Laser powered X-rays: generation and observation

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Introduction

X-rays are a form of electromagnetic radiation, like visible light or radio waves - but at a much higher energy. They penetrate deeply into matter and deposit energy in a targeted way, which has led to their widespread use in medical imaging, security scanning and radiotherapy. X-rays are created when highly energetic electrons are violently accelerated by strong electric fields. These conditions can occur when ultra-high intensity laser pulses hit solid targets, and we predict this will produce a highly efficient X-ray source in future laser facilities. These X-rays also give us a glimpse into the underlying electron motion, which is very difficult to detect. Currently this X-ray source is purely theoretical - we've never actually confirmed these X-rays can be produced experimentally, due to background X-rays from a different process.

Plasma X-rays

Modern laser pulses can reach intensities >10²¹ Wcm⁻² - over a billion times more intense than the surface of the Sun! When these lasers hit the target, there is enough energy present to rip electrons from the solid atoms, forming a plasma. X-rays are emitted as plasma electrons accelerate in the laser fields (synchrotron radiation), which will become very efficient when lasers become more powerful.

Background X-rays

The laser also pushes plasma electrons into the target, which is a problem. Electrons emit X-rays in this region when they scatter from the electric fields of solid atoms (bremsstrahlung radiation). These X-rays dominate emissions at modern day laser intensities, making the plasma X-rays (which are the key to efficient sources) difficult to study. How can experiments tell these X-rays apart?

Simulating X-ray emissions

Our X-ray detectors do not tell us where the X-rays come from, only how many there are. To distinguish plasma X-rays from solid ones, we simulate the entire laser-solid interaction. Just like white light is made from light of different colours, our emissions are made from X-rays of different energies. By plotting the relative proportions (dE/dEγ) of each X-ray energy present (Eγ), we can build up an energy spectrum.

We have recreated an actual experiment in our simulation code EPOCH, and have shown the X-ray energy spectra for both processes (Fig. 2.). While background X-rays may be more efficient overall, we have found that plasma X-rays dominate in the circled energy range. If we see a bulge in the total emission of the experimental data here, then we have not only showed that plasma X-rays are present in these systems - but we also have evidence to support our claim that these plasma electrons will provide a good X-ray source for next generation lasers, by validating our codes!

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