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New 28 GHz Plasma ECR Heating System for the WEGA Stellarator

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Introduction

WEGA is a medium sized classical $l = 2$, $m = 5$ stellarator operating at IPP Greifswald since 2001 [1]. A 28 GHz Electron Cyclotron Resonance Heating (ECRH) System has recently been installed on WEGA for plasma production and heating studies at 0.5 T magnetic fields. The ECRH system generates centrally peaked plasma density and temperature profiles that are required for basic plasma physics studies and for evaluation of a new Heavy Ion Beam Probe diagnostic.

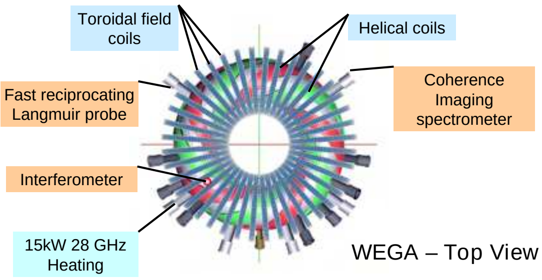

Figure 1: Location of the heating system and diagnostics on the WEGA stellarator.

In water load tests, the Gyrotron has produced up to ~ 15 kW RF output power. The system has since been set up for initial second harmonic extraordinary (X2) mode heating of the WEGA

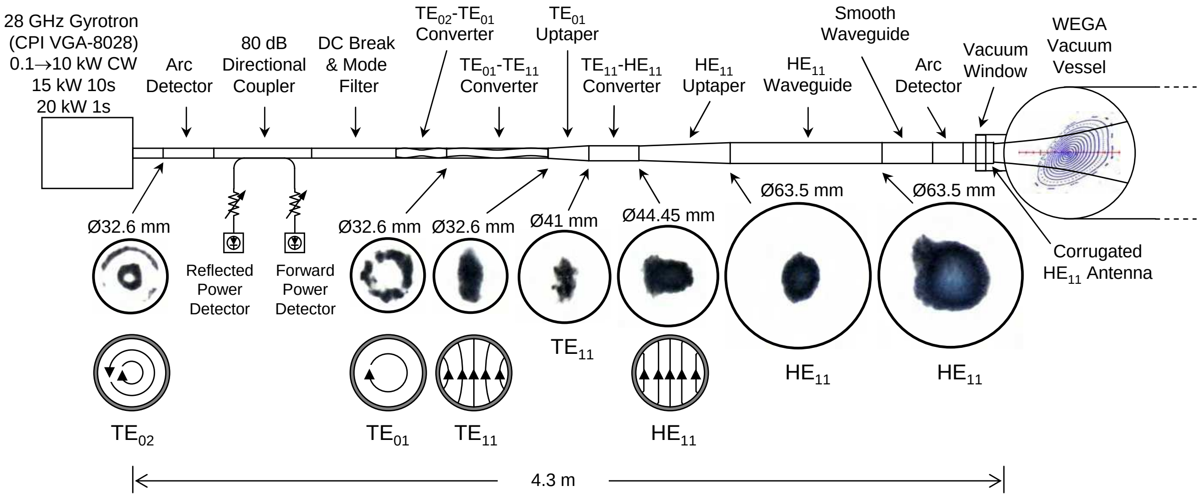

Figure 2: Schematic layout of 28 GHz ECRH system for initial experiments. Measurements of the waveguide mode profiles are also shown.

plasma with an expanding Gaussian beam launched from an HE_{11} antenna, as shown in Fig. 2. First results of these experiments are presented.

Results and Discussion

Initial Ar discharges were made with the magnitude of the magnetic field on axis $|\mathbf{B}_0| = 0.5$ T, rotational transform $\iota/2\pi = 0.2$ and gas fill pressure $p_{\text{fill}} = 3.0 \times 10^{-6}$ mbar.

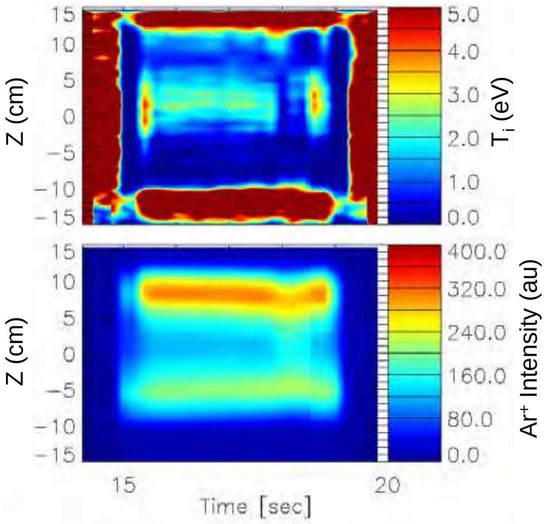

Figure 3: Ar^+ 488.0 nm light emission intensity and ion temperature T_i during Gyrotron plasma heating for $|B_0| = 0.5$ T.

