Wendelstein 7-X

NEWSLETTER

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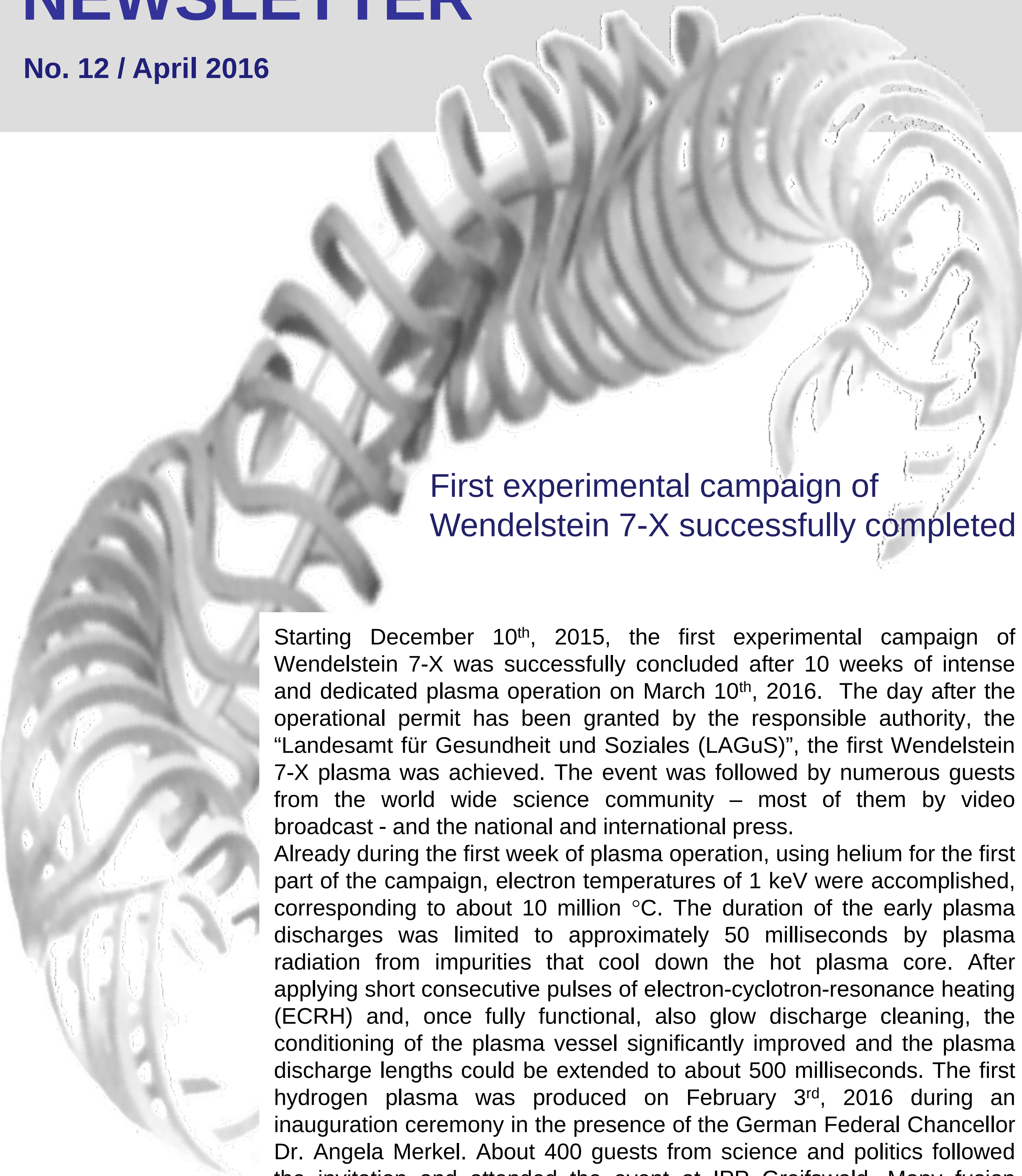
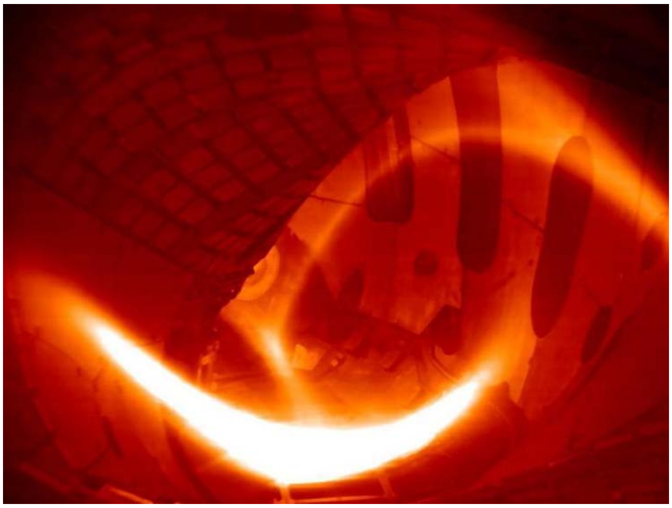


