**Response to Referees‘ Comments on PST-2025-0163**

Title: **The High-Q Approach Notch Filter Design for 60 GHz Collective Thomson Scattering System**

﻿Authors: ﻿ Chen LUO (罗辰), Peng SHI （石鹏）, Xiaoliang LI（李小良）, Yilun ZHU (朱逸伦), Shasha QIU, Logan HIMES, Neville LUHMANN Jr.

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 red is our reply*, and *the text in blue is what is added/modified in the revision.*  
  
**Reviewer: 1**

Comments to the Author  
I am pleased to review this manuscript on millimeter-wave technology development for fusion diagnostics. The authors’ focus on collective Thomson scattering (CTS) is particularly commendable, as it is a key diagnostic tool for burning plasmas. As highlighted in the manuscript, a major challenge in CTS diagnostics is the interference caused by high-power (MW-level) incident millimeter waves, which can disrupt scattered signal detection and even risk damaging sensitive receivers. The notch filter proposed by the authors addresses an urgent need in the field, offering a promising solution to mitigate these issues.   
  
A key innovation of this work focuses on the improvement of the notch filter’s quality factor (Q). As the authors note, CTS-compatible notch filters must simultaneously achieve a narrow notch bandwidth and a wide pass bandwidth, as a challenging trade-off. Additionally, manufacturability and high production yield are critical for practical deployment. The authors address these challenges by optimizing cavity dimensions to balance performance requirements. Compared to the fabrication approach described in Himes, Logan, et al. (Journal of Instrumentation, 2024), the proposed design demonstrates lower fabrication complexity and higher robustness, reinforcing its feasibility for real-world implementation. This work presents a timely, innovative, and well-executed solution to a pressing diagnostic challenge in fusion research. The methodology is sound, the design is practical, and the findings hold significant reference value for the field. I enthusiastically recommend this manuscript for Accept after minor revisions.  
  
1. The manuscript provides a clear description of the 60 GHz CTS system structure, but the origin of the scattering spectrum bandwidth is not explicitly discussed. If this has been addressed in prior literature, a brief citation and discussion would strengthen the background. Alternatively, if this is based on the authors’ calculations, including the estimation method and key results (e.g., theoretical assumptions, numerical models, or experimental benchmarks) would enhance reproducibility and reader understanding.

*Response: Thank you very much for your comments.*

2. Section 3 directly presents the high-Q design without outlining the progression from lower-Q or intermediate-Q configurations. While not strictly necessary, a short discussion on the rationale for selecting the final Q-factor (e.g., trade-offs between notch depth, bandwidth, and fabrication constraints) would make the optimization process more transparent and educational for readers.

*Response: Thank you very much for your comments.*

3. The proposed filter employs 4 cavities, whereas recent work (e.g., Qiu et al., RSI 2024) utilizes 8 cavities for similar applications. Could the authors briefly clarify the motivation behind this difference?

*Response: Thank you very much for your comments.*

**Reviewer: 2**

组件，能够有效提升CTS 接收信号的信噪比并抑制无效信号，同时起到保护探测系统的作用，对发展稳定可靠的CTS 诊断系统非常重要。针对原稿，主要提以下几个问题和建议：  
1. CTS 在国内外装置上主要应用于电子密度扰动的测量比较多，但应用于测量ion temperature, velocity distribution 较少，专业性更强，建议作者在文中适当的地方增加一点这方面介绍。

*Response: Thank you very much for your helpful suggestions. The related expression has been added in Section I as below.*

*The millimeter-wave Collective Thomson Scattering (CTS) diagnostics[25] is an essential system for probing burning plasmas in current experimental fusion devices, as shown in Fig. 1. By analyzing the Doppler-shifted spectrum of scattered millimeter-wave signals, CTS provides access to both electron density fluctuations and ion kinetic properties. The spectral width and asymmetry encode information about the ion temperature and velocity distribution: thermal broadening reflects the ion temperature, while frequency shifts relative to the probing wave indicate bulk plasma flow. In addition, modifications of the spectral shape by energetic ions enable the study of fast-ion dynamics. Compared with density fluctuation measurements, however, extracting ion temperature and velocity distribution is significantly more demanding, requiring higher spectral resolution, accurate calibration, and effective suppression of stray radiation. Despite these challenges, CTS remains a powerful non-invasive diagnostic for magnetically confined plasmas such as tokamaks and stellarators, supporting studies of energy confinement, transport processes, and fast-ion behavior.*

2. 文中提到的CTS 系统中，作者提到以前采用了传统的滤波技术，offering 60 dB attenuation at the gyrotron frequency...作者重点工作是设计了新颖的Notch Filter，请问新颖点体现在哪些地方或主要是原有结构上的一个改进提升？为什么以前的fiter设计方式仍可以应用于CTS 测量？建议作者在文字逻辑上再阐述清楚一些。

*Response: Thank you for your valuable comment. The previously adopted quasi-optical frequency selective surface (FSS) notch filters indeed provided sufficient attenuation (∼60 dB) at the gyrotron frequency, and thus they can still be applied in CTS measurements. However, they suffer from several drawbacks when used in next generation burning plasma devices, such as relatively large size, complicated installation, high fabrication difficulty at higher frequencies, poor thermal robustness, and noticeable insertion loss.*

*In contrast, the waveguide-type notch filter developed in this work offers several advantages:*

***(1) Compactness and Integration:*** *The waveguide filter can be directly installed between the receiving feedhorn and the semiconductor receiver circuit, ensuring compact integration into the diagnostics receiver system.*

***(2) High Selectivity with Low Insertion Loss:*** *Benefiting from strong electromagnetic confinement in the waveguide, the filter exhibits lower insertion loss and higher frequency selectivity, which are critical for high-resolution spectral measurements in CTS.*

***(3) Greater Power Handling Capability:*** *The waveguide structure provides higher tolerance to stray high-power radiation compared with quasi-optical filters, enhancing the robustness and reliability of the receiver system.*

*Furthermore, through careful optimization of the filter geometry, we achieved a high-Q response near 60 GHz, which is particularly important for precise ion kinetic measurements with CTS. This waveguide-based approach not only addresses the limitations of quasi-optical filters but also provides a more robust and scalable solution for future fusion diagnostics systems.*

*The related expression has been revised in Section I.*

*Frequency-selective surface (FSS) quasi-optical notch filters have been previously deployed, offering about 60 dB attenuation at the gyrotron frequency [26]. Such filters are still applicable to CTS measurements, but they suffer from several drawbacks, including relatively large size, complicated installation, high fabrication difficulty at higher frequencies, limited thermal robustness, and noticeable insertion loss. To address these issues and meet the demands of future fusion pilot plants, a newer waveguide-based notch filter approach [27][28] is being developed as an alternative. The waveguide design provides superior protection and compact integration, with advantages of high fabrication yield, low insertion loss, and greater tolerance to stray high-power radiation. This filter, designed for a V-band (55–65 GHz) plasma diagnostics receiver module, exhibits strong rejection near 60 GHz, is compatible with WR-15 standard waveguides, and can be directly installed between the receiving feedhorn and the semiconductor receiver circuit. Furthermore, by optimizing the filter geometry, a high-Q response is achieved, which is particularly important for precise ion kinetic measurements with CTS. These innovations improve both reliability and integration, providing a more robust solution for high-resolution measurements in next-generation fusion experiments.*

3. 作者采用了新颖Notch Filter 设计，建议作者增加介绍一些该设计的理论知识依据，以增加文章内容的饱和度，不然全文仅针对CTS 系统设计了一个组件和开展了模拟分析，感觉文章的深度不够。  
4. 文章总体上基于CTS 诊断需求，设计了Notch Filter，主要对设计结构开展了一些模拟分析和结果展示，缺乏实验数据验证（换言之，读者怎么相信你的模拟结果和设计结构就是最优和可靠的？）。建议作者可以增加一些模拟对比分析结果，比如作者最终选用的是8级结构，为什么不选择6 级或者10 级？可以模拟不同级数的Notch Filter 结构，进行对比图展示，这样内容更充分和饱满。  
5. 作者通过分析与计算，最终确定了适用于CTS 的滤波器组件结构的尺寸参数，全部嵌套在文字语句中不清晰。建议作者把文中涉及到的重要设计参数尺寸之类的整理出来，做成表格展示，方便读者查看和借鉴。  
6. 图2 展示地有点简单粗糙，建议完善，可以把装置结构等多做些标记，同时把CTS 结构体现地更清楚明白一些，帮助读者理解CTS 在装置上的真实结构。