Laser-based Technologies / Medical Technology and Diagnostics

Laser-plasma-based X-ray source

Minimising of beam divergence in high-resolution medical imaging

Technology

This invention concerns a compact source of X-rays produced via the Thomson scattering of a laser beam by an electron beam with an energy of approx. 150 MeV. The electron beam is accelerated in a plasma wave of extremely high field strength, which is driven by a high-powered laser. The X-rays are produced by Thomson scattering when a small part of the laser pulse is redirected and allowed to interact with the accelerated electrons in collision geometry. The hard X-rays produced can be used for a variety of applications. In particular, a key intended application is medical imaging using fluorescence spectroscopy.

Innovation

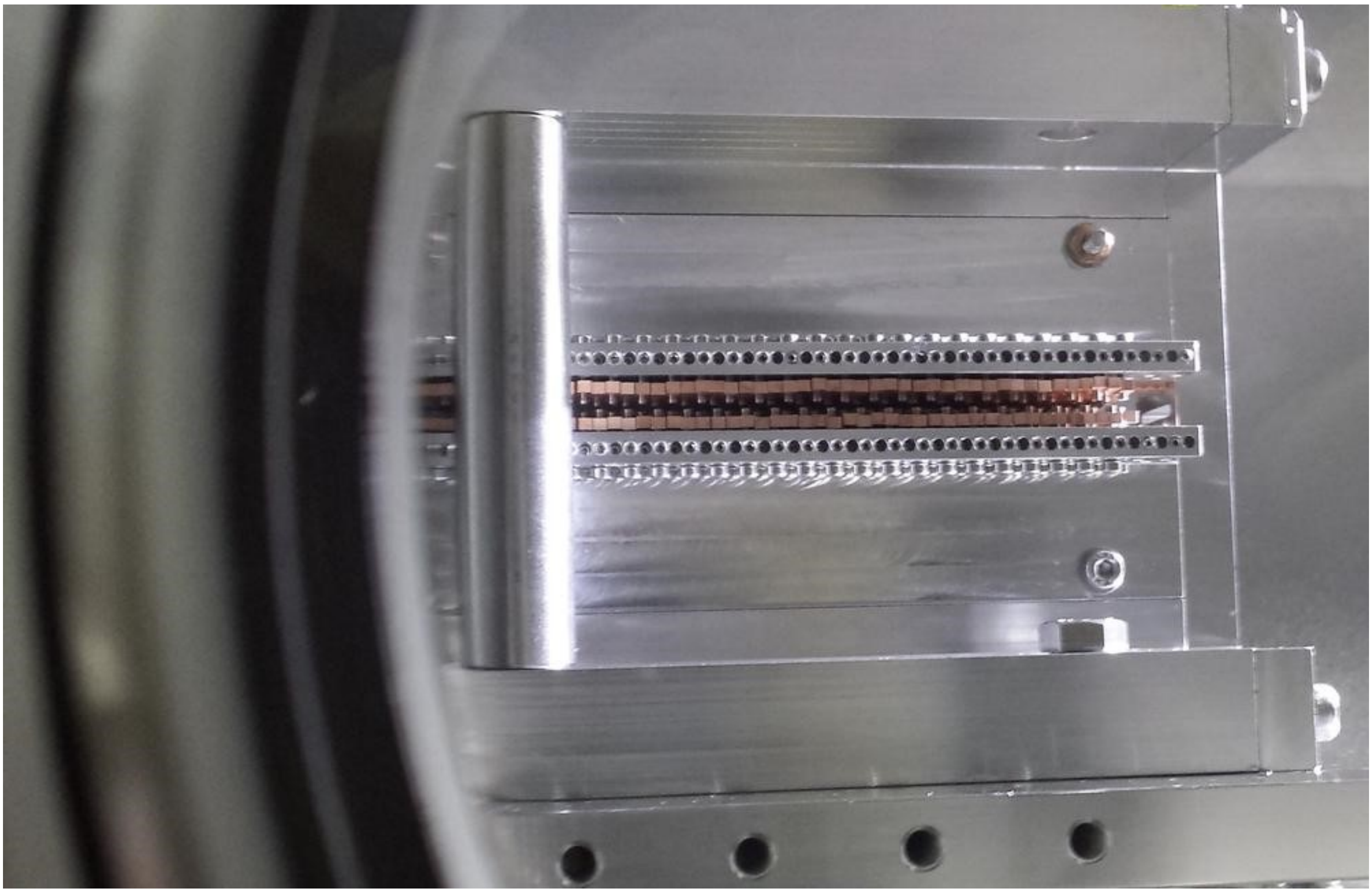
The principle of using plasma acceleration on electron beams has been well-established for several years. A notable feature of this invention is that hard X-rays of high quality are created, whose beam focus is optimally adapted to the electron laser collision point. In contrast to more complex external focussing using magneto-optical systems on the electron beam, this invention manages without additional beamlines – it is controlled entirely by the decrease in density of the gas in the plasma cell.

