# $Al\text{-}ZrO_2$ optical coating for ITER First Mirror

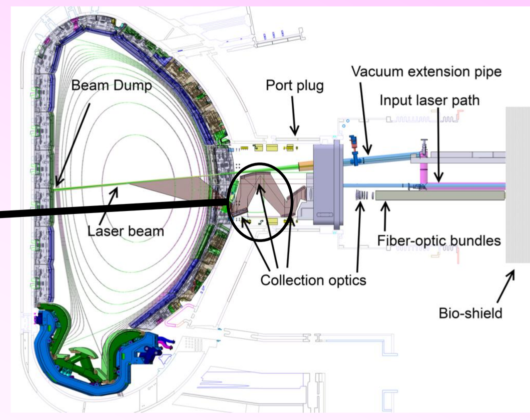
Z. Azdad[a], L. Marot[a], L. Moser[a], R. Steiner[a] and E. Meyer[a]

[a] Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

**P2-012**

## Introduction / Motivation

- Metallic First Mirrors (FMs) will play a crucial role for ITER optical diagnostic systems.
- Example of core LIDAR diagnostic port plugs
  G.A. Naylor et al, 15th International Conference on Laser Aided Plasma Diagnostics, Jeju, Korea 2011

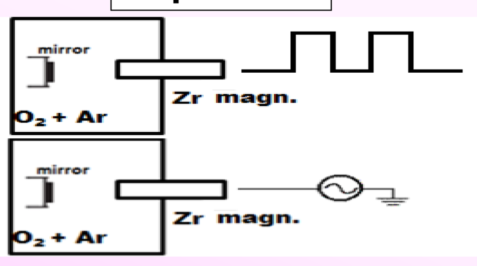



- Being the first element of the optical path, FMs are likely to suffer from erosion and deposition (beryllium, tungsten from the main wall) which can degrade the FMs reflectivity.
- The choice of the material that will be used as a coating for FMs must respect several criteria (high stability under neutron bombardment, high reflectivity in the visible and IR range..). Zirconium is known for being the most radiation-resistant ceramic*. Under this scope it will be tested as a protective layer for Al on Stainless Steel (SS) for the construction of FMs.

* A. Meldrum, L.A. Boatner, R.C. Ewing, Phys. Rev. Lett. 88 (2002) 025503.

## Experimental

**Deposition**

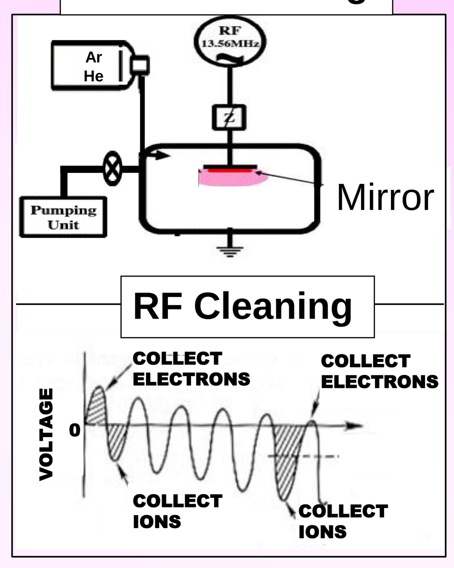



Investigation of the optical and structural properties of $ZrO_2$ deposited under different oxygen percentage was conducted on Si(100) substrate using both Pulsed DC and RF reactive magnetron sputtering.

The best deposition condition of stoichiometric $ZrO_2$ was selected for mirror coating .The coated SS-Al-$ZrO_2$ system was then coated by Al/W and $Al_2O_3$ using pulsed DC technique to simulate the dust deposition in ITER. Al is used as proxy for Be.

