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Probing Extreme Physics with Plasma Accelerators

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Plasma based particle accelerators driven by high intensity lasers are well suited as probes of extreme conditions. They are sources of electron, *x*-ray and gamma-ray beams with unique properties and, crucially, are readily synchronised with laser driven experiments which re-create extreme conditions usually only found in astrophysical environments.

This talk describes the key properties that make laser wakefield accelerators powerful tools for discovery and highlights three areas where we are making progress in the study of extreme conditions: extreme electromagnetic fields, extreme temperatures and photon-photon physics.

Extreme conditions can readily be created in the laboratory using high-power lasers. Collisions between femtosecond laser pulses and high energy electron beams can recreate the extreme electromagnetic fields found on the surface of neutron stars, approaching the critical field strength of quantum electrodynamics. Dense plasmas with temperatures exceeding 10 000 K (1 eV), such as those found in the centre of gas giant exoplanets can be generated using the *x*-rays produced by picosecond laser pulses. Picosecond lasers can also be used to generate dense *x*-ray fields that enable us to study photon-photon scattering processes that occur in the vicinity of blackholes.

However, in the laboratory these extreme conditions can only be created for a very short period of time, and so we need ultrafast probes to study them. Laser wakefield accelerators can produce GeV electrons, keV *x*-rays and MeV gamma photons which have durations measured in femtoseconds. Laser wakefield accelerators can also be co-located with lasers used to create extreme conditions and femtosecond/micrometre overlap is possible making them ideal for pump-probe experiments of extreme conditions.

This talk provides an overview of progress in our attempts to study extreme conditions in three areas: the measurement of radiation reaction in strong EM fields [1,2,3]; the development of single-shot *x*-ray absorption spectroscopy for studying warm dense matter [4,5]; and the development of a platform for studying photon-photon physics [6,7].

These experimental capabilities showcase how the specific capabilities of laser-plasma accelerators can be exploited to study a diverse range of physics.

References

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