Bharathidasan University

Tiruchirappalli – 620 024, Tamil Nadu, India

Programme: M. Sc., Physics

Course Title : Lasers and Nonlinear Optics

Course Code : 22PH401

Unit II

Advanced Lasers and Nobel Prizes

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Department of Physics

Story of Alfred Nobel

1833-1896

www.alamy.com - C7RMHT

Known for: inventing dynamite and holder of 355 patents

Contributions that have conferred the greatest benefit to humankind in the areas of Physics, Chemistry, Physiology or Medicine, Literature, Economics and Peace.

621 prizes to **992** laureates

(1901- 2023)

117 prizes to **225** laureates in **Physics**

Guess……………….

First Nobel Prize in Physics:	W.C. Rontgen (X-rays, 1901)
How many times Nobel prize in Physics was awarded?:	112 times (1916, 31, 34, 40, 41, 42)
Two times Nobel prize award winner in Physics:	John Bardeen (Superconductivity, 1972) (Semiconductors, 1956)
Nobel Prize in Physics for Einstein and Newton:	Photoelectric effect (1921) and Nil
How many times Nobel Prize was awarded to laser based concepts:	Seven

Light and Nobel Prizes

1902 Physics
Lorentz and Zeeman
The Zeeman Effect, Electron Oscillator Model

1903 Physiology or Medicine
Finsen
Phototherapy – use of UV light to treat Lupus

1907 Physics
Michelson
The Michelson Interferometer & Precision Measurements

1908 Physics
Lippmann
Colour Photography based on Interference

1911 Physiology or Medicine
Gullstrand
Description of the Refractive Optics of the Eye

1912 Physics
Dalén
Solar-based regulator for buoys and lighthouses

1918 Physics
Planck
Energy Quanta

1919 Physics
Stark
The Stark Effect

1921 Physics
Einstein
Photoelectric Effect & services to theoretical physics

1922 Physics
Bohr
Atomic Structure and the nature of radiation

1923 Physics
Millikan
Elementary Charge and the Photoelectric Effect

1927 Physics
Compton
The Compton Effect

1930 Physics
Raman
Raman scattering

1932 Physics
Heisenberg
Creation of Quantum Mechanics

1933 Physics
Schrodinger and Dirac
New Productive Forms of Atomic Theory

1945 Physics
Pauli
Pauli Exclusion Principle

1953 Physics
Zernike
Phase Contrast Microscope

1954 Physics
Born
Statistical Interpretation of the Wavefunction

1955 Physics
Lamb
Fine structure of the H Spectrum (Lamb Shift, QED)

Light, Lasers and Nobel Prizes

1964 Physics
Townes, Basov, and Prokhorov
Maser-Laser Principle

1966 Physics
Kastler
Precision studies of optical resonances

1967 Physiology or Medicine
Granit, Hartline, and Wald
Physiological and chemical visual processes in the eye

1967 Chemistry
Eigen, Norrish, and Porter
Flashlamp Pump-Probe Studies of Chemical Reactions (μs)

1971 Physics
Gabor
Holography

1981 Physics
Bloembergen and Schawlow
Laser Spectroscopy

1981 Physiology and Medicine
Hubel and Wiesel
Information Processing in the Visual System

1989 Physics
Ramsey, Dehmelt, and Paul
Atomic Clocks, the Ion Trap

1997 Physics
Chu, Cohen-Tannoudji, and Phillips
Laser Cooling and Trapping

1999 Chemistry
Zewail
Femtochemistry

2000 Physics
Alferov and Kroemer
Optoelectronics, Semiconductor Heterostructures

2001 Physics
Cornell, Ketterle, and Wieman
Bose Einstein Condensation

2005 Physics
Glauber, Hall, and Haensch
Quantum Optics, Spectroscopy, Optical Frequency Comb

2008 Chemistry
Shimomura, Chalfie, and Tsien
Green Fluorescent Protein GFP

2009 Physics
Kao, Boyle, and Smith
Optical Fiber Communications ; Imaging and the CCD

2012 Physics
Haroche and Wineland
Individual Quantum Systems

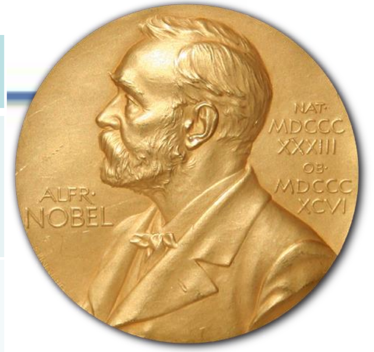
2014 Physics
Akasaki, Amano, and Nakamura
The Blue LED and Energy-Saving White Light Sources

