Electron Bernstein Waves at the WEGA Stellarator - Heating and Emission

M. Otte, H.P. Laqua, E. Chlechowitz, M. Glaubitz, S. Marsen, Y. Podoba, T. Stange, F. Wagner, R. Wolf and D. Zhang

Max-Planck-Institut für Plasmaphysik, EURATOM Ass., Greifswald branch, Wendelsteinstr. 1, 17491 Greifswald, Germany

matthias.otte@ipp.mpg.de

The application of electron cyclotron resonance heating (ECRH) for high density and high beta operation in magnetically confined plasmas is limited due to reflections of the heating wave at the associated density cut-off that prohibits a propagation of the heating wave into the central plasma region. However, overdense operation in stellarators [1] and at high beta in spherical tokamaks beyond the density cut-off are of vital interest and can be achieved by an alternative heating concept utilizing electron Bernstein waves. It is based on the conversion of an incident electromagnetic wave into an electrostatic Bernstein wave (EBW) and not limited by an upper density limit.

Experiments based on EBW heating have been performed in helium and argon plasmas at WEGA. WEGA is a classical five period $l = 2$ stellarator with a very flexible magnetic configuration which allows quasi-steady state operation at 0.5 T for about 20 s. The EBWs have been generated with a 28 GHz ECRH system (10 kW cw) via a two-step conversion process at the plasma edge starting from second harmonic electromagnetic O- to X-waves and a subsequent conversion at the upper hybrid layer into EBWs. For the given conditions EBWs can only propagate inside the plasma above a density threshold (O-mode cut-off) of $n_e = 1 \times 10^{19}\,\mathrm{m}^{-3}$. The density threshold could be reached with the 28 GHz microwave heating system only and, alternatively, under more complex conditions by transient additional heating via the Ohmic transformer or by non-resonant 2.45 GHz magnetron ECH (26 kW cw). Once the density threshold has been reached, the additional heating sources could be switched off and the plasma heating was sustained by EBWs only. Angular scans of the launching antenna were additionally performed to optimize the mode conversion.

The density was determined by a single-channel 80 GHz interferometer measuring the central line averaged density and a Langmuir-probe installed on a fast reciprocating manipulator. While the typical radiation and electron temperature during second harmonic O- or X-mode heating are in the order of a few 10 eV only, a radiation temperature of up to more than 10 keV could be observed in the central region of the plasma by a 12-channel radiometer when reaching the OXB state [2]. The existence of a high energy electron tail could be confirmed by soft x-ray measurements obtained with a pulse height analyzer. A 12-channel bolometer also demonstrated a strong increase of the radiated power from the central plasma region during the OXB state. Furthermore, a sniffer probe, which measures the fraction of the non-absorbed 28 GHz stray radiation, showed a significant drop when reaching the threshold density indicating an improved absorption of the incident waves. It is assumed, that the observed central mean energy of 10 keV is due to a small fraction of super thermal electrons in the central region strongly coupled to the EBWs, while the bulk electrons remain at a temperature of a few 10 eV.

[1] H.P. Laqua et al., Phys. Rev. Lett. **78**, 18 (1997) 3467
[2] H.P. Laqua et al., 18th Topical Conference on RF Power in Plasmas, **I8** (2009)