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THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2023 "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter" to **Pierre Agostini**, The Ohio State University, Columbus, USA, **Ferenc Krausz**, Max Planck Institute of Quantum Optics, Garching and Ludwig-Maximilians-Universität München, Germany, and **Anne L'Huillier**, Lund University, Sweden.

The Nobel Prize 2023 **in Physics**

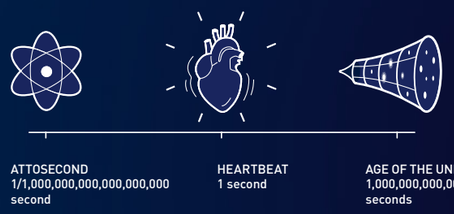
Electrons in pulses of light

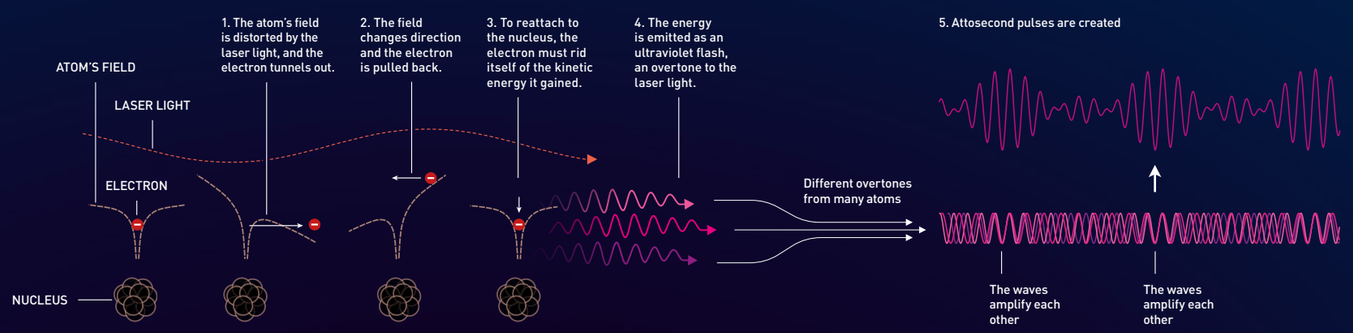
Through their experiments, this year's laureates have created flashes of light that are brief enough to take snapshots of electrons' extremely rapid movements. Anne L'Huillier discovered a new effect from laser light's interaction with atoms in a gas. Pierre Agostini and Ferenc Krausz used this effect to demonstrate that they could create shorter pulses of light than were previously possible.

The faster an event, the faster a picture needs to be taken if it is to capture the instant. A tiny hummingbird can beat its wings 80 times per second. We can only perceive this as a whirring sound and a vague, blurred movement. To human senses, rapid events flow together, and very brief instants are impossible to perceive. A highly focused photograph of a hummingbird in flight requires an exposure time that is much shorter than a single wingbeat.

This year's laureates have conducted experiments that show how to produce pulses of light that are short enough to depict the processes occurring inside atoms and molecules.

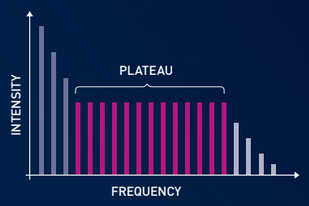
In the world of electrons, positions and energies change at speeds of between one and a few hundred attoseconds, where an attosecond is one billionth of a billionth of a second.





Example of an experimental set up

The trick to making shorter pulses is combining more and shorter wavelengths of light. The key is the overtones in laser light – *overtones* have several cycles for every cycle in the original wave.



In **1987**, Anne L'Huillier and her colleagues were able to produce and demonstrate overtones in infrared laser light transmitted through various noble gases. The experiment showed there was a plateau with many overtones of about the same intensity.

In **2001**, Pierre Agostini succeeded in producing and investigating a series of light pulses. Each pulse was just 250 attoseconds long.

In **2001**, Ferenc Krausz worked on a different type of experiment. He managed to isolate an individual pulse with a duration of 650 attoseconds.

Pierre Agostini
Born 1941 in Tunis, Tunisia. Professor at The Ohio State University, Columbus, USA.

Ferenc Krausz
Born 1962 in Mór, Hungary. Director at Max Planck Institute of Quantum Optics, Garching and Professor at Ludwig-Maximilians-Universität München, Germany.

Anne L'Huillier
Born 1958 in Paris, France. Professor at Lund University, Sweden.

Photo: Portrait of Pierre Agostini: Krystal Kenney; Portrait of Ferenc Krausz: Thorsten Naeser; Portrait of Anne L'Huillier: Charlotte Cordes Berg

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More information about the Nobel Prize in Physics 2023 is available at *www.kva.se/nobelphysics2023* and *www.nobelprize.org*, with video and detailed information about the prize and the laureates.

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