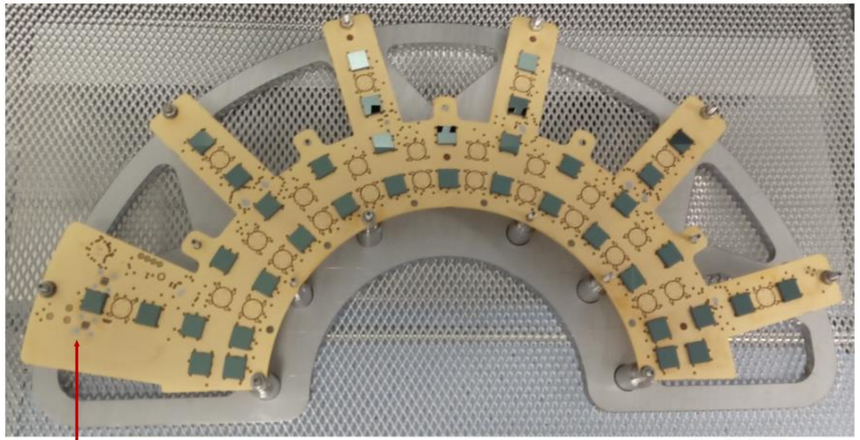
Stray light workshop summary

Alena Ananyeva, Andreas Freise

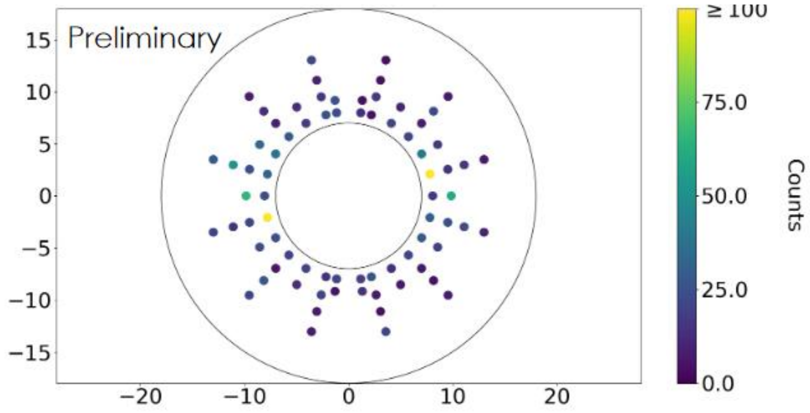
Instrumented baffle for Virgo input mode-cleaner end-mirror
Speaker: Lluïsa-Maria Mir (IFAE)

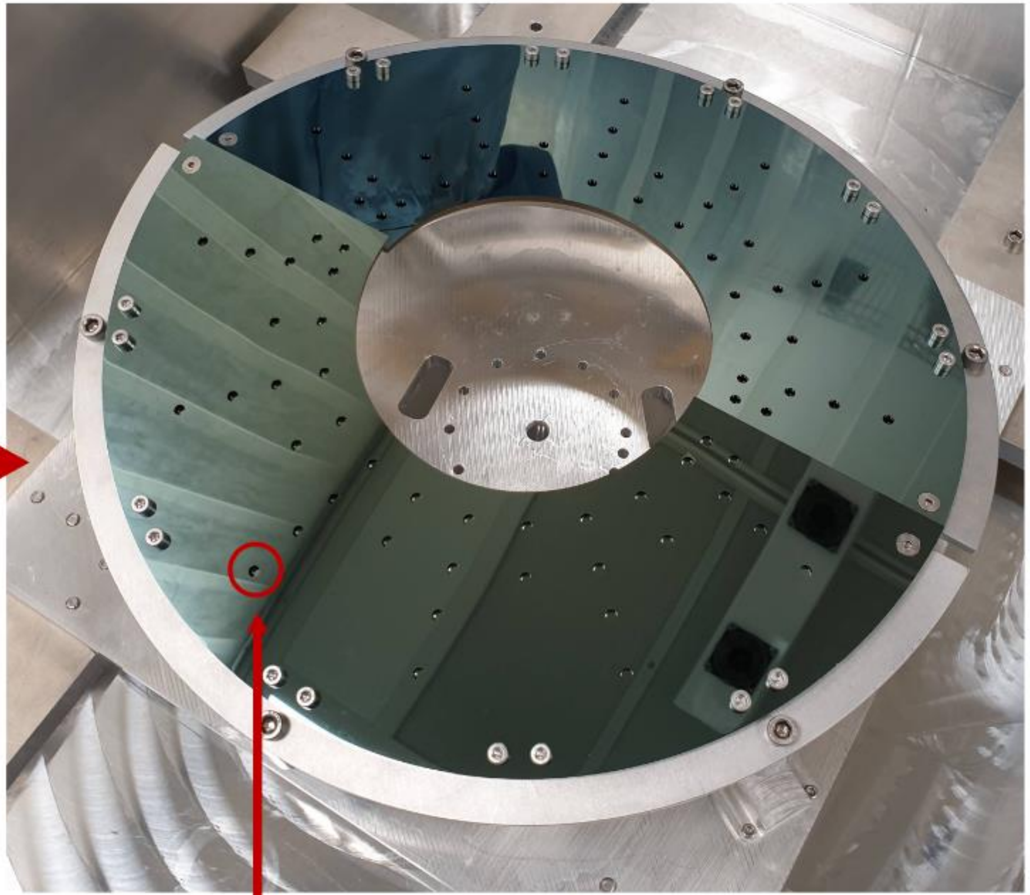


Credit: IFAE

38 photodiodes

Gold plated to dissipate heat



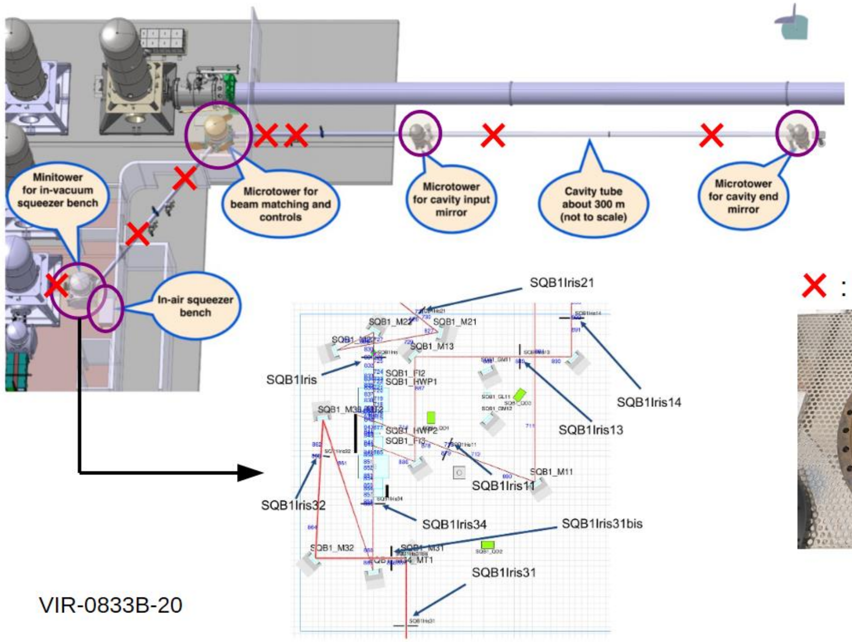


Credit: IFAE

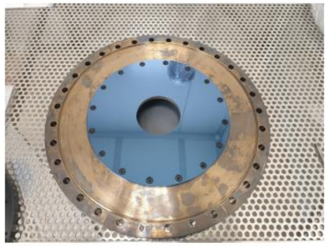
76 holes (4 mm of diameter)

Scattered light study in Advanced Virgo Plus
Speaker: Eleonora Polini (LAPP)

Mitigation on squeezing system



× : baffles



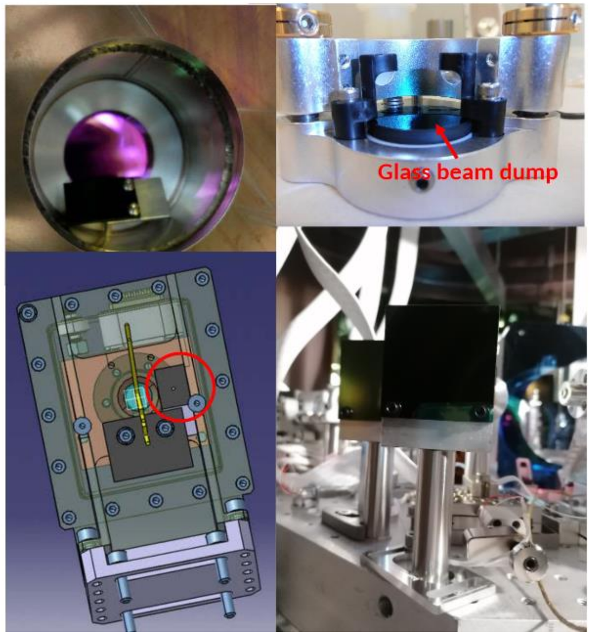
Credit to IFAE

VIR-0833B-20

Mitigation strategies

Some of the *mitigation strategies* adopted for Advanced Virgo Plus:

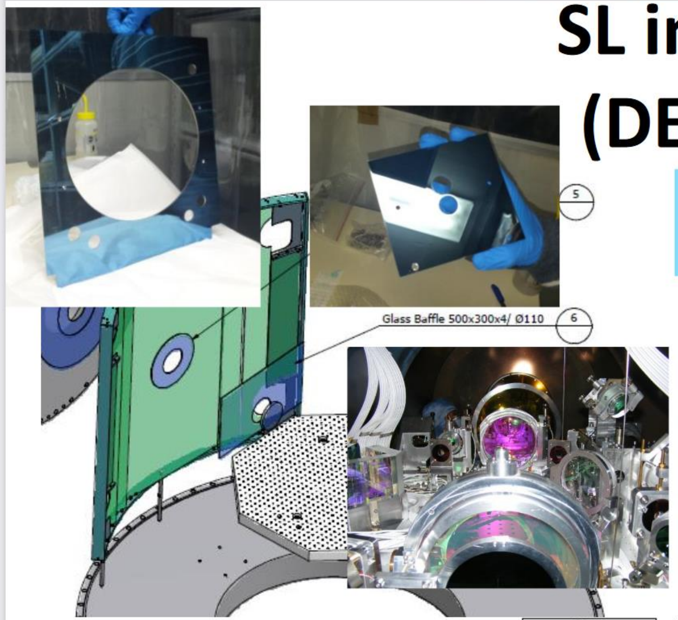
- Wedge optimization
- Diaphragms installation
- Baffle installation
- Absorbing disks behind mirrors
- Diaphragms on quadrants
- Small beam dumps
- Dumpers on photodiodes
- Lens tilting
- Absorbing screws



Summary of Stray Light Mitigation Strategies at 2G interferometers
Speaker: MARIO MARTINEZ PEREZ (ICREA/IFAE-Barcelona)

