IR Irradiation on H_2O-Coated Silicate Grains

From Dust Vibrational Excitation to Ice Structural Change

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Background

- Selective IR irradiation can induce ice restructuring, desorption, and energy transfer within ices [1, 2]
- Previous studies were conducted on ices deposited on gold substrates
- Silicate grains are a large fraction of the cosmic dust and may play an active role in IR-induced energy dissipation, vibrational coupling, and ice evolution at the ice–dust interface

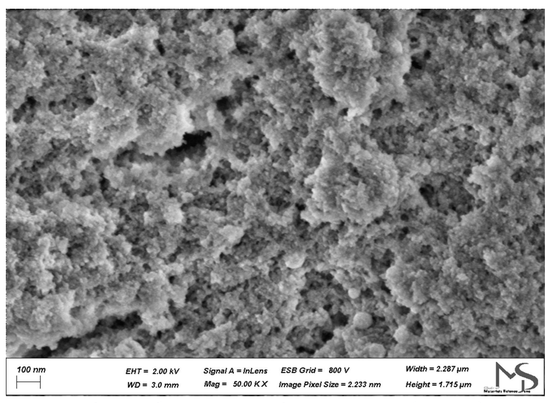
Goal of the study:

Investigate how silicate substrates effect
- vibrational energy transfer
- ice-dust interface chemistry
- ice structure

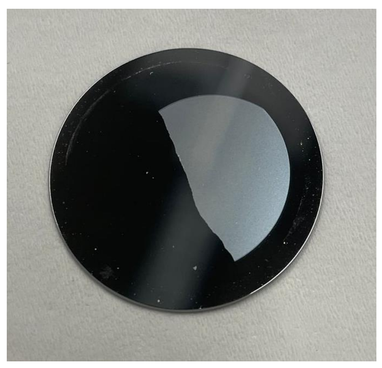
following selective IR irradiation on interstellar ice analogs

Method

Cosmic dust analog
- Produced with the Laser ablation and solid-particle beam apparatus
- Amorphous olivine ($MgFeSiO_4$) on a Ruthenium (Ru) substrate
- Half coverage to allow for comparison with/without silicate



Scanning Electron Microscope (SEM) image of the produced dust analog showing an amorphous structure



Ru substrate covered with $MgFeSiO_4$ (light gray area)

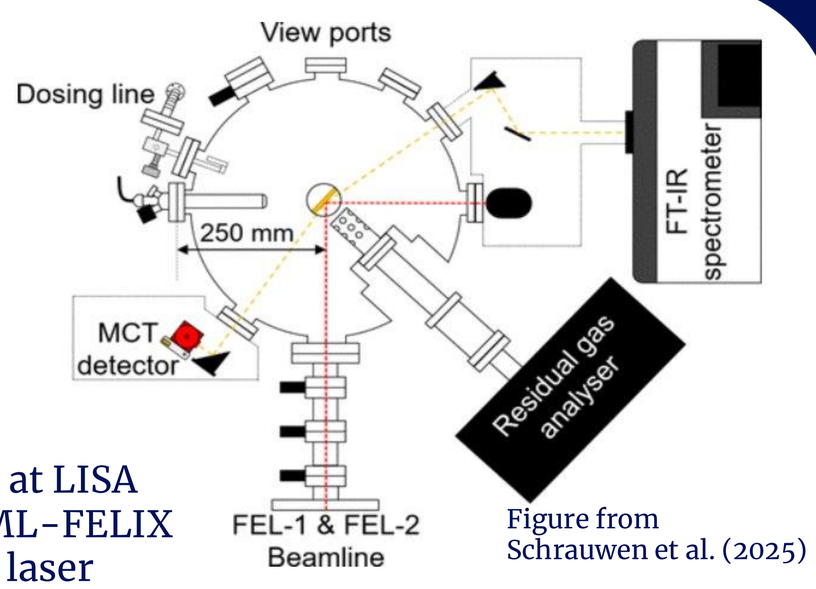


Figure from Schrauwen et al. (2025)

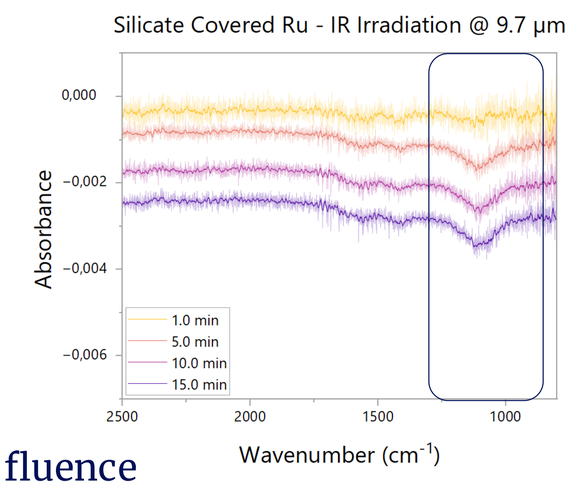
Experiments at LISA with the HFML-FELIX free electron laser
- FELIX-2 (2.7-45 µm, 10 Hz)
- Low temperature (10K) and UHV (1E-10 mbar)
- Selective irradiation
  - 9.7 µm - *in-resonant with water and silicate*
  - 21.9 µm - *in-resonant with silicate*

