SCIENTIFIC REPORT (PART 2)	
EUROPEAN COMMISSION RESEARCH DG HUMAN POTENTIAL PROGRAMME	HIGH-LEVEL SCIENTIFIC CONFERENCES SCIENTIFIC REPORT

Contract No	HPCFCT –2002 - 00258	Event No 2	

Summary (maximum 2 pages, page 1)

Ultracold Gases and their Applications

San Feliu de Guixols (Costa Brava), Spain, 10 – 15 Septembwer 2005

http://www.esf.org/conferences/pc05095

Scientific Highlights:

The discovery of the phenomenon of Bose-Einstein condensation – macroscopic occupation of a single quantum state - in dilute ultracold clouds of trapped atoms in 1995 (Eric Cornell, Carl Wieman, Wolfgang Ketterle, Nobel Prize of 2001), stimulated tremendous developments in the field of quantum gases. It has been revealed that extremely dilute and cold trapped Bose-condensed gases, with temperatures in the nanokelvin regime and eight orders of magnitude lower densities than in liquid helium, manifest collective (condensed matter) behaviour. This makes quantum gases ideal candidates for studying condensed matter phenomena, such as superfluidity, strong correlations etc. At the same time, presenting evolving condensates as coherent matter waves brings in analogies with photon optics. At the present stage, global fundamental problems of the field are related to the appearance of irreversibility in a quantum system with a large number of particles, kinetics of quantum phase transitions, and the nature of superfluid pairing in strongly interacting systems. Potential applications include atom lasers – devices for the generation of coherent matter waves, atom interferometry, high-precision atomic clocks, and systems for quantum computing.

The field of quantum gases is now highly interdisciplinary, bringing together researchers from atomic physics and quantum optics, condensed matter physics, nuclear and high-energy physics, non-linear physics. This is due to an extraordinary level and wide spectrum of scientific activity in the last few years and a high potential for future developments. One can mention the creation of low-dimensional quantum gases by tightly confining the motion of particles in one or two directions (MIT, ENS, Orsay and elsewhere); the accumulation of bosonic atoms in an optical lattice and the observation of the quantum Superfluid-Mott Insulator transition in this system (Munich and elsewhere); the creation and melting of vortex lattices in rapidly rotating Bose condensates (JILA, ENS), which draws prospects towards achieving strongly correlated quantum Hall states; the creation of spinor Bose-Einstein condensates representing a gaseous analogue of condensed matter magnetic systems (JILA, MIT, Hamburg, Atlanta); achieving a strongly interacting regime and superfluidity in Fermi gases, which brings in analogies with neutron matter (JILA, MIT, ENS, and elsewhere).

The main emphasis at the conference was put on future applications of quantum gases and on fundamental problems which can be termed as "hot topics" of the field. The talks of Bill Phillips (Nobel Prize of 1997, USA) and Alain Aspect (France) were to a large extent oriented in the direction of atom optics with Bose condensates, in particular for creating atom lasers and developing atom interferometry. Chip technologies for guiding cold atoms were discussed by Ed Hinds (UK), and the talk of Peter Zoller (Austria) was partially related to the creation of new systems for quantum information processing with cold atoms.

The breakthrough results on hot topics reported at the conference include the creation of vortex structures in strongly interacting Fermi gases, which is the first direct manifestation of superfluidity in these systems representing a dilute analogue of neutron matter (Wolfgang Ketterle, USA). Another highlight of the conference is related to revealing a novel temperature-dependent behaviour of widely studied Kasimir-Polder forces describing the interaction an ensemble of atoms with a surface. These results were reported by Eric Cornell (experiment, USA) and by Sandro Stringari (theory, Italy). Recent remarkable achievements on the observation of Josephson oscillations in real time for Bose-condensed atoms in an irregular lattice were presented by Marcus Oberthaler (Germany). In the same spirit, one may quote the observation of coherent dynamics in spinor Bose-Einstein condensates, which represent a gaseous analogue of solid magnets (Mike Chapman, USA; Klaus Sengstock, Germany). On the theory side, the major highlights are related to revealing novel strongly correlated Quantum Hall states for rapidly rotating bosons (Nigel Cooper, UK), and to developing exact non-perturbative methods for finding local many-body correlations in one-dimensional Bose gases (Vadim Cheianov, Denmark).

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Training:

Training was one of the main components of the conference, and 65 participants out of 160 were young researchers from 17 countries, including 9 EU Members and Associated States. A general introduction to the topics of the conference was given in 5 tutorial talks presented by Nobel laureats Bill Phillips, Wolfgang Ketterle, and Eric Cornell (USA), by Peter Zoller (Austria), and by Sandro Stringari (Italy). Leading contributions to the field were presented by 24 invited speakers and 3 of them were young scientists. All young scientists got a possibility to present their work in the 2 poster sessions (more than 100 posters in total) and two of them were selected to give brief oral talks. Practically all young scientists from the EU and Associated States received grants covering the conference fee and a contribution towards their travel expenses.

