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DEVELOPMENT OF A LIGHT-SCATTERING MEASUREMENT FACILITY FOR THE CHARACTERIZATION OF STRAY LIGHT SOURCES IN GW OPTICS

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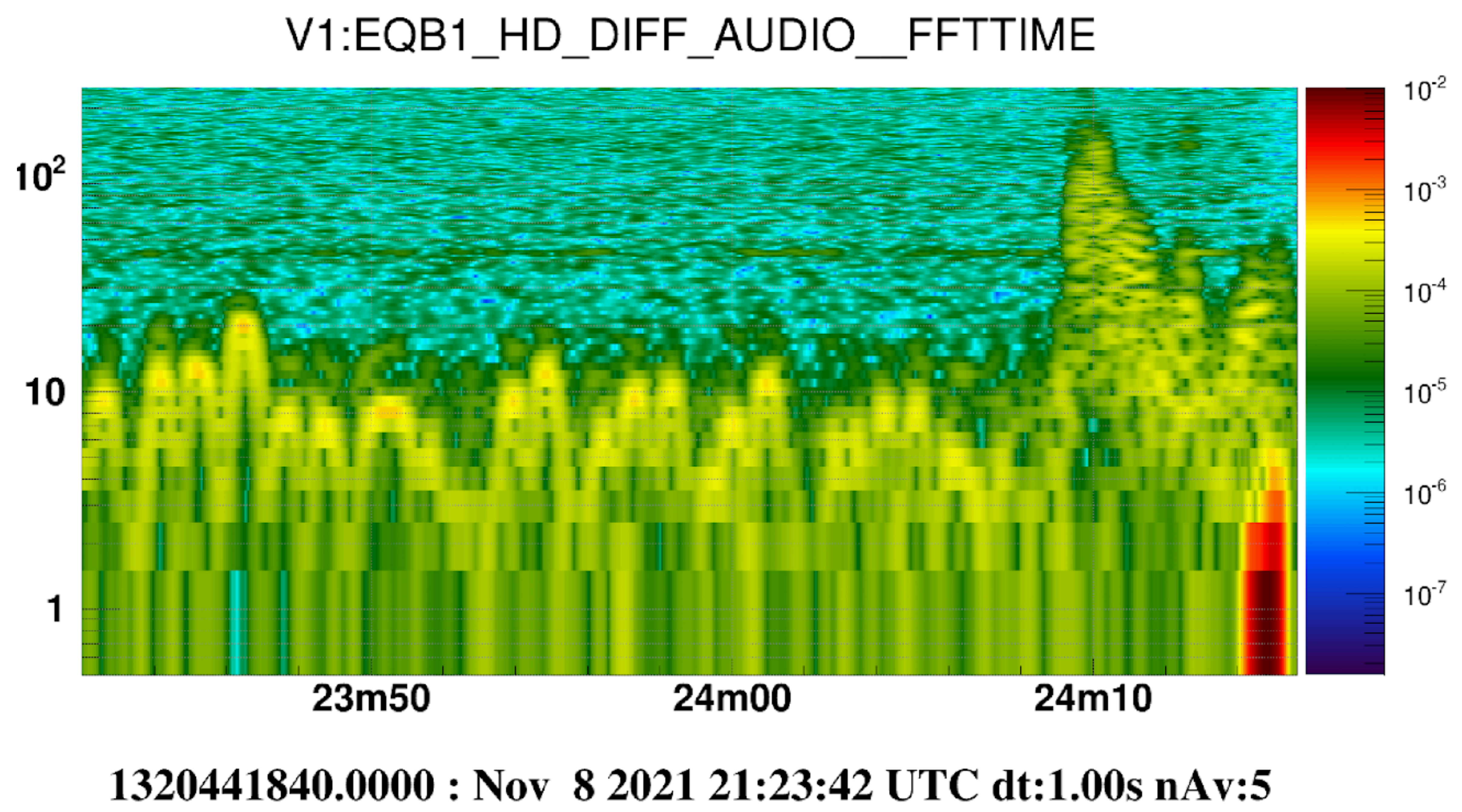
STRAY LIGHT NOISE

