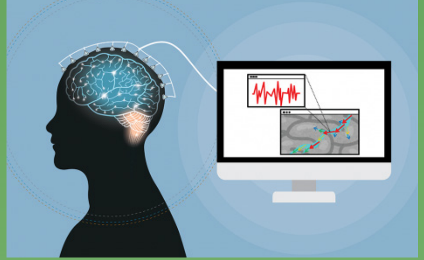
The future is quantum



The great theoretical physicist and Nobel Laureate, Richard Feynman, in his 1959 speech “There’s plenty of room at the bottom” proposed computing with quantum spins in atoms. Today quantum computers able to crack problems unsolvable with classical computers are being developed. These computers use basic units of information called quantum bits or ‘qubits’, which are a more complex and powerful version of the information-carrying ‘bits’ used today in conventional computing.

A classical bit can be 0 or 1, but a qubit can represent 0, 1 or a superposition of both which can greatly expand the computational power of the machine provided the quantum states can be controlled and measured while being isolated from the environment. In the late 1990s visionary architectures and quantum algorithms triggered an explosion of interest in the field. The past decade has seen major government initiatives and industrial programmes aimed to make the vision a reality.

Prototypes of 10 to 50 qubit computers are already being used to develop quantum software for practical applications and to train the next generation of personnel in quantum information technology. Single qubits are used in laboratories as sensors to exploit quantum superposition and entanglement for non-invasive diagnostics at the cellular level.

In anticipation of progress in the field of quantum technology, researchers are already setting up longer-term projects to harness the potential of these new developments, including the introduction of novel quantum-based sensors for studying processes in the human brain. Accelerator-based techniques are applied to make the quantum states in diamond and other materials for the new sensors.

It is likely development of new quantum technologies will have a widespread impact on society with a similar transformative effect as the introduction of classical information technology over the past 50 years. In addition, addressing the challenge of building and operating a range of quantum devices is likely to advance humanity’s understanding the quantum foundations of the universe with yet unforeseeable implications.

The full article is available at:
https://www.iaea.org/newscenter/news/the-future-of-tech-building-quantum-technology-with-ion-beam-accelerators

63rd IAEA General Conference Side Event on

Building Quantum Technology with Ion Beam Accelerators

18 September 2019
11.30 a.m. to 1.00 p.m.
Conference Room M6 (M building, ground floor)

PROGRAMME

11:30-11:40	**Opening and Welcome** Ms Najat Mokhtar, DDG-NA
11:40-11:55	**Einstein’s revolution: quantum technology for the 21st century quantum computer** Mr David N. Jamieson (Australia)
11:55-12:05	**Quantum-based diagnosis from the single cell to complex brain functions** Mr Takeshi Ohshima (Japan)
12:05-12:15	**Applied nuclear science for new-generation single-photon sources: towards safer global communication with quantum cryptography** Mr Paolo Olivero (Italy)
12:15-12:25	**Quantum information and fusion energy** Mr Thomas Schenkel (USA)
12:25-12:35	**Accelerators as tools for discovery – How the IAEA is bridging the gap** Ms Aliz Simon IAEA Physics Section (NAPC)
12:35-13:00	**Questions and Answers**

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Building Quantum Technology with Ion Beam Accelerators

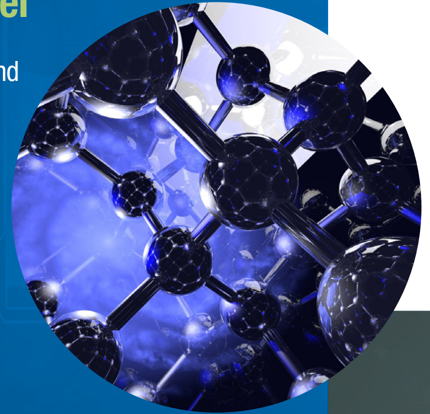
63rd IAEA General Conference Side Event I 18 September 2019
Conference Room M6 (M building, ground floor) I 11.30 a.m. to 1.00 p.m.

Entering the Quantum Technology Era: Accelerators as tools for discovery

The first quantum revolution transformed the world into the highly connected, technology-driven society we see today. With the second quantum revolution we will enter the quantum technology era. The rise of the new field of quantum technology is due to a radical reappraisal of fundamental quantum mechanical principles including superposition and entanglement for new approaches to sensing, the simulation of real-world quantum systems, secure information transmission and other applications. The new technology promises to address problems difficult or impossible to solve with present-day classical technology. We can soon expect secure optical fibre communication systems based on information encoded on quantum states of photons, ultra-high precision clocks, sensors for medical diagnostics, customized drug design using quantum computers, simulations of complex physical systems including fusion and more sophisticated machine learning.