VIR-0406A-12
VIR-0127A-13
VIR-04824A-14
VIR-0009A-16

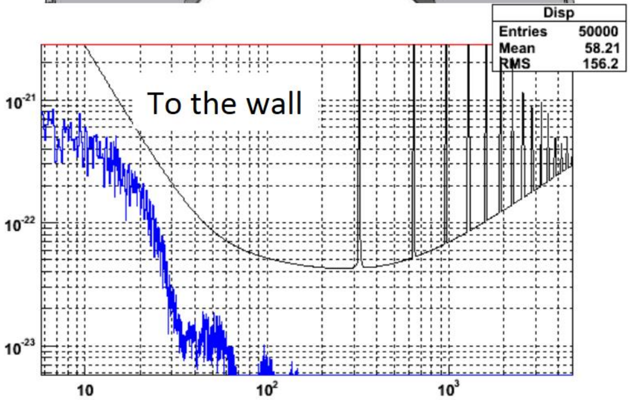
SL in benches (DET tower)

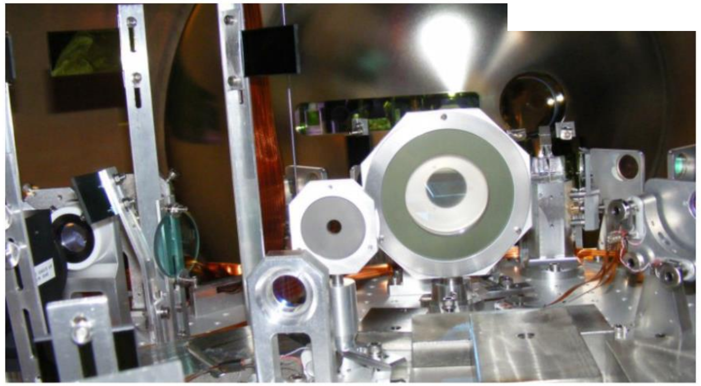


$$h(t) = G\cdot\sin(2\cdot\frac{2\pi}{\lambda}\cdot x(t))$$

Studies to place baffles at the
Instead of suspending them

→ The solution must be at th
to suppress SL and ghost bear
baffles/diaphragms





Intense R&D on materials for the baffles
by the time of the preparation for Virgo

EGO VIRGO
AdV SLC:
Characterization of Silicon Carbide for constructing baffles and beam dumps in AdV

EGO VIRGO
AdV SLC:
Characterization of Diamond-Like Carbon for coating baffles and beam dumps in AdV

CNRS Centre National de la Recherche Scientifique INFN Istituto Nazionale di Fisica Nucleare
EGO VIRGO
AdV SLC: Characterization of AR coatings on stainless-steel for construction of baffles and beam dumps in AdV

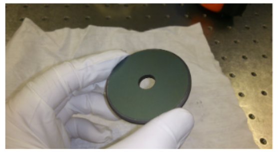
VIR-0482A-14

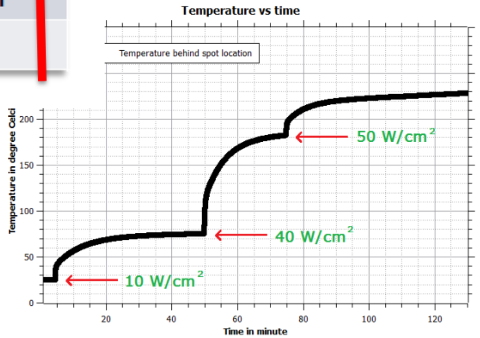
V.Bavigadda, G.Pillant, A.Magazzu, and A.Chiummo
EGO - European Gravitational Observatory
Date: December 10, 2014

Material	LIDT	TIS
SiC + AR	30kW/cm2	~20-50ppm
DLC + AR	500W/cm2	~500-1000ppm
AR-on-steel	>50W/cm2	~300-500ppm
Abs. Glass + AR	~1W/cm2	~100ppm

cost

Other important considerations:
- Temperature dependence
- Scalability with surface dimension
- Reproducibility
- Cost (no much SiC+AR used)

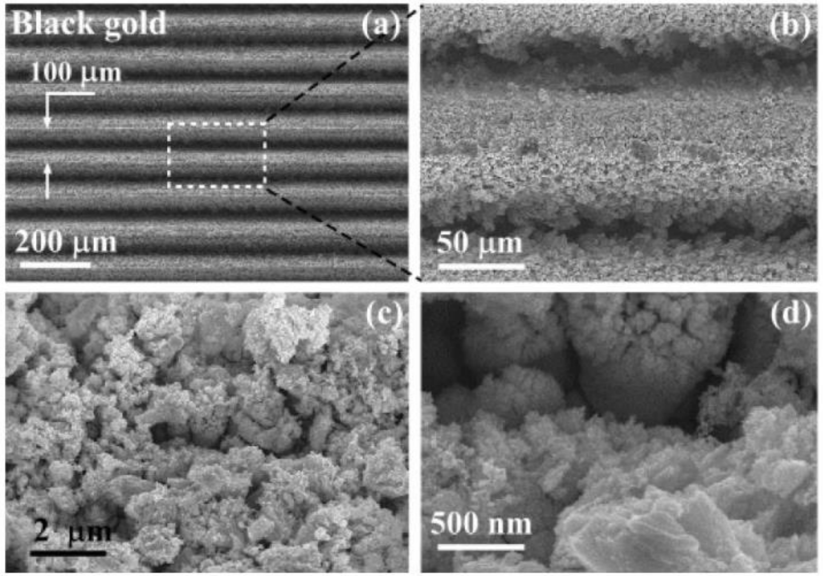




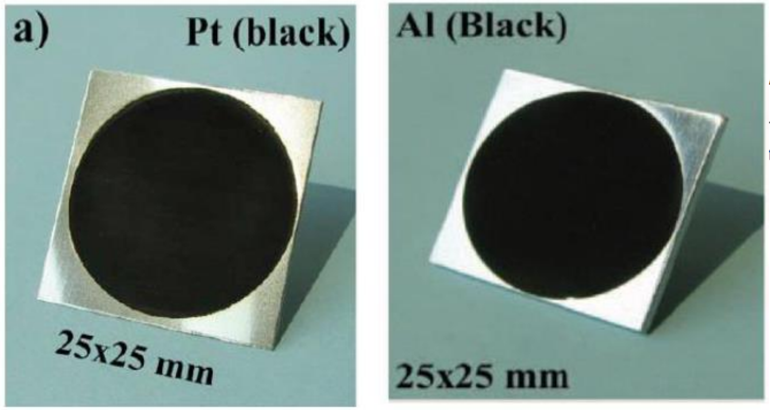
Microstructuring and high-absorption coatings for scattered light reduction Speaker: Mrs Cailing Fu (RWTH Aachen)

Laser Blackening

Microstructure examples



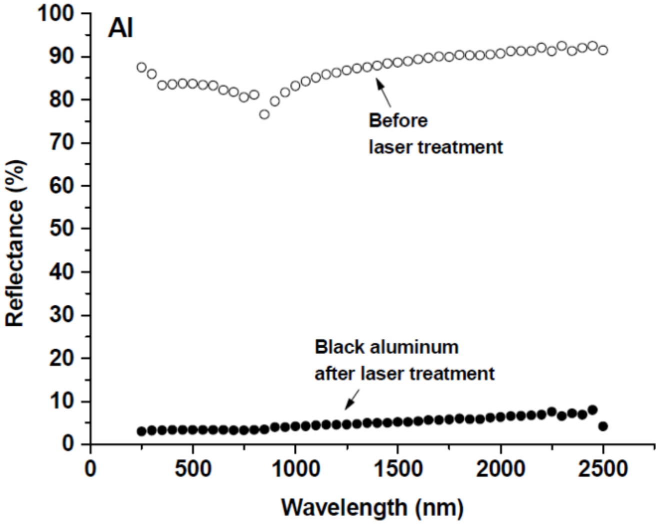
A. Y. Vorobyev and Chunlei Guo, Black Metals Through Femtosecond Laser Pulses



Laser Blackening

Reflectance of Black aluminum

- Reflectance of black Al at 1064 nm: 5%
- Reflectance of black Al at 1550 nm: under 10%, about 7%



Anatoliy Y. Vorobyev and Chunlei Guo, 2010, Solar Absorber Surfaces Treated by Femtosecond Laser

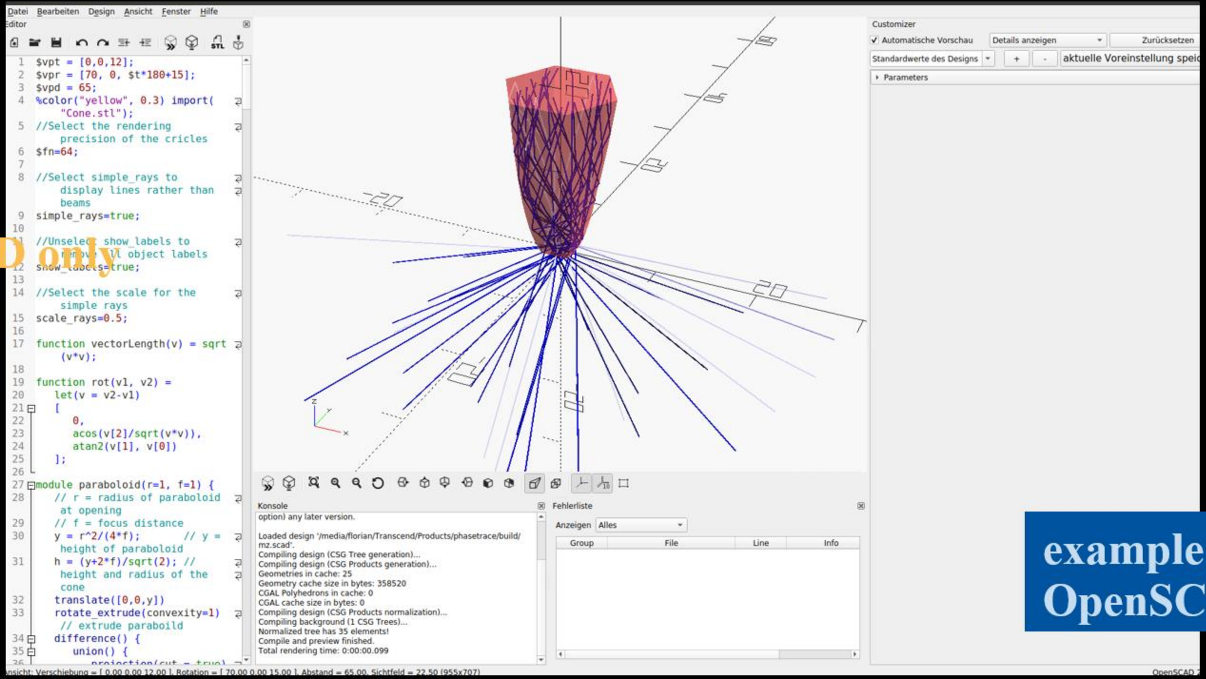
PhaseTrace - Towards a user friendly scattered light simulation
Speaker: Thomas Bretz (RWTH Aachen University)

Example: Similar design for own GUI?

