

IPP



Analysis of plasma dynamics in the island divertor of W7-X

HEPP Progress Talk 05.05.2025

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framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion), Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them

Scrape-off layer of Wendelstein 7-X





- Complex 3D shape
- Five fold symmetry
- Core plasma surrounded by five magnetic islands
- The islands are intersected by divertor plates which form the island divertor



Transport in the island divertor





Transport in the island divertor





Understanding of profiles and transport in island divertor is critical:

- gives boundary for core plasma
- determines particle and energy exhaust
- determines wall loads

Turbulence and instabilities are key factors:

- drive perpendicular transport
- very efficient due to long connection length

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Passive and active spectroscopy





Active line ratio spectroscopy





State population density from collisional radiative models (CRMs) dependent on

- electron density n_e (I_{667nm}/I_{728nm})
- electron temperature $T_e(I_{728nm}/I_{706nm})$

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Thermal helium beam diagnostic at W7-X





Fast thermal helium beam diagnostic





- Use in vessel components and LOS of the existing helium beam system
- Existing system: **spectrometer**
 - 40 Hz time resolution
- New: polychromator system
 - 32 channels
 - 1 MHz time resolution (25000 faster)
 - 10 kHz $T_{\rm e}$ and $n_{\rm e}$ reconstruction (250 faster)
 - First volumetric divertor diagnostic with high temporal resolution

Validation of fast system



Standard puff rate:

- HGW: $5 * 10^{18} 1/s$
- Garching: 2 * 10¹⁹ 1/s

Fiber core diameter:

- HGW: 160 μm
- Garching: 400 µm
- \rightarrow Factor of about 25 lower intensity
- → Desired puff for polychromator system: 5 * 10¹⁹ 1/s



Validation of fast system

Standard puff rate:

- HGW: $5 * 10^{18} 1/s$
- Garching: 2 * 10¹⁹ 1/s

Fiber core diameter:

- HGW: 160 μm
- Garching: 400 μm
- \rightarrow Factor of about 25 lower intensity
- → Desired puff for polychromator system: 5 * 10¹⁹ 1/s
- \rightarrow Desired puff is not perturbing the plasma globally or locally





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2D-profiles





Fast profile analysis: n_e and T_e modulation with 480 Hz



Mode averaging (preliminary)





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• Averaged over 39 cycles

20241127.044

Mode averaging (preliminary)





• Averaged over 39 cycles

Fast detachment analysis





MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK | S. HÖRMANN | 05.05.2025



Long range correlation of two divertors







Conclusion

New helium beam polychromator with 1 MHz time resolution at W7-X:

- Required gas puff does not perturb the plasma
- Fast 1D $T_{\rm e}$ and $n_{\rm e}$ reconstruction in the divertor
- Measurement of $T_{\rm e}$ and $n_{\rm e}$ mode and burst propagation
- Investigation of fast detachment process and burn-through
- Long-range correlation measurements and determination of toroidal propagation and wavenumbers

Similar measurements are being conducted at ASDEX Upgrade





