensate trapping and lasing
* Polariton Josephson junctions, parametric scattering
* Investigation of superfluid properties of MC polariton condensates
* Strong MC polariton coupling under electrical injection at room temperature
* Room temperature operation of electrically-pumped polariton laser
* Theoretical treatment of non-equilibrium effects in MC polariton condensates

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Duration: We wish to apply for 60 months.

Budget estimate (in €) by type of activities and per year of the Programme

First Steering Committee Meeting

12 persons, 2 days: 12 x (2 x 100 + 500) = 8400

Science meetings (includes subsequent Steering Committee Meetings)

Annual workshop costs for 80 people: 80 x (4 x 100 + 500) + 12 x 2 x 100 = 74400

Grants for Short and Exchange Visits

50 short visits of 3 days: 50 x (3 x 100 + 500) = 40000

15 exchange visits of 1 month: 15 x (1600 + 500) = 31500

Activity	2009	2010	2011	2012	2013	2014	Total
Science Meeting	8400	74400	74400	74400	74400	74400	
Short Visits		40000	40000	40000	40000	40000	
Exchange visits		31500	31500	31500	31500	31500	
Administrative Costs		5000	5000	5000	5000	5000	
Publicity, Websites and Publications		5000	5000	5000	5000	5000	
Totals	8400	155900	155900	155900	155900	155900	**787900**

Section III:

List of names and full coordinates of the **envisaged Steering Committee members listed by country** in alphabetical order**:**

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● 1994 Masters in Physics, University of Århus, Denmark
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Employment record:
● 2007-2008 Guest Prof. at the Department of Physics, University of Trento, Italy
● 2005- Associate Prof. at the Niels Bohr Institute, University of Copenhagen, Denmark
● 2002-2005 Assistant Prof. at the Niels Bohr Institute, University of Copenhagen, Denmark

Research interests:
● Strongly correlated Fermi systems
● Superfluidity, rotation and vortices
● Mesoscopic systems
● Dipolar atomic gases
● Hydrodynamics and collective modes
● Quantum Transport
● Bioinformatics

Publications/Experience:
● Co-organizer of conference on coldt atomic gases and quark gluon plasmas
● Proposal Reviewer for National Science Foundation (NSF), USA. Referee for Phys. Rev. Lett., Phys. Rev. A, Phys. Rev. B, J. Phys. B., Europhys. Lett., New J. of Phys, and Bioinformatics

Five more recent relevant publications:
1. *Quantum phases of a two-dimensional dipolar Fermi gas*, G. M. Bruun and E. Taylor, arXiv:0809:1422v1.
2. *Probing spatial spin correlations of ultracold gases by quantum noise spectroscopy*, G. M. Bruun, Brian M. Andersen, Eugene Demler, and Anders S. Sørensen, arXiv:0809.0312v1.
3. *Collisional Properties of a Polarized Fermi Gas with Resonant Interactions*, G. M. Bruun, A. Recati, C. J. Pethick, H. Smith and S. Stringari, Phys. Rev. Lett.. **100**, 240406 (2008).
4. *Twin peaks in rf spectra of Fermi gases at unitarity in the normal phase*, P. Massignan, G. M. Bruun, and H. T. C. Stoof, Phys. Rev. A **77**, 031601(R) (2008).
5. *Detection of BCS pairing in neutral Fermi fluids via Stokes scattering: the Hebel-Slichter effect*, G. M. Bruun and Gordon Baym, Phys. Rev. Lett. **93**, 150403 (2004).

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Benoît Deveaud-Plédran was born in France in 1952. In 1971, he entered Ecole Polytechnique in Paris where he specialised in physics. In 1974, he joined the National Center for research in Telecommunications (CNET). He undertook studies on the main impurity centers in III-V semiconductors, and in 1984, he defended his PhD thesis at the University of Grenoble. His team became interested in semiconductor microstructures and launched studies on the structural and optical properties of superlattices based on gallium arsenide. These studies highlighted for example vertical transport in superlattices as well as the quantisation of excitonic energies in a quantum well. In 1986 he joined the team of Jag Shah in Bell Laboratories (Holmdel, USA) and took part in the development of the first luminescence set-up having a temporal resolution better than 1 picosecond, permitting study of ultrafast processes in quantum wells. Returning to France in 1988, at CNET, he established a laboratory for highspeed studies of optical and electronic properties of semiconductor materials. He was appointed Professor in Physics at EPFL in October 1993; his research team studies the physics of ultrafast processes in semiconductor micro- and nano-structures and in devices that use them. He has been the Director the Institute of Micro and Optoelectronics since 1998, and of the Institute of Quantum Photonic and Electronics from 2003 to 2008. His team takes an active part in the "Quantum Photonics" National Center of Competence in Research, of which he was the Deputy Director from 2001 to 2005 then the Director since July 2005. As of 2008, he is Dean for Research at EPFL and president of the research commission.
He was a divisional editor of Physical Review Letters from 2001 to 2007.

