

The illustration shows how electrons (blue) collide with a laser beam (green/magenta) and emit gamma rays (yellow).

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Intense laser experiments provide first evidence that light can stop electrons

By hitting electrons with an ultra-intense laser, researchers have revealed dynamics that go beyond ‘classical’ physics and hint at quantum effects.

Whenever light hits an object, some of the light scatters back from the surface of the object. However, if the object is moving extremely fast, and if the light is incredibly intense, strange things can happen.

Electrons, for example, can be shaken so violently that they actually slow down because they radiate so much energy. Physicists call this process *radiation reaction*.

This radiation reaction is thought to occur around objects such as black holes and quasars (supermassive black holes surrounded by a disc of gas). Being able to measure radiation reaction in the lab will therefore provide insights into processes that occur in some of the most extreme environments in the universe.

Radiation reaction is also interesting to physicists studying effects beyond ‘classical’ physics, as the equations (known as Maxwell’s equations) that traditionally define the forces acting on objects fall short in these extreme environments.

Now, a team of researchers led by Imperial College London have demonstrated radiation reaction in the lab for the first time. Their [results](#) are published 7 February in the journal *Physical Review X*.

They were able to observe this radiation reaction by colliding a laser beam

one quadrillion (a billion million) times brighter than light at the surface of the Sun with a high-energy beam of electrons. The experiment, which required extreme precision and exquisite timing, was achieved using the Gemini laser at the Science and Technology Facilities Council's Central Laser Facility in the UK.

Photons of light that reflect from an object moving close to the speed of light have their energy increased. In the extreme conditions of this experiment, this shifts the reflected light from the visible part of the spectrum all the way up to high energy gamma rays. This effect let the researchers know when they had successfully collided the beams.

Senior author of the study, Dr Stuart Mangles from the Department of Physics at Imperial, said:

"We knew we had been successful in colliding the two beams when we detected very bright high energy gamma-ray radiation. The real result then came when we compared this detection with the energy in the electron beam after the collision. We found that these successful collisions had a lower than expected electron energy, which is clear evidence of radiation reaction."

Study co-author Professor Alec Thomas, from Lancaster University and the University of Michigan, added:

"One thing I always find so fascinating about this is that the electrons are stopped as effectively by this sheet of light, a fraction of a hair's breadth thick, as by something like a millimetre of lead. That is extraordinary."

The data from the experiment also agrees better with a theoretical model based on the principles of quantum electrodynamics, rather than Maxwell's equations, potentially providing some of the first evidence of previously untested quantum models.

Study co-author Professor Mattias Marklund of Chalmers University of Technology, Sweden, whose group were involved in the study, said:

"Testing our theoretical predictions is of central importance for us at Chalmers, especially in new regimes where there is much to learn. Paired with theory, these experiments are a foundation for high-intensity laser

research in the quantum domain.”

However more experiments at even higher intensity or with even higher energy electron beams will be needed to confirm if this is true. The team will be carrying out these experiments in the coming year.

The team were able to make the light so intense in the current experiment by focussing it to a very small spot (just a few micrometres - millionths of a metre - across) and delivering all the energy in a very short duration (just 40 femtoseconds long: 40 quadrillionths of a second).

To make the electron beam small enough to interact with the focussed laser, the team used a technique called *laser wakefield acceleration*.

The laser wakefield technique fires another intense laser pulse into a gas. The laser turns the gas into a plasma and drives a wave, called the wakefield, behind it as it travels through the plasma. Electrons in the plasma can surf on this wake and reach very high energies in a very short distance.

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