Acceptance Speech of

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Co-Winner of the 2005

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Your Royal Highness, Prince Sultan Ibn Abd Al Aziz
Your Royal Highnesses
Your Excellencies
Distinguished Guests

It is a great honor for me to receive the King Faisal International Prize in Science 2005.

Just 100 years ago, a young patent officer in Switzerland, who later became the most famous scientist who ever lived, Albert Einstein, suggested that light is made up of particles, today called photons. He soon realized that these quantum particles behave in a very strange way, which is fundamentally in conflict with how objects should behave, both according to everyday experience and to fundamental philosophical ideas of reality. His many fundamental philosophical ideas on these unusual particles have led today to many technological applications.

The quantum world is rather strange because an individual event in quantum physics in general has no causal chain that would explain why an event happened specifically the way it did. Also, the state of a particle may depend on the measurement applied to another distant particle. These ideas could most clearly be demonstrated through experiments on individual particles and quantum systems. Such experiments became possible only during the later decades of the 20^{th} century.

I consider myself privileged that I had the opportunity to work on such experiments from early on. With my group, we were not only able to show that the behavior of the individual particles followed the quantum theory, we could also discover some new surprising phenomena. This way, we laid, unknowingly in the beginning, the foundations of a new information technology, which, I believe, will be an essential one in the 21st century. This technology will be introduced via the novel ideas of quantum communication and quantum computation.

My first experiments in this field, exactly 30 years ago, were carried out using neutrons, particles inside atoms. In those experiments we were concerned mainly with the wave nature of matter. Today such experiments have become worldwide activities. I recall the first phenomenon we experimentally verified, back in 1975 at the University of Vienna, was the confirmation that certain particles - called fermions - are not the same when rotated completely around once. You have to rotate them twice to obtain the same objects again!

In the 1980s I decided to turn to experiments on photons, the particles of light, because here one can work with the phenomenon known as "entanglement". In my opinion this is the most fascinating quantum phenomenon. Entanglement means that two or more systems might be connected in a much stronger way than what is allowed by classical physics. We developed novel sources for entangled photons; which allowed us to study entanglement in a much greater detail than before, to employ it in many new experiments, and to apply it in new information protocols.

One of the most striking phenomena is entanglement between three or more particles; in general these particles are photons. After having measured two photons, one can predict with certainty the measurement result for the third photon. Interestingly, and for us at that time quite surprising, quantum mechanics predicts for the third photon exactly the opposite behavior predictable by classical physics or by common logic. We were able to realize for the first time such states, to demonstrate their counter-intuitive behavior, and to verify their potential use by putting them to work in communication and computation applications.

A quantum computer will operate immensely faster than all existing computers. Such a computer will utilize entanglement to a highly extended degree. It is still open how such computers will operate in detail. One possibility is to use only photons and standard optical components. We were able to demonstrate that a future quantum computer can be realized this way.

If I might be allowed to dream about the future, then I envisage an Internet where quantum computers are connected via entanglement-based communication links. A particularly fascinating field in this area, called Quantum teleportation, is now at the well-developed stage where it can work outside laboratories and can cover distances of the order of a few kilometers. Another application is quantum cryptography, which is a way to exchange messages in full secrecy where the security is guaranteed by laws of Nature. In the entangled-state quantum cryptography we use entanglement to provide keys to encrypt secret messages. Many laboratories, worldwide, including ours, are working on these applications. I expect that, within a few years, banks and large companies will be able to employ these 'absolutely confidential' communication methods.

In conclusion: we have seen how a new technology has been created, basically because physicists were interested in answering questions about the fundamental nature of the world, philosophical questions of the kind that bothered Einstein. Here we see again a very important lesson. Basic research can lead to a new technology in ways unforeseen even by the early participants in this work. I, therefore, firmly believe that the present preference, and strong focus, in many countries, for applied research is too limited.

I am very grateful and I feel deeply honored for having been chosen a winner of the King Faisal International Prize in Science 2005, and I would like to stress that I would not be here without the support of my family, particularly of my wife, and without the collaboration of many colleagues, many of whom became friends, over the years.