**Response to Referees‘ Comments on RSI: RSI25-AR-01434R**

Title: Optimization and Active Stabilization of a Far-Infrared Laser for NSTX-U High Poloidal WavenumberScattering Diagnostics

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We very much appreciate the referees’ comments and suggestions which obviously improve the quality of our manuscript. The manuscript has been revised accordingly. Below, we have provided details on our response to the referees. *The text in blue is our reply*, and *the text in red is what is added/modified in the revision.*

**Reviewer: 1**

Comments to the Author

1. Page 3: "A dielectric-coated silicon wafer optimized for dual functionality, while achieving 98% transmission in the FIR range and reflecting 99% of the incident CO2 laser radiation". Please consider to give more information about the structure of this part of the laser as could be expected from a scientific instrument journal article.

*Response: Thank you very much for your comments. Actually I should refer this sentence to the paper :”* *Development of Laser Based Plasma Diagnostics for Fusion Research on NSTX-U” on page 177 and page 178. The detail description of this silicon wafer has added in the paper :”* The silicon wafer is coated with thin layers of germanium and zinc sulfide, forming a high/low refractive index pair. Each layer has a thickness equal to one-quarter of the CO₂ laser wavelength in its respective medium, which enhances the reflection of the CO₂ laser. Meanwhile, the transmission in the FIR range is strongly influenced by the thickness of the silicon wafer due to coherence effects.*”*

1. Page 4: In the first paragraph the feed-in description is not very clear. It seems that the 1m focal length lens focuses the beam through the input coupler, consisting in a metal mirror with a hole in the center but the sentence describes a lens for collimation. In figure 4, it is mentioned a "focus lens". This should be re-arranged in order to be more coherent. Another point is that the laser waveguide is not described : the material and dimensions are important to understand the system and to interpret the beam profiles presented later.

*Response: Thank you very much for your comments. This focus lens is used to both focus the beam size so the beam could shine into the center hole of the metal mirror. Beside this, I also add an description about the cavity of the waveguide in the page 3 as :”* These optical elements are housed within the FIR laser system, forming the complete resonant cavity structure in the laser cavity waveguide. The waveguide consists of a borosilicate tube approximately 62 inches long with an inner diameter of 1.5 inches, surrounded by an outer water-cooling tube with a diameter of 2.375 inches to dissipate heat generated by the CO₂ laser.*”. I have rephrased the sentence to avoid the confusion:”* Inside the input window, as shown in Fig. 3, a rear mirror with a 4 mm-radius central aperture is positioned adjacent to the FIR input window. A focusing lens with a 1 m focal length is used to reduce the beam radius, creating a narrow waist near the input window. This allows the CO₂ beam to pass through the copper mirror via the central hole and then expand within the cavity. As illustrated in Fig. 3, the beam continues to expand during reflections between the two mirrors inside the cavity. This configuration enables controlled beam expansion within the FIR cavity while minimizing back-reflected power that could disrupt CO₂ laser stability..*”*

1. Page 7: "...marked as # 1)". These sentence seems to refer to Fig. 7, please add "Fig. 7".

*Response: Thank you very much for your comments. I have added the Fig.7 in the sentence.*

1. Page 7: First paragraph: the dielectric-coated silicon wafer in the described again, please refer to the description of page 3.

*Response: Thank you very much for your comments. I have referred to the description of page 3 for this sentence.* The front mirror (designated as # 2 in Fig. 7), which is also shown in Fig. 3, is used to couple the FIR and CO₂ wavelengths.

1. Page 11: First paragraph, some aspects like the feed-in system has already been described before. Third paragraph: "As demonstrated in Fig. 9, ": It seems that the sentence refers to Fig. 10.

*Response:* Thank you very much for your comments. I referred back to the feed-in system simply to summarize the work we have done to improve the coupling coefficient. Regarding the third paragraph, it actually refers to Fig. 10. Thank you for pointing that out!

1. Page 12: The figure obtained in figure 12 is clearly periodic with a FIR half-wavelength period as expected (upper figure). It is less obvious for the bottom figure, perphaps a Fourier transform could be used to visualize more clearly the different periodicities that are probably present. When the cavity length changes (which optics is really moving ?), it changes also the feedback to the CO2 laser changing potentially the pumping conditions. So the behaviour could be more complicated than a simple Fabry-Perot cavity, more cavities can be involved.