Challenges

Producing usable X-ray beam calls for a high stability in the laser driving the plasma wave, as well as a special adaptation of the electron beam for a small divergence of the Thomson scattering, which is achieved by varying the density of the gas in the plasma. This is important because in X-ray fluorescence imaging, for example, the size of the X-ray beam determines the spatial resolution. The size of the X-ray beam at the site of the specimen is determined by its divergence at the source, which in turn is determined mainly by the divergence of the electron beam.

possible applications

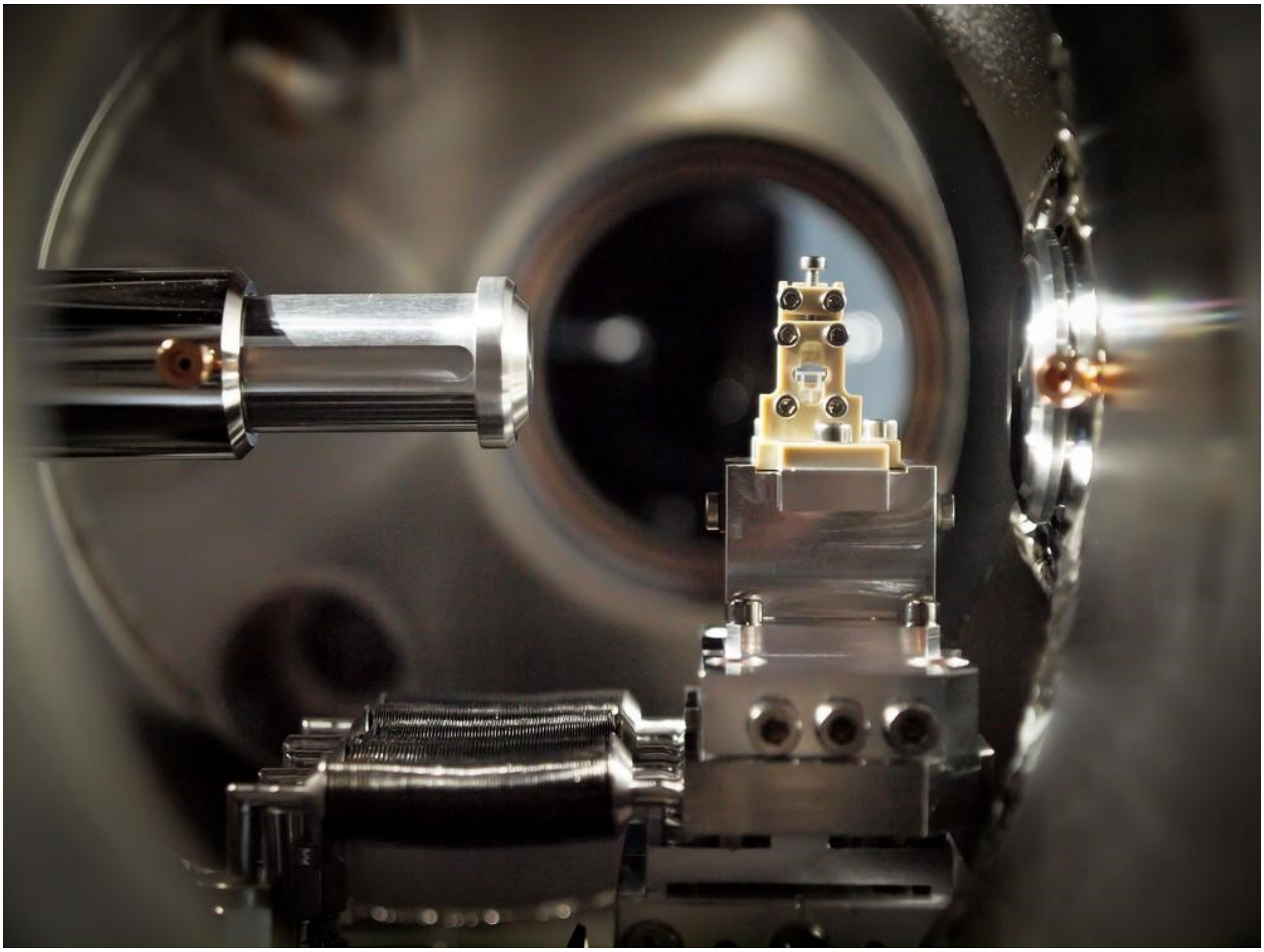
A typical application of compact plasma accelerators is seen in medical imaging, in particular producing X-rays using Thomson scattering. Further applications are the generation of radiation in undulates or direct use of the electron beam (diffraction, microscopy).



