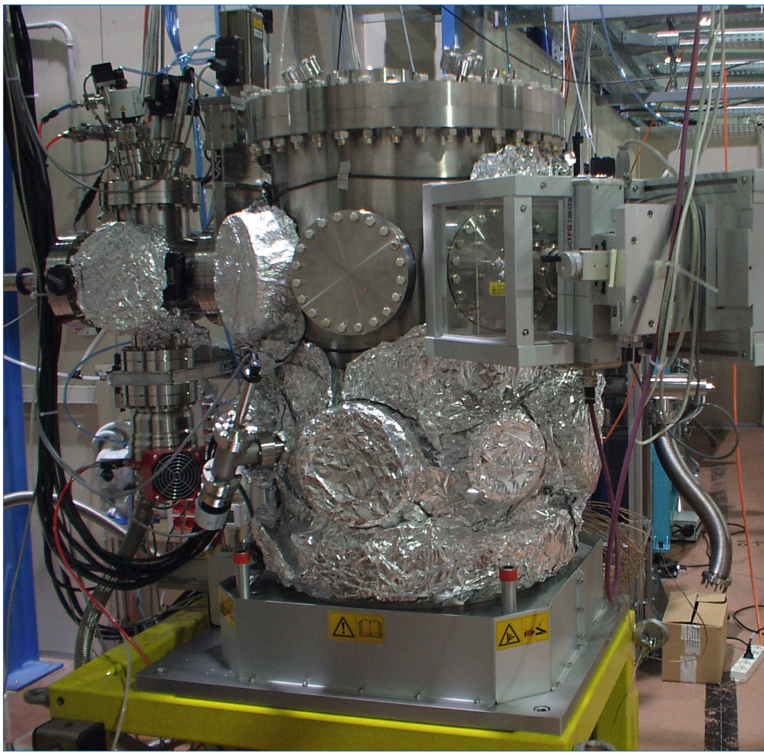
The Multiple Benefits of Accelerators

Accelerators are machines that use high voltages to produce artificial radiation in the form of beams of energetic particles. They are more versatile and safer than radioactive sources because the energy can be varied, and when the accelerator is turned off, so is the radiation.

There are currently about 30 000 accelerators operating globally. About 99% of them are used for industrial and medical applications and only about 1% is used for basic research in science and technology.



The ultra-high vacuum chamber (UHVC) end station at the IAEA beam line at the Elettra synchrotron in Trieste, Italy. This state-of-the-art X-ray fluorescence beam line can be used to analyse which chemical elements are found in a material. One of the advantages of this advanced technology is its ability to produce 2D and 3D maps showing the chemical analysis of the material being tested. (Photo: IAEA)

What are accelerators used for?

The most common usages include:

- Medical imaging and cancer treatment;
- Sterilization of medical equipment and food products;
- Radioisotope production;
- Processing semiconductors;
- Vulcanizing rubber and modifying polymer properties to improve the quality of rubber;
- Cleaning industrial flue gases (for instance, combustion exhaust gas produced at power plants) and purifying water;
- Mineral and oil prospecting;
- Cargo screening; and
- Radiocarbon and other radiometric dating.

How do they work?

Accelerators have the power to accelerate particles to final energies that span an enormous range — from a few electronvolts (eV) to nearly one teraelectronvolt (1000 billion eV) — and can speed up electrons, protons or any other charged particles to be used in the production of X-rays, neutrons and radioisotopes. The unit electronvolt is used to measure energy. It is defined as the amount of energy an electron gains after being accelerated by 1 volt of electric potential.

Accelerator technology makes a valuable contribution to the technological progress which can also contribute to a country's economic development.

This technology is also used to sterilize medical items such as catheters, cotton gauze and surgical

Ion beam irradiation can be used to initiate mutations which can lead to plant varieties with better properties. This is an example of rice that has received ion beam irradiation at Chiang Mai University, Thailand.

(Photo: Chiang Mai University, Thailand)

equipment. Huge amounts of boxes with medical items can be sterilized within just a few hours on a conveyor belt at an accelerator facility.

Another application area is the food sector where irradiation beams are used to improve food safety. Irradiation enables a longer shelf life without impacting the nutritional value of food items.

Accelerator origins and types

Accelerators have been around for more than 80 years. In 1929, Dr Robert Jemison Van de Graaff, an American physicist, successfully demonstrated how a high voltage machine could accelerate particles. The first particle accelerators were quickly at the forefront of discoveries in nuclear physics and chemistry. The concept and technology of accelerators developed so rapidly that by the end of the 1930s several types had been invented: the Van de Graaff generator, the linear accelerator (also known as the linac), and the cyclotron.

Linac is a particle accelerator, a device most commonly used for external beam radiation treatments for patients with cancer. The linear accelerator is used to treat all parts and organs of the body. It delivers high-energy X-rays to the exact area of the tumour.

Cyclotron is a complex machine that accelerates charged particles in a vacuum outwards from the centre along a spiral path. During the acceleration process, charged particles gain significant energy. The energized charged particles then interact with stable material that is placed in their path. The interaction transforms stable materials into medically useful radioisotopes that are used to make radiopharmaceuticals.

