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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 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 on toroidal plasma confinement experiments around the world.

These experiments had plasmas lasting seconds, but fusion reactors will require continuous fueling. The next stage of pellet fueling experiments will be carried out using the Wendelstein 7-X (W7-X) stellarator facility (major radius = 5.5 m) at the Max Planck Institute for Plasma Physics in Greifswald, Germany. W7-X has superconducting magnetic coils and is designed to sustain plasmas for ~ 30 minutes. Exploratory experiments on W7-X in 2018 [1, 2] showed that injection of fifty, 2-mm H_2 pellets at velocities ~ 200 m/s could sustain high-density (peak ~ 10^{20} m^{-3}) plasmas heated with 5 MW of microwave power with electron and ion temperatures ~ 3 keV for about a second.

Over the last four years, a team of researchers from the United States (ORNL, PPPL), Germany (IPP), and Japan (NIFS) has developed a Continuous Pellet Fueling System (CPFS) for W7-X (Fig. 1). The CFPS will inject 3-mm H_2 or D_2 pellets into W7-X at speeds of ≤1000 m/s with a repetition rate of ≤10 Hz. The pellet size, speed, and repetition rate can be controlled in real time to maintain optimum plasma profiles. The major design challenge [3] was extrusion under screw pressure of a ribbon of solid hydrogen at a constant temperature of 15 K, maintained by cryocoolers.

In testing at ORNL, the CFPS achieved pellet repetition rates of up to 10 Hz for periods of 10 seconds (Fig. 2) and 4 Hz for periods of minutes (Fig. 3), which is sufficient to begin the 2022 long-pulse campaign on W7-X. Progressive improvements in repetition rate will be made onsite at IPP by the US team as plasma pulse lengths increase.

The CFPS is now physically installed at W7-X by IPP and ORNL staff. Integration into the W7-X operational control system will continue in August–September 2022. Experimental commissioning of the entire W7-X facility will take place over the subsequent months, with the physics research campaign beginning in November 2022.

The CPFS also serves as a prototype for ORNL development of pellet fueling for ITER, which will required even higher fueling rates.

In this issue . . .