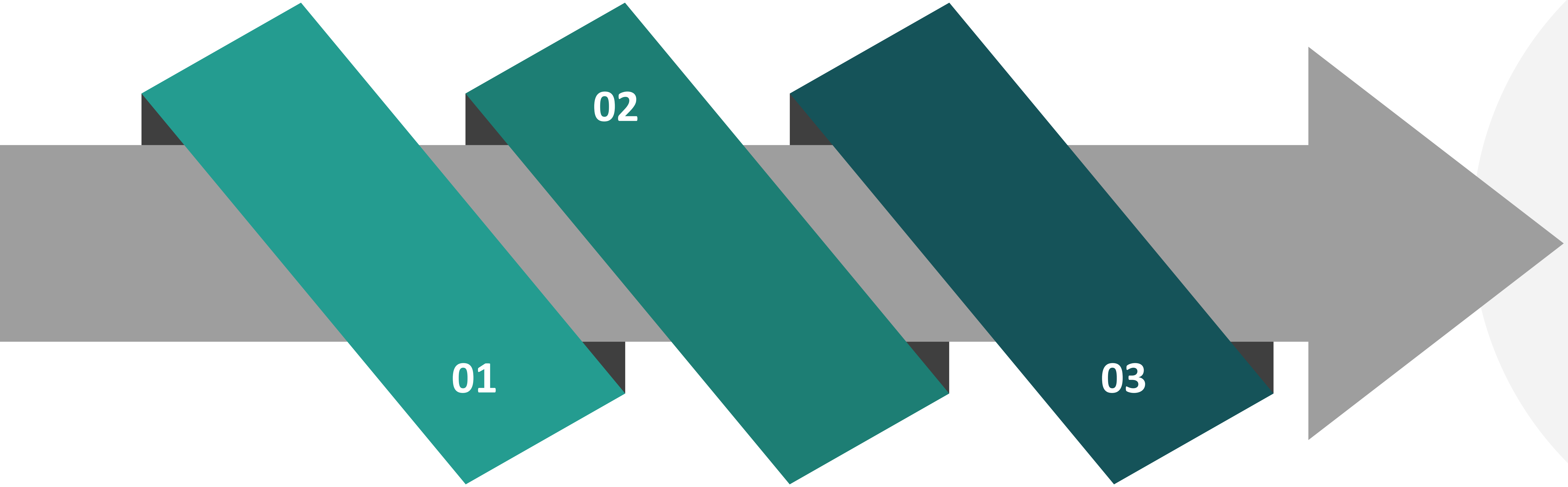
Stray light: all the light that follow a different path rather than the intended one

3 steps process:

- Generation of stray light
- Scattered light exits the main path and it is reflected by vibrating parts
- Re-enter the interferometer introducing additional amplitude and phase noise



PHASE NOISE



Elements movement

$$\vec{X}(t) = \sum_{i=1}^{N} \left(\vec{A}_i \sin\left(2\pi\omega_i t + \phi_i\right) \right)$$

Seismic and acoustic noise

$$0.1 \div 30Hz$$

Phase modulation

$$\Delta\phi(t) = \frac{2\pi}{\lambda}\left(\vec{r} - \vec{i}\right) \cdot \vec{X}(t)$$

