High Speed Lithium Pellet Injector Commissioning in ASDEX Upgrade to Investigate Impact of Li in an All-metal wall Tokamak

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ABSTRACT

Encouraging results with respect to plasma performance have been observed earlier in several tokamak devices (TFTR, NSTX, etc) when injecting Lithium. Recently, a pedestal broadening resulting in an enhanced energy content during transient ELM-free H-mode phases was achieved in DIII-D. Experiments are also planned at ASDEX Upgrade, aiming to investigate the impact of Li in an all-metal wall tokamak and trying to enhance the pedestal operational space. For this purpose, a Lithium pellet injector has been developed, capable of injecting pellets carrying a particle content ranging from $1.82 \cdot 10^{19}$ atoms (0.21 mg) to $1.64 \cdot 10^{20}$ atoms (1.89 mg). The foreseen maximum repetition rate is about 3 Hz. Free flight launch from the torus outboard side without a guiding tube is envisaged. In such a configuration angular dispersion and speed scatter are low, and a transfer efficiency exceeding 90 % was achieved in the test bed. Pellets will be accelerated in a gas gun; hence special care must be taken to avoid deleterious effects by the propellant gas pulse. Therefore, the main plasma gas species must be applied as propellant gas, leading to speeds ranging from 500 m/s to 800 m/s. In order to minimize the residual amount of gas to be introduced into the plasma vessel, a large expansion volume equipped with a cryopump is added into the flight path. Currently, the injector is under commissioning in a test bed expected to be installed and operational at ASDEX Upgrade by May 2015.

INTRODUCTION & AIM

- Lithium injection has yielded promising results in several reactors, of note lower H recycling and a general pedestal increase, leading to an improved H factor
- An optimal injection rate of **15 mg/s** was found in DIII-D
- Li injection is planned for ASDEX Upgrade for May 2015, with an aim to enhance the operational space for pedestal studies and characterize the use of Li on an all-metal wall device

	DIII-D	NSTX	EAST
Delivery method	Dropper	Inter-shot evaporation, (Dropper)	Dropper, (Morning evaporation)
Pedestal Width	Increased	Increased	?
Pedestal Height	Increased	Increased	?
H-factor	Increased	Increased	Unchanged
Edge fluctuations	Increased	Decreased	Increased
Radiated power	Steady during EF	Ramp during EF	Steady during EF
Effect on ELMs	Delayed	Eliminated	Eliminated
Recycling	Unchanged	Reduced	Reduced

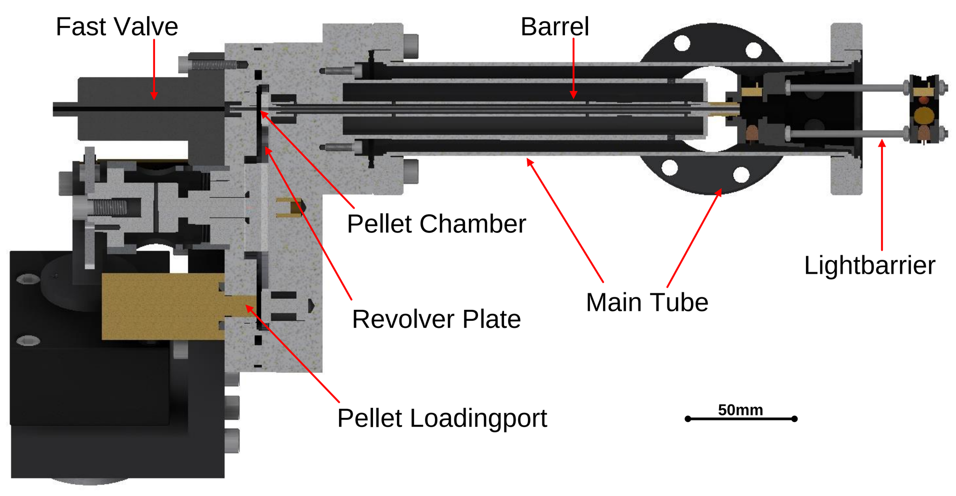
R. Maingi – Effect of Li on DIII-D, NSTX, and EAST
AUG Seminar – 10/24/14

- High-speed mm-sized pellets are planned, as opposed to the previously used µg dust dropper method. Due to the greater penetration, scaling and reduced tungsten wall gas retention rates, an optimal injection rate of **3-6 mg/s** is envisaged

WORKING PRINCIPLE

- Lithium is manually extruded into pellets in the pneumatically-actuated revolving magazine
- Pellets are then accelerated via a gas pulse.
- The main plasma species is used as propellant gas in order to minimize harm to the plasma.
- Pellet speed is measured via two light barriers

The pellets enter the torus in free flight from the outboard side, with a **maximum of 10^{21} Li atoms/plasma discharge** expected



