Europe gets together to harness quantum physics

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The long cherished goal of applying the strange properties of quantum mechanics to the macroscopic world we inhabit has been brought closer by a series of recent developments. The exciting progress was made in the important field of quantum optics and discussed recently at a high level conference organised by the European Science Foundation in collaboration with the Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (FWF) and the Leopold-Franzens-Universität Innsbruck (LFUI).

Quantum optics is fundamental to the whole field of quantum science, because it deals with the interactions between light and matter at the elementary level that determine ultimately how atoms and molecules behave. A thorough understanding of quantum optics in its broadest sense has the potential to lead to new (quantum) technologies that will help define the 21st century, according to Professor Jörg Schmiedmayer, who chaired the ESF conference.

Quantum science has great potential to revolutionise the worlds of computing and communications, enabling massive increases in processing power, data storage densities, and data transfer rates. Although most of the applications are still many years away, dramatic progress has been made laying the groundwork for projects at the laboratory level that demonstrate the concepts on a small scale. A gratifying aspect of the conference, according to Schmiedmayer, was the exceptionally high standard of contributions made, and excitement generated, by young researchers, who will be the standard bearers for the field over the important two decades to come. "The hot topic sessions, where mostly young researches presented their results, were definitively among the highlights of the conference," said Schmiedmayer. "At these very new science was discussed, science that was not even envisioned three years ago. Many results had not yet been presented elsewhere before."

Significant progress was noted for example in quantum communication, which promises to enable totally secure transmission of information over communications networks. It is easy to scramble information in such a way that it is totally undecipherable to anyone except the recipient, providing one has a secret key known only to both parties. The problem lies in transmitting that key between the parties while being sure it has not been eavesdropped in the process. Quantum cryptography uniquely provides a mechanism that gives that absolute assurance, for example through exploitation of quantum entanglement, in which the state of two particles is quantum correlated so that any attempt to intercept one would lead to a detectable change in the other. Applied to communications this enables both parties to know that nobody else has intercepted that key, which can then be used safely to scramble the actual information to be transmitted. Quantum Key Distribution (QKD) has already been demonstrated in the laboratory, but only over distances up to 150 Kms because at larger scales the optical fibres, or the air in free space, used to transmit the light signals absorbs and /or scrambles the individual photons, which then lose their quantum state. At the conference major steps towards realizing a 'quantum repeater' to faithfully connect communication channels were presented, which should allow eventually quantum communication to be extended over much longer, perhaps global, distances.

Quantum science and thereby quantum optics methods also have great potential for quantum computers, which promise to deliver undreamed of processing power. The conference heard about new experiments with superconducting quantum circuits, which could be used in future for novel integrated circuits involving quantum effects, a remarkable progress that brings the heart of quantum optics into solid state devices and electronic (quantum) circuits.

There was also great interest at the conference in high fidelity quantum gates in ion traps, according to Schmiedmayer. Ion traps were the first devices where quantum computation schemas were proposed and implemented. Now with high fidelity quantum operations, ion traps are the ideal platform to build and research quantum logic components for future scalable quantum computers. The idea is that ions, which are atoms or molecules that have lost or gained electrons from their outer shells, are suspended in free form in an electromagnetic field so that their energy levels can be manipulated precisely, down to the level of individual quanta. This could potentially be exploited to store and transfer information within a quantum computer.

A third topic was concerned with quantum simulations, where the tools of quantum optics are used to 'build' well controlled experimental models of theoretical concepts, which are in themselves too hard to be solved completely either by analytic methods or by simulation on classical computers. Such quantum simulations hold the promise to give us insight into some of the big outstanding problems in solid state physics, like the mechanism behind high temperature super conductivity, or problems on quantum magnetism. The conference heard about how to build specific 'interactions' needed to build such simulation models in the laboratory, or how quantum coherence and its dynamics can be probed in low dimensional systems

A forth focus was on Quantum Technologies and precision measurements. Remarkable progress was reported in controlling mechanical oscillators, bringing them close to the quantum regime, and the promise to put the 'quantum' into mechanics or small nano-objects in the very near future. There was great interest also in an experiment that demonstrated high fidelity Bloch oscillations by controlling atom-atom interactions. This opens the possibility for ultra precise quantum measurements with BEC's, an aspect which was believed to be very difficult because of the non linear nature of these systems.

There were many more exciting results and concepts presented and discussed. The conference fulfilled its objectives by bringing together people in these diverse quantum fields, and starting to take quantum mechanics into the material solid state world, according to Schmiedmayer.

Source: European Science Foundation