Nobel Prize in Physics 2023

For Prelims: Nobel Prize in Physics 2023, Electron Dynamics, Attosecond Pulses, Femtoseconds, Spectroscopy.

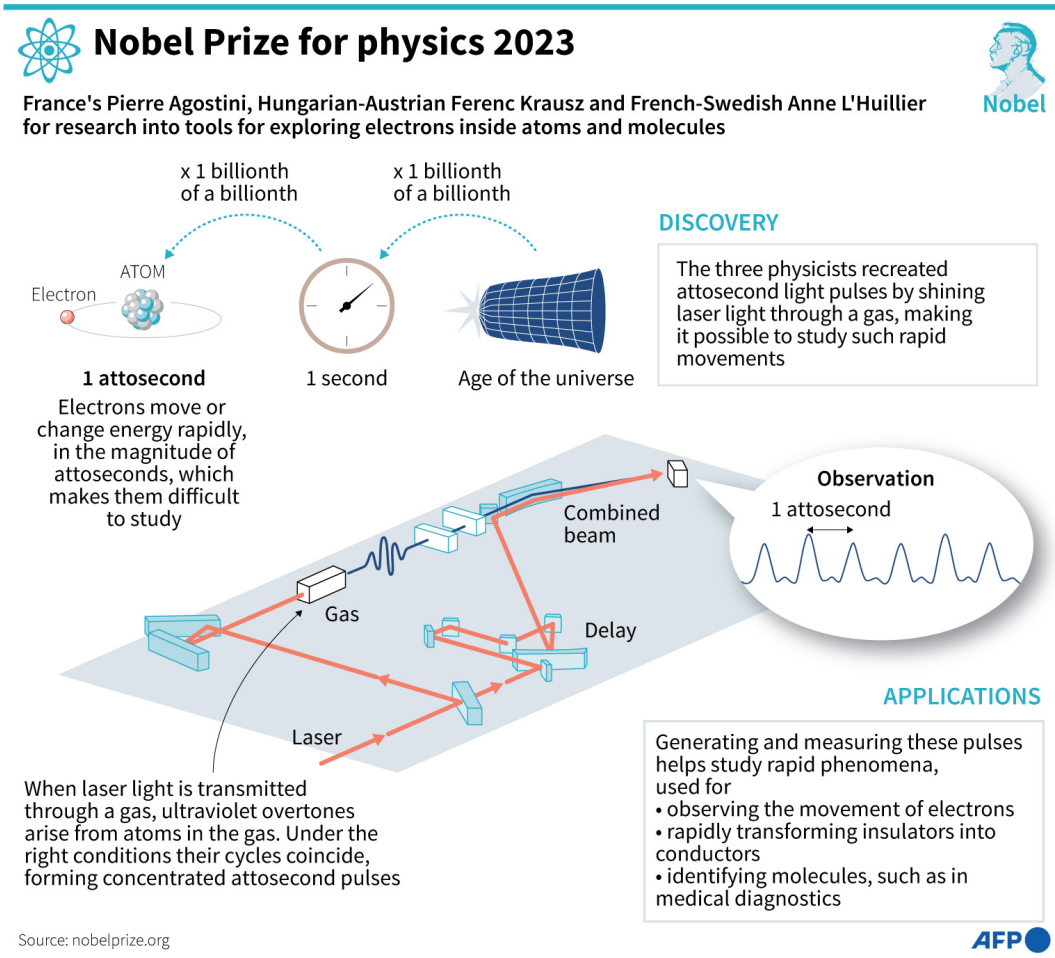
For Mains: Applications of Attosecond Physics

Source: TH

Why in News?

The **2023** Nobel Prize **for Physics** has been awarded to three distinguished scientists: **Pierre Agostini, Ferenc Krausz, and Anne L'Huillier.**

- Their groundbreaking work in the field of experimental physics has led to the development of **attosecond pulses,** enabling scientists to directly observe and study the **rapid dynamics of** electrons **within matter.**



What is Electron Dynamics?

- **Electron dynamics** refers to the study and understanding of the behavior and motion of electrons within atoms, molecules, and solid materials.
    - It encompasses various aspects of electron behavior, including their **movement, interactions with** electromagnetic fields**, and responses to external forces.**
- **Electrons** are fundamental particles with a **negative charge** and they orbit the dense nucleus. For a long time, **scientists had to rely on indirect methods to understand electron behavior,** akin to taking a photograph of a fast-moving race car with a long exposure time resulting in a blurry image.
    - The rapid motion of electrons rendered them **nearly invisible to conventional measurement techniques.**
- Atoms in molecules exhibit movements on the order of **femtoseconds**, which are **incredibly short time intervals**, constituting a **millionth of a billionth of a second.**
    - Electrons, being lighter and interacting even faster, operate within the **attosecond realm, a billionth of a billionth of a second (1×10−18 of second).**

Note: An attosecond pulse is an **incredibly brief burst of light** that lasts for attoseconds.