A. Alexiou. Konditionierung und charakterisierung eines modizierten raumtemperatur - festkörper pellet injektors. Bachelor's thesis, Munich University of Applied Sciences, 2011

Pellet sizes

Three pellet sizes are available for testing, with the largest being chosen as most suitable for the injection rate goals

Ø 1.5 x 2 mm	Ø 1 x 2 mm	Ø 0.5 x 2 mm
1.89 mg	0.84 mg	0.21 mg
$1.64 \cdot 10^{20}$ atoms	$7.29 \cdot 10^{19}$ atoms	$1.82 \cdot 10^{19}$ atoms

Magazine size

- 36 pellets / magazine
- 1 magazine / day (manual extrusion)

Approx. 4 plasma discharges at max. Li injection rate per day

Repetition rate

Injection frequency: Currently 1 pellet / 5 seconds

Under improvement

The hard limit is 3Hz (pneumatic actuator feeding frequency)

Transfer rates

1. 94,4% transfer rate (pellets that reach the target/pellets shot)
2. 97% mass transfer efficiency (mass of pellets that hit/expected mass)

Overall transfer efficiency in lab > 90%

Angular dispersion

- Very low angular dispersion, σ<1°

HOWEVER:
Li pellets deform and smear on contact. **No guiding tube can be used** (transfer efficiency drop from 90% to 30%)
Direct free flight launch is required.

ALSO:
Due to the softness of Li, **pellets pose no threat to other reactor components**

Pellet speeds

- Pellet speeds depend on propellant gas species and pressure.
- For Deuterium as propellant gas, speeds of **500 m/s** (20 bar) - **800 m/s** (80 bar) are expected
- Good speed scatter has been measured, σ= 30m/s

Propellant gas flux

- Propellant gas flux is directly dependent on pressure

100 mbar·l (20 bar) → $2.416 \cdot 10^{21}$ atoms/pellet
700 mbar·l (80 bar) → $1.691 \cdot 10^{22}$ atoms/pellet

The effect of the propellant gas flux in the torus will be **sizeable if uncontained**

PROPELLANT GAS FLUX REDUCTION

In order to reduce the incoming propellant gas flux into the torus, several measures have been taken into effect:

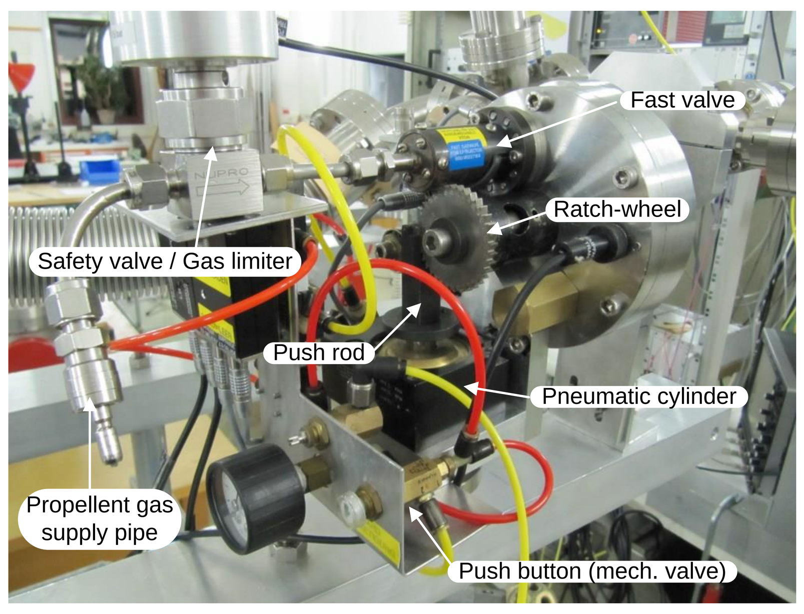
- Low pellet speeds are to be preferentially envisaged, as **low pressures** lead to significantly lower gas fluxes
- An **expansion vessel** has been designed and commissioned, with a turbomolecular pump and additional cryopump supplying **increased suction power** in a volume 30 times greater than the original
- A **nylon aperture** has been included, to further reduce gas inlet