RWTH AACHEN UNIVERSITY

Easy access to setup parameters defined in the script

Note that OpenSCAD only works as a powerful 3D display



example: OpenSCAD

Thomas Bretz (RWTH Aachen University), GWADW 2021 19

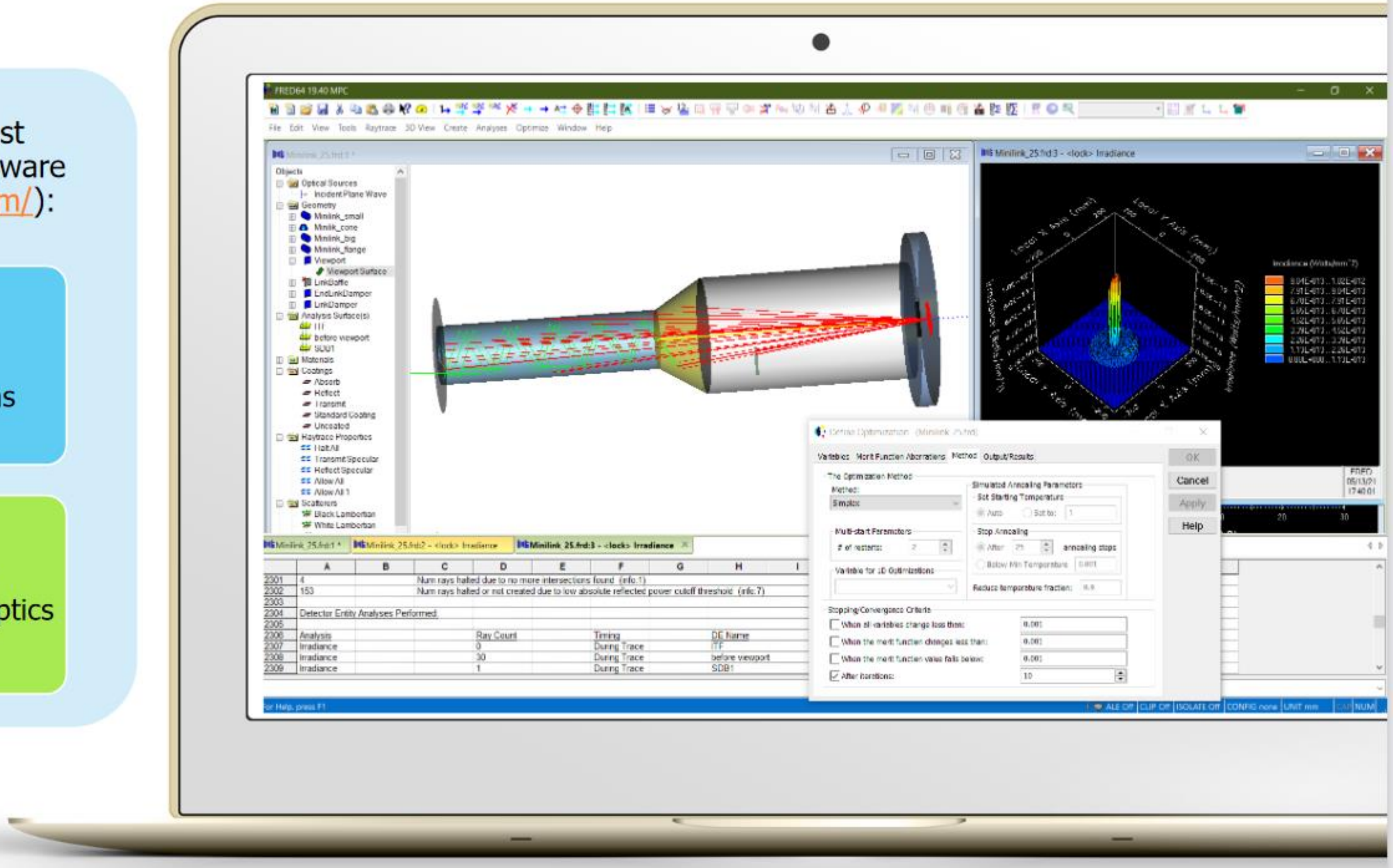
Dust scattering simulations

Photon ENGINEERING

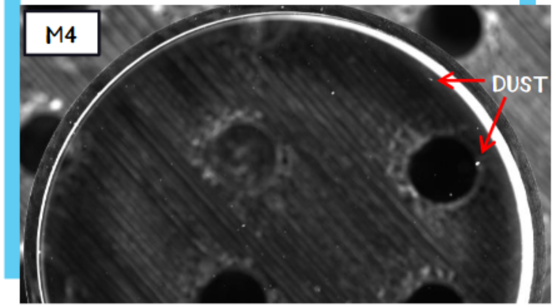
Simulations of stray light from dust are performed via FRED Optical Software Engineering (https://photonengr.com/):

Particle distributions from wafers' images will be the **input** values for the simulations

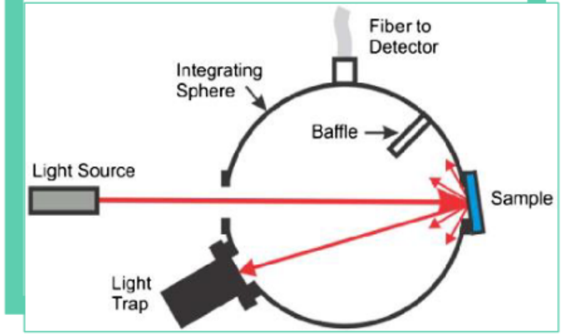
Wafer -> particle distribution -> scattering model to apply to nearby optics

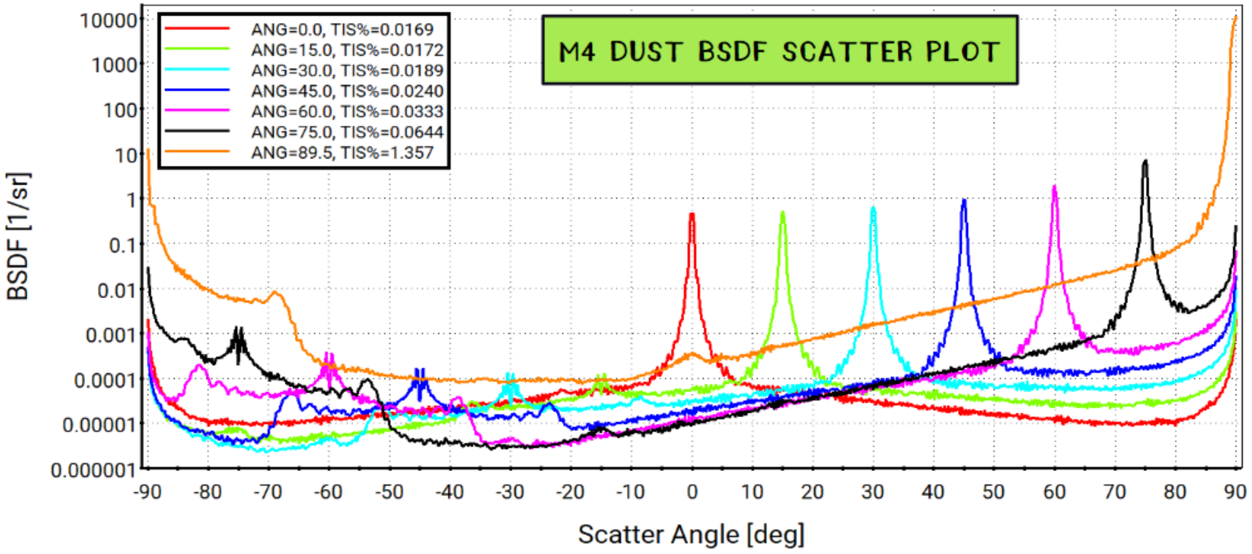


Stray light from dust in Virgo
Speaker: Beatrice D'Angelo (Istituto Nazionale di Fisica Nucleare)



Extract dust distributions of two mirrors used in O3 in SQZ → Put the distributions in FRED and derive dust BSDF & **TIS** → Measure TIS directly at 0° AOI with an Integrating Sphere → Results obtained @0° AOI are **comparable** (table)





Mirror	Integrating Sphere TIS [ppm]	Dust Analyses TIS [ppm]
M4	258(4)	169
M5	241(12)	228

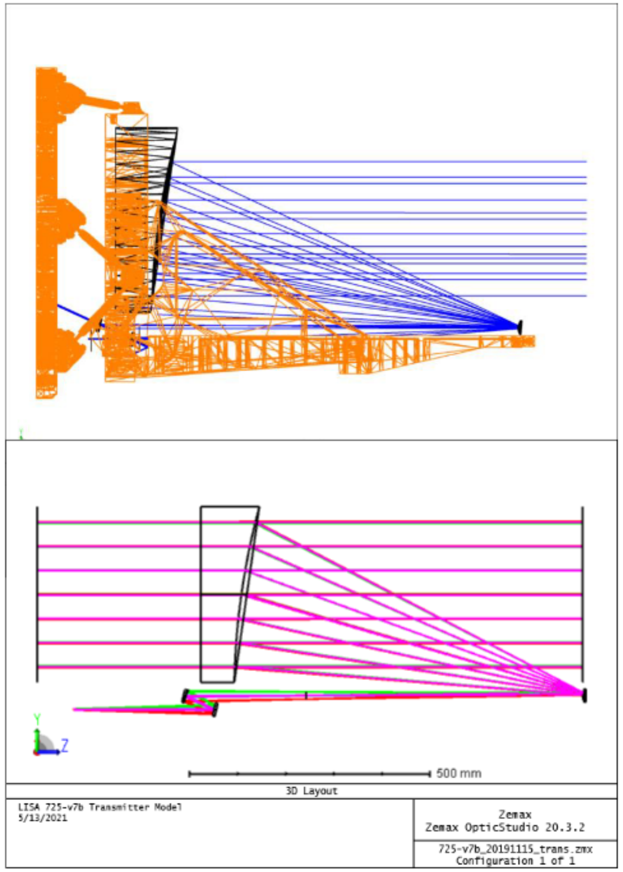
Dust scattering simulations

Efforts to Mitigate the Effects of Stray Light in the LISA Telescope
Speaker: Corey Austin (NASA)