How did Scientists Achieve Attosecond Pulse Generation?

- **Background:**
    - In the **1980s**, physicists managed to create **light pulses lasting just a few femtoseconds.**
        - At that time, it was believed that this was the shortest achievable duration for light pulses.

        - However, to '**see' electrons in action, an even shorter pulse was needed.**
- **Advancements in Attosecond Pulse Generation:**
    - In **1987, Anne L'Huillier** and her team at a French laboratory achieved a significant breakthrough.
        - They passed an **infrared laser beam through a** noble gas, leading to the generation of **overtones**—waves of light with wavelengths that were integer fractions of the original beam.
        - The overtones generated in the gas were in the form of ultraviolet light. Scientists observed that when multiple overtones interacted, they could either **intensify each other through constructive interference** or cancel each other out through destructive interference.
            - By **refining their setup,** physicists managed to create i**ntense attosecond pulses of light.**
    - In **2001, Pierre Agostini** and his research group in France successfully produced a series of 250-attosecond light pulses.
        - By combining this pulse train with the original beam, they conducted rapid experiments that offered unprecedented insights into electron dynamics.
    - Simultaneously, **Ferenc Krausz** and his team in Austria developed a technique to isolate individual 650-attosecond pulses from a pulse train.
        - This breakthrough allowed researchers to measure the energy of electrons released by **krypton atoms** with remarkable precision.

What are the Applications of Attosecond Physics?

- **Studying Short-Lived Processes:** Attosecond pulses enable scientists to capture 'images' of ultrafast atomic and molecular processes.
    - This has profound implications for fields such as **materials science, electronics, and catalysis**, where understanding rapid changes is crucial.
- **Medical Diagnostics**: Attosecond pulses can be employed in medical diagnostics to **detect specific molecules based on their fleeting signatures**. This promises improved medical imaging and diagnostic techniques.
- **Advancing Electronics:** Attosecond physics may lead to the **development of faster** electronic devices**,** pushing the boundaries of computing and telecommunications technology.
- **Enhanced Imaging and Spectroscopy**: The ability to manipulate attosecond pulses opens up possibilities for **higher-resolution imaging and spectroscopy**, with applications in fields ranging from **biology to astronomy.**

Who are the Other Recent Nobel Laureates in the Field of Physics?

- **2022**
    - **Alain Aspect, John F. Clauser and Anton Zeilinger "for experiments with** entangled photons, establishing the **violation of Bell inequalities and pioneering quantum information science"**
- **2021**
    - "for groundbreaking contributions to our understanding of complex systems"
        - **Syukuro Manabe and Klaus Hasselmann** "for the physical modeling of Earth's climate, quantifying variability and reliably predicting global warming"
        - **Giorgio Parisi** "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales"
- **2020**
    - **Roger Penrose** "for the discovery that black hole **formation is a robust prediction of the general theory of relativity"**
    - Reinhard Genzel and Andrea Ghez "for the discovery of a supermassive compact object at the center of our galaxy"
- **2019**
    - "For contributions to our understanding of the evolution of the universe and Earth's place in the cosmos"
        - **James Peebles** "for theoretical discoveries in physical cosmology"
        - Michel Mayor and Didier Queloz "for the discovery of an **exoplanet** orbiting a solar-

type star”

- **2018**
  - “For groundbreaking inventions in the field of **laser physics”**
    - **Arthur Ashkin** “for the **optical tweezers** and their application to biological systems”
    - **Gérard Mourou and Donna Strickland** “for their method of generating high-intensity, ultra-short optical pulses”
- **2017**
  - **Rainer Weiss, Barry C. Barish and Kip S. Thorne** “for decisive contributions to the **LIGO detector** and the observation of gravitational waves”

UPSC Civil Services Examination Previous Year Question (PYQ)

Prelims

Q. Who among the following scientists shared the Nobel Prize in Physics with his son? (2008)

(a) Max Planck
(b) Albert Einstein
(c) William Henry Bragg
(d) Enrico Fermi

Ans: (c)

Q. Nobel Prize winning scientist James D. Watson is known for his work in which area? (2008)

(a) Metallurgy
(b) Meteorology
(c) Environmental protection
(d) Genetics

Ans: (d)

Mains

Q1. The Nobel Prize in Physics of 2014 was jointly awarded to Akasaki, Amano and Nakamura for the invention of Blue LEDs in the 1990s. How has this invention impacted the everyday life of human beings? **(2021)**

Q2. Discuss the work of ‘Bose-Einstein Statistics’ done by Prof. Satyendra Nath Bose and show how it revolutionized the field of Physics. **(2018)**