SAINTS PERSPECTIVES

Things Exceptional (Nobel Prizes)

The Nobel Prize in Physics 2023

3 October 2023.

The Nobel Prize Committee

Announced that the

2023 Nobel Prize in Physics

Is awarded jointly to

Anne L'Huillier, Pierre Agostini and Ferenc Krausz

for producing pulses of light
so short that they are measured in attoseconds

Description

An **attosecond** is a billionth of a billionth of a second—a unit of time so short that there are as many attoseconds in a single second as there have been seconds since the Big Bang, 13.8bn years ago.

Electrons are particles inside atoms and they move incredibly fast - in billionths of a second - in mere fractions of an attosecond. Prior to the laureates' breakthroughs, they effectively appeared as blurs under the most advanced microscopes - their movement and behaviour was too rapid to follow.

Ultra-fast lasers work in the same way that strobe lighting can help capture useful images of fast-moving objects in the everyday world. A hummingbird, for example, can beat its wings 80 times per second. To human eyes, this looks like a blur. Use a high-speed camera and a strobe light flashing faster than the hummingbird’s wings beat, though, and it is possible to take detailed pictures of the bird in flight.

Their work demonstrated a way to create extremely short pulses of light that can be used to capture and study rapid processes inside atoms.
This work demonstrated that these almost unimaginably short pulses - like an ultra high-speed shutter - could be used to study how electrons behave.

"Attosecond physics" is bringing important processes inside atoms and molecules into sharper focus. The development is likely to lead to even more accurate electron

microscopes, much faster electronics and new tests able to diagnose diseases at a much earlier stage.

Generating pulses of light short enough to watch electrons began with the work of **Professor L'Huillier. In 1987** she was working at the Saclay Nuclear Research Centre, near Paris, experimenting with lasers and noble gases such as argon or neon. She found that the lasers imparted energy into the gas atoms, knocking their electrons loose. When those electrons were eventually recaptured, they released energy in the form of light.

Those light waves interacted with each other in turn. Where their peaks coincided, they would become more intense. When one wave's peak met another's trough, though, the light's intensity would fall. And sometimes, if the light waves interacted in just the right way, they produced pulses of ultraviolet light that lasted for just a few hundred attoseconds.

In 2001 Pierre Agostini, also working in France, built Prof L'Huillier's observation into a workable piece of technology, designing a way to produce a series of pulses of light that lasted for 250 attoseconds each.

At around the same time, Dr Krausz, working independently in Vienna, managed to produce a series of pulses lasting for 650 attoseconds each.

Possible Applications

Nowadays scientists have shortened the pulses of light even further, down to dozens of attoseconds. These ultra-fast disco lights are still not quite quick enough to freeze-frame electrons in their orbits around atoms, but a blurry camera is better than no camera at all. Before attosecond light was available, scientists could only talk about the probability that an electron might be in a particular place at a particular time. The pulses can also be used to measure how closely electrons are bound to an atom's nucleus, and how long it takes for one to be pried loose during a chemical reaction.

Other applications are further away. Attosecond pulses of light might help to create ultra-fast electronics, in which a semiconductor is prodded to switch between its insulating and conducting states far faster than it can today. The pulses can also be used to nudge large molecules, which then go on to emit characteristic radiation that depends on their precise chemical makeup. That could be used to analyse blood

samples, for instance, with a view to picking up even the smallest markers of disease.

Prize amount:

11 million Swedish kronor, to be shared equally between the Laureates.

About the Winners

Pierre Agostini, Anne L'Huillier and Ferenc Krausz

Prof L'Huillier, who is based at Lund University in Sweden, is only the fifth woman to win a physics Nobel.

Prof Pierre Agostini is based at Ohio State University in the US,

Prof Ferenc Kraus is at Max Planck Institute of Quantum Optics in Germany.

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Previous Winners of the Nobel Prize in Physics

- 2022 - Alain Aspect, American John Clauser and Austrian Anton Zeilinger for **research into quantum mechanics** - the science that describes nature at the smallest scales;
- 2021 - Syukuro Manabe, Klaus Hasselmann and Giorgio Parisi were given the prize for **advancing our understanding of complex systems**, such as Earth's climate;
- 2020 - Sir Roger Penrose, Reinhard Genzel and Andrea Ghez received the prize for their **work on the nature of black holes**;
- 2019 - James Peebles, Michel Mayor and Didier Queloz shared the prize for **ground-breaking discoveries about the Universe;**
- 2018 - Donna Strickland, Arthur Ashkin and Gerard Mourou were awarded the prize for their **discoveries in the field of laser physics.**

The Nobel Assembly, consisting of 50 professors at Karolinska Institutet, awards the Nobel Prize in Physiology or Medicine. Its Nobel Committee evaluates the nominations. Since 1901 the Nobel Prize has been awarded to scientists who have made the most important discoveries for the benefit of humankind.

References

A Nobel Physics prize for electron-watchers
The Economist, Oct 3rd 2023

Nobel Prize for 'attosecond physicists' Agostini, L'Huillier and Krausz
BBC News