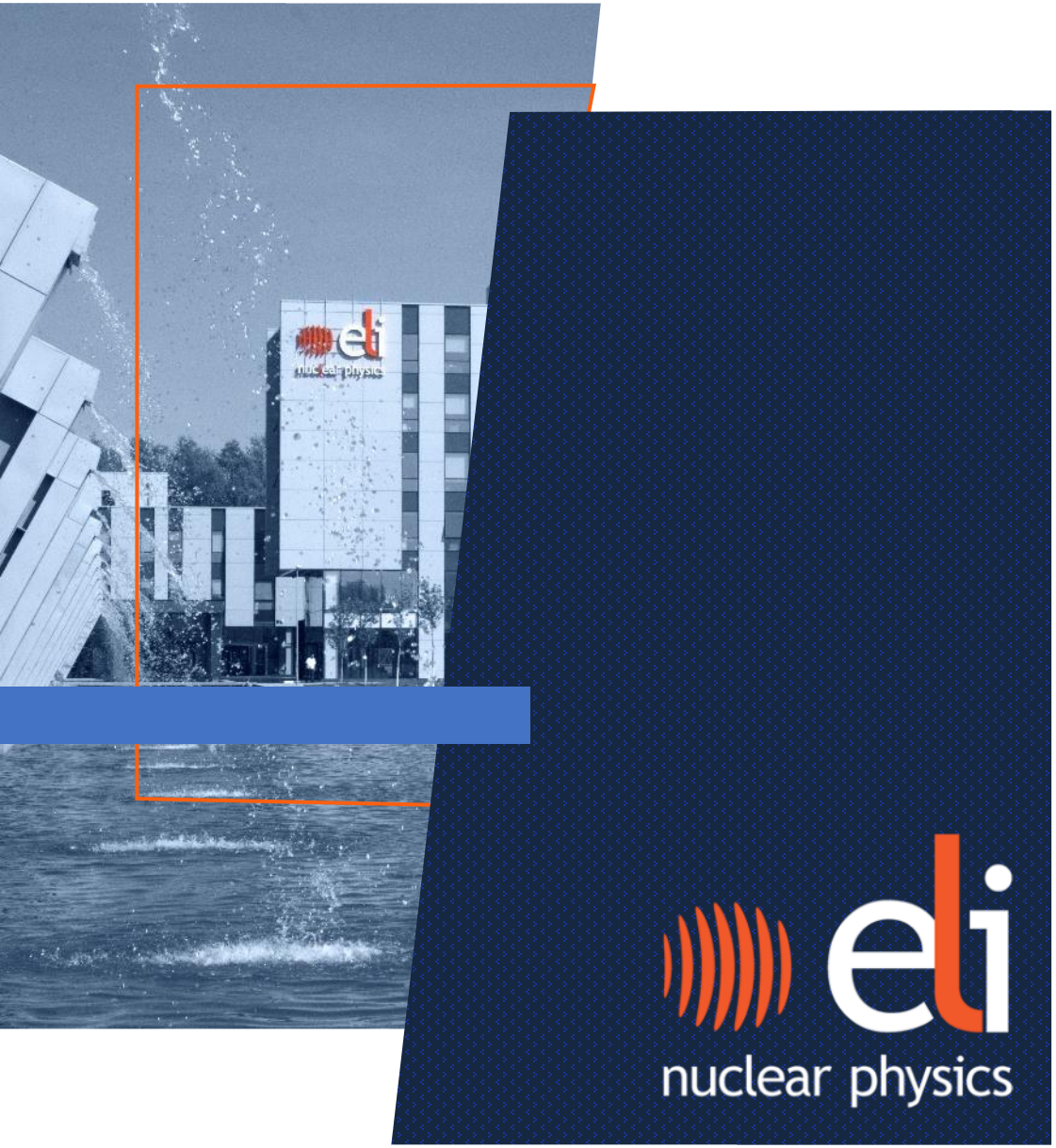

Contamination reduction in vacuum systems using Silica gel

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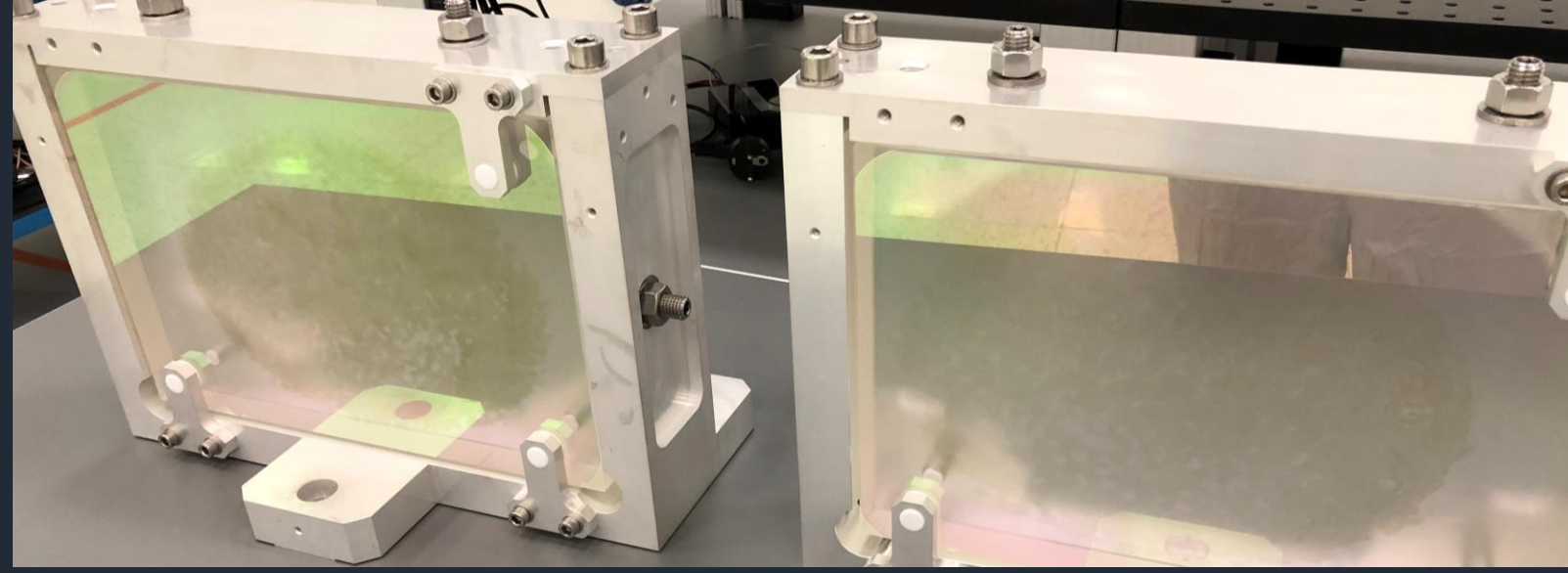
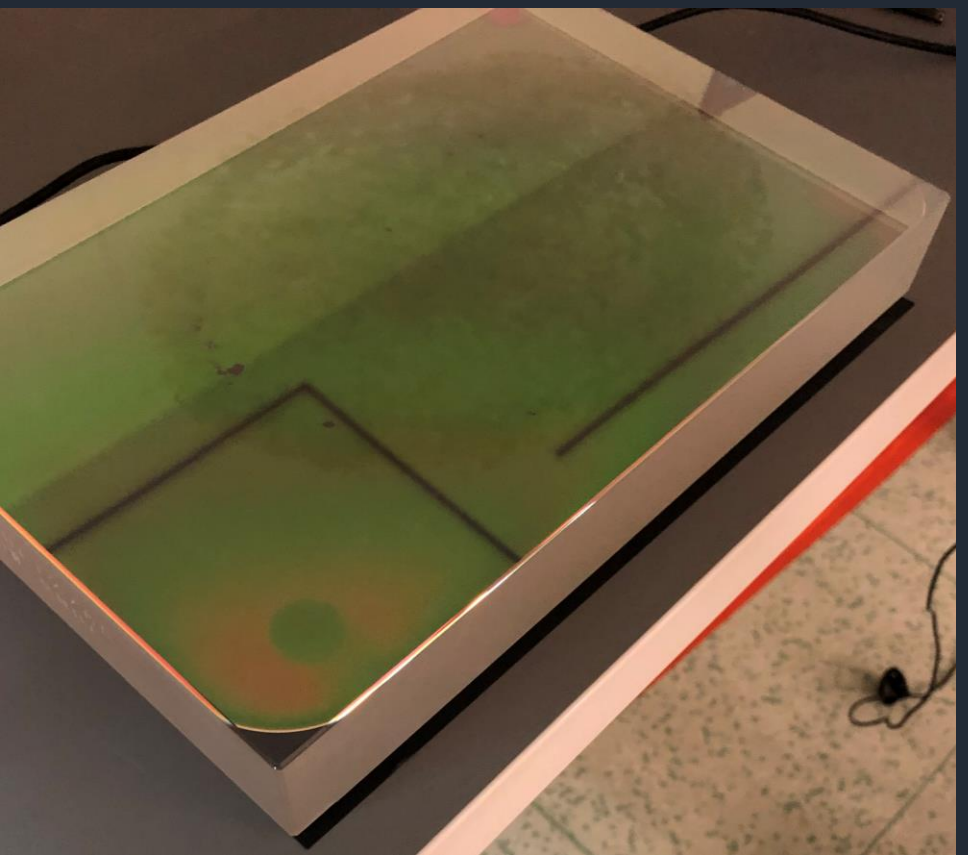
