# Development of Nanolayered Composites for 3rd Gen Gravitational Wave Detector Optical Coatings


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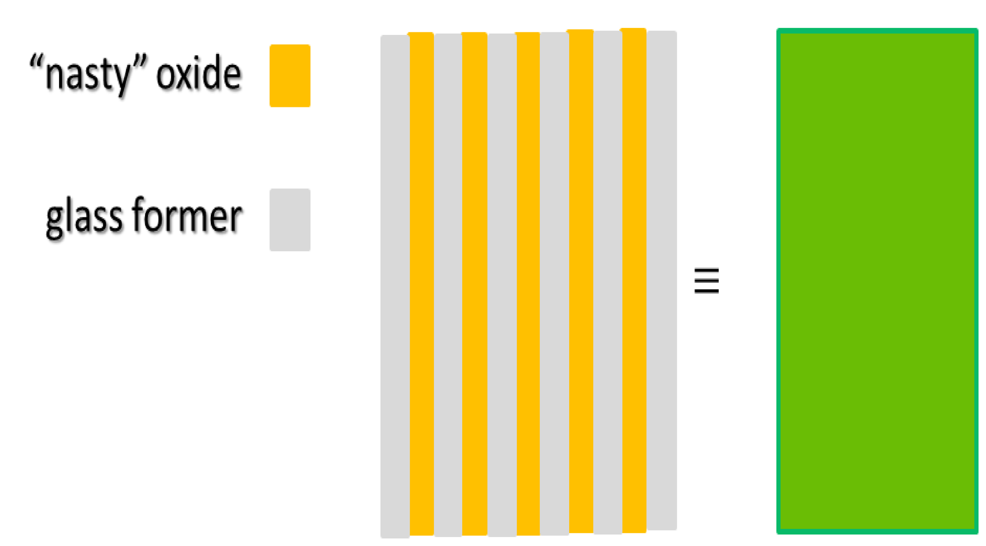
## nm-Layered Composite for Optical Coatings – What, Why and How

- The goal of coating R&D : optically dense, stable, materials with low mechanical losss down to cryo temperatures …

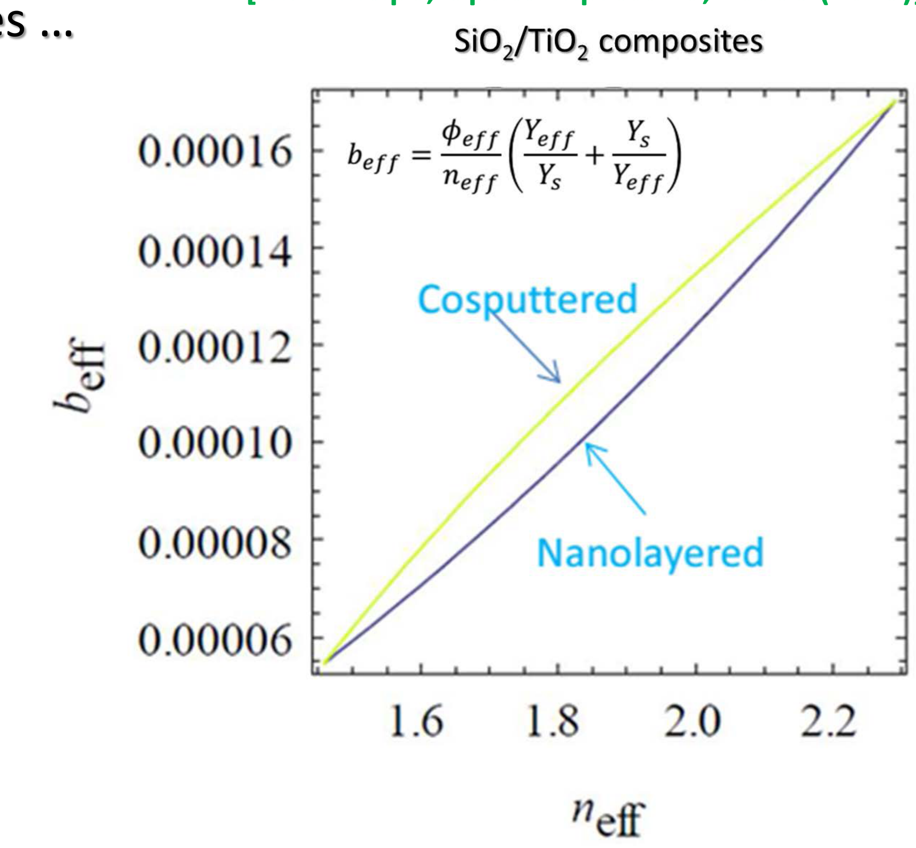
  - Alternating nm-scale layers of e.g. $TiO_2$ (or $HfO_2$, or $ZrO_2$) and a good glass-former, e.g. $SiO_2$ (or $Al_2O_3$);
  - Allow using materials without mechanical loss cryo-peak (e.g., $TiO_2$ and $HfO_2$) that are otherwise "nasty" (spoiled by annealing);
  - Stabilize "nasty" materials (e.g., $TiO_2$, $HfO_2$) against crystallization upon annealing (spoiling optical & mechanical material losses);
  - Nanolayered composites are typically less noisy than *optically equi-valent* cosputtered amorphous mixtures using the same ingredients;
  - Mild technological challenges compared, e.g., to crystalline coatings;
  - Amenable to simple modeling (via *effective medium theory*), hence easily engineerable. [I. Pinto et al., LIGO Document G1301061]




