High performance Interference coatings for Blue Laser Fusion optical enhancement cavity Inertial Fusion Energy Driver

Aaron Davenport[1], Carmen S. Menoni[1], Trevor Cohen[2], Morgan Pattison[2]

[1]Electrical and Computer Engineering, Colorado State University, Fort Collins, CO,USA, [2]Blue Laser Fusion, Goleta, CA, USA

carmen.menoni@colostate.edu

COLORADO STATE UNIVERSITY

BLUE LASER FUSION

RISE | INERTIAL FUSION SCIENCE AND TECHNOLOGY HUB

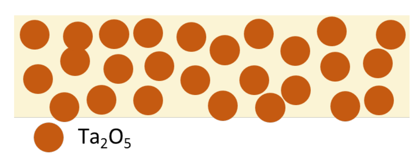
Abstract

This work describes amorphous oxide mixtures engineered for multilayer dielectric coatings intended to be implemented in optical enhancement cavities operating at λ~ 1μm. The deposition process, the materials and their different properties (composition, and optical properties) are presented.

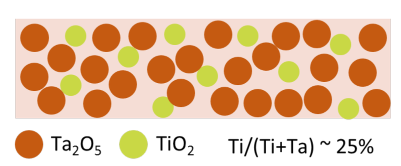
Materials and applications

Engineered amorphous oxides and mixtures

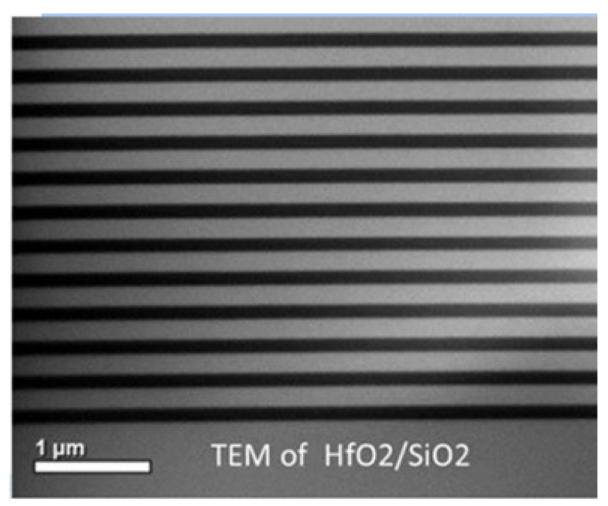
- Binary oxides, HfO_2, Ta_2O_5, GeO_2, Sc_2O_3.....



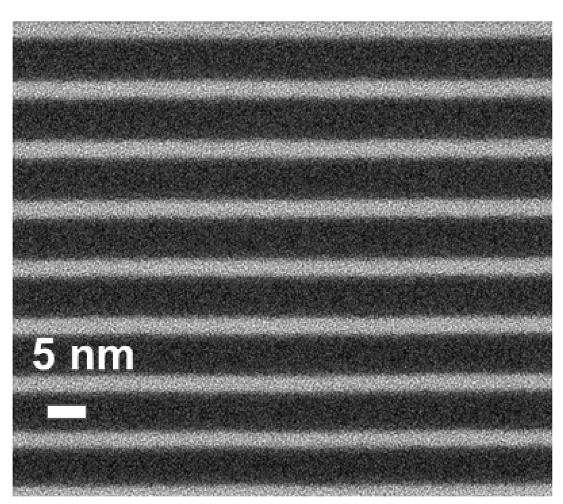
- Mixtures: i.e. TiO_2:Ta_2O_5, HfO_2: SiO_2, TiO_2:GeO_2