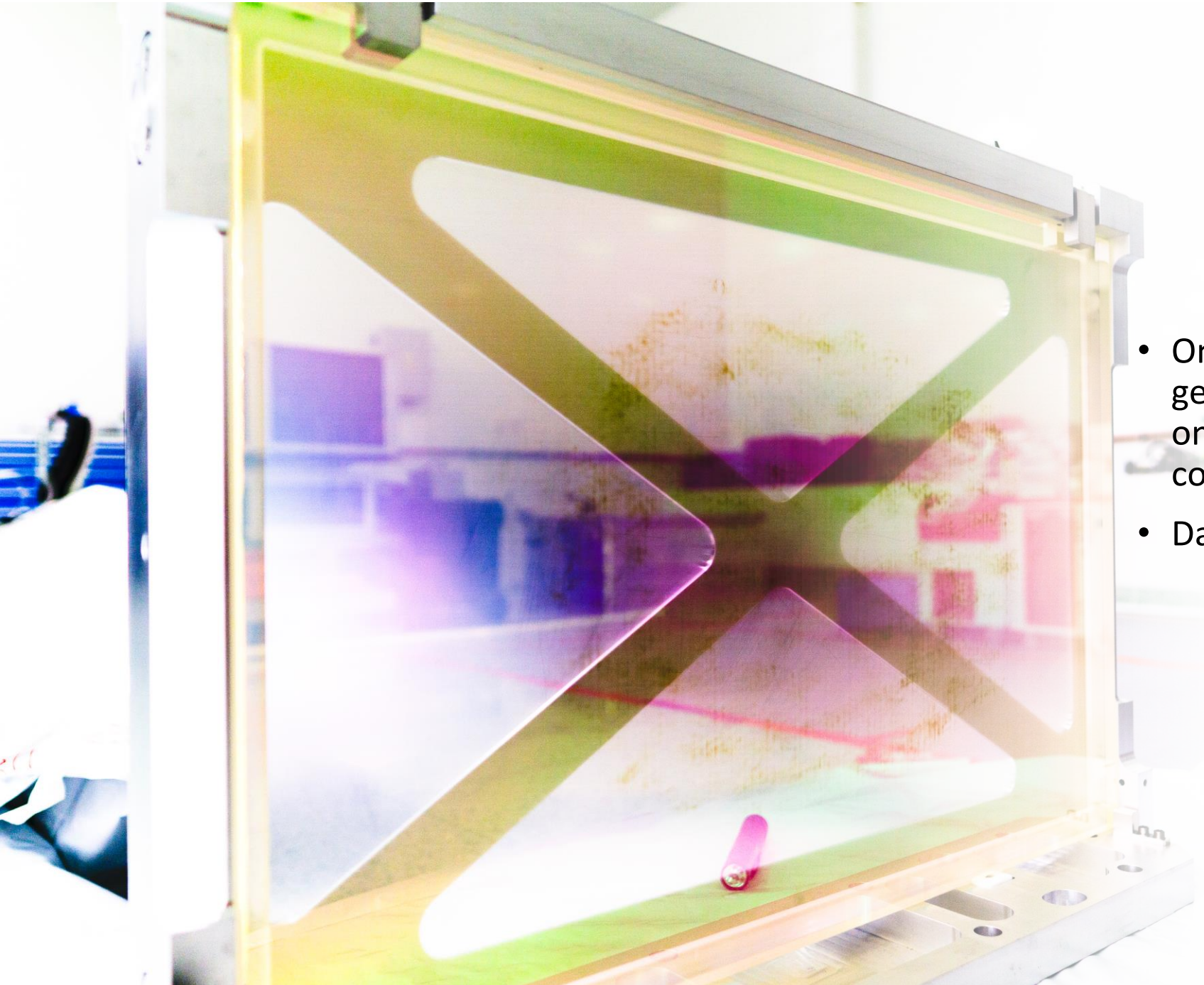
Motivation





- We discovered signs of contamination of dielectric mirrors used in the vacuum chambers on 1 PW line after ~ 1000 shots (December 2021).
- **Critical problem** from the point of stable operation of the laser system.



