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 $>10^{21}$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?

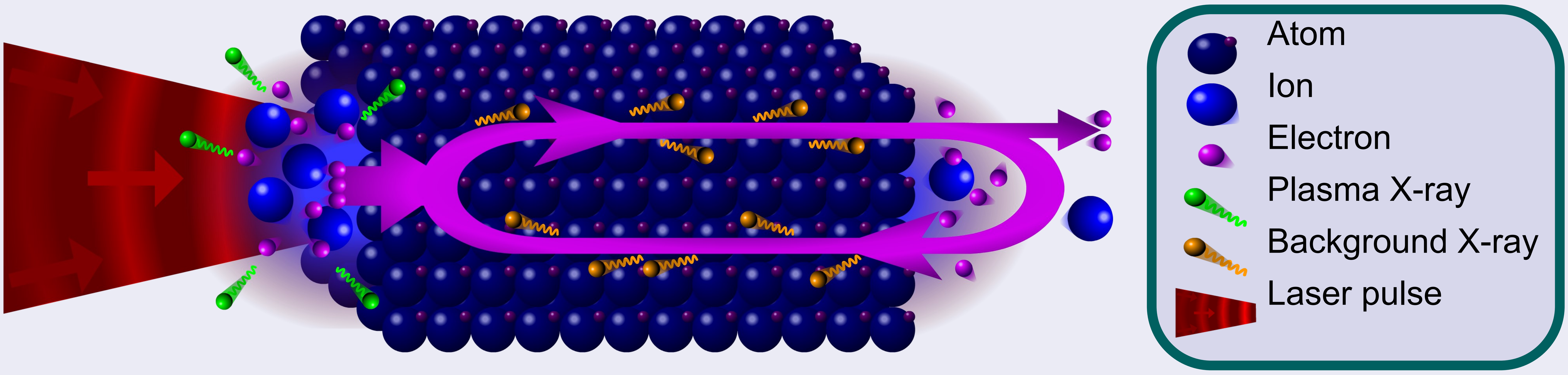

Fig. 1. Schematic diagram showing the laser-solid interaction. Laser rips electrons from atoms on the front surface and pushes them into the solid. The heavier ions don't move as much, and they attract the negative electrons back to the front as they have a positive charge

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/dE_γ) of each X-ray energy present (E_γ), 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 over-all, 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!

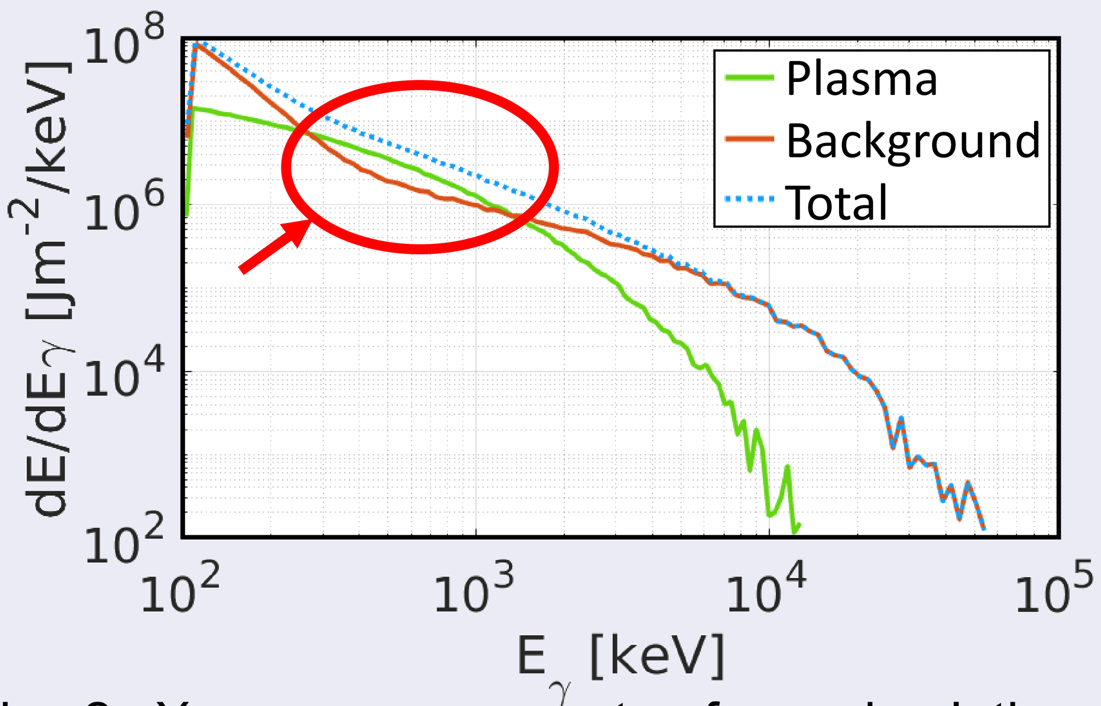

Fig. 2. X-ray energy spectra from simulating an experiment. Plasma X-rays dominate the emission in the circled region

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