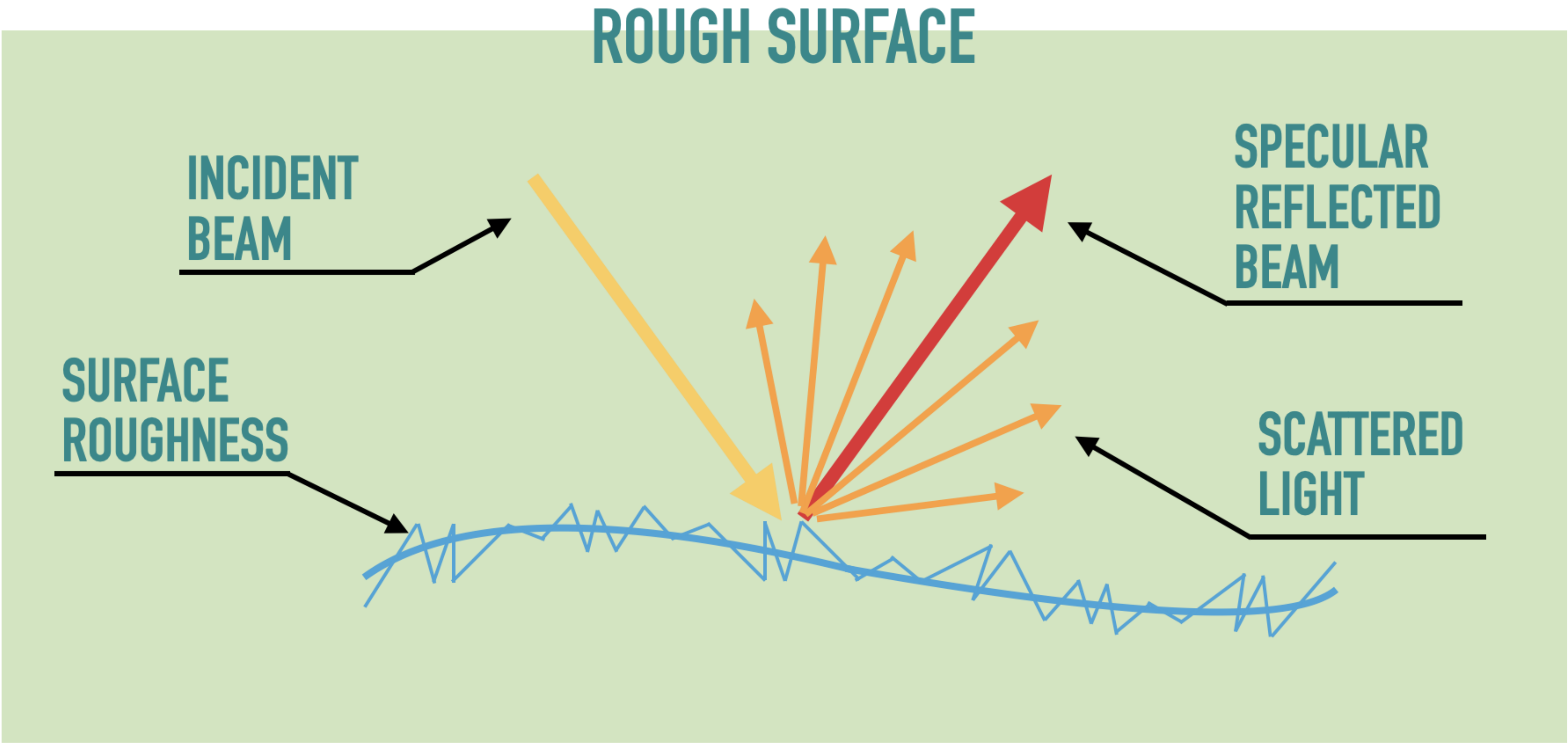
Interferometer additional noise

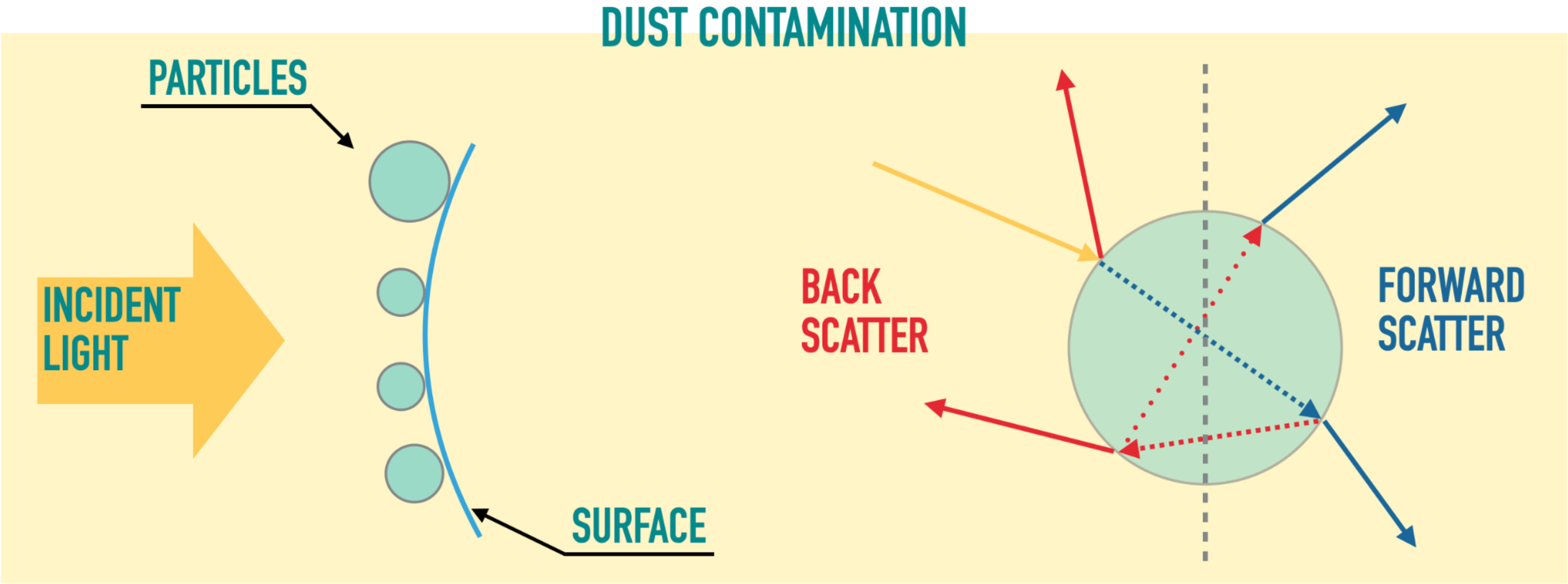
$$\Delta h(t) = G \cdot sin\left(\frac{4\pi}{\lambda}X(t)\right)$$