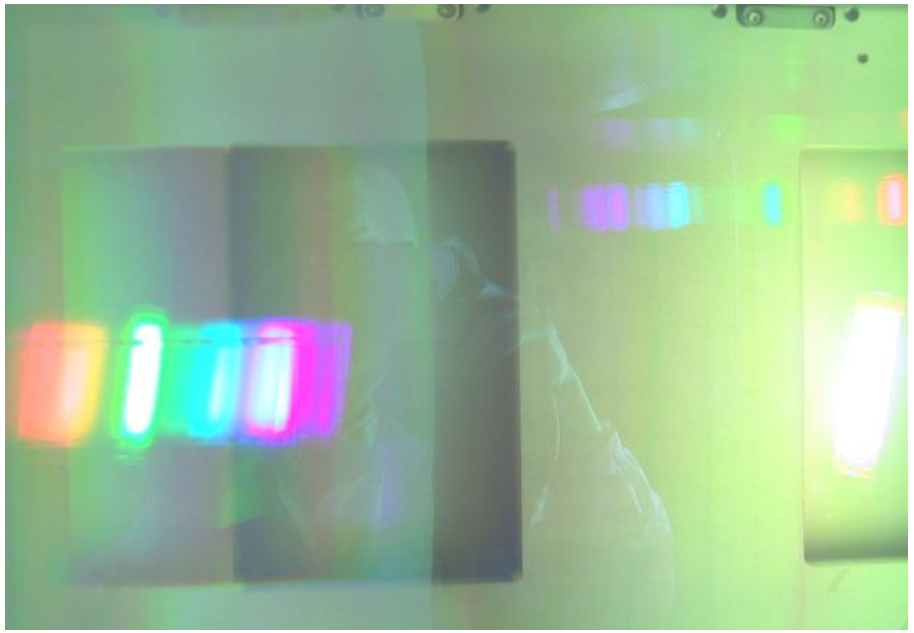
Motivation

- On 10 PW line ~ 800 shots generated the carbonization of one of the large mirrors from the compressor.
- Date: October 2023

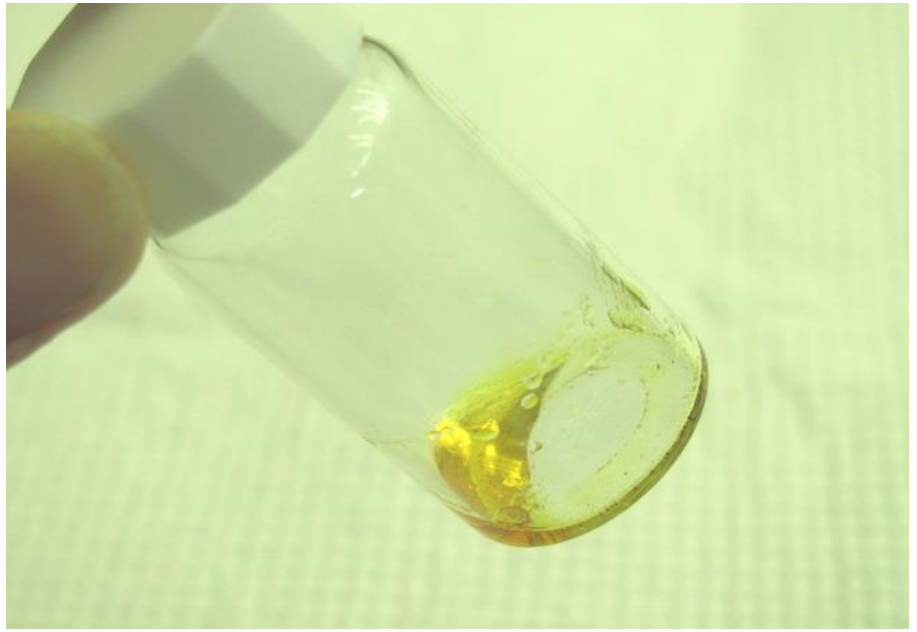
Introduction of the phenomena

- Contamination problem in vacuum chambers was previously observed in ILE Osaka. Fogging was noticed 3 days after optics was put from vacuum to air and Damage threshold dropped ½ ~ ⅓ in ns region.

Fogged Rinsed



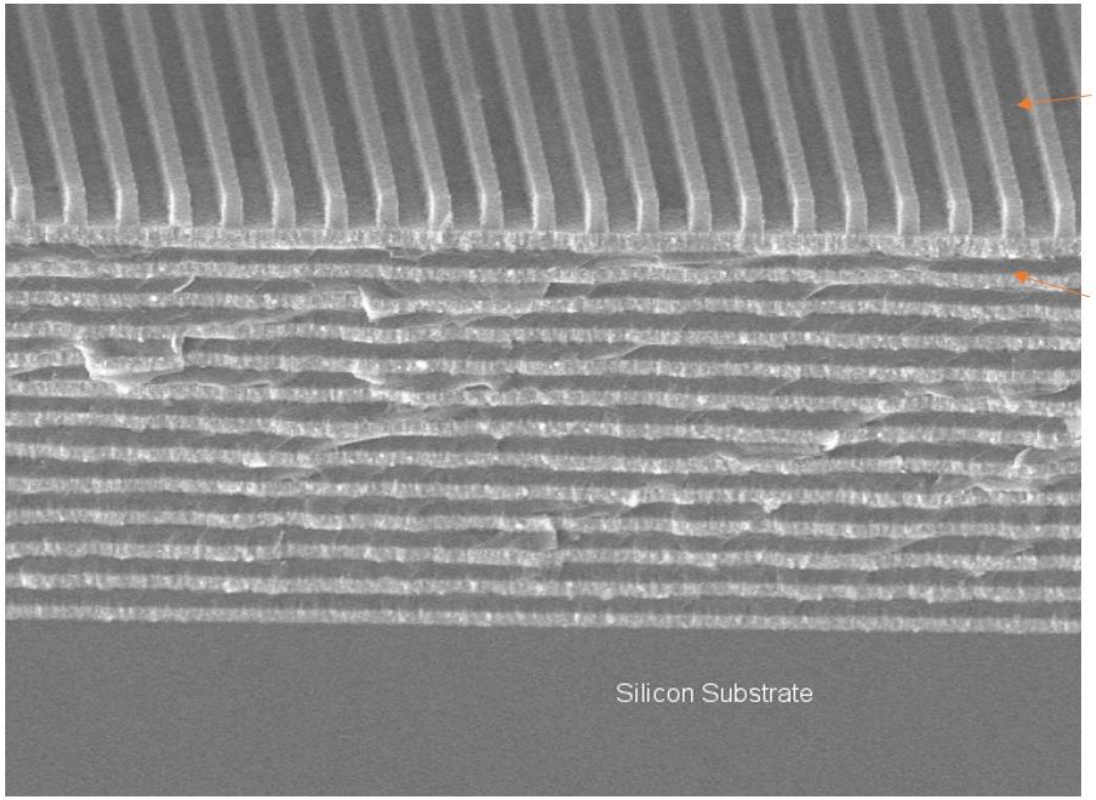
Contaminated grating



Accumulated oil from grating surface

Introduction of the phenomena

Structure of coated layers

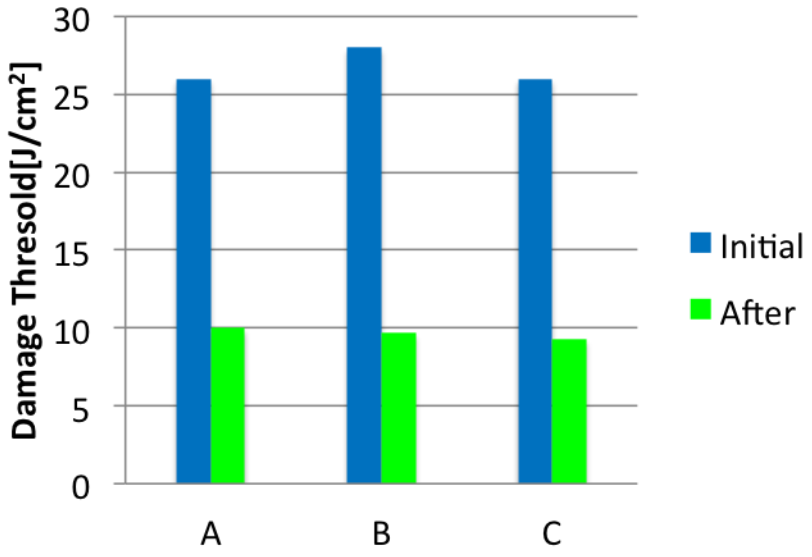


- The mirrors we use have multi-layer dielectric coatings.
- Coating layers have pillar structures, and they are well known to absorb the humidity, and, in the absence of humidity, they absorb the organic vapours from the vacuum.