First experimental campaign of Wendelstein 7-X successfully completed

Starting December 10th, 2015, the first experimental campaign of Wendelstein 7-X was successfully concluded after 10 weeks of intense and dedicated plasma operation on March 10th, 2016. The day after the operational permit has been granted by the responsible authority, the “Landesamt für Gesundheit und Soziales (LAGuS)”, the first Wendelstein 7-X plasma was achieved. The event was followed by numerous guests from the world wide science community – most of them by video broadcast - and the national and international press.

Already during the first week of plasma operation, using helium for the first part of the campaign, electron temperatures of 1 keV were accomplished, corresponding to about 10 million °C. The duration of the early plasma discharges was limited to approximately 50 milliseconds by plasma radiation from impurities that cool down the hot plasma core. After applying short consecutive pulses of electron-cyclotron-resonance heating (ECRH) and, once fully functional, also glow discharge cleaning, the conditioning of the plasma vessel significantly improved and the plasma discharge lengths could be extended to about 500 milliseconds. The first hydrogen plasma was produced on February 3rd, 2016 during an inauguration ceremony in the presence of the German Federal Chancellor Dr. Angela Merkel. About 400 guests from science and politics followed the invitation and attended the event at IPP Greifswald. Many fusion researchers and the interested public around the world could participate by following the video life stream.

Since these first discharges, an intense experimental programme was conducted until March 10th. There was steady progress and finally plasmas lasting up to 6 seconds could be achieved at 600 kW ECRH power. The initial limit for the energy injected into the plasma was doubled from 2 MJ to 4 MJ, after it became evident that the plasma limiters, which define the plasma boundary, were far from reaching critical temperatures. Plasmas with the highest densities and temperatures were achieved at 4 MW heating power applied for up to one second. At line-averaged electron densities of about 2×10^{19} m^{-3} the central temperatures reached 10 keV (~100 million °C) for the electrons and 1 keV (~10 million °C) for the ions. At slightly higher densities close to 3×10^{19} m^{-3}, electron and ion temperatures of about 7 keV and 2 keV, respectively, were achieved.