Telescope Stray Light Model in Zemax

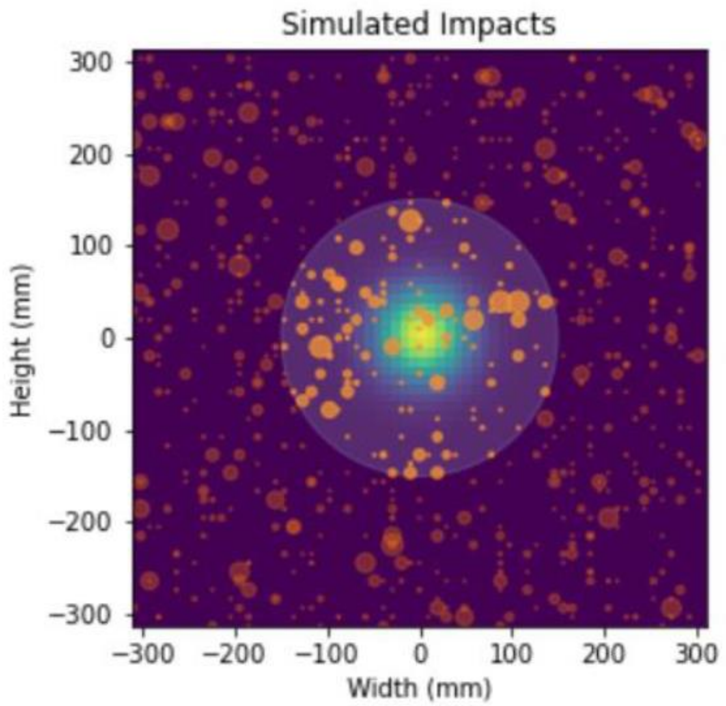
- Development Team
  - Corey Austin – NPP (GSFC)

- Development Highlights
  - Constructed non-sequential and sequential optical stray light models based on L3Harris CAD model
  - Compared model's performance to science requirements
  - Used to study propagation of transmitted stray light in the telescope
  - Used to study power throughput loss in the telescope
    - Sequential model: losses due to micrometeoroids, diffraction
    - Non-sequential model: transmitted stray light losses



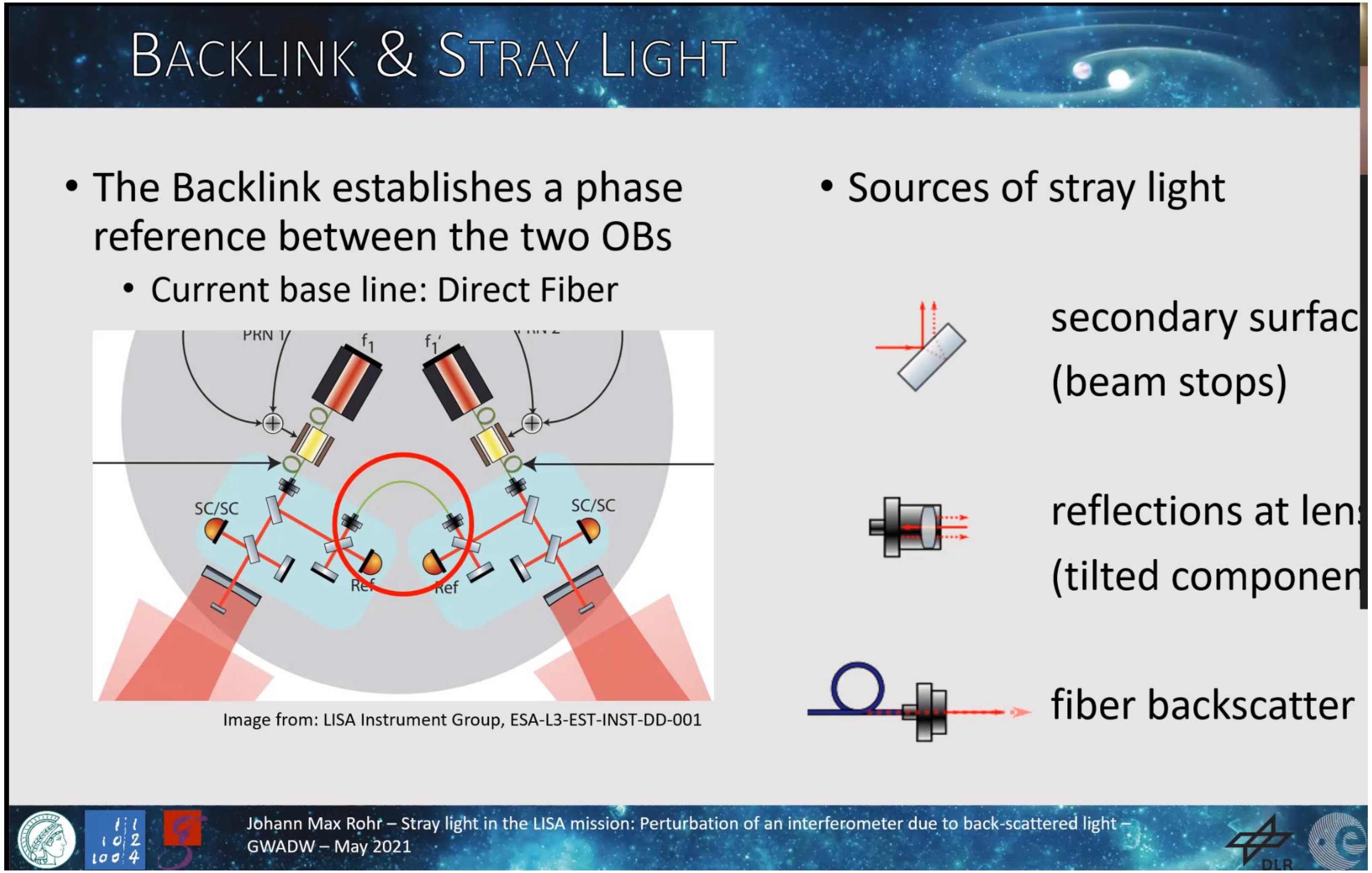
Micrometeoroid Analysis

- Monte Carlo simulation to understand the effects of micrometeoroid impacts over the expected mission duration
- Uses Grün micrometeoroid flux model along with several damage crater models to generate a distribution of craters
- Craters are randomly located on the surface of the M1 mirror
- Using data from the Zemax model, compute the power throughput loss from the craters
- Model can also be used to complement work previously done by Len Seals studying backscatter from impact craters

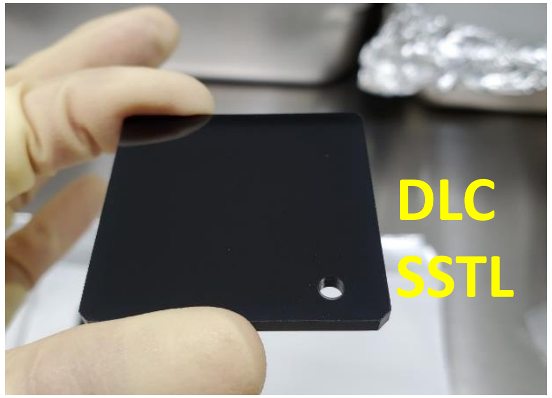


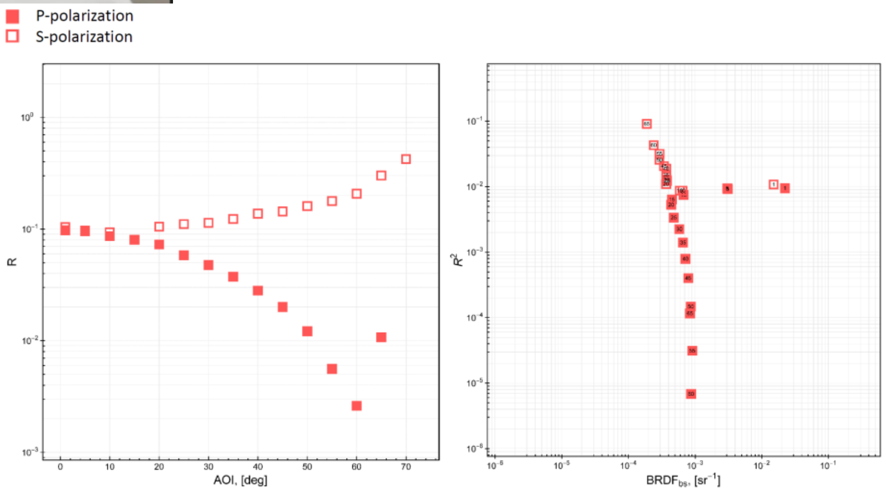
Stray light in the LISA mission: perturbation of an interferometer readout due to back-scattering from an optics and from the backlink optical fibre.

Speakers: Johann Max Rohr (Albert Einstein Institute Hannover (Germany)) , Michel Lintz (Laboratoire ARTEMIS, OCA, CNRS)



Mounts and hardware are successfully coated with DLC and black nickel!





Pliable 1145-0 Al coil (thick foil 0.003”) is considered for wrapping objects in-situ
LIGO-T2000608

General Requirements Document - Stray Light Improved Control (SLiC) LIGO-E1600332

LIGO	LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY REQUIREMENTS DOCUMENT	E1600332 Document No	-v4 Rev
		Sheet 4	
General Requirements Document - Stray Light improved Control (SLiC)			

Aperture Size

For all baffles with an aperture the base-line requirement is as follows: -

The beam size ω (aka w) values quoted in D0902828-v5 are the 1/e^2 radii (see section 1.2 of T1000581-v1 and Table 2 of T0900043-v11). Peter suggested/requested a 10x factor on the size of the baffle apertures. Consequently:

D_b = Min{ D_o, 20 * w}
D_b = Baffle Aperture Diameter
D_o = Optic Diameter
w = 1/e^2 beam size (radius)

^Note if e.g. EQ stops are in the 20w path then consideration will need to be given to adjust this requirement. Refer to image in appendix 1 below. Any other objects in front or behind a baffle especially those which are within the laser path and within the baffle diameter are required to be moved away or replaced with a coated version or require its own baffle (example: LIGO-D1700261 aLIGO, SLiC, BALLAST MASS BAFFLE)

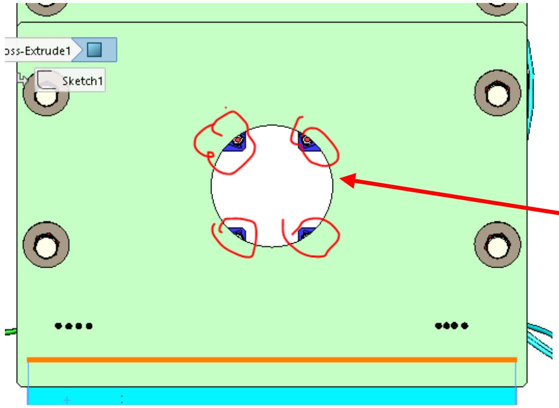
Size (Global)

HAM ISI "baffles" should extend across all of the cages from the HAM ISI table (including the suspension spacer) up to (and including) coverage of the suspended intermediate mass. Consideration up to 20w should be investigated for areas with large beams e.g. PR3 and SR3. (*All with unique spacers (in height) that are LLO and LHO specific.)