Introduction of the phenomena

- Contamination induces:

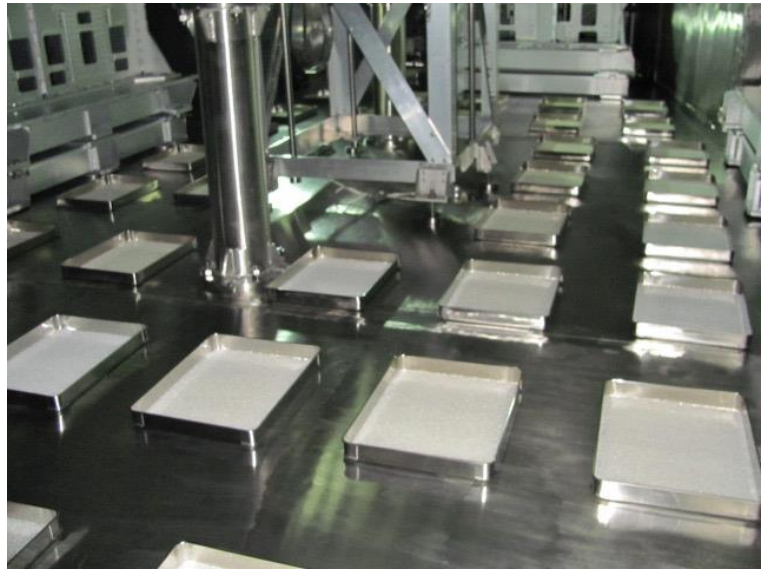
1) The change of reflective indexes of coated materials
2) The dropping of damage threshold in the ns regime
3) The carbonization will finally induce laser damage to the coating.



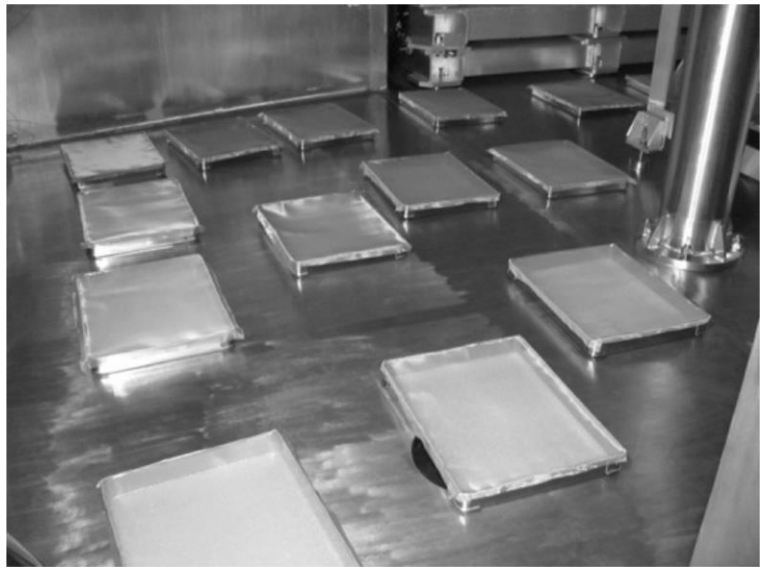
Change of LIDT for 3 samples

Countermeasure

- ILE Osaka used a large amount of silica gel to absorb the contaminants from the vacuum chamber. This method was transferred to ICR Kyoto (Japan) and Sandia Laboratory (USA).



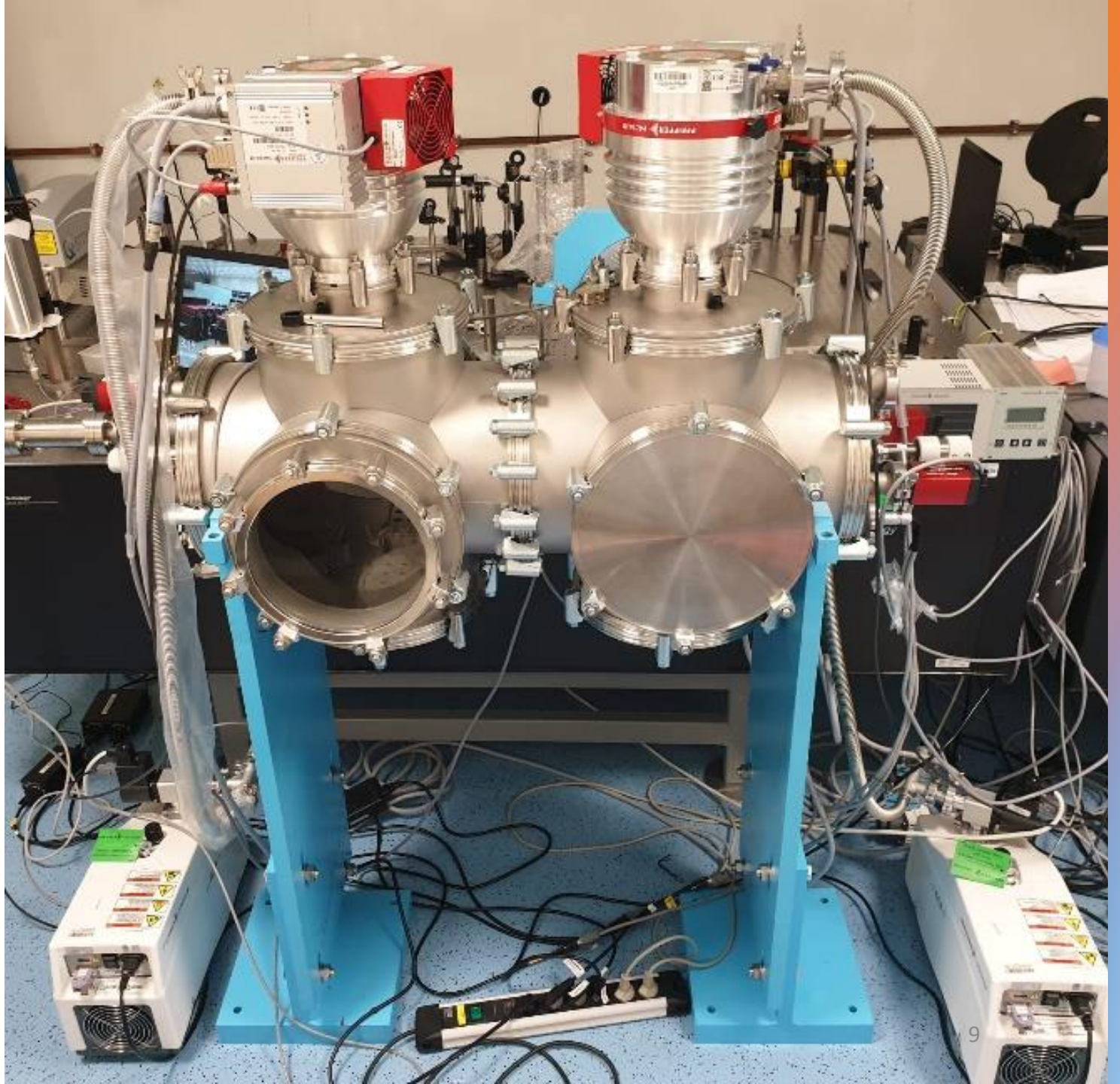
ILE-Osaka without mesh in 2013
(particle contamination was observed due to emissions of Si gel itself)