Response: Thank you for your insightful comments. We agree that the bottom figure in Fig. 12 shows less obvious periodicity. Applying a Fourier transform is indeed a good suggestion, and we will consider this approach to better visualize the different periodicities present. Regarding the cavity length changes, it is primarily the metallic mesh and front mirror (as shown in Fig.3, which both are on the translational optical platform) that moves, which also affects the feedback to the CO₂ laser and can modify the pumping conditions. We acknowledge that this makes the behavior more complex than a simple Fabry-Pérot cavity, and it is possible that multiple cavities are involved in the observed response, which causes the structure of CO2 laser intensity during scanning the cavity. I have added the description for the optics movement: Both the metallic mesh and the front mirror are mounted on translational optical stages along the waveguide axis, allowing the cavity to be adjusted by moving the two optics using stepper motors.

1. page 13: "without compromising system performance": a few lines below, the authors mention that this improvement comes at the cost of reduced FIR power, it is not fully coherent. This part could be re-written to be more clear. It could be also mentioned that the increase of formic acid pressure increases the absorption of the pump beam and thus reduces the amplitude of the standing waves resulting in a smoother curve when the cavity length is scanned.

Response: Thank you very much for your valuable suggestion. We agree that this part was not fully coherent and have revised the text for clarity. As you suggested, we have modified the explanation as follows: increasing the formic acid pressure enhances the absorption of the pump beam, which reduces the amplitude of the standing waves and results in a smoother curve when the cavity length is scanned.

1. Page 17: A part of reference 24 is missing.

Response: Thank you for your comments. Actually, the reference 24 is related with Page 2 on the first sentence: The system utilizes an optically pumped far-infrared (FIR) laser with formic acid (HCOOH) vapor serving as the gain medium. It is pumped by a 150 W CO₂ laser operating on the 9R20 line (wavelength = 9.27 μm), which drives rotational transitions to generate the 693 GHz FIR signal [24].

**Reviewer: 2**

Comments to the Author

1. The manuscript is mostly clear, but a few grammatical errors and awkward phrases could

benefit from proofreading. Examples: “Mythology” should be corrected to “Methodology” in the

author's contributions

Response: Thank you for your careful review and helpful comments. We have carefully proofread the manuscript and corrected the grammatical errors and awkward phrases. Specifically, “Mythology” has been corrected to “Methodology” in the author contributions section.

1. The power stability improvement after feedback activation is shown qualitatively, adding

RMS fluctuation or standard deviation values would strengthen the claim.

Response: Thank you for your valuable suggestion, here I have added the description as fellow: As shown in Fig. 14, without auto-adjustment, the output power decreases to zero within 4 minutes, whereas with auto-adjustment, the output remains in the range of 75% to 100% over an extended period.

1. The paper could be strengthened by comparing the proposed FIR laser system to other

diagnostic approaches (e.g., microwave or other laser-based systems) in terms of performance,

cost, or complexity. This would better highlight the system’s unique advantages

Response: Thank you for this valuable suggestion. We agree that including a comparison with other diagnostic approaches would strengthen the paper. In the revised manuscript, we have added a brief discussion comparing the proposed FIR laser system with microwave- and other laser-based systems in terms of performance to better highlight the unique advantages of our approach.

This capability enables comprehensive coverage of the predicted electron temperature gradient (ETG)[[15](#_ENREF_15)] and other electron-scale turbulence spectra. Compared to millimeter-wave diagnostics[[16-23](#_ENREF_16)], laser-aided diagnostics provide enhanced spatial resolution and wider wavenumber range and also simplifying optical alignment duo to low refractive effect compared to 270/280 GHz high k scattering system(ref1.Development and preliminary results of 270 GHz microwave forward scattering diagnostic system on the experimental advanced superconducting tokamak (EAST) ,ref2.Microwave scattering system design for scale turbulence measurements on NSTX).

1. The font size of Fig. 9e is too small. Please replace it with a bigger font size.

Response: Thank you for this valuable suggestion. We have modified the figure with bigger font size.

