Experimental Results from the WEGA Stellarator

M. Otte[1], D. Andruczyk[1], A. Komarov[2], A. Kozachek[2], L. Krupnik[2], H.P. Laqua[1], O. Lischtschenko[1], S. Marsen[1], Y.Y. Podoba[1], M. Schubert[1], F. Wagner[1], G.B. Warr[1] and A. Zhezhera[2]

[1] *Max-Planck-Institut für Plasmaphysik, Euratom Association, Wendelsteinstr. 1, 17491 Greifswald, Germany*

[2] *NSC Kharkov Institute for Physics and Technology, Academicheskaya 1, Kharkov 61108, Ukraine*

Introduction

WEGA is a medium sized classical stellarator using a l=2, m=5 configuration operating at the Greifswald branch of the IPP in a modernized version since 2001 [1]. The machine is mainly used for educational training, testing of new diagnostics and for basic research in plasma physics. WEGA has a very flexible magnetic configuration due to additional vertical field and compensation coils. For plasma generating and heating two microwave heating systems operating at a frequency of 2.45GHz (26kW cw) and 28GHz (10kW cw) respectively are available. Further details are presented on poster P1.54 at this conference. Furthermore, the new and complex segment orientated control system including the data acquisition for Wendelstein 7-X will be installed and tested at WEGA.

ECR Heating with 28GHz microwave system

Up to now the plasmas were exclusively generated by a microwave heating system operating at 2.45GHz. Although we could demonstrate over-dense plasmas by applying a mode conversion process from **O**rdinary to e**X**traordinary and subsequently to electrostatic **B**ernstein-waves (OXB) with a plasma density of $n_e > 10 \times n_{e,cutoff} = 7.5 \times 10^{16}\,m^{-3}$ [2], the temperature is limited to about $T_e = 3–12$ eV for $B_0 = 0.06$T operation. The local deposition of the Bernstein waves could be

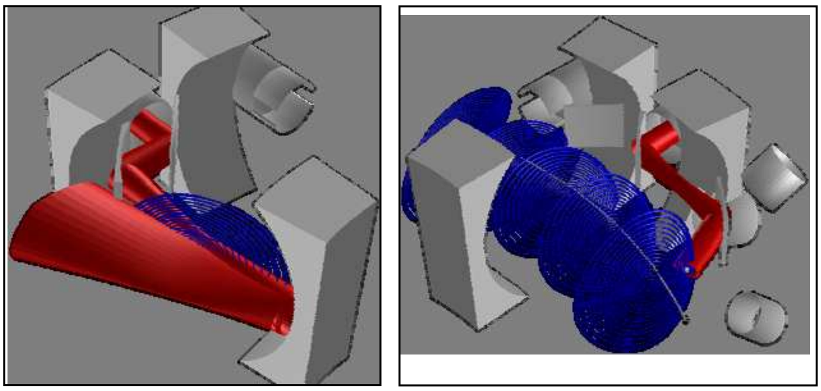

Fig. 1 *Setup for X2 (left) and OXB (right) heating scenarios with the 28GHz ECR heating system.*

measured by Langmuir probes during power modulation experiments with a modulation frequency of 12kHz which results in a timescale that is much smaller than the typical confinement time of about 1ms.

For B_0=0.5T operation a more efficient microwave new heating system was installed [4]. The microwave source is a 28GHz gyrotron with a power of P_{ECRH}=10kW cw and can be modulated with a frequency of 10kHz. The system was tested and calibrated calorimetrically. Two operation scenarios will be realized: heating via second harmonic X2 and OXB mode conversion. The X2 mode heating antenna, which is currently installed, focuses the beam in the plasma center and allows multiple reflections with the metallic plasma vessel. During initial results in Ar discharges centrally peaked plasma parameters could be measured with Langmuir probes. Furthermore off-axis heating could be realized as can be seen in Fig. 2 by changing slightly the resonant magnetic field strength. However, during H_2 discharges complete temperature profiles can no longer be determined by Langmuir probe measurements. For further details see also poster P1.54 at this conference.

Startup of a HIBP Diagnostic

In collaboration with the Institute for Plasma Physics in Kharkov/Ukraine a Heavy Ion Beam Probe (HIBP) diagnostic was setup (see Fig. 3) [5]. The diagnostic is optimized for operation at a magnetic field strength of B_0=0.5T and will be used during 28GHz ECR heating operation. The diagnostic principle is based on the difference of the Larmor radii of highly energetic ions with a different ionization state. In WEGA primary Na^+ ions with an energy of about 33keV are used as primary beam particles; the secondary Na^{++} beam is detected. Energy analysis of the secondary beam yields the electrostatic plasma potential inside the secondary ionization volume with an estimated spatial resolution of around 1.5cm. Radial profile scans can be obtained using an electrostatic deflection system to vary the injection angle of the primary beam. Due to the strong dependency of the secondary ionization cross section on the electron energy, the secondary signal intensity is very sensitive to the existence of supra-thermal electrons. The intrinsic