ILE-Osaka with mesh in 2014
(particle contamination was removed)

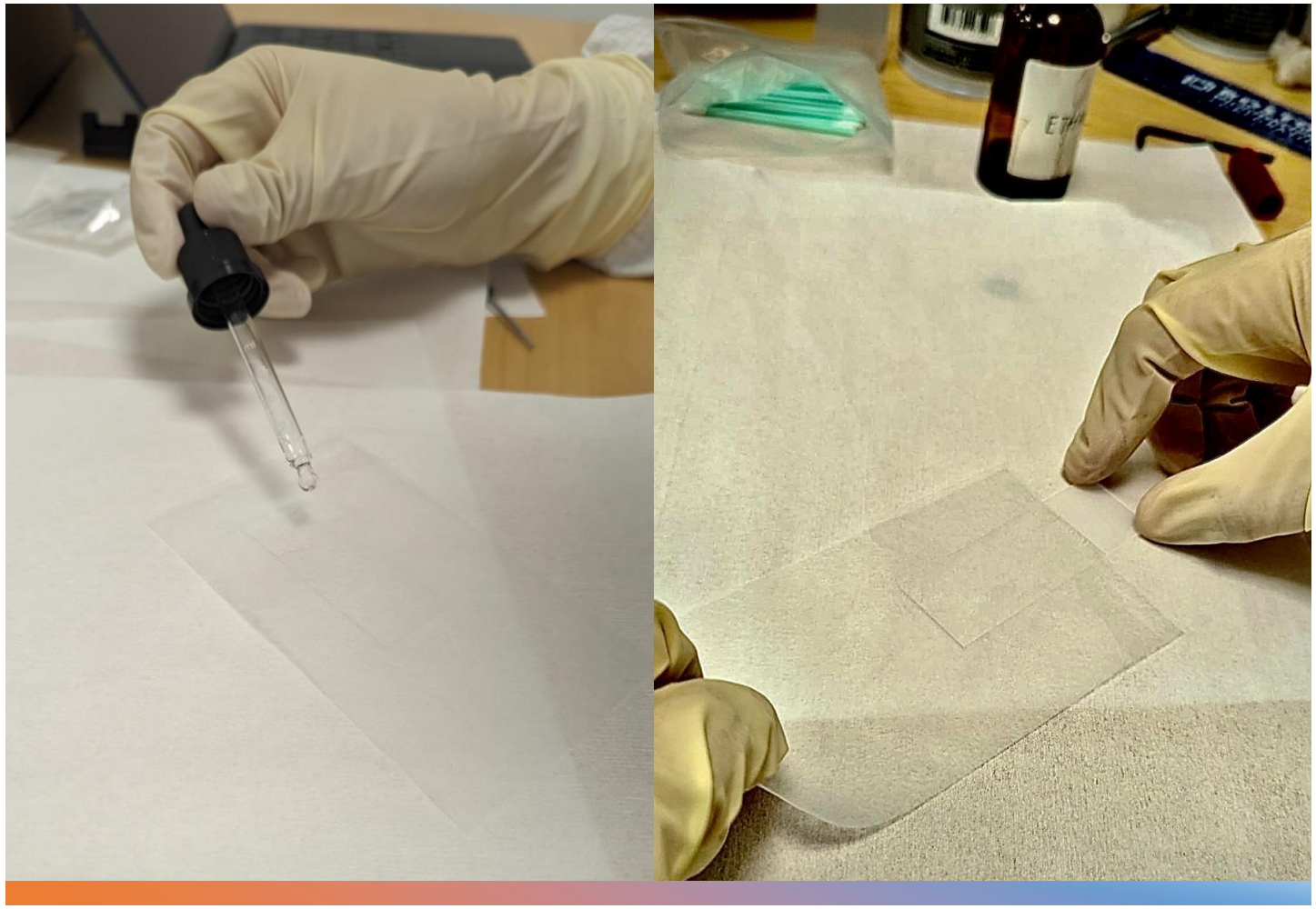
Countermeasure

We need to make sure the particle contamination caused by the silica gel is minimal. To check this, we need to put some control samples in vacuum and then inspect them to see the default contamination induced by the vacuum chamber itself.

