European Science Foundation Conference
QUANTUM OPTICS
San Feliu, 2002.

Chairman: Tilman Esslinger, Vice-chair: Astrid Lambrecht, Advisory chairman: Klaus Mølmer

Background:

Atomic systems are presently a focus of current research in quantum optics. Most of this research was triggered by the demonstration of Bose-Einstein condensation (Nobel Prize 2001). During this meeting various presentations addressed the following new frontiers in this field. Several experiments are now focusing on atomic species which obey the Fermi statistic. These so called fermions should show a phase transition at ultra low temperatures which is similar to the phase transition that occurs in solid-state systems when they become superconducting. A second line of research uses Bose-Einstein condensates loaded into periodic potentials created by laser light, which are called optical lattices. A wealth of quantum phenomena, which have so far been associated with solid-state physics, should become observable in these artificial crystals. The physics of ultracold atoms now enters the regime of strongly correlated systems, a regime which is dominated by the interaction between the particles. In particular, the observation of a transition from a superfluid to a Mott insulating phase was recently demonstrated. New directions, such quantum computation, emerge from this experiment and were extensively discussed during the conference.

Prospects for applications of ultracold atoms are twofold. The most precise atomic clocks are already using laser cooled cesium atoms. Further cooling of cesium atoms is necessary for even better atomic clocks. At the conference progress in this direction was presented. Actually, one of the groups achieved Bose-Einstein condensation with cesium atoms just two weeks after the conference. This is a milestone towards more precise cesium clocks, which are the building blocks for the global positioning system. A second line of applications is emerging from atomic gases prepared in optical lattices. Many-body quantum states can now be precisely engineered, as required for the realization of quantum logic operations with neutral atoms. On each trapping site exactly one atom can be prepared and may act as a quantum bit to store information. Several methods to carry out logic operations on such an atomic ensemble have been proposed and presented at the conference.

The longstanding goal of producing ultracold and dense clouds of molecules is being attacked from two different directions. One direction pursues a direct cooling of the molecules by employing novel techniques to decelerate the molecules and to subsequently trap them. Another approach has very recently been successfully demonstrated and was presented at the conference. Starting from a Bose-Einstein condensate of rubidium 85 atoms and employing resonantly enhanced interactions between the colliding atoms it has been possible to coherently produced rubidium molecules from the Bose-Einstein condensate. This opens up the novel field of super-chemistry, i.e. chemistry with superfluids.

The advances of quantum optics with photons have been dramatic during the recent years. Besides progress in fundamental research there has been a substantial trend towards applications. The first commercial system for quantum cryptography has recently been launched by a firm based in Geneva. Pioneers in this technology gave presentations at the conference.

Summary:

The conference brought together top level researchers in quantum optics from almost every European country or associated state. This reflects the tendencies that smaller countries are getting increasingly involved in quantum optics research. It was also possible to invite several speakers from non-European countries, such as United States of America and Japan. In this respect co-sponsoring by QUIPROCONE, was very helpful. During the conference links to US and Japanese groups could be intensified or established. This relation is particularly important for recruiting European Post-Docs who have gone to the US and who are now considering to come back to Europe. The awareness for technological applications of quantum optics was increased both by the talks on quantum cryptography and the presentation on solid state devices. In conclusion, the meeting has strengthened and widened the leading role of Europe in the field of Quantum Optics.

Scientific Highlights:

Quantum Atom Optics

Several presentations were covering the emerging field of Quantum Atom Optics. In particular, Alain Aspect presented results on Bose-Einstein condensation with meta-stable Helium atoms. This novel experiment opens the avenue to direct measurement of the statistics of Bose-Einstein condensates by atom counting. New conceptual ideas for atoms and molecules trapped in optical lattices were presented by Klaus Molmer. Thorough insight into the recently observed superfluid-insulator transition was given by Keith Burnett, Dieter Jaksch and Wilhelm Zwerger.

Molecules and Interactions

The amazing progress which was recently achieved in the field of ultracold molecules was highlighted by Elizabeth Donley and Gerard Meijer. Elizabeth Donley presented the stunning results achieved in a Bose-Einstein condensation experiment with rubidium 85. The condensate was transferred into a coherent superposition of atoms and molecules. Gerard Meijer presented a series of novel methods to cool and trap molecules.

Coherent Atomic Sources

New approaches to expand the range of atomic species that can be cooled to ultralow temperatures were presented by several speakers. A novel trap design to cool atomic cesium was discussed by Rudolf Grimm. Just two weeks after the conference the group reported on their breakthrough to achieve a longstanding goal: Bose-Einstein condensation with cesium atoms. Bose-Einstein condensation in cesium is of particular importance since it is used for the time standard. An innovative method to cool different atomic species was presented by Jack Harris from Harvard.

New Directions in Ultracold Atoms

Substantial advances in the manipulation of ultracold fermions were reported by Massimo Inguscio and Shin Inouye. The major goal of these experiments is to observe a BCS-type of phase transition, as it occurs in superconductors. Achieving this would be comparable to the first experimental realization of an atomic Bose-Einstein condensate.

From Quantum Physics to Technology

The state of the art in quantum cryptography was reported by Nicolas Gisin and Christian Kurtsiefer. Using single photons in telecom optical fibers and in free space were demonstrated as cornerstones for inherently secure communication systems. The group of Gisin in Geneva has recently been able to commercialise their cryptography system. New directions for quantum computing were shown by Michael Fleischhauer who proposed phase-gates for photons.

Poster sessions:

During the two poster sessions new ideas were circulated and the latest developments were presented. For example several posters devoted to experiments and theory of ultracold atoms in optical lattices were presented. The poster sessions lasted until midnight and were well received by all conference participants.

Training:

At the conference cutting-edge research in Quantum Optics was presented and the latest results become accessible to the young participants. Some of these results were indeed presented by young researchers, who also act as role models for other young participants. The informal atmosphere of the conference stimulated lively discussions directly after the talks, during the coffee breaks and, in actual fact, during the whole conference. The presence of senior scientists at the poster sessions and their high interest in the work of the younger participants gave the latter valuable feedback and perspectives for the future. Young researchers who just entered the field discussed their work with expert scientists in the field and established personal contacts. This is the central starting point for collaboration and efficient exchange of workforce between the different European laboratories. The training impact of the Quantum Optics Conferences series has been instrumental in the development of the leading position of Europe in the field of Quantum Optics.