SPECTRAL MODELLING OF NEUTRAL BEAM FOR DOPPLER SHIFT SPECTROSCOPY DIAGNOSTICS OF INTF

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Objective

- The Doppler shift spectroscopy diagnostics set up is envisaged for measurement of beam divergence before uniformity and stripping losses for 100 keV DNB of ITER.
- Establish the diagnostics set up by beam spectral modelling of the H beam (To be tested on Indian Neutral Beam Test Facility INTF)
- Chose diagnostics set up parameters for obtaining good signal to noise ratio and error in divergence measurements as < 10%.
- Modelling of Doppler Shifted spectrum for all operational conditions.

\[
I(\lambda) = \frac{1}{\lambda^2 \cdot \lambda_{\text{beam}}} \cdot \exp \left( \frac{-(\lambda - \lambda_0)^2}{\lambda_{\text{beam}}^2} \right) \cdot \frac{1}{4\pi \cdot R_{\text{eff}}} \cdot Q_{\text{beam}} \cdot \cos \theta \cdot \frac{\Delta \lambda}{\lambda}.
\]

Beam Emission Spectrum Modelling

- Beam Geometry
- Beam Parameters
- Ion source parameters

Determine Estimated value Calibration

\[
\Delta \lambda = \lambda_0 \cdot \cos \theta \quad \text{- (2)}
\]

Spectral line emitted from a particle moving relative to an observer appears shifted in wavelength due to Doppler effect.

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy</td>
<td>100 KV (ns)</td>
</tr>
<tr>
<td>Aperture Arrangement</td>
<td>4 x 4 Group</td>
</tr>
<tr>
<td>Pulse Height</td>
<td>60 A</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>500 ns</td>
</tr>
<tr>
<td>Current Density</td>
<td>100 A/m\textsuperscript{2}</td>
</tr>
<tr>
<td>Beam Parameters</td>
<td></td>
</tr>
<tr>
<td>Beamlet Path length</td>
<td>30 m</td>
</tr>
<tr>
<td>LOS path length</td>
<td>1.25 m</td>
</tr>
<tr>
<td>Typical Beam path length (bottom)</td>
<td>3.2 m</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaturalBroadening (\Delta \lambda_1)</td>
<td>0.0313 nm</td>
<td>0.005 nm</td>
</tr>
<tr>
<td>Instrument Broadening (\Delta \lambda_2)</td>
<td>0.084 nm</td>
<td>0.10% \Delta \lambda_1</td>
</tr>
<tr>
<td>Beam Focusing (\Delta \lambda_3)</td>
<td>0.324 nm</td>
<td>20% \Delta \lambda_1</td>
</tr>
<tr>
<td>Voltage Ripple (\Delta \lambda_{\text{ripple}})</td>
<td>0.002 nm</td>
<td>1% \Delta \lambda_{\text{ripple}}</td>
</tr>
</tbody>
</table>

Table 3

Determination of Calibration Factor of DSS Diagnostic set up

- Parameters :
  - Acceleration Voltage : 15 KV
  - Beam Current : 0.58 A

Divergence error less than 10% for LOS angle 80-100 deg. Beam current 0.1 A

Derivation of reaction rate (Vacuum beam density)

\[
\frac{\partial n}{\partial t} + \nabla \cdot (n \cdot v) = -\nabla \cdot \left( \frac{n \cdot \chi}{\rho} \right) - \nabla \cdot \left( \frac{n \cdot \chi}{\rho \cdot \Gamma} \right) + \frac{\partial}{\partial t} \left( \frac{n \cdot \chi}{\rho \cdot \Gamma} \right)
\]

Rate Equations to calculate the beam fractions along the beamline

Gas Density Profile computed using MCGF code

Modelled Doppler Shifted Spectrum for 30 A - 100 keV H- Beam considering the parameters in Table 2. The SWR is \(10^{-4}\). Target emissions (emissions from dissociative excitation of background gas) are also shown in this figure.

Future Work

- Model the stripping loss of the beam
- Model the spectra for a non-homogeneous beam
- Hardware procurement for testing and installation

Conclusion

- The Doppler Shift Spectrum based on optical emission spectroscopy for neutral beam (H\textsuperscript{0}) of 100 keV energy is modelled and the parameters for the diagnostic setup have been established.
- The modelling shows that a relatively high signal to noise ratio (>100) even for low beam current (1A) has been achieved for the proposed diagnostic setup.
- The beam divergence measurement can be measured with error < 10% considering the parameters in Table 1.

Future Work

- Model the stripping loss of the beam
- Model the spectra for a non-homogeneous beam
- Hardware procurement for testing and installation