SCATTERING SOURCES

Main sources:

- Scattering from rough surfaces: due to not perfectly smooth surfaces
- Scattering from dust contamination: dust deposition on optical surfaces



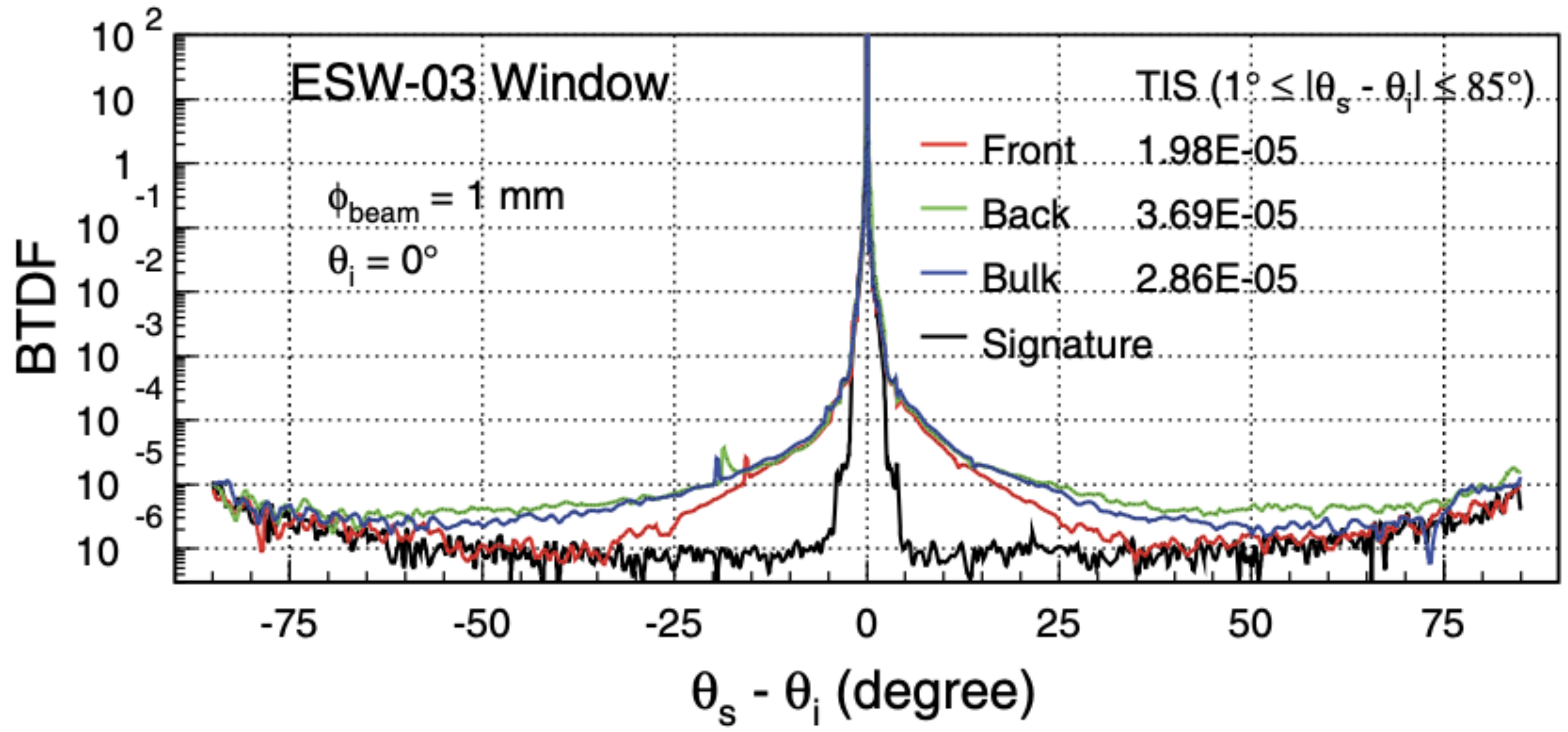


