ITER EDGE THOMSON SCATTERING

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INTRODUCTION

Many of ITER’s performance limiting mechanisms are expected to exist and interact at the plasma edge. The H-mode edge pedestal parameters are high leverage variables of models used for predicting ITER’s success, in measures ranging from core reactivity to divertor erosion. For example, the pedestal temperature is critical in determining the L-H transition. According to many transport models, once H-mode is reached, the H-factor and $Q$ are strongly related to the pedestal pressure. Several classes of ELM instabilities are sensitive to the edge pressure profile shape and also affect performance. The ITER divertor scenario counts on impurity radiation from the plasma edge to reduce power flow to the divertor plates, a mechanism that also affects the edge pedestal region. It is therefore reasonable to expect that, during ITER operation, the edge $T_e$ and $n_e$ profiles are likely to become key operational indicators, and ideally, they would be available for use in feedback control for discharge optimization.

One of the tools identified to probe this important area is edge Thomson scattering, providing local measurements of electron temperature and density. Distinct from other Thomson scattering systems planned to probe the ITER core and divertor regions, the edge Thomson system was conceived to provide profiles of the edge pedestal region with high spatial resolution. In this report, we will first review the current expectations for the ITER edge parameters, and compare these with the measurement goals currently defined for edge $T_e$ and $n_e$. We will then summarize the evolution of thinking in this area, which is currently at a Phase 2 (of 4) level of design. The design consists of a conventional imaging system making use of a top port on ITER for both the laser and the collection optics. There are several advantages of the top (versus midplane) geometry which will be highlighted. We will then describe a preliminary design which will serve as a reference for further discussion concerning access/performance tradeoffs. While we are aware of no fatal problems at present, there are challenging issues which will strongly affect the design. It appears that target measurement goals can be achieved with adequate
access, using available laser/detector technology. However, the important assessment of radiation streaming, and its effect on the survivability of the collection optics and relay fibers await further study. Another key issue is contention for space with other systems in the top port, such as the glow discharge system and the vessel inspection system.

EDGE PROFILE EXPECTATIONS AND TARGET MEASUREMENT GOALS

An excellent summary of the expectations for the ITER edge pedestal characteristics was given by Janeschitz. Based on measurements of edge parameters on CMOD, ASDEX-U, DIII-D and JET (many of which are edge Thomson measurements), and on accepted models describing operational limits and edge transport barrier mechanisms, projections are made to predict the ITER edge operational space in terms of \( n_e \) and \( T_e \). Of particular importance for the ITER edge Thomson design is the expected pedestal width. This will dictate the required spatial resolution, with strong impacts on all aspects of the design. For an H-mode scenario with Type I ELMS, the case with the steepest gradients, reference 1 projects that the ITER pedestal width at the midplane will be in the range of 9-19 cm. This compares to an experimental value of 6 cm on JET. For an H-mode pedestal density limit of \( 6 \times 10^{19} \text{m}^{-3} \), assuming pedestal pressure is limited by ideal ballooning, this range in widths corresponds to pedestal temperature projections in the range of 4 - 8 keV, increasing at lower densities.

Gradient scale lengths for the electron temperature and density in the ITER scrape off layer are expected to be in the range of 2-4 cm at the midplane, projecting linearly with machine size from existing devices. The gradient scale lengths in both the edge pedestal and the SOL are found to shorten as the H-factor improves on existing devices.

<table>
<thead>
<tr>
<th>parameter</th>
<th>param. range</th>
<th>spatial res.</th>
<th>time res.</th>
<th>precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_e )</td>
<td>0.05-10 keV</td>
<td>0.5 cm</td>
<td>10 ms</td>
<td>10%</td>
</tr>
<tr>
<td>( n_e )</td>
<td>(0.05-3) ( 10^{20} \text{m}^{-3} )</td>
<td>0.5 cm</td>
<td>10 ms</td>
<td>5%</td>
</tr>
</tbody>
</table>

Target measurement goals for edge \( T_e \) and \( n_e \) are given in Table 1. It appears that the target spatial resolution of 0.5 cm is more than adequate to resolve the expected edge pedestal gradient and also adequate for the SOL gradients. This is, however, a technically challenging goal when coupled with achievement of the desired precision at the lowest densities. We have chosen to interpret the spatial resolution goal as appropriate for the image quality of the optical design. However, we also recognize that access constraints on the optical throughput may result in the need to average spatially or temporally to achieve the desired precision at low density. Given the expectations discussed