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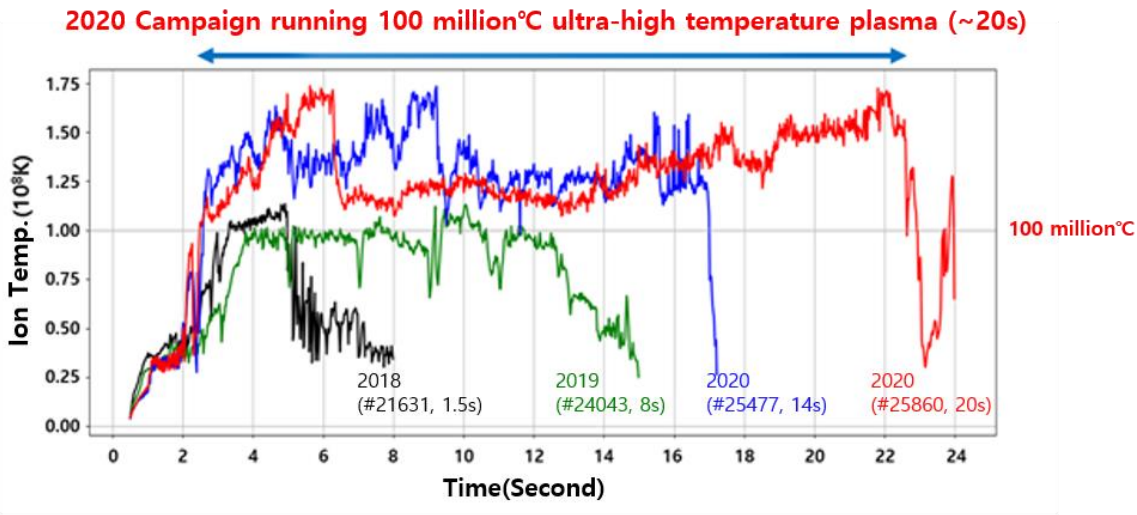
## Recent Research

# The Korean artificial sun KSTAR sets a new world record of 20-second-long operation at 100 million degrees

**- Aiming to operate continuously high-temperature plasma over 100 million degrees for 300 seconds by 2025**




The Korea Superconducting Tokamak Advanced Research (KSTAR), a superconducting fusion device also known as the Korean artificial sun set a new world record as it succeeded in maintaining high-temperature plasma for 20 seconds with an ion temperature exceeding 100 million degrees.

On November 24, the KSTAR Research Center at KFE announced that in joint research with Seoul National University (SNU) and Columbia University in the United States, it succeeded in the continuous operation of plasma for 20 seconds with an ion temperature higher than 100 million degrees, which is one of the core conditions of nuclear fusion in the 2020 KSTAR Plasma Campaign.

It is an achievement to extend the eight-second plasma operation time during the 2019 KSTAR Plasma Campaign by more than two times. In its 2018 experiment, KSTAR reached a plasma ion temperature of 100 million degrees for the first time (retention time: about 1.5 seconds).

Recreating the fusion reactions of the sun, given its ultra-high temperature and density, on earth requires heating and the maintenance of ion temperatures exceeding 100 million degrees after fueling a fusion device such as KSTAR and dividing nuclei into ions and electrons to create a plasma state.

Thus far, there have been other fusion devices that have briefly managed plasma at temperatures of 100 million degrees or higher. None of them broke the barrier of maintaining the operation for ten seconds or longer. This represented the operational limit of a normal conducting device,* and it was difficult to maintain a stable plasma state in the fusion device at such a high temperature for a long time.

* Limits of a normal conduction device: Unlike KSTAR, a fusion device that features a superconducting magnet, existing fusion devices based on normal conducting magnets such as copper magnets cannot be operated for an extended period of time because when a high electric current runs through the magnet to create a magnetic field that is strong enough to confine plasma, the magnet overheats due to its resistance.

In its 2020 experiment, KSTAR improved the performance of the internal transport barrier (ITB) mode, one of the next-generation plasma operation modes developed in 2019 and succeeded in maintaining the plasma state for a long period of time, overcoming the existing limits of the ultra-high-temperature plasma operation.

Director Si-Woo Yoon of the KSTAR Research Center at the KFE explained, "The technologies required for long operations of 100 million-degree plasma are the key to the realization of fusion energy, and KSTAR's success in maintaining high-temperature plasma for 20 seconds will be an important turning point in the race for securing the necessary technologies for long high-performance plasma operation, a critical component of a commercial nuclear fusion reactor in the future."

