Reactive, Ion-Assisted Deposition of E-Beam Evaporated Ti for High Refractive Index TiO_2 Layers and Laser Damage Resistant, Broad Bandwidth, High Reflection Coatings

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Z Backlighter

Sandia National Laboratories

Exceptional service in the national interest

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Optical Interference Coatings Conference 2013

Overview

What we do…

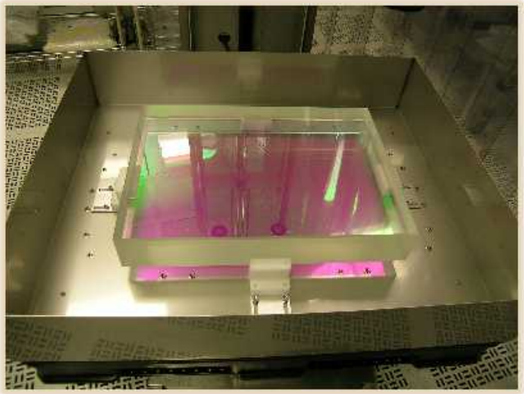
Deposit optical coatings consisting of HfO_2/SiO_2 layer-pairs on large optics for Sandia's Z-Backlighter Lasers using e-beam evaporation. HfO_2 is deposited by reactive evaporation of Hf in O_2 back pressure; sometimes we use ion-assisted deposition (IAD).

What we want to do…

Increase the bandwidth of our high reflection (HR) optical coatings while still maintaining good laser damage resistance.

Our approach…

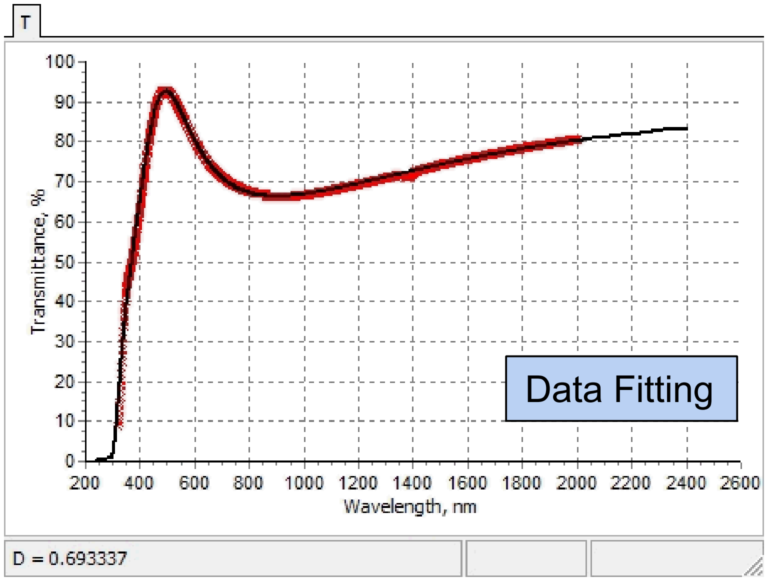
Utilize a 42-layer, quarter-wave, HR coating design centered at 1054 nm, for 45^{o} AOI, Ppol. Replace some of the inner HfO_2 layers with higher-index TiO_2 layers to increase HR bandwidth, and measure the laser damage resistance of these coatings.