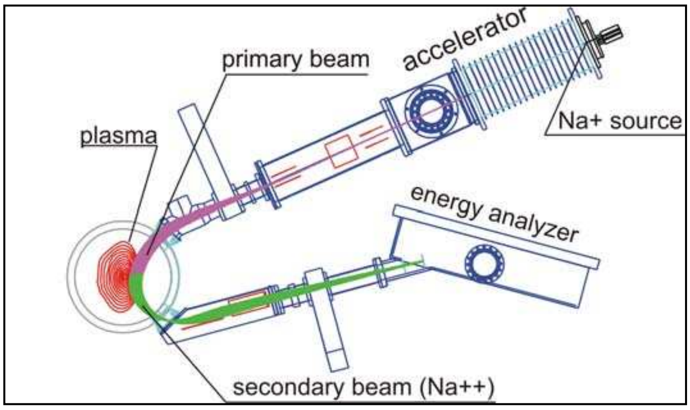

Fig. 3 *Setup of the Heavy Ion Beam Probe (HIBP) diagnostic at WEGA.*

temporal resolution is high enough to measure plasma parameters in experiments with modulated heating power. As a first result the plasma potential of V_{pl}=42V was obtained in a helium discharge which is comparable to results from Langmuir probe measurements.

Fluctuation measurements

Two probe systems installed at WEGA are used to study electrostatic fluctuations. They give insight into the spatio-temporal structure of fluctuations. A poloidal array of 13 probes is used to study the properties perpendicular to the magnetic field. An additional reference probe separated from the array by L_c=170cm in toroidal direction is used to study the three-dimensional structure of fluctuations. The existance of a direct connection length parallel to the magnetic field between the probe systems could be shown in field line tracing calculations and has been verified experimentally. Probes are stationary biased to measure I_{sat} and V_{fl} respectively. Looking at density fluctuations in frequency space, turbulent broadband spectra are obeserved with most power below some 10kHz. Depending on the discharge parameters additional coherent modes appear in the spectrum meaning a weaker developed turbulence. Based on the experience from comparable experiments [3], turbulence in WEGA is expected to be driven by the drift instability. Experiments at WEGA show several indications for drift waves. Radial profiles show the strongest fluctuation amplitude near the separatrix, where the pressure gradient is located. The cross-phase between density and potential fluctuations is found to be close to zero. The scaling of turbulent structures in dependence on the drift parameter ρ_s is studied by varying the ion mass and the magnetic field over a wide range. In wavenumber space more spectral power is shifted towards smaller scales with decreasing ρ_s. The three dimensional character of turbulence in WEGA could be shown in toroidally resolved measurements as can be seen in Fig. 4. As expected for drift waves the

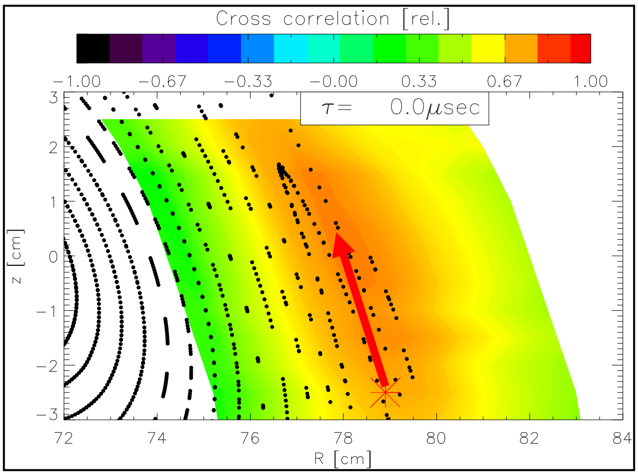

Fig. 4 *Cross correlation between reference probe (*) and data from probe array.*

parallel wavenumber is finite with $k_{||} << k_{\perp}$. The turbulent structures propagate in toroidal direction with $v_{||} \approx 200$km/s.

Prospect

In the near future it is planned to open a new field of operation with respect to the new heating scenarios of the 28GHz system which will also affects the diagnostics used so far:

- Flux surface measurements at B_0=0.5T with additional compensation coil
- Investigations of fluctuation and transport inside magnetic islands
- Measurements of plasma currents due to OXB plasma heating for 2.45 and 28GHz ECR heating scenarios
- Investigations of neo-classical transport and suprathermal electrons for X2 mode ECR heating at 28GHz
- Characterization of the 28GHz plasmas
- Installation of further diagnostics and tests (especially for W7-X)

Furthermore, the new segment orientated and steady state control system and data acquisition system of W7-X will enhance the possibilities for an integrated operation of WEGA.

References

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