"A dream of next generation interference coatings: is it possible to overcome intrinsic laser damage resistance?"

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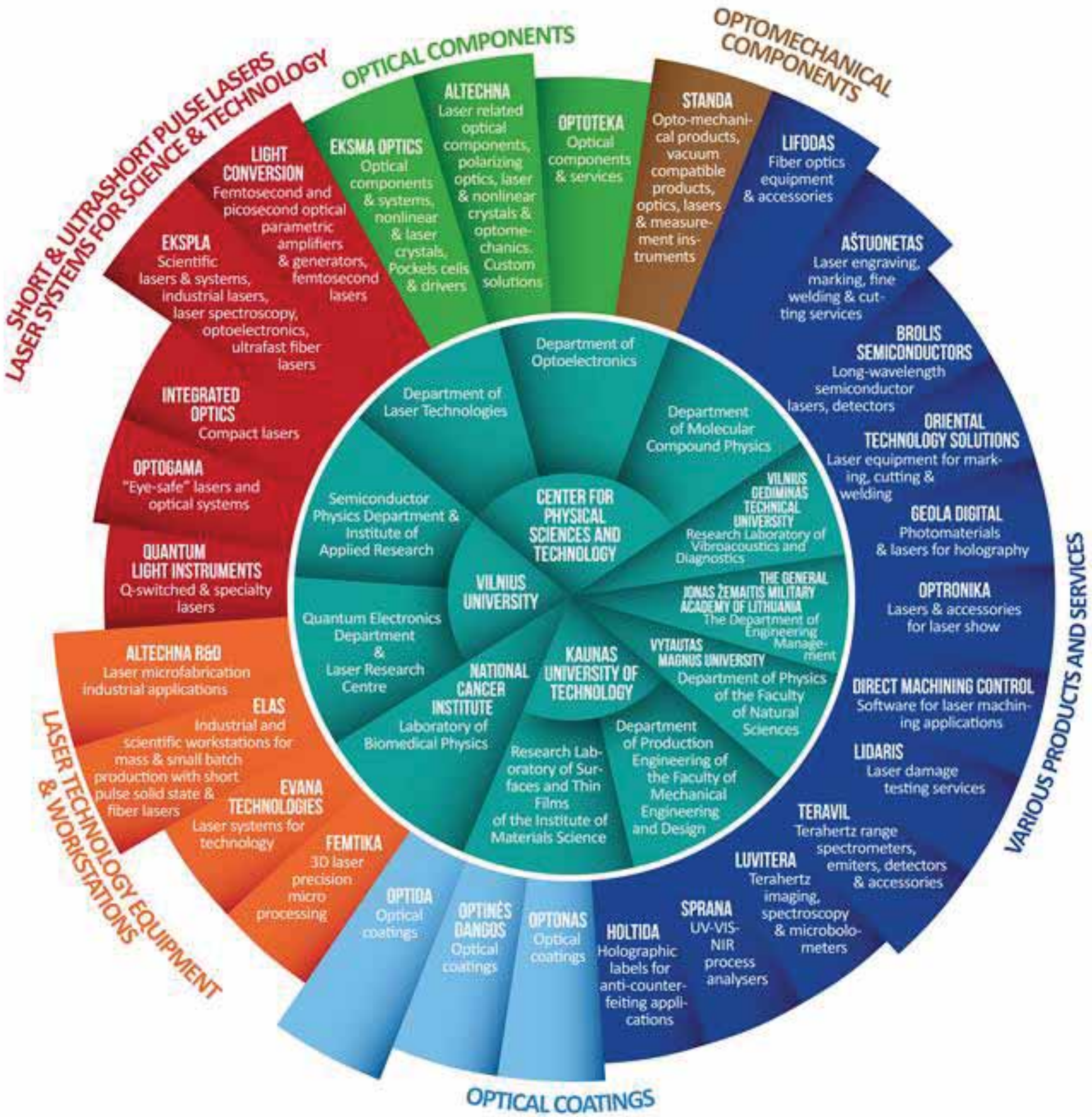
Buchs, CH 2017-04-12

LITHUANIA



LASER

TECHNOLOGIES

IN VILNIUS:

ECOSYSTEM OF 35 ORGANIZATIONS

Community dealing with optics and lasers:

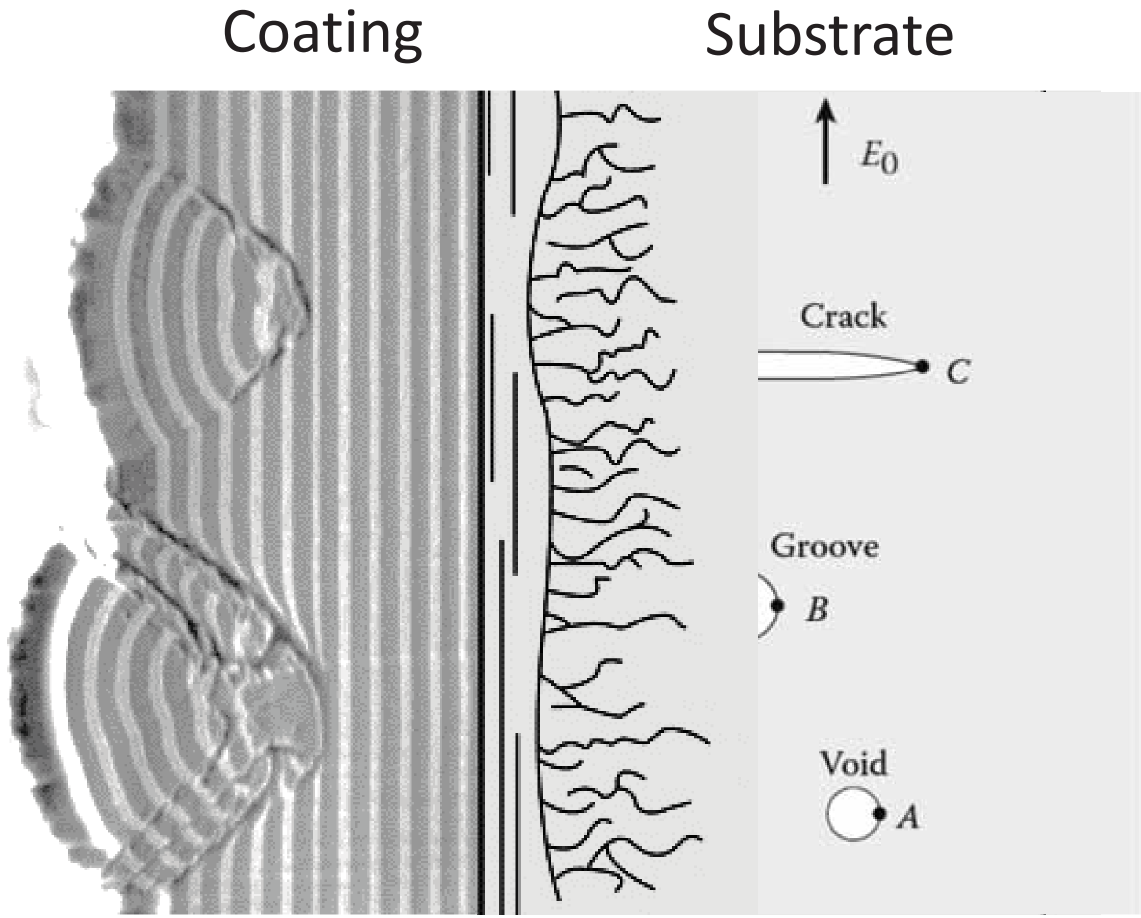
~1000 people

Outline of the talk

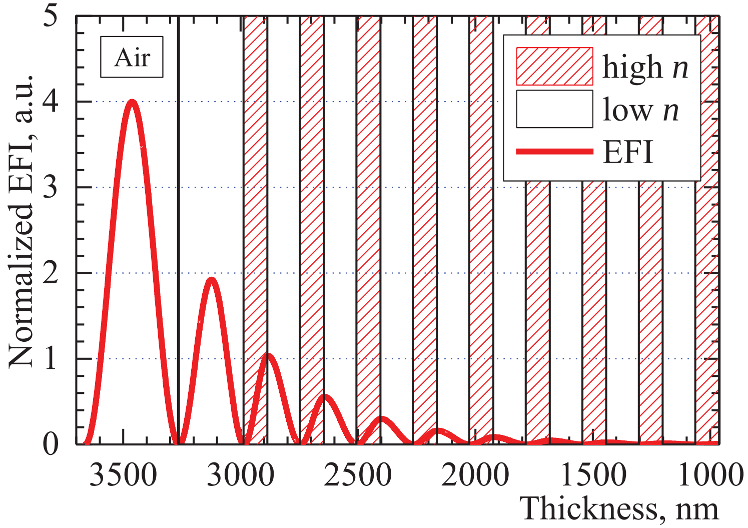
- Motivation
- Introduction
  - Concept of next generation coating technology
  - Production principle
- Design of experimental HR coatings
- First results
  - Characterization of experimental samples
  - Discussion
- Concluding remarks