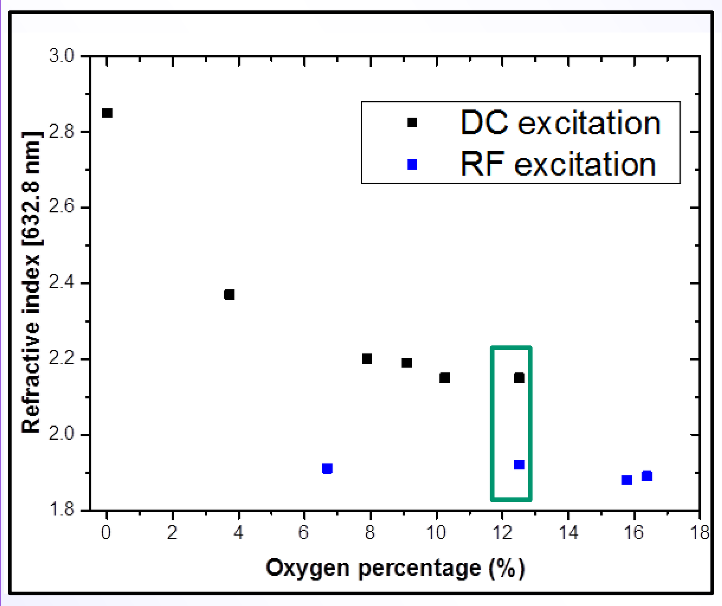
The plasma cleaning was done on Ø 23 mm SS-mirror using a RF generator (13.56MHz). He and Ar were used as sputtering gases. Various self-biases and cleaning times were tested.

**Plasma cleaning**

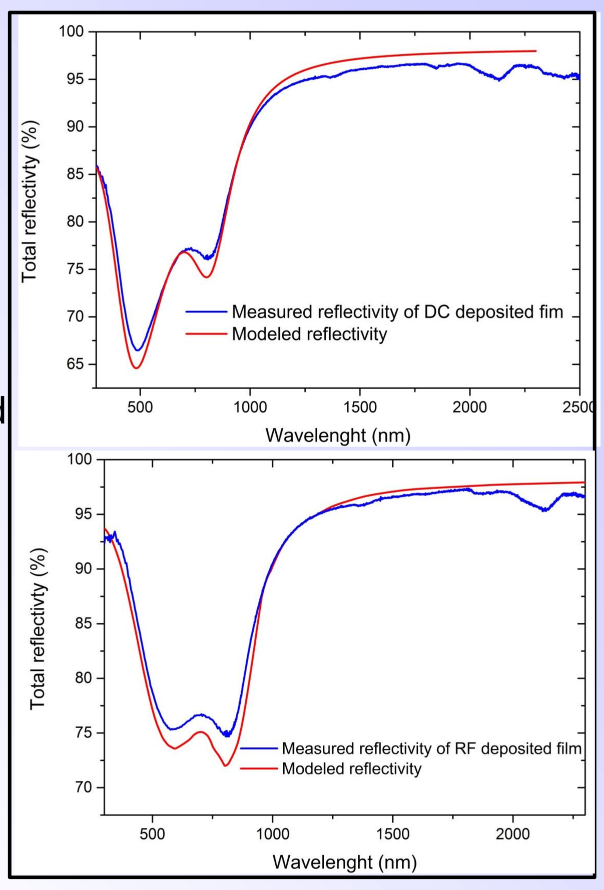



## Optical and structural properties of $ZrO_2$

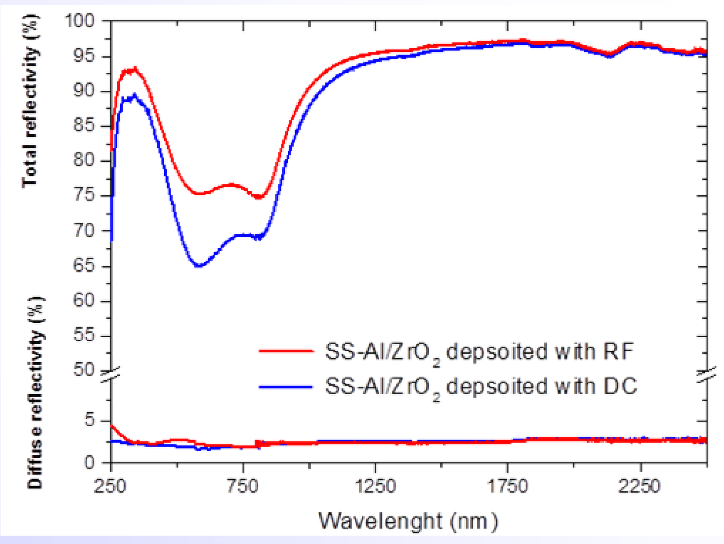
Different films were deposited on Si(100) for different oxygen and argon percentage using RF and Pulsed DC reactive magnetron sputtering. They were all characterized by Spectroscopy Ellipsometry (SE).