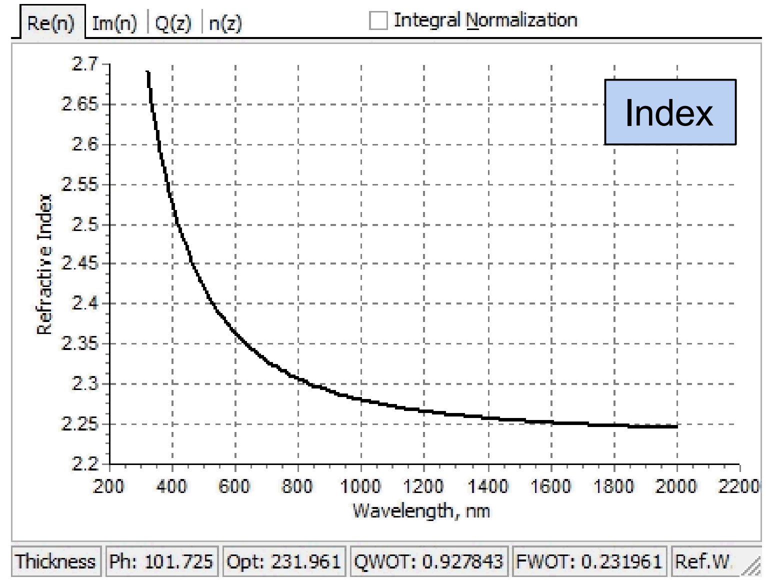


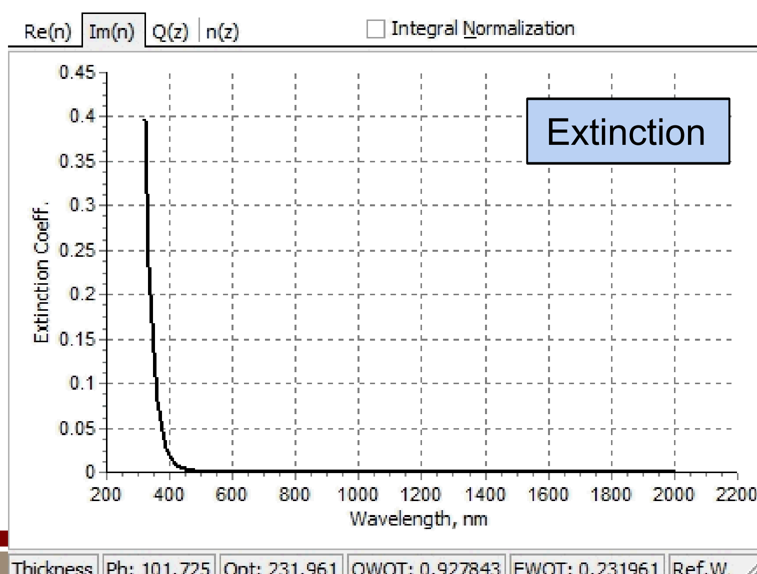
TiO_2 Single-Layers

- Reactive evaporation of Ti (pellets) in O_2 back pressure using IAD to optimize index of refraction
- Tested different temperatures, deposition rates, O_2 back pressures, and IAD settings for 100 nm thick layers
- Measured the spectra of TiO_2 single layers using Lambda 950 spectrophotometer
- Analyzed the single layer spectra with OptiChar software in terms of index of refraction (n) and extinction coefficient (k)
  - We selected the normal dispersion model (Cauchy) for index and UV/Vis model (exponential) for absorption

Example of TiO_2 Single-Layer Characterization in OptiChar







Formulas:

Cauchy: $n(\lambda)=A_0+A_1/\lambda^2+A_2/\lambda^4$

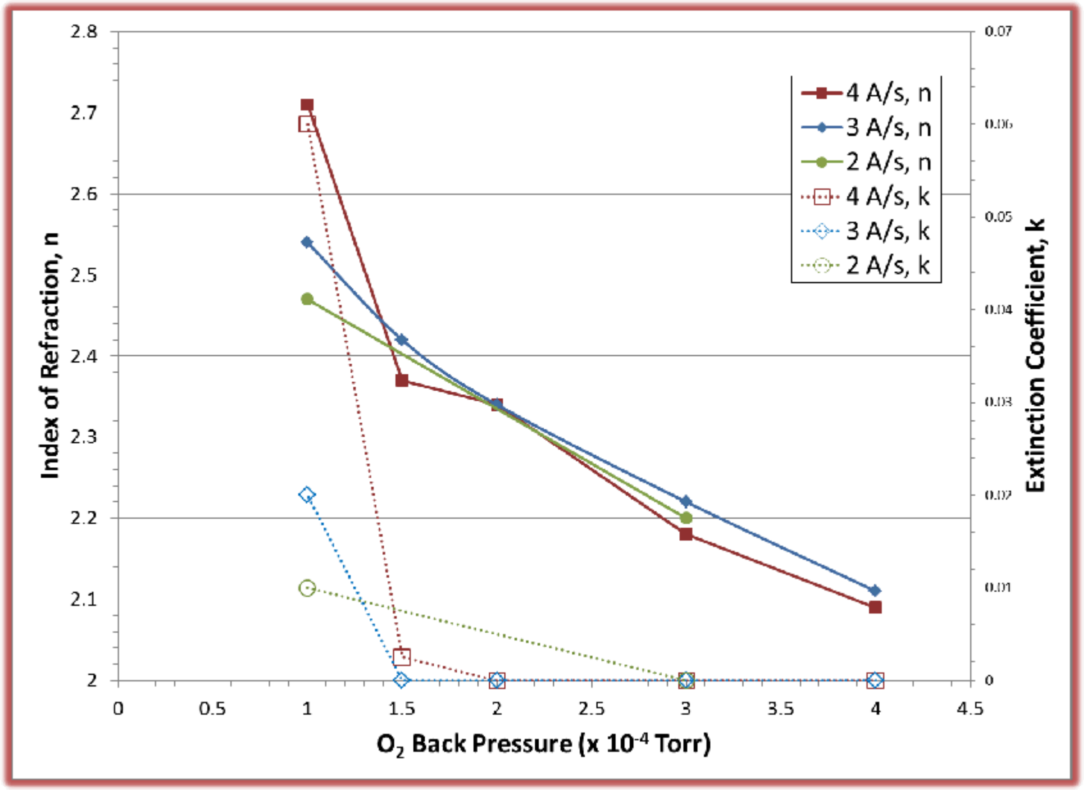
- $A_0=2.233316$
- $A_1=0.046818$
- $A_2=0$