Initiators of laser damage: extrinsic defects

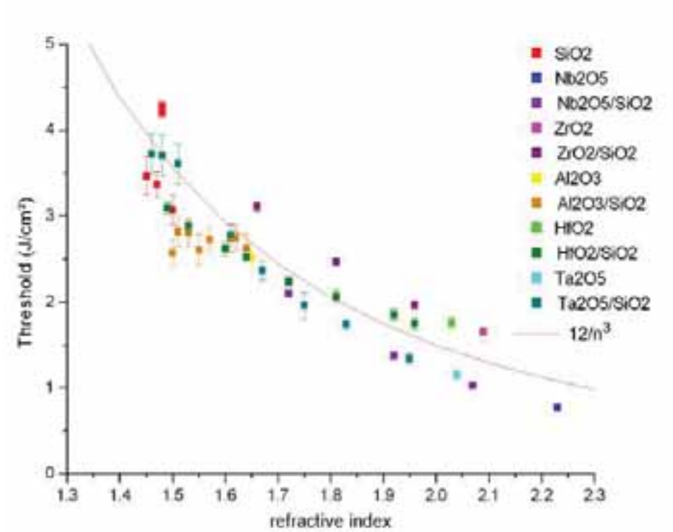
- Christopher J. Stolz, , Justin E. Wolfe, , Paul B. Mirkarimi, James A. Folta, , John J. Adams, , Marlon G. Menor, Nick E. Teslich, , Regina Soufli, , Carmen S. Menoni, , Dinesh Patel, **Substrate and coating defect planarization strategies for high-laser-fluence multilayer mirrors Original Research Article** *Thin Solid Films, Volume 592, Part B, 1 October 2015, Pages 216-220*
- **T. Suratwala,** L. Wong, P. Miller, M. Feit, J. Menapace, R. Steele, P. Davis, D. Walmer, "Sub-surface mechanical damage distributions during grinding of fused silica," Journal of Non-Crystalline Solids **352** (2006) 5601.
- N. Bloembergen, "Role of Cracks, Pores, and Absorbing Inclusions on Laser Induced Damage Threshold at Surfaces of Transparent Dielectrics," Appl. Opt. **12**, 661-664 (1973)



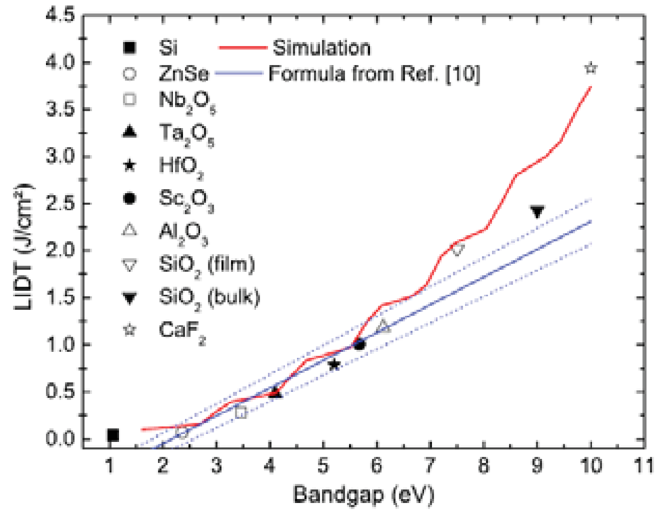
Fundamental laser damage resistance limit is defined by intrinsic damage



Carl M. Liebig et al., Optical Engineering, 2007. **46**(2): p. 023801. Lowry, J., et al., Appl. Opt., 1999. **38**(10): p. 2083-2085.



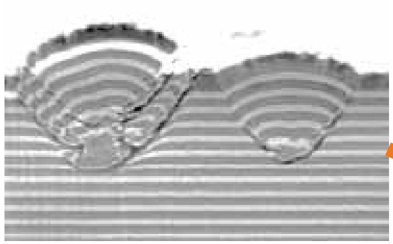
Benoit Mangote et al OPTICS LETTERS Vol. 37, No. 9, May 1, 2012

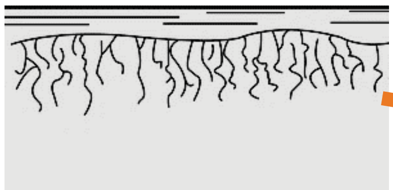


Gallais et al. J. Appl. Phys. 117, 223103 (2015)

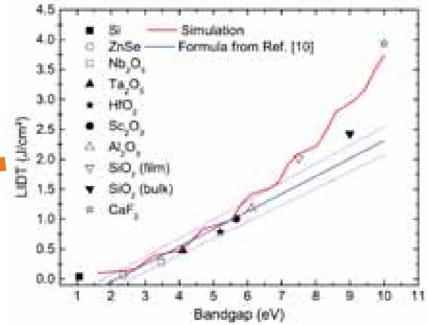
1-on-1 LIDT testing:

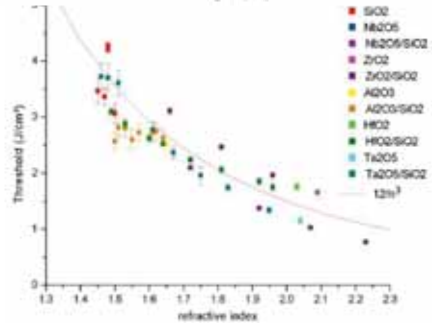
Ta_2O_5 coating irradiated by 1064 nm, 5 ns pulses

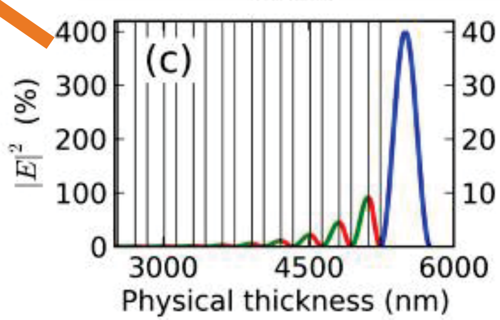




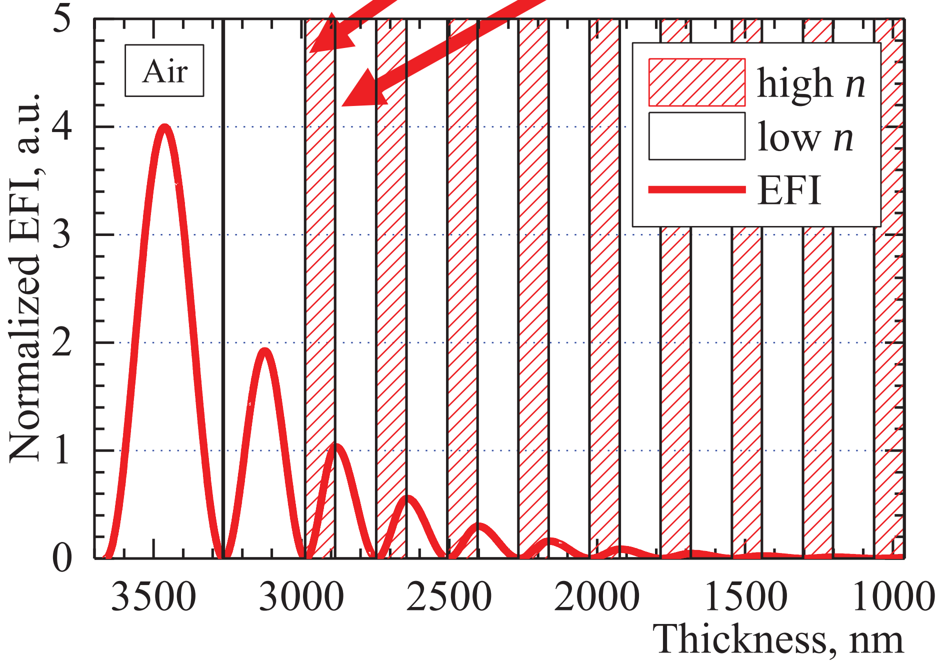
Krol, H., Gallais, L. Grezes-Besset, C., and Natoli, J.-Y., Investigation of nanoprecursors threshold distribution in laser-damage testing, *Optics Communications*, 256, pp. 184–189 (2005)



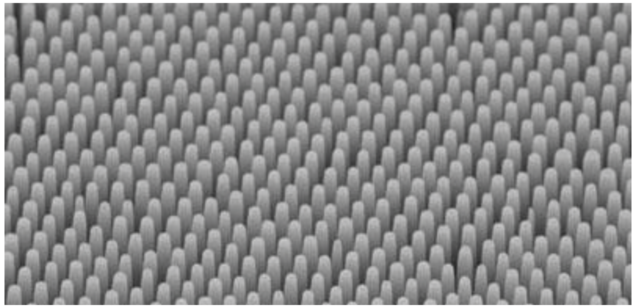




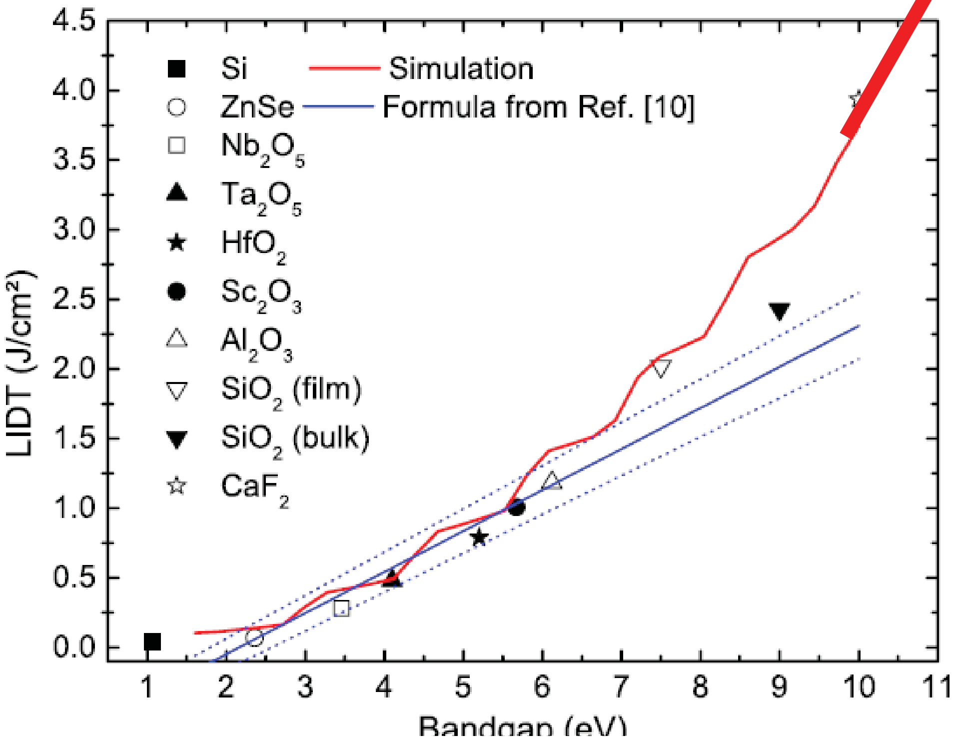
SAD - „Standard Approach“ Deposition:
different materials for different H and L layers

