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PhD Thesis report Ing. Jakub Svoboda

Garching, 6th of June 2025

To the doctoral committee of Ing. Jakub Svoboda,

I evaluated the thesis submitted by Mr. Svoboda with the following conclusions answering your requests:

1) How much the topic of the thesis is up to date?

The thesis topic, which involves applying tomographic inversions to diagnostic measurements in tokamaks, is not entirely up to date. The candidate provides a review of the main tomographic methods and how to work with them. While Mr. Svoboda has developed tools to apply established methods and combined various existing tools into one toolset, the thesis does not incorporate the latest developments in the field, such as Gaussian Process tomography. As a result, the thesis handles the established base of methods well, but it does not make use of cutting-edge developments. The application of tomographic methods to line integrated measurements is an important topic of fusion research, as one has to deal with a restricted number of measurements and measurement noise, which is usually compensated by including prior knowledge. The balance between the prior information and accurate reconstruction of the measurements makes this a challenging field.

2) What are the methods applied in the thesis?

The candidate reviews several methods for tomographic inversion and mainly applies the Minimum Fisher regularization, which is a well-established method for tomography in fusion environments. His thorough review of the methods also discusses the evaluation and interpretation of tomographic results, which is a valuable contribution since many other works in the field neglect this aspect.
Mr. Svoboda created a forward model for the SXR diagnostic of COMPASS-U based on the open-source code package Cherab, which he used to evaluate the performance of the diagnostic. However, he did not draw a conclusion from this evaluation.
Additionally, he investigated two methods to derive either the electron temperature or the tungsten density from the measurements of the SXR diagnostic, applying two different filter sets. Although he put significant effort into calculating Bremsstrahlung and selected line radiation, he neglects various other effects, such as other impurities. For the evaluation, he assumes either full knowledge of the plasma state and composition and does not include uncertainties from such measurements. He only selects some parameters to be unknown, while not evaluating the impact of noise from the others. While he concludes that the evaluation of the electron temperature in not realistic, he does not draw this conclusion for the tungsten density, even though this suffers the same deficiencies.

3) Whether the goal of the thesis has been achieved?

The goals of the thesis are vaguely defined, with statements such as "contribute to the design" and "apply tomographic methods to contribute to various experiments." Mr. Svoboda has touched on all of the goals of the thesis and developed a toolset to evaluate the performance of the diagnostic. However, he does not draw hard conclusions from the methods, instead applying them as a proof of principle. The thesis is missing the next step, which would involve applying the methods in a broader base, using e.g. more and different phantom profiles to identify deficiencies or strengths of the methods. The conclusions drawn by the candidate are trivial and would not even require such a sophisticated toolset. For example, he concludes on page 92 that "Clearly, the higher seeding rates result in higher radiated power in the divertor area and higher total radiated power," which is a straightforward result that does not necessitate any complex analysis. Or that “the regularisation should be different in different parts of the reconstruction area” which is already applied by many existing codes and does not represent a new insight.

4) What is the scientific value of the results?

The developed code package, Tomotok, and the forward model for the SXR diagnostic in COMPASS-U can be useful tools, which represent a small improvement compared to existing methods. Since the candidate does not draw strong conclusions, the scientific value of the thesis is limited, mainly to the design, optimization and interpretation of diagnostic measurements at COMPASS-U. The candidate's application of tomographic inversion in other tokamaks primarily demonstrates that the method is applicable, but it lacks any comparison to other existing methods or conclusions. While the candidate shows potential by applying and evaluating tomographic methods, within the framework of the written thesis he does not make use this potential.

5) What is your overall evaluation on the thesis, i.e. whether you recommend it for presentation and defense or not?

The candidate has potential, given his experience with tomographic codes and applications to different diagnostics at various tokamaks. However, the student does not draw significant conclusions out of the work.

There are several questions which shall be answered by the student in order to show the profoundness of the work:

For the tomography (Ch. 1):

- Which is the advantage/disadvantage of each of the tomography methods? For which kind of application which one should be preferred?
- What are the different optimizations/regularisations which one would apply for peaked radiation profiles (e.g. from SXR) versus hollow and asymmetric profiles (e.g. from Bolometry)?
- Can one develop an optimization scheme from the presented evaluation of the tomography performance (Fig. 1.12) which would help to further optimize the LOS setup?
- What is the effect of reflections in a tomographic inversion, and how can those be treated? Which influence have inaccuracies in positioning of the LOS? Can these be overcome?

For the evaluation of the tungsten density or temperature by the ratio method (Ch. 2):

- How big is the influence of noise of the measurements? How big is the impact of uncertainties from other measurements needed for the evaluation (ne, Te, plasma composition)? How big is the influence of (minimally) present other impurities, or unknowns in the emission of W?

- The aging of diodes was given as argument to use two SXR systems with different filters instead of one. Is the aging, however, the same if the SXR cameras use different filters? Does the aging act the same on all wavelength?
- For the calculation of the radiative charge Z_{rad}, which data is needed and is that available with sufficient accuracy and spatial resolution?
- Given these uncertainties, is the benefit of a doubled SXR system worth the installation?

For the application of tomography (Ch. 3):

- What improvement showed your work in comparison to existing methods?
- The conclusion that more LOS in the divertor leads to a better resolution is a trivial result. Can one define what features can still be resolved by a diagnostic and which ones not?
- The lack of divertor cameras for the JET case shows that diagnostics should have redundant measurements for the essential areas. How would such a system look like for a JET bolometry, how for the COMPASS-U SXR system?

The answers to these questions would significantly strengthen the thesis and increase its scientific value. A significant part of this work might already be done, but it is not included in the thesis text. The candidate has demonstrated his ability to work with tomographic codes and apply them to different diagnostics, but the thesis lacks the depth and analysis required to make a meaningful impact in the field. Therefore, the student has to answer the above questions thoroughly, either previous to the defense, or at the defense [depending on the format of the defense] in order to show the profoundness of his work.
I propose that the candidate further improves the thesis, but it is up to the committee [and the format of the defense] whether it should be accepted as is for the defense, and the candidate shows then at the defense further details by answering e.g. the questions above.

With best regards,

Max-Planck-Institut für Plasmaphysik

Matthias Bernert