Responses to Reviewers' Comments for Manuscript EC21

High power mm-wave loss measurements of ITER ex-vessel waveguide components at the FALCON test facility at the Swiss Plasma Center

Addressed Comments for Publication to

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by

Timothy P. Goodman et al.

Dear Editor,

Please find enclosed the revised version of our previous submission entitled “High power mm-wave loss measurements of ITER ex-vessel waveguide components at the FALCON test facility at the Swiss Plasma Center ” with manuscript number EC21. We would like to thank you and the reviewers for the valuable comments which help improving the quality of our manuscript. In this revision, we have carefully addressed the reviewers’ comments. A detailed point-by-point response to the comments from Reviewer 1 are given below.

Sincerely,

Timothy P. Goodman et al.

Authors' Response to Reviewer 1

General Comments. The paper reads well and is dense with detailed information relevant for the experiment and assessment. My only comment on the overall layout of the paper is that from section 3 onwards one is in a continuum of experimental work without apparent guidance what is next and what is the next objective. Perhaps after section 2 (Measurement layout) a few sentences can be spent on organization of the work? The approach of measurement followed by immediate interpretation and discussion I experienced as completely fine.

Response:

Thank you for your careful reading and for your comments/suggestions. A paragraph which gives the layout of the paper has been added at the end of section 2.

Comment 1

1) Introduction

- "The Ohmic losses scale as $diameter^3$". A reference (or a reminder why) is helpful. It is an important number in the assessment of high-power waveguide losses.
- Toward the end of the section, the theoretical loss rate of Al waveguides being nearly a factor 10 larger: this is rather shocking but also demonstrates the importance of the work. A reference is crucial here too. For the reader to investigate / understand this. Likely in the references within it may be found but it is a good service to the reader to explicitly give it here.

Response:

Thank you for these comments.

- The reference [18] is given for this scaling. Ref. 24 also shows this.

- I believe this is referring to the last sentence of the introduction. There a theoretical value is given and it is stated that the measurements are ≈10x higher (paraphasing). The reference 11 is given for experiments with 63.5mm waveguide and the reference 16 has been added for the theoretical value with 63.5mm waveguide.

Comment 2

2) Measurement layout

Photos are used to show the layout and positions of mitre bends and waveguides. While this is good for an overall impression of the facility, I have difficulty understanding the actual set-up such as discussed in Figures 5, 6 and 7. I know it is late to commission a good sketch showing loads, mitre bends and waveguides, but it would benefit the description of the experimental work much.

Response:

We totally agree. Sketches have been added to Fig. 5 and 7 to facilitate the understanding.

Comment 3

3)Mitre Bends

- "According to theory, mirror losses are half as large in the H-plane." The same comment as in the introduction, a reference is very helpful. This is very specialised knowledge and it is important to make it available to this community.
- "Since the RF beam (and therefore the heat flux) is not centered on the first MB". This reads as if one is aware of this, or that it follows from the description. But I cannot recall it. A short phrase in advance to clarify is helpful.
- Fig 3. Very interesting data. Maybe a shortcoming on my behalf, but it took me quite some time to realise the temperature difference is plotted. It may be because I (by mistake) interpreted in the caption 'temperature change' as the evolution of the temperature in time. The same perhaps in the 3-rd sentence in Section 5. Perhaps one could consistently write "temperature difference" (as is used in the paper as well).
- Consider changing "evidenced" to "showed", for added clarity (also in section 4, 3rd sentence and section 6, 2nd sentence).
- The fast change in acceleration voltage, the microwave response, and the subsequent response by the thermos-couple. For thermal analysis and understanding this is very useful data. Consider a zoom on, say, the first 20 seconds.

Response:

We appreciate all these comments.

- Reference 24 has been added here.
- The sentence has been modified to clarify.

- The caption is changed and difference in temperature or temperature difference is now used throughout.
- These have all been changed as suggested.
- Instead, reference [23] has been added, where this is shown in greater detail.

Comment 4

4) Stainless Steel WGs

- I may have missed it in the description, but how are the waveguides coupled at the centre notch in Fig. 5 and 6? (the possible sketch asked for in the measurement layout would be helpful).
- "From the fit parameters, we find the baseline WG absorption rate is a factor of 7.3 to 8.1 times theory". Reference? (unless already given at the earlier request).

Response:

Thank you again for your comments.

- Based on a previous comment sketches have been added to Figs. 5 and 7. These are showing the coupling between the waveguides. We hope its clear.
- The following sentence was added before discussing the modeling results: 'The model parameters are the result of fitting the data from several shots.' The fits are part of the results of this paper.

Comment 5

5) WGs far from MBs

- The measurements in the resonator to find the conductivity at microwave frequencies: very good. But the authors could / should also compare with relatively simple equations for surface resistance as a function of frequency? For example, in the book by Goldsmith (Quasioptical Systems, 1997, e.q. 5.95).
- Fig.7 has compact and interesting data. But quite some variables. Perhaps one could print above each section (4 to 5.3, 5.3 to 6.8, 6.8 to end) which waveguide (material) is used?
- The fore-last sentence starting with "Using this pair": I have difficulty understanding what is said. What is meant with "explicit"? Please consider rephrasing the sentence.

Response:

We thank the reviewer for this comments.

- The equation referenced in the comment is indeed the one that is used for the frequency dependence; however, that equation does not account for surface factors such as contamination, material's imperfections such as variability or potential cracks, (for the alloys that are used), etc. which are only significant when the skin depth is small; as in the case of high frequency. The point here is that bulk conductivity measurements found in databases may not, and in our case - do not, correctly characterise the absorption behaviour. The sentence has been rephrased to refer to surface resistivity (alternatively, conductivity).
- The materials are reported in the figure to simplify the understanding.
- The text is more explicit when referring to the "pair" and a question is added to the previous paragraph to clarify what the simulation is trying to answer.

Comment 6

6) Conclusions WGs

- Again, I repeat how useful these measurements are and this data is. I know it is not up to the authors to revise the theory that predicts the much lower losses, but as it is such an important item: could the authors make some suggestions as to why the losses in practice are so much larger? Hints to this may have come available during the experiments. This would enable other colleagues to be careful when designing a highpower transmission line using text book theory.
- In relation to this: maybe a word can be said (here, or in section 5) to why the COMSOL simulations give a better match to experiment as opposed to theory? (or perhaps I misunderstood and the large deviations from theory only occur in close vicinity of the MTBs, not far away as in Fig. 7).

Response:

- Two sentences and one reference have been added to the conclusions. One points out that load reflections have been invoked to explain higher losses in previous experiments; the second (and the reference) points out that the load reflection coefficients are similar to those expected for the ITER Upper Launcher.
- The words "thermal" and "enhanced" have been added in the first sentence of section 5 to clarify that COMSOL is not used for RF simulations - only the heat transfer part: as stated, the heat flux is applied to match the temperature measurements. It is not the theoretical value of heat flux.