

# Development and improvement of a Blower Gun Pellet Injector for application in thermonuclear fusion devices

## THE BLOWER GUN

For the purpose of plasma fueling and plasma experiments on the new fusion experiment W7-X, pellets consisting of cryogenic hydrogen have to be injected into the plasma. The Blower Gun, which was formerly used as injector at ASDEX Upgrade, was chosen for this task.

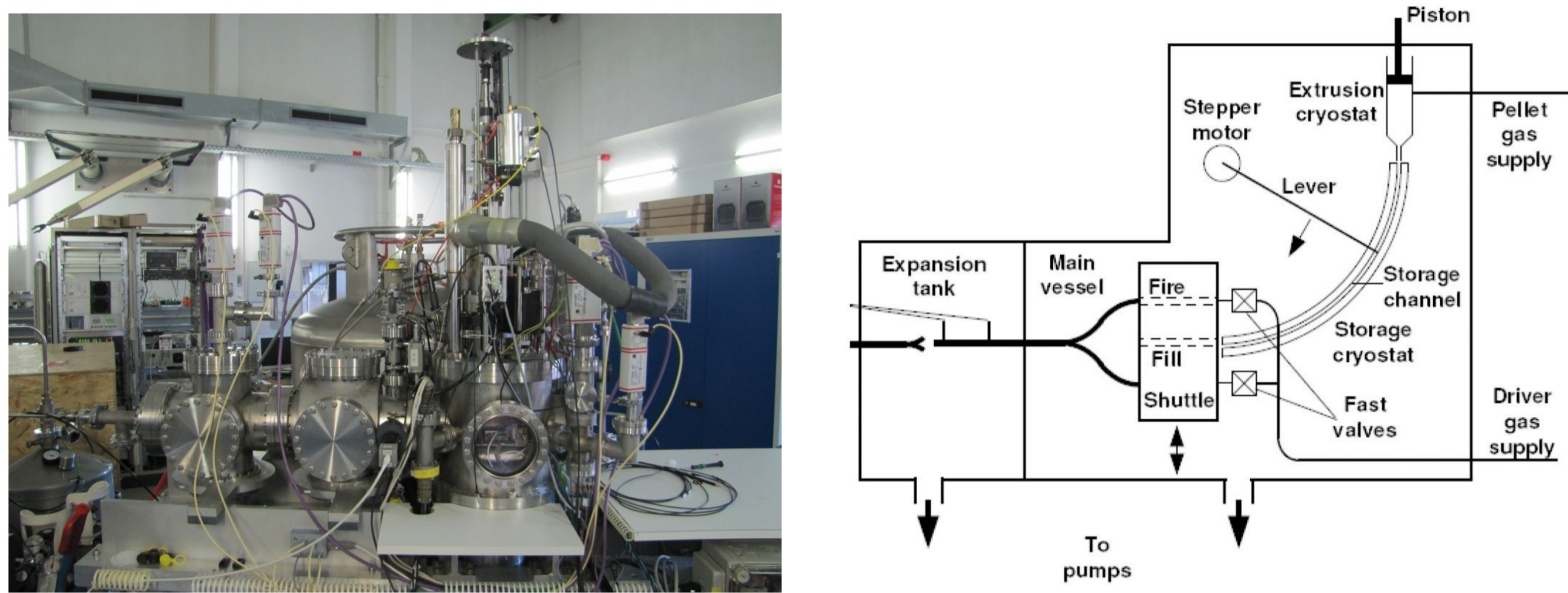


Figure 1: Blower Gun and its principal of operation

- 1) Hydrogen is injected into the liquid helium cooled extrusion cryostat
- 2) A pneumatic piston pushes the ice through a nozzle, forming a cylindrical ice rod with 2mm diameter
- 3) The ice rod is pushed into the liquid helium cooled storage cryostat, where the ice is stored until pellets are requested
- 4) The lever moves into the storage channel, cuts off the ice rod and pushes the ice rod into one drilling of the shuttle
- 5) The shuttle is moved, shearing off a pellet from the ice rod and transporting it in front of a fast gas valve
- 6) The valve is opened and a short pulse of propellant gas (He) accelerates the pellet into the barrel. Simultaneously, the second drilling is filled with ice

The pellets have to fulfill certain requirements in order to be suitable for W7-X:

- Use of hydrogen pellets for the first operational phase
- Fueling size pellets to ensure, that a sufficient amount of hydrogen is deposited in the plasma
- The pellets must withstand the mechanical and thermal stress that occurs in the Blower Gun and the guiding tube, that connects the injector with the plasma vessel

From empirical data and ablation simulations it was determined, that cylindrical pellets with 2mm diameter and 2mm length are suitable. The Blower Gun was modified to create and accelerate these pellets. Afterwards, the injector was equipped with a guiding tube segment, similar to the W7-X system. This setup was tested for different repetition rates, propellant gas pressures and pellet materials.

