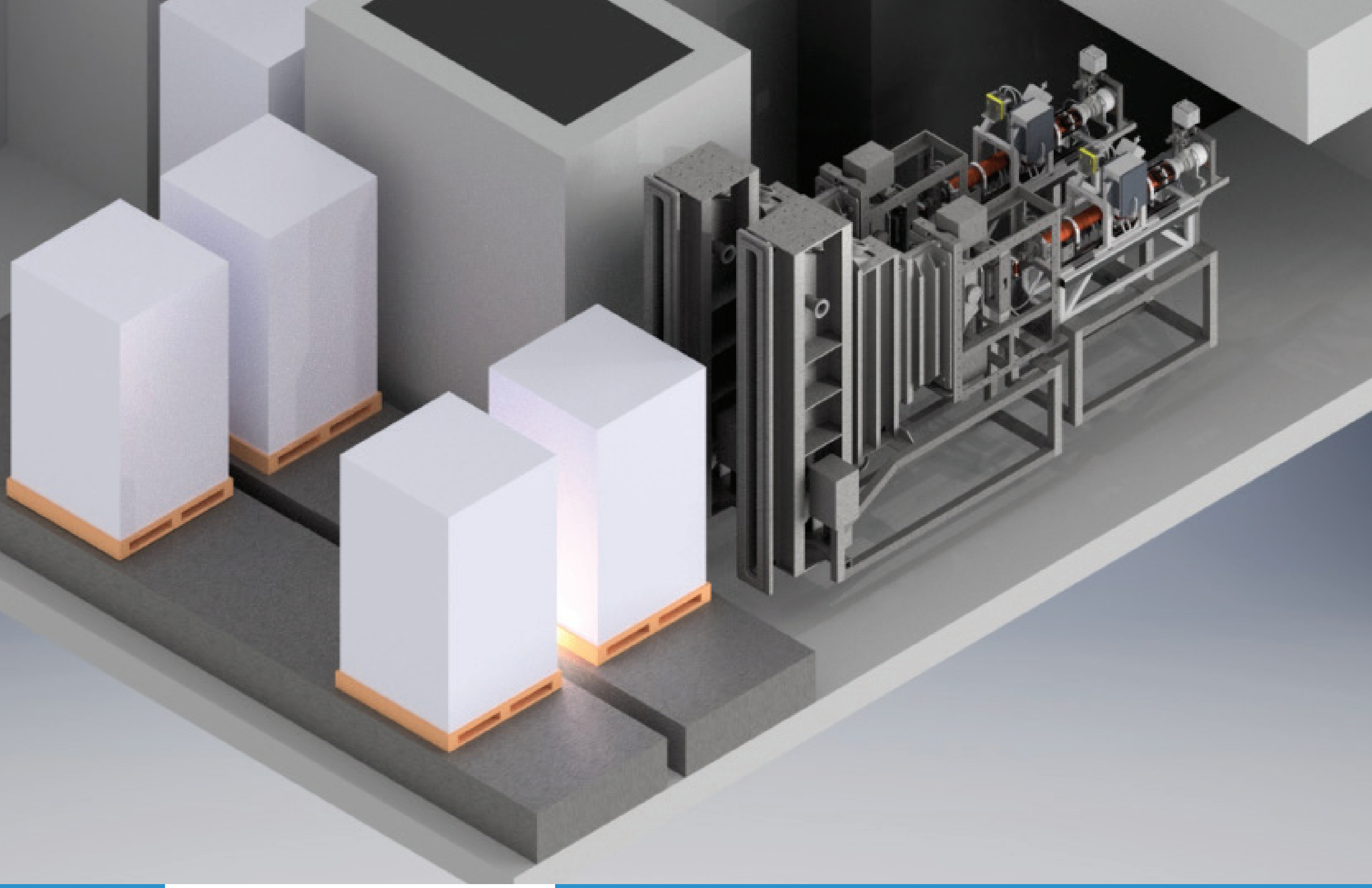

factsheet

X-rays

Within a year of their discovery by Roentgen in 1895, X-rays were applied to medical diagnosis and therapy. It took another century before they started to be used for industrial processing.

X-rays refers to electromagnetic radiation (no rest mass, no charge) of high energies travelling at the speed of light and ionizing matter essentially via indirect ionization. Like gamma radiation, X-rays are high-energy photons, but gamma rays are emitted at defined energies during the radioactive decay of elements such as cobalt-60. X-rays are emitted as a spectrum of energies in a continuous way by the interaction of accelerated electrons with atoms' electrons and nuclei.