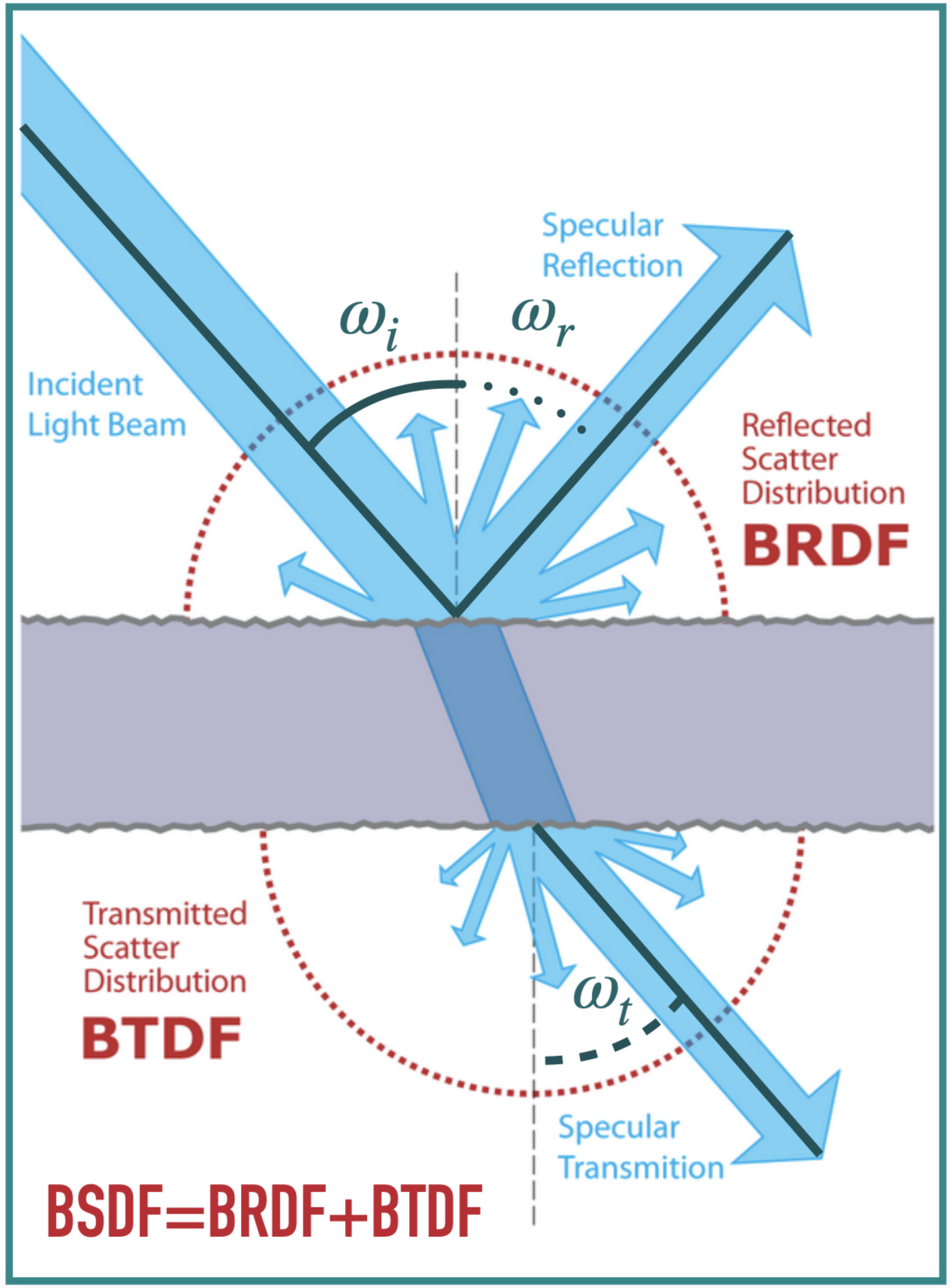
BSDF

Bidirectional Scattering Distribution Function:

$$BSDF(\theta,\omega) = \frac{I_{sc}}{I_{in}\cos\omega_r \cdot \Omega} + \frac{I_{sc}}{I_{in}\cos\omega_t \cdot \Omega}; [BSDF] = sr^{-1}$$