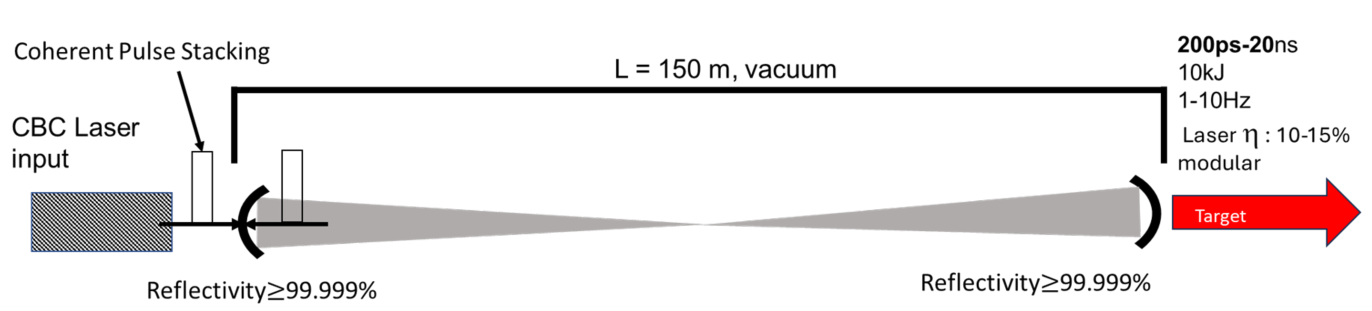
Multilayer dielectric coatings



Nanolaminates

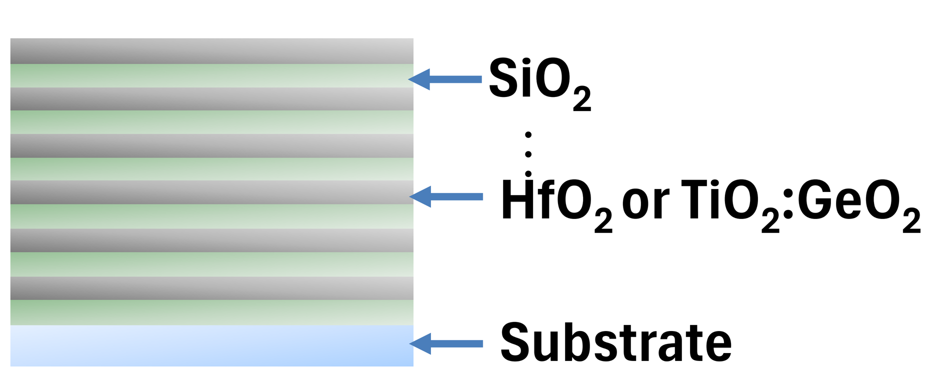


Optical Enhancement Cavity



Mirror Coatings Requirements

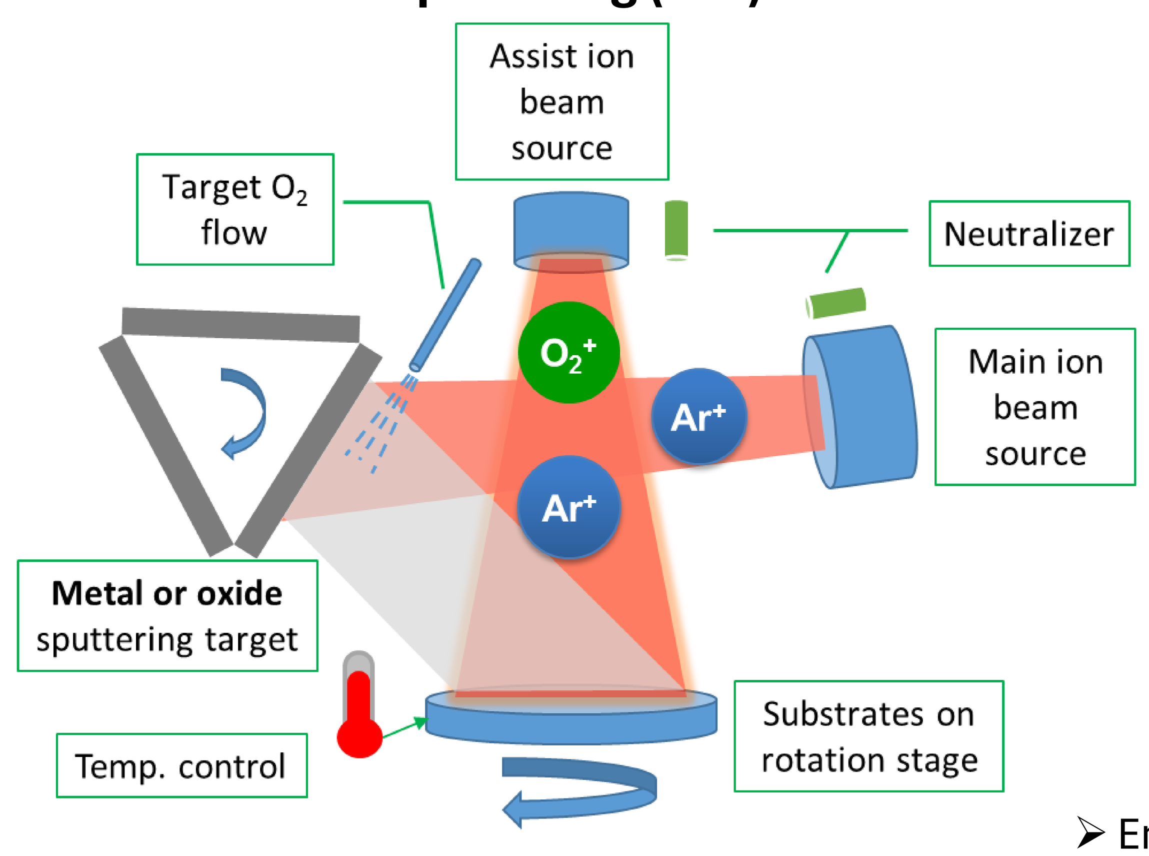
Reflectivity >99.999% at λ ~1 µm
Low absorption loss < 1 ppm at λ ~1 µm
High laser damage threshold for ns pulse duration



- Amorphous SiO_2 offers the lowest absorption and highest damage threshold (low refractive index layer)