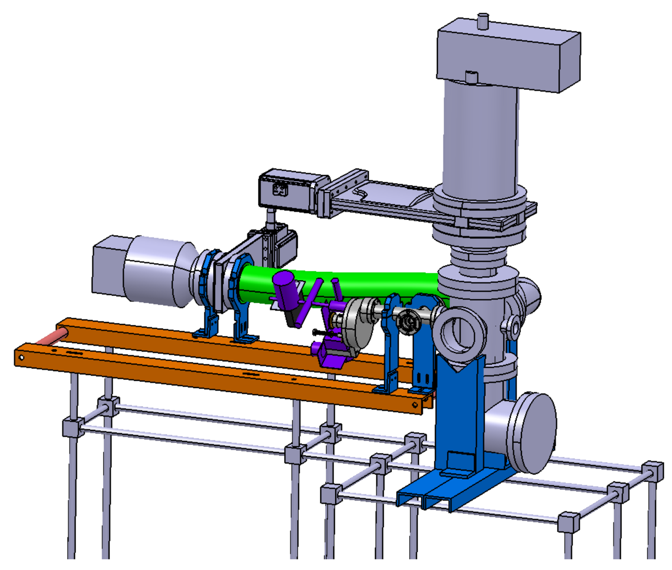
TEST BED CONSTRUCTION AND TESTS

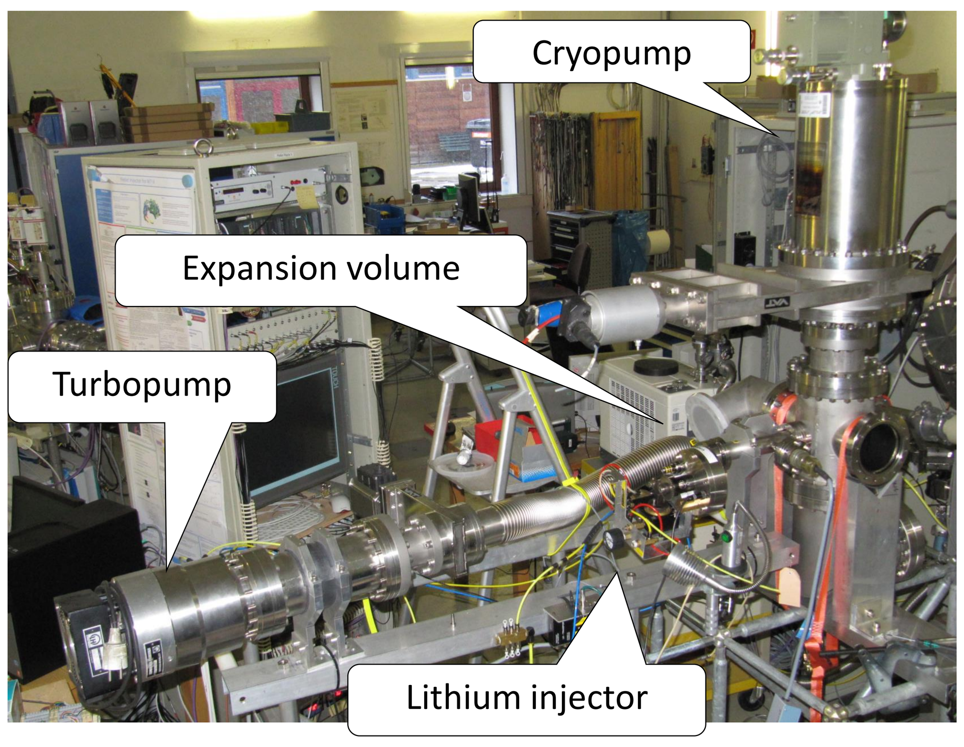
In order to ensure the correct functioning of the machine for use in ASDEX Upgrade, an equivalent setup was installed in a test bed:

The following tests have been performed or are underway:

- Calibration of the lithium injector for all 3 pellet sizes
- Speed and speed scatter measurements
- Reduced propellant gas flux rate measurements
- Gas flux reduction factor calculations
- Angular dispersion measurements
- Transfer rates calculations

