Italian Researchers Unveil Light-Powered Nanomotor with Reversible Motion

A team at the University of Bologna develops the world's first molecular motor that changes rotation direction by altering light color

Researchers at the University of Bologna have developed the first Italian-made rotating nanomotor and the only one in the world capable of reversing its direction of rotation simply by changing the color of light that powers it.

The breakthrough molecular motor – named **ROAR (Reversible Optically Activated Rotary motor)** – has been designed, built, and experimentally validated by a multidisciplinary research team at the University of Bologna. The study has been published in *Nature Chemistry*.

Measuring just billionths of a meter, ROAR is powered entirely by light and represents a significant advance in the rapidly evolving field of artificial molecular machines. Unlike previous light-driven nanomotors, which rotate in only one fixed direction, ROAR can switch between clockwise and counterclockwise motion by tuning the wavelength of the incoming light.

"This ability to reverse motion using light alone is unprecedented," said **Massimiliano Curcio**, researcher at the University of Bologna's Department of Industrial Chemistry and co-coordinator of the study. "It allows us to control movement at the molecular level with a level of precision previously seen only in biological systems."

How ROAR works

ROAR is a synthetically accessible molecule that initially adopts a linear shape. When exposed to light, it changes its structure, bending its rotating segment toward a stationary unit. Under continuous illumination, the molecule cycles through three distinct shapes—linear, left-bent, and right-bent – via a sequence of coordinated molecular motions that together generate directional rotation in space.

"This rotation can be compared to a dancer performing a pirouette," explained **Massimo Baroncini**, professor at the University of Bologna and co-coordinator of the research. "A series of vertical and horizontal molecular movements ultimately results in a full, controlled rotation."

What sets ROAR apart is its **wavelength-dependent behavior**. When the color of the activating light changes, the direction of rotation reverses – a long-standing goal in molecular motor research.

"The most innovative feature of ROAR is its ability to switch rotation direction simply by changing the color of light," said **Luca Muccioli**, professor of

Industrial Chemistry at the University of Bologna. "This mechanism, common in living systems, has been sought for decades. We achieved it by exploiting how ROAR's bent molecular forms interact differently with light."

A platform for future technologies

The project is the result of a three-year collaboration between the **Center for Light Activated Nanostructures (CLAN)** – a joint research center of the University of Bologna and Italy's National Research Council (CNR), directed by Professor Alberto Credi – and the University's Computational Chemistry C2χ group, coordinated by Professor Marco Garavelli.

Artificial molecular motors are considered a key enabling technology for future applications, including **solar energy conversion and storage, smart materials, soft robotics, and targeted biomedical systems**. Because ROAR is light-powered, it offers advantages in terms of remote control, energy efficiency, and compatibility with biological environments.

The researchers are now working on next-generation versions of ROAR that operate using **visible and infrared light**, wavelengths that are abundant in sunlight and safer for biological applications.

"In the long term, our goal is to integrate these molecular motors into advanced functional systems," the researchers said, "from adaptive materials to light-controlled biomedical devices."

The study, titled **"Wavelength-steered directional rotation in an autonomous light-driven molecular motor,"** appears in *Nature Chemistry*. All authors are affiliated with the University of Bologna.