Size (Local)

The following detail assumes the SLiC baffles will be made from a couple of sections per suspension "cage" structure or per assembly. The size all comes down to the limitation of the coating chamber, depending on the coating technique used:

1. **DLC coating:** the substrate can be a big as ⌀35"(diameter) - LIGO-C1700089-v2;
2. **Black Ni coating:** the substrate can be a big as 48" x 30" - LIGO-C1700090-v3;
3. **AR coated Black Glass:** segments no bigger than 9" x 24" - LIGO-L1500091;
4. **Uncoated black glass** comes in sheets 4' x 4' and the baffle size is limited by practicality



The aperture is usually defined as 20w of the beam or as large as the optic (for large beams). Hardware within the aperture needs to be covered or coated

Apertures / Holes

Consideration needs to be given to the finish of the apertures / holes for the laser beam. Refer to OMC black glass shroud components LIGO-E1500047 for glass baffles. SSTL baffles are recommended to have a machined bevel on the back side (assuming the laser enters from the from side). Example for SSTL baffle with a beveled aperture LIGO-D1700296. Mounting holes can be water jet (for glass only) ot laser cut (for SSTL)

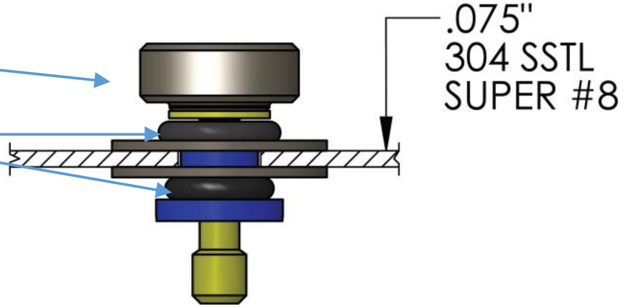
Damping

Local damping of individual segments of the baffle should be provided via o-rings at the mounting locations. Refer to LIGO-T1700511 *Assembly and Damping Guidelines for SLiC Baffles* [It should also be noted that global damping, in the form of 2x SUS cube dampers is also present on each HAM SUS "cage" structure.]

Coated crew cap

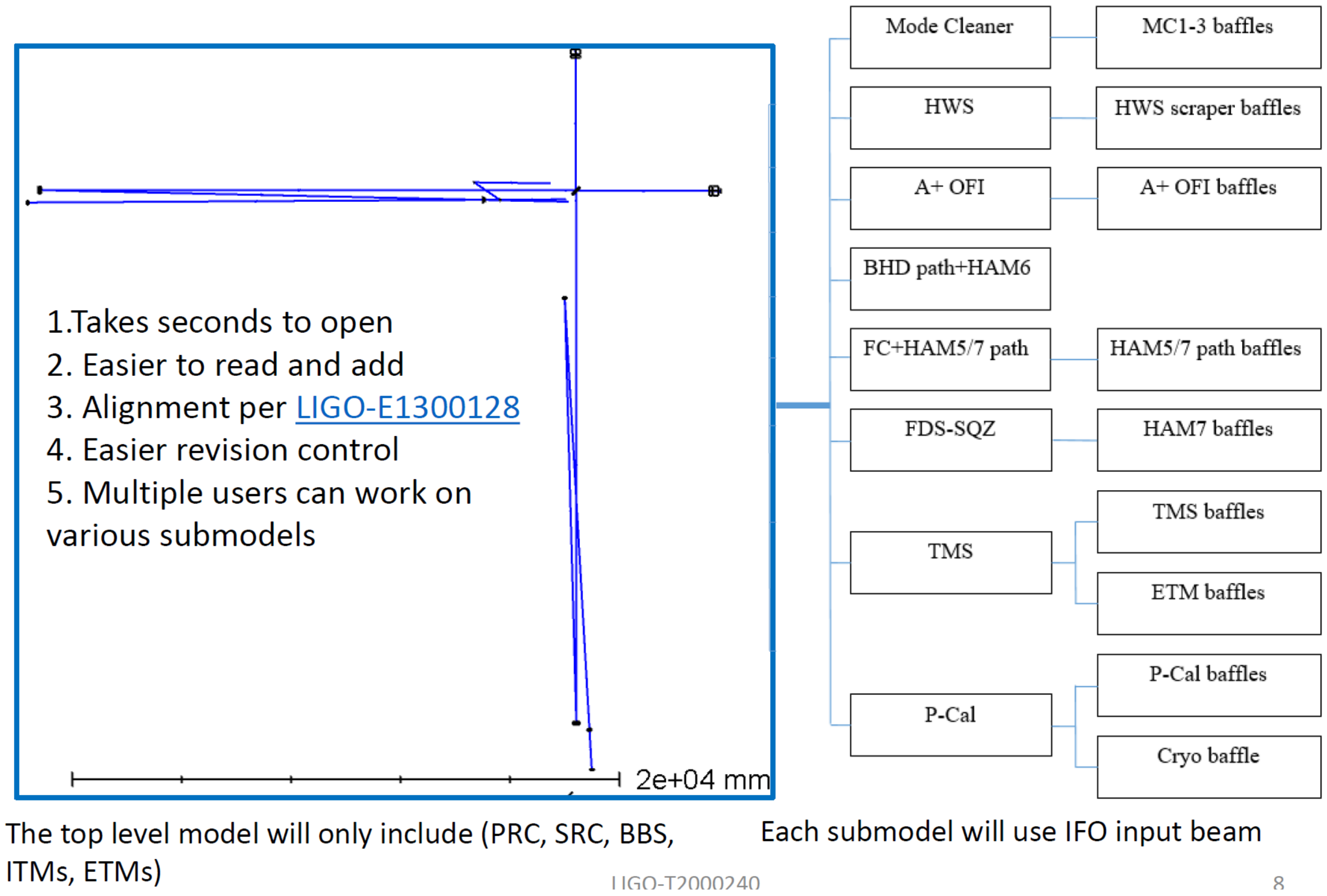
Viton o-ring

LIGO-D1700232



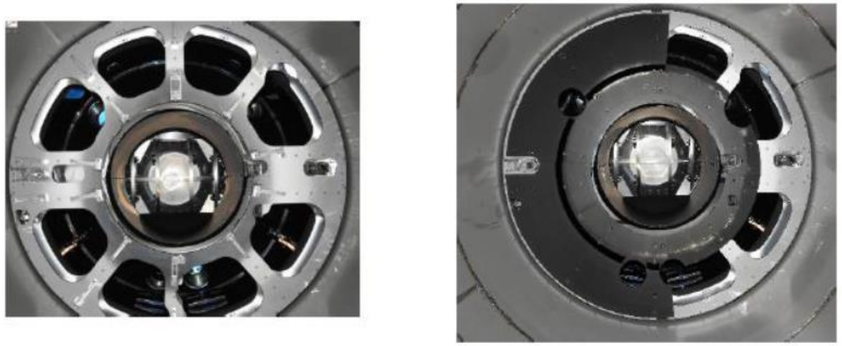
Zemax model of A+ configuration of LIGO

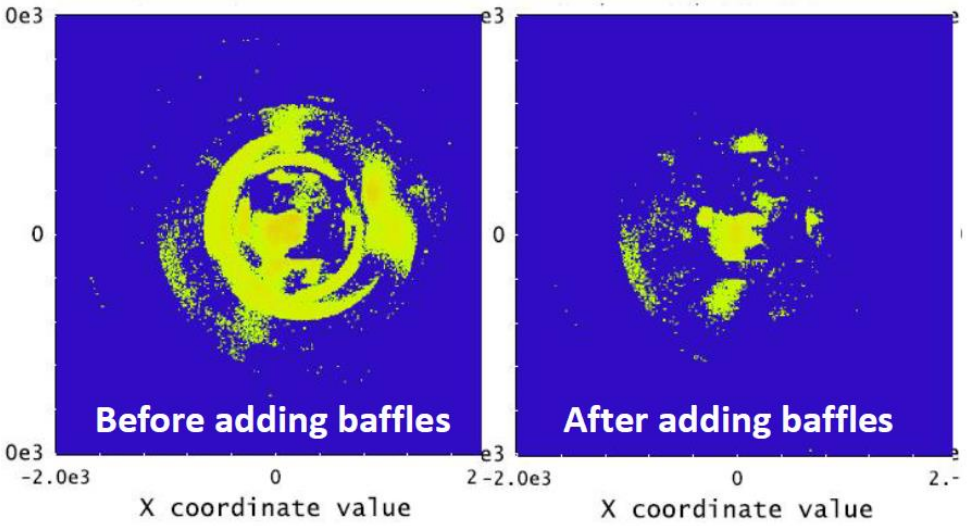
The model is used for beam preparation, ghost beams hunting and other stray light analysis. The beams can be exported as a step file and added to the solid works model which helps to position baffles apertures, check for beam clippings and etc



Tree structure Zemax model of the interferometer: (slide ref LIGO-T2000240). How to use the model LIGO-E2000223.

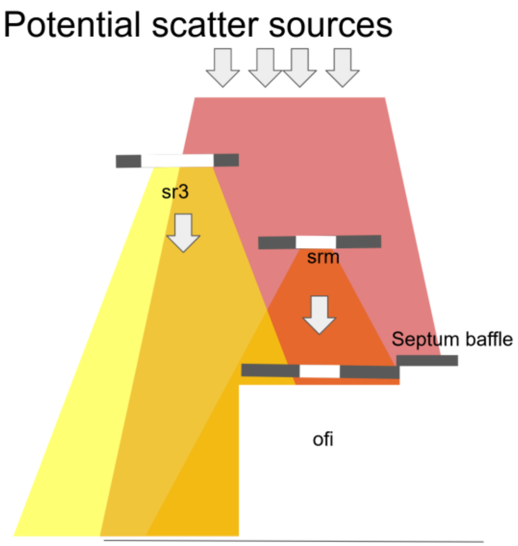
Zemax stray light analysis example:

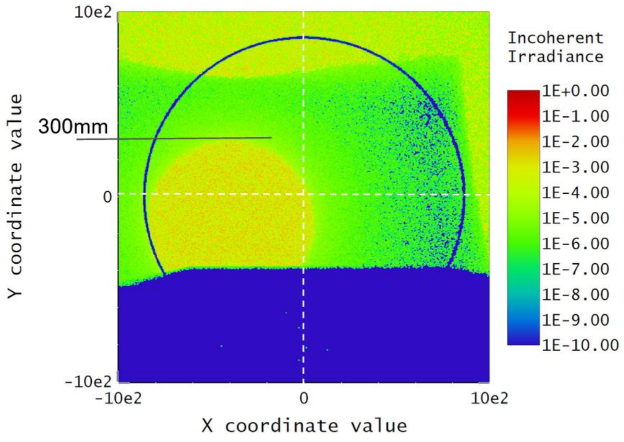




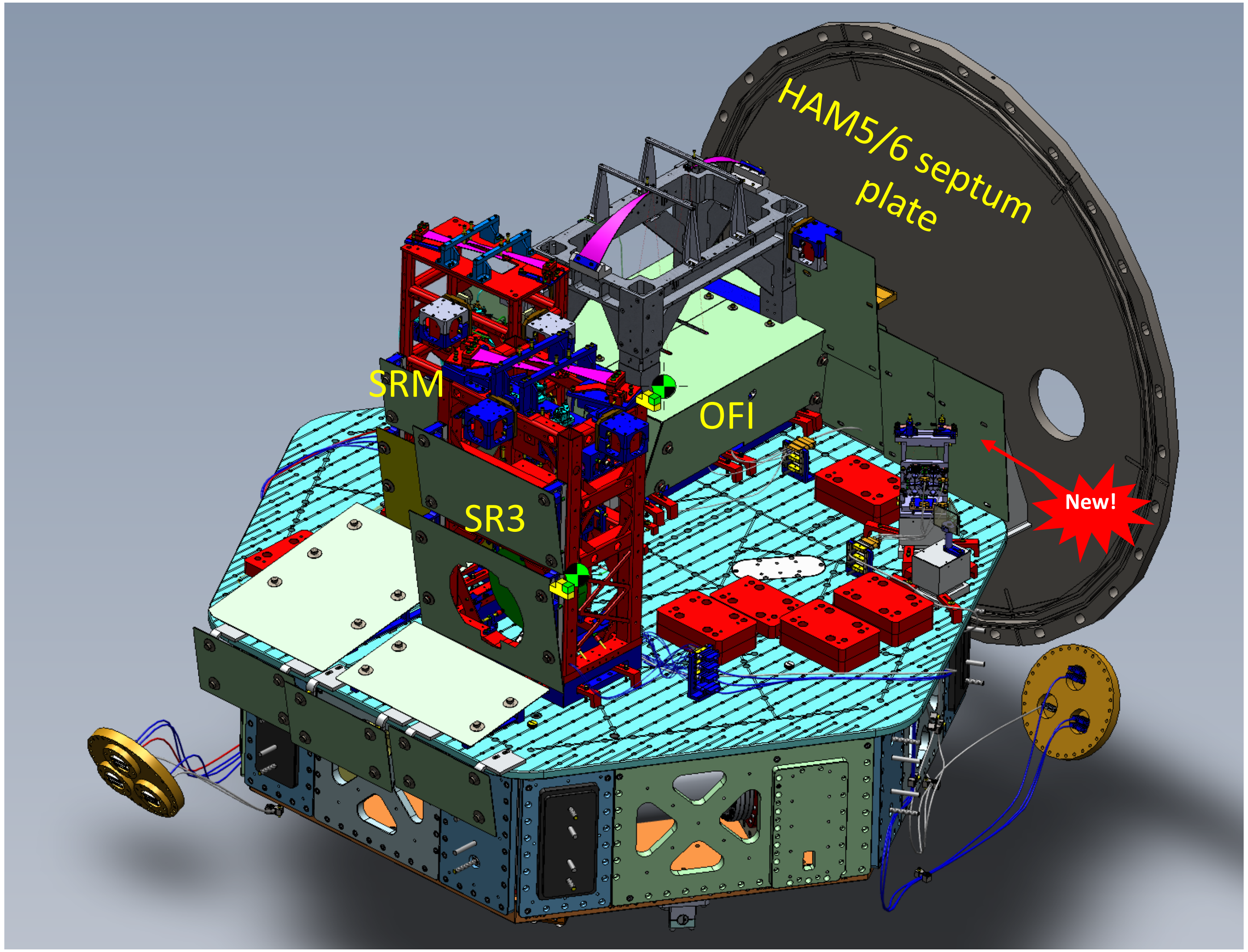
A “wall baffle” in HAM5 and HAM6 to cover the septum plate separating 2 vacuum volumes

HAM5/6 septum is a known source of noise coupling



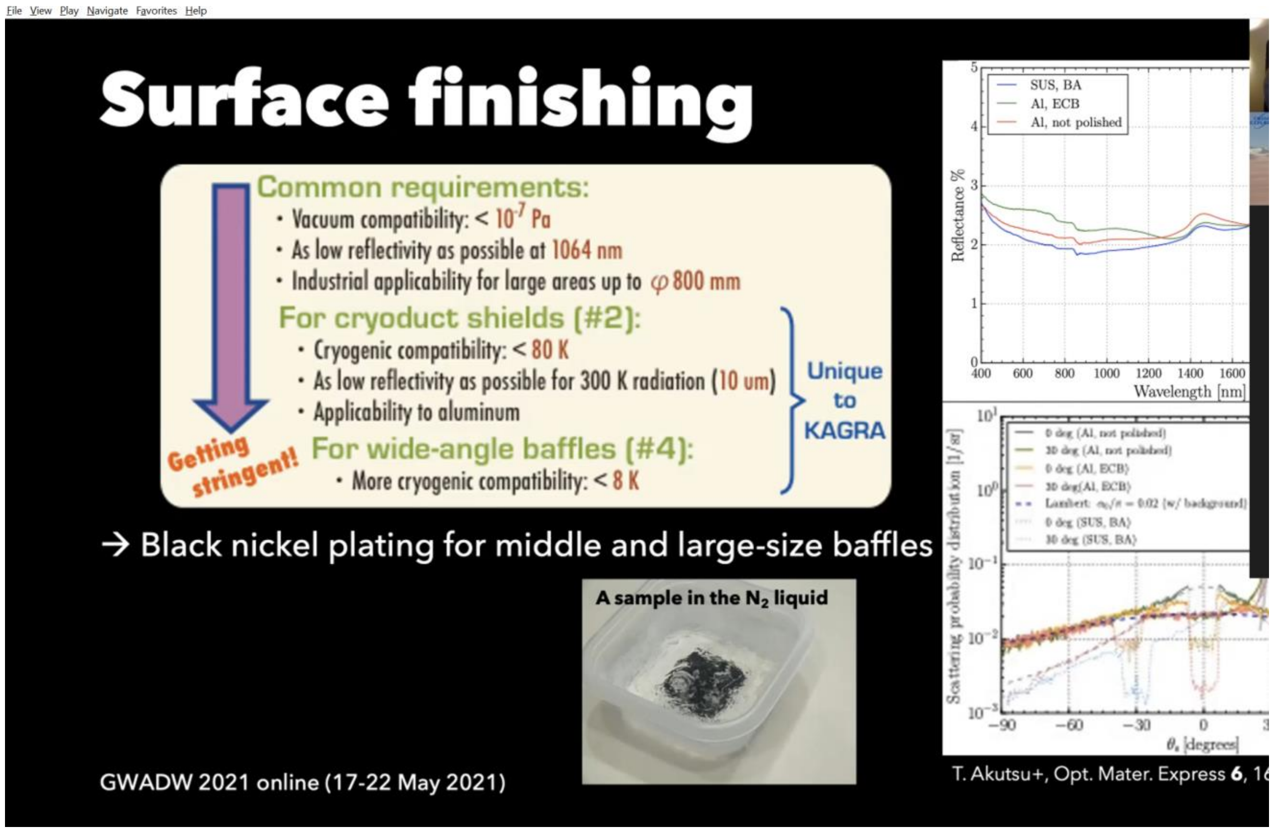


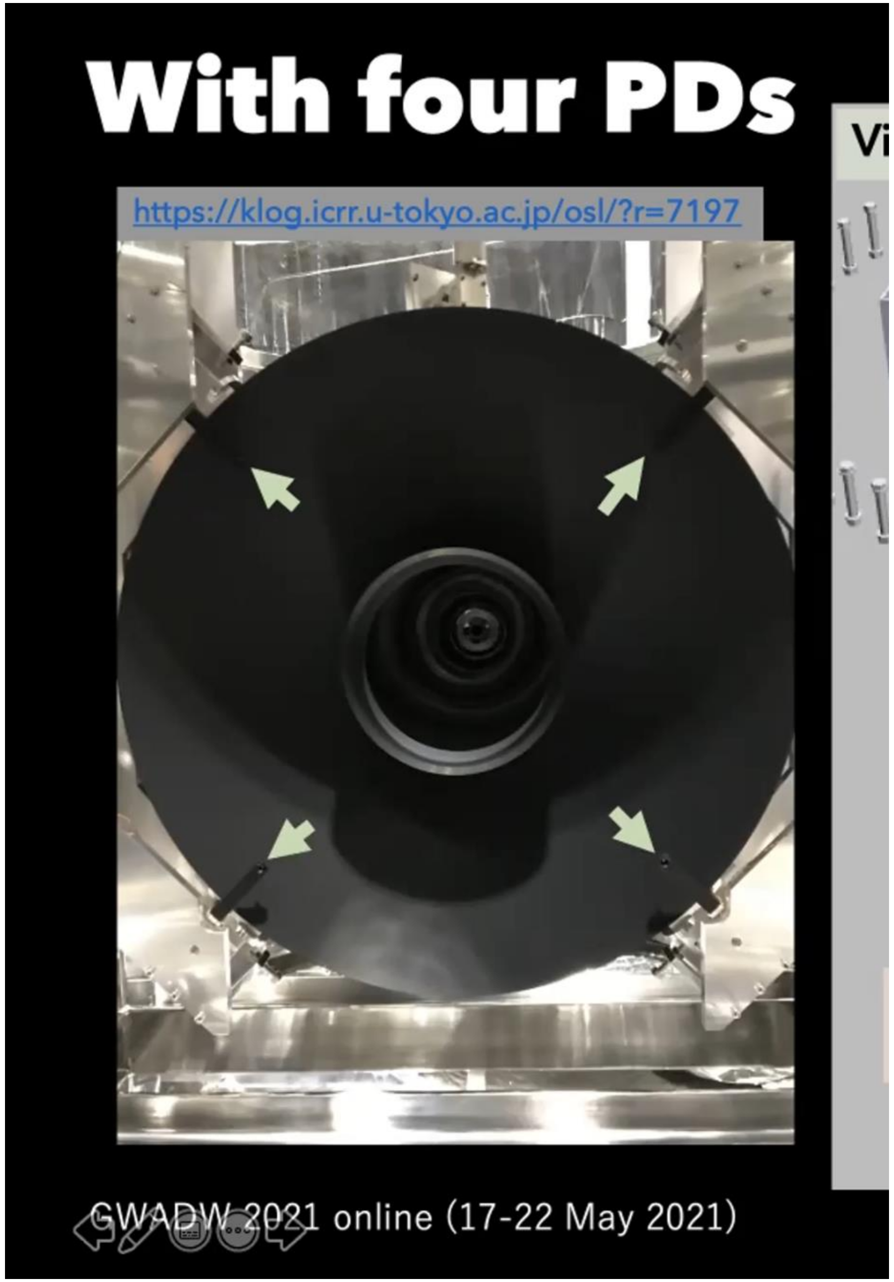
Detector image: SRM scatter on the septum. Blue area is the shadow from the ISI table, Green is the SRM AR baffle shadow (100mm diameter aperture per the ECR). Only the bottom AR baffle is considered in the model.