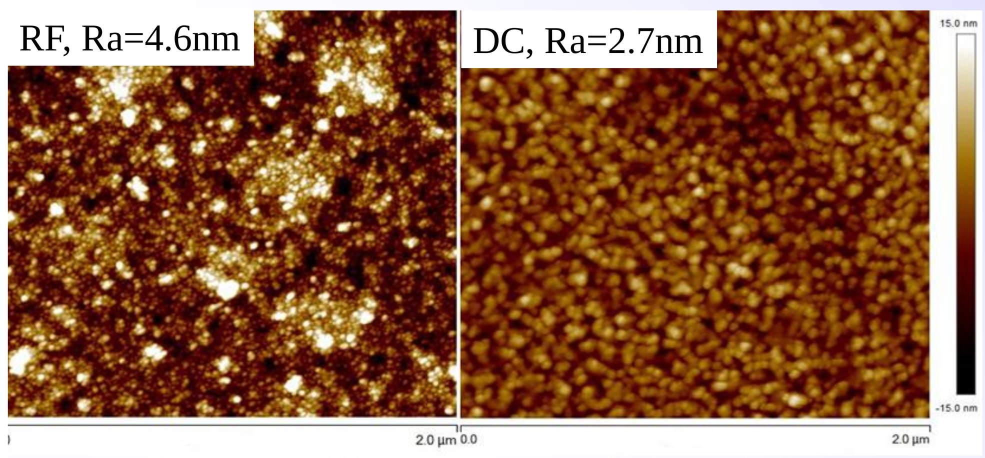



Modeled and measured reflectivity of the Selected $ZrO_2$ coating deposited on Al.

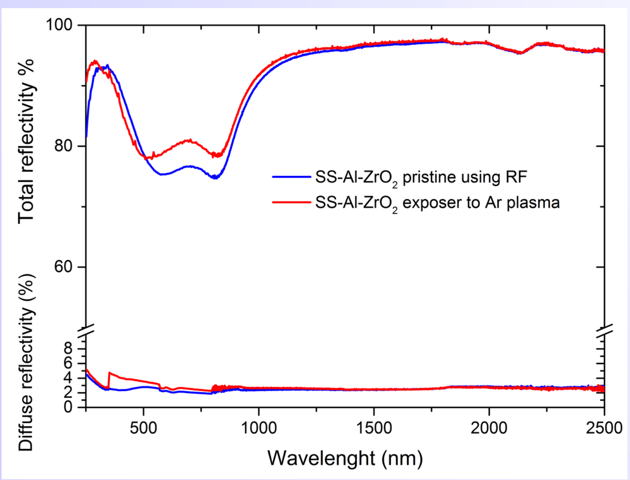


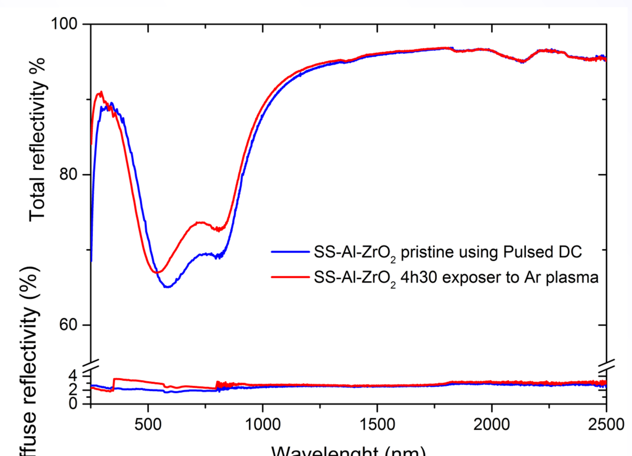

Using an optimized model of SE the thickness was evaluated at nano-metric level.




The response of the 55 nm deposited film on SS-Al substrate shows a high total reflectivity for RF deposited film compared to pulsed DC film while the diffuse reflectivity exhibits an opposite trend. This difference in the diffuse reflectivity is attributed to the difference in roughness measured by AFM (2.7 and 4.6 nm for pulsed DC and RF deposited film respectively).



