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HGF-Forschungsbereich / Research Field	*Energy*
HGF-Programm / Programme	***Nuclear Fusion***
HGF-Thema / Topic	*Tokamak Physics*
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Detailergebnisse / Details

TEC Main Topic 6 — Dynamic Ergodic Divertor (DED)

The primary goal of the topical group is the application of the DED to the TEXTOR plasma and the understanding of the resulting physics.

Electric currents in the coils of the DED superimpose a resonant perturbation magnetic field to the equilibrium field of the plasma; this additional field “weaves” the magnetic field lines such that a field line fills a whole volume instead of a surface. This ergodisation increases the plasma transport at the boundary such that the deposited heat will be distributed over a relatively large wall area – in a future fusion reactor, the high heat flux density to the walls is one of the critical issues. In addition, the DED of TEXTOR is unique in so far as the perturbation field can rotate with a velocity up to the order of the ion drift velocity in the plasma edge. By this rotation, new possibilities may open up for improving the plasma confinement.

After two years of installation work, the DED has been taken into operation in June 2003. In about 250 discharges the DED was applied successfully. In about half of the discharges the DED was operated in the DC mode and the rest is shared in the 2 Hz mode (55), the 2 kHz mode (58) and in the 7 kHz mode (15). During 2003, the DED was operated in the fine m/n = 12/4 current distribution mode which is relevant in particular for questions of plasma-wall interaction. End of 2003, the DED configuration has been switched to the coarse m/n = 3/1 mode; aim of this operation is the investigation of the interaction of islands deeply within the plasma.

So far the following measurements have been performed:

- IR thermography in order to visualize the characteristic stripe pattern in front of the DED coils and expected from the near field of the DED; this strip pattern is shown in the figure. Un-uniformities of the heating arise from the imperfection of the alignment of the DED divertor target tiles. The distribution of the heat flux has been related to results of field line tracing and it is being analysed to which path the power takes through the rather complicated ergodic boundary layer to the target plates.

- Probe measurements for obtaining the local values of the electron density and temperature at the target plate.

- Diverse spectroscopic measurements yielding the fluxes of recycling deuterium, and the released impurity distributions.

- Analysis of the screening efficiency of the ergodic zone against impurity influx to the plasma core for different plasma conditions.

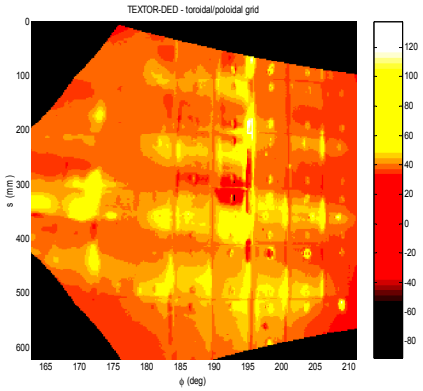
- Atomic beam measurements for deriving the local transport coefficients in the ergodic and laminar zones. These data are the basis for tests of different transport theories based on nonlinear dynamics.

- Development of a new Hall probe for obtaining the current pattern induced into islands of the ergodic zone.

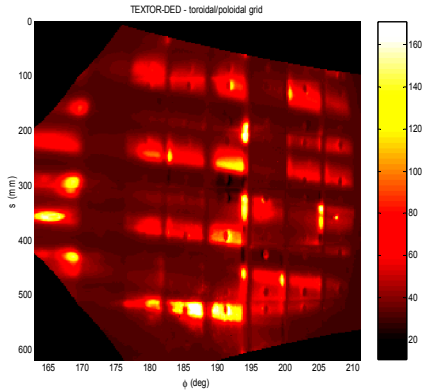
- Electron temperature and density profile measurements for analyzing the global confinement properties.

- Determination of the structure of the rotating magnetic field waves by sets of Mirnov coils. It has been found that the rotating mode spectrum is modified by the presence of the DED field with characteristic differences during static and dynamic operation.

- In addition to the specialized diagnostics, the whole set of standard diagnostics has been applied to investigate the influence of the DED on the plasma.



Thermographic image for the case of low edge ergodization



Thermographic image for the case of high edge ergodization

For the analysis of the DED, the following theoretical work has been performed during the recent year:

- For investigating the particle transport in the ergodic area, a new mapping method for the guiding centre motion of ions and electrons has been derived and improved. It has been shown that the ergodisation is more pronounced for counter-rotating particles than for co-rotating ones.

- In order to characterise the perturbed edge zone, the code “Atlas” has been prepared showing the ergodic zone, the field line connection length of the laminar zone and the strike zones of the magnetic field lines at the divertor target plate for different plasma conditions

(I_p, β_{pol}). The atlas is a major tool for referring a specific measurement with respect to the complicated 3-D structure of the ergodized edge plasma.

- The 3-D code EMC3 for the plasma transport in the laminar and ergodic zones of the DED plasma has been developed. The code has converged for a series of interesting plasma conditions.

- The penetration of the rotating perturbation field into the plasma is still an unsolved problem in case of an ergodic background field pattern. With respect to the DED, several groups (TEC partners, groups in Graz/Austria, Sao Paulo/Brazil, Kharkov/Ukraine and Novosibirsk/Russia) are contributing. The groups are using different techniques, such as the analysis of low frequency wave propagation, an analytical linear model or a non-linear numerical code. The different methods calculate the shielding current induced in the edge of the plasma due to the rotating magnetic field, the radial decay of the perturbation field into the plasma and the force transferred from the external coil currents to the plasma.

Collaborations

The group participates in an international effort of exploiting positive effects of ergodisation on fusion devices. The efforts concentrate on the mitigation of Edge Localized Modes (ELMs); these ELMs are a prominent feature of so called High Confinement Discharges (H-modes) and are linked with high transient power losses. It has been shown on DIII-D (San Diego / USA) that the ELMs were suppressed or largely reduced by the application of an external resonant perturbation field. For a fusion reactor, methods are investigated to reduce these extreme heat fluxes. The group collaborates in this respect with the fusion groups in Cadarache/France (Tore Supra) and San Diego/USA (DIII-D).

- Finally, an international workshop on Stochasticity in Fusion Edge Plasmas (SEP) has been established which held a meeting in October in Jülich. In the workshop, recent efforts and developments on stochasticity were presented; an aim is the coordination of related activities in the different laboratories. The papers will be published in the highly recognized journal Nuclear Fusion. It is planned to organize the workshop biannually.