2014 Chemistry
Betzig, Hell, and Moerner
Super-resolution microscopy

2018 Physics
Ashkin, Mourou, and Strickland
Optical Tweezers & Biophotonics
Chirped Pulse Amplification

2017: Gravitational wave detection and laser interferometery
2020: Observation of black holes building on laser guide star adaptive optics

Nobel Prizes and Lasers



Year	Nobel Laureates	Contribution
1964	Charles H. Townes, Nicolay G. Basov, Aleksandr M. Prokhorov	Maser
1981	Nicolaas Bloembergen, Arthur Leonard Schawlow	Precision laser spectroscopy
1997	Steven Chu, Claude Cohen-Tannoudji, William D. Phillips	Laser cooling of atoms
2000	Zhores I. Alferov,Herbert Kroemer	Semiconductor lasers
2005	John L. Hall,Theodor W. Hänsch	Frequency comb generation with mode-locked lasers
2009	Charles K. Kao , Willard S. Boyle, George E. Smith	Fiber optic communication
2018	Arthur Ashkin, Gerard Mourou, Donna Strickland	Optical tweezer and generating USP
2023	**Pierre Agostini, Ferenc Krausz and Anne L'Huillier**	**Generating attosecond light pulses**

Nobel prizes and Lasers

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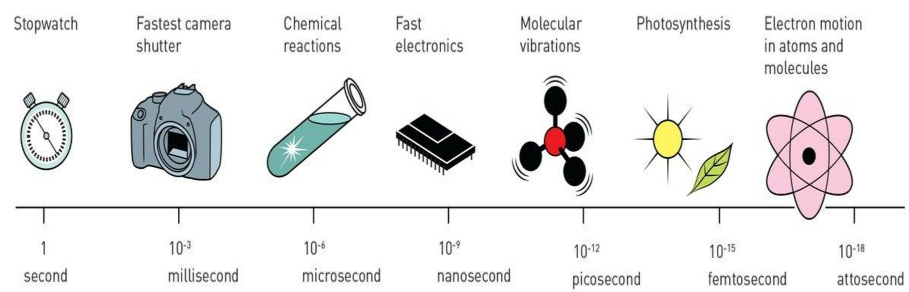
Nobel Prize in Physics for 2018…..

For ground breaking invention in the field of laser Physics.

Optical tweezers make it possible to observe, turn, cut, push and pull with light.



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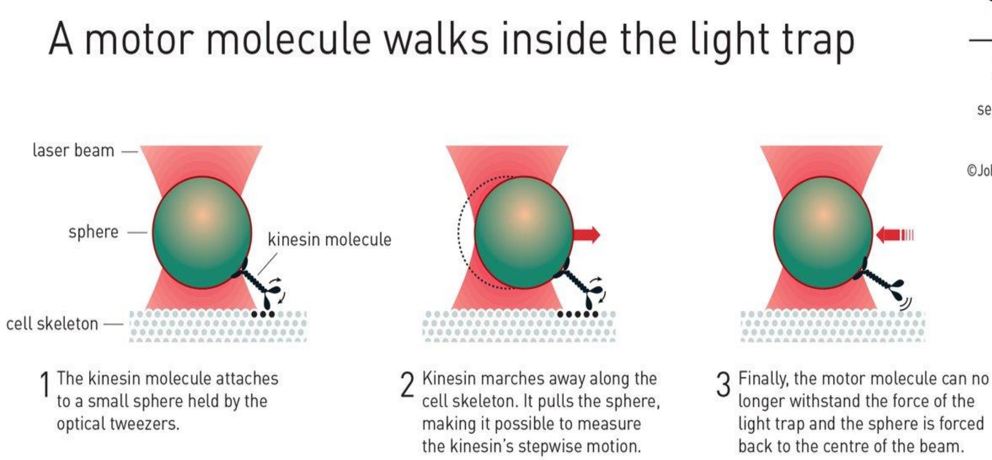