$$n_{eff} = \left[r_H n_H^{\,2} + (1-r_H) n_L^{\,2}\right]^{1/2}, \quad r_H = \frac{d_{H,tot}}{d_{L,tot} + d_{H,tot}}$$

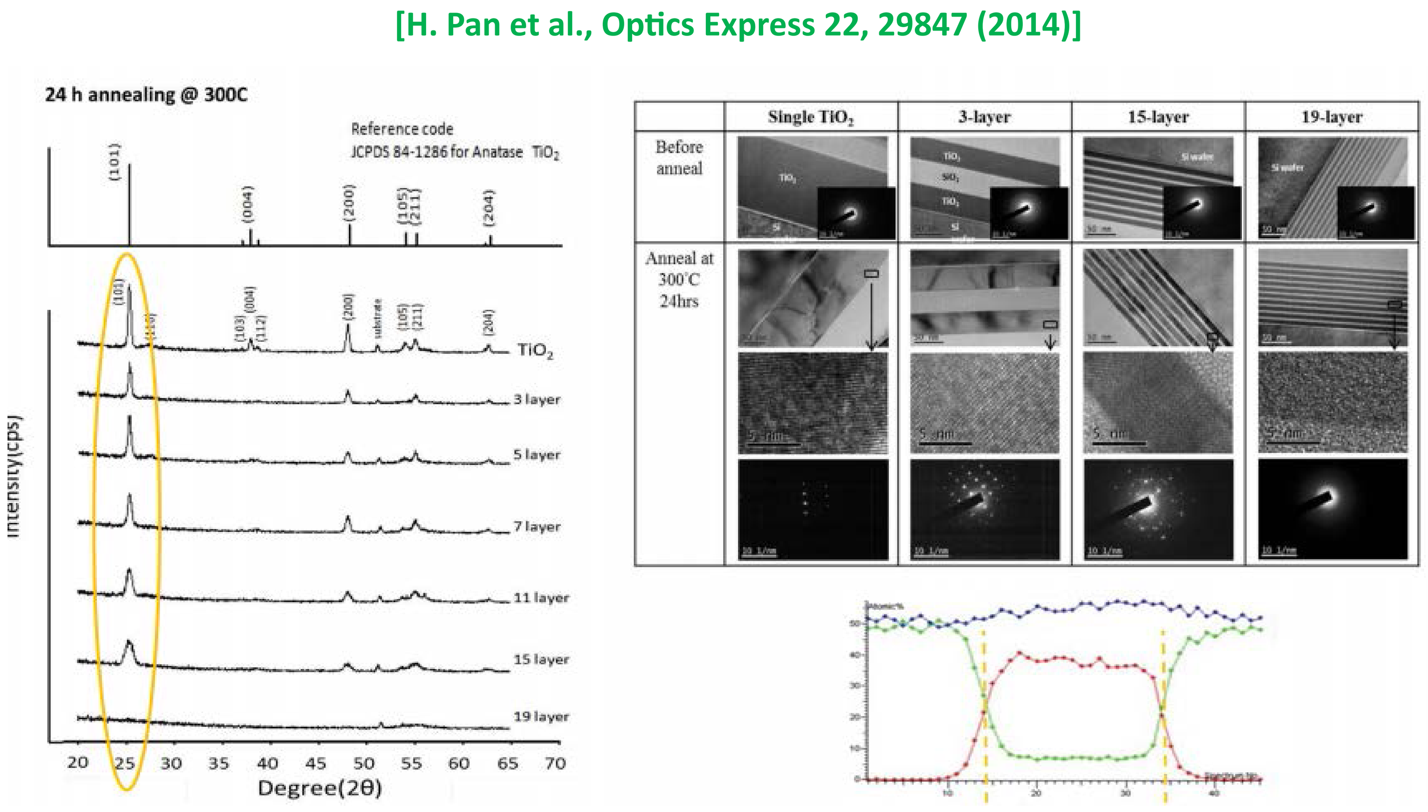
[M. Principe, Optics Express 23, 10938 (2015)]

