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Development of a Virtual FVC System and Forward Model for Shattered Pellet Injection Tracking in KSTAR

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In Tokamak devices, plasma disruption pose a critical threat to device integrity, occurring when the plasma loses stability or confinement. As the operating power of Tokamak devices increases, the potential damage from disruptions becomes more severe, making disruption mitigation essential – especially given the expectations for future high-power fusion reactors. Shattered Pellet Injection (SPI) has been adopted as a mitigation technique for such disruptions. Following ITER's decision to utilize SPI, many Tokamak facilities have begun investigating its effectiveness. At KSTAR, SPI has been implemented using two injection ports, and for each port, a single Fast Visible Camera (FVC) is used to monitor the trajectories of injected pellets [1]. However, accurately determining pellet trajectories remains challenging, primarily due to optical distortion introduced by the camera lens system and the fundamental limitation that a single 2D image cannot fully capture 3D motion. To improve FVC image analysis, we have constructed a virtual FVC system within an existing virtual KSTAR environment [2], focusing on reproducing the real camera's field of view and image characteristics including optical distortion. Using this virtual setup, we formulate a forward model of the FVC system to develop an analysis scheme capable of inferring 3D spatial information from 2D images captured by the real FVC. We present synthetic images generated by the forward model and compare them with real FVC image to validate the model and demonstrate its applicability to trajectory analysis.

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