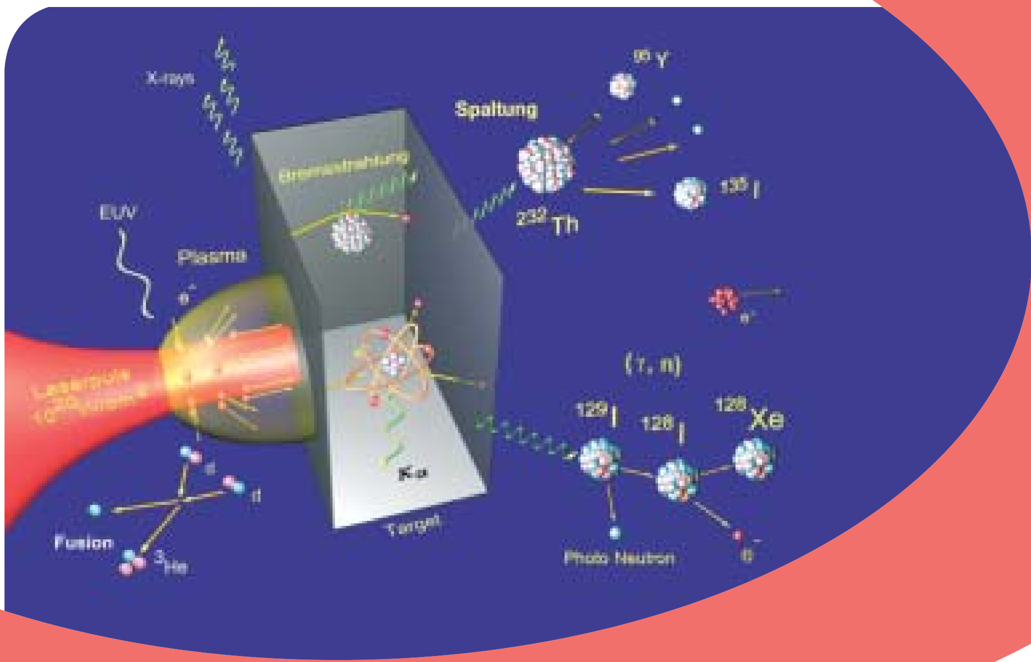
Laser transmutation studies



Powerful lasers lead to lab-scale nuclear fission

The ability to generate powerful laser beams using desktop equipment makes it possible to initiate nuclear reactions without recourse to large-scale reactors or particle accelerators. The Joint Research Centre (JRC), a Directorate-General of the European Commission, has pioneered this technology and, in collaboration with several partner institutes, is researching its use for the transmutation of various radioactive isotopes. Investigating actinides and long-lived fission products promises potential solutions to nuclear waste disposal problems, and other studies could increase the accessibility of medical radiotherapies. The JRC is also providing a solid grounding for young European scientists in modern nuclear physics.

The JRC Institute for Transuranium Elements (ITU) in Karlsruhe, Germany, initially proposed the idea of using laser radiation to split uranium in 1990. However, at the time, laser sources of sufficient power were not available. Within a few years, enormous strides were made in laser technology; the advent of chirped pulse amplification has boosted intensities to levels of 10^{20} W/cm^2.

When focused onto a tantalum metal target, the beam generates a plasma with temperatures of ten billion degrees (10^{10}K), comparable to those believed to have occurred around one second after the 'big bang'. If the resultant accelerated electrons are directed at a secondary metal target, they create a stream of gamma photons energised at 10 to 20 million electron volts (MeV) – more than sufficient to initiate nuclear reactions.

In conjunction with the UK Rutherford Appleton Laboratory and its large VULCAN laser system, the JRC first successfully demonstrated laser-induced fission of metallic uranium (uranium-238) in 2000. By 2003, similar success had been achieved with thorium-232, in collaboration with the University of Jena in Germany, using its table-top laser.

New waste treatment route

Recently, in the context of partitioning and transmutation strategies for nuclear waste management, emphasis has been placed on the long-lived fission products iodine-129 and technetium-99.

With a half-life of 15.7 million years, high radiotoxicity and mobility, iodine-129 is one of the nuclear industry's primary risk considerations. There are also problems with the handling of iodine – it is corrosive, volatile and highly mobile. Ideally, the iodine-129 released during nuclear fuel reprocessing should be isolated in a form that can be transmuted to stable products using nuclear technology.

A joint JRC and University of Jena publication announced the first successful laser transmutation of this isotope. Ongoing research indicates that it is possible to convert long-lived iodine-129 into iodine-128, which then decays with a half-life of 25 minutes to the stable inert gas xenon-128.

Healthcare potential

In the medical field, actinium-225 is a very promising candidate for treating cancers by means of alpha-immunotherapy. At present, however, actinium-225 must be produced in cyclotrons, meaning the radioactive product has to be transported in a timely fashion to treatment sites. The JRC is investigating the feasibility of transmuting radium-226 into actinium-225 by table-top laser. If power can be scaled up by some 100 times, it would then be possible to provide individual hospitals with their own on-the-spot production units. Another potential application is the laser activation of micro-particles for cancer therapy. With appropriate host and starting isotope materials, high intensity laser irradiation can produce active particles suitable for the treatment of various forms of the disease. Current interest lies in the simultaneous activation of both ß- and ß+ emitters for therapy and visualisation.

Training opportunities

The JRC is committed to helping nurture the excitement of scientific discovery in future generations of nuclear scientists. In collaboration with international partners such as the University of Jena, the Universities of Glasgow and Strathclyde, and Rutherford Appleton Laboratory (RAL), sound training in advanced and industrially relevant aspects of nuclear technologies is provided to young science students, stimulating their intellectual curiosity and creativity. The JRC is also actively engaged in promoting research, publications, lectures and other forms of education and professional networking, and in encouraging the development of new techniques and equipment to advance nuclear research.

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