Ion beams are created when charged particles are accelerated. The IAEA supports their use for research on the effects of radiation on materials and in the development of applications for materials analysis.

Ion beam methods can also be used to analyse cultural heritage items in a non-destructive way. The composition of inks, paints and glazes on ceramics and glasses can be examined to determine where works of art or archaeological artefacts come from. The method can also reveal whether an article is fake or genuine; whether it has been altered in the past; what mechanisms of corrosion and deterioration have been at work; and how affected artefacts can be preserved.

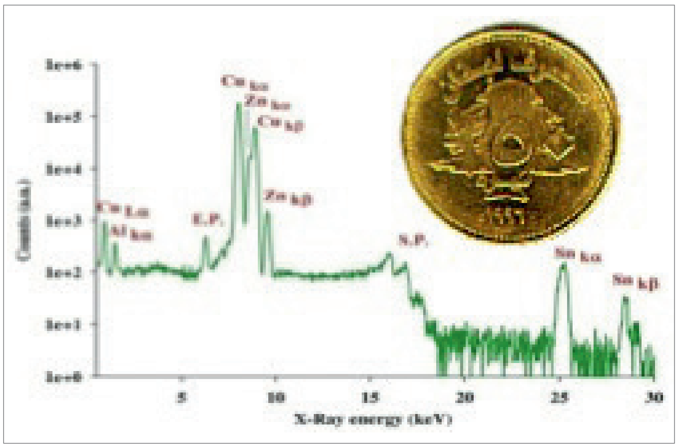
In the field of materials modification, ion beams are used in nanotechnology, such as the creation of nanofabricated structures; semiconductors and electronic devices, for instance by ion implantation; and DNA modification, for instance mutagenic breeding of plants.

Neutrons are used for material probes and can be generated in reactors or by accelerators. The most intense accelerator based neutron sources are called spallation sources, which send high-energy ions into a heavy metal target. A spallation source consists of a high-powered accelerator that brings protons with energies of greater than 0.5 GeV (gigaelectronvolt) into a heavy metal target, such as mercury or tungsten. These metals 'spall off' free neutrons in response to the impact. They are the world's brightest source of neutrons for research.

Synchrotrons and free electron lasers are sources of electromagnetic radiation generated by electrons moving almost with the speed of light. This technology is widely used in many scientific disciplines and by industry. Synchrotrons are also often referred to as 'light sources'. In science and technology the word 'light' generally refers to electromagnetic radiation, in which most wavelengths of light are invisible. The light produced is microwave, infrared, visible, ultraviolet, X-ray and gamma-ray light.

To produce specific light beams from an accelerator, magnets are used to direct particle beams through the accelerator to emit focused light that is directed away from the accelerator in beam lines to experimental areas used in research and training.

Synchrotron radiation is used in a wide range of scientific disciplines: materials science; energy research; protein crystallography;



A graph of an ion beam analysis of a Lebanese 250 lira coin to determine its layer composition and thickness. This kind of analysis through nuclear technology can be used to assess and authenticate coins or other ancient artefacts.

(Photo: Lebanese Atomic Energy Commission)

environmental science; chemistry; life or biosciences; microelectronics; geological sciences, including extraterrestrial matter studies; and palaeoenvironmental analysis.

Free electron laser sources are utilized to study the properties of condensed matter; nanomaterials; molecular and atomic processes; and biological systems.

In addition, **electron accelerators** are machines that produce and use intense beams of electron radiation to irradiate products. These are mainly used in industry to modify polymer-based products in order to improve their mechanical, thermal, chemical and other properties, to sterilize medical and pharmaceutical goods or to clean wastewater or disinfect materials such as cultural artefacts.

Accelerators provide high dose rates and sufficient scanning speed of electron beams. The radiation beam choices are dependent on the purpose and material to be treated.

Accelerators and international cooperation

The IAEA supports Member States in the development of accelerator applications. To support these programmes, the IAEA cooperates

The SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) Centre, is a "third-generation" synchrotron light source in Allan, Jordan, near Amman. This facility is the Middle East's first major international research centre for science applications. The inner storage ring, or booster, with deflection and focusing magnets through which the electron beams circulate as they are accelerated. The precise beams of light produced include microwave, infrared, visible, ultraviolet, X-ray and gamma-ray light. (Photo: D. Calma/IAEA)

with external institutions through mutual agreements. Elettra in Trieste, Italy, and the Ruđer Bošković Institute in Zagreb, Croatia, are two such partners. The IAEA also contributes to the scientific and technology efforts at the European Organization for Nuclear Research (CERN) and the International Centre for Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME).

At CERN, researchers help serve the international community to gain a better understanding of the benefits of accelerator technology. They collaborate to promote the many benefits of this state-of–the-art technology for development.

SESAME in Jordan is the Middle East's first major international research centre. It has been established under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and is closely modelled on CERN. SESAME will cover research and applications in a wide range of areas from biology, archaeology and medical sciences to materials science, physics, chemistry, and life sciences. It aims to build scientific cooperation in the region and with neighbouring countries.

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