Title: Laser-plasma accelerators and radiation sources

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Abstract:

In this talk we will review progress in developing laser-plasma based accelerators and radiation sources by the ALPHA-X team. These next-generation, ultra-compact devices have a niche potential for some applications, and could become widespread because of their lower cost and compactness when compared with conventional technology. The ALPHA-X project at the University of Strathclyde in Scotland has been driving forward a research programme, since 2000, to develop these novel technologies. Significant progress has been made towards controlling and characterising the beams from laser-plasma wakefield accelerators (LWFAs) since the first demonstration of controlled acceleration in 2004, which was published as one of the trio "Dream Beam" papers in Nature by the ALPHA-X team. Notably, acceleration of ultra-short duration bunches of electrons to 80-800 MeV has been demonstrated with percent-level energy spread, picocoulomb charge and 1 pi mm mrad emittance. The 10's of microns diameter LWFA "structure" traverses a few millimetres before dephasing. This results in an accelerator that is up to three orders of magnitude shorter than a conventional accelerator for the same energy. The dramatic reduction in size results in ultra-short electron bunches that are much shorter than from conventional accelerators. To determine the duration of the 1-10 pC bunches from the LWFA we have measured coherent transition radiation emitted as the bunches pass through a thin metal foil, and found it to be surprisingly short, approximately one femtosecond, which is two orders of magnitude shorter than bunches from most conventional accelerators. A consequence of this is that the peak current can be up to 10 kA, even for modest charges. We will discuss the energy apportioning conundrum of where the laser energy delivered to the plasma ends up, which gives rise to some uprising conclusions. The plasma structures have very large fields, which can exceed 100 GV/m and drive transverse betatron motion of the accelerating electrons. This gives rise to wiggler-like hard x-ray radiation. We will discuss experiments carried out to observe femtosecond duration gamma-ray betatron emission, where photon energies of up to 7 MeV have been measured. The peak brilliances measured are similar to fourth generation synchrotron sources, but in a photon energy range that is not accessible to conventional light sources. Finally, we will discuss several applications of these particle and radiation sources, such as compact FELs and ion-channel lasers, and medical applications including radiotherapy and imaging.