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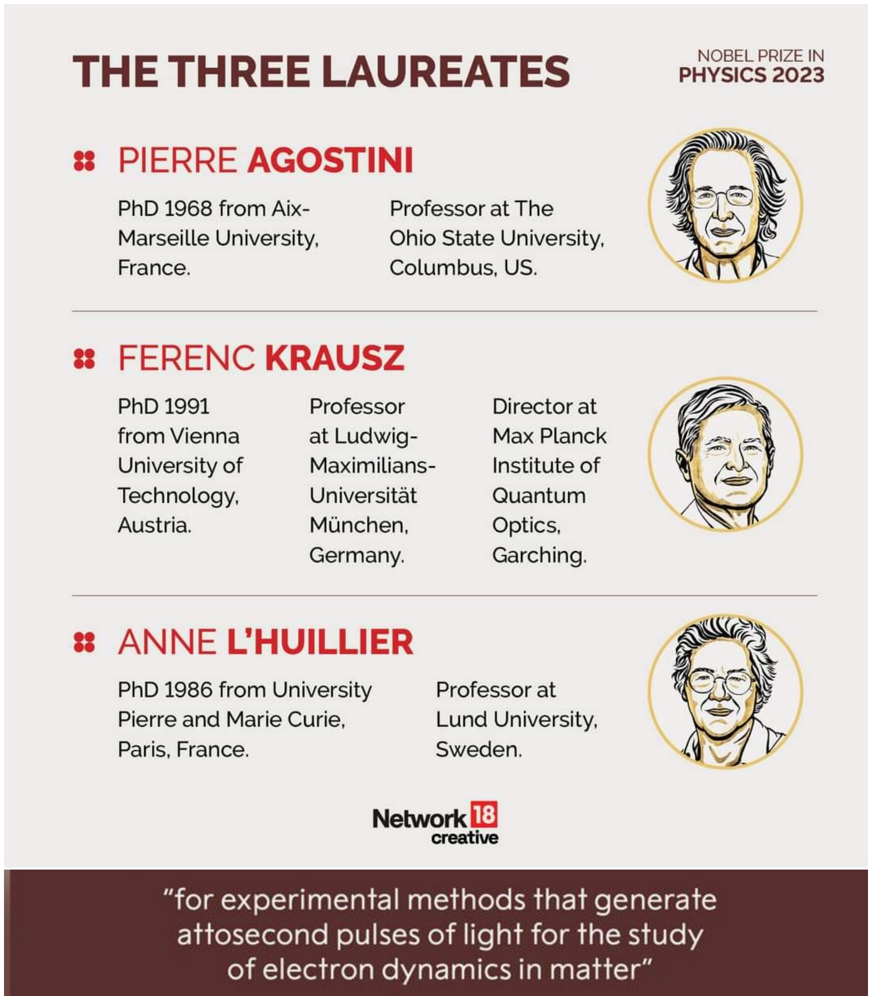
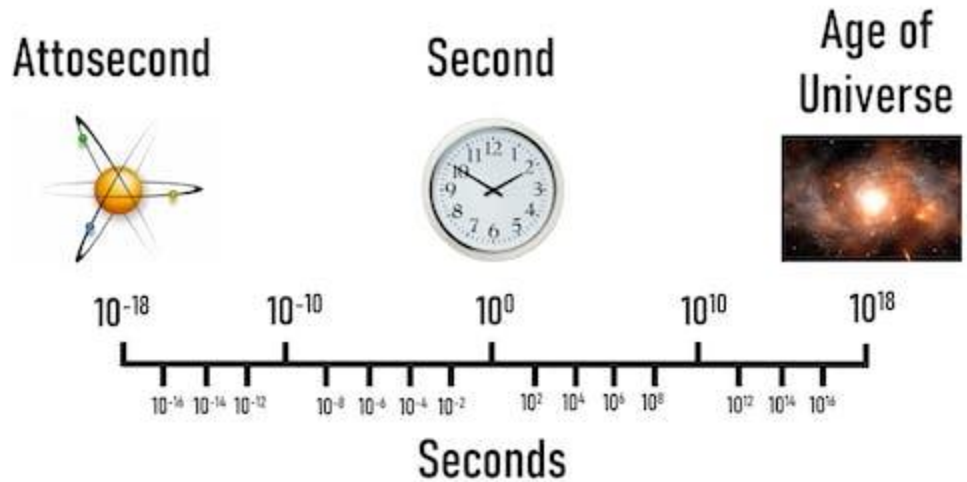
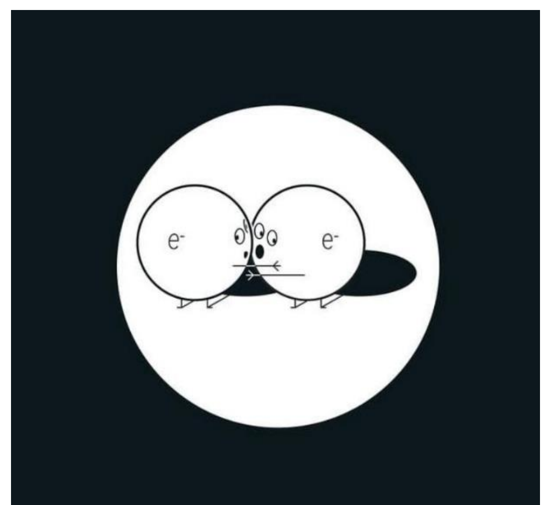
With ultrashort and intense laser pulses, we can see events that previously seemed instantaneous.