CDR https://dcc.ligo.org/LIGO-G2100167

Stray-light control in KAGRA
Speaker: Tomotada Akutsu (National Astronomical Observatory of Japan)





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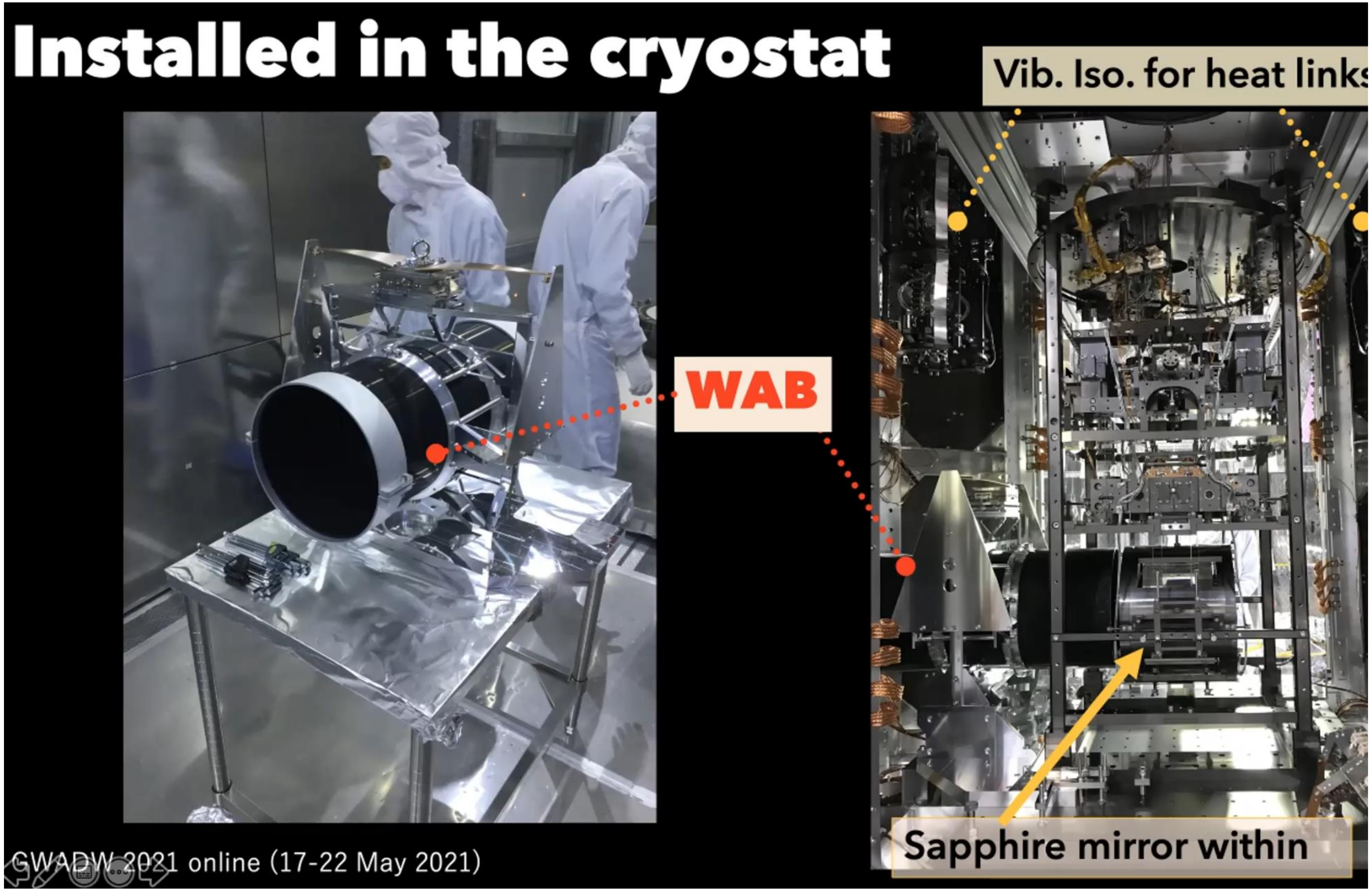

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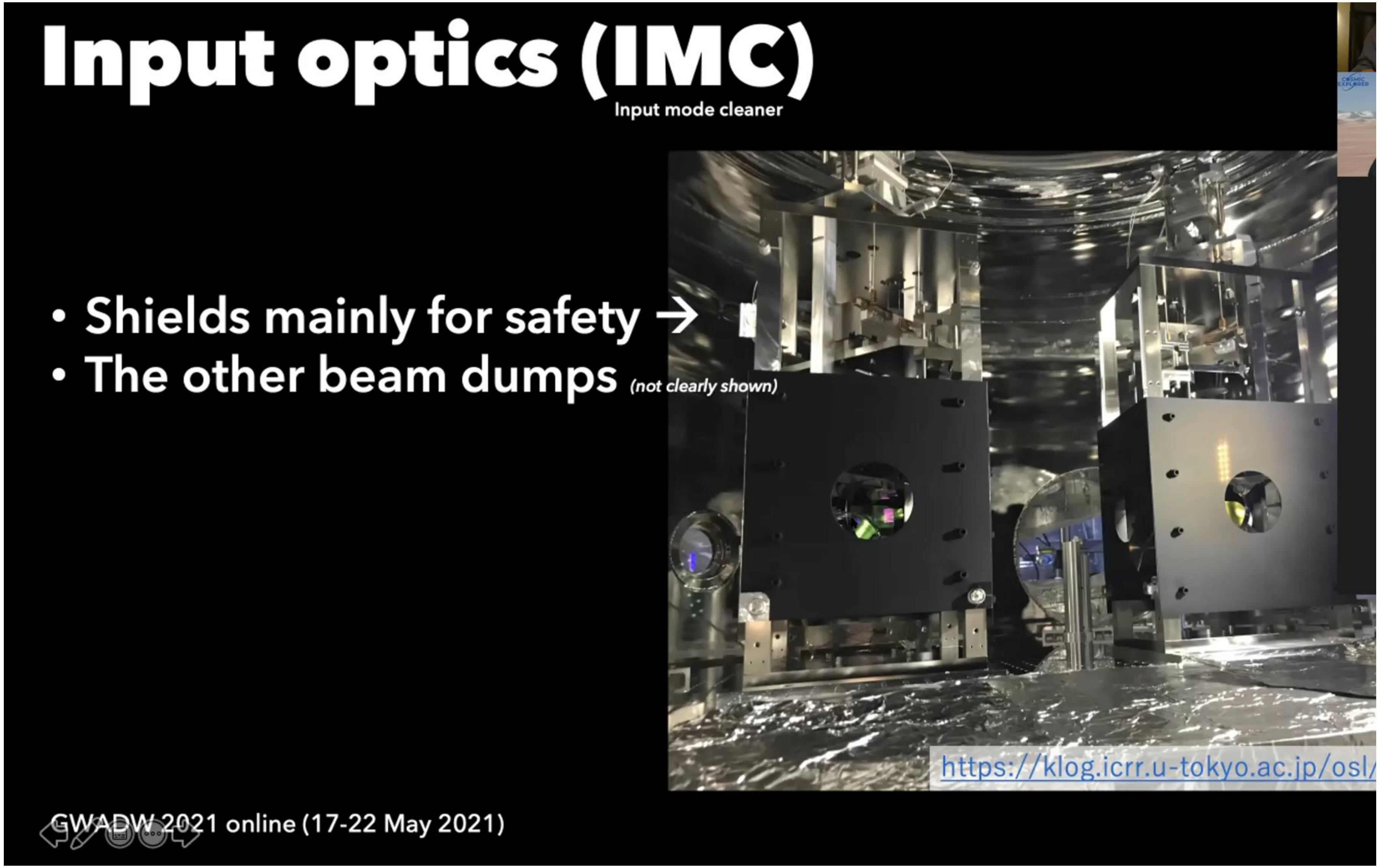
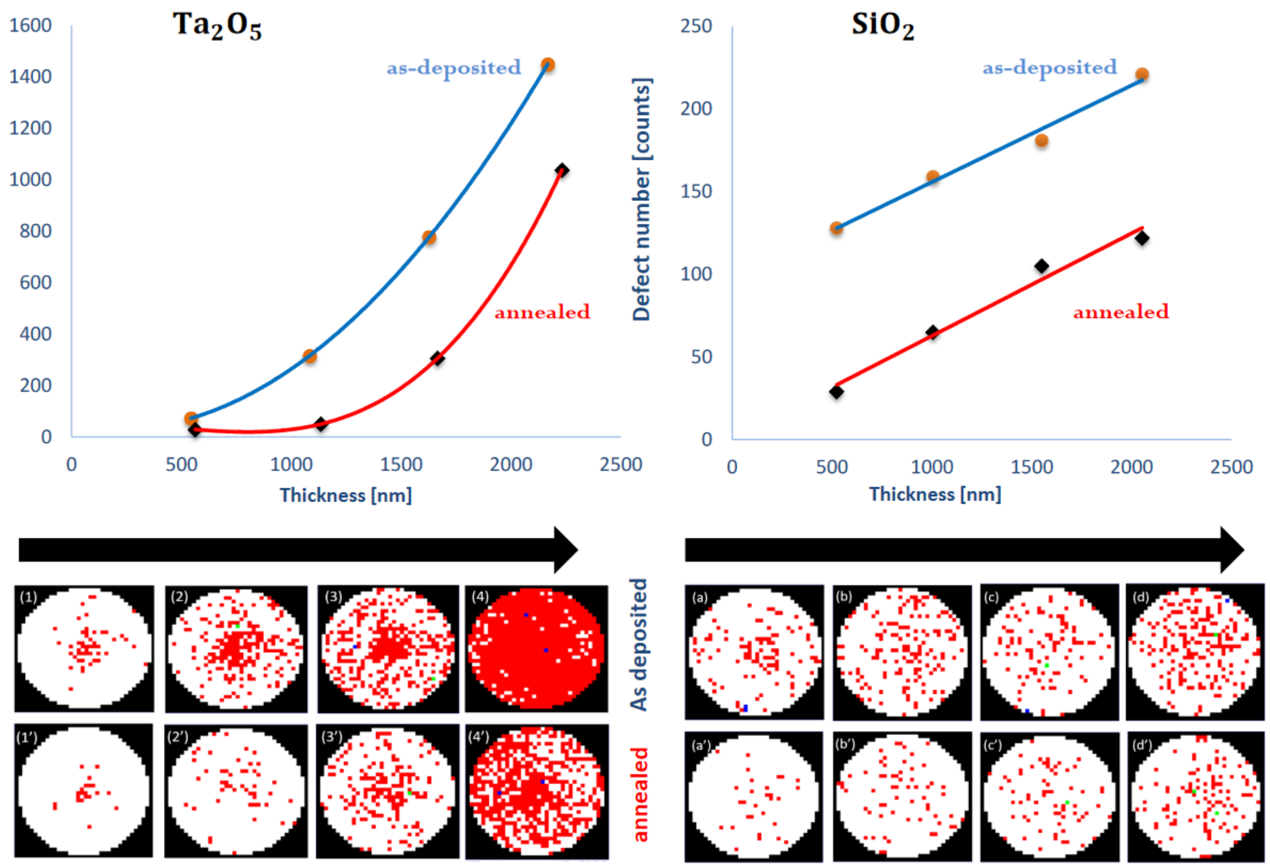


