INTRODUCTION TO SINGLE CRYSTAL DISPERSION INTERFEROMETER (SCDI) AND ITS MEASUREMENT IN KSTAR FOR PLASMA DISRUPTION MITIGATION STUDY

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1. INTRODUCTION

In fusion plasma research, continuous electron density diagnostics in the time domain is crucial, and interferometers are widely used for this purpose. Among them, dispersion interferometers (DIs) have the advantage of using only a single laser while inherently reducing phase signal fluctuations caused by environmental changes. Due to this benefit, DIs are currently in operation or under development in various fusion research devices, including ITER [1], LHD [2], W7-X [3], DIII-D [4], EAST [5] and HL-2A [6]. However, conventional DIs typically require the use of a non-linear crystal (NLC) twice. In the wavelength range commonly used for fusion plasma diagnostic interferometer, NLCs have low efficiency in generating second harmonic beams [7]. As a result, using them twice necessitates a higher-power laser. Additionally, the efficiency of the system is affected by the focusing and alignment of the fundamental beam entering the NLC [6], requiring precise optical alignment. To overcome these limitations, single crystal dispersion interferometer (SCDI), which requires only a single use of the NLC, has been developed and is operating in KSTAR. This presentation will discuss the challenges associated with using NLC in DIs and compare SCDI with conventional DIs used in fusion plasma diagnostics. Furthermore, electron density data obtained from SCDI installed on KSTAR during plasma disruption mitigation studies will be introduced.

2. DRAWBACK OF USING NON-LINEAR CRYSTAL IN DISPERSION INTERFEROMETER

The laser wavelength range used in the DI of fusion devices is generally 9–11 um [1-7]. In this range, the efficiency of generating a second harmonic beam using a nonlinear crystal is low [7], requiring a high-power laser to achieve sufficient output. This can be summarized as follows based on the references.

Laser wavelength	Power of fundamental beam	Power of second harmonic beam	Name of device
10.6um	7W	50uW	LHD [2]
10.6um	20W	Not mentioned in ref.	W7-X [3]
10.59um	27W (before plasma)	50mW	DIII-D [4]
	0.3W (after plasma)	“too small to measure”	
9.3um	15W	138uW	EAST [5]

Table 1. Power of laser beam and second harmonic beam at various dispersion interferometer

Additionally, the efficiency of second harmonic beam generation depends on how the fundamental beam is incident on the nonlinear crystal and how precisely it is focused [6]. Therefore, to obtain sufficient second harmonic beam power, it is essential to maintain precise optical alignment.

3. SCHEME OF SINGLE CRYSTAL DISPERSION INTERFEROMTER

Since it is advantageous to minimize the use of NLCs, KSTAR developed a DI that uses a NLC only once and named it the single crystal dispersion interferometer (SCDI). The scheme of the SCDI is as follows.

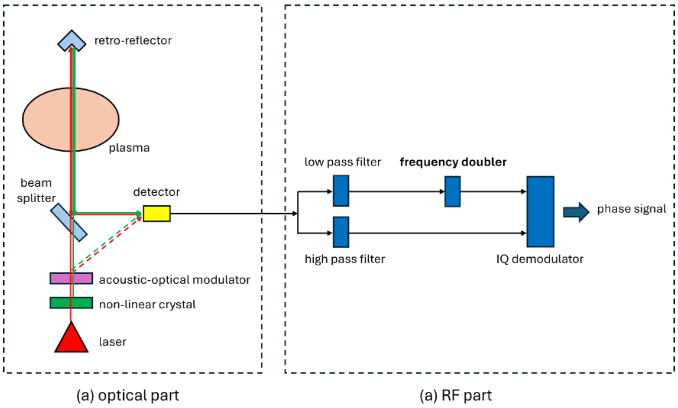

Figure 1 Scheme of single crystal dispersion interferometer

As shown in Figure 1(a), the SCDI uses a NLC only right in front of the laser. And, as seen in Figure 1(b), when processing the signal in the RF circuit, an RF circuit component called a frequency doubler is used. This component replaces the role of the second NLC in other DIs by performing frequency doubling electronically.

4. EXPERIMENTAL RESULT DURING PLASMA DISRUPTION MITIGATION STUDY PLASMA

KSTAR, in collaboration with ITER, is studying the dual symmetric shattered pellet injection effect as part of its plasma disruption mitigation study [8-9]. In this study, the SCDI has been used to measure the abrupt and large change of electron density caused by shattered pellet injection. To reduce the influence of laser beam refraction issues and fringe jump issues, the SCDI employed a 1064 nm wavelength, which is approximately ten times shorter than the wavelength typically used in DIs [1-7]. However, using such a short wavelength makes the system ten times more sensitive to phase signal fluctuations caused by environmental changes. Despite these challenges, the SCDI successfully measured the electron density change induced by shattered pellet injection. In contrast, the two-color interferometer in KSTAR, which uses a 10.6um wavelength [10], failed to measure the electron density in the same shots due to longer wavelength.

5. CONCLUSION

DIs are widely used in fusion research for electron density diagnostics. However, a key challenge has been the need to use a NLC twice. To overcome this, KSTAR has developed and operated a SCDI by replacing the second NLC with an RF component, specifically a frequency doubler. This system has successfully diagnosed abrupt and large changes in electron density for plasma disruption mitigation research.

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