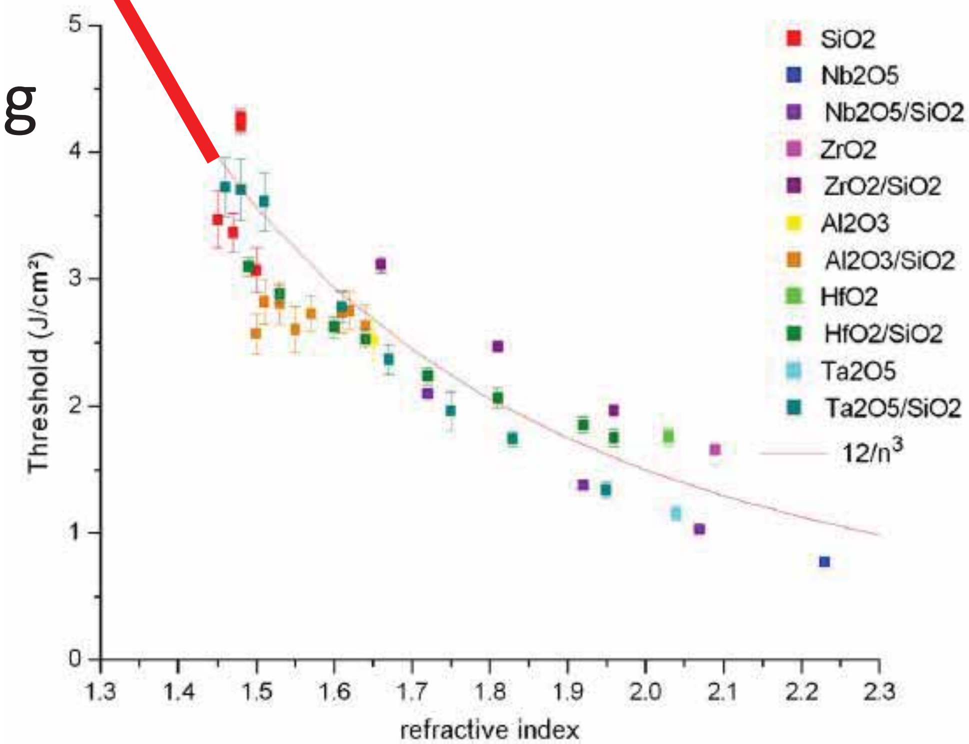


Solution: design artificial ultra low *n* materials in high band-gap matrix



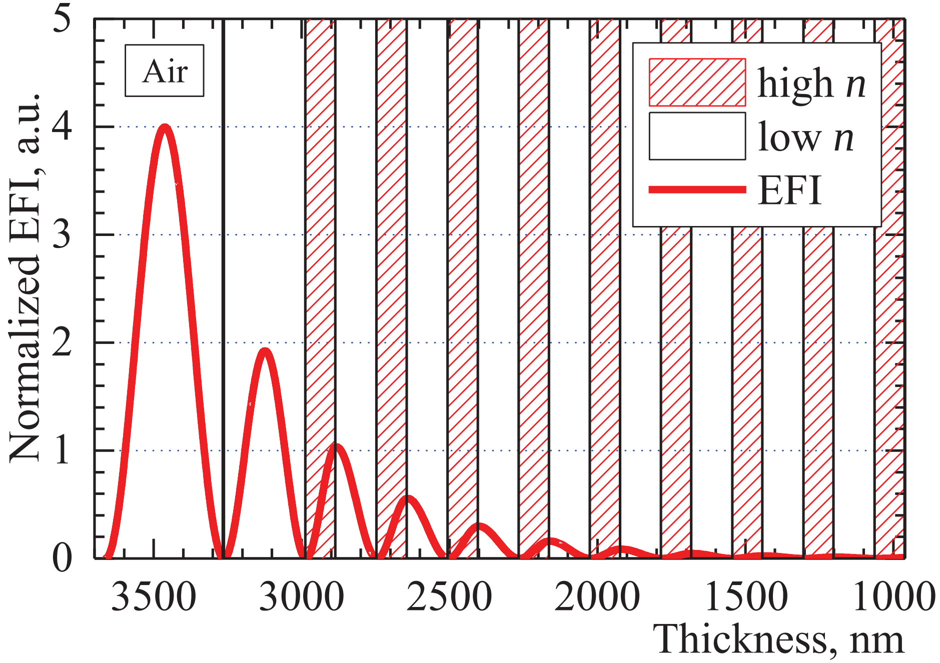
Interferometric lithography:
„single layer“
R coating



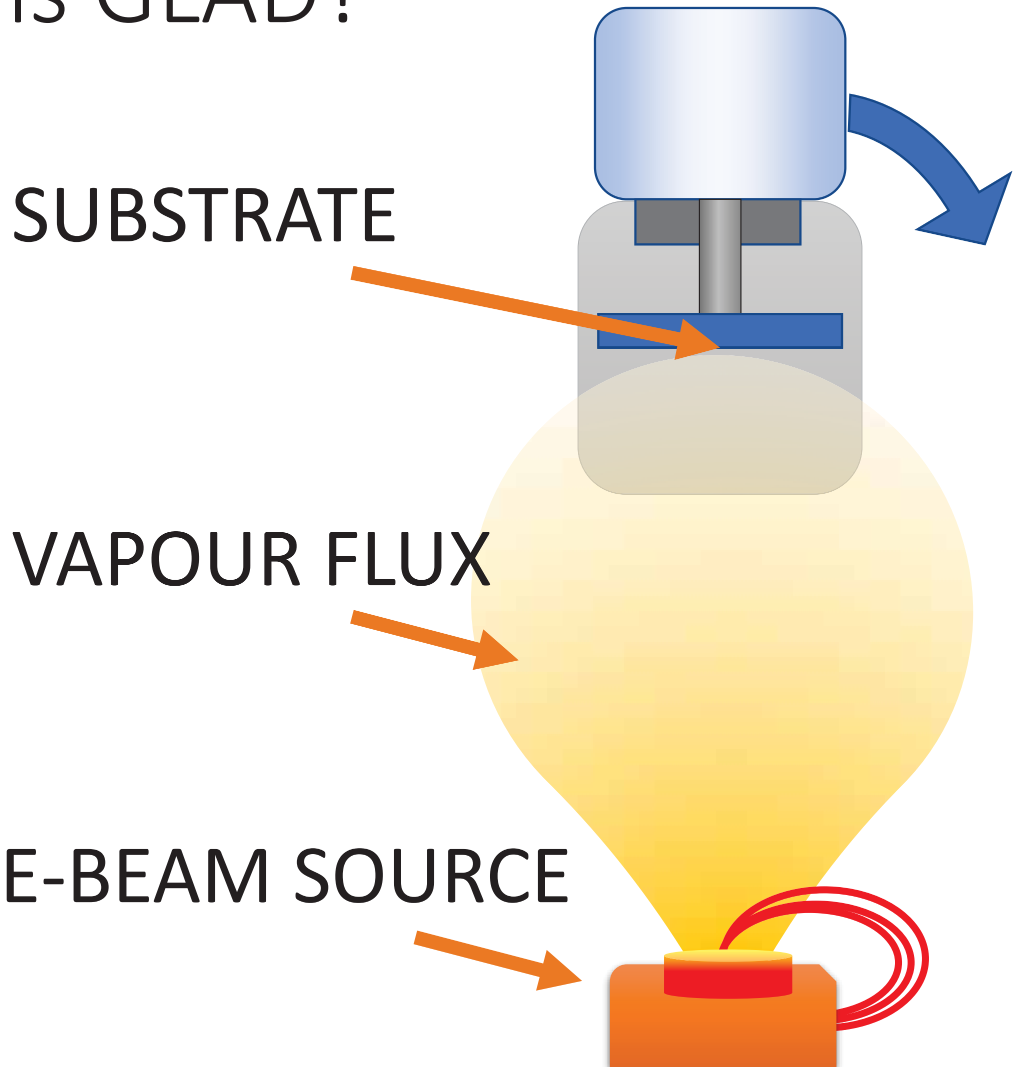


GO for GLAD! - use:

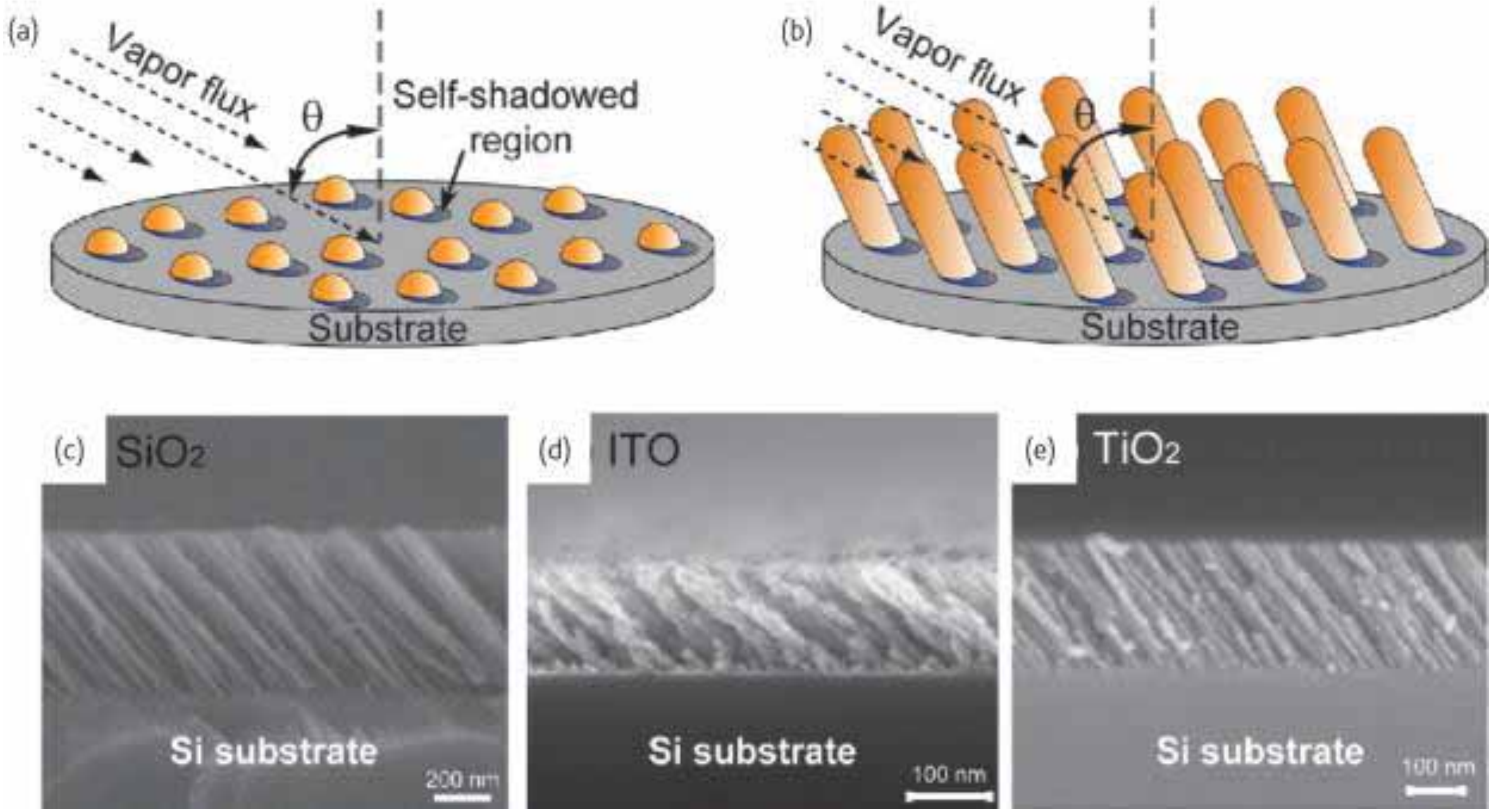
same material but different porosity



What is GLAD?

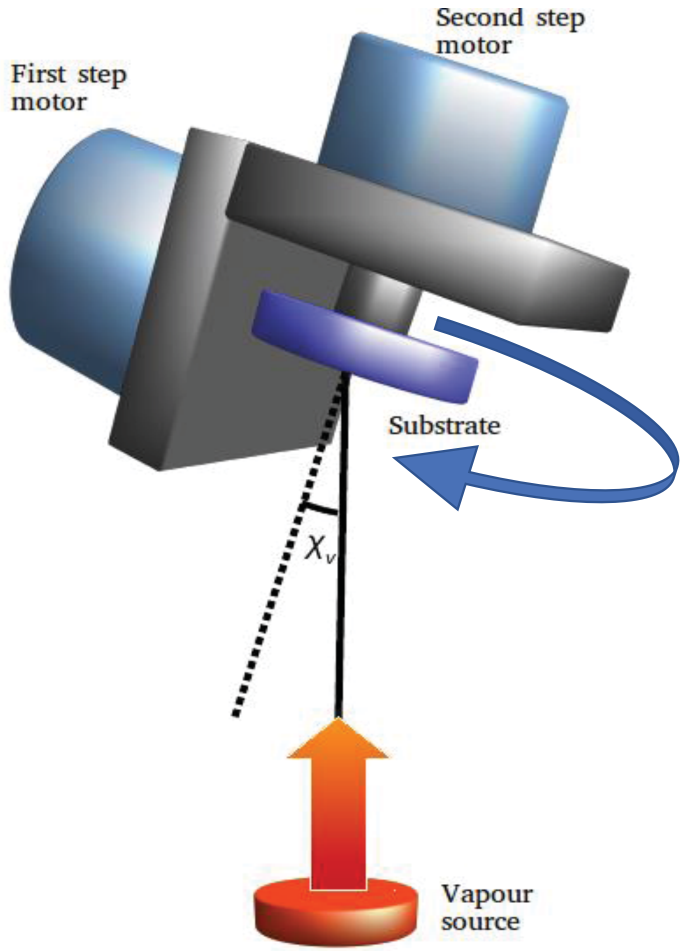


GLAD approach on stationary substrates coatings are birefringent



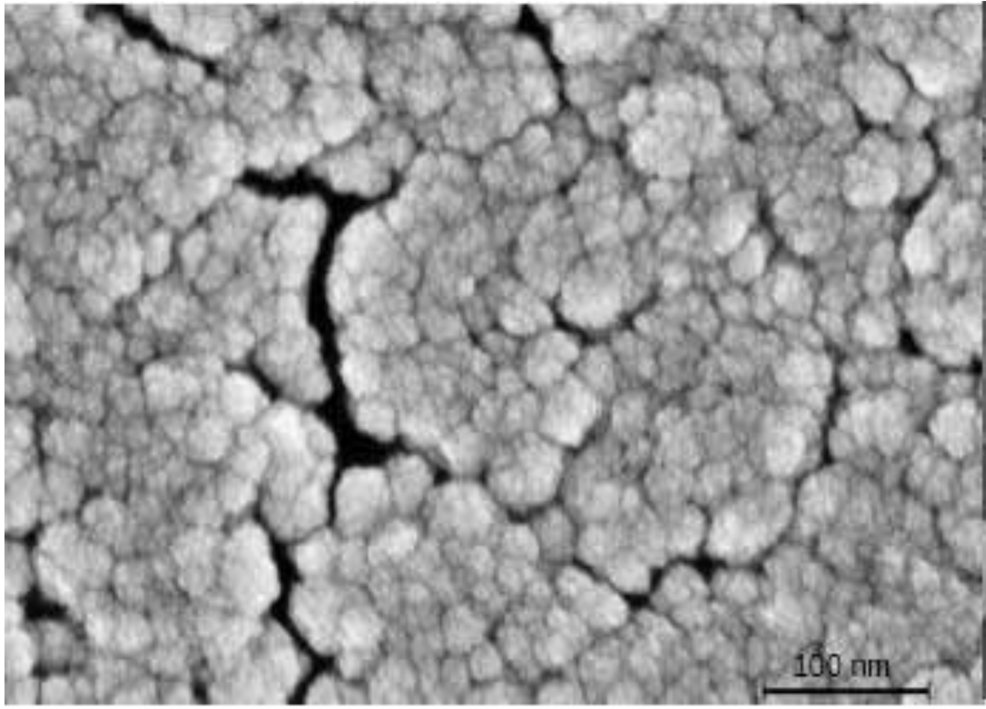
How we do it?


