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Continuous cryogenic pellet fueling system for the W7-X stellarator

Toroidal magnetic fusion reactors such as ITER will be fueled by cryogenic deuterium-tritium pellets (15 K) accelerated to high velocity (200–1000 m/s) into the hot plasma. Over the last 40 years, Oak Ridge National Laboratory (ORNL) and its partners have developed the physics and technology of pellet fueling and demonstrated its use in large tokamak and stellarator plasma confinement experiments around the world.

These experiments used plasmas lasting some seconds, but power reactors will require continuous fueling. The next stage of pellet fueling experiments will be carried out using the Wendelstein 7-X (W7-X), a large (major radius = 5.5 m) stellarator device at the Max Planck Institute for Plasma Physics (IPP), in Greifswald, Germany. W7-X has superconducting magnetic coils and is designed to sustain high-performance plasmas for up to 30 minutes.

Exploratory experiments on W7-X in 2018 [1] showed that the injection of 50 2-mm H_2 pellets at a velocity of 200 m/s could sustain a high-density (peak ~ 10^{20} m^{-3}) plasma heated with 5 MW of microwave power with electrons and ions at temperatures ~ 3 keV for about a second. Physics analysis shows that these pellet-fueled plasmas have reduced turbulent transport, which improves the plasma energy confinement [2].

An international team is now constructing a continuous, high-speed pellet system to fuel W7-X plasmas in quasi steady-state conditions. The team includes researchers from ORNL, IPP, Princeton Plasma Physics Laboratory (PPPL) and the National Institute for Fusion Science (NIFS) in Japan.

The W7-X continuous pellet fueling system will inject 3-mm H_2 or D_2 pellets into W7-X at speeds of up to 1000 m/s with a repetition rate of up to 10 pellets/s. The pellet size and repetition rate will be controlled in real time to maintain optimum plasma profiles for confinement.

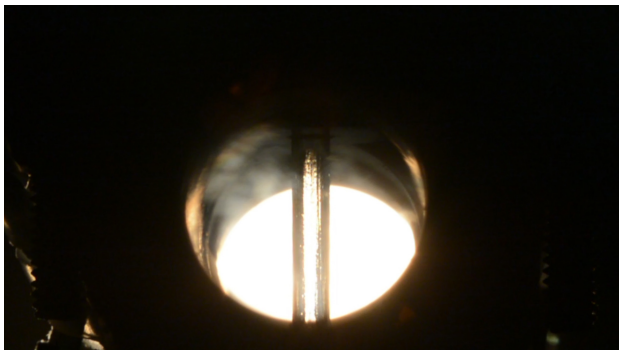

Fig. 1. Continuously extruded H_2 ribbon, 3-mm diameter.

The major challenge for the design of the pellet system was extrusion under screw pressure of a ribbon of solid hydrogen while maintaining a constant temperature of 15 K using cryocoolers for cooling (Fig. 1).

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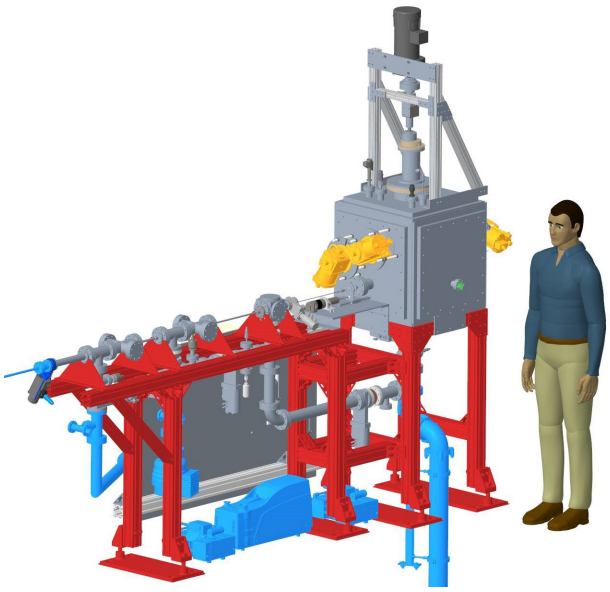

Fig. 2. Continuous pellet fueling system for W7-X.

The continuous pellet system is now being assembled at ORNL (see drawing in Fig. 2) and will be fully tested in autumn 2021 before shipment to Germany in early 2022 and integration into the W7-X facility in 2022, with plasma experiments starting late that year.

References

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[3] S. J. Meitner et al., IEEE Trans. Plasma Sci., **48**, 1585 (2019).

