Overview of TJ-II Experiments

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TJ-II: $R = 1.5 \text{ m}; a = 0.2 \text{ m}; M=4; l=1.$
Contents

• Plasma wall interaction in TJ-II.
• Li Coating.
• Density control and improvement of performance.
• Magnetic topology effects
• Transitions to enhanced confinement regimes:
  – Low density.
  – High density: H mode.
• Final Remarks
P-W Interaction in TJ-II

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P-W Interaction in TJ-II

2 Instrumented Limiters, 180 °

But: *no limiter effect for <2.5 cm insertion in ECRH plasmas*
PW Interaction and Edge Diagnostics

PW mainly on Helical limiter (VV)

- Supersonic He beam (ne, Te, Ti)
- Recip. Langmuir Probes
- Reflectometry
- Fast Cameras
- etc..

\[ \phi = 85.3^\circ \]
Density control under wall saturation (ECRH)

Wall Conditioning:
- Metal walls +He GD+Ar GD: He release, Enhanced Particle Confinement transition (EPC, F.L. Tabarés et al PPCF 2001)
- Boronization: O-carborane+He GD, 4 Ovens:1g/oven, 80ºC
  ..... wall saturation ( <20 discharges)+ EPC

Saturation @ $4 \times 10^{20}$
Interaction area <1m$^2$

Particle balance in B
Density control under wall saturation (ECRH)

Shot # 16455

ECRH (GR1+GR2)

- SXR (a.u.)
- ECE5
- Hα (a.u.)
- PARATRON
- CV
- \( n \times 10^{18} \text{ cm}^{-3} \)

B walls: saturation

cut off

ne-crit.
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Lithium as plasma face material

Why Li?

- Very low Z

TJ-II: first stellarator operated under Li walls
Lithium coating in TJ-II

- 4 ovens, symmetric, tangential LOS
- 4 g deposited each time (600°C)
- Role of background pressure:
  - HV: line of sight

As deposited (HV)

Deposition on top of B-coated Walls

Re-distribution by plasma: Improving with operation time!!
Li Coating Technique

4 Lithium ovens: 2 fixed (side windows) and 2 in retractable manipulators (top windows)

Emission of Li injected from a retractable oven

1 gr of Li per oven, heated to ~600 °C during Ne GD
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Impact on plasmas ECRH

- Higher gas fuelling in Li walls required
- Less CV emission

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Density control improvement

- Density control is better and better with plasma operation
Profile shape: impurity & ne behavior

non collapsing

collapsing

same global parameters but...

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Profile shape: impurity & ne behavior

same global parameters but...

<table>
<thead>
<tr>
<th>Non collapsing</th>
<th>Collapsing</th>
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<tbody>
<tr>
<td><strong>BELL</strong></td>
<td><strong>DOME</strong></td>
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<tr>
<th>Shot # 17941 LITHIUM</th>
<th>Shot # 17931 LITHIUM</th>
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<tbody>
<tr>
<td>ne (10^{19} \text{ m}^{-3}), Wdia (kJ), SXR (a.u.)</td>
<td>ne (10^{19} \text{ m}^{-3}), Wdia (kJ), SXR (a.u.)</td>
</tr>
<tr>
<td>Prad (kW)</td>
<td>Prad (kW)</td>
</tr>
<tr>
<td>time (ms)</td>
<td>time (ms)</td>
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**Central impurity peaking**

**Edge thermal instability**

emissivity (W cm\(^{-3}\))

emissivity (W cm\(^{-3}\))

\(Z_{eff}\)

\(n\)

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Li coating: Operational range enlarged

Operational Window: B vs Li

wall / plasma

- B / H
- Li / H
- Li / He

Bivariate Fit of $W_t_{SXR\_max}$ By $den_t_{SXR\_max}$

• Li/He (NBI 1+2)

$\langle n_e \rangle \times 10^{19} m^{-3}$

$W$ kJ
Energy Confinement

\[ \text{tau } E (s) \]

\[ n (t \text{ max } W) \]

- Boron
- Li (dome)
- Li (bell)
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Magnetic topology & transport: iota effects

\[ \chi = \frac{\iota}{2\pi} \]

rational q

q = \iota/2\pi
Magnetic topology & transport: iota effects

\[ q = \frac{\iota}{2\pi} \]

Diagram showing magnetic topology and transport with rational q and \( q = \frac{\iota}{2\pi} \).
Magnetic topology & transport: iota effects
Magnetic topology & transport: iota effects

ECH, shot by shot. Thomson scattering
Magnetic topology & transport: iota effects

$\mathbf{n_e}: 5 \times 10^{18}$

$\mathbf{n_e}: 9 \times 10^{18}$

ECH, dynamic, single shot. ECE

See EX/P5 - 29 Lopez-Bruna et al.
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development of the edge velocity shear layer
development of the edge velocity shear layer

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development of the edge velocity shear layer

- shear layer starts to form at $\rho_0 = 0.68$, where the density gradient is maximum
- It propagates radially outwards and inwards at $v \approx 2$ m/s

The process of disappearance of the velocity shear layer is the direct opposite

These results suggest a two step process in the edge shear formation:
1) a seeding mechanism linked to plasma gradients
2) an amplification process in which edge shearing rates and fluctuations are self-organized near marginal stability

See EX/P5 – 31: Estrada et al.
First evidence of long range correlation during transitions

See EX/P5-30: Pedrosa et al.
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L - H Transition (I)

- NBI Heated plasmas.
- Li coated wall (low recycling conditions).
- Density and stored energy increase spontaneously.
- Confinement time is doubled after the transition.
- Pedestal is developed in density profile.
- No changes in $T_e$.
L - H Transition (II): ELMs

- The Reflectometer detects turbulence reduction during L – H transition.
- After about 10 ms, ELMs appear and are visible in Hα.
- Turbulence increases during ELMs.
Final Remarks

• Li Coating has been proven as a powerful tool to improve density control, leading to significant extension of operational domain and increase in confinement.

• Magnetic configuration scan indicates correlation between local iota and electron thermal transport

• Confinement transitions at low density show basic physics: shear layer development at internal position and long range turbulence correlation.

• Due to the performance improvement, transitions to enhanced confinement regime are observed showing the pattern of the stellarator H mode: way open to high density high beta experiments
TJ-II Team Posters

- **TH/P3 – 18:** “Kinetic simulation of heating and colisional transport in a 3D tokamak”.

- **TH/P4-15:** “Flux-expansion divertor studies in TJ-II”
  F. Castejón, J.L. Velasco, A. López-Fraguas, A. Tarancón, J. Guasp, F. Tabarés, M.A. Pedrosa, E. de la Cal, and M.A. Ochando

- **EX/P5 - 29:** “Footprint of the Magnetic Configuration in ECH Plasmas of the TJ-II Flexible Heliac”

- **EX/P5-30:** “Multi-scale physics during shear flow development in the TJ-II stellarator”
  C. Hidalgo, M.A. Pedrosa, C. Silva, J.A. Alonso, D. Carralero, B.A. Carreras, E. de la Cal, T. Kalhoff, B. van Milligen, and J.L. de Pablos

- **EX/P5 – 31:** “Characterization of the perpendicular rotation velocity of the turbulence by reflectometry in the stellarator TJ-II”
  T. Estrada, T. Happel, C. Hidalgo.