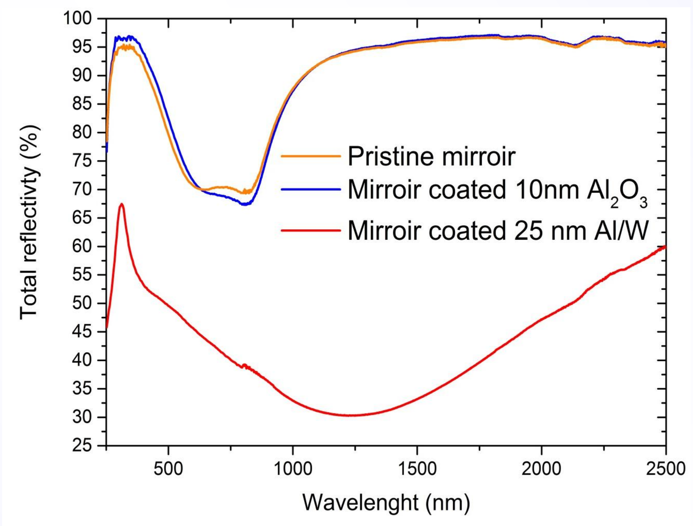



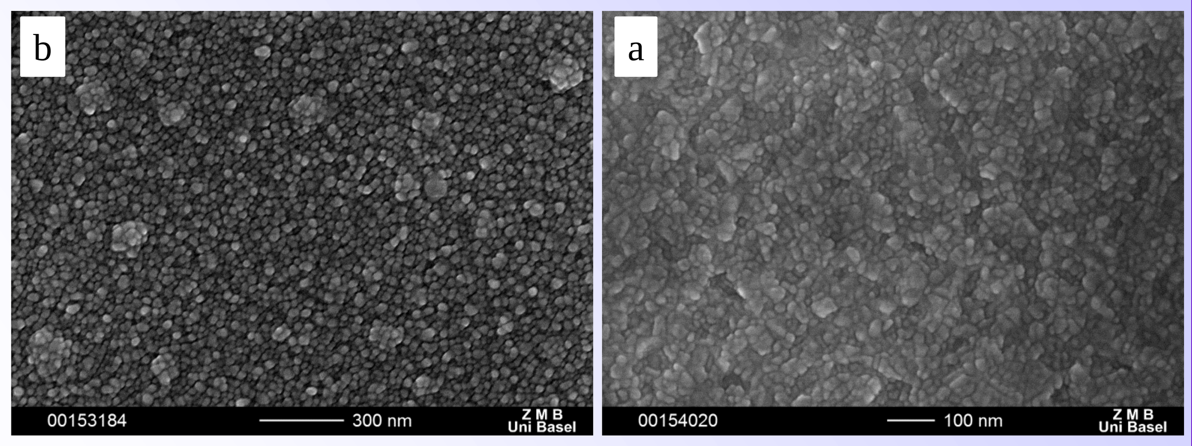

The exposure of $ZrO_2$ to Ar plasma shows that for both film the sputtering rate is 0.02 nm/s. A slight increase of the diffuse reflectivity is observed for both films.

**Optimization of the optical and structural properties of $ZrO_2$ thin films was performed. The RF reactive magnetron sputtering was selected to coat the mirror**

## Plasma cleaning

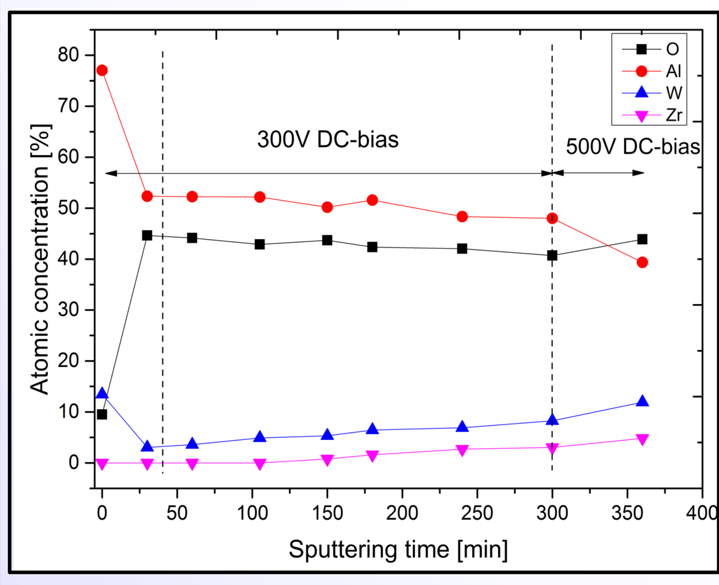
Characterisation of Al/W and $Al_2O_3$ dust film on a Al/$ZrO_2$ mirror