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FY2021 LHD Research Forum

The FY2021 Large Helical Device (LHD) Research Forum was held 12–16 July 2021 via Zoom. This forum is intended to allow proponents to present and discuss ideas for experiments to be conducted in the upcoming 23rd LHD experiment campaign, which will last from the middle of October 2021 until the middle of February 2022. Previously, meetings such as this forum have been held for each topical group. However, we determined to hold the LHD Research Forum for proponents and co-proponents because we believe that we can conduct experiments more efficiently and effectively if all the proponents and co-proponents know and understand all the experiment ideas. Because of the COVID-19 pandemic, the LHD Research Forum was held via Zoom.

For the upcoming campaign, 192 experiment idea proposals were submitted. Of these, 47 (about 1/4) were from overseas institutions. The topical groups have been renewed for the remaining two (23rd and 24th) LHD experiment campaigns. The areas addressed by the renewed topical groups are as follows: (1) multi-ion, (2) turbulence, (3) spectroscopy, and $4) instability. The breakdown of experiment idea proposals by topical group was as follows: 58 in the multi-ion plasma topical group, 39 in the turbulence topical group, 41 in the spectroscopy topical group, and 54 in the instability topical group. Almost all proposals require experiment time allocation in the 23rd experiment campaign, and thus those needed to be explained and discussed in the forum. The experiment idea proposals were submitted by 111 proponents, 40 of whom (about 1/3 of the total) are affiliated with overseas institutions. The number of the experiment idea proposals from overseas is significantly higher than the previous campaign. In total, 111 proponents and 187 co-proponents participated in the LHD Research Forum.

In consideration of the time differences, the first morning sessions of the forum were scheduled to accommodate proponents in the US, and the late afternoon sessions of the forum were scheduled to accommodate proponents in the EU. Typically, 8–9 experiment idea proposals were presented in each session. Sessions were typically attended by about 30–50 participants, who discussed experiment idea proposals explained by the proponents. All experiment idea proposals will be reviewed by the topical group leaders. The review will take into account each proposal's scientific quality and consistency with the research priorities of the 23rd LHD experiment campaign, based on the explanations and discussions at the LHD Research Forum and the content of the experiment idea proposals. The detailed program of the 23rd LHD experiment campaign will be announced to all the proponents and co-proponents around the beginning of September.

Finally, we would like to thank all the participants in the LHD Research Forum. Some EU and US colleagues joined the forum in the very early morning or very late night in their time zone. Especially, we would like to thank once again all those who made such a great effort to participate in the forum. We believe that the 23rd LHD experiment campaign will be the most fruitful experiment campaign based on the beneficial discussions in the LHD Research Forum.

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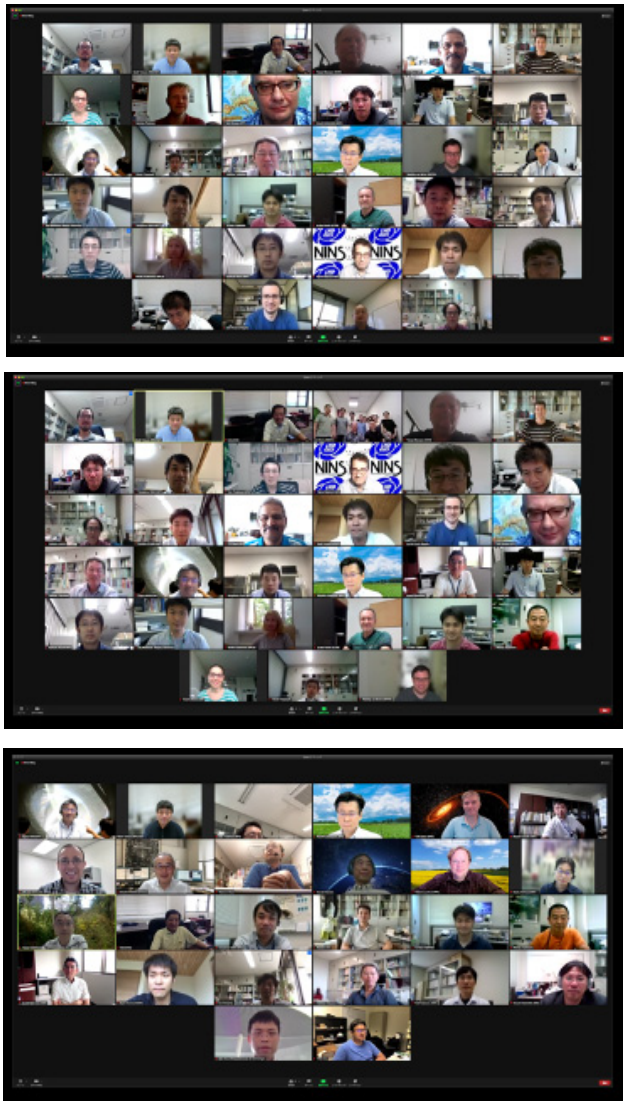

Fig.1. Screenshots (group photos) of participants of FY2021 LHD Research Forum on Zoom.