Characterization of light scattering point defects in gravitational wave detector coating layers

Speaker: Sihem Sayah (LMA)

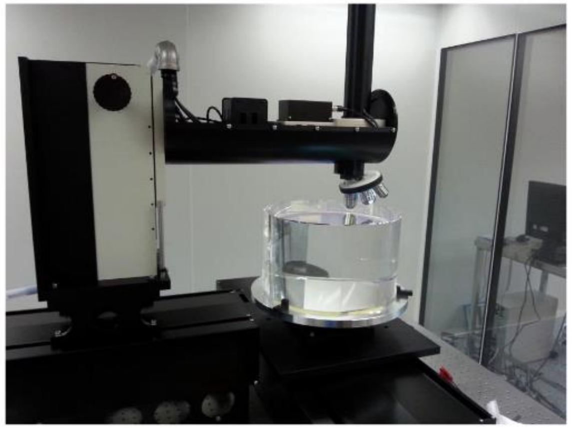
Defect density

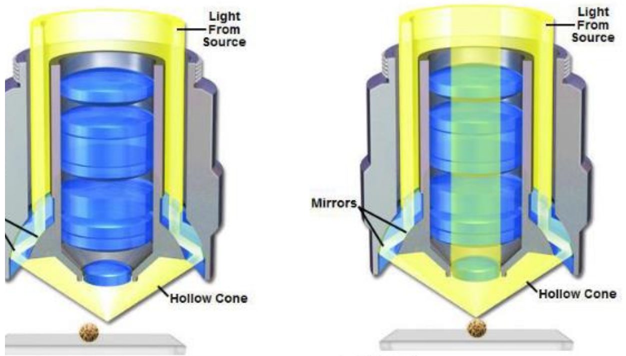


Defects detection : instrument

Detection defects done with the profilometer

- Using dark-field
- 256 grey levels
- Mapping large surface, by squares of 513x513 µm²
- Ø 18 mm on 1" sample





Crédits Olympus

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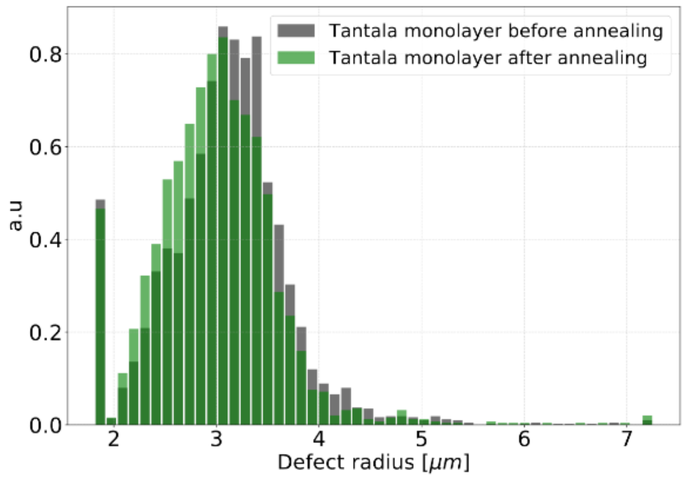
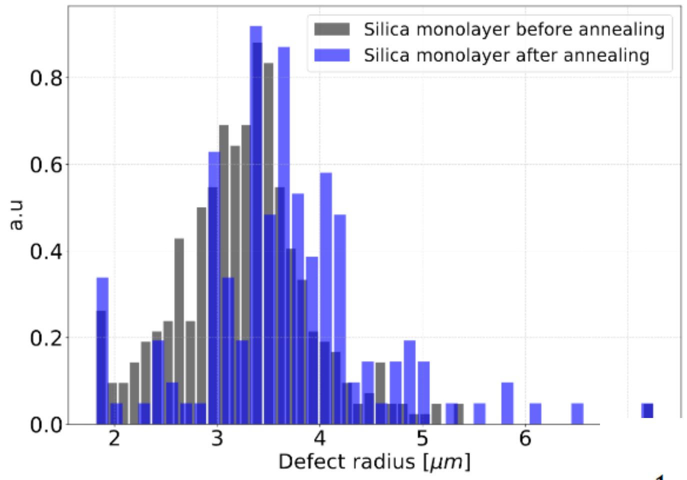
LMA LABORATOIRE MATÉRIAUX AVANCÉS

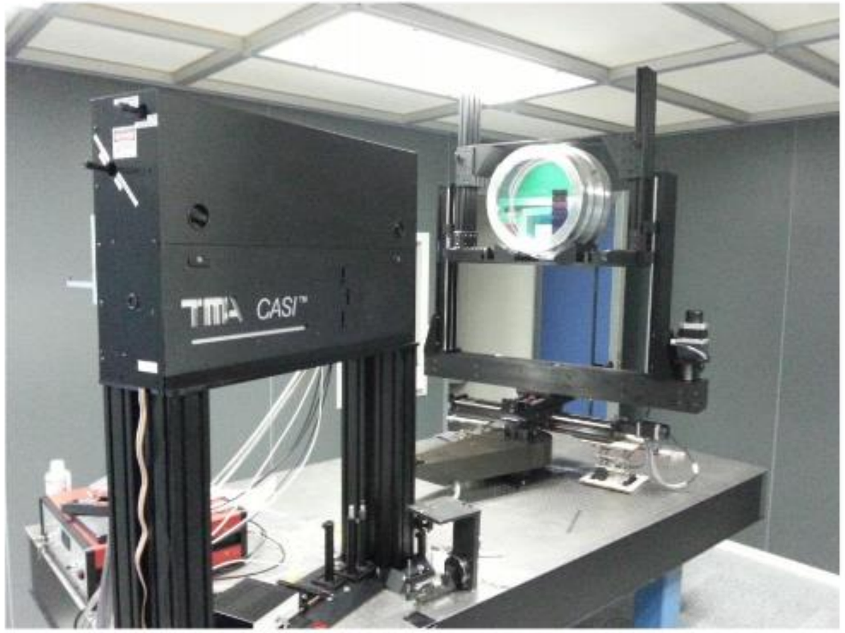
7

Size of the defect

Study carried out with Ta2O5 and SiO2 monolayers for different thicknesses







- More defects inside the Ta2O5 than SiO2
- Median size defect ≈ 3 μm
- Post deposition annealing cure the defects (also observed by LIGO G2000374-v2)

S.Sayah et al., Appl. Opt. **60**, 4068-4073 (2021) https://doi.org/10.1364/AO.415462

EGO EUROPEAN GRAVITATIONAL OBSERVATORY — LMA LABORATOIRE MATÉRIAUX AVANCÉS

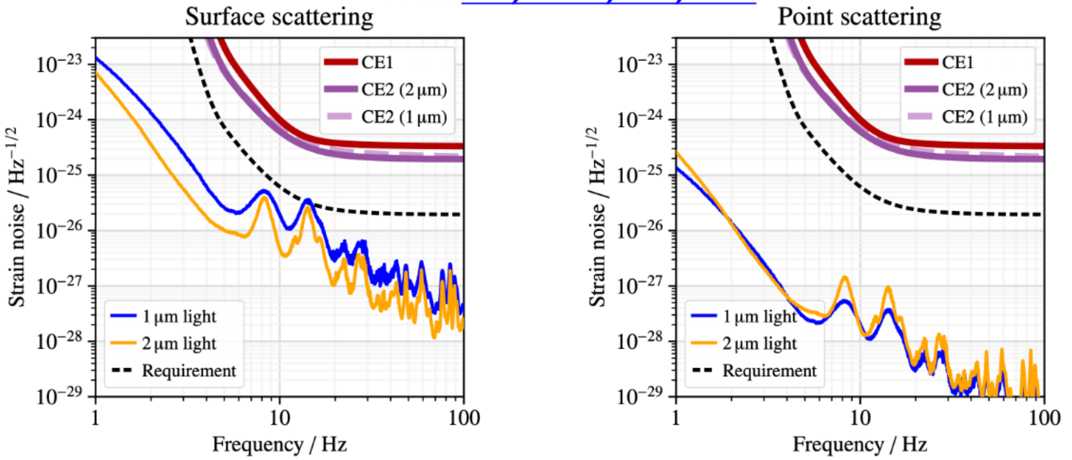
1. Development of a reliable image processing
2. We have more defect in tantala monolayers than silica monolayers (factor 10)
3. The defect density is dependant to the layer thickness
4. Annealing reduces by factor 2 the defect density
5. The defect size median is about 3 μm for each materials
6. Working on scattered light simulation

Light scattering noise in Cosmic Explorer
Speakers: Gabriele Vajente (Caltech) , Joshua Smith (California State University Fullerton)

Estimating CE Surface Roughness Requirements

- Backscattering estimates carried out by Yuntao Bai (Caltech) https://dcc.ligo.org/LIGO-T1900854
- surface roughness: mostly scattering to narrow angles (using green power law)
  - point defects: scattering to wide angles (using BRDF=1e-4 1/Sr)

From [Hall, Kuns+, PRD, 2021](#)

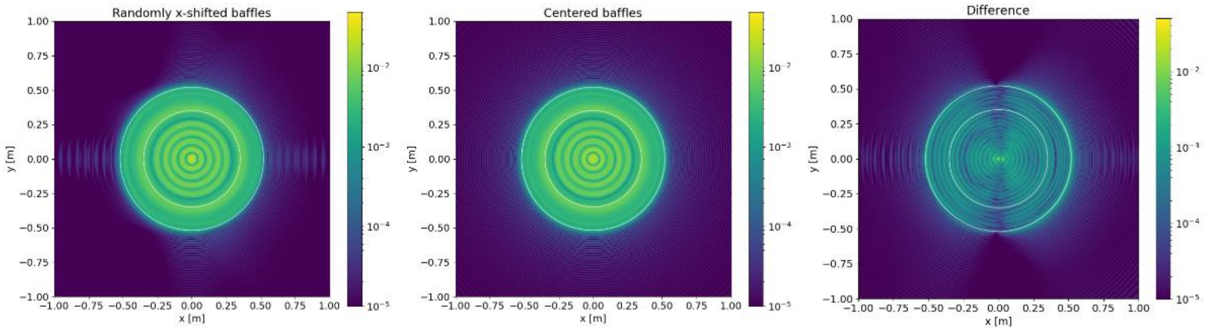


5

- Mirror roughness
  - Computed for points and roughness
  - Points seem ok
  - Roughness requirement comparable PSDs for aLIGO for spatial scales < few cm
  - Must extend to 70-80cm diameter and larger spatial scale

Example result

- Cosmic Explorer cavity, 100 baffles equally spaced, radius 52 cm
- ITM T=1.4%, ETM T=5ppm
- No mirror maps, mirror radius 35 cm



Inner circle: test mass size
Outer circle: baffle size

- Noise from baffle clipping
  - Developed a modeling framework
  - Computed distortion of the intra-cavity fields due to the baffle clipping and diffraction
  - Noise and coupling to be computed

Combined model

- Seeded by single source ray, input to the interferometer at the Power Recycling Mirror (PRM)