

Radiation reaction when a light-speed electron beam collides with a high-intensity laser

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Electromagnetic radiation is pervasive. It comes in many forms, including radio waves, microwaves and high-energy X-rays and gamma rays. But what, precisely, is it?

Electromagnetic [radiation](#) is the energy emitted by a charged particle such as an electron when it accelerates. When the accelerating particle releases this energy, it experiences a recoil force called a radiation [reaction](#). Normally, radiation reaction forces are too small to consider, but they do become significant in laser-plasma interactions and astrophysical contexts, where high-electromagnetic fields and high-electron energies come into play.

A paper published in the journal *Physical Review X* presents evidence of a radiation reaction occurring when a high-intensity laser pulse collides with a high-energy electron [beam](#). A team of scientists supported by the EU-funded TeX-MEx and SF-QFT projects conducted this experiment using the Astra Gemini laser belonging to the Central Laser Facility in the United Kingdom.

The dual-beam Astra Gemini laser generates two synchronised laser beams, which together deliver a quadrillion (10^{15}) watts of power. In the experiment, one laser pulse was used to produce a bunch of high-energy electrons through a process known as laser-wakefield acceleration, while the second laser was directed at the electron bunch. When the electron

beam and laser pulse collided, the electrons oscillated in the second laser's electromagnetic field and scattered the laser beam's photons, which were detected as [gamma rays](#). The electrons' energy loss also resulted in a radiation reaction.

The difficulty of achieving a collision may be better appreciated if we consider the fact that laser pulses are thinner than a human hair and, with each lasting 45 quadrillionths of a second, had to hit what one of the scientists described as "micron-sized electron bullets" traveling at near-light speed. A collision was thought to be successful when high-[energy](#) gamma radiation was detected. Taking these infinitesimal speeds and widths into account, together with added factors such as [electron beam](#) variations from shot to shot and laser pointing and timing, it's quite clear why only a small number of collisions were successful.

The measurements obtained were used to compare quantum and classical models of radiation reaction. It was found that classical models tended to overestimate radiation reaction forces and gamma ray energies compared to quantum models. It was also concluded that the data was more consistent with a quantum electromagnetic model, but the fact remained that this only occurred slightly over 68 percent of the time and further studies were needed to properly assess different models.

The project team's main challenge going forward is to combine high-[laser](#) intensities, beam stability and high beam energies simultaneously in future experiments in order to gather enough data for a systematic study of quantum radiation reaction.

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