SUBSTRATE


Second step
motor
First step
motor
Substrate
χ_v
Vapour
source

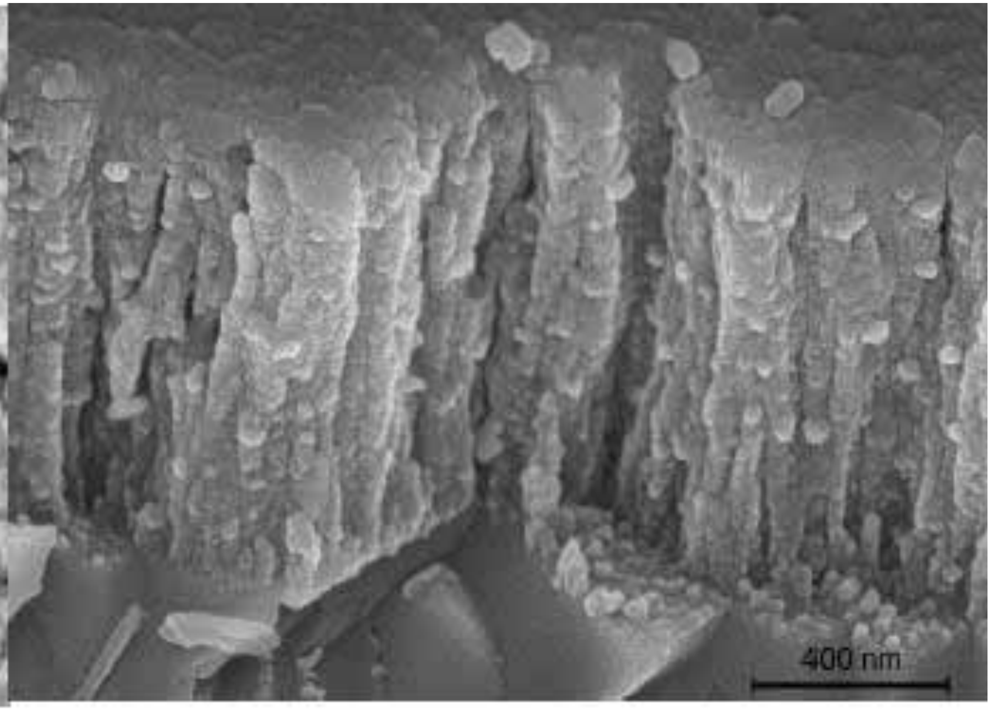
GLAD: VOLUME FRACTION POROSITY

TOP VIEW



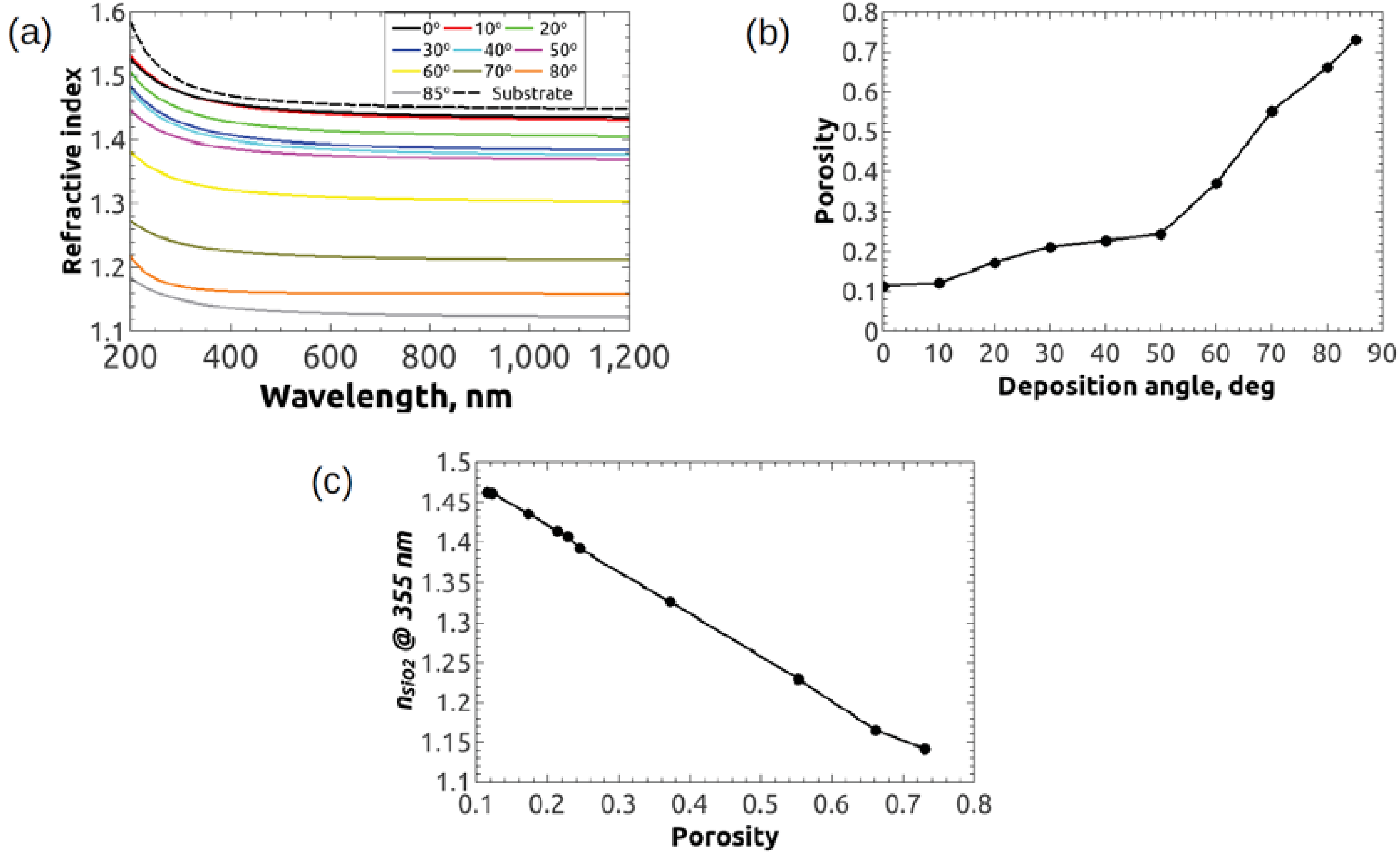
70 deg + Rotation

CROS-SECTION



70 deg + Rotation

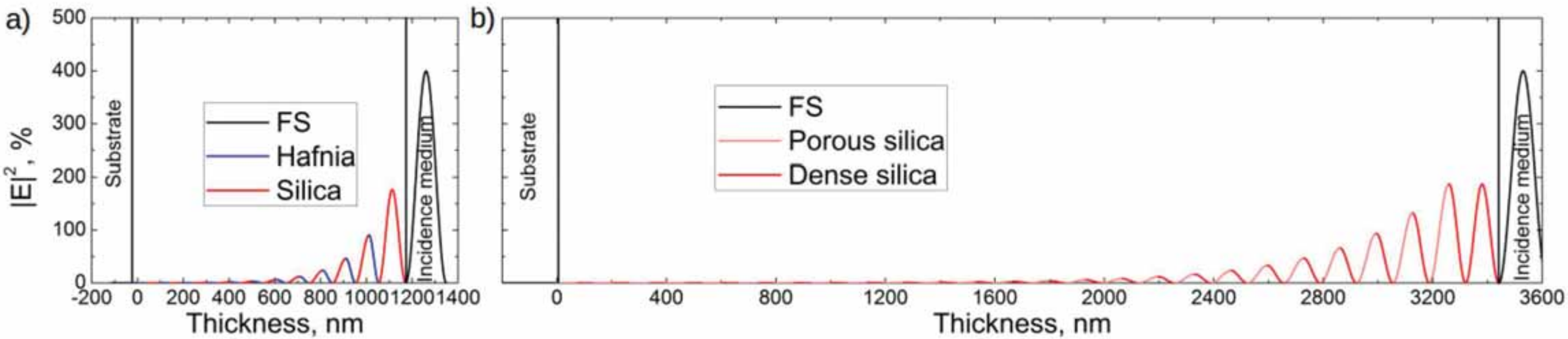
Calibration of refractive index for silica GLAD single-layers



Designing of „new generation“ porous/non-porous all-silica HR mirrors

SAD Reference:

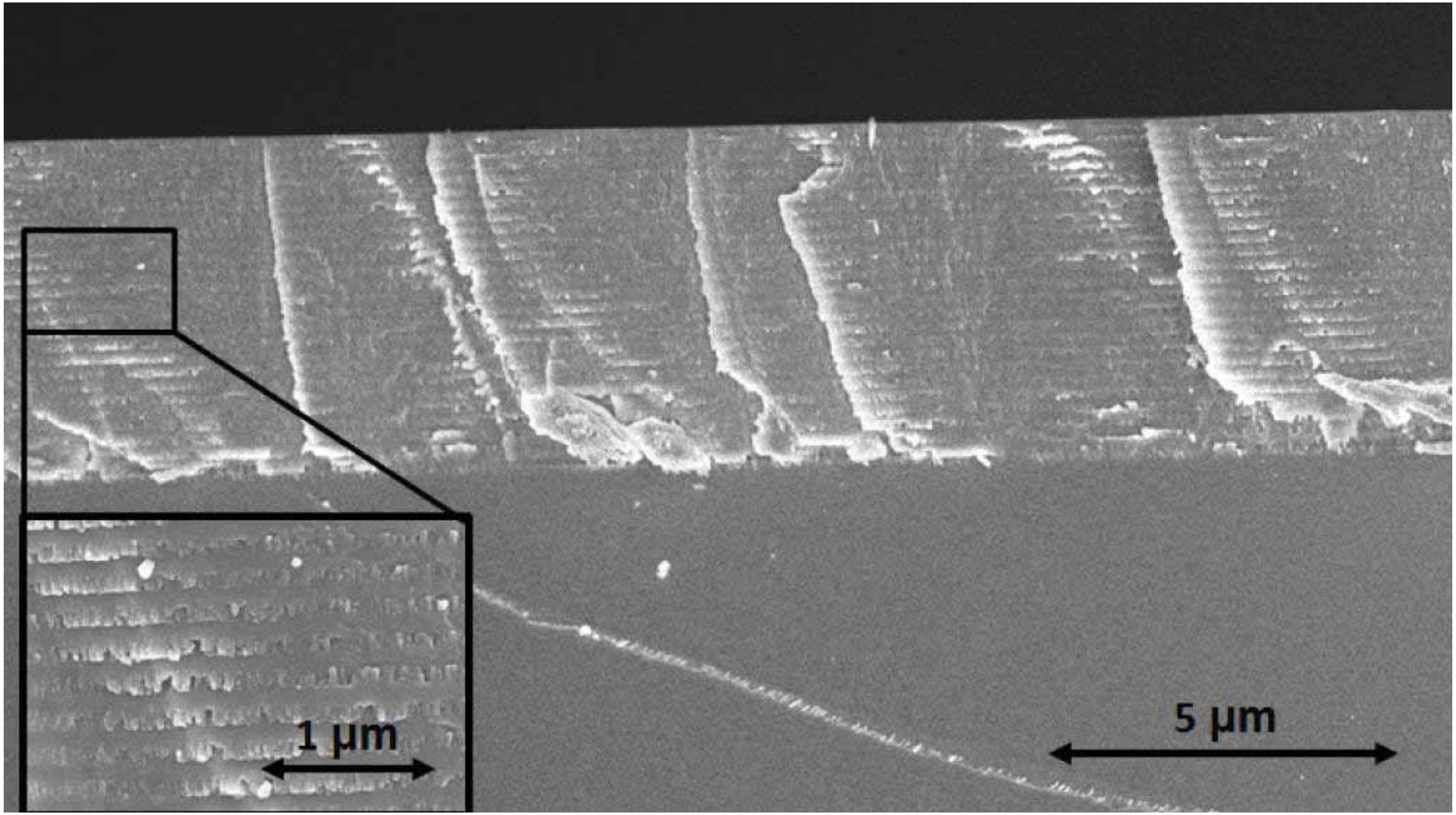
GLAD Experimental:



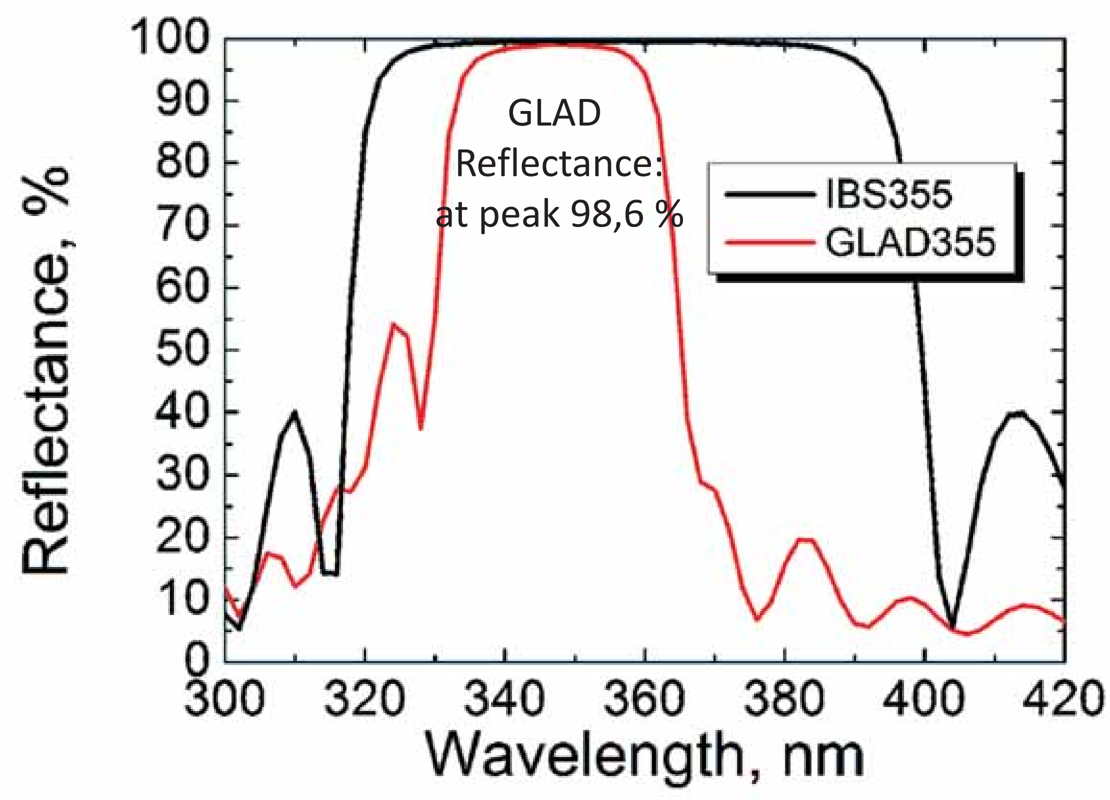
Hafnia/Silica: IBS

ALL-Silica: E-Beam

All-Silica Mirrors are Possible by Varying GLAD angle!