Exponential: $k(\lambda)=B_1\exp(B_2\lambda^{-1}+B_3\lambda)$

- $B_1=72946.15213$
- $B_2=0$
- $B_3=-37.880308$

TiO_2 Single-Layer Analysis Results

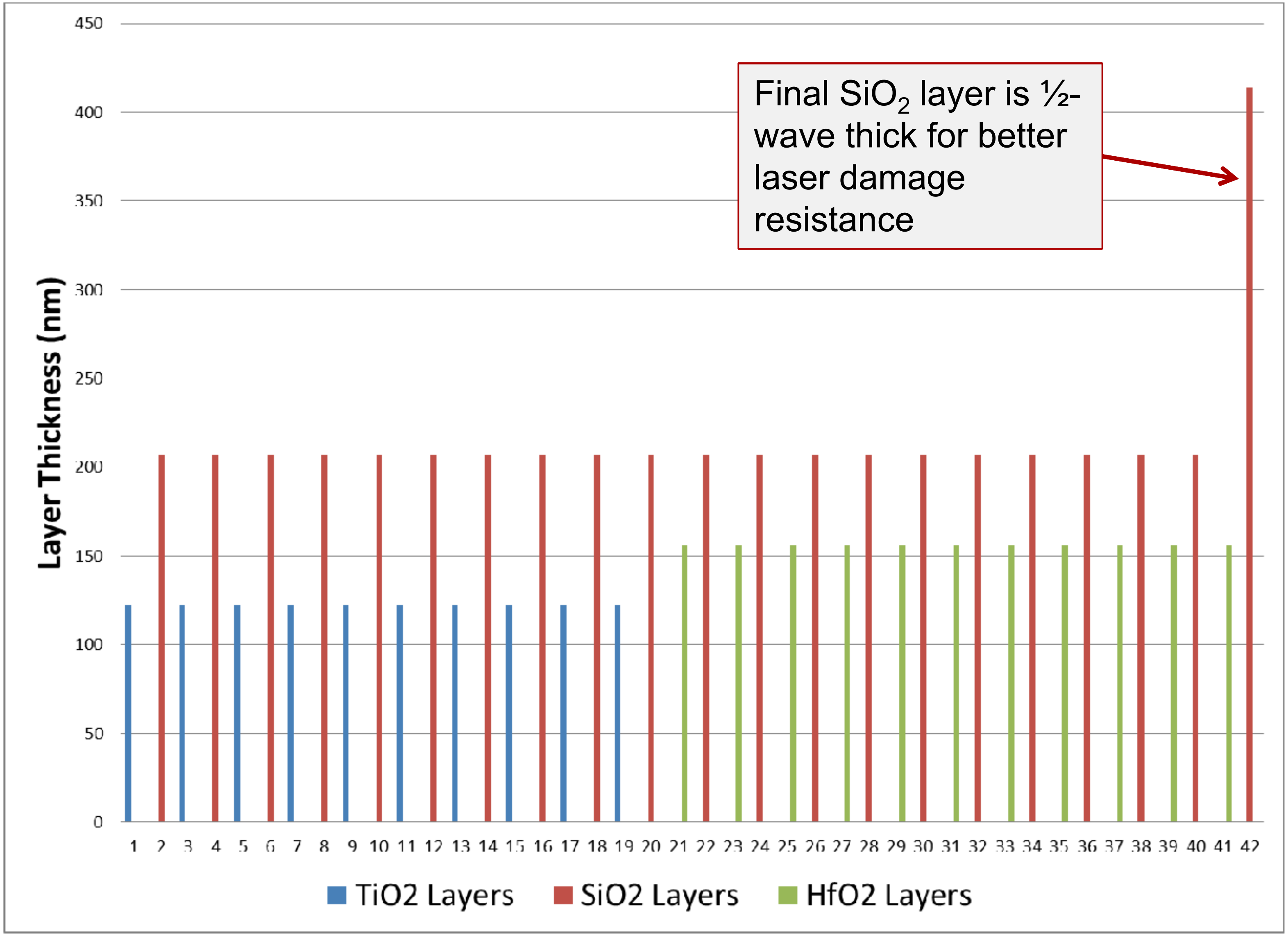
- Initial tests indicated higher indices at 200 °C (maximum chamber temp.) and IAD beam current/voltage of 600 mA/400 V
- Varied the O_2 back pressure and deposition rate to find the highest index and lowest absorption TiO_2 layers