Nobel Prize in Physics 2023



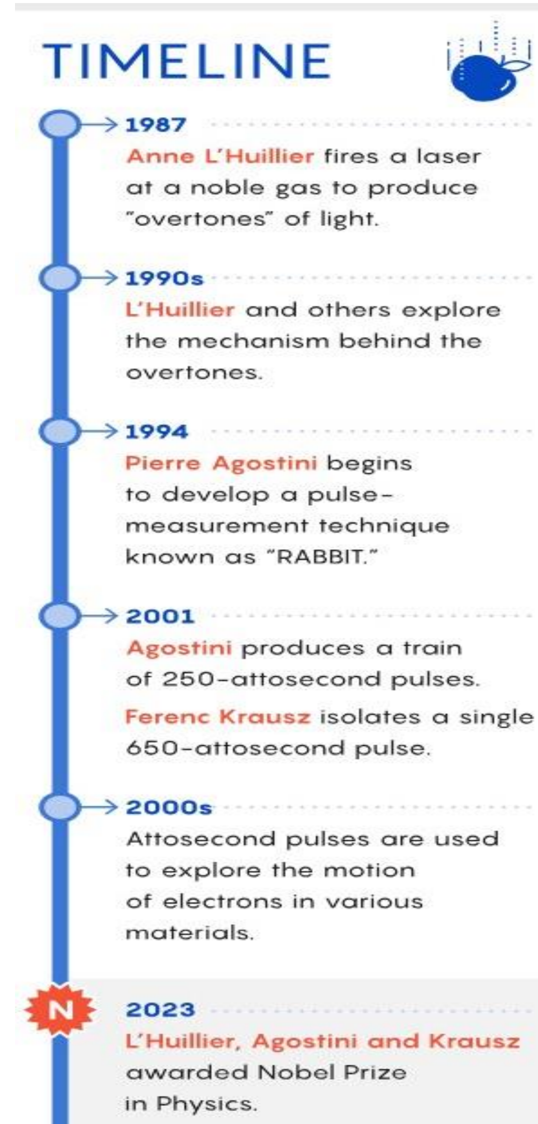




Time to explore the **world of electrons!!!**

for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter

- In 1987, **Anne L'Huillier** discovered that many different overtones of light arose when she transmitted infrared laser light through a noble gas.
- In 2001, **Pierre Agostini** succeeded in producing and investigating a series of consecutive light pulses, in which each pulse lasted just 250 attoseconds.
- At the same time, **Ferenc Krausz** was working with another type of experiment, one that made it possible to isolate a single light pulse that lasted 650 attoseconds.



