Laser-Driven Sources for Applications

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Laser generated plasmas offer a rich source of radiation and particle emission with unique properties that can be optimized and exploited for many applications. Traditionally, high brightness sources for use in applications have relied on large particle accelerator facilities and users who wished to carry out application experiments would do so using various beamline end stations at such facilities. With the development of the new generation of multi-TW to PW class lasers over the past two decades, the peak brightness and energy range of laser-based sources has increased orders of magnitude together with equivalent reduction in pulse duration. Reliable bunches of electrons can be generated in the MeV to GeV energy range with pulse durations in the femtosecond range. These can be generated either in solid target interactions or in underdense laser wakefield acceleration interactions. These electrons, in turn, can generate x-ray and gamma ray radiation via Bremsstrahlung in high density targets or via Betatron emission in underdense plasmas. Due to the highly relativistic nature of the interactions, this x-ray emission occurs in a narrow forward directed beam-cone, preserving many of the directional properties of the electron source bunch and the short, femtosecond scale, time duration of the electron source bunch. Alternatively the electrons can be used to accelerate protons and ions by generating an intense sheath field with TV/m electric acceleration fields at the exit of a thin foil target or through direct acceleration inside dense thin foil targets accelerated via ponderomotive pressure at ulra-high intensities. These short bunches of electrons and ions can in turn generate a range of secondary particles ranging from positrons to neutrons and muons.

Application areas for these sources are just now starting to emerge as we learn how to control and tune these sources to give the desired energies and fluences for different applications. Electrons, protons, x-rays, and gamma rays can be used for ultrafast time resolved radiography and imaging. The small source size allows for high resolution and enhanced imaging techniques such as x-ray phase contrast imaging. These have been applied in plasma studies, materials studies and industrial imaging. The radiation sources are also being studied for applications in radiotherapy and rapid radioisotope production on demand. Current and anticipated source characteristics will be outlined and examples of some of the application areas explored to date will be given.