Design of Ultra-fast Charge eXchange Recombination Spectroscopy diagnostic on EAST tokamak

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A four-testing-channel Ultra-Fast Charge eXchange Recombination Spectroscopy (UF-CXRS) diagnostic is under developing on the EAST tokamak and a 128-channel upgraded one will be combined with the existing 128-channel Beam Emission Spectroscopy to diagnose plasma pressure. This diagnostic is based on the active charge exchange to measure ion temperature with a time resolution at the order of μs and a spatial resolution of 1 cm. The main component design and selection together with simulations and test results are presented in this report.

1. Introduction

The insufficient understanding of pedestal physics comes partly from the lack of diagnostic data. Pedestal, which means a sharp pressure gradient in edge plasma, is the most important sign of L-H transition [1,2]. Unfortunately, Langmuir probe[3], the only diagnostic which can measure the density and temperature fluctuations simultaneously, can not intrude into the pedestal area. In recent years, many spectroscopy and microwave diagnostics are developed on EAST and similar tokamaks, such as Beam Emission Spectroscopy[4,5] and Doppler Reflectometer[6]. In the last three year, EAST device has finished developing many sets of Charge eXchange Recombination Spectroscopy diagnostics and caught the radial ion temperature distribution[7]. But the time resolution is limited in the order of several mini-seconds and is not sufficient for pedestal diagnostic. On DIII-D tokamak, Ultra-Fast Charge eXchange Recombination Spectroscopy (UF-CXRS) diagnostic is developed in recent years[8-10], and the ion temperature signal is caught in a time resolution of micro-seconds. In this article, we present the design of this kind of diagnostic on EAST tokamak.

2. Main idea of UF-CXRS

The injected NBI particles will collide with the C6+ impurity particles and exchange charge. The electrons will moved to excited state of the impurity particles and irradiate light

when the particles de-excite to lower state. By means of collecting the irradiated light to the diagnostic system, we can deduce the ion temperature of plasma.

Four trial UF-CXRS channels arranged as a rectangle will be firstly developed in the center area of BES view plane, which has an excellent spatial resolution of about 1 centimeter. By means of adding a dichroic mirror into the BES optical path to induce parts of light into the UF-CXRS system, we can integrate this two diagnostic together. The designed optical path is shown in figure 2. The F number is designed 2.5 and NA number is 0.22. As shown in figure 1, the red, blue and green optical paths exhibit the three status of object plane, which mean three different view plane in the core, in the middle and in the edge.

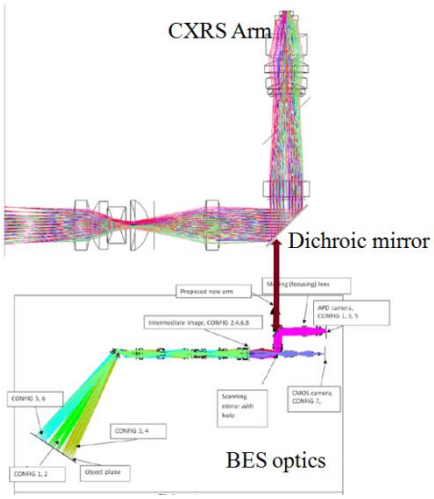

Figure 1, optical path of UF-CXRS.

Fibers are one of the key components of this diagnostic. Fused silica fiber with a core diameter of 0.2mm is chosen as the transmitting component. 39 fibers are compactly arranged as one channel and the occupy rate reaches 0.63. AR coating is coated in the surface to ensure a transmission of higher than 99% in the wavelength of 529nm.

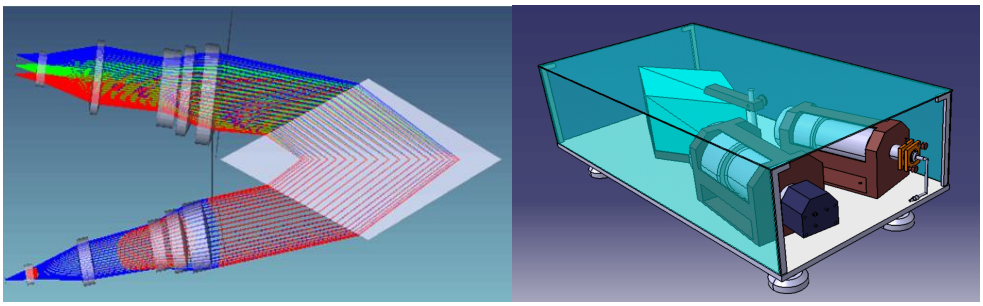

Figure 2, the optical (A) and mechanical (B) design of spectrometer.