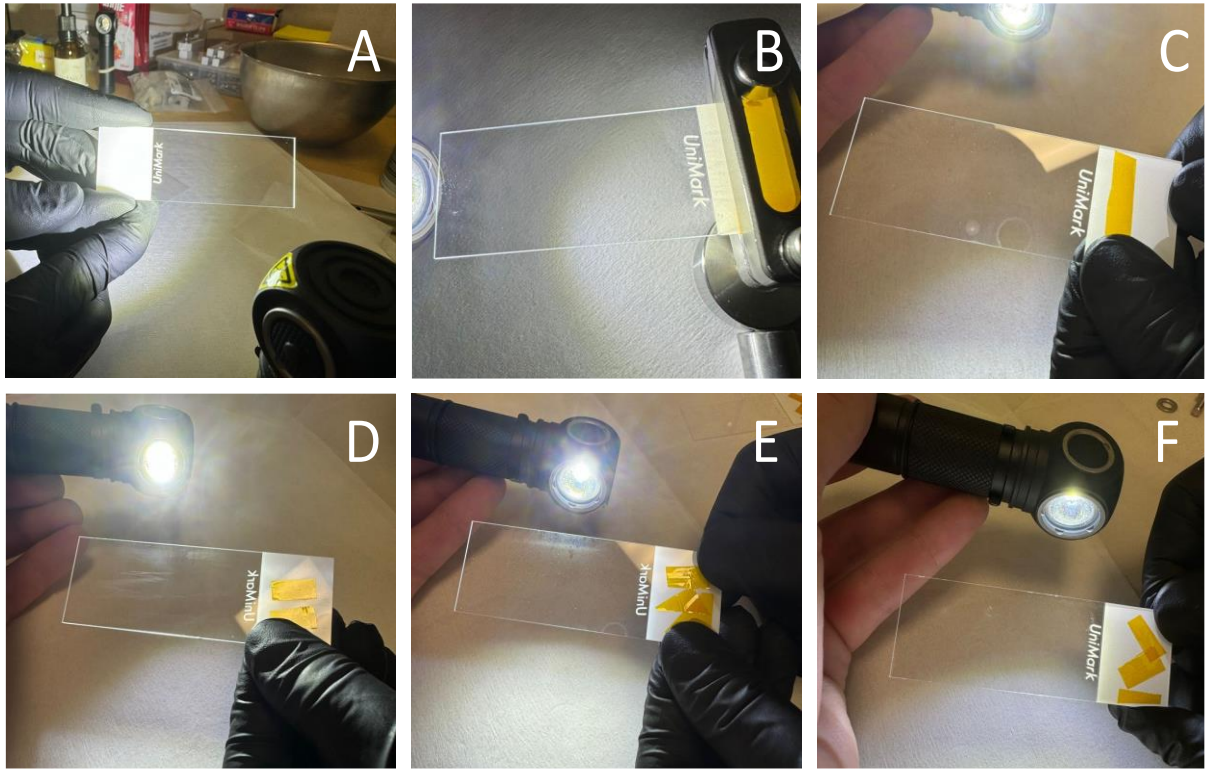


Need of confirmation

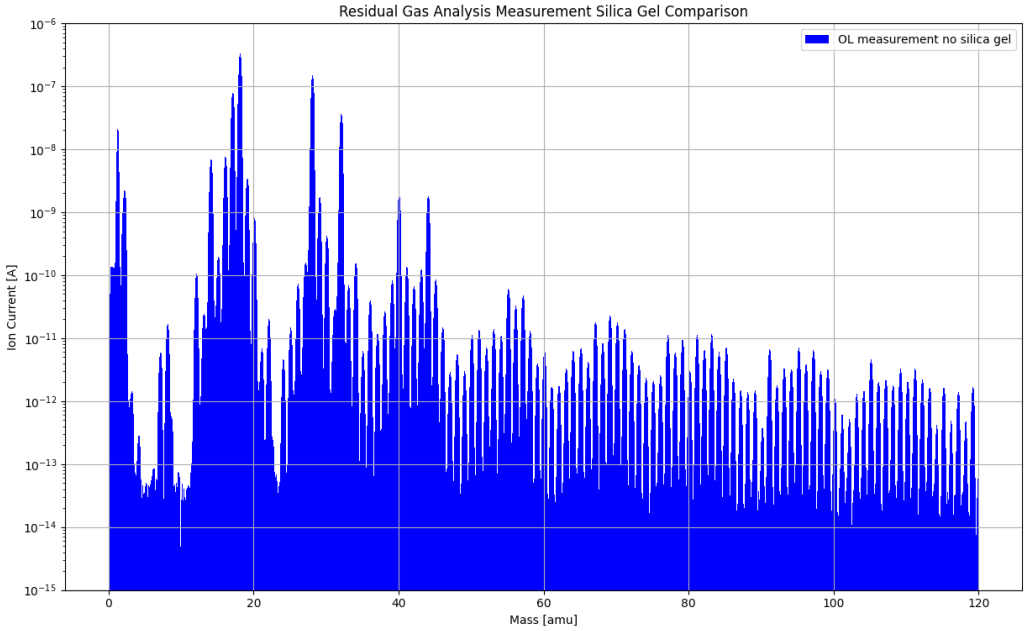
- First step we took was cleaning the glass plates used for the vacuum particle control sample using the drag wiping technique.



Vacuum test, without silica gel



RGA data without silica gel

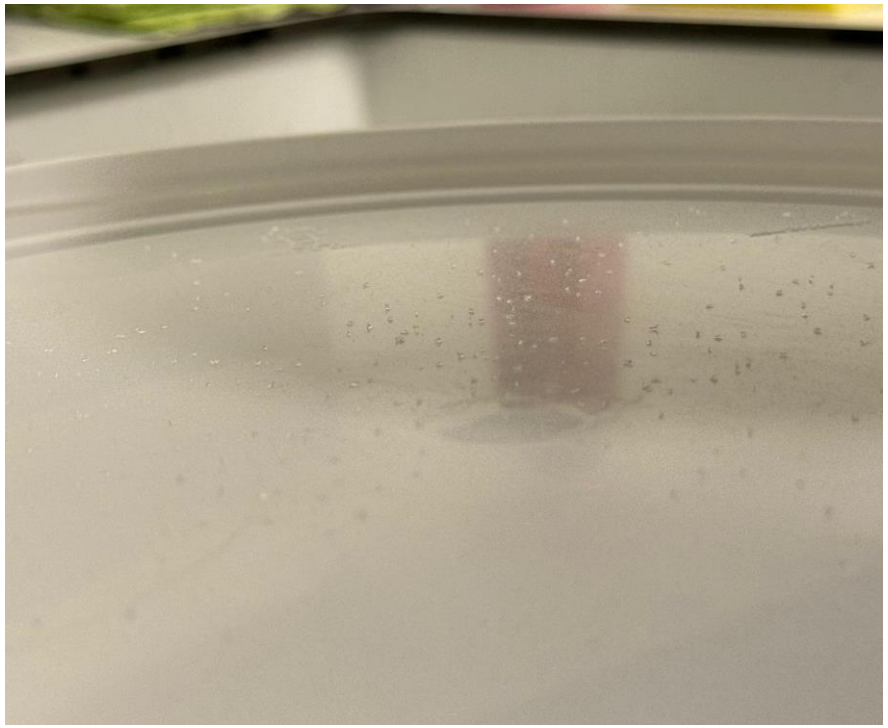


Preparation of silica gel

1) Clean up all tools that will be used in the vacuum or just simply to manipulate the silica gel (ex: metal trays, SUS mesh, sieve, scoop,etc).

Preparation of silica gel

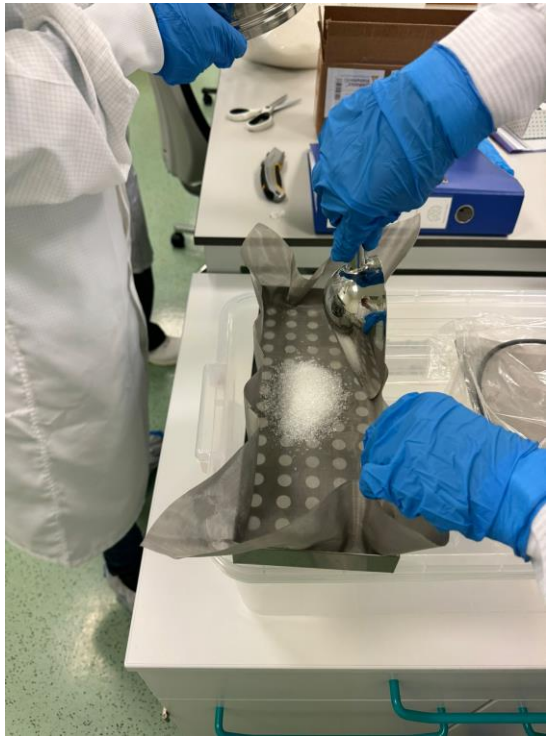
2) Sieving the silica gel to remove the small particles.