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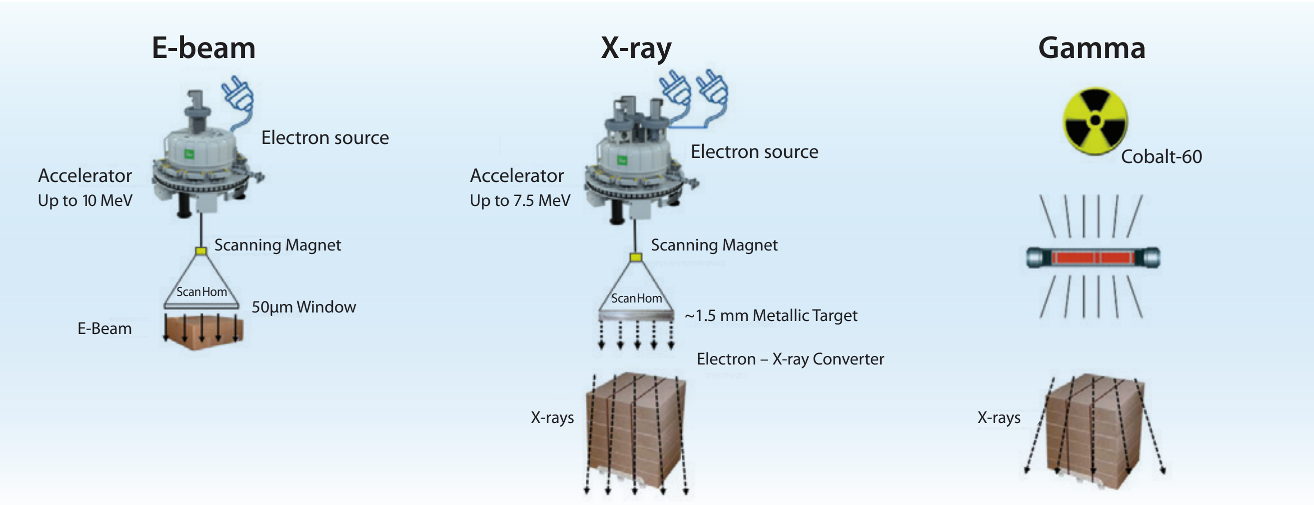
X-rays are characterized by their mean and maximum energies, which may range from thousands of electron-volts (keV) to millions of electron-volts (MeV).

For industrial use, X-rays are produced by high energy accelerators (usually 5 MeV or greater) in which a narrow beam of accelerated electrons is scanned onto a metallic target typically 1 to 2 meters long. Because the generation of X-rays is proportional to the square of the atomic number Z of the target material, high Z elements such as gold, tungsten or tantalum are used.

The abrupt deceleration of the electrons by the electric field of the atomic nuclei and atomic electrons produces electromagnetic radiation (*bremsstrahlung* or 'braking radiation' in German).

Only a few percent of the kinetic energy of the electrons is converted into X-rays as most of the energy of the primary electrons is lost due to backscattering and generation of heat in the target making cooling of the target and of the scanning horn necessary at high power. The conversion efficiency increases with the energy of the incident electrons and the Z of the target, from typically 8% at 5 MeV to 12% at 7 MeV for tantalum.

Like gamma rays, high energy X-rays are very penetrating in matter and lead to more uniform dose distributions than electron beams. The dose rates are typically of the order of kilograys per minute, somewhat higher than gamma rays and much lower than accelerated electrons.



When medical devices are treated at energies higher than 5 MeV, the possibilities of induced radioactivity must be assessed (ISO 11137-1). For the treatment of food, the energy of X-rays must not exceed 5 MeV (Codex Alimentarius and ISO 14470) but three countries (USA, India and Canada) allowed energies up to 7.5 MeV.

The first X-ray facility still in operation was built in Hawaii, USA, to irradiate fresh fruits and vegetables in 2000. The first multipurpose X-ray facility was installed in Bridgeport, USA in 2002. The first large scale industrial facility dedicated to X-ray sterilization of medical devices in pallets was commissioned in Daniken, Switzerland in 2010. This facility can process hundreds of pallets per day with 560 kW of electron beam power, equivalent to a few millions of curies of cobalt-60. Many recently installed accelerators were designed to function in dual mode, using electrons beams or X-rays depending on the characteristics of the product to be treated.

Over recent years, X-ray technology has appeared increasingly attractive as an alternative to gamma radiation, but so far the economics seem to be favorable only where volumes to be treated are large and when electron beam processing is not possible.

Various companies offer self-shielded irradiators used in laboratories and hospitals across the world to irradiate blood, live animals and biological specimens, to render insects sterile (Sterile Insect Technique SIT), for cell research or viral inactivation.

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