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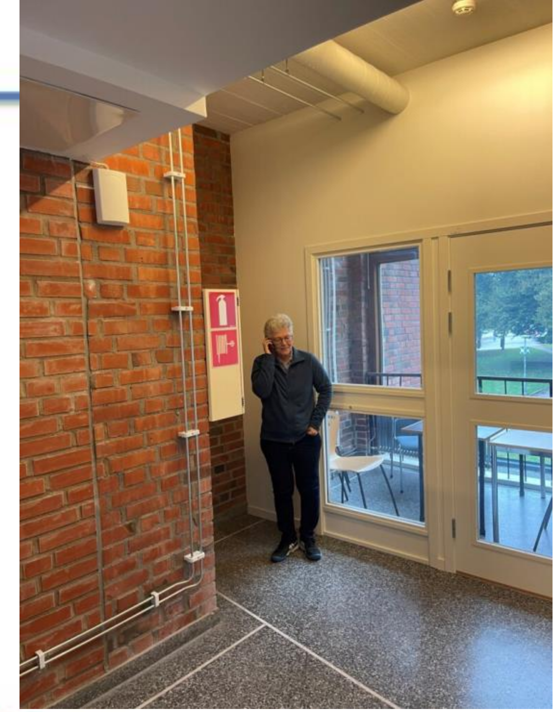
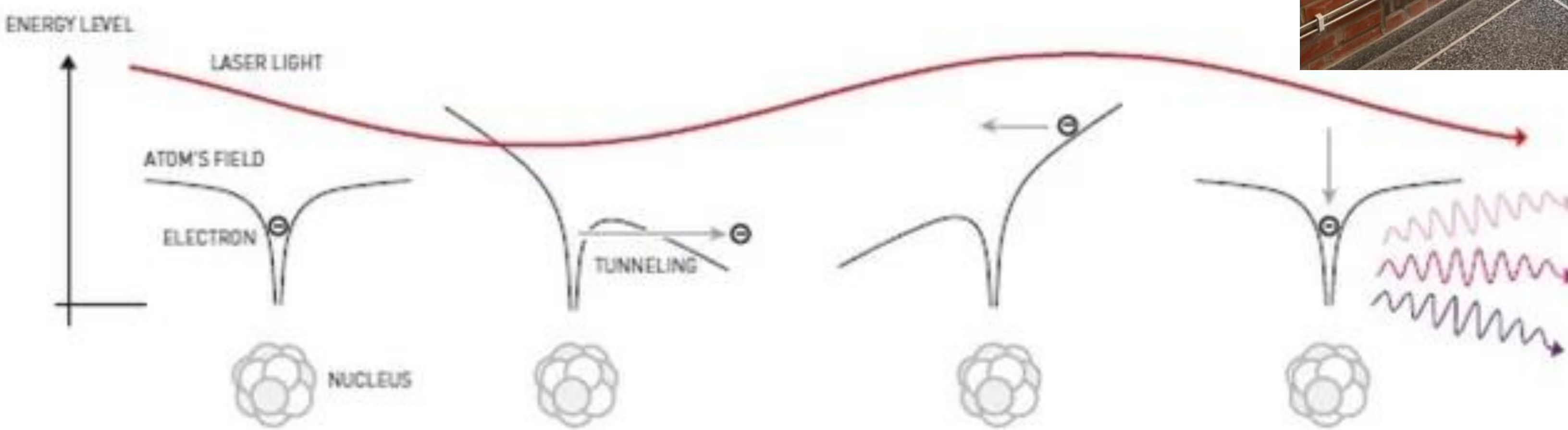


Laser light interacts with atoms in a gas

Experiments that created overtones in laser light led to the discovery of the mechansim that causes them. How does it work?



