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Анотація

В статті розглядається розробка китайського «штучного сонця» наступного покоління, знаменуючи собою ще один крок до використання керованого ядерного синтезу.

Ключові слова: штучне сонце, Токамак, спалювання плазми, термоядерний синтез.

Abstract

The article examines the development of China's next-generation "artificial sun", marking another step toward the use of controlled nuclear fusion.

Keywords: artificial sun, Tokamak, plasma combustion, thermonuclear fusion.

Introduction

The pursuit of controlled nuclear fusion – replicating the energy-generating process of the Sun – has long been a cornerstone of global energy research. In this context, China's recent advancements with the Huanliu-3 (HL-3) tokamak reactor represent a significant leap forward. By achieving extreme plasma conditions and integrating cutting-edge diagnostic and heating technologies, the HL-3 project not only strengthens China's position in fusion science but also brings the world closer to realizing a clean, virtually limitless energy source. This article explores the key milestones, innovations, and future directions of the HL-3 reactor within the broader landscape of nuclear fusion development.

China has announced a milestone in the development of its next-generation "artificial sun", marking another step towards harnessing controlled nuclear fusion.

For the first time, the Huanliu-3 (HL-3) tokamak reactor in Chengdu has achieved a plasma state with ion temperatures of 117 million degrees Celsius and electron temperatures of 160 million degrees, edging closer to the extreme conditions required to ignite fusion – the same process that powers the Sun, according to researchers.

Dual 100 million degrees' milestone

"Our experiment has achieved the 'dual 100 million degrees' milestone, along with a significant overall performance improvement, marking the entry of China's nuclear fusion research into the burning plasma experiment stage," said Zhong Wulü, chief designer of China Circulation-3 at CNNC.

"Our self-developed systems for heating, control, and diagnostics were put into operation for the first time, with technical indicators reaching a world-leading level and setting multiple new records in China's nuclear fusion research."

Previously, the HL-3 has made innovative exploration of core energy confinement approaches, successfully suppressed the instability of core magnet fluid that hinders the increase of atomic nucleus temperature, and overcame key challenges in current and density profile control.

It was the first time for China to achieve repetitive discharges with the atomic nucleus temperature exceeding 100 million degrees Celsius, confirming the country's leading position in fusion technology.

HL-3 is equipped with core technologies

The HL-3 is equipped with core technologies like compact Thomson scattering ploychromators and the world's first set of a triple grating precision spectrometer with twice the accuracy of international counterparts.

The CNNC underlined that the tokamak systematically overcame key technical barriers in fusion diagnostics such as high spatial-temporal resolution, strong resistance to radiation interference, and millisecond-level dynamic response. Some of these critical technologies have been added to the International Tokamak Physics Activity (ITPA) joint diagnostic experiment project.

Compared with the Experimental Advanced Superconducting Tokamak (EAST) in Hefei – China's other artificial sun known for long-duration plasma experiments – the HL-3 is larger, newer, entirely home-grown and designed not only for research but also to help realise a working fusion power plant, reported SCMP.

Two self-developed plasma heating systems

In addition, a prototype tri-band spectrometer system for ITER's charge-exchange recombination spectroscopy diagnostics has completed its initial technical validation on HL-3, demonstrating the capabilities for simultaneous ion temperature measurements and impurity monitoring, which will improve ITER measurement capabilities.

The HL-3 team has also successfully commissioned two self-developed plasma heating systems – a high-power electron cyclotron heating system and a 7 MW neutral beam injection system – during recent facility upgrades.

Reports have revealed that future HL-3 research priorities include increasing heating power capacity to pursue scenarios with higher fusion triple product and operation with a higher temperature wall to decrease recycling levels and, eventually, in-vessel tritium retention.

Machine-learning applications are also being integrated for real-time plasma shaping control, instability suppression, and disruption prediction – critical developments supporting the facility's transition to high-performance plasma operations to be followed by deuterium-tritium plasmas, as per reports.

Summary

China has achieved a major breakthrough in nuclear fusion research with the Huanliu-3 (HL-3) tokamak reactor, reaching plasma ion temperatures of 117 million °C and electron temperatures of 160 million °C – crossing the "dual 100 million degrees" threshold required for initiating fusion reactions. This milestone marks China's entry into the burning plasma experimentation phase and confirms its leadership in fusion technology. The HL-3, entirely self-developed and equipped with cutting-edge systems for heating, diagnostics, and control, has demonstrated significant improvements in energy confinement and plasma stability. Innovations include a precision triple grating spectrometer and advanced diagnostic tools now integrated into international collaboration projects such as the ITPA. Additionally, HL-3 has validated technologies for ITER, including charge-exchange spectroscopy and two proprietary plasma heating systems. Future research will focus on enhancing heating capacity, improving plasma-wall interactions, and integrating machine learning for real-time plasma management – advancing toward the ultimate goal of a sustainable fusion power plant.

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