Relevant publications:

1. *Coherent Control of Polariton Parametric Scattering in Semiconductor Microcavities;* S. Kundermann, M. Saba, C. Ciuti, T. Guillet, U. Oesterle, J.L. Staehli, and B. Deveaud Phys. Rev. Lett. **91**, 107402 (2003).
2. *Bose-Einstein Condensation of Exciton Polaritons;* J. Kasprzak, M. Richard, S. Kundermann, A. Baas, P. Jeambrun, J. Keeling, F. M. Marchetti, M. H. Szymańska, R. André, J. L. Staehli, V. Savona, et al., Nature **443**, 409 (2006), Cover page of Nature.
3. *Second order time correlations within a polariton Bose Einstein condensate in a CdTe microcavity;* J. Kasprzak, M. Richard, A. Baas, B. Deveaud, R. André, et al., Phys. Rev. Lett. **100**, 067402 (2008).
4. *Synchronized and desynchronized phases of exciton-polariton condensates in the presence of disorder;* A. Baas, K. G. Lagoudakis, M. Richard, R. André, Le Si Dang, et al., Phys. Rev. Lett. **100**, 170401 (2008).
5. *Quantized vortices in an exciton-polariton condensate;* K.G. Lagoudakis, M. Wouters, M. Richard, A. Baas, I. Carusotto, R. André, Le Si Dang, B. Deveaud-Plédran, Nature Physics **4**, 706 (2008).

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- 09/1985 – 06/1990: B. Sc. in Physics, University of Crete, Heraklion, Greece

Employment record:
- 09/2001 – 09/2007: Docent, Lund Institute of Technology, Lund, Sweden
- 09/2000 – 08/2001: Göran Gustafsson Fellow, Royal Institute of Technology, Stockholm, Sweden
- 04/1997 – 08/2000: NORDITA fellow and Marie Curie (European Union) fellow, Copenhagen, Denmark

Research interests:
- Confined atoms at ultralow temperatures
- Nonlinear effects and solitary waves
- Superfluidity of confined and finite systems: vortex states, persistent currents, etc.
- Fluid mechanics and hydrodynamic description of systems
- Numerical methods of non-linear differential equations: relaxation, diagonalization of matrices of large dimensionality
- Physics of semiconductors: BEC of excitons, optical properties, elementary excitations, nonlinear phenomena, transport properties

Publications/Experience:
- Referee of more than 100 papers for Phys. Rev. A, Phys. Rev. B, and Phys. Rev. Lett., etc.

Five more recent relevant publications:

1. *Stability of persistent currents in a Bose-Einstein condensate confined in a toroidal trap,* M. Ögren and G. M. Kavoulakis, Journal of Low Temp. Phys. **154**, 30 (2009).
2. *The absence of fragmentation in Bose-Einstein condensates,* A. D. Jackson, G. M. Kavoulakis, and M. Mageiropoulos, Phys. Rev. A **78**, 063623 (2008).
3. *Manipulating the rotational properties of a two-component Bose gas*, J. Christensson, S. Bargi, K. Kärkkäinen, Y. Yu, G. M. Kavoulakis, M. Manninen, and S. M. Reimann, New Journal of Physics **10**, 033029 (2008).
4. *Metastability of persistent currents in trapped gases of atoms,* K. Kärkkäinen, J. Christensson, G. Reinisch, G. M. Kavoulakis, and S. M. Reimann, Phys. Rev. A **76**, 043627 (2007).
5. *Mixtures of Bose gases under rotation*, S. Bargi, J. Christensson, G. M. Kavoulakis, and S. M. Reimann, Phys. Rev. Lett. **98**, 130403 (2007).

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Member of Editorial Board:
Solid State Communications (1995-present),
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Fellow, American Physical Society 2007.
Member of the Institute of Physics.
Chair, NATO ARW on *Coherent Optical Interactions in Semiconductors,* 1993
Chair, Euroconferences on Quantum Optoelectronics for NanoTechnology 2002-2204.
Organising and Programme Committees of numerous conferences.

