Study of disruption generated runaway electrons on J-TEXT tokamak

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Contents

• Motivations
• Introduction of J-TEXT
• Regime of runaway current generation
• Suppression of runaway generation by RMP
• Dissipation of runaway current by MGI
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Motivations

- Suppression or controlling of runaway electrons on ITER is essential for the safe operation.
- Understanding the physics of RE production, transport, and amplification during disruptions is essential.
- MGI is one of the candidates for the mitigation of runaway electrons. To achieve the Rosenbluth density in ITER appears to be impractical.
- Externally applied magnetic perturbations could enhance runaway loss rate.
- Alternative is to dissipate runaway current following disruption.
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### Research topics

- MHD activity & Disruption
- Edge physics
- Confinement & Transport

### Diagnostic content

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>content</th>
</tr>
</thead>
</table>
| Magnetic            | Poloidal array: 1*24  
                      | Toroidal array: 1*8 (midplane)  
                      | Saddle coils: 5+8 (n=1)  
                      | Moveable probe: 2*1 |
| Temperature         | ECE: 1*8, ~2cm resolution  
                      | XICS: T_e & T_i at core  
                      | Spectrometer: T_i at edge |
| Density             | HCN: 1*7 (5cm resolution)  
                      | POLARIS: 1*17 (3cm resolution)  
                      | Faraday angle |
| Rotation            | XICS: ±10cm  
                      | Spectrometer: CV at 0.5a~0.9a  
                      | CIII at 0.8a~a |
| Radiation           | SXR: 5*16; HXR: 4*3; Ha(1*16); CIII,CV (1*16); XUV(4*16+8*20) |
| Other Tools         | RMP, SMBI, MGI, Biasing |

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Max. Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major/Minor radius (R, a)</td>
<td>1.05 m/0.26m</td>
</tr>
<tr>
<td>Toroidal field (B_T)</td>
<td>2.3 T</td>
</tr>
<tr>
<td>Plasma current (I_p)</td>
<td>240 kA</td>
</tr>
<tr>
<td>Electron Density (n_e)</td>
<td>1-5 \times 10^{19} m^{-3}</td>
</tr>
<tr>
<td>Electron temperature (T_e)</td>
<td>~0.8 keV</td>
</tr>
</tbody>
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Regime of runaway current generation

5.6bar Ar MGI, Bt=2.3T, Ip=180kA, ne=1*10^{19} m^{-3}
MGI was fired at 0.4s

Runaway free shutdown by He

Runaway current plateau induce by moderate Ar MGI

Runaway free shutdown by mixture of He&Ar (9:1)

Runaway free shutdown by Ne

With 5-10 times plasma inventory Ar injection, runaway current plateau are provoked, the amplitude of plateau depends on the current quench rate. Above 10 times plasma inventory Ar injection, it is runaway free shutdown.
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Reduction of runaway generation by RMP on TEXTOR

Runaway generation was reduced by enhancement of runaway loss rate.

Suppression of runaway generation by RMP

Enhancement of runaway loss rate by RMP at the flattop phase

The stochastic regime contribute to runaway loss rate.

The large size magnetic island formed by the m/n=2/1 RMP could improve the confinement of runaway electron seed which is favorable for the generation of runaway current.
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Dissipation of runaway current by MGI

- To achieve the Rosenbluth density in ITER appears to be impractical.
- Alternative runaway mitigation is allow runaway generation with good runaway beam position control.
- Soft landing of runaway current or dissipating runaway current by large amount of high Z impurities is desired.

Ar MGI at 0.4s to induce stable runaway current plateau.

Enhancement of SX and AXUV signals from 0.406s demonstrated the strong interaction between runaways and Ar impurities.
Runaway current decay during the interactions.

\[ W_{RE} = \frac{1}{2} L_p I_p^2 \]
\[ W_{\text{mag}} = 41 \text{kJ} \]
\[ W_{RE} = 12 \text{kJ} \]
\[ P_{\text{rad}} = 0.2 \text{kJ} \]

\[ N_{RE} = 2 \pi R_0^* I_{RE}/c_e, \text{ 100kA runaway current is about } 1.37 \times 10^{16} \text{ runaway electrons.} \]
\[ 5 \text{MeV, 100kA runaway beam, } W = 11 \text{kJ} \]

\[ W_{RE} = 12 \text{kJ} \]
\[ P_{\text{rad}} = 5.7 \text{kJ} \]

About half of runaway beam energy is dissipated by radiations.
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Runaway free fast shutdown by MGI: He, Ne, mixture of He&Ar (9:1), large amount Ar (>10 times plasma inventory).

It is about 30%-70% runaway current conversion efficiency with Ar MGI (5-10 times plasma inventory).

Both the amplitude and the length of runaway current can be reduced by the application of moderate RMP strength during the disruptions. When the current of RMP is 6 kA, the induced runaway current plateau is even higher than that without RMP.

The large size magnetic island formed by the m/n=2/1 RMP could improve the confinement of runaway electron seed which is favorable for the generation of runaway current.

The runaway current plateau has been dissipated by Ar MGI. The enhancement of radiation contribute to the dissipation.
Thanks for your attention!
Back slides
Two sets of RMP coils:

**SRMP (static RMP):**
- Consists of 5 coils.
- Outside of vacuum vessel;
- Powered separately

**DRMP (Dynamic RMP):**
- Inside of vacuum vessel;
- Consists of 12 coils;
- Can operate in DC or AC mode, producing static or rotating RMPs

# J-TEXT RMPs structure

<table>
<thead>
<tr>
<th></th>
<th>Static RMP</th>
<th>Rotating RMP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coils</strong></td>
<td>SRMP</td>
<td>DRMP DC</td>
</tr>
<tr>
<td><strong>$f_{\text{RMP}}$</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mode structure</strong></td>
<td>Many high n modes, 2/1 RMP</td>
<td>2/1 RMP</td>
</tr>
<tr>
<td>$b_{r}^{2/1}$</td>
<td>0.63 Gs/kA</td>
<td>2.6 Gs/kA</td>
</tr>
<tr>
<td>$b_{r}^{3/1}$</td>
<td></td>
<td></td>
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</tbody>
</table>