CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

Plasma Position Stabilization @GOLEM

TV@J 2025

Daniela Kropáčková

Motivation

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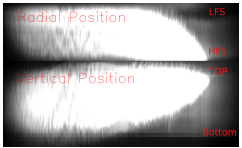
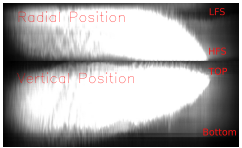


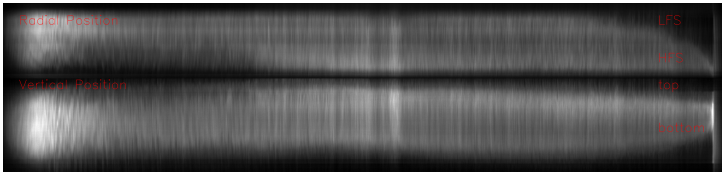
#39121; $\tau_{\mathrm{dur}} = 7.2\,\mathrm{ms}$

Motivation



#39121; $\tau_{\mathrm{dur}} = 7.2\,\mathrm{ms}$

With the help of external stabilization:



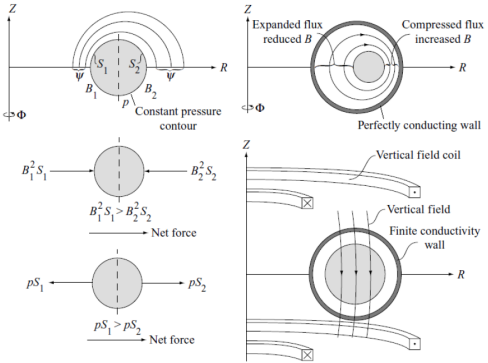
#39125; $\tau_{\mathrm{dur}} = 20.76\,\mathrm{ms}$

Motivation

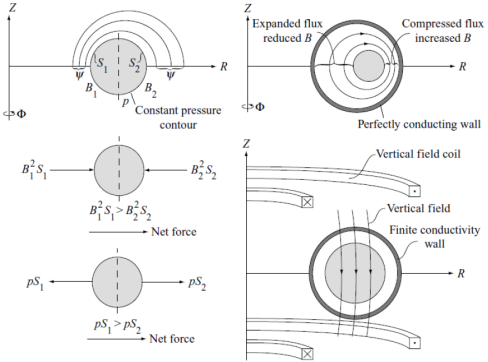
- Compensate for the forces acting on the plasma
- Keep plasma in the center of the chamber - important for the electrostatic probes measurement, etc.
- Improve discharge quality

Brief Theoretical Background

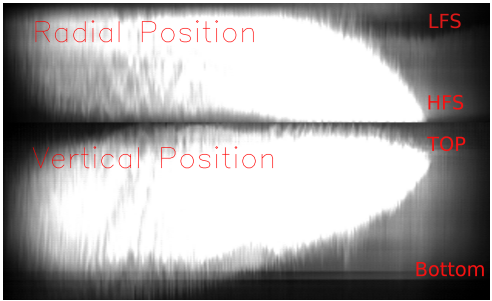
Theory:


Z
R
Φ
S_1
S_2
B_1
B_2
p
Constant pressure contour
Expanded flux reduced B
Compressed flux increased B
Perfectly conducting wall
$B_1^2 S_1$
$B_2^2 S_2$
$B_1^2 S_1 > B_2^2 S_2$
Net force
pS_1
pS_2
$pS_1 > pS_2$
Net force
Vertical field coil
Vertical field
Finite conductivity wall

Theory:



Practice:



#39121; $\tau_{\mathrm{dur}} = 7.2\,\mathrm{ms}$

Factors Affecting Plasma Position and Stabilization

Iron Transformer Core

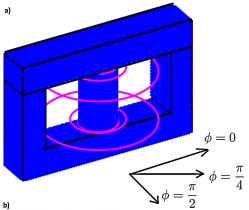
- Affects mag. field in its vicinity
- Potential reason of plasma movement toward HFS

Copper Shell

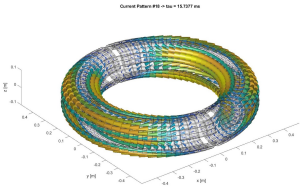
- Affects mag. field generated by external stabilization coils

Stray Fields

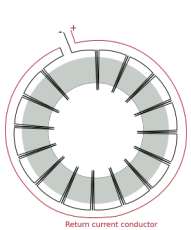
- Sources:
  - Induced vessel currents
  - Toroidal field coils misalignment (error fields)



Markovič et al. (2015)



Yanovskiy (2021)

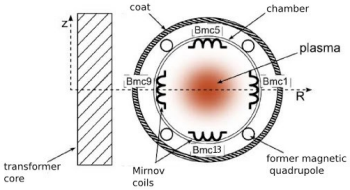


Plasma Position Measurement

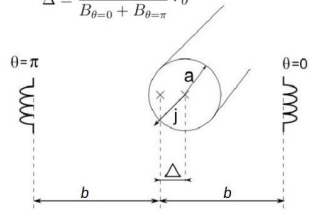
Mirnov Coils

- Passive magnetic diagnostic
- Sensitive to parasitic signals

MHD ring



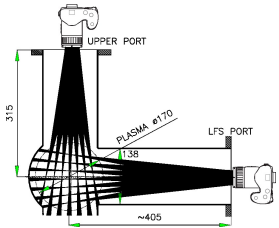
$$\Delta = \frac{B_{\theta=0} - B_{\theta=\pi}}{B_{\theta=0} + B_{\theta=\pi}} \cdot b$$