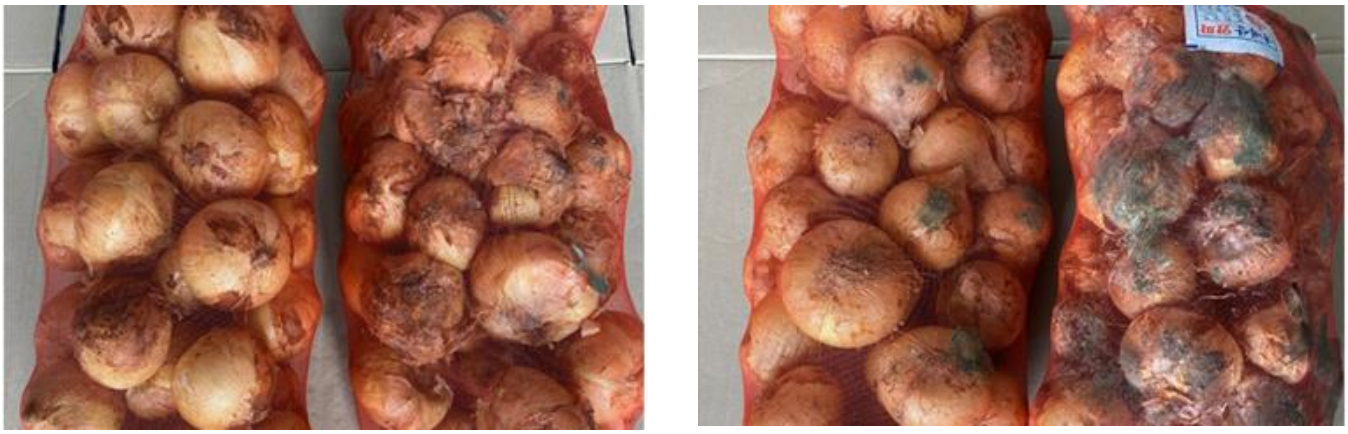
"The success of the KSTAR experiment in the long high-temperature operation by overcoming certain drawbacks of the ITB modes brings us a step closer to the development of technologies leading to the realization of nuclear fusion energy," added Yong-Su Na, a professor in the Department of Nuclear Engineering at SNU, who has been jointly conducting research on the KSTAR plasma operation.

KSTAR is going to share its key experiment outcomes in 2020, including this success, with fusion researchers around the world at the IAEA Fusion Energy Conference to be held in May of 2021.

The final goal of KSTAR is to succeed in continuous operation of 300 seconds with an ion temperature higher than 100 million degrees by 2025.

## Innovation comes with plasma - For the storage and distribution of agricultural produce

**- KFE's Institute of Plasma Technology has paved the way for a paradigm shift in the storage and distribution of agricultural produce with their "Plasma-Technology-Based Smart Storage System."**



**Organic Onion** **Regular Onion**

The "Plasma-Technology-Based Smart Storage System" has recorded excellent scores in germ and mycete tests prior to its deployment at farms. The picture on the left is of organic onions, while that on the right show regular onions. In each picture, only the onions on the left had plasma technology applied while stored for a month.

"Agriculture and ICT met to evolve into smart farms. Likewise, the crops grown on smart farms will meet with a smart storage system to accelerate agricultural innovation," explained Dr. Seong-Bong Kim, the Director of the Division of Plasma-Bio Convergence. Plasma technology, which has already made substantial contributions to state-of-the-art industries such as the semi-conductor and medical industries, can change the paradigm of produce storage as well. The plasma storage system is a smart storage system that integrates three key elemental technologies (micro-organism sterilization, aging suppression, and respiration suppression) and the storage environment factors of the temperature and humidity for proper control. It is an eco-friendly technology to hinder the respiration and aging of farm products and to sterilize micro-organisms by plasma technology without the use of chemicals.

Existing low-temperature storage applications focus on minimizing the respiration of produce by lowering the temperature, as animals in hibernation do so as to sustain life. However, the typical temperature of a low-temperature storehouse was around 5℃, which caused cold damage to the stored products. During sizzling summers, electricity bills were another burden, with some storehouses even shutting down due to the high bills resulting from high electricity demand during heat wave periods.

“Until recently, key factors at a low-temperature storehouse were to control the temperature and humidity. However, controlling only these two factors led to limits with regard to the ability to restrict decomposition by micro-organisms, aging and respiration, as there are fungi and germs propagating even at low temperatures. Also, ethylene is not removed,” said Director Kim.

Hence, plasma storage systems are attracting more attention given their ability to control factors such as aging and respiration. The repression of aging and respiration is an original technology novel to existing storage systems. Being the most intricate technique, plasma catalyst hybrid technology was completed to adsorb ethylene selectively, which is the main substance causing the maturation of produce, and to remove it by means of plasma. In addition, a smart automatic control system was developed to enable customized, independent module control depending on the crop by modulizing each function of sterilization, aging suppression and respiration suppression.

### - Aiming at operation recipe development based on demonstration data

“Korean fruits and vegetables are renowned overseas for their taste and quality. As the best condition differs from each product, we are planning to complete the optimal storage recipes which even take each product’s distribution stages into account through ceaseless demonstrations.”