Ion temperature and emission profiles, measured with the Coherent Imaging interference Spectrometer [2], are shown in Fig. 3. Note the high values of T_i at the edge of the plasma are not realistic as the ion emission is too low for reliable calculations to be made.

Profiles of electron density (n_e), temperature of thermal electron population (T_{es}) and temperature of fast electron population (T_{ef}) determined from Langmuir probe measurements are shown in Fig. 4. The electron density profile is normalised to match the line-integrated density measured by a 3.7 mm wavelength interferometer that probes through the centre of the plasma. The Langmuir probe is swept from -100 V to $+50$ V in 256 steps with a dwell time of 60 μs per step, while the probe is moved into the plasma over a ~ 3 s period. Individual points in the density and temperature profiles are determined by fitting a two temperature model [3] to the average of five measured Langmuir probe characteristic curves.

The T_i profile is centrally peaked, with $T_i^{max} = 5$ eV, before the fast reciprocating Langmuir probe enters the plasma at 15.5 s. The change in the light intensity at 18 s is due to the probe holder entering the edge of the plasma. When the probe is removed from the plasma at 18.5 s the T_i profile recovers its centrally peaked profile.

Heating the electrons with the Gyrotron RF power generates a fast electron population. Through collisions, this generates the slow thermal electron population and heats the ions. The centrally peaked ion temperature profile indicates the electron density profile is also centrally peaked, as the electrons are the only source of heating. As shown in the time trace of the ion temperature profile, the Langmuir probe causes a flattening of the profile when it is inserted into the plasma for measurements. Thus the electron density and temperature profiles determined with the Langmuir probe are flat or hollow.

The magnitude of the magnetic field calculated in the Gyrotron polodial plane for $|\mathbf{B}_0| = 0.5$ T and $\iota_0/2\pi = 0.2$ is shown in Fig. 5. The field varies by at least 20% over the radial extent of the closed flux surfaces. Fig. 6 shows the resonance region for optimum heating of the electrons is rather broad, as can be expected from the large plasma size and broad ECRH launching beam.

Future plans

A lens will be used to focus the Gaussian beam emanating from the end of the waveguide into the centre of the plasma where, using ISS95 [4], average electron temperatures $< T_e >= 50$ eV and electron densities $n_e < 5 \times 10^{18}$ m^{-3} are expected.

The system will be used to generate suprathermal particles for fast particle confinement studies in different magnetic configurations (various ι) in the stellarator geometry. It can also be used for such studies in stellarator-tokamak hybrids, when a power supply for the WEGA ohmic heating coils is installed.

The ECRH system has been designed with potential future use for overdense OXB mode heating of the WEGA plasma in mind, where an oblique launch arrangement is required. Here, using ISS95, average electron temperatures $< T_e >=$ 25 eV and electron densities $n_e > 10^{19}$m^{-3} are anticipated. This is ideal for wave physics studies and to test W7-X divertor diagnostics.

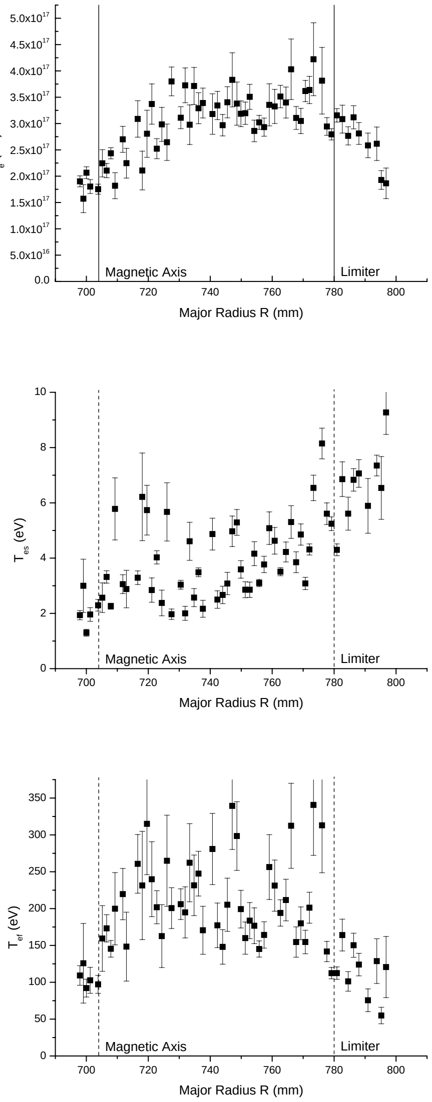

Figure 4: Profiles of electron density (n_e), temperature of thermal electron population (T_{es}) and temperature of fast electron population (T_{ef}) determined from Langmuir probe measurements of the Gyrotron plasma.

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