$SiO_2/TiO_2$ composites



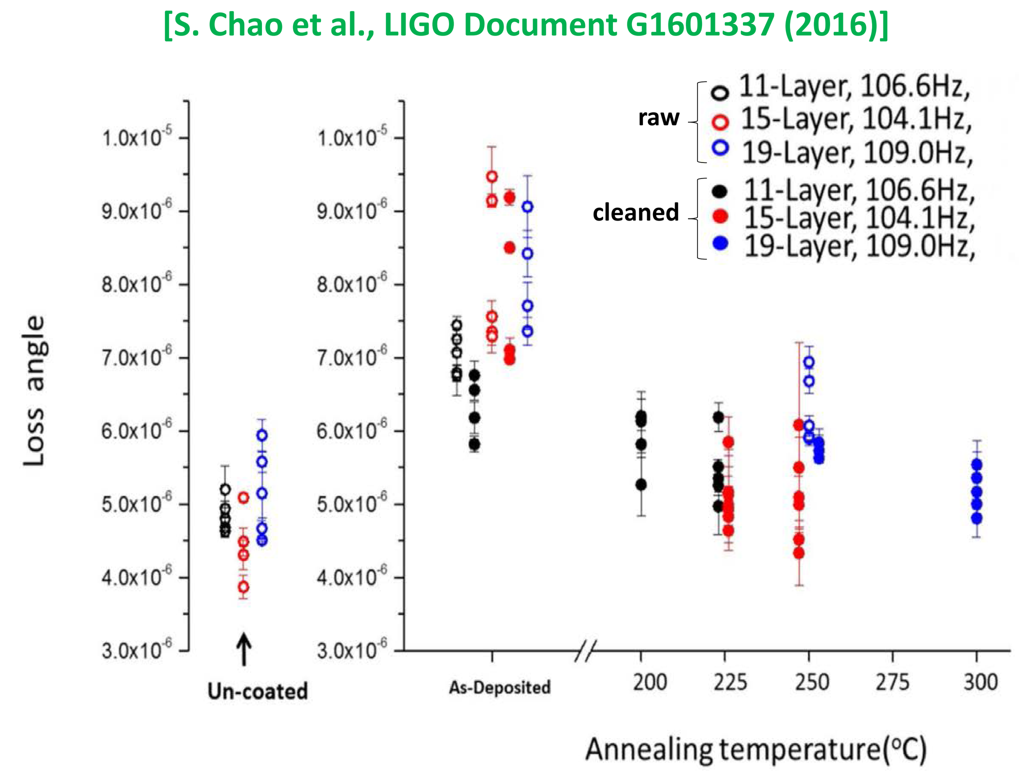

## Ongoing Experimental Work Confirms Expectations

[H. Pan et al., Optics Express 22, 29847 (2014)]



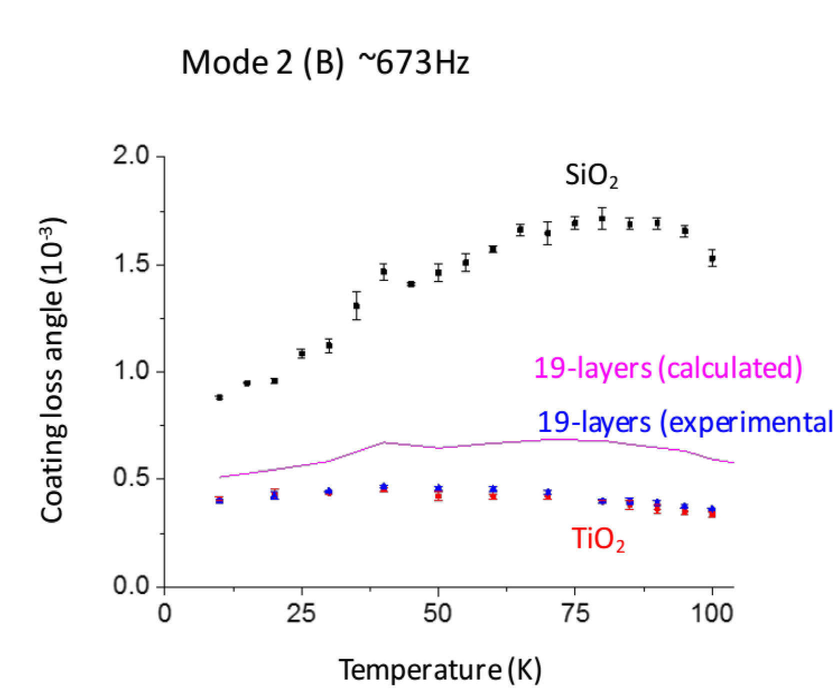

Titania/Silica nanolayered films with different number/thickness of the nanolayers with n = 2.065. Left: XRD spectra after 24h annealing @ 300C. Top-right: TEM & ED images . Bottom-right: EDXRD interface profile reconstruction. Anatase peak highlighted.

[S. Chao et al., LIGO Document G1601337 (2016)]




Measured loss angle of cantilever witness samples (naked, coated as deposited; coated after 24h annealing).

[S. Chao et al., LIGO Document G1701200 (2017)]