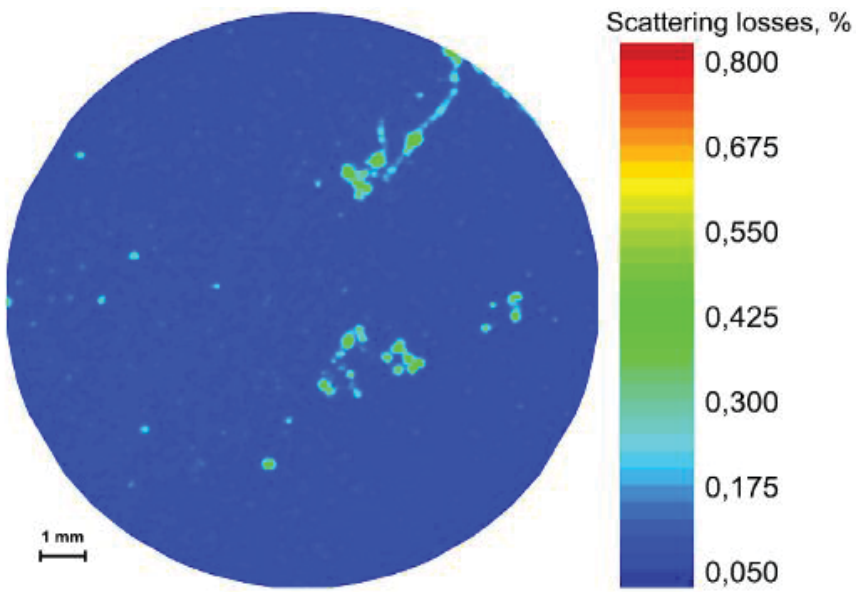


Spectral performance of both samples

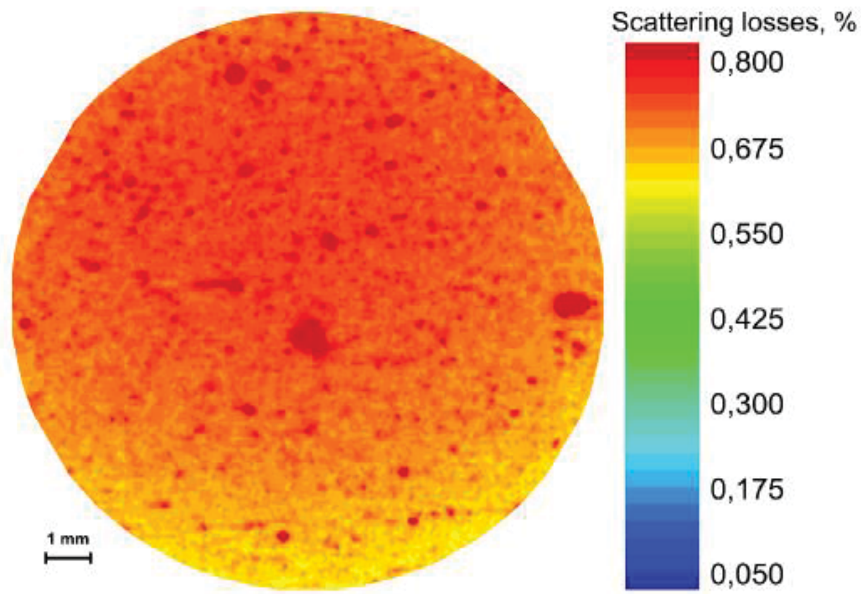


Mapping of Total Integrated Scattering (TIS) @355 nm

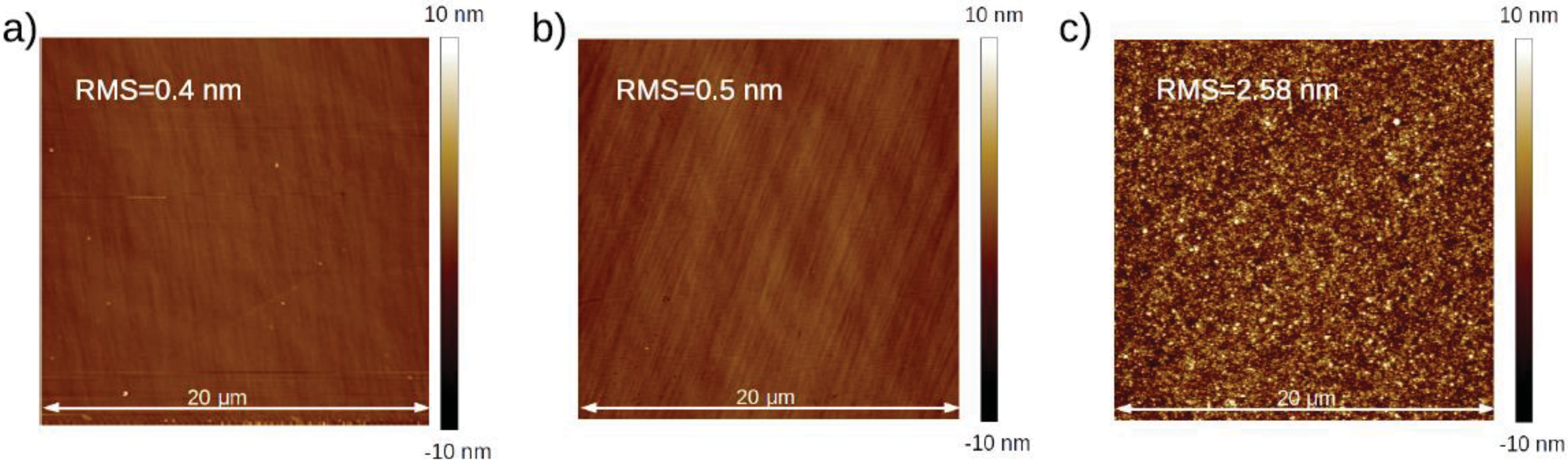
Hafnia/Silica: IBS



ALL-Silica: E-Beam



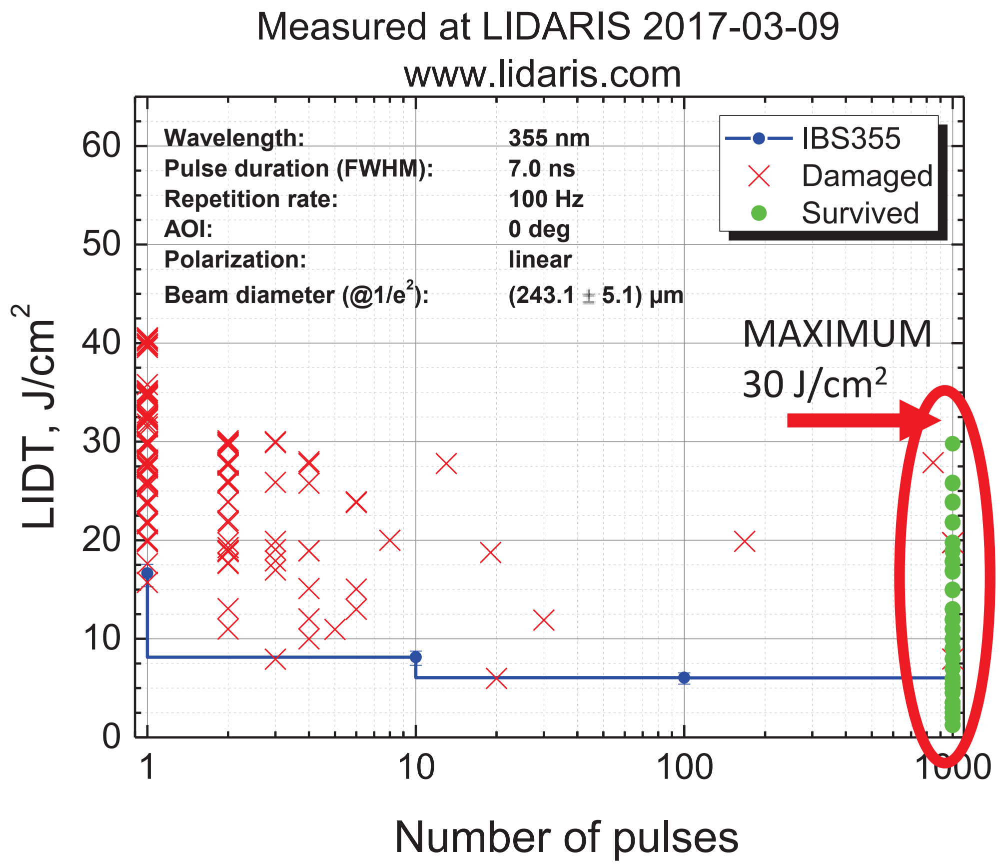
AFM Roughness



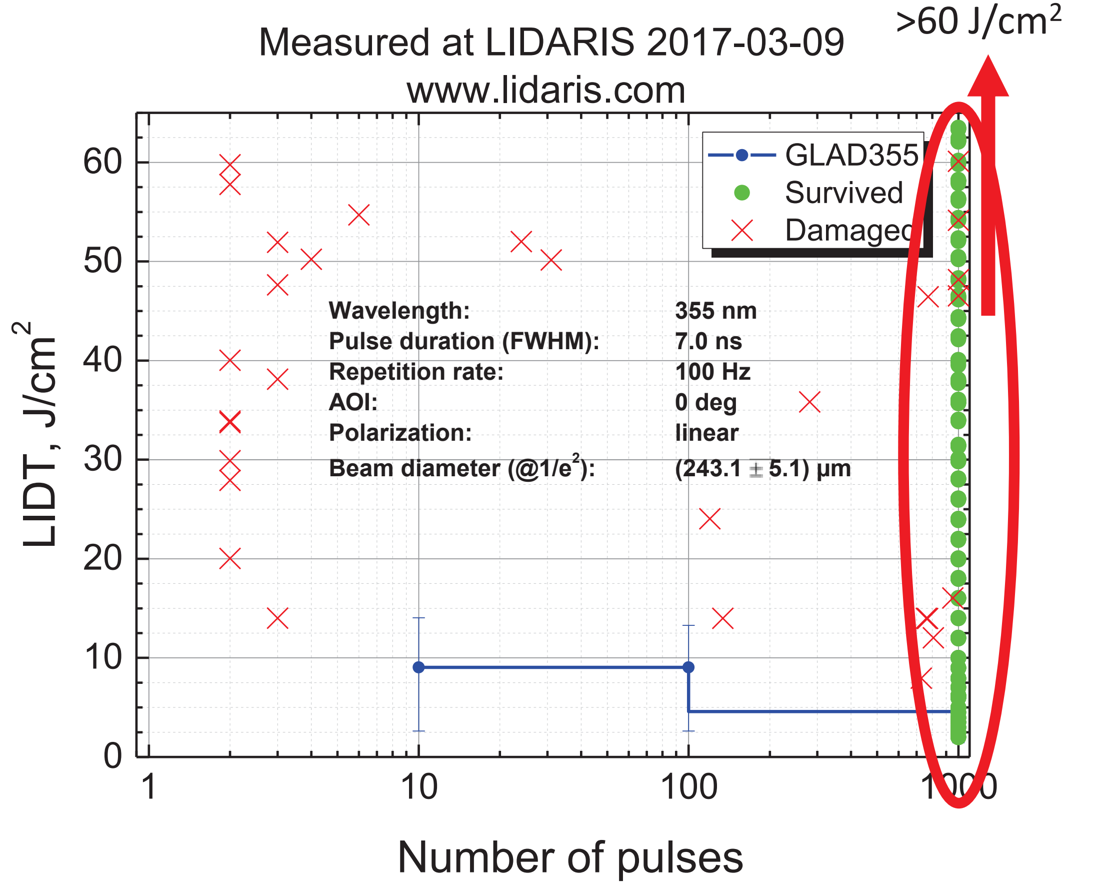
Fused silica substrate | Hafnia/Silica: IBS | ALL-Silica: E-Beam

First results of LIDT in UV
(ISO 1000-on-1, 355 nm, 0 deg, 4 ns)

Hafnia/Silica: IBS

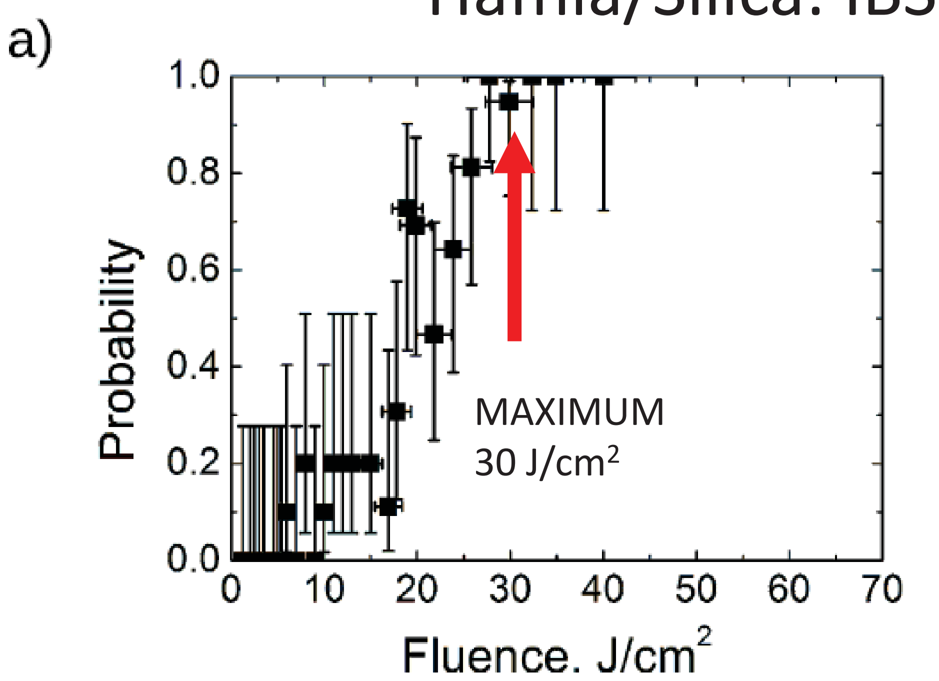


ALL-Silica: E-Beam

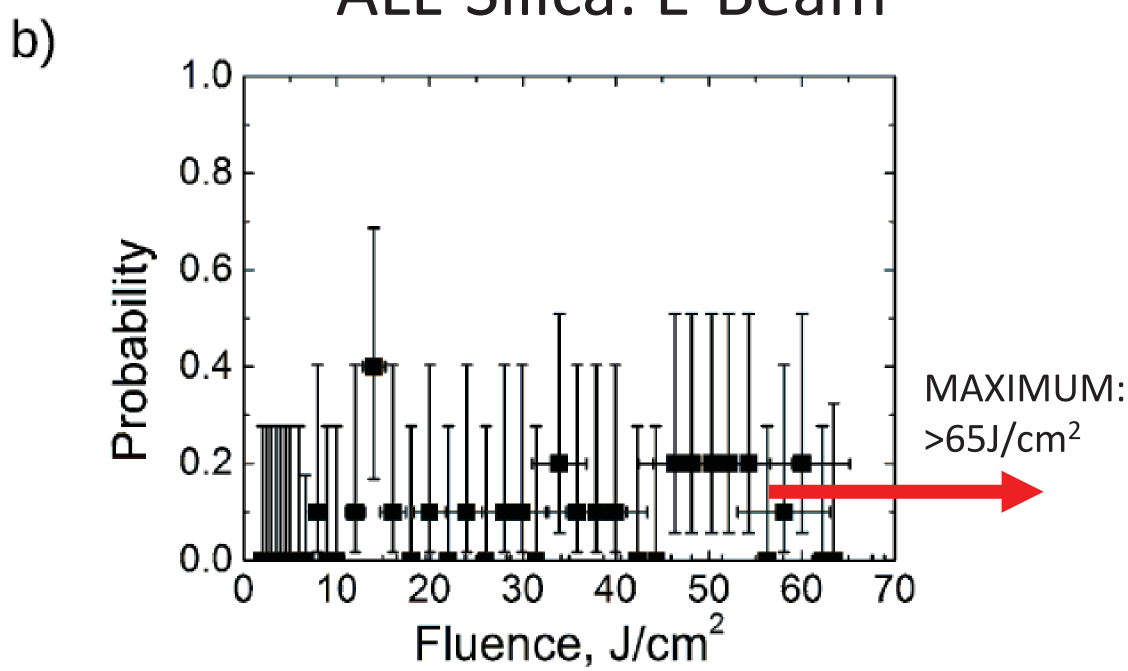


First results of LIDT in UV
(ISO 1000-on-1, 355 nm, 0 deg, 4 ns)