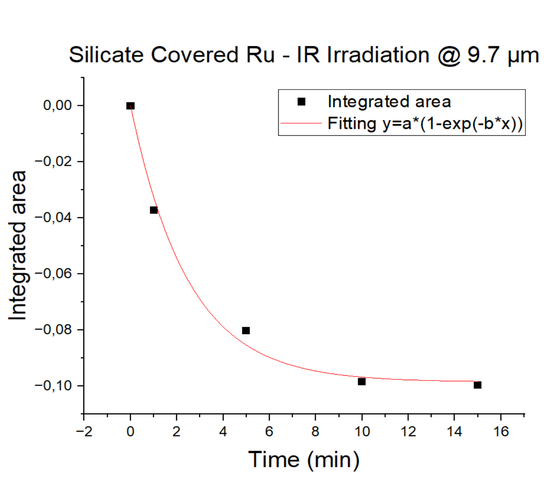
Silicate processing

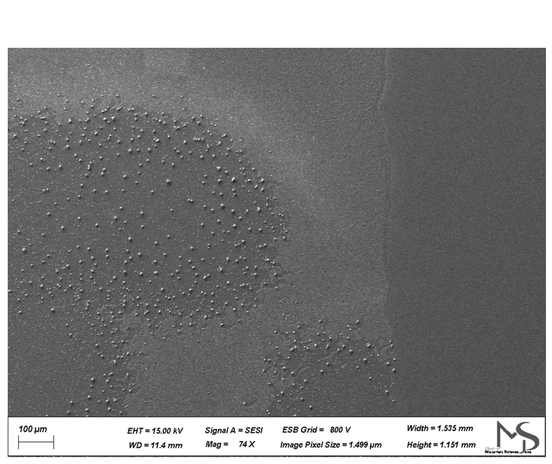
Irradiation parameters
- Wavelength: **9.7 µm**
- Power: 19.5 mJ

Show difference spectra following stepwise irradiation of silicate (without ice coverage)

The Si-O feature clearly decrease with increased fluence







The integrated area over the Si-O feature follow an exponential trend, indicating silicate desorption

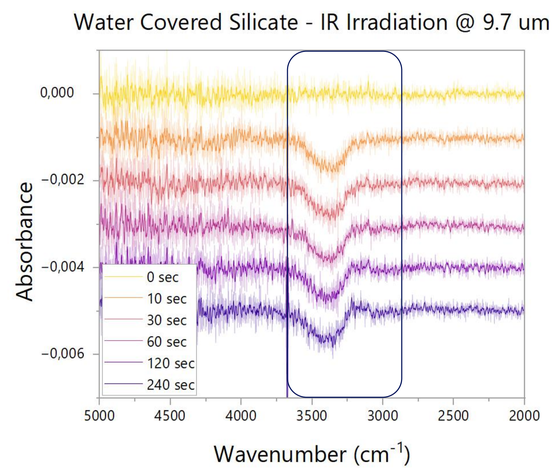
Silicate processing confirmed by SEM scan

Water processing

Irradiation parameters
- Wavelength: **9.7 µm**
- Power: 23.1 mJ

Difference spectra following stepwise irradiation of water covered silicate

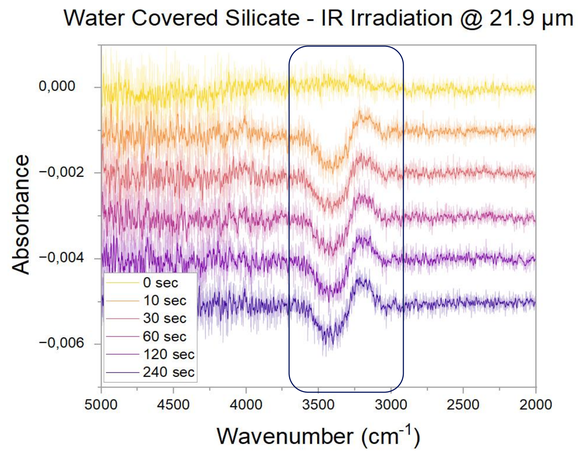
The OH feature show clear spectral change



Energy transfer from silicate to water

Irradiation parameters
- Wavelength: **21.9 µm**
- Power: 25.6 mJ

Difference spectra following stepwise irradiation of water covered silicate



The OH feature show clear water restructuring following vibrational excitation for silicate

References

[1] Noble, J. A., Cuppen, H. M., Coussan, et al. (2020). Infrared Resonant Vibrationally Induced Restructuring of Amorphous Solid Water. The Journal of Physical Chemistry C. 124:20864-20873. https://doi.org/10.1021/acs.jpcc.0c04463
[2] Slumstrup, L., Thrower, J. D., Hopkinson, A. T., et al. (2025). CO desorption from interstellar icy grains induced by infrared excitation of superhydrogenated polycyclic aromatic hydrocarbons. Astronomy and Astrophysics. 704. https://doi.org/10.1051/0004-6361/202556399
[3] Schrauwen, H. G. M., Dijkhuis, T. M., Ioppolo, S., et al. (2025). Infrared Irradiation of H2O:CO2 Ice: A Combined Experimental and Computational Study of the Dissipation of CO2 Vibrational Excitations. ACS Earth and Space Chemistry. 9. doi: 10.1021/acsearthspacechem.5c00030