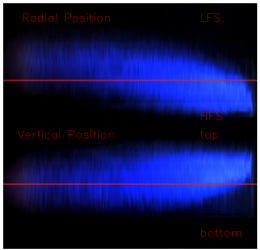


Fast Cameras

- Signal is not affected by magnetic fields
- Not available in real-time

Photron FASTCAM Mini UX100





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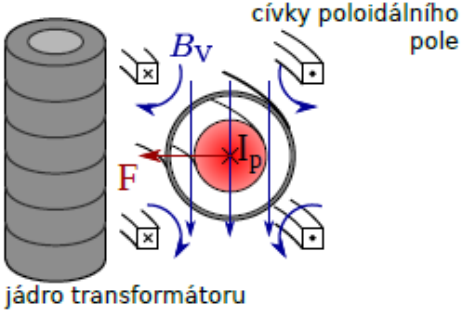
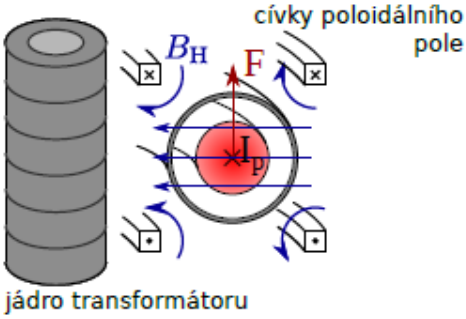
Plasma Position Stabilization



Horizontal Stabilization



Vertical Stabilization

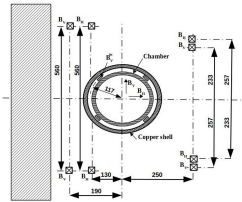
Plasma Position Stabilization Windings

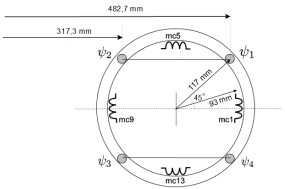
External Stabilization

- To stabilize plasma in horizontal and vertical direction; (4x8)
- Current amplifier:
  - Vertical: 5xKepco - max 100A
  - Horizontal: 4xKepco - max 80A

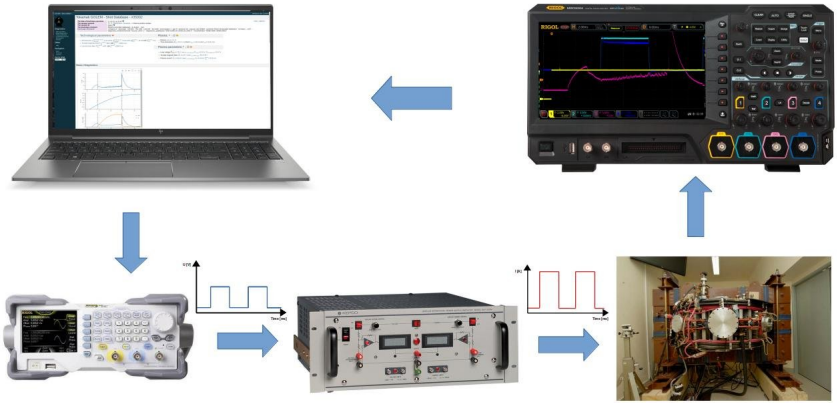
Inner Quadrupole

- Previously used to stabilize the plasma in the horizontal direction
- Also utilized for vertical magnetic field measurements
- Located between copper shell and vessel; (4x1)





Generating the Feedforward Control Signal



Miniproject Goals

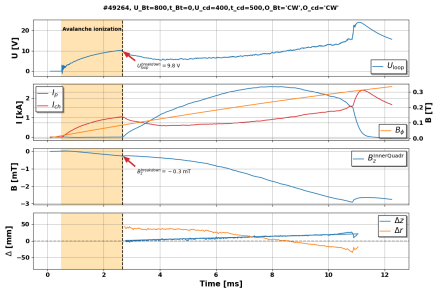
- Process diagnostic signals to determine plasma position
- Perform discharges with predefined currents in stabilization windings to improve discharge performance (e.g., plasma duration, position in the center)
- Analyze the impact of the generated magnetic field on discharge performance

Bonus: Assisted Plasma Breakdown

$$E_{\text{townsend}} \geq \frac{99 \cdot p(\text{Pa})}{\ln(3.75 \cdot p(\text{Pa}) L_{\text{conn}}(\text{m}))}$$

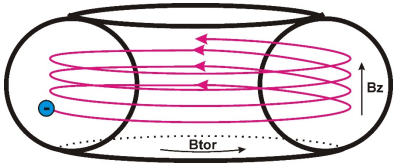
$$U_{\text{loop}} = 2\pi R E$$

$$L_{\text{conn}} \propto a \frac{B_\phi}{B_\perp}$$



Goals:

- **Employ stabilization windings to generate a magnetic field that reduces the required** $U_{\text{loop}}^{\text{breakdown}}$
- **Analyze the impact on** $r(t_0)$ **and** $z(t_0)$



References

Markovič, T., Gryaznevich, M., Ďuran, I., Svoboda, V., and Pánek, R. (2015). Development of 3D ferromagnetic model of tokamak core with strong toroidal asymmetry. *Fusion Engineering and Design*, 96-97:302–305. Proceedings of the 28th Symposium On Fusion Technology (SOFT-28).

Yanovskiy, J. (2021). private communication.