ITER-specific design

S. Cirant

<table>
<thead>
<tr>
<th>Wednesday, June 6</th>
<th>Henderson</th>
<th>Design status of the ITER upper port launcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:40</td>
<td>Takahashi</td>
<td>Development of ITER Equatorial EC Launcher for Reliability Improvement</td>
</tr>
<tr>
<td>16:05</td>
<td>Bongers</td>
<td>Recent developments of the Upper port ECH&amp;CD launcher systems for ITER based on the remote steering concept</td>
</tr>
<tr>
<td>16:55</td>
<td>Goodman</td>
<td>Ten Years of Experience in Integrated Control of the Multi-Megawatt ECW system on the TCV Tokamak</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thursday, June 7</th>
<th>Moro</th>
<th>Beam characteristics including general astigmatism effects in the Remote Steering ITER ECRH Upper Launcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:30</td>
<td>Platania</td>
<td>Numerical calculations of beam patterns for the ITER ECRH Upper Launcher</td>
</tr>
<tr>
<td>14:20</td>
<td>Poli</td>
<td>Performance Evaluation of the Remote- Steering Option for the ITER EC Upper Launcher</td>
</tr>
<tr>
<td>14:45</td>
<td>Ramponi</td>
<td>Physics analysis of the ITER ECW system for an optimized performance</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Friday, June 8</th>
<th>Serikov</th>
<th>Nuclear analyses for the ITER ECRH launcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:45</td>
<td>Strauss</td>
<td>Thermal and electromagnetic study of the UPP for the ECRH in ITER</td>
</tr>
<tr>
<td>11:10</td>
<td>Heidinger</td>
<td>Structural system of the ECH Upper Port Plug for ITER</td>
</tr>
<tr>
<td>11:50</td>
<td>Henderson</td>
<td>Interface issues associated with the ITER ECH system</td>
</tr>
</tbody>
</table>

4th IAEA TM on "ECRH Physics and Technology for ITER ", 6 – 8 June 2007, Vienna
ITER-specific design evolution

- FS launching mm-wave optics (Henderson, Platania, Takahashi), port plug structure (Heidinger, Strauss, Serikov) and physics applications (La Haye, Ramponi) are being more and more detailed.

- FS design effort is focusing on reliability (Henderson, Takahashi): mirror steering mechanism, mirror vs. w.g. bend.

- FS neutron shielding and compatibility is verified (Serikov)

- RS conceptual design is optimized (Bongers, Moro, Poli): “long” dogleg, tapered SQW, curved SQW

- preionization project has been started (Rao)

- slow control issues are being tackled (Goodman)

- Real Time Control (Hennen)

- System (Source-TL-EPL) integration.
Enhanced Performance (EP) Launcher

1. Spread out steering ranges
   Access in to ρ=0.4 (sawteeth)

2. Limit steering range, use QO design + cnt-ECCD mirror, add poloidal tilt

M. Henderson, K. Takahashi, G. Ramponi
ECHULA (ECH Upper LAuncher) partners:
CNR Milano, CRPP Lausanne,
FOM Rijnhuizen, FZK Karlsruhe,
IPP Garching / IPF Stuttgart

Design and testing of
the ITER ECRH Upper Launcher

Detailed design of the internal shield (front part)

Radial cutaway

To be filled with shielding material

Radial/Toroidal cutaway

Different design of manifolds due to
mm-wave channels

Individual arrangement of teh connection bores

Design of rear part depends strongly on additional input
(such as future of mitre bend design)
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RF Beam Propagation in the modified design

Peak heat load (1MW trans.)
M1: Parabolic
2.4MW/m² --> 1.2MW/m² (4.35e-8Ω•m)
M2: Flat
3.2MW/m² --> 2.3MW/m² (1.56e-7Ω•m)
1.7MW/m²
Efficiency : 98.7% (M1:Rx/y=6/12m)
97.3% (M1.Rx/y=12/24m)

- Present FS design + QO trans. Line leads to the increase of reliability.
- Next phase:
  Thermal analysis of mirrors

M1: curved mirror
M2: plane mirror
FS2: shield inlet
FS3: shield outlet
P: Plasma

4th IAEA TM on "ECRH Physics and Technology for ITER ", 6 – 8 June 2007, Vienna
Results of High Power Test - Axial $\Delta T$ distribution

- $\Delta T$ between the bends (1m) is significantly high.
- Anomalous $\Delta T$ at No. 11 & 15 was observed.
- Distance b/w bends is short --> Direct cooling is essential.

Axial distribution of $\Delta T$ at 0.5MW/240s

0.5MW/1000sec
Critical component: Bellows

Bellows (cyclic fatigue)

- Most susceptible to cyclic fatigue
- ITER lifetime: ~23’000 cycles
- Present design: ~150’000 cycles (based on EJMA with SS bellows)
- Investigating Alloy718 and NiCo
- Analyzing thermal treatment effects (ITER database points out uncertainty)
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- FS design effort is focusing on reliability (Henderson, Takahashi): mirror steering mechanism, mirror vs. w.g. bend.
- FS neutron shielding effectiveness is verified (margins for more space for the bams?) (Serikov)
- RS end-optics design is optimized (Bongers, Moro, Poli): “long” dogleg, tapered SQW, curved SQW
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Potential of Improvements of the RS Design

A comparison of the short and long RS launcher versions on all Critical Design Issues motivated to progress with the short RS launcher design

Conventional approach at present design based on the Short limited range RS launcher design
  ✓ Introduction of non constant curvature front mirrors
  ✓ Optimization of the SCW shape: Tapered SCW
  ✓ Dedicated range launchers

New design concepts
  ✓ Curved SCWs: (No front mirrors)
  ✓ Replace SCWs by confocal set of mirrors: (No SCWs)

Important in all cases
  ✓ Taking into account the General Astigmatism by A. Moro and E. Poli tomorrow 13:40 and 14:30
Surface optimization [3]

Preliminary results show the possibility to increase $F(\beta, w^*)$ in a localized region of the parameters space.

In the RS short range criterion $\eta_{NTM} > 1.2$ is not met for $q = 1.5$.

(2000 mm, 8.49°)
$F(\beta, w^*, q \sim 1.5, \gamma = 12^\circ) = 38.3$ (AU)

(850 mm, 25°)
$F(\beta, w^*, q \sim 1.5, \gamma = 12^\circ) = 51.9$ (AU)

Next steps:
- fully characterize the best candidate pair ($R_{tor}$, $\Psi_{ori}$) with $w_{\xi}(z)$, $w_{\eta}(z)$ and $\varphi_{w}(z)$.
- include the lower row (mechanical constraints?)
- include a beam tracing run to characterize in terms of localized heating and stabilization efficiency $\eta_{NTM}$.
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• Real Time Control.

• System (Source-TL-EPL) integration: see Henderson talk!
general interest high power design evolution

• Variable frequency gyrotron
• Long-term end-mirror reflectivity (erosion/deposition)
• FADIS.
• Improved RS.
• ?
in summary...

Discussions should continue!