Ω = detector subtending solid angle



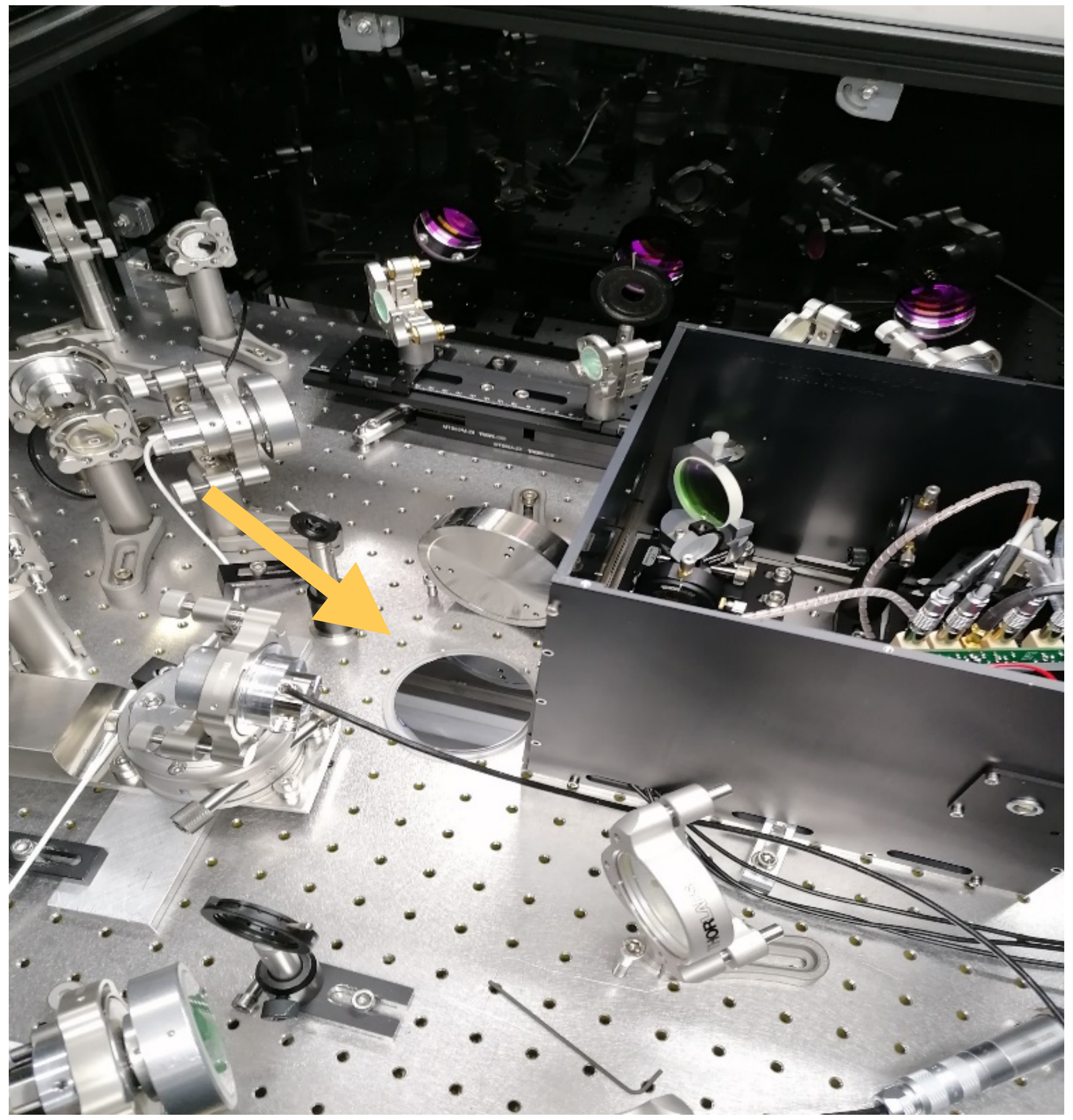


DUST MONITORING