The pellets were observed using light barriers and shadowgraphy cameras, both before and after the guiding tube segment.

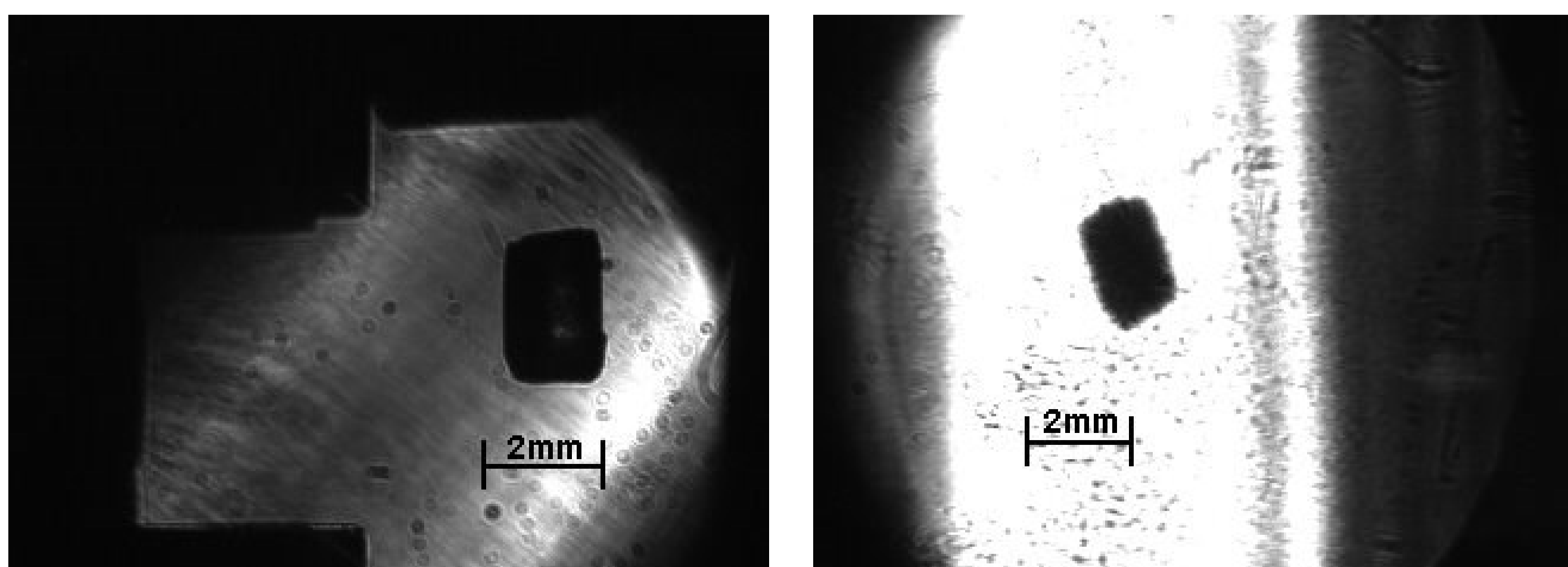


Figure 2: Hydrogen pellet before and after guiding tube (10 Hz, 2 bar)

