Analysis of tomographical reconstructions obtained from COMPASS tokamak data

Jakub Svoboda1,2, Martin Imrišek1,3, Jan Mlynář1, Ondřej Ficker1,2, Michael Komm1,3, Vladimír Weinzel1

1Institute of Plasma Physics of the CAS, Prague, Czech Republic
2FNSPE, Czech Technical University in Prague, Czech Republic
3Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

INTRODUCTION

Tomographical inversion uses line integrated measurements of tokamak plasma radiation to provide spatial profiles. The emissivity reconstruction g is to be retrieved from line integrals: $f = T_{g}G$, where $T_{g}$ is a geometry matrix. Special inversion algorithms must be used because of limited number of detectors and view angles. At COMPASS and other tokamaks Minimum Penalty Regularisation (MPR) has been applied and proved to be robust and reliable compared to other techniques. It contributed e.g. to transport studies and to Runaway Electron studies. Two sets of semiconductor photodiode detectors are used for tomography at COMPASS. Tomographic measurements are obtained using AXUV photodiode and Soft X-ray (SXR) is measured using L3D5-ST with beryllium filters with 10 μm thickness.

Tomography algorithm

Tomography is a method for reconstructing the spatial profile of the plasma emissivity from a set of line integrals. The basic idea is to retrieve the emissivity field from the line integrals using a reconstruction algorithm. The most commonly used algorithms are based on minimizing a functional, which includes a data fidelity term and a regularization term. The data fidelity term ensures that the reconstructed emissivity field is consistent with the observed line integrals, while the regularization term smooths the reconstructed field and reduces noise. The most commonly used regularization methods are isotropic smoothing and anisotropic smoothing along flux surface.

Comparative analysis and post-processing

Displaying combined reconstructions or comparing results is the most part possible by using the same computation grid for all reconstructions. These data can be further processed to obtain additional information about profiles or evolution of radiated power.

Combining reconstructions

- Multiple reconstructions can be combined into one image using RGB coding.
- However different diagnostic systems can have varying spectral sensitivity and thus different signal magnitudes.
- Therefore normalisation is required for this method.
- These images are then used for identifying regions of interest for further analysis.
- Resulting color of each pixel is determined by mixing basic colors with ratios determined by normalised radiated power.

STABLE MAGNETOHYDRODYNAMIC MODE

- Stable magnetohydrodynamic (MHD) mode occurred during pulse 6071
- Data reconstructed using different regularization methods
- Anisotropic smoothing is in most handy used (depends on EIT)
- Verified by isotropic smoothing (independent of EIT)
- Emissivity maximum rotated differently
- Magnetic axis from EIT results seemed to be out of rotational center
- EIT results were shifted and used for anisotropic regularisation

SAWTOOTH INSTABILITY

- Sawtooth is a common instability occurring in tokamak plasma
- Named after characteristic shape of SXR radiation evolution
- Below we can see normalized radiated power reconstructed by both SXR and SXR and Soft X-ray (SXR) is measured using L3D5-ST with beryllium filters with 10 μm thickness.
- Profiles measured by AXUV and SXR radiation are on the right
- The first profile is taken right before collapse of SXR profile, that is significantly peaking in the plasma centre
- The second one is taken immediately after the collapse when increase in AXUV recorded power can be observed
- The third one is taken after several milliseconds when SXR profile started to peak again, the AXUV profile is shifted more towards the plasma edge

PLASMA DETACHMENT

- Plasma detachment is a regime with substantial power dissipation in the edge plasma.
- Particles leaving plasma interact with injected impurity (nitrogen) before reaching PFCs.
- This helps to significantly reduce heat fluxes on the divertor PFCs.
- As a result of this interaction a strong emission occurs in divertor area, its evolution is of interest.
- Saturation of undamaged camera occurred during pulse 15977 before disruption preventing reconstruction of emissivity immediately prior disruption.
- Evolution of normalised radiation after impurity seeding can be seen in graphs below, impurity seeding rate used in 15972 was approximately half of that used in 15977, total radiated power was approximately 5 times larger at the end of observed interval for shot 15977.

SUMMARY

- Post-processing tools were successfully implemented to tomographic reconstruction of COMPASS tokamak data
- Anisotropic smoothing using EIT results can improve general shape of emissivity on whole poloidal section especially for reconstructions of hollow profile, as seen in sawtooth example
- However its accuracy has to be considered when examining small scale phenomena as demonstrated by MHD example
- Steeper increase of divertor radiation was observed for shot with greater seeding rate
- Normalisation required by universal nature of post-processing tasks is limiting for phenomena requiring absolutely calibrated data.
- Development of tools for only one reconstruction series with absolutely calibrated data is planned.

Acknowledgement

This work has been carried out within the framework of the project COMPASS II - Research (No. CZ.02.1.01/0.0/0.0/16_019/0000914) and co-funded from European structural and investment funds. This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. BG/06181830/64097/14.

References