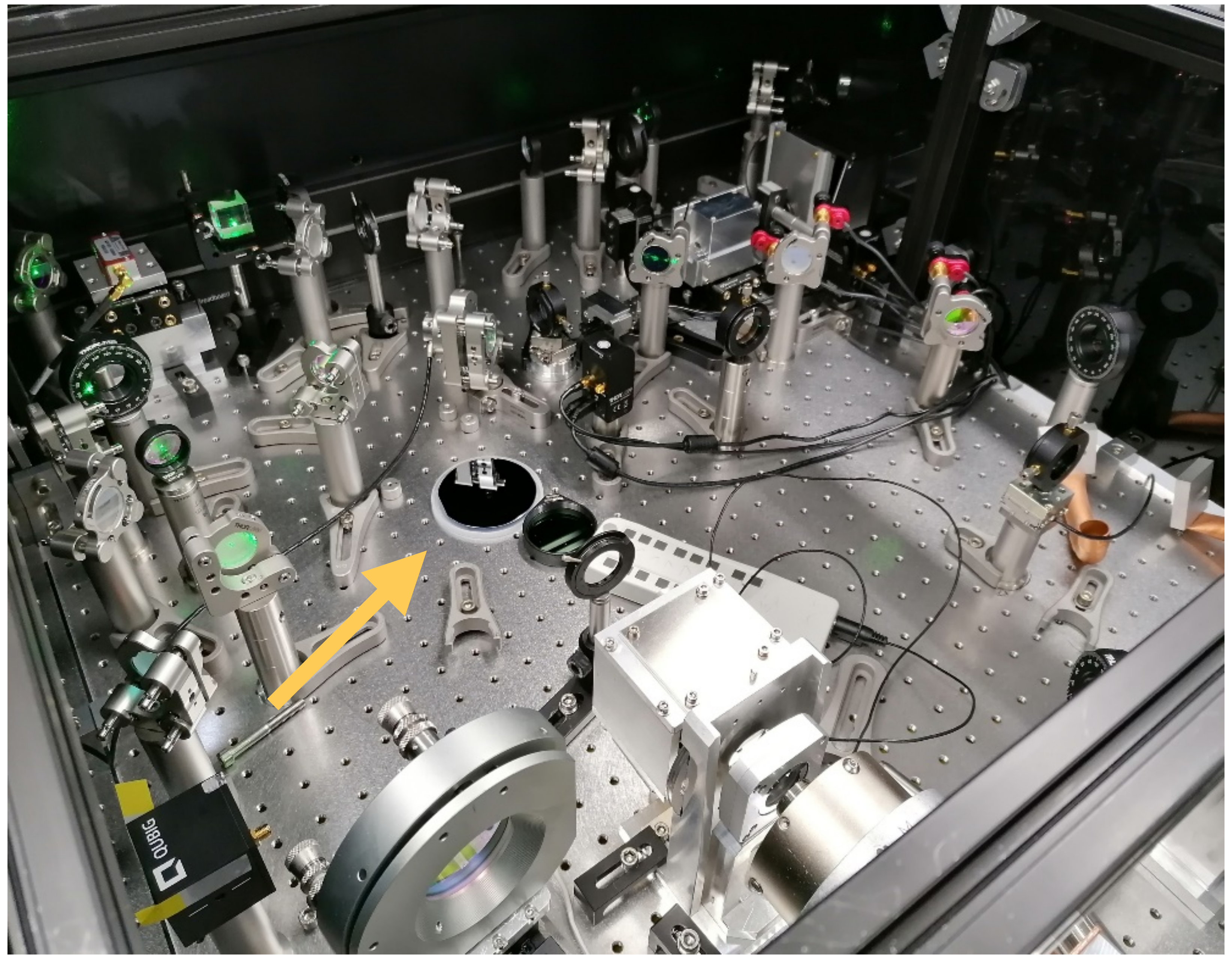
Why — To reconstruct the dust distribution