Figure 2 shows the optical (A) and mechanical (B) design of spectrometer. The key component of grism grating is composed of three parts, i.e., one VPH volume grating and two grisms. One of this grism is used to make the incident light satisfy Bragg diffraction condition, and the other is used to limit the angle of outgoing light. This spectrometer is design to have a wavelenght range of 529±3nm. The grating efficiency for the working spectral ranges is higher than 90%. The F number is 2.74. The spectral resolution is about 0.23nm which determines the minimum of the diagnosed ion temperature of 0.38kev. The magnification of this machine is designed of 1.12 at horizontal direction and 1 at vertical direction and the image plane size is 18.4×13mm.

Specification	Value
Grating size	100*192mm
Slit size	0.66(H)*13mm(V)
wavelength range	529±3nm
f number and NA	2.74/0.18
Focal Length	200mm
Effective Aperture	73mm(Collimated)； 100mm(Focused)
Angle of view	6°
Resolution	>150lp/mm
Number of elements	5/6
Transmission	~0.90
total length of lens	~260mm

Table 1, the main parameters of lens.

The transmission of the commercial lens which are easily got from Canon or Nikon are about 0.5 because of the many lens. Our diagnostic is only used to transmit the light at a certain wavelength, so we design and fabricate collimated and focused lens for UF-CXRS. The main parameters of these lens are shown if table 1. The MTF comparison of customered and commercial lens are shown in figure 3 (a-c), and one can clearly see that the designed lens under fixed wavelength band is superior to commercial lens.

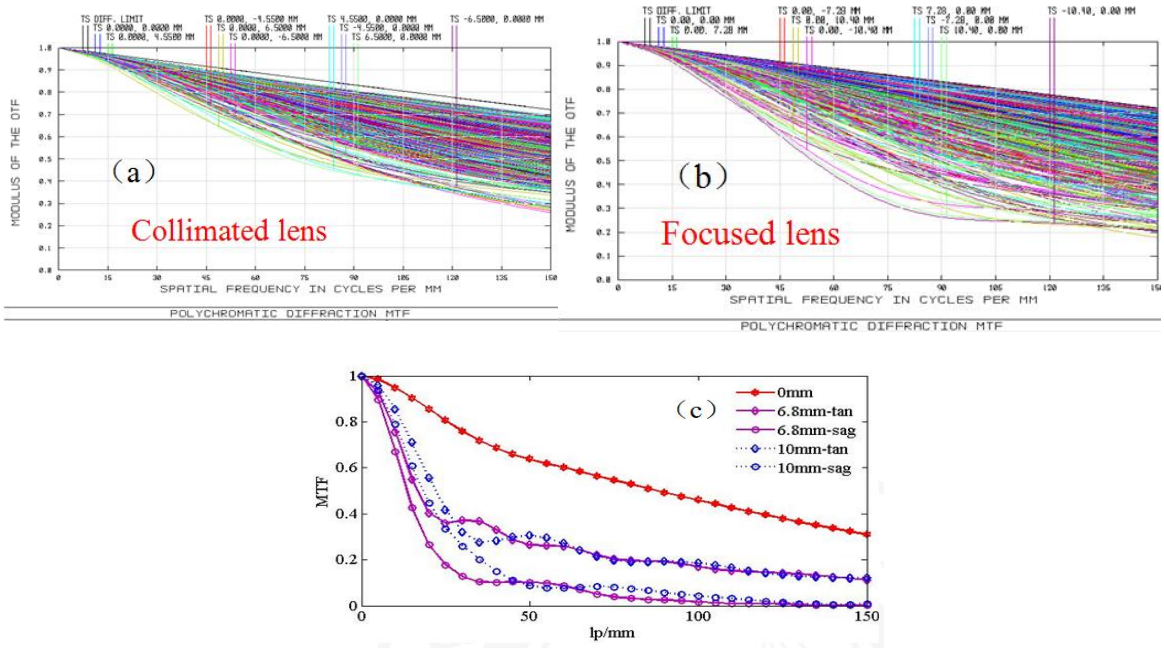

Figure 3, MTF of collimated lens (a) , focused lens (b), and commercial lens (c), respectively.

3. Conclusion

The design of UF-CXRS diagnostic is finished. Four-channel UF-CXRS diagnostic is integrated into the BES system to get the distribution of plasma pressure. It will have a time resolution of higher than 100k and a spatial resolution of 1 centimeter. By means of changing the angle of lens, this diagnostic can cover a view range of from R=1850mm to 2350mm with a minimum ion temperature of 0.38kev.

Acknowledgments

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