Five recent publications:
1. *All-optical measurement of Rashba coefficient in quantum wells,*
P. S Eldridge, W. J. H. Leyland , P. G. Lagoudakis, O. Z. Karimov, M. Henini, D. Taylor, R. T. Phillips, and R. T. Harley, Phys. Rev. B **77** 125344 (2008).
2. *Moving nanoparticies with Raman scattering,*
M. Ringler, T.A. Klar, A. Schwemer, A.S. Susha, J. Stehr, G. Raschke, S. Funk, M. Borowski, A. Nichtl, K. Kürzinger, R.T. Phillips, J. Feldmann, Nano Letters **7** 2753-2757 (2007).
3. *Hole g factors in GaAs quantum dots from the angular dependence of the spin fine structure,*
I. Toft and R. T. Phillips, Phys. Rev. B **76** 033301 (2007).
4. *"Plug and play" single-photon sources*
X. L.Xu, I. Toft, R. T. Phillips, J. Mar, K. Hammura, and D. A.Williams, Appl. Phys. Lett. **90** 061103 (2007)
5. *Time-resolved four-wave-mixing spectroscopy of excitons in a single quantum well*
J. A. Davis, J. J. Wathen, V. Blanchet, and R. T. Phillips, Phys. Rev. B **75** 035317 (2007)

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● Director of the Linnaeus Centre of Excellence "Nanoscience and Quantum Energineering" at the Swedish Research Council (2006-2016) (in cooperation with L. Samuelson at the "Nanometer Structure Consortium" in Lund).
● Author of more than 80 papers, H-index 20 (publishing activity since 1994).
● Organizer of five international conferences/workshops during the last years, as for example the recent "International Symposium on Cold Atoms and Atomtronics", at Örenäs Castle, Sweden, Nov. (2007).
● More than 20 invited lectures at international conferences during the more recent years (among those, the APS March Meeting in Denver, 2007).
● Recipient of the 'INGVAR' award (10 Mio. SEK) of the Swedish Foundation for Strategic Research, 2001.

Five more recent relevant publications:_
1. *Energy gaps and interaction blockade in confined quantum systems*, K. Capelle, M. Borgh, K. Kärkkäinen, and S. M. Reimann, Phys. Rev. Lett. **99**, 010402 (2007).
2. *Mixtures of Bose gases under rotation*, S. Bargi, J. Christensson, G. M. Kavoulakis and S. M. Reimann, Phys. Rev. Lett. **98**, 130403 (2007).
3. *Universality of many-body states in rotating Bose and Fermi systems*, M. Borgh, M. Koskinen, J. Christensson, M. Manninen and S. M. Reimann, Phys. Rev. A **77**, 033615 (2008).

4. *Universal Vortex formation in rotating traps with bosons and fermions*, M. Toreblad, M. Borgh, M. Koskinen, M. Manninen, and S. M. Reimann, Phys. Rev. Lett. **93**, 090407 (2004).
5. *Electronic structure of quantum dots*, S. M. Reimann and M. Manninen, Rev. Mod. Phys. **74**, 1283-1342 (2002) (invited review).

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• Member of the Editorial Board of *Sem. Science and Technology* (1994-) & *European Physics Letters* (2007-).
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• Member of the Semiconductors Committee (C8) of the IUPAP, (1994-97; 2000-); Secretary of the Semiconductors Committee of the IUPAP, (2002-2005).
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• Member of Program and Advisory Committees of ~25 International Conferences.

Five recent Publications:
1. *Quantum-fluid dynamics of microcavity polaritons*, Nature **457**, 291 (2009), A. Amo, D. Sanvitto, D. Ballarini, F. P. Laussy, E. del Valle, M. D. Martin, A. Lemaitre, J. Bloch, D. N. Krizhanovskii, M. S. Skolnick, C. Tejedor and L. Viña.
2. *Control of non-Markovian effects in the dynamics of polaritons in semiconductor Microcavities*, Phys. Rev. B **78**, 035312 (2008), F..J. Rodríguez, L.Quiroga, C.Tejedor, M. D. Martin, L. Viña and R. André.
3. *Observation of Resonant Behavior in the Energy Velocity of Diffused Light*, Phys. Rev. Lett. **99**, 233902 (2007), R. R. Sapienza, P.D. García, J. Bertolotti, M.D. Martín, A. Blanco, L. Viña, C. López, and D. S. Wiersma.

4. *Transition from the strong- to the weak-coupling regime in semiconductor microcavities: polarization dependence*, Appl. Phys. Lett. **90**, 201905 (2007), D. Ballarini, A. Amo, M.D. Martin, L. Viña, D. Sanvitto, M.S. Skolnick and J. S. Roberts.
5. *Polariton and spin dynamics in semiconductor microcavities under non-resonant excitation,* J. Phys.: Cond. Matt. **19**, 295204 (2007), M. D. Martín, G. Aichmayr , A. Amo, D. Ballarini, Ł. Kłopotowski, and L. Viña.