How — Exposing Si wafer on SQZ benches

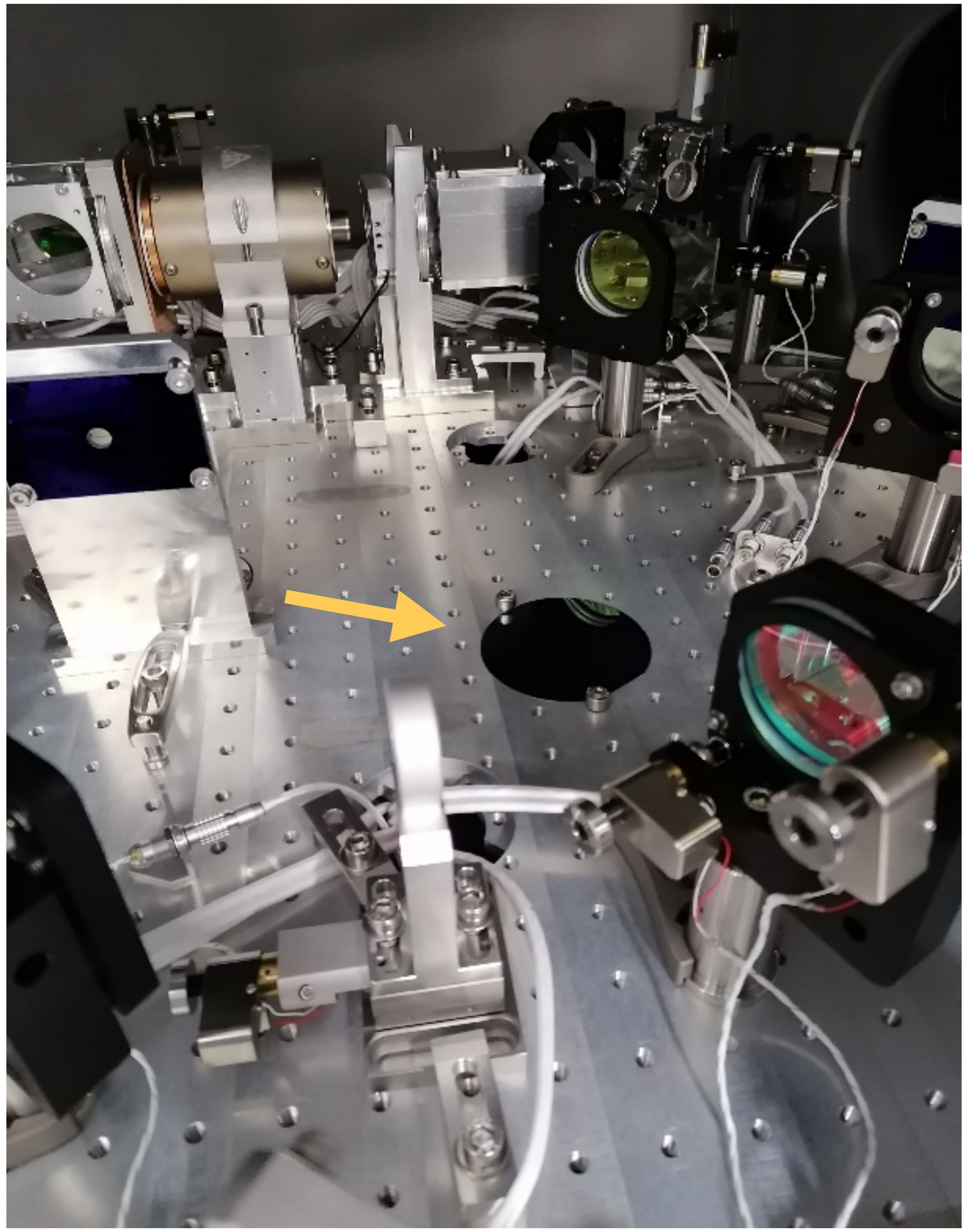
Goal — Monitoring the environment CL



EQB1



EQB1



SQB1

