Laser Cooling of Positronium

For Prelims: AEgIS, **Positronium**, **European Organization for Nuclear Research (CERN)**, Gamma-ray laser**,** Laser Cooling, **Quantum Electrodynamics (QED)**, Atomic Nucleus

For Mains: Significance of AEgIS in formation of AntiHydrogen and measurement of earth's gravitational acceleration on AntiHydrogen.

Source: IE

Why in News?

The **AEgIS collaboration** has achieved a significant breakthrough by demonstrating the **laser cooling of** Positronium**.**

- The experiment was performed at the **European Organisation for Nuclear Research**, more popularly known as CERN, in Geneva.

What are the Key Highlights of the Study?

- **About AEgIS:**
  - Anti-hydrogen Experiment: Gravity, Interferometry, Spectroscopy (AEgIS) is a collaboration of physicists from a number of countries in Europe and from India.
  - In 2018, AEgIS became the **first in the world to demonstrate the pulsed production of antihydrogen atoms.**
- **Aim:**
  - This is an important precursor experiment to the formation of antiHydrogen and the measurement of Earth's gravitational acceleration on antihydrogen in the AEgIS experiment.
  - This scientific feat could open prospects to produce a gamma-ray **laser** that would eventually allow researchers to look inside the atomic nucleus and have applications beyond physics.
- **Positronium:**
  - Positronium, comprising a bound electron (e-) **(matter)** and positron (e+) **(matter)**, is a fundamental atomic system.
    - Electrons and positrons are leptons. They interact through electromagnetic and weak forces.
  - Since Positronium is only made up of electrons and positrons, and no usual nuclear matter, it has the unique **distinction of being a purely leptonic atom**.
    - Due to its very short life, it annihilates with a half life of **142 nano-seconds**. Its mass is **twice the electron mass.**
- **Cause of Choosing Laser Cooling as the Method:**
  - Positronium is the **lightest known particle system**, and it's extremely unstable. When produced in the clouds for experimental studies, positronium zips around at a huge range of velocities, making it really difficult to pin down.

    - One way to resolve this would be to **cool down the positronium** which would **slow its particles** so more accurate measurements of its properties could be taken.
- **Laser Cooling:**
    - It is a method of **temperature reduction** based on particles absorbing and emitting photons. If **laser light** is directed along the path of incoming particles, those particles will **absorb the photon, and re-emit** it in a random direction that changes its momentum and slows it down.
        - Scientists **first proposed** the method of laser cooling for positronium decades ago **in 1988.**
    - Experimentalists achieved laser cooling of **Positronium atoms,** reducing their temperature from **~380 Kelvin to ~170 Kelvin** using an alexandrite-based laser system.
- **Significance and Future Prospects:**
    - Laser cooling of Positronium opens avenues for spectroscopic comparisons necessary for **Quantum Electrodynamics (QED)** studies.
    - **High-precision measurements** of the properties and **gravitational behaviour of antimatter** could reveal new physics and provide insights into the matter-antimatter asymmetry.
    - The creation of a Bose-Einstein **condensate** of antimatter, proposed as a means to produce coherent **gamma-ray light,** holds promise for **fundamental** and **applied research**, including peering into the **atomic nucleus.**
        - In a **Bose-Einstein condensate, matter (or antimatter)** is in a coherent state analogous to photons in a laser beam, and individual atoms lose their independent identity. This allows many atoms to be stored in a small volume.

Conclusion

The AEgIS experiment's success in laser cooling Positronium marks a significant advancement in antimatter research at CERN. This achievement not only contributes to our understanding of fundamental physics but also holds potential for groundbreaking discoveries and applications in the future.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Q. The efforts to detect the existence of Higgs boson particle have become frequent news in the recent past. What is/are the importance of discovering this particle?

1. It will enable us to understand as to why elementary particles have mass.
2. It will enable us in the near future to develop the technology of transferring matter from one point to another without traversing the physical space between them.
3. It will enable us to create better fuels for nuclear fission.

Select the correct answer using the codes given below:

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (a)