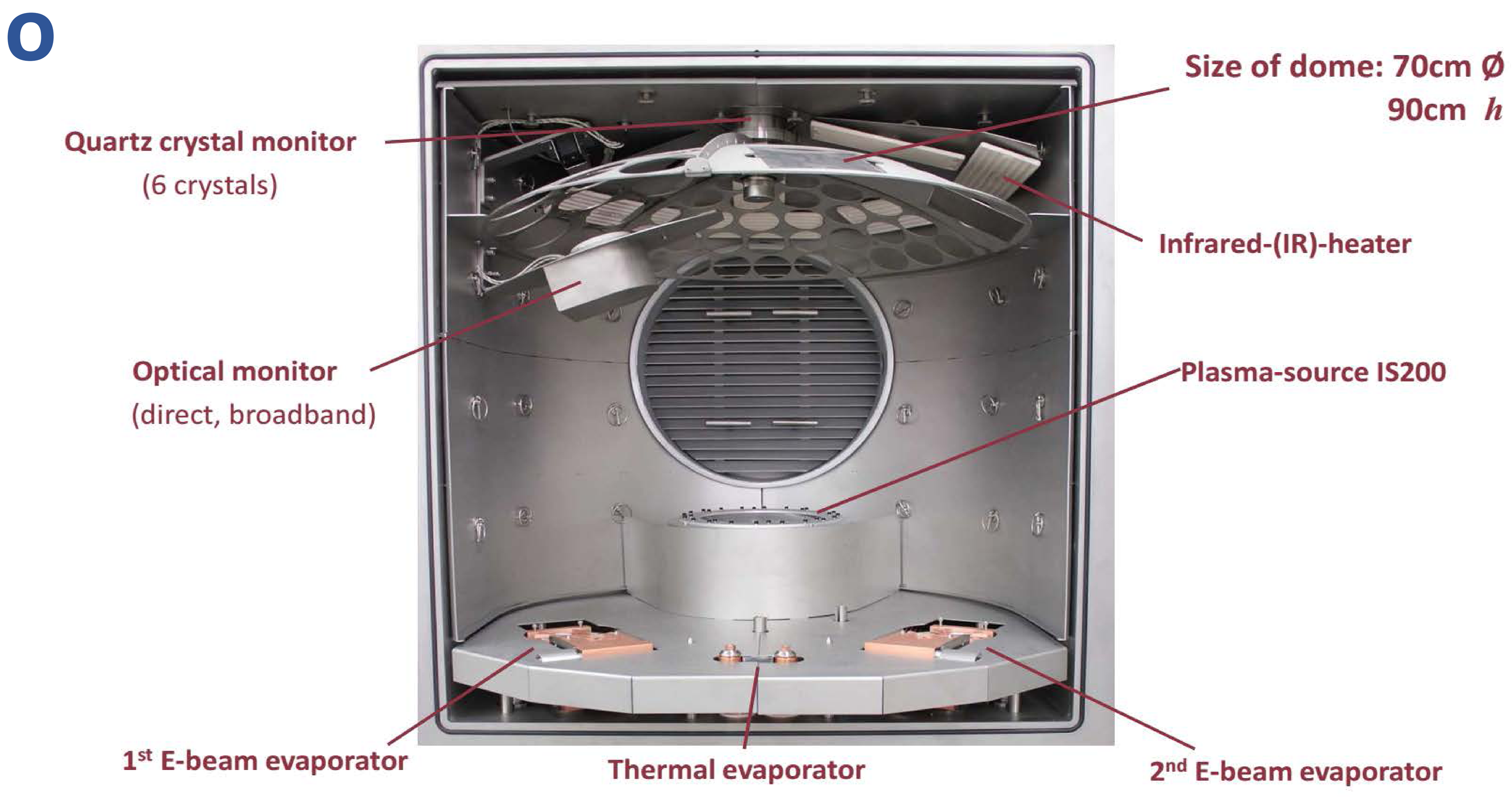

Measured cryogenic loss angle of cantilever witness samples (QWL) after 24h annealing). $SiO_2$ seems to be "covered out".

## New Coating Facility at USannio

Custom version of Optotech OAC-75F

- Plasma assisted deposition
- Dual eb-gun
- Multimaterial (up t0 6) deposition
- Fully programmable GUI
- IBS as possible future option

Will be used for small scale prototyping of nm-layered composite based HW coatings. Local characterization and testing will be done in collaboration with the Laboratoy led by prof. F. Bobba (University of Salerno) and the INFN AdCOAT working groups (Rome "TorVer-Gata", Genoa, Perugia).





Under commissioning (clean room); next test run planned September, 2017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