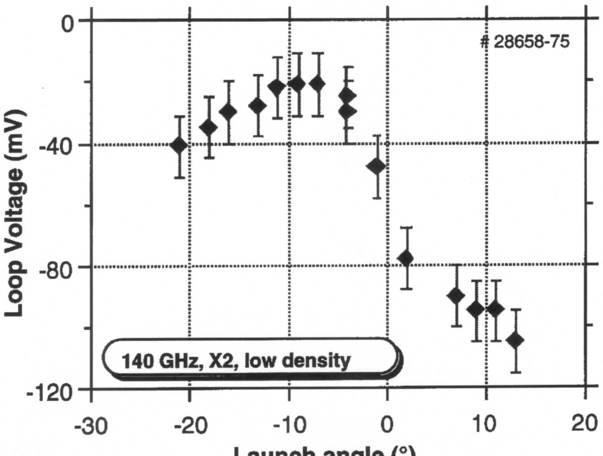
stellarator news

Published by Fusion Energy Division, Oak Ridge National Laboratory
Building 9201-2 P.O. Box 2009 Oak Ridge, TN 37831-8071, USA
Editor: James A. Rome Issue 36 November 1994
E-Mail: jar@ornl.gov Phone: (615) 574-1306

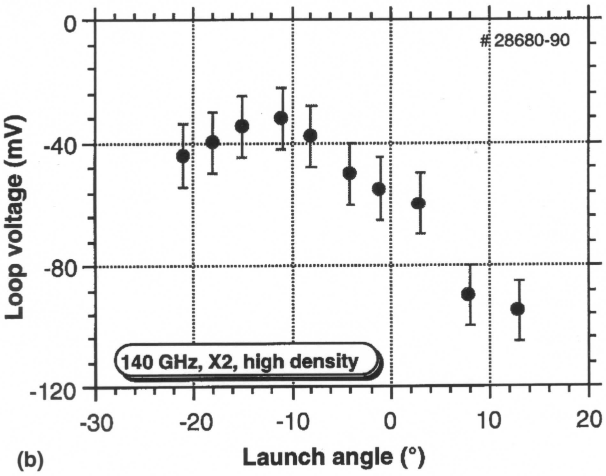
140-GHz electron cyclotron current drive experiments at W7-AS

The existing experimental data base on Electron Cyclotron Current Drive (ECCD) was restricted up to now to low-density operation because of the comparatively low cut-off densities for the applied electron cyclotron resonance heating (ECRH) frequencies. The application of 140 GHz at W7-AS extends the accessible density range towards $n_{e,crit} = 1.2 \times 10^{20}\ m^{-3}$ (second harmonic X-mode launch from the low field side). Stellarators are particularly suited for basic ECCD experiments because the relatively small EC-driven currents at the given power level can be measured with high accuracy and are not masked by the large inductive currents present in tokamaks.

The experiments at W7-AS aim at an extension of the existing data base and were performed at $B_0 = 2.5$ T and an edge rotational transform $\iota\!\!\!-(a) = 0.34$ in an optimum confinement regime. The plasma net current was feedback-controlled ($I_p = 0 \pm 200$ A) by compensating both the pressure-driven bootstrap current and the EC-driven current component with an inductively driven current. A deterioration of the global confinement by the current-induced change of the edge rotational transform is avoided by this method. A change of the magnetic shear at fixed $\iota\!\!\!-(a)$ is, however, introduced, which modifies the confinement to some degree. The launch angle was scanned from shot to shot in long-pulse operation (1 s) to ensure a quasi-steady state for the internal currents. The required loop voltage is plotted in Fig. 1 as a function of the launch angle of a narrow 0.4-MW, 140-GHz



(a)



(b)

Fig. 1. ECCD with 140 GHz, second harmonic X-mode launch: the loop voltage required for compensation of both the bootstrap current and the EC-driven current component is displayed as a function of the launch angle for (a) low density ($1.5 \times 10^{19}\ m^{-3}$) and (b) high density ($7 \times 10^{19}\ m^{-3}$).

In this issue . . .

microwave beam in the X2 mode. Two cases with low ($n_{eo} = 1.5 \times 10^{19}$ m^{-3}, $T_{eo} = 2.5$ keV) and high ($n_{eo} = 7 \times 10^{19}$ m^{-3}, $T_{eo} = 0.9$ keV) plasma density are shown. The loop voltage at perpendicular launch (0°, no ECCD) is required to compensate the bootstrap current alone. Positive (negative) launch angles correspond to co (counter) current drive with respect to the bootstrap current direction. The bootstrap current I_{boot} (DKES code) and the inductively driven current I_{ind} was calculated (neoclassical conductivity) for each shot, based on the measured profiles of temperature and density.