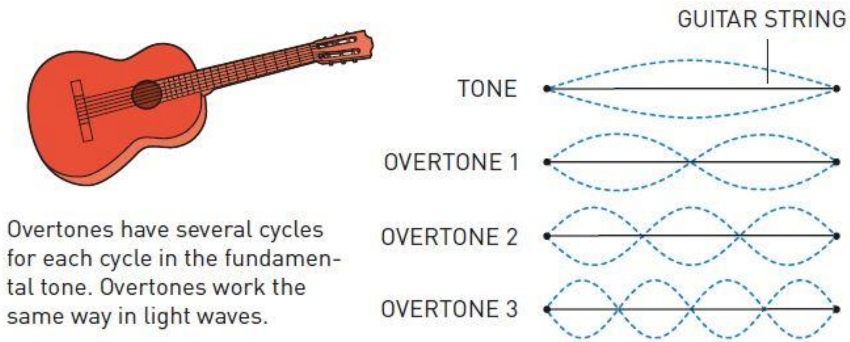
1 An electron that is bound to an atom's nucleus cannot normally leave its atom; it does not have enough energy to lift itself out of the well created by the atom's electrical field.

2 The atom's field is distorted when it is affected by the laser pulse. When the electron is only held by a narrow barrier, quantum mechanics allow it to tunnel out and escape.

3 The free electron is still affected by the laser field and gains some extra energy. When the field turns and changes direction, the electron is pulled back in the direction it came from.

4 To reattach to the atom's nucleus, the electron must rid itself of the extra energy it gained during its journey. This is emitted as an ultraviolet flash, the wavelength of which is linked to that of the laser field, and differs depending on how far the electron moved.

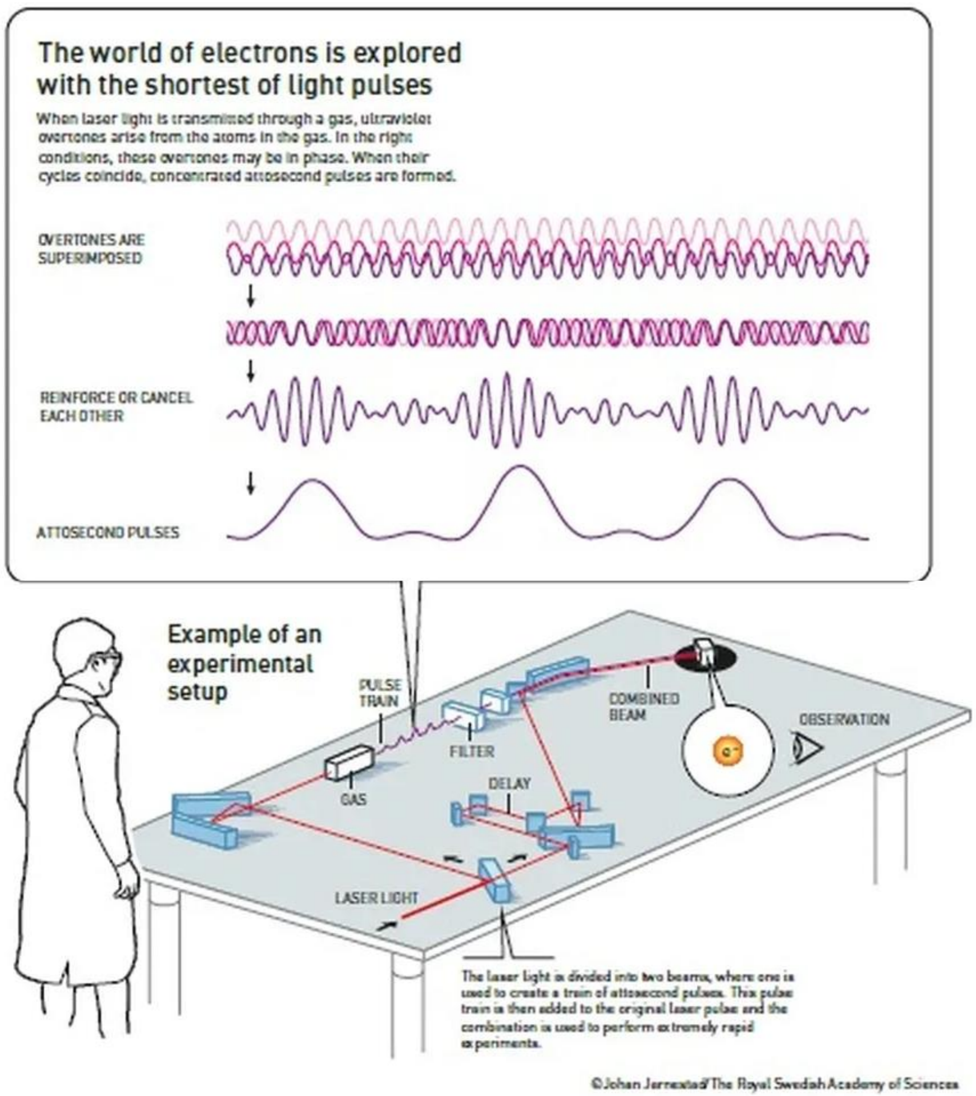
for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter



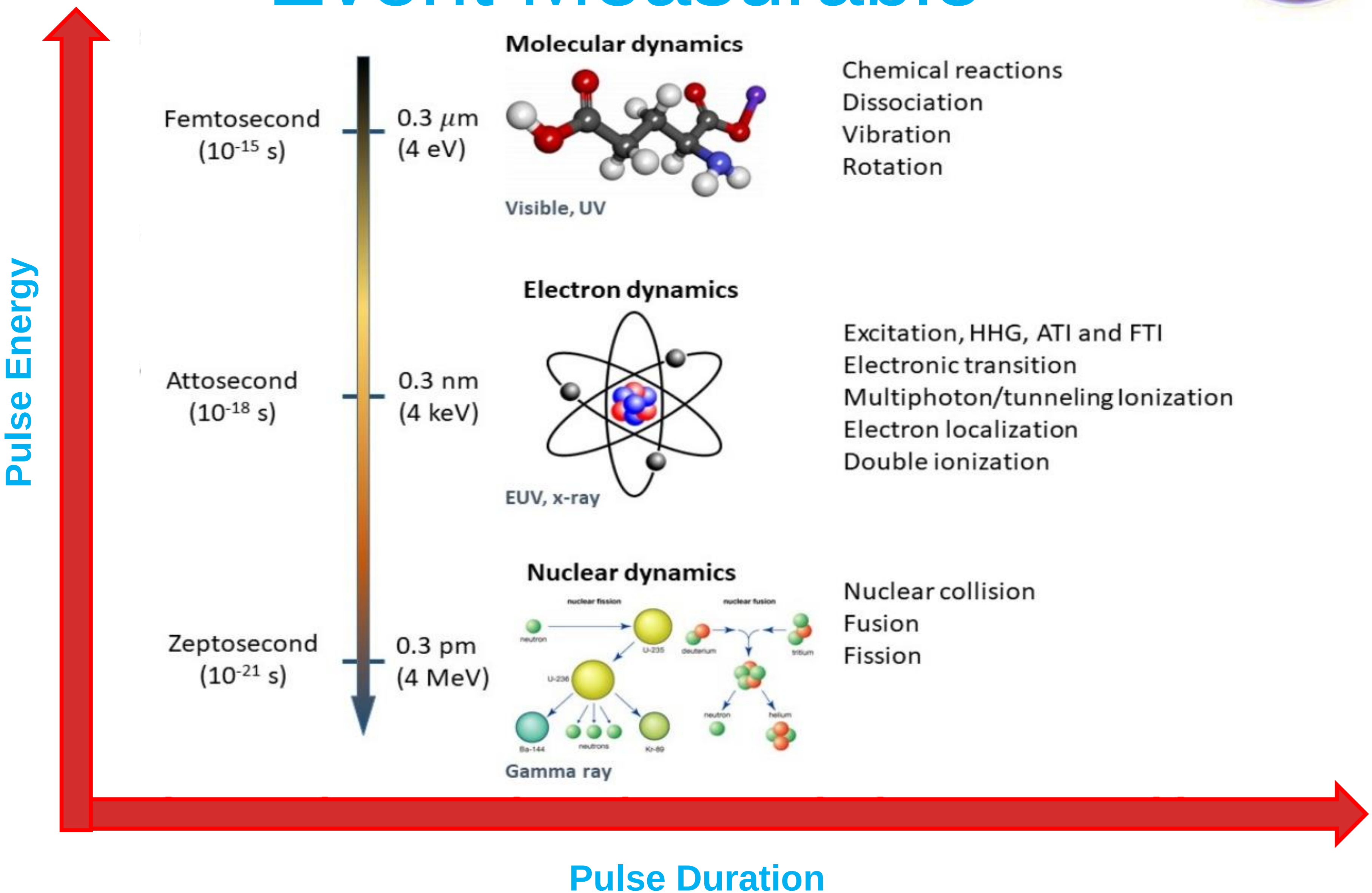
Agostini and his group developed a technique called Rabbit, or "reconstruction of attosecond beating by interference of two-photon transitions."- String of laser pulses lasted for 250 attoseconds