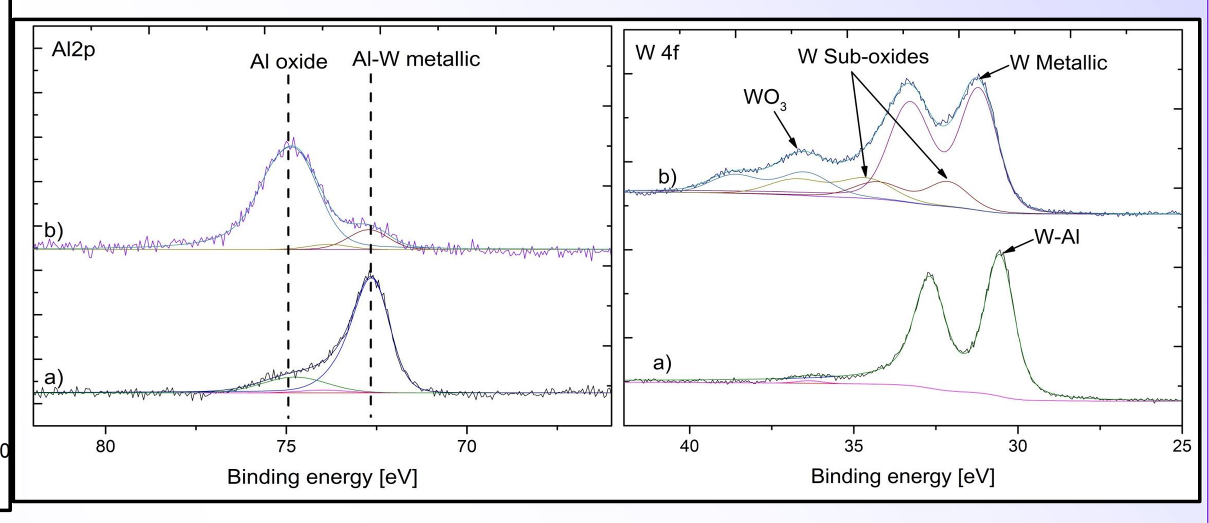




Ø 23 mm SS-Al-ZrO2 mirrors were coated with 10 nm of dense $Al_2O_3$ (a) and 25 nm of dense Al/W (b)

Cleaning in several steps with ambient exposure

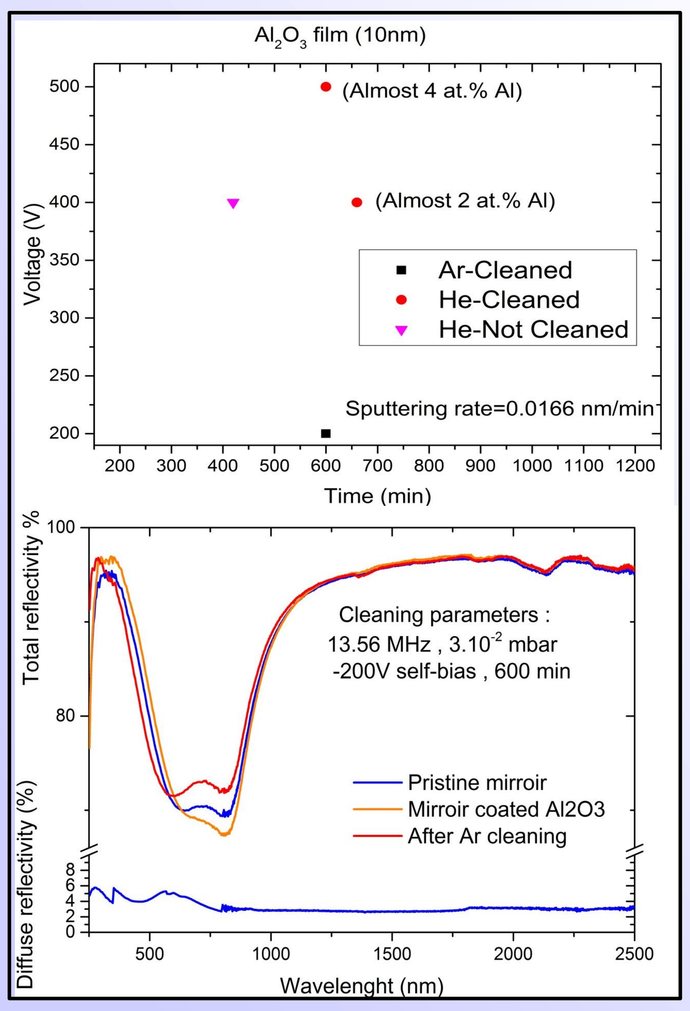



XPS measurements (Al 2p and W 4f) of an Al/W film (a) as deposited (t=0min) and (b) after 300 min cleaning.