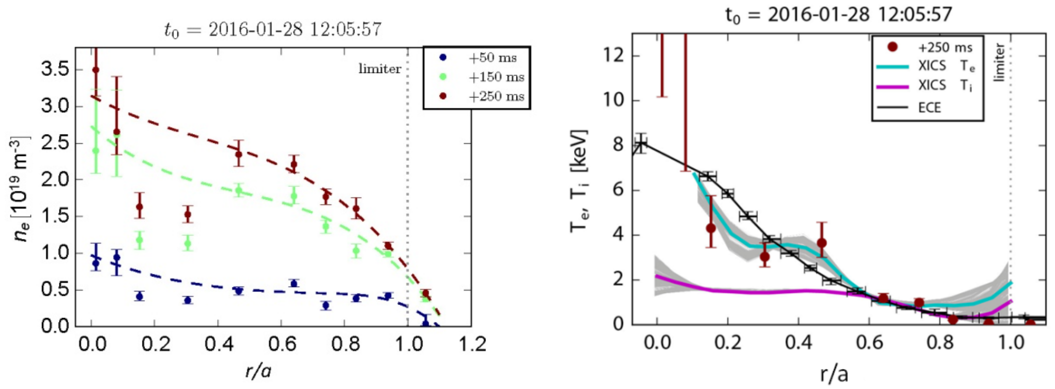


Video image of the first hydrogen plasma. The image shows a tangential view into the plasma vessel with wall structures and port openings (providing diagnostics access). The visible light emission from the plasma forms a three-dimensional torus, emitting at the edge (the hot plasma core does not emit large amounts of visible light). The interface between the confined plasma and the boundary plasma is visible by the transition from low light levels to the strongly light emitting regions (courtesy of IPP in collaboration with Wigner RCP, Hungary)

The success of the first experimental campaign exceeded our initial expectations. Originally, the aim was to perform an integral commissioning of the Wendelstein 7-X plasma operation, including ECRH and the first set of plasma diagnostics (more than 20). However, swift progress enabled many in-depth physics studies. Not least, this was made possible by the extremely reliable operation and interplay between the various technical systems of Wendelstein 7-X, in particular the cryoplant, the superconducting magnet system, the device control, and the micro-wave tubes of the ECRH system.

Overall 940 discharge programmes were performed. 92 of them were technical tests, 446 were dedicated to the development of the basic plasma performance (e.g. plasma-vessel conditioning), and 402 were dedicated to physics studies. This allowed for a first assessment of the confinement properties of the Wendelstein 7-X magnetic field configuration, the investigation of transport at the plasma boundary, the influence of external error fields (produced by the so-called trim coils) on the heat load distribution on the plasma limiters, first electron-cyclotron current drive experiments, and 2nd harmonic O-mode heating, which is important for heating the plasma at high densities.

There was a strong participation by our international partners, and more than half of the physics programme involved collaborations: In about 40% of the physics experiments, proposals were conducted in the frame of European collaborations and in 24% with partners from the US. The largest part of the experiments, however, involved all parties which can be seen as a successful implementation of the one-team-approach.



Radial profiles of electron densities (left) and plasma temperatures (right) of a helium plasma heated by 4 MW of ECRH. The electron temperature and density can be obtained from scattering of laser light on the plasma electrons (Thomson scattering). Electron cyclotron emission (ECE) measures the electron temperature. From imaging X-ray spectroscopy (XICS) profiles of electron and ion temperatures can be inferred (courtesy of S. Bozhenkov, G. Fuchert, M. Hirsch, A. Langenberg, N. Pablant and E. Pasch)

After the completion of the first experimental phase, the focus is now on the careful analysis of the data. The measured data have to be validated, which often means that diagnostic calibrations have to be repeated. Numerical codes not only support the evaluation of the experimental results but allow for a first comparison with theoretical predictions.

The preparations for the next experimental campaign have already started. The plasma vessel has been vented and many peripheral systems have been removed to gain access to the plasma vessel. During the next 14 months, the so-called test divertor unit (TDU) will be installed. It is an inertially cooled island divertor with exactly the shape of the water cooled steady-state high heat flux divertor, which is currently manufactured and is planned to be installed after the next experimental campaign. With the inertially cooled TDU and the full coverage of heat shields and baffles with carbon tiles, Wendelstein 7-X will be ready for high power plasmas (8 MW) lasting up to 10 seconds. This campaign is scheduled to start in the first half of 2017.

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