Director Kim expects that the completion of recipes tailored for each type of produce will ensure competitive quality for both domestic and export markets.

In addition, another dream of creating a new agricultural distribution system is being realized by transferring related technologies to local companies. The performance has already been proved for the plasma storage system with demonstration tests that began in 2019. Commercialization is planned to begin in earnest from 2021, when additional demonstrations and module, equipment and system tests are to be completed.

The four plasma technology-based smart storage system testbeds located at the Institute of Plasma Technology, Gunsan

The MoU concluded on the 17th of July of 2020 among the Institute of Plasma Technology, and Jeollabuk-do Wanju-gun, and Jeonbuk Technopark was a milestone in relation to this plan. With the MoU, the three institutions will start joint research on plasma technology support and solutions, demonstrate and run a plasma-smart storage system in Wanju-gun, and cooperate closely in various fields such as smart agriculture policies and the organization of new projects. The Institute of Plasma Technology will extend trial projects nationwide based on Wanju-gun’s example after finishing the demonstrations.

## Issues & Focus

### KFE held opening ceremony

From the left, Professor Seung Jeong Noh(KFITA), Chief Commissioner Jeong-Won Lee (KFE Incorporation Commission), Dr. Gyung-Su Lee(Former president of NFRI), Congressman Sang-Min Lee, First Vice Minister Byung-Seon Jeong(MIST), President Suk Jae Yoo(KFE), Congressman Seung-Rae Jo, Congressman Yeung-Shik Kim, Acting Chairperson Sun-Hwa Hahn (NST), President Hyung-Shik Shin (KBSI)

KFE held a commencement ceremony on the 27th of December of 2020 to celebrate its new beginning as an independent research institution.

KFE began its research in January of 1996 as a project division of KBSI. After 20 years, in October of 2005, it was established as an affiliated research institute of KBSI, referred to as NFRI. Given the increasing need for a fusion-specialized research institution, an act in the Korean National Assembly was passed in April of 2020 to promote NFRI to KFE. Accordingly, KFE commenced as an independent institution on the 20th of November of 2020.

During the opening ceremony, only President Suk Jae Yoo and invited speakers attended in person according to the COVID19 quarantine policy. Attendants were the First Vice Minister Byung-Seon Jeong from MSIT; Congressman Sang-Min Lee of the Daejeon Yuseong District; Congressman Seung-Rae Jo and Congressman Yeung-Shik Kim from the Science, ICT, Broadcasting, and Communications Committee of the National Assembly; Acting Chairperson Sun-Hwa Hahn from the National Research Council of Science & Technology; Chief Commissioner Jeong-Won Lee of the KFE Incorporation Commission; President Hyung-Shik Shin of KBSI; Dr. Gyung-Su Lee who was the former president of NFRI; and Commissioner Seung Jeong Noh of KFITA. Others including KFE employees celebrated the opening through a YouTube live broadcast.

President Yoo commented through his opening speech, “We should be fully prepared for the vocation, for which what we do is not just mere research and development but will solve the energy problems of the future for good.” He also revealed the institutional vision “to shift the research focus from fundamental studies to core technologies for fusion energy demonstrations as well as to achieve innovations making use of the fourth industrial revolution to lay the foundation for a virtual fusion reactor.”

Vice Minister Jeong of MSIT added, “The hope of commercializing fusion energy was shown in a series of events from the completion of KSTAR in 2007 to the success of 2020 of the 20s operation at 100 million ℃. Twenty-five years have passed with the devotion of every scientist at KFE. Still, commercializing fusion energy to be delivered to us will take approximately another 35 years. There remains a path for us to go with a broader, further and longer perspective. Many say the carbon neutrality is achievable within the year 2050 if we realize our fusion plans. I would like to ask KFE to succeed in the demonstration so that fusion is more than just a possibility and will be the obvious alternative and to make an effort to communicate and unite with others despite beginning as an independent research institute.”

## KFE held 8th KO-CN JCM & 16th KO-JP JCM

The 8th Korea-China JCM and the 16th Korea-Japan JCM were held via video conferences due to COVID19, respectively, on the 7th-8th of December and on the 10th-11th of December. Government officials and renowned scholars gathered to discuss national policies related to fusion R&D and collaborations using KSTAR and devices in each country as well as collaborations for ITER.

In particular, at the KO-CN JCM, progress toward the HHLT ISO standard was shared, while the KO-JP JCM members discussed the impact of both countries' de-carbonization policies on fusion R&D directions.

Through the two JCMs, Korea recognized the importance of cooperation in area of fusion with China and Japan and agreed to implement remote collaborations proactively in 2021. With the end of the COVID-19 pandemic, the KO-CN JCM of 2021 will be held in China, while the KO-JP JCM will be held in Korea.