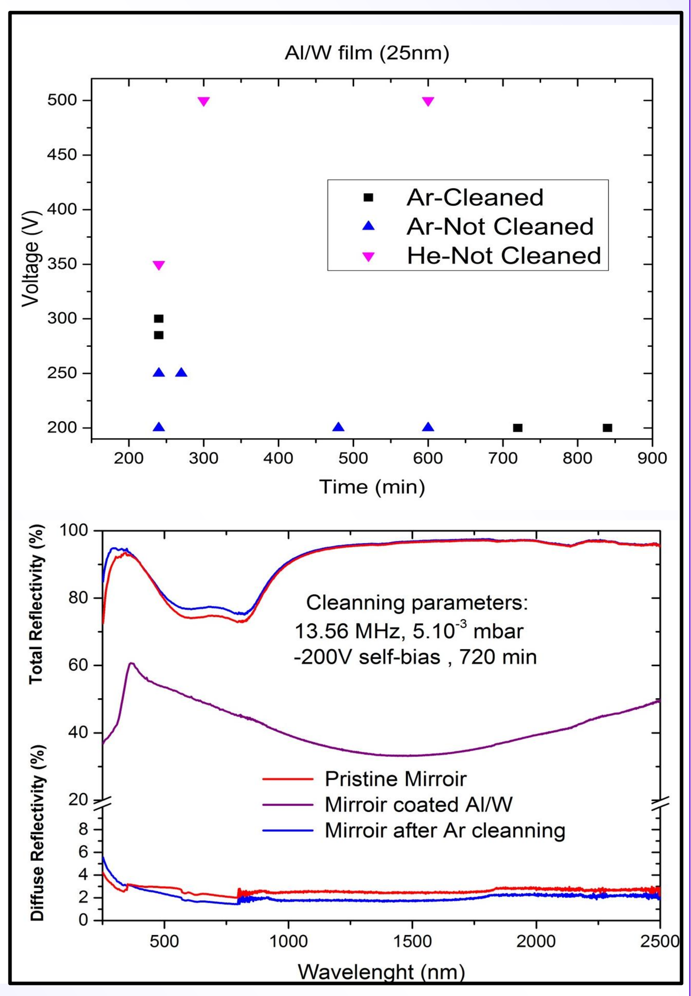



Time step cleaning of Al/W was not successful due to the formation of $Al_2O_3$ and W oxides after each cleaning step.

Results of plasma cleaning of A/W and $Al_2O_3$ films using Ar and He gas for several times and energies




Cleaning with argon and helium using 13.56 MHz RF plasma with different self-bias and time cleaning was performed




**Continuous cleaning method of both $Al_2O_3$ and Al/W films was successfully achieved using Ar. He could clean $Al_2O_3$ films while for Al/W the cleaning under these conditions was not possible.**

## Acknowledgements

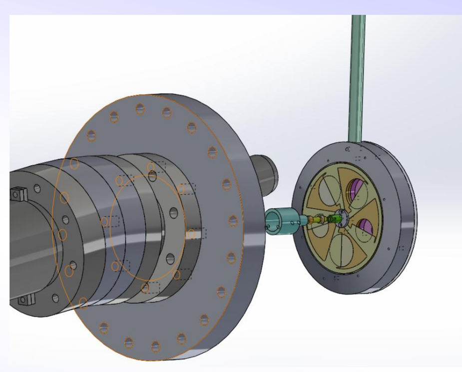
**This work has been carried out in the context of Contract F4E-OPE-649 which has been funded with support from Fusion from Energy. The opinions expressed are those of Contractor only and do not represent Fusion for Energy's official position.**

**The Swiss Federal Office of Energy, the Federal Office for Education and Science, the Swiss National Foundation (SNF) and the Swiss Nanoscience Institute (SNI) are acknowledged for their financial support.**

**This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission**

## Future Experiments

Multiple cycle cleaning of uniform and non-uniform Al/W or $Al_2O_3$ films on SS-Al-$ZrO_2$, single crystalline, polycrystalline and nanocrystalline molybdenum, and rhodium mirrors will be carried out simultaneously.



## Conclusion

- **Parameter of deposition of $ZrO_2$ films were optimized to obtain the desired optical properties and sputtering resistivity required for ITER FM's.**
- **Time step cleaning led to an oxidation of the deposited films. The formation of an oxide layer could explain the longer time needed for complete removal of films and should be considered in ITER conditions.**
- **Ar appeared to be more efficient for $Al_2O_3$ and Al/W removal, while He showed some weakness for $Al_2O_3$ and was not able to remove Al/W under the used conditions.**