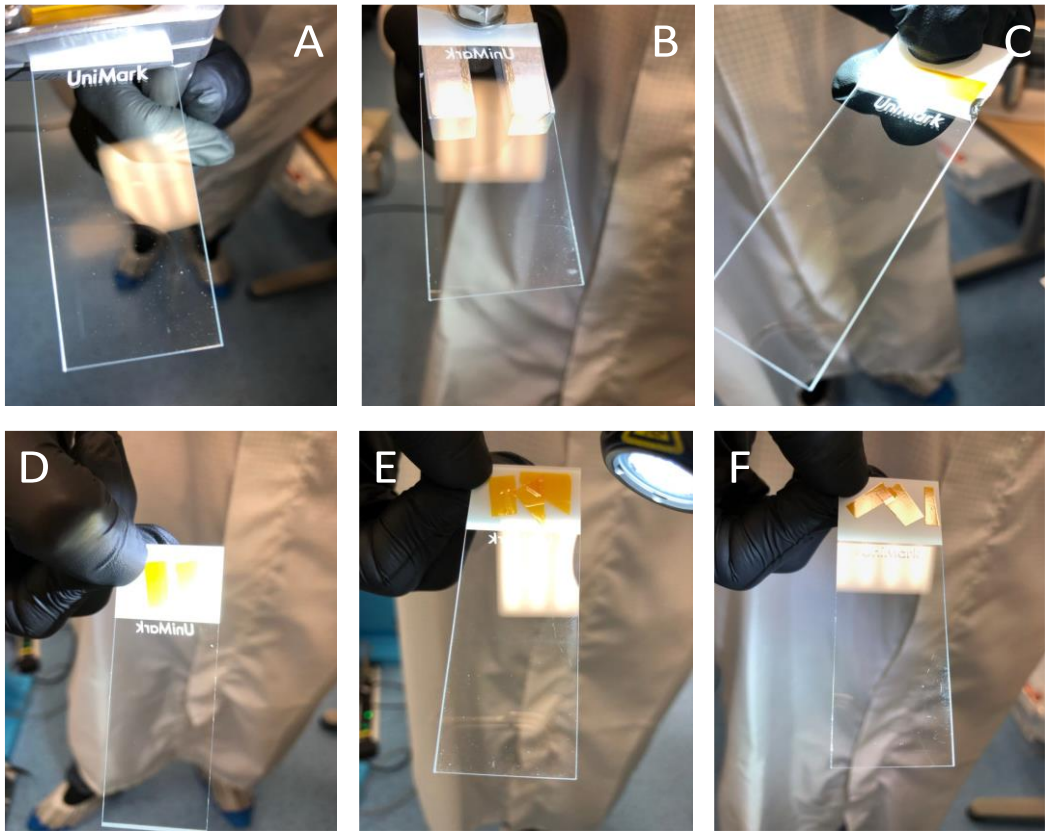
This process should be done under a ventilator.

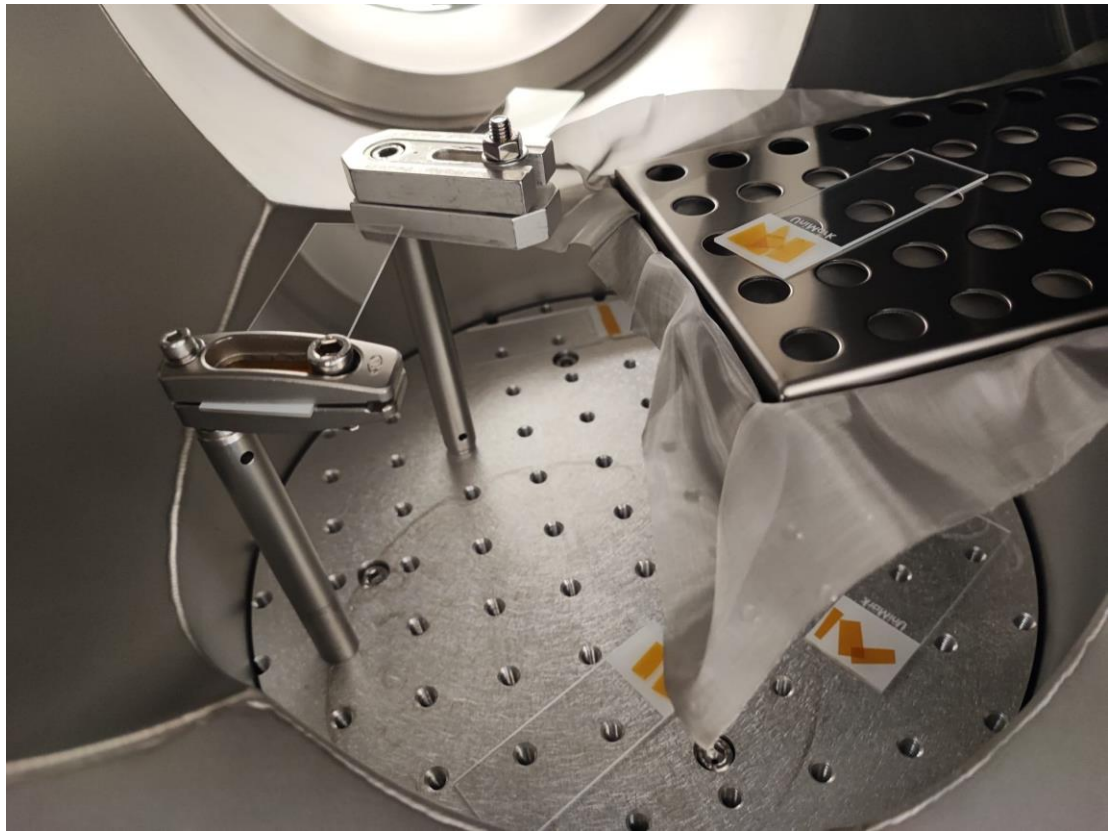
Preparation of silica gel

3) Baking silica gel inside the oven. at 150℃ for 4 hours.