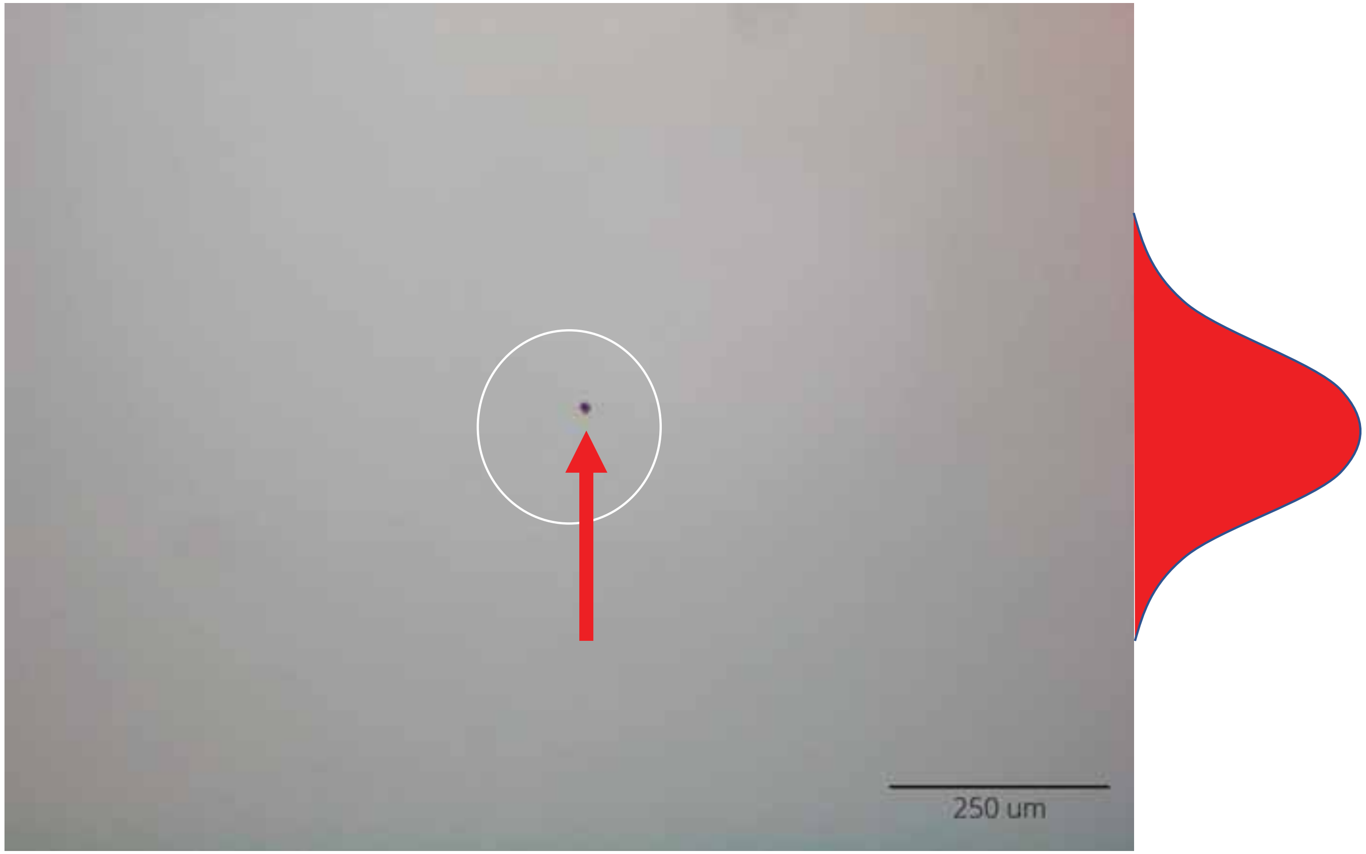
Hafnia/Silica: IBS



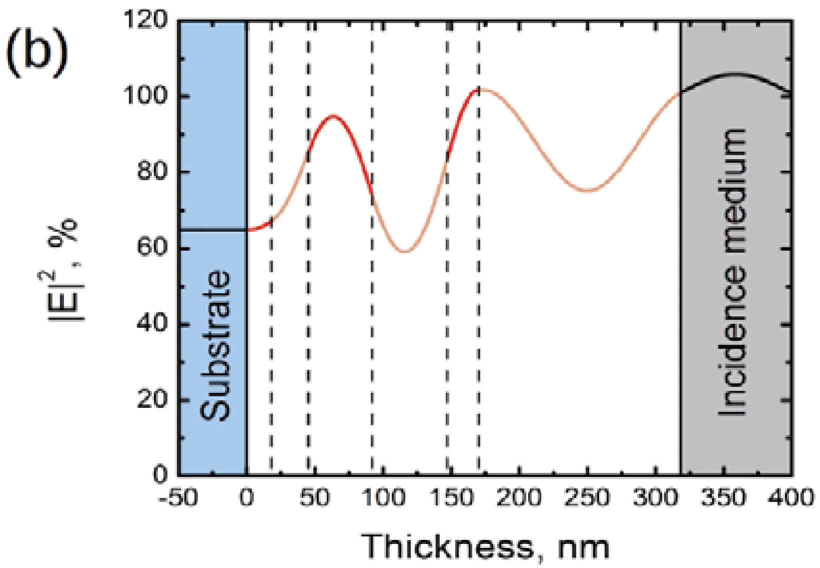
ALL-Silica: E-Beam

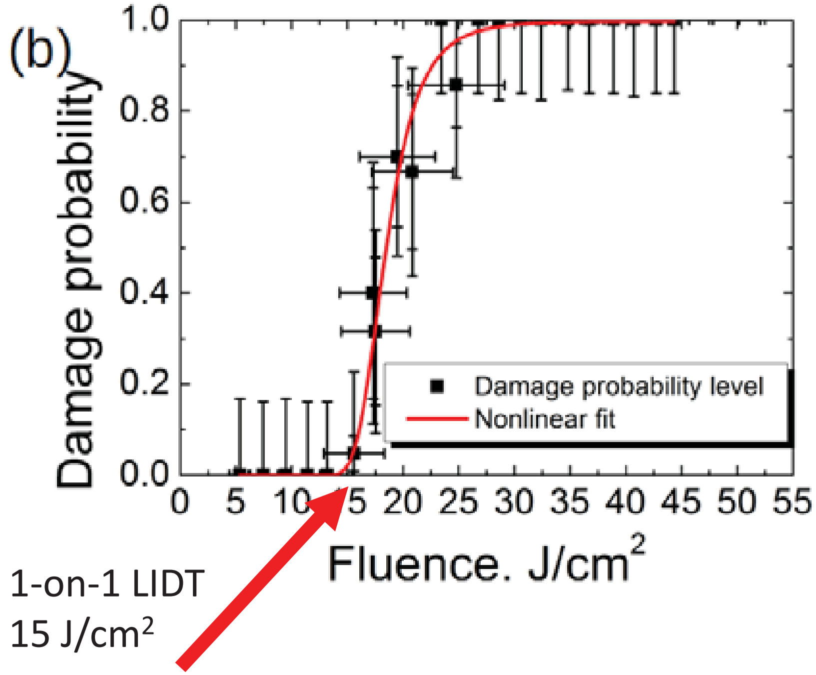


Typical Damage Morphology:
light intensified by extrinsic nodular defects



Multilayer AR coatings can be also produced in GLAD way!





TOMAS TOLENIS et al - Vol. 7, No. 4 | OPTICAL MATERIALS EXPRESS , (2017)

Conclusions

- All-silica HR coating was produced by GLAD technique for the first time and indicate at least 2x higher LIDT potential for UV applications (with respect to SAD hafnia/silica IBS coating);
- Intrinsic damage threshold of coatings can be increased by using “effective refractive index” materials;
- Large roughness and thus scattering losses should be overcome in order to exploit full potential of GLAD technology;
- GLAD technology is also applicable for production of multilayer AR coatings.

More information:

Tomas Tolenis, Lina Grinevičiūtė, Linas Smalakys, Mindaugas Ščiuka, Ramutis Drazdys, Lina Mažulė, Rytis Buzelis & Andrius Melninkaitis, “Next generation highly resistant mirrors featuring all-silica layers”, Scientific Reports 7, Article number: 10898 (2017) doi:10.1038/s41598-017-11275-0

Tomas Tolenis, Lina Grinevičiūtė, Rytis Buzelis, Linas Smalakys, Egidijus Pupka, Simas Melnikas, Algirdas Selskis, Ramutis Drazdys, and Andrius Melninkaitis, "Sculptured anti-reflection coatings for high power lasers," Opt. Mater. Express **7**, 1249-1258 (2017)