# Schlieren diagnostic for propellant gas flow characterization of Shattered Pellet Injectors of the ITER DMS

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The ITER Disruption Mitigation System (DMS) [1] utilizes Shattered Pellet Injector (SPI) technology [2], for which it is critical that the pellet arrives at the shattering head intact, with minimal propellant gas and debris, injecting solid material into the plasma to maintain disruption mitigation efficiency. The ITER DMS Support Laboratory at the Centre for Energy Research is developing an SPI system [3] to study pellet formation, launch and shattering. This paper studies gas flow during the pellet launch process.

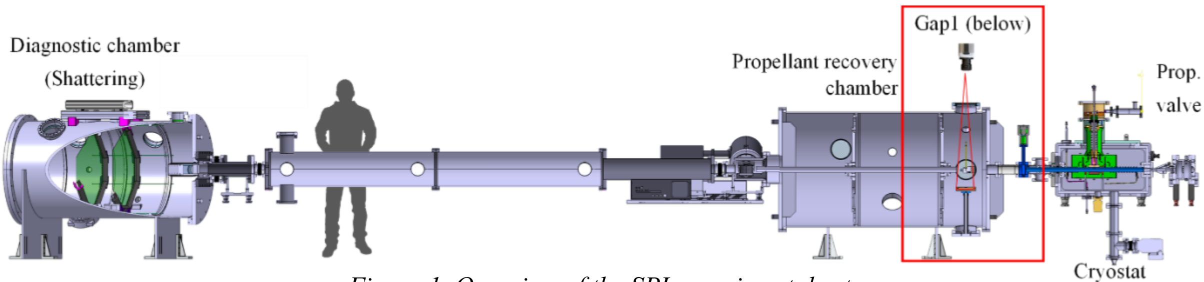


*Figure 1. Overview of the SPI experimental setup*

The overview of the experimental setup can be seen in figure 1. The pellet is formed by cooling a barrel section in the cryostat with liquid He, then injecting gas (H, D, Ne or mixed) into it, which de-sublimates on the barrel surface, and forms a pellet. The pellet is launched with high pressure Hydrogen gas, ejected from a fast valve [4]. There are several gaps in the barrel allowing in-flight observation of the pellet, equipped with optical diagnostics. This work focuses on developing a schlieren diagnostic in gap1.

Schlieren imaging [5] allows the visualization of density gradients in the light path by placing a camera and a small light source in the double focal distance of a spherical mirror. Disturbances of the refraction index in front of the mirror cause slight deviation of the reflected light path which then can be blocked by a knife edge causing intensity variation registered by the camera. We developed and installed a Schlieren diagnostic on our SPI test bench, which is routinely operated and can detect the gas flow around the pellet mid-flight. The principle and experimental setup of the Schlieren diagnostic in gap1 can be seen in figure 2.

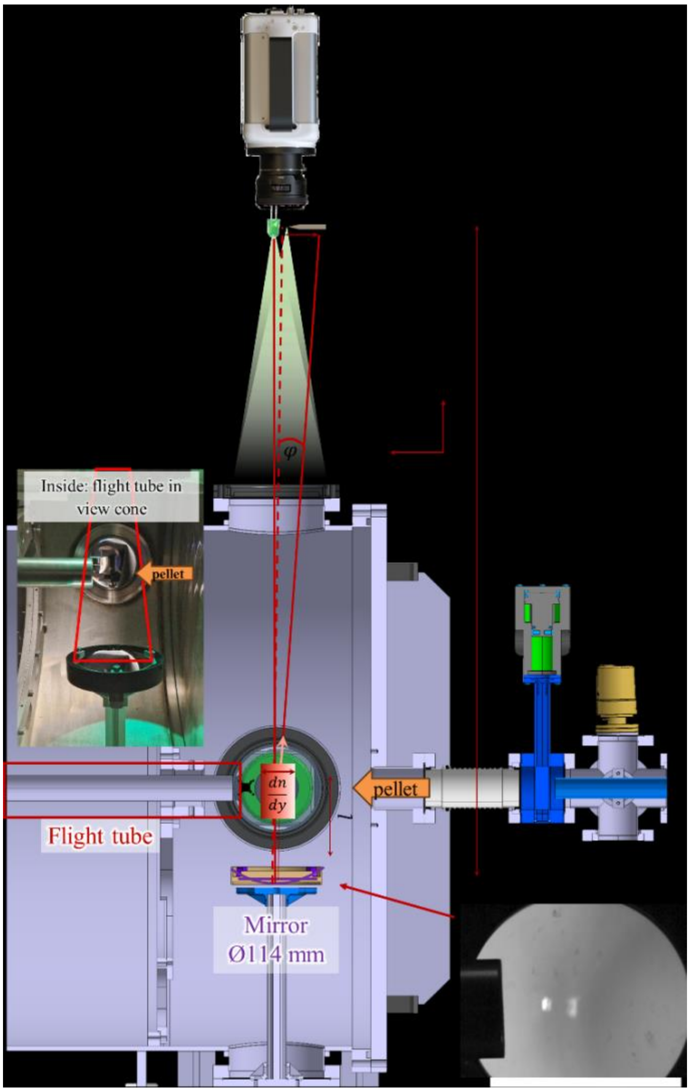


*Figure 2. Overview of the schlieren experimental setup*

*Figure 3. Shockwaves observed at the flight tube*

Shockwaves braking off the flight tube in the field of view are evidence of a supersonic gas flow as shown in figure 3. The case in the larger image depicts an experiment without a pellet, ejecting only propellant gas from the fast valve, while the smaller image within shows a pellet launch case, supplying direct evidence of propellant gas flow well before the pellet. The Mach-number of the shockwaves can be calculated from the slope of the shockwave, which can be used for computational fluid dynamics (CFD) simulation validation.

*Figure 4. Stages of a pellet launch: Hydrogen dust (a), fragments (b) and the pellet with a shockwave (c)*

When looking at a pellet launch process, three phases of the launch can be identified as shown in figure 4. First, a solid hydrogen dust cloud arrives (4a), which is followed by larger hydrogen ice fragments (4b), then the pellet arrives last (4c). The shockwave at the flight tube is formed when the cloud arrives, and remains after the pellet has passed.

Dimension reduction on the motion picture data can depict the entire launch process in one panorama image (figure 5, right), which can be further reduced to a single time series for each pellet launch, allowing the comparison of several launches.