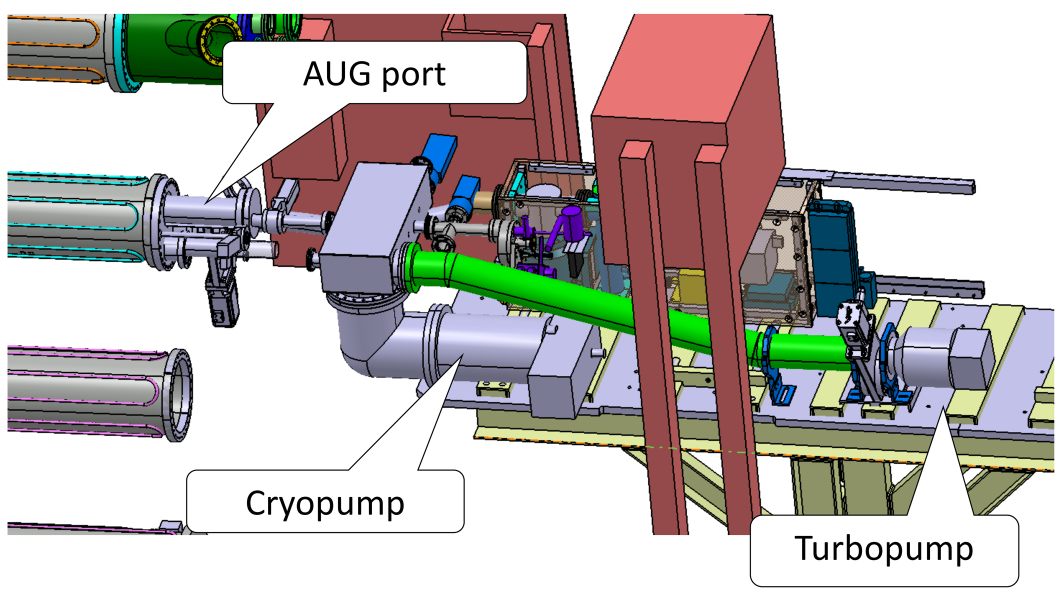


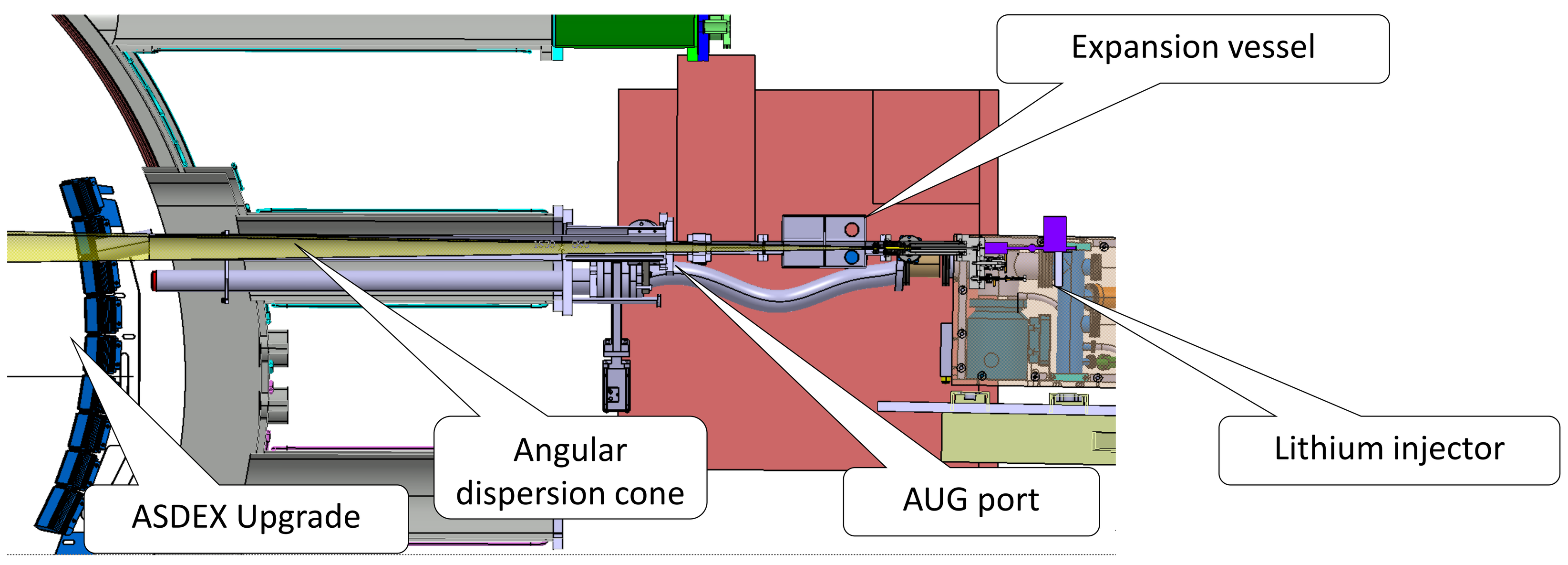




INSTALLATION AT ASDEX UPGRADE

- The Lithium injector is to be installed at ASDEX Upgrade in May 2015
- Experiments will begin in June 2015 for the upcoming Summer campaign
- Port S16 Bo has been chosen for entry, with a direct outboard horizontal line of sight to the plasma center





OUTLOOK & CONCLUSIONS

- The lithium pellet injector will supply ASDEX Upgrade with high speed, high transfer efficiency lithium pellets at repetition rates sufficient to ensure meeting the estimated optimum injection rate
- No guiding tube can be used, but lithium pellets do not pose a threat to reactor components
- Measures are being taken to reduce the propellant gas fluxes entering the torus. A reduction of 30 times the previously measured values is expected
- Torus Hall installation is programmed for May 2015. Experiments are planned for June – July 2015
- Pedestal broadening is expected, thus enhancing the operational space for pedestal studies

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