Krausz's group used a slightly different method known as streaking to produce and study individual bursts, each lasting 650 attoseconds.

L'Huillier and her colleagues bested them both with a laser pulse lasting just 170 attoseconds.



Light Makes Even the Shortest Event Measurable



Attosecond Applications

Attosecond science

1st era

High-harmonic generation (HHG)

Exploration of how atoms and molecules ionize in intense laser fields.

2nd era

Understanding laser-driven attosecond dynamics in HHG and quantum systems

Tabletop X-ray laser from the EUV to the keV; sculpting the HHG spin (polarization) and orbital angular momentum

3rd era

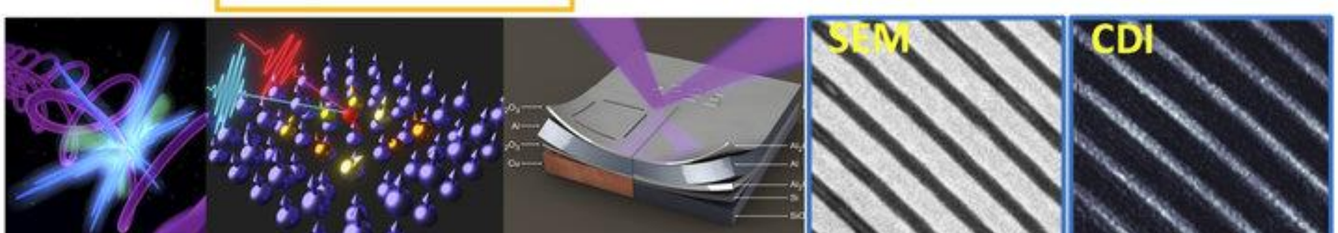
Capturing intrinsic attosecond timescale dynamics in materials

Probing electron-electron scattering and screening in materials; capturing coupled charge, spin, phonon, and photon physics.

4th era

Broad impact in imaging and characterization

Imaging with attosecond time resolution and nanometer spatial resolution. Applications in nanotechnology, nanoelectronics, and future biomedical applications.



Light science | Magnetics/ARPES | Metrology | Imaging

Books for Study:

1. **K.R. Nambiar**, Lasers: *Principles, Types and Applications* (New Age Inter-national Publishers Ltd, New Delhi, 2014).
2. **B.B. Laud**, *Lasers and Nonlinear Optics,* 3rd Edn. (New Age International Pvt. Ltd., New Delhi, 2011).
3. **Ralf Menzel**, *Photonics* (Springer-Verlag Berlin Heidenberg, New York, 2007)

Books for Reference

1. **Richard L. Sutherland**, *Handbook of Nonlinear Optics*, (Marcel Decker Inc, New York, 2003)
2. **R.W. Boyd**, *Nonlinear Optics, 2nd* Edn. (Academic Press, New York, 2003)
3. **W.T. Silfvast**, *Laser Fundamentals* (Cambridge University Press, Cambridge, 2003)
4. **Y.R. Shen**, *The Principles of Nonlinear Optics*, (Wiley & Sons, New Jersey, 2003)