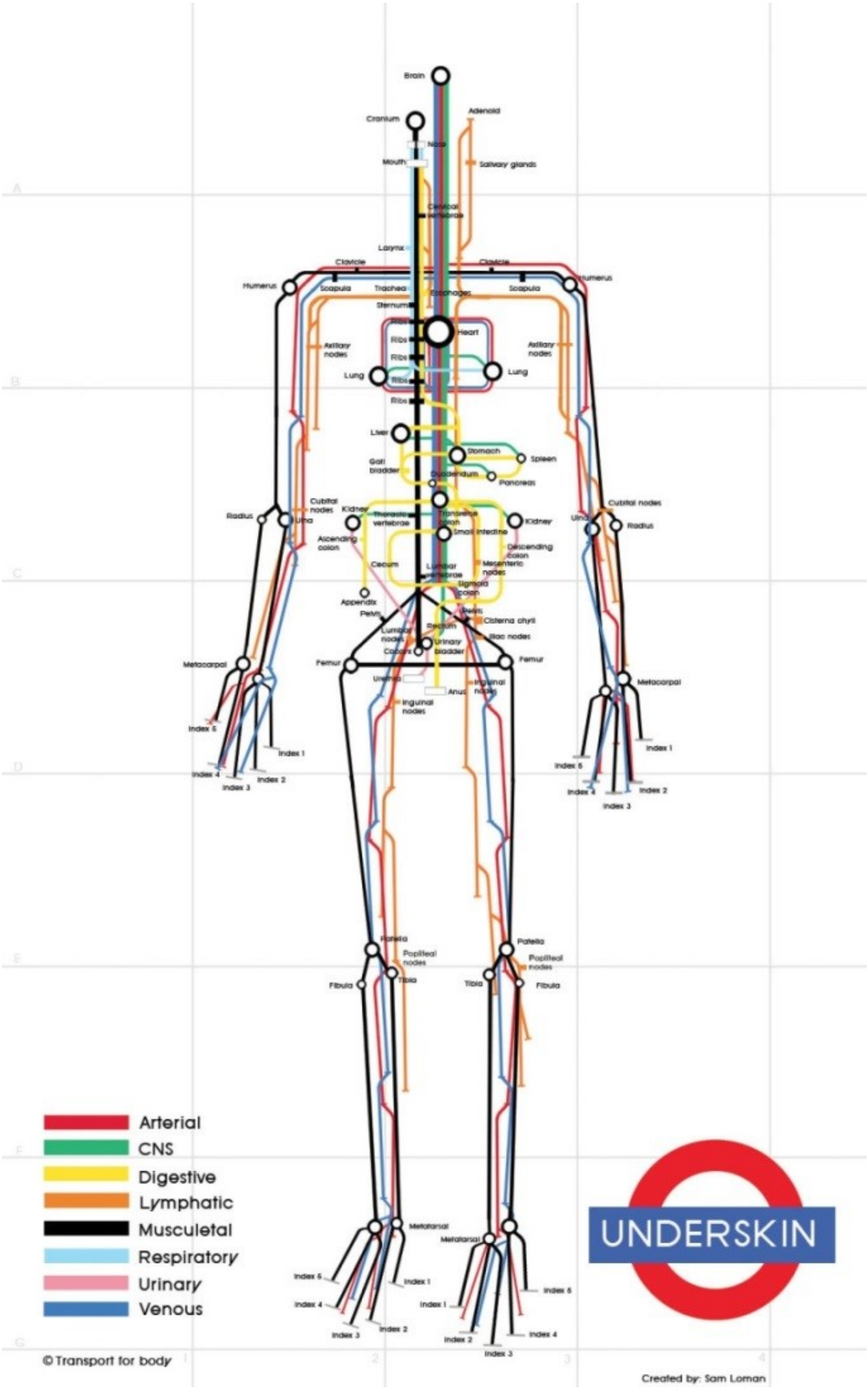
The undulator, the magnetic slalom course of LUX. Photo: Maximilian Trunk, University of Hamburg

Benefits

Fluorescence spectroscopy with hard X-rays can be used in the medical imaging of early-stage tumours, as well as in pharmacokinetics (measuring how pharmaceuticals spread through the body). The radiation exposure, for example during breast cancer screening, is lower than in current methods and the sensitivity is significantly higher. That’s why X-ray fluorescence is produced by gold nanoparticles that are injected into the body and can be specifically functionalised using tumour antibodies. Therefore, The nanoparticles then bind specifically only to tumour tissue. The extremely compact electron accelerator makes it possible to make such facilities available not only in accelerator laboratories but also in hospitals. Since the development of high-power lasers is progressing rapidly, it can be assumed that plasma accelerators for this application can be manufactured very inexpensively in a few years.



The plasma cell of LUX (centre) produces high-speed electrons. Photo: Niels Delbos, University of Hamburg



Early tumour detection and pharmacokinetics using functionalised nanoparticles – these are key applications of compact X-ray sources based on laser plasma acceleration and Thomson scattering.

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