- Amorphous HfO_2 or TiO_2:GeO_2 are excellent choices for high index layers in the stack as can achieve low absorption and high damage threshold
- To reach ultra-low absorption coatings need to be annealed to temperatures of ~600 °C for extended periods

Deposition techniques

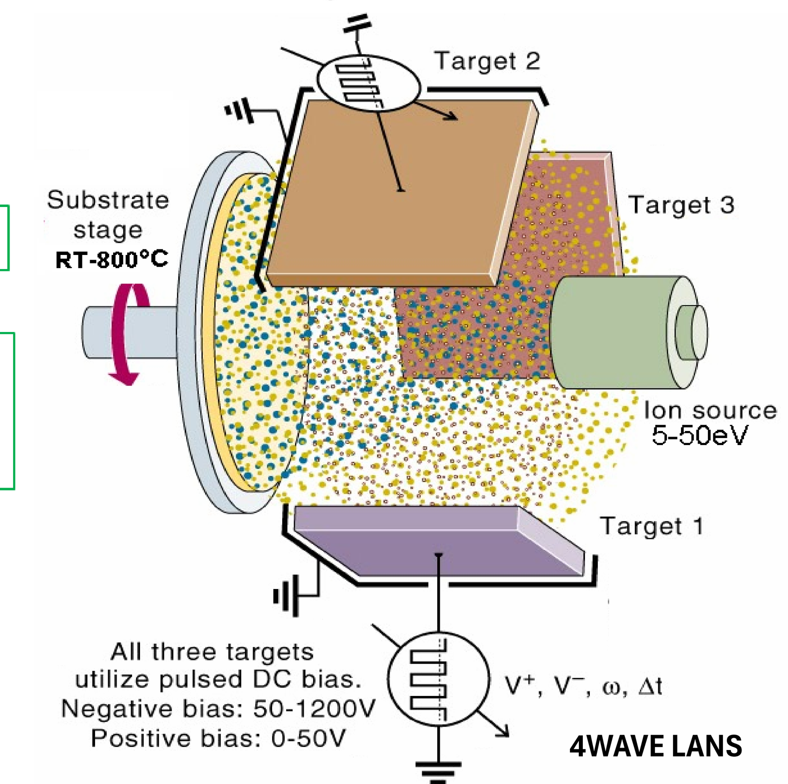
Ion Beam Sputtering (IBS)



- Gridded ion source
- Second ion source
- Direct control over:
  - Ion beam current.
  - Ion beam voltage.

- Reactive gas partial pressure.
- Temperature.
- Dense coatings, and environmentally robust.

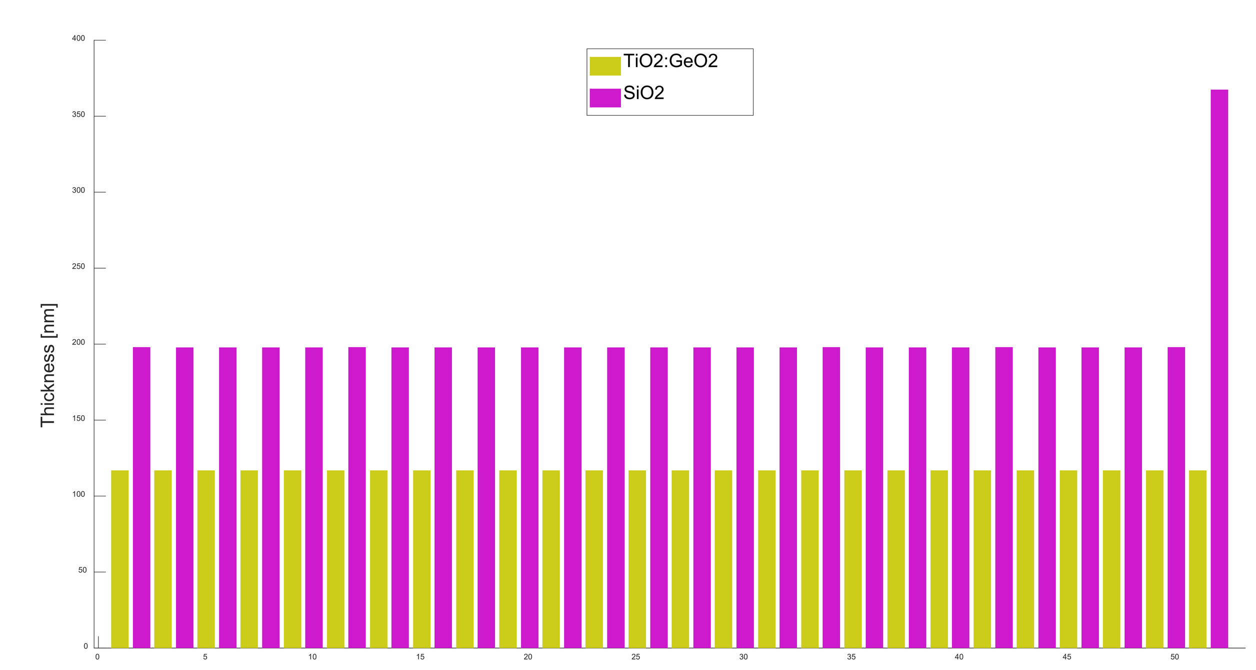
Biased Target Deposition (BTD)



- End-Hall ion source.
- Up to three metal targets biased simultaneously .
- Pulse and width period control for each target. Used to create mixtures with different cation concentrations.
- Reactive gas flows near the substrates surface for oxidation or nitridation reactions.

Mirror coating design

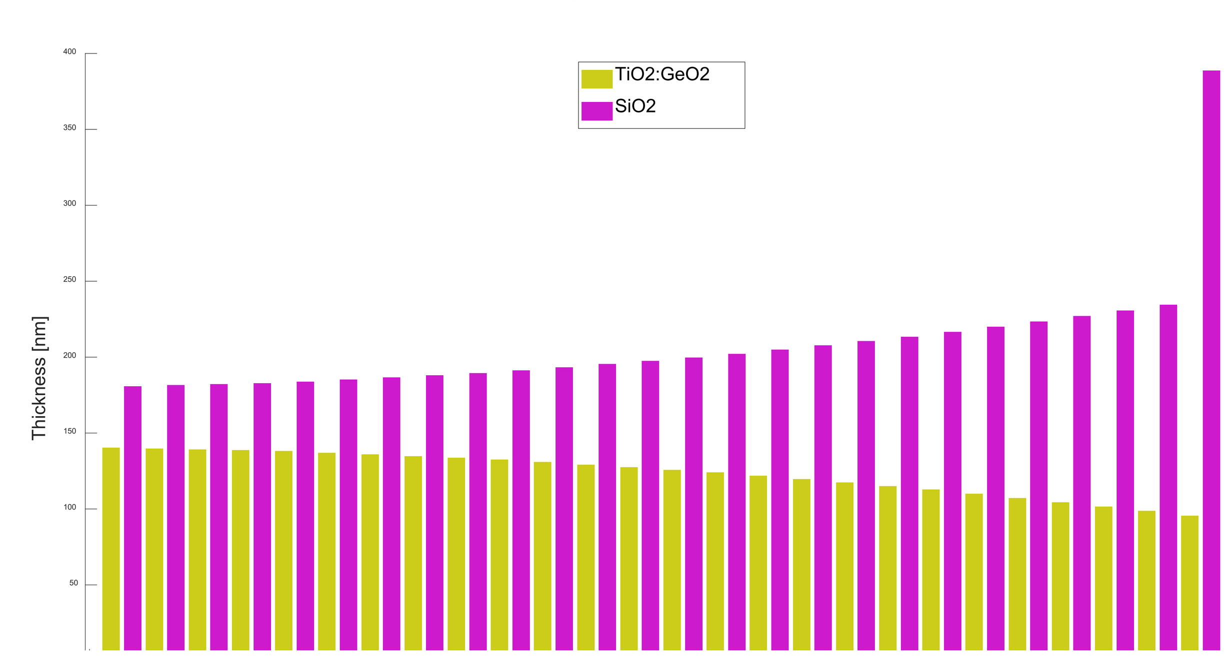
Design 1: 52 layers



Quarter wave stack
Thickness:
3.282 μm for TiO_2:GeO_2
5.374 μm for SiO_2

TiO_2:GeO_2 Ratio: 0.379
SiO_2 Ratio: 0.621

Design 2: 52 layers

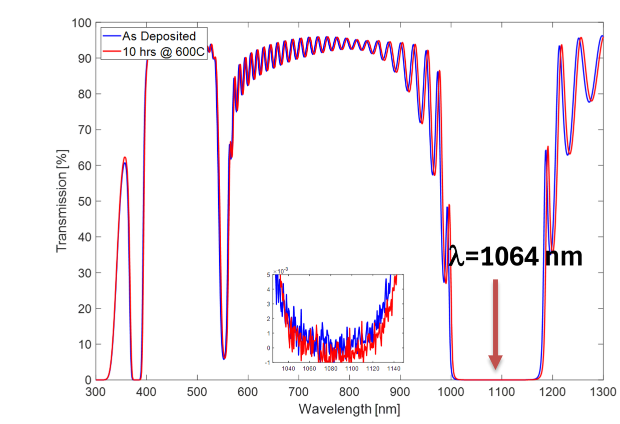


Non-Quarter Wave stack
Thickness:
3.211 μm for TiO_2:GeO_2
5.416 μm for SiO_2

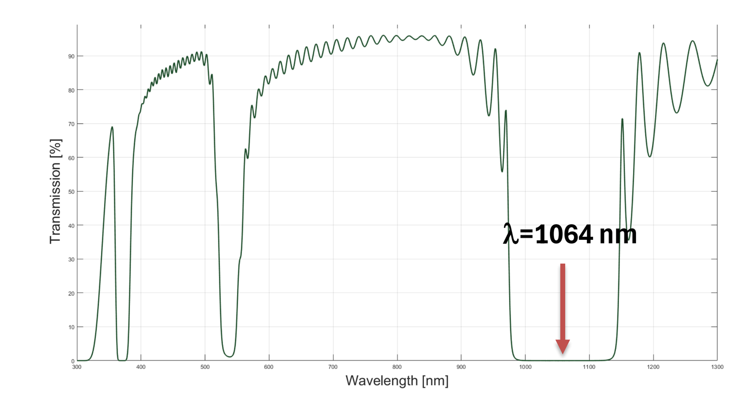
TiO_2:GeO_2 Ratio: 0.372
SiO_2 Ratio: 0.628

Mirror Optical Properties

Transmission vs Wavelength



The transmittance at λ=1064 nm reduced from 6 ppm to 3 ppm after annealing for 10 hrs at 600°C



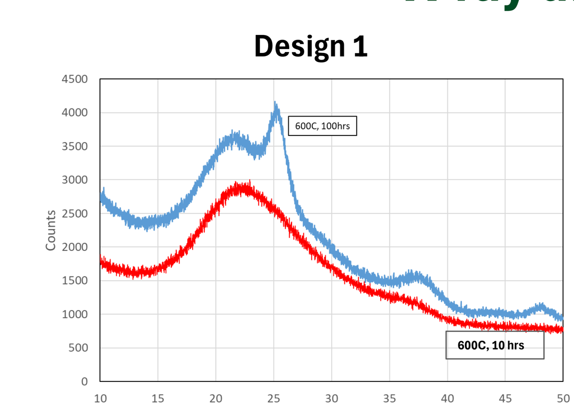
Tranmittance: 10 ppm at λ=1064

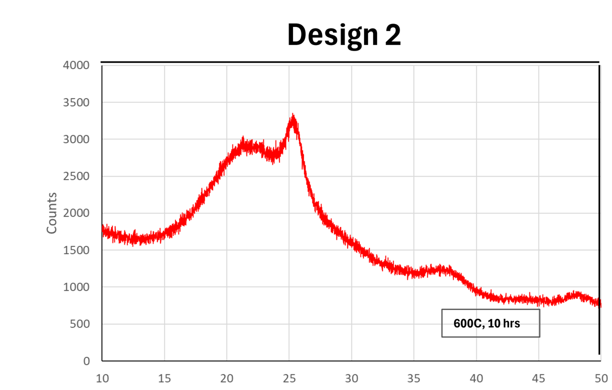
Absorption loss at λ=1064 nm

Sample ID	AD		600C, 10hrs	
	α (ppm), Front	α (ppm), Back	α (ppm), Front	α (ppm), Back
Design 1 - UVFS	272	156	5.20	10.0
Design 2-UVFS	143-152	107-110	3.3	6.1 – 6.5

Mirror Structural Properties

X-ray diffraction (XRD)





Earlier onset of crystallization

Residual stress in multilayer dielectric coatings

Run	# Layers	As Deposited (MPa)	600°C 10 hr. (MPa)
Design 1	52	-189	-74
Design 2	52	-177	-62

Summary

High reflectance coatings for λ~ 1μm with 52 layers demonstrated to achieve:

- Transmission T= 3 ppm after annealing for 10 hrs at 600 °C.
- Annealing reduces absorption loss, reaching values of 3.3 ppm after 10 hrs annealing at 600 °C.
- Residual stress: compressive, low, -62 MPa after 10 hrs annealing at 600 °C.
- Incipient crystallization in Design 2 after 10 hrs annealing at 600 °C.

Future work includes: increase the annealing cycle length to further reduce absorption to < 1ppp and carry out laser damage tests

Acknowledgements

This work is supported by the U.S. Department of Energy (DOE), Office of Science, Fusion Energy Sciences, under Awards No. DE-SC0024882: IFE-STAR and DE-SC0023878.