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Applications of laser wakefield accelerators for biomedical imaging[1]

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Laser-wakefield accelerators driven by high-intensity short-pulse lasers are a proven compact source of high-energy electron beams, with energy gains of $\sim$ GeV energy in centimetres of plasma demonstrated. One of the main proposed applications for these accelerators is to drive synchrotron light sources, in particular for x-ray applications. It has also been shown that the same plasma accelerator can also act as a wigglers, capable of the production of high brightness and spatially coherent hard x-ray beams. In this latest work, we demonstrate the application of these unique light-sources for biological and medical applications. The experiments were performed with the Astra Gemini laser at the Rutherford Appleton Laboratory in the UK. Gemini produces laser pulses with energy exceeding 10 J in pulse lengths down to 40 fs. A long focal length parabola ($f/20$) is used to focus the laser down to a spot of size approximately 25 μm (fwhm) into a gas-cell of variable length. Electrons are accelerated to energies up to 1 GeV and a bright beam of x-rays is observed simultaneously with the accelerated beam. The length of the gas cell was optimised to produce high contrast x-ray images of radiographed test objects. This source was then used for imaging a number of interesting medical and biological samples. Full tomographic imaging of a human trabecular bone sample was made with resolution easily exceeding the $\sim 100\,\mu$m level required for CT applications. Phase-contrast imaging of human prostrate and mouse neonates at the micron level was also demonstrated. These studies indicate the usefulness of these sources in research and clinical applications. They also show that full 3D imaging can be made possible with this source in a fraction of the time that it would take with a corresponding x-ray tube.

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