

1. Rare Earth Magnets - Science & Technology

Breakthrough in rare-earth magnetism promises more efficient quantum technologies. Researchers at JNCASR have discovered a new form of "orbital-driven" ferromagnetism in Neodymium Nitride (NdN) thin films, challenging the traditional understanding that magnetism arises solely from electron spin. This breakthrough lays the foundation for Orbitronics, a new technology utilizing electron orbital momentum to create faster, more energy-efficient quantum and memory devices.

1. The Breakthrough Overview

Institution - Researchers at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) have achieved a significant milestone in material science.

Material Studied - The research focused on Neodymium Nitride (NdN), specifically in the form of single-crystal thin films.

The Discovery - They identified a new form of magnetism known as "Orbital-Driven Magnetism."

Key Deviation - Unlike traditional magnetism, which is governed by electron spin, this new form is driven by the electron's orbital angular momentum

2. Core Concepts & Mechanism

A. Rare-Earth Magnetism

Definition - This refers to magnetic properties exhibited by elements in the lanthanide series (Rare-earth elements).

Key Elements - Includes Neodymium (Nd), Samarium (Sm), and Dysprosium (Dy).

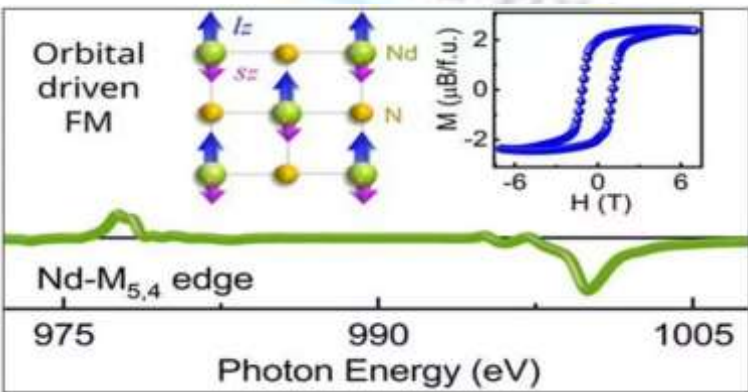
Utility - These elements are critical for manufacturing high-strength permanent magnets essential for modern machinery.

Feature	Traditional Spin-Based Magnetism	Orbital-Driven Magnetism (New Discovery)
Primary Driver	Electron Spin - The intrinsic angular momentum of the electron itself.	Orbital Angular Momentum - The motion of the electron orbiting the nucleus.
Theoretical Basis	Standard Condensed Matter Physics models.	Represents a paradigm shift from conventional theories.
Dominant Context	Most common magnetic materials (Iron, Cobalt, Nickel).	Observed in specific Rare-earth materials like NdN thin films .
Technological Goal	Spintronics - Uses electron spin for data storage	Orbitronics - Uses orbital motion for higher efficiency.

B. The Paradigm Shift - Spin vs. Orbital Magnetism

Traditional View - Conventional theories attribute magnetism primarily to the "spin" of electrons within atoms.

New Observation in NdN - In Neodymium Nitride, the ferromagnetism is not driven by spin, but by the orbital motion of the electron around the nucleus.



3. The Emerging Field - Orbitronics

The study of this new magnetism has opened doors to Orbitronics, an advanced evolution of spintronics.

Definition - A field of technology that exploits the orbital angular momentum of electrons—in addition to their spin—to store, process, and manipulate information.

Advantages over Classical/Spintronic Systems -

Energy Efficiency - Lower power consumption for operations.

Capacity - Higher data storage potential.

Speed - Faster processing capabilities compared to current silicon-based electronics.

Key Applications of Orbitronics

Quantum Computing – Development of Qubits (Quantum bits) that utilize both spin and orbital degrees of freedom for complex calculations.

Data Storage – Revolutionizing hard drives and memory devices to be more compact (miniaturized) and faster.

Magnetic Devices – Creation of highly efficient magnetic sensors and next-gen memory architectures.

4. Subject Profile – Neodymium (Nd)

General Characteristics

Identity – A chemical element in the lanthanide series with the symbol Nd and Atomic Number 60.

Appearance – A rare-earth metal that is silvery-white, soft, and malleable.

Thermal Property – Possesses a high melting point of approximately 1,024°C.

Occurrence & Extraction

Source – Found in minerals such as Monazite and Bastnäsite.

Isolation – Rarely found in its pure form in nature; it is usually extracted alongside other rare-earth elements through mining.

Applications of Neodymium

High-Performance Magnets (NdFeB) – Neodymium-Iron-Boron magnets are the strongest commercially available permanent magnets.

Usage – Electric motors, wind turbines, hard drives, and clean energy tech like Electric Vehicles (EVs).

Laser Technology – Used in Neodymium-doped lasers (Nd -YAG).

Usage – Medical treatments (eye surgery, skin treatments), material processing (cutting/welding), and defense systems.

5. Implications for Future Technology

The discovery at JNCASR has profound implications for the future of electronics and quantum mechanics –

Designing Orbitronic Materials – Scientists can now focus on engineering materials specifically designed to have strong orbital contributions, which is the prerequisite for orbitronic devices.

Overcoming Limits – By tuning both spin and orbital moments, technology can surpass the physical limitations of current spin-based information technologies.

Green Technology – The push towards "Green IT" is supported by orbitronics, as it promises devices that are significantly more energy-efficient, reducing the carbon footprint of data centers and supercomputers.

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