Ion Beam Accelerators have a key role in materials modification at an atomic level

Around the world, many countries, multinational companies and international organisations have launched major initiatives to explore the potential applications of the new technology. Today an international consortium of scientists who are participating in their national flagship quantum technology research programmes are working under the auspices of the IAEA. The consortium is working on projects that apply accelerator-based techniques to promote the development of materials and applications for the new quantum technologies. The key research fields described here are part of the IAEA coordinated research project (F11020).



The second quantum revolution will lead to advances in multiple fields that could hardly be imagined until quite recently – from super-enhanced computing power to sensors that could study multiple brain functions in real time, even tracking human thoughts. It is an exciting time and the IAEA is already working with our Member States to research and help exploit some of the enormous potentials that are now becoming possible.

Najat Mokhtar, DDG-NA

PRESENTATIONS & SPEAKERS

David N. Jamieson / Australia

Einstein's revolution: quantum technology for the 21st century quantum computer

Einstein's most revolutionary idea, of the light quantum, has led to the concept for a radically new type of computer that uses the rules of quantum mechanics to process information encoded in quantum bits, qubits. Large-scale quantum computers overcome limitations of classical computers on specific tasks such as quantum chemistry for drug design.nEspecially promising qubits are ion implanted donor atoms in isotopically pure semiconductors including silicon. Successful development of large-scale devices that can solve important problems requires overcoming formidable scientific and technical obstacles. We will need to manipulate and interrogate single atoms with unprecedented precision. This presentation looks at the emergence of quantum technology and how we are building the first quantum machines.

Takeshi Ohshima / Japan

Quantum-based diagnosis from the single cell to complex brain functions

Diamond is one of the most beautiful and valuable gem stones. However, diamond is not only a gem stone, but also can act as a quantum sensor by means of a nitrogen-vacancy complex in the diamond crystal lattice called the NV center. Light emitted from the NV center in diamond nanocrystals can reveal the temperature, magnetic field and electric field in microscopic cellular structures. Such information is very useful to understand gene expression mechanisms of diseases such as cancer. Larger crystals containing NV centers can detect extremely weak magnetic fields such the ones from the brain. This can be applied to magnetoencephalography to monitor brain function. Nuclear techniques including ion implantation and irradiation are being used to create useful NV centers in diamond for these new applications.

Paolo Olivero / Italy

Applied nuclear science for new-generation single-photon sources: towards safer global communication with quantum cryptography

The second quantum revolution opens ground-breaking perspectives towards the establishment of a global "quantum internet", which will enable intrinsically safe communication among countries and institutions across the world. A key technological asset towards this highly strategic goal is the optimization of fully reliable emitters of individual quanta of light on demand, usually referred as "single photon sources". The use of accelerator-based techniques represents a powerful tool to engineer this class of innovative devices.

Thomas Schenkel / USA

Quantum information and fusion energy

Emerging quantum simulation capabilities can advance our fundamental understanding of nuclear technologies. In fusion energy sciences, quantum simulations promise to enable faster and more detailed simulations of fusion processes. This can lead to breakthroughs in our ability to predict and better control fusion processes. This presentation will describe this exciting opportunity space of quantum information and our quest for fusion energy.

David N. Jamieson is a professor of physics at the University of Melbourne where he applies his research expertise in the field of ion beam physics to test some of the key functions of a revolutionary quantum computer constructed with single donor atoms in silicon. He manages the directed ion beam programme in the Australian Research Council Centre of Excellence for Quantum Computation and Communication Technology.

Takeshi Ohshima is the Leader of the Quantum Sensing and Information Materials Research Group at the National Institutes for Quantum and Radiological Science and Technology, Japan. He uses ion beams to engineer colour centers for quantum technologies including the nitrogen-vacancy centre in diamond and the silicon vacancy center in silicon carbide. He is a partner in the Japanese Q-LEAP project aimed at the development of diamond-based quantum sensors for brain magnetometry.

Paolo Olivero is an associate professor of physics at the University of Turin in Italy, where he coordinates a research programme on the development of optically active defects in wide bandgap semiconductors for applications in quantum communication and sensing. His research activity is particularly focused on the application of energetic ion beams for the micro fabrication and quantum-optical functionalization of artificial diamond, to be used for cellular biosensing. Since 2017 he is the vice-director of the inter-departmental centre "Nanostructured Interfaces and Surfaces" of the University of Torino.

Thomas Schenkel is a physicist and senior scientist at Lawrence Berkeley National Laboratory, where he is the Program Head for Fusion Science and Director (interim) of the Accelerator Technology and Applied Physics Division. His research interests include novel accelerator concepts, materials far from equilibrium, exploration of fusion processes, and the development of spin qubit architectures.