Vacuum test, with silica gel

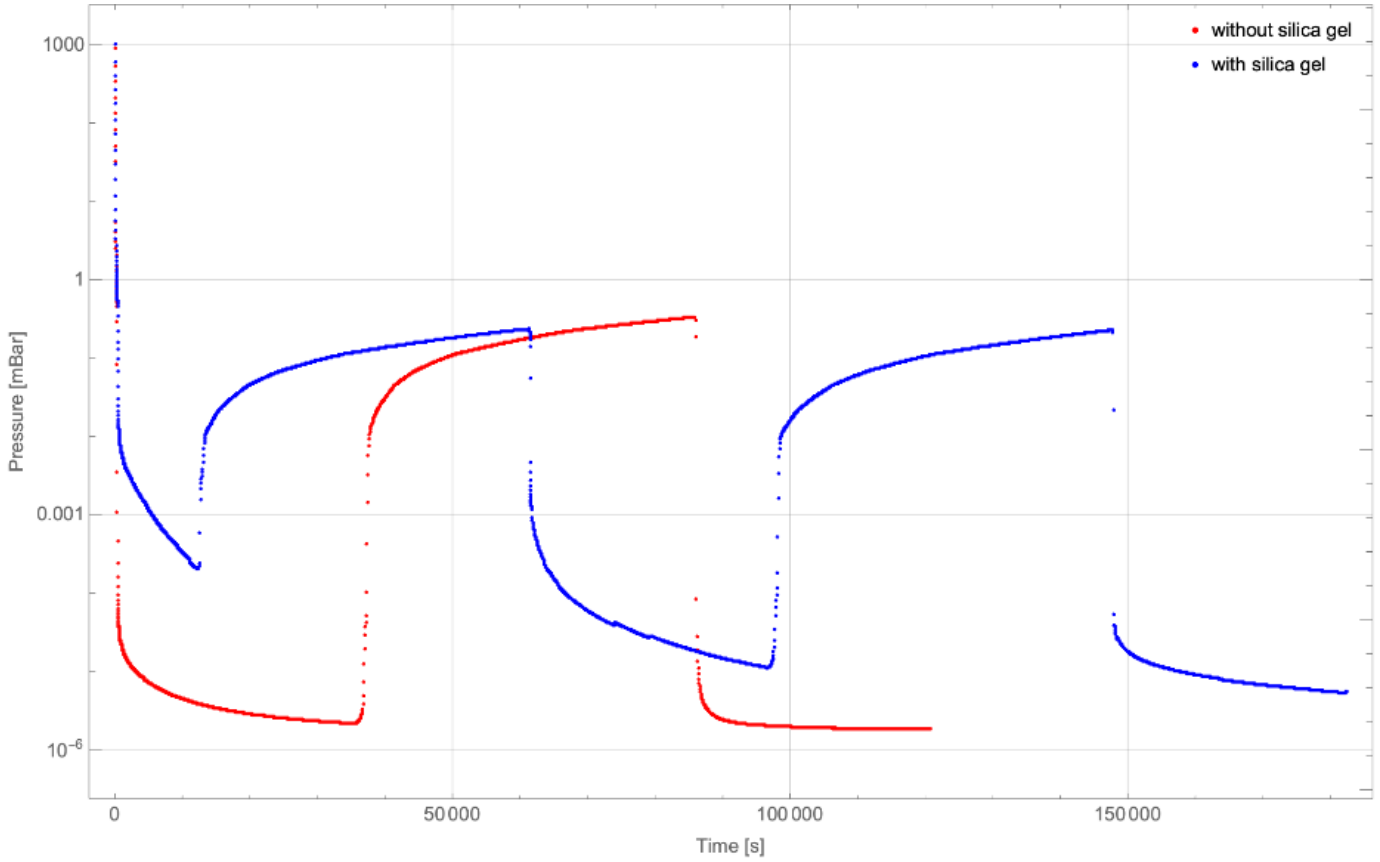




Particle contamination from silica gel was not observed.

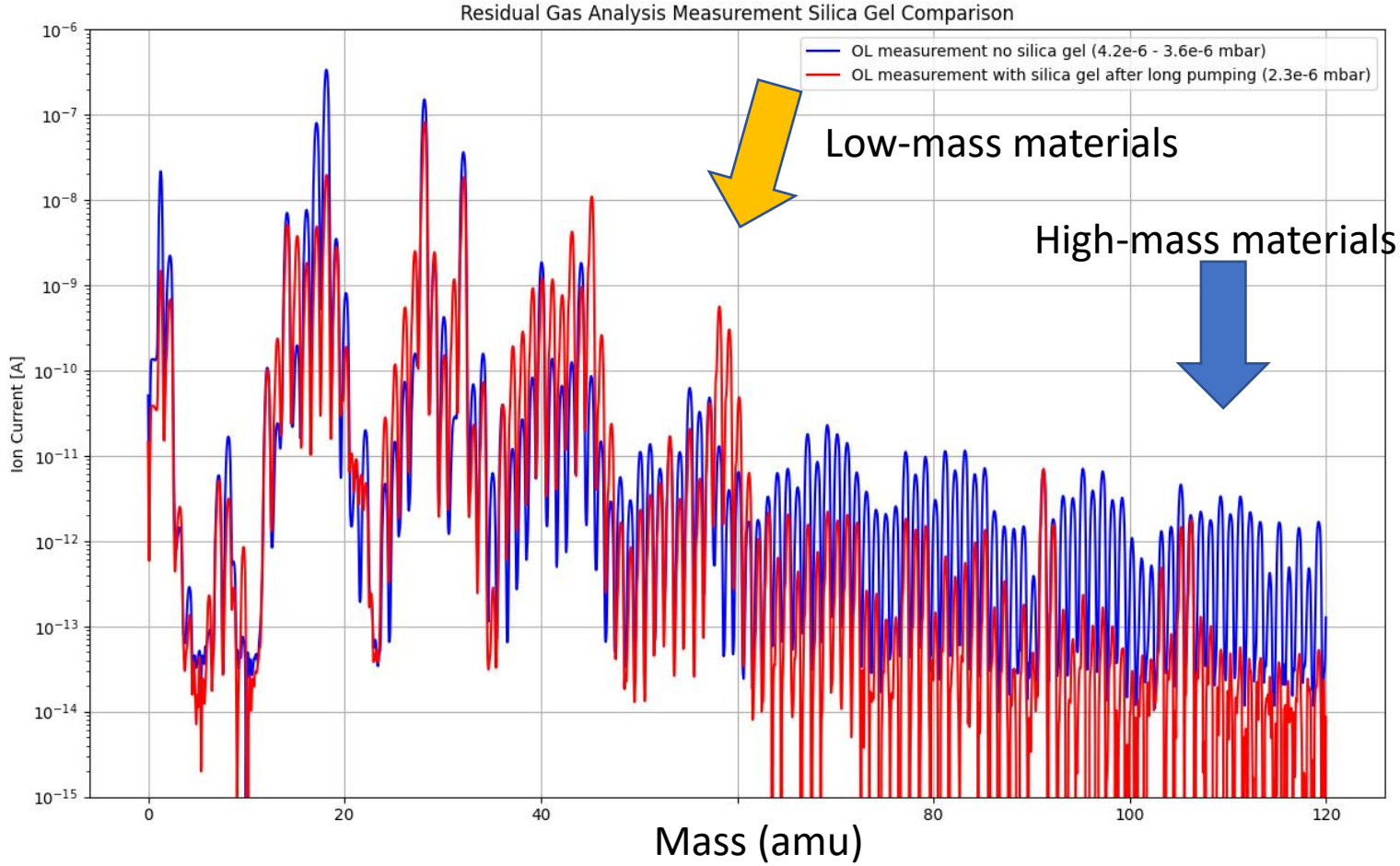
Pump speed decrease

- Without silica gel the pressure reaches to 3.4e-6 mbar in 10 hours. With silica gel the final pressure is 5.9e-6 mbar after 20 hours. The plotted values are the average of the 60 scans.
- We need longer time to reach the final pressure, but it is not a critical issue for the system.



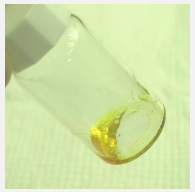
Results

Without silica gel
With silica gel

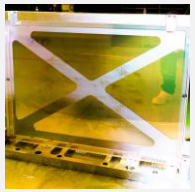


RGA data showed that silica gel is strongly absorbing large-mass numbers molecules but it emits low-mass number materials (less than 58). These materials are supposed to be organic solvents and gases.

Conclusion



Organic oils will be anyway accumulated in the coating layers during vacuum operation.



After that, the contamination will be carbonized by laser pulse irradiation.

Optics contamination remains a critical problem for large-scale laser systems.

Future steps

We will continue the evaluation of the effect of silica gel on cleaning optics and vacuum chambers.

We performed dispersion measurements which confirmed that after cleaning optics using water-alcohol mixture dispersion comes back to an appropriate value as for a clean(new) mirror.

After this confirmation, we will start to install silica gel to the actual beam lines of LBTS.

We will publish the results as soon as possible because this contamination is a common problem in large-scale laser systems in the world.