Fusion Engineering and Design 174 (2022) 112984

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Fast visible camera diagnostic for dual shattered pellet injections at KSTAR

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A B S T R A C T

Direct imaging from fast visible cameras can provide intuitive information for the detailed dynamics of a fusion plasma. Images with different toroidal positions help our understanding of the 3D structure of the plasma phenomena. Fast-Visible camera (FVC) system was installed in KSTAR to investigate the assimilation process during plasma disruptions induced by Shattered Pellet Injections (SPIs). Since these events are highly non-axisymmetric and good toroidal coverage and high spatial and temporal resolution is required, the field of view of each camera is oriented towards the injection tube of each of the two SPIs, which are located toroidally opposite to each other. To investigate fragment penetration and ablation using images from a FVC, all components of the system should be able to support a fast frame rate due to the speed of shattered fragments of several hundreds of meter per second. The KSTAR FVC system typically uses a complementary metal-oxide-semiconductor (CMOS) with 10,000 frame per second at a resolution of 832 × 600 pixel typically for SPI experiments and its maximum frame rate is up to 600,000 frames per second with 64 × 8 pixels resolution. A hybrid optical system that consists of 2.04 m long relay optics mounted in the viewport cassette and a 4.5 m long imaging fiber bundle secures sufficient distance to reduce the harmful effects on the sensitive fast camera from radiation, neutron impact, and strong magnetic field. This paper reports the installation of the FVC system on KSTAR is introduced and semi three-dimensional observations of disruption mitigation processes during SPIs.

1. Introduction

Simultaneous multiple shattered pellet injection (SPI) is a baseline method of disruption mitigation in ITER for reducing thermal and electro-magnetic loads in addition to the prevention of runaway electrons [1]. However, the feasibility of simultaneous multiple SPIs has not been fully investigated in an exactly symmetric configuration [2]. Recently, geometrically symmetric dual SPIs were installed in KSTAR to verify the feasibility of simultaneous multi-injections of SPIs from different toroidal positions. The installed dual SPIs were operated successfully with promising results for adopting a simultaneous multi-injection strategy in ITER [3].

To understand the penetration and assimilation mechanism of SPI, modeling and simulation studies are accompanying experiments [4–6]. In KSTAR, for better understanding of rapid plasmas termination processes, SPI-specific diagnostics such as fast bolometry and short wavelength interferometry were concurrently installed along with symmetric dual SPIs [7,8]. Multi-view imaging, which visualizes each SPI, provide the distinguishing information of injection timing in dual SPIs and the resulting assimilation process depending on their timing difference [9]. In addition, individual images provide basic information such as a penetration depth and speed of the fragments, which will be utilized in designing the ITER disruption mitigation system.

This paper organized as follows. Section II introduces the dual view fast visible camera systems in KSTAR. Section III describes the specific view for the SPI tubes in detail, and section IV presents the multi-view image measurement for SPI experiments. Finally, section V summarizes the conclusions and analysis plans.

2. Installations of fast visible camera systems

The overall layout of the fast visible camera (FVC) system on KSTAR is shown in Fig. 1. Fig. 1(a) depicts the layout from the top view with the field of view of each camera. As shown in Fig. 1(b), both cameras are biased towards the upper part of the port in order to see the injection tube of SPIs located at the lower part of the vacuum vessel. The fast visible camera system in KSTAR is largely divided into three parts, namely, the cassette with inserted relay optics, the optical imaging fiber bundle, and the CMOS camera with its shielding box. Fig. 2 gives a conceptual diagram of these parts and a detailed image inside CMOS camera shielding box.

The design of cassettes and inserted optics was upgraded from the existing in-vessel imaging system [10] and it was duplicated for dual measurements. The purpose of the hybrid optical system of the cassette

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https://doi.org/10.1016/j.fusengdes.2021.112984
Received 5 July 2021; Received in revised form 7 December 2021; Accepted 9 December 2021
Available online 14 December 2021
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