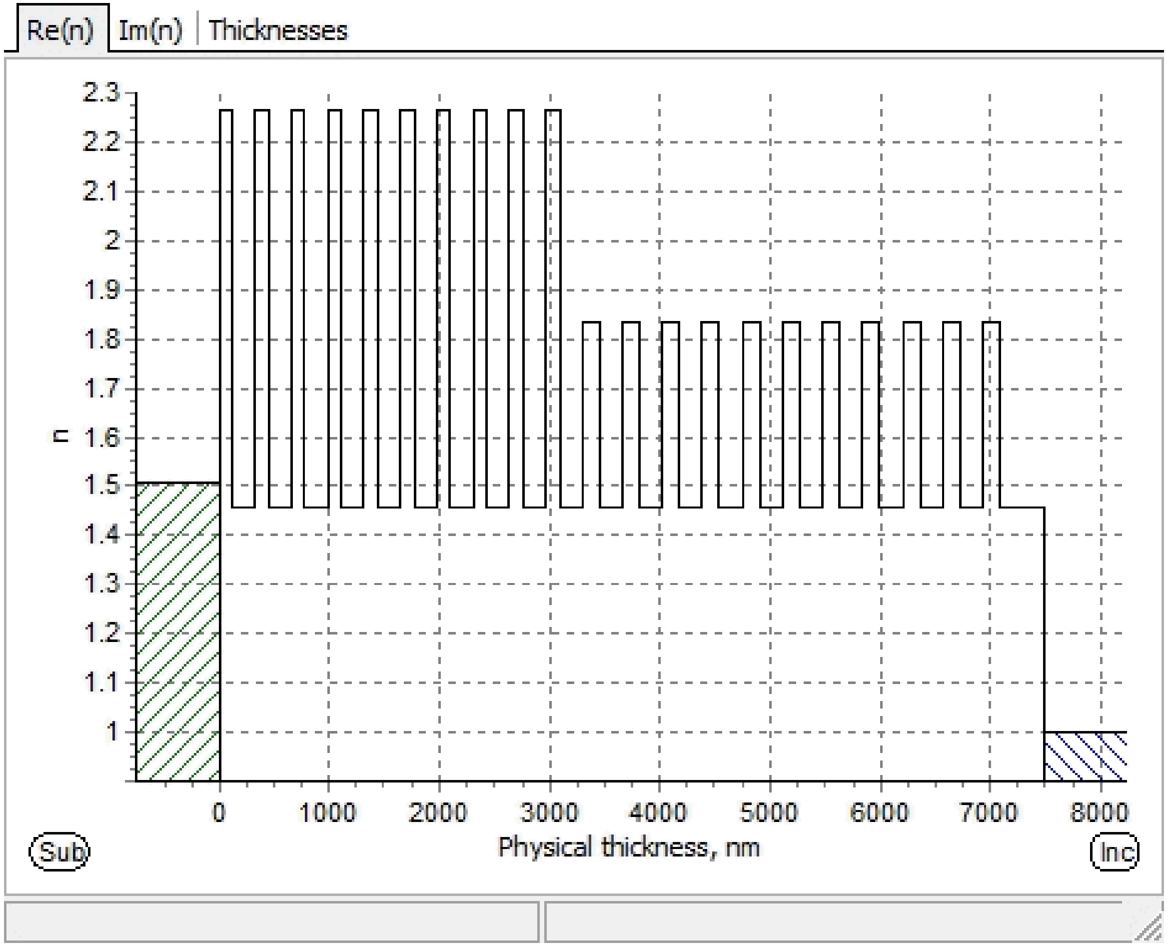
Optimal TiO_2 Deposition Settings:

- O_2 back pressure:1.5x10^{-4} Torr
- Deposition rate: 3 Å/s

Example of 42-Layer HR Design with 10 TiO_2 Layers

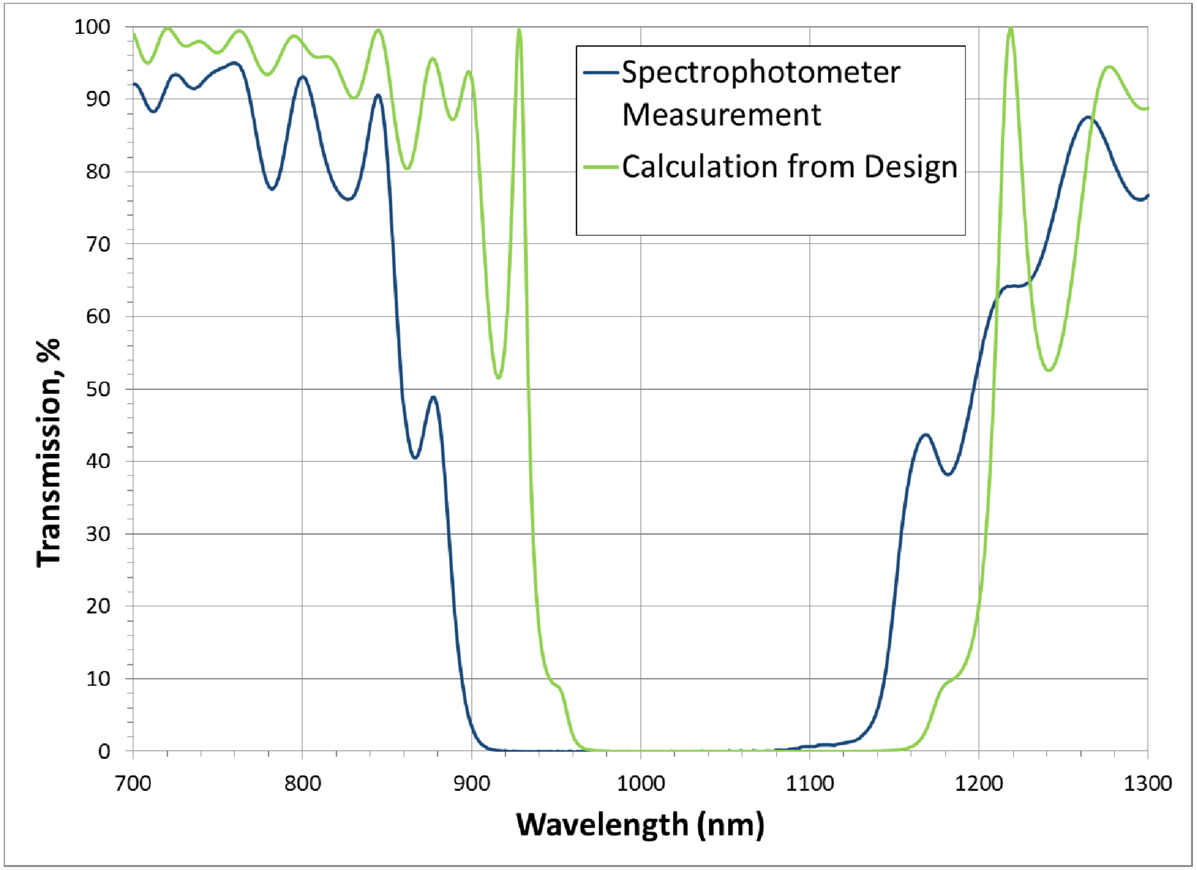


Example of 42-Layer HR Design with 10 TiO_2 Layers



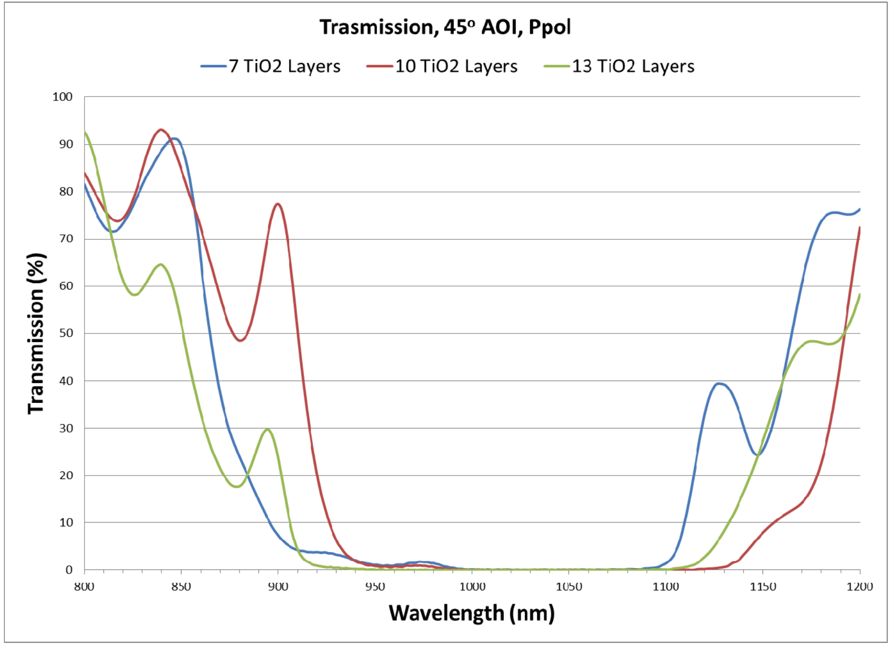
Bandwidth of Initial 42-Layer HR Coating with 13 TiO_2 Layers