## PELLET SPEED

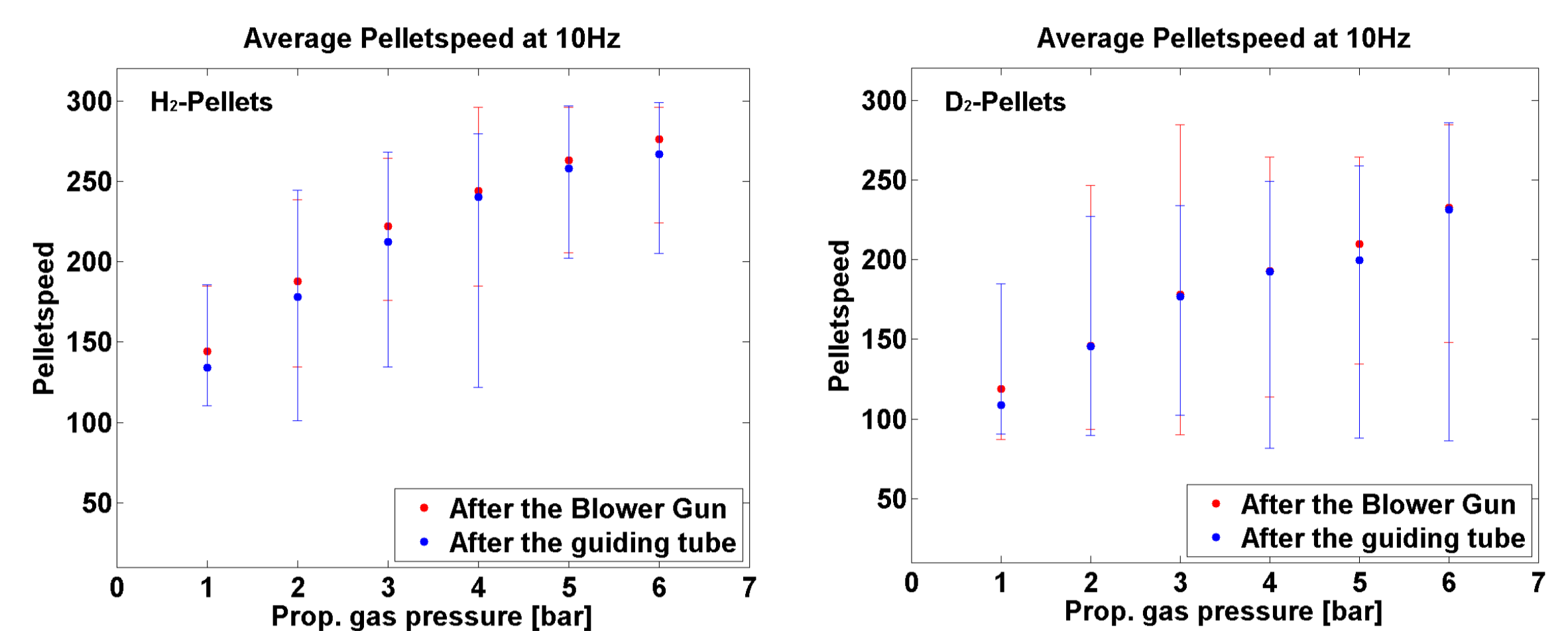


Figure 3: Pellet speeds for hydrogen and deuterium pellets

The pellet is accelerated by friction between its surface and the propellant gas. The speed increases with the gas pressure although the gain at higher pressures decreases. The pellet speeds depend on the pellet material and show a wide scatter due to shallow impacts in the gun barrel. The loss of speed through the guiding tube is minimal.

