Physics Aspects of the Dynamic Ergodic Divertor (DED)

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Outline

Motivation, aims

Experimental set-up

Ergodic zone

Laminar zone

Dynamic Aspect
Motivation:

• The next fusion device (ITER) will have a fusion power of about 1.5 GW

• => 300 MW $\alpha$-particle heating

• This power goes to divertor plates, if plasma edge is not radiatively cooled

• Assuming a divertor length of 30 m and a strike point width of 2 x 4 cm => power density of 12.5 kW/cm$^2$

• For these power fluxes, no technical solutions are known
Plasma Edge Radiation: too low
Limiter Heat Load: excessive

Plasma Edge Radiation: dominating
Limiter Heat Load: tolerable
Set-up

• **4 quartets** of perturbation coils plus two compensation coils

• **4 Phases** ===> Rotation of perturbation field

• **f**: DC, 50 Hz, band 1 kHz - 10 kHz

• Arrangement at **HFS** with continuous winding in vessel

• Maximum perturbation current: **15 kA**

• Resonance: \( q(r_{\text{res}}) = 3; \ r_{\text{res}} = 0.43 \ldots 0.46 \text{ m} \) (\( a=0.46 \text{ m} \))

• **Base modes**: \( m/n = 12/4; 6/2; 3/1 \) and mixture of 12/4 + 6/2
Final coil design

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Wide angle view in TEXTOR
DED - Spulenkühlung

- Wasserkühlung
- isolierte Kupferleiter
- Heliumgas

Konditionierung bei 250 °C
He auspumpen
Temperaturhub: 110 °C → 250 °C

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Scientific aims for DED program

DC-operation

• Comparison to other ergodization experiments
• Optimisation of the radiation belt
• Optimisation of particle exhaust
• Investigation of a helical divertor

Low frequency operation:

• Smearing out of local peaks of heat flux
1 kHz - 10 kHz operation

• Smearing out of local heat fluxes
• Generation of temporal ergodization
• Generation of a differential plasma rotation
• Improvement of plasma confinement
• Delay of disruption limit
• Plasma compression in front of pump limiter
$I_{pol} = 480 \text{ kA}$, $r_{res} = 44.26 \text{ cm}$
30% perturbation current
100 % perturbation current
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\[ I_{\text{pol}} = 480 \text{ kA}, r_{\text{res}} = 44.3 \text{ cm} \]

\[ \beta_{\text{pol}} = 1; R_0 = 174 \text{ cm} \]

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$I_{pol} = 550 \text{ kA}, r_{res} = 46.7 \text{ cm}$

$\beta_{pol}=1; R_0=174 \text{ cm}$
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\[ I_{\text{pol}} = 600 \text{ kA}, r_{\text{res}} = 48.33 \text{ cm} \]

\[ \beta_{\text{pol}} = 1; R_0 = 174 \text{ cm} \]

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resistive width: 2.5 cm; m=20

Amplitude

radius (m)
Summary

The DED-coils are continuous helical windings located at the HFS inside the vessel.

The Dynamic ergodic divertor will most likely provide a sufficient ergodization level at the plasma edge.

A laminar zone will form the main contact region with the wall; a 2D and 3D modeling was successful.

The field rotation imposes a torque at the plasma edge which is probably sufficient for generating a differential plasma rotation.

The differential rotation may lead to a suppression of turbulence and an improvement of the confinement; locked modes should be accelerated again.