The oral talks, poster sessions, and informal discussions provided an excellent opportunity for young scientists to interact and establish contacts with leading physicists in the field of quantum gases. This allowed them to get a complete overview of the field, to gain understanding of future prospects, and find new opportunities for employment. Regarding the role of young scientists at the conference, it is also worth mentioning their active participation in the round table on the future of the conference series on Bose-Einstein condensation.

European Added Value:

The conference was the major event in the field of quantum gases in the last 2 years, covering the most important aspects of the field and confirming the European leadership in this direction. It was of great interest for European groups working on quantum gases. Even increasing the number of participants to 160 we were able to accept only about a third of the applicants. The participants of the conference represented 24 countries from all over the world, including 10 from the EU and Associated States. Among other countries one should mention the USA (26 participants), Japan (6), Australia (5). This has stimulated the beginning and continuation of collaboration between individuals and groups in Europe and between Europe and other parts of the world. The development of collaboration is reflected by the fact that 42 of the conference participants are presently working outside their home countries. In particular, there were 9 EU scientists currently working outside Europe.

The European Added Value of the conference is also emphasized by the fact that at the conference we had coordination meetings of the ESF Quantum Degenerate Dilute Systems Programme (QUDEDIS) and of the International Cold Atom Network (Intercan).

Additional Information:

The conference was accompanied by a satellite meeting on spinor Bose-Einstein condensates, organized by Maciej Lewenstein (Spain) and Klaus Sengstock (Germany) on September 8-9 at the University of Barcelona.

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SCIENTIFIC REPORT (PART 3)	
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Public Outreach[2] (maximum 1 page)

This conference belongs to the series of Bose-Einstein condensation conferences sponsored by ESF starting from 1995. The subject of these series dates back to 1924, when Bose and Einstein predicted that a dilute Bose gas can exhibit the phenomenon of Bose-Einstein condensation – macroscopic occupation of a single quantum state below a certain critical temperature. Since that time the physics community has been dreaming of creating such a system. The key argument was that dilute gases, in contrast to liquid helium, allow a microscopic *ab initio* description providing a reliable test of fundamental theories. The prediction was realized in 1995 in remarkable experiments at JILA (Eric Cornell and Carl Wieman) and at MIT (Wolfgang Ketterle), where Bose-Einstein condensation has been achieved in dilute trapped clouds of alkali atoms by means of optical and evaporative cooling. This discovery, awarded by the Nobel Prize in 2001, stimulated dramatic growth and striking developments in the field of quantum gases. It has been revealed that extremely dilute and cold trapped quantum gases, with temperatures in the nanokelvin regime and eight orders of magnitude lower densities than in liquid helium, manifest collective (condensed matter) behavior. Successful experiments on interference of two Bose-Einstein condensates (MIT, 1997) present evolving condensates as coherent matter waves and bring in analogies with photon optics. At the present stage, the field of quantum gases is strongly expanding, in particular by creating novel ultracold quantum systems, such as strongly interacting dilute Fermi gases, strongly correlated atoms in optical lattices, "exotic" (rapidly rotating and/or dipolar) quantum gases. Potential applications of quantum gases include atom lasers – devices for the generation of coherent matter waves, atom interferometry, high-precision atomic clocks, systems for quantum computing. These developments bring in analogies with objects studied in atomic physics and quantum optics, condensed matter physics, nuclear and high-energy physics, non-linear physics, and attract researchers from all these fields. This makes the field of quantum gases highly interdisciplinary and provides an extraordinary level and wide spectrum of scientific activity, with a high potential for future scientific and technological developments.

The key idea of the conference was to address future technological applications of quantum gases and to discuss exciting fundamental problems related to "hot topics" of the field. The major oral sessions and poster contributions of the conference included:

- atom optics with Bose-Einstein condensates and chip technologies for guiding cold atoms, with emphasis on applications for atom interferometry, atom lasers, and atomic clocks (6 oral talks and 20 posters)
- novel systems for quantum information processing with cold atoms and new physics with strongly correlated atoms in optical lattices (10 oral talks and 35 posters)
- new physics with spinor Bose-Einstein condensates – gaseous analogues of solid magnets, and with low-dimensional Bose-condensed gases (4 oral talks and 15 posters)
- investigation of strongly interacting Fermi gases, representing a dilute analogue of neutron matter (9 oral talks and 25 posters)
- "exotic" quantum gases, including rapidly rotating and dipolar gases, gases of metastable atoms and excitons (9 oral talks and 12 posters)

The conference was the major event in the field in the last 2 years and it had 160 participants from 24 countries, including 10 countries of the EU and Associated States. The largest delegations were from Germany (28), USA (26), France (20), Italy (14), UK (14), emphasizing the leading position of Europe in the field. The 65 young participants of the conference got an excellent possibility for training on the basis of 29 invited talks of leading scientists, 9 short talks, 2 poster sessions and informal discussions, which is an important contribution to the training of a new generation of scientists for work in the academic world and in industry.

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