## TRANSFER EFFICIENCY

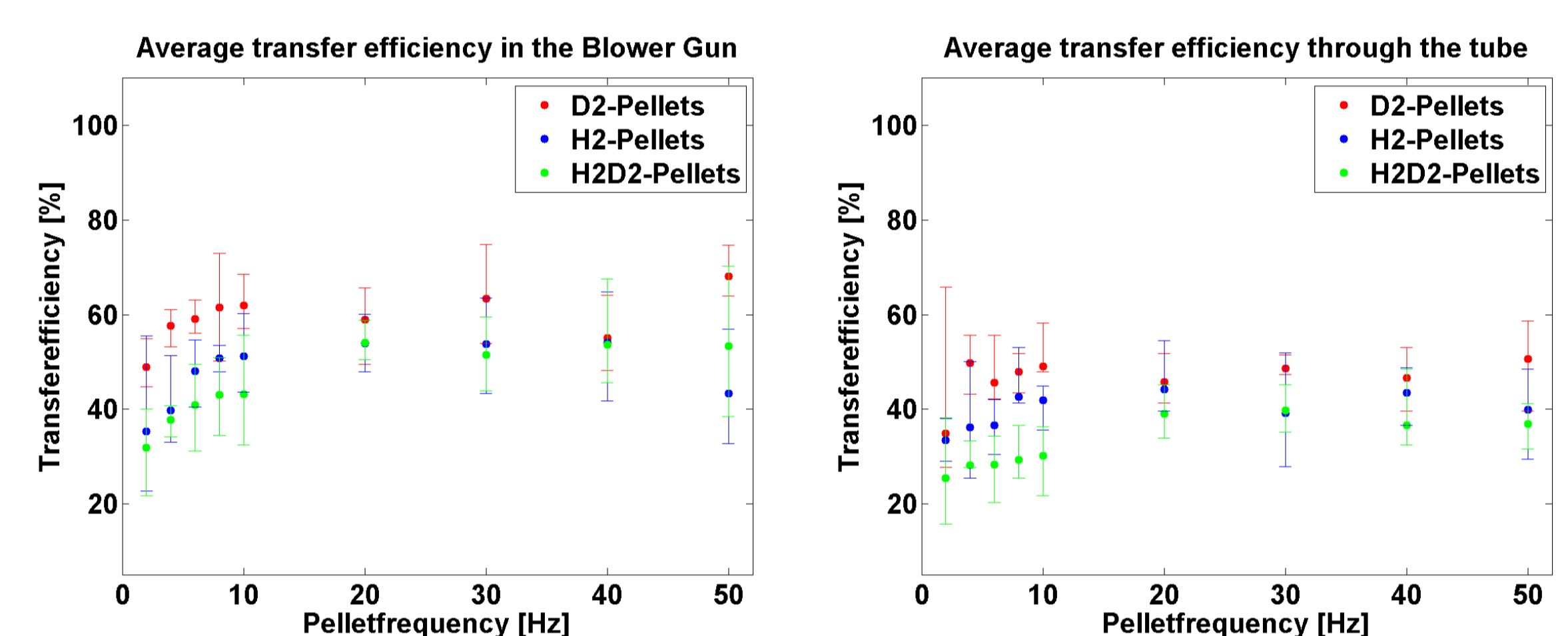


Figure 4: Fraction of remaining pellet mass before and after the tube

The pellets lose between 40% and 60% of their original mass during the acceleration in the injector. This is due to convective heat transfer from the propellant gas to the pellet. The loss of mass is therefore strongly dependent on the propellant gas pressure. An influence of the pellet material was also observed. The loss of mass in the guiding tube is about 10% due to the Leidenfrost effect.

## TRANSFER RATE

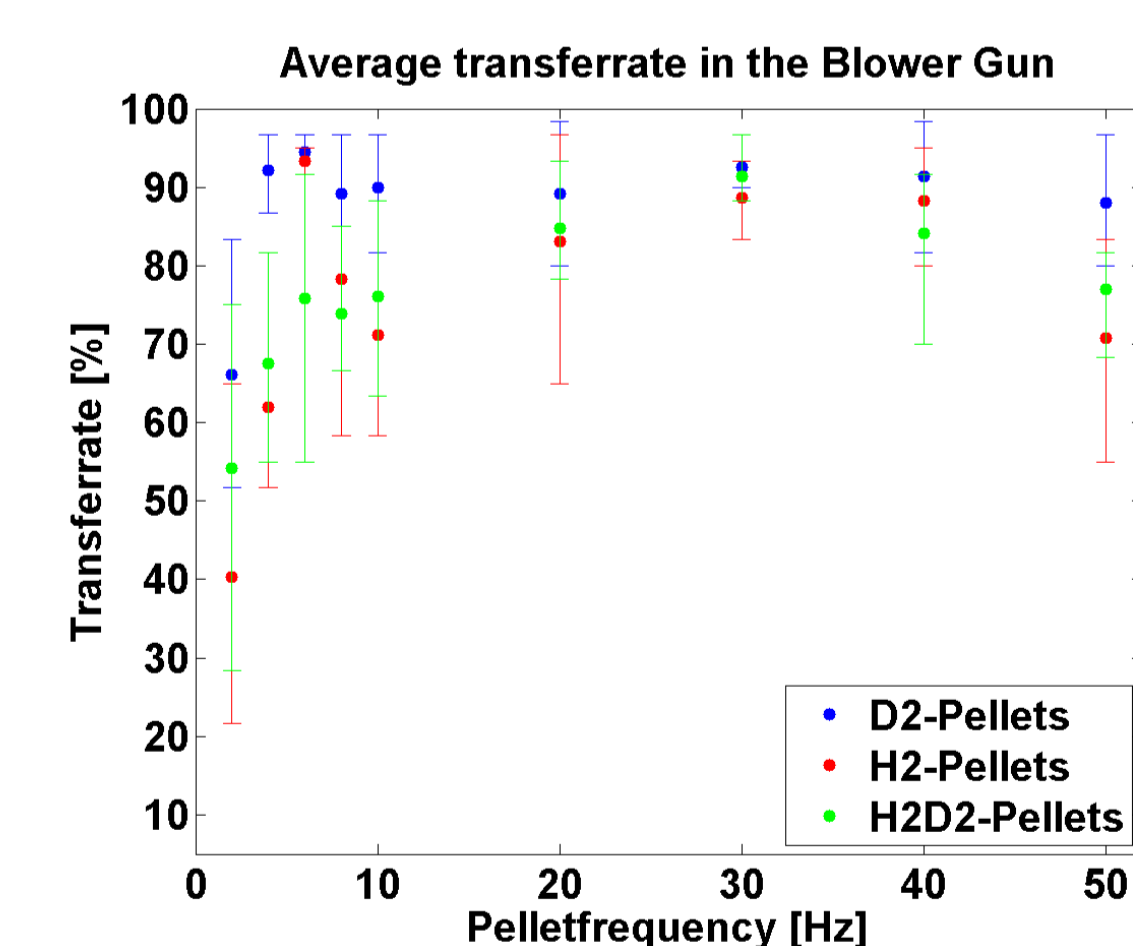


Figure 5: Fraction of remaining pellets after the Blower Gun

Pellets are lost during acceleration due to steep impacts in the barrel. This effect is strong at low repetition rates because of longer melting time near the shuttle and therefore lower pellet quality. The transfer rate through the guiding tube shows the same effect but at overall rates near 100%.

## SUMMARY

The Blower Gun pellet injector meets the requirements for application at W7-X. The planned guiding tube system is suitable for the injector.

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