We assume a linear superposition of the three current components, and the 'missing current' $\Delta I = I_p - I_{boot} - I_{ind}$ is then attributed to the EC-driven current and plotted in Fig. 2 as a function of the launch angle. The measured residual plasma current I_p is in general negligible as compared to the bootstrap and inductive current for sufficiently large launch angles. The comparison with an independent theoretical ECCD modeling based on linear theory [1] is shown for both cases. The EC-driven current is calculated within the 'adjoint approach' [2], taking into account the measured profiles of n_e and T_e and trapped particle effects in the 3D geometry of the stellarator. Keeping in mind the simplifying assumptions in both the bootstrap current calculations and the linear CD-theory, we arrive at a remarkable agreement. It is worth noting that the EC-driven currents ΔI are determined from the difference of two much larger quantities I_{boot} and I_{ind}, especially in the high-density case. The absolute values of the driven current as well as the characteristics of the launch angle dependence are well described and support previous results at W7-AS [3] in the low-density regime at 1.25 T, second harmonic X-mode ECCD with 70 GHz.

V. Erckmann, M. Romé, and U. Stroth for the W7-AS Team
IPP Garching, Germany
E-mail VOE@SAT.IPP-GARCHING.MPG.DE
Phone 0049-89-3299-1963

REFERENCES

[1] FISCH, N.J., BOOZER, A.H., Phys. Rev. Lett. **45** (1980) 720.

[2] ANTHONSEN, T.M., CHU, K.R., Phys. Fluids **25** (1982) 1295.

[3] ERCKMANN, V., GASPARINO, U., *Review of Electron Cyclotron Resonance Heating and Current Drive in Toroidal Fusion Plasmas*, accepted for publication in Plasma Physics and Contr. Fusion.

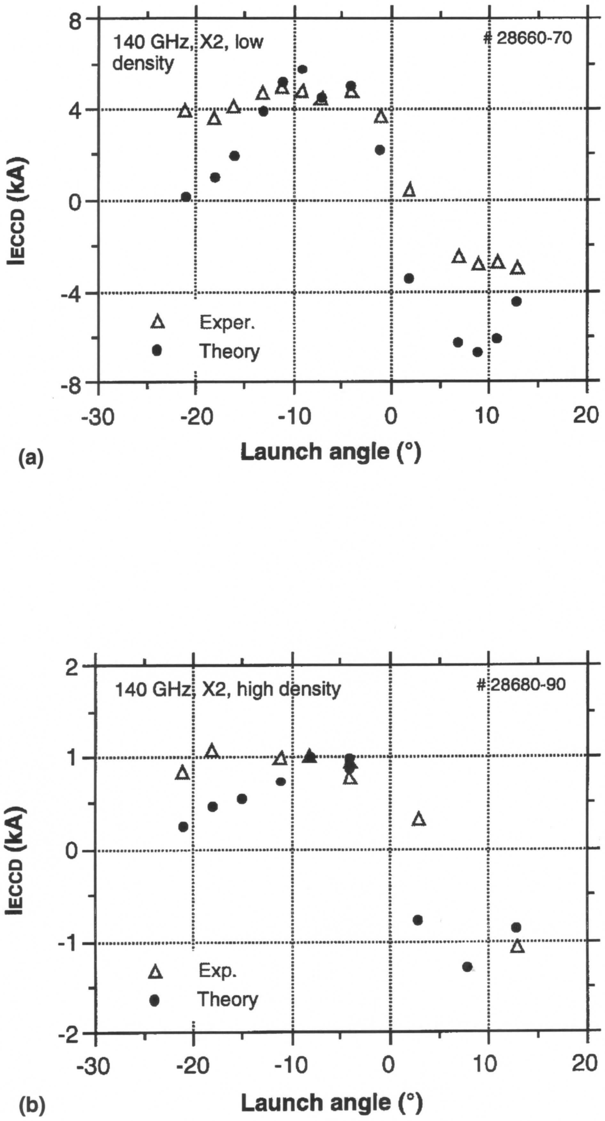


Fig. 2. Comparison of the EC-driven current derived from the measured plasma profiles and loop voltage (triangles) with the theoretical ECCD modelling (dots) for the two cases (a) low density and (b) high density of Fig. 1. The EC-driven current is considerably reduced at increased density, as expected from theory.