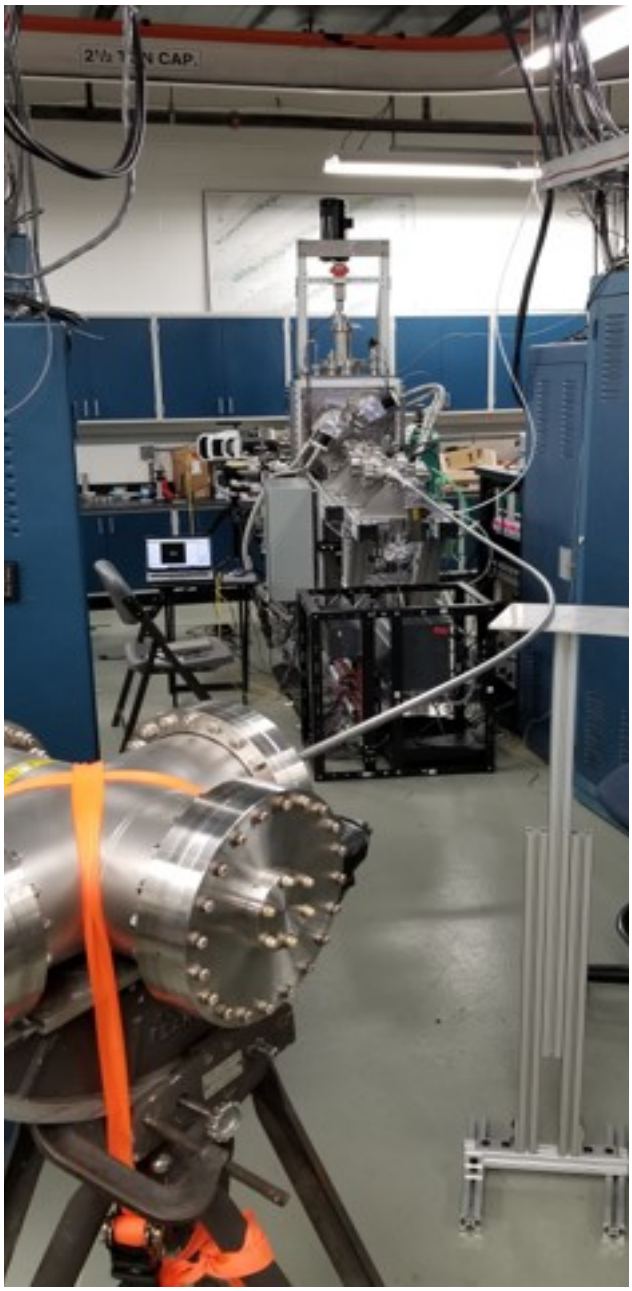

Fig 1. CFPS during testing at ORNL

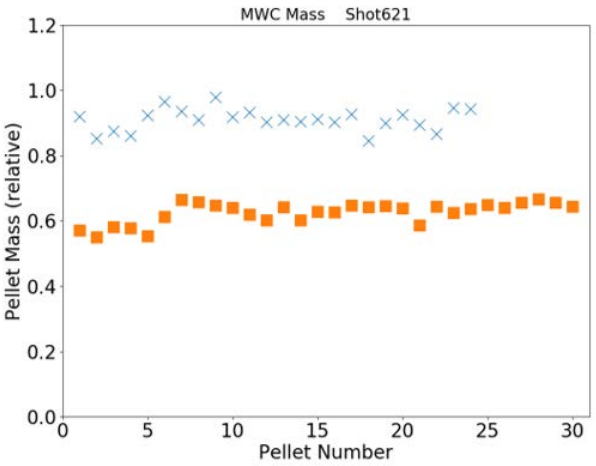

Fig. 2. Short-pulse, high-repetition rate Testing of the 3 mm diameter H_2 pellets was demonstrated using the 2.7-mm (length) nozzle.Blue: 8 Hz for 3 s. Orange: 10 Hz using the pellet sizer to reduce the size.

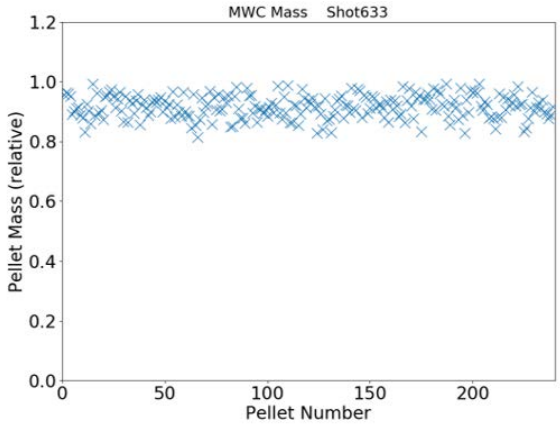

Fig. 3. Masses of 3-mm pellets with the 2.7-mm nozzle (length) opening for 1 minute of pellet production at 4 Hz. Limited only by the data system duration capability.

References

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FY2022 LHD Research Forum

The FY2022 Large Helical Device (LHD) Research Forum was held 11–15 July 2022 via Zoom. The LHD Research Forum was organized with the idea that proponents and co-proponents can conduct experiments at LHD more efficiently and effectively if they know and understand all the submitted experiment ideas. We are pleased to have received experiment proposals from Japan, Asia, Europe, and the United States. Usually, creating opportunities for people from different time zones to come together is challenging. Still, due to the change in lifestyle brought about by the COVID pandemic, we now know of a helpful tool, Zoom, for such a meeting. So, once again, the LHD Research Forum was opened via Zoom.

For the 24th LHD experiment campaign, we received 209 proposals form 102 participants. Information on these proposals is presented in Table 1.

Table 1. Experiment Proposals for the 24th LHD experimental campaign

	FY2022	FY2021
Total proposals	209	192
Proposals from overseas	52	47
Proposals by topical group		
TG1, Multi-ion plasma	58	58
TG2, Turbulence	47	39
TG3, Spectroscopy	36	41
TG4, Instability	68	54
Proponents	102	111
Proponents from overseas	32	40

We note that about 1/4 of the total proposals were from overseas as was the case in the previous campaign. While the number of proposals is higher than in the previous campaign, we also observe a significant increase in proposals for the Instability topical group (TG4) but a decrease for those for the Spectroscopy topical group (TG3). Compared to the last campaign, the number of experimental proposals decreased. One possible reason for this may be that the operational phase OP2.1 of W7-X in Germany is scheduled at about the same time as the LHD campaign. However, since more than half of the overseas experimental proposals came from Europe, other reasons may be possible.

More than 90% of the proposals required an experimental time allocation during the 24th experiment campaign, which was explained and discussed in the LHD Research Forum. The proponents defended the experimental proposals. As in the previous forum, considering the time difference, the forum's morning session was set up primarily for US proponents, while the late afternoon session was mainly for EU proponents. There were always 20–40 participants in each session to discuss the experiment ideas described by the proponents. Topical group leaders will review all experiment idea proposals. The review will consider each proposal's consistency with the research priorities of the 24th LHD experiment campaign (considering that it is the final deuterium campaign) and the scientific quality, based on the explanations and discussions at the LHD Research Forum, the experimental proposals, and presentations.

I regret to inform you that, because of the financial constraints arising from drastic increases in fuel cost and the depreciation of the yen, the 24th LHD experiment campaign period will be shortened by nearly two months. The 24th LHD experiment campaign will be started at the end of September 2022 and will be finished by the end of December 2022, NOT by the beginning of February 2023. Therefore, the experiment period allowing use of deuterium will be from the end of September 2022 until the beginning of December 2022. I would highly appreciate it if I could get your understanding that the number of proposals is high and the number of shots requested is more than can be accommodated; thus, compromises will have to be made. The detailed program of the 24th LHD experiment campaign will be announced to all proponents and co-proponents around the end of August.

Once again, we would like to thank everyone who participated in the LHD Research Forum. Unfortunately, as described above, the 24th LHD experiment campaign period will be shorter than previous campaigns. Still, we expect that it will be the most fruitful experimental campaign based on the productive discussions at the LHD Research Forum.

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Fig. 1. Screenshots (Group photos) of participants of FY2022 LHD Research Forum on Zoom.