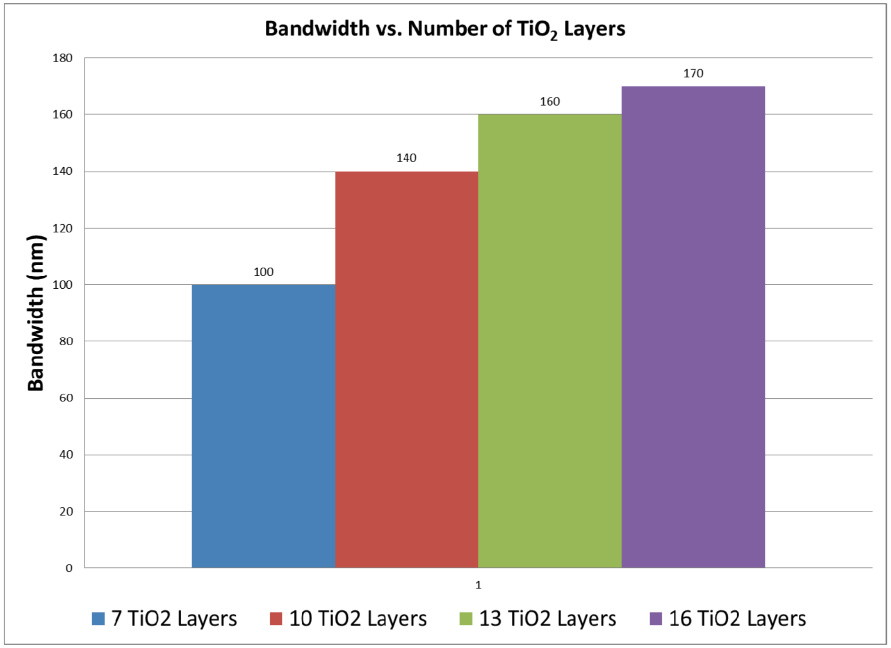
- 45^o AOI, Ppol, HR bandwidth = 180 nm
- We expect a coating with refined calibration of the deposition process to have an HR spectral band well centered on 1054 nm and to not exhibit the shoulder we see near 1100 nm (HR bandwidth would be 220 nm without the shoulder)



Bandwidth Dependence on Number of TiO_2 Layers in 42-Layer HR Coatings

- Reconfigured e-beam sources, now using 1.6×10^{-4} Torr O_2 back pressure to study 42-layer HR coatings with 7, 10, 13, 16 TiO_2 layers
- High polarization purity achieved using a Glan Thompson polarizer in Lambda 950 spectrophotometer

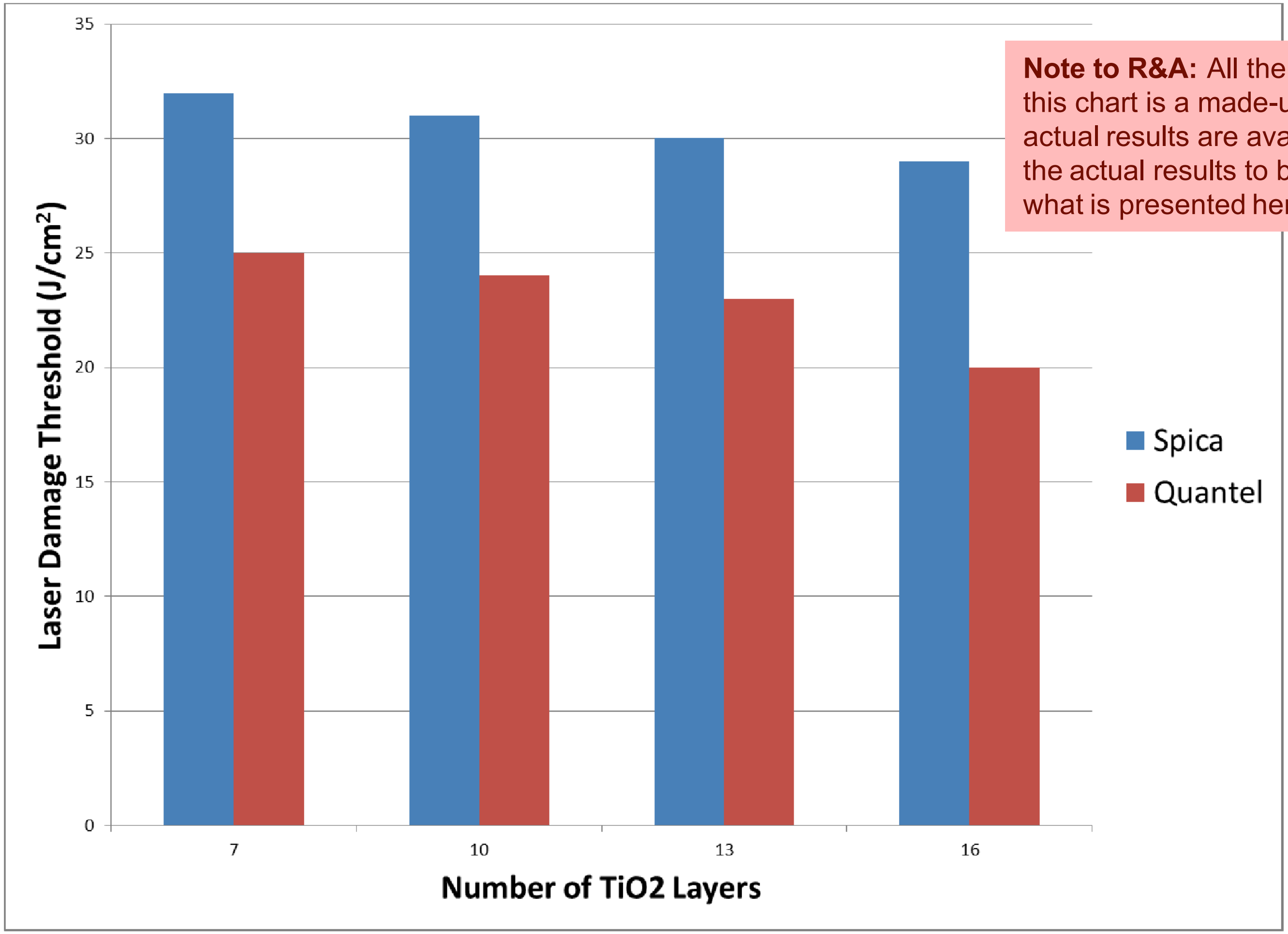




Note to R&A: The transmission data for “16 TiO2 Layers” will be added once we have these results (we could not complete the coating last night due to the power outage)

Note to R&A: The bandwidth data for “16 TiO2 Layers” is a made-up placeholder for now, as we are waiting for the actual results. We expect the actual results to be in the ballpark of what is shown here.

Laser Damage Threshold vs. Number of TiO_2 Layers



Note to R&A: All the data presented in this chart is a made-up placeholder until actual results are available. We expect the actual results to be in the ballpark of what is presented here.

Test Protocols at 1064 nm, 45° AOI, Ppol:

- Spica: NIF-MEL Method with 3.5 ns laser pulses
- Quantel: ISO Damage Frequency Method (ISO Standard 11254-1) with 10 ns pulses

Summary

- Identified coating parameters for high-index, low-absorption TiO_2 layers via reactive, IAD, e-beam evaporation of Ti
- We have obtained HR bandwidth vs. laser damage threshold results as the number of TiO_2 layers replacing HfO_2 layers increases
- Further studies are needed to establish the optimal bandwidth/laser damage threshold tradeoff