Optimizing Beam Profiles for FIR Lasers: Challenges and Solutions

Introduction

Electron turbulence is crucial in tokamak research because it significantly impacts the energy transport within the plasma, often contributing more than ion turbulence, and directly affects the overall efficiency of fusion reactions by causing significant heat loss through the rapid movement of electrons within the plasma1. understanding and mitigating electron turbulence is key to achieving successful fusion in a tokamak device. The high-k scattering system is using a scattering process to measure small-scale fluctuations in plasma density. As the high-k wave launch into plasma and receive the scattering signal from special angle, the fluctuation intensity could be determined where the fluctuation wavelength satisfies the Bragg condition k = 2kisin (), here k is the fluctuation wavenumber, ki is the incident wavenumber, and θs is the scattering angle between the incident beam path and the receive beam path.

A 693 GHz poloidal high-k𝜃 scattering system, being jointly developed by the Princeton Plasma Physics Laboratory (PPPL) and the University of California at Davis (UC Davis), is targeted to study predicted ETG modes with improved k𝜃 range and resolution. The source of the scattering system is an optically pumped far-infrared (FIR) using formic acid (HCOOH) vapor, pumped by a 150 W CO2 laser at the 9R20 line. The CO2 laser with 9.695um wavelength is focused in the FIR system and stimulated 693 GHz signal from HCOOH vapor. The output laser of the FIR is then coupled into the waveguide and transmitted to the launch optics to minimize attenuation. The launch optics are used to adjust the launch beam angle to meet different measurement requirements. The key point here is that the FIR beam should have a Gaussian profile for maximum coupling with the waveguide. The FIR system contains different types of mirrors for wave resonance, which mainly include copper mirrors with a hole in the center, mesh grids, and dielectric wafers. The beam profile is highly sensitive to the angle of the mirrors in the FIR system; even a slight change of 0.1° can significantly alter the beam shape. However, the adjustment of mirrors in the FIR system is rarely discussed in the literature and is not yet sufficiently developed for practical applications. In this paper, we will present a method for mirror adjustment, demonstrating significant improvements in the beam profile after the adjustment.

Reference:

1: Qi, Lei. "Energy transfer of trapped electron turbulence in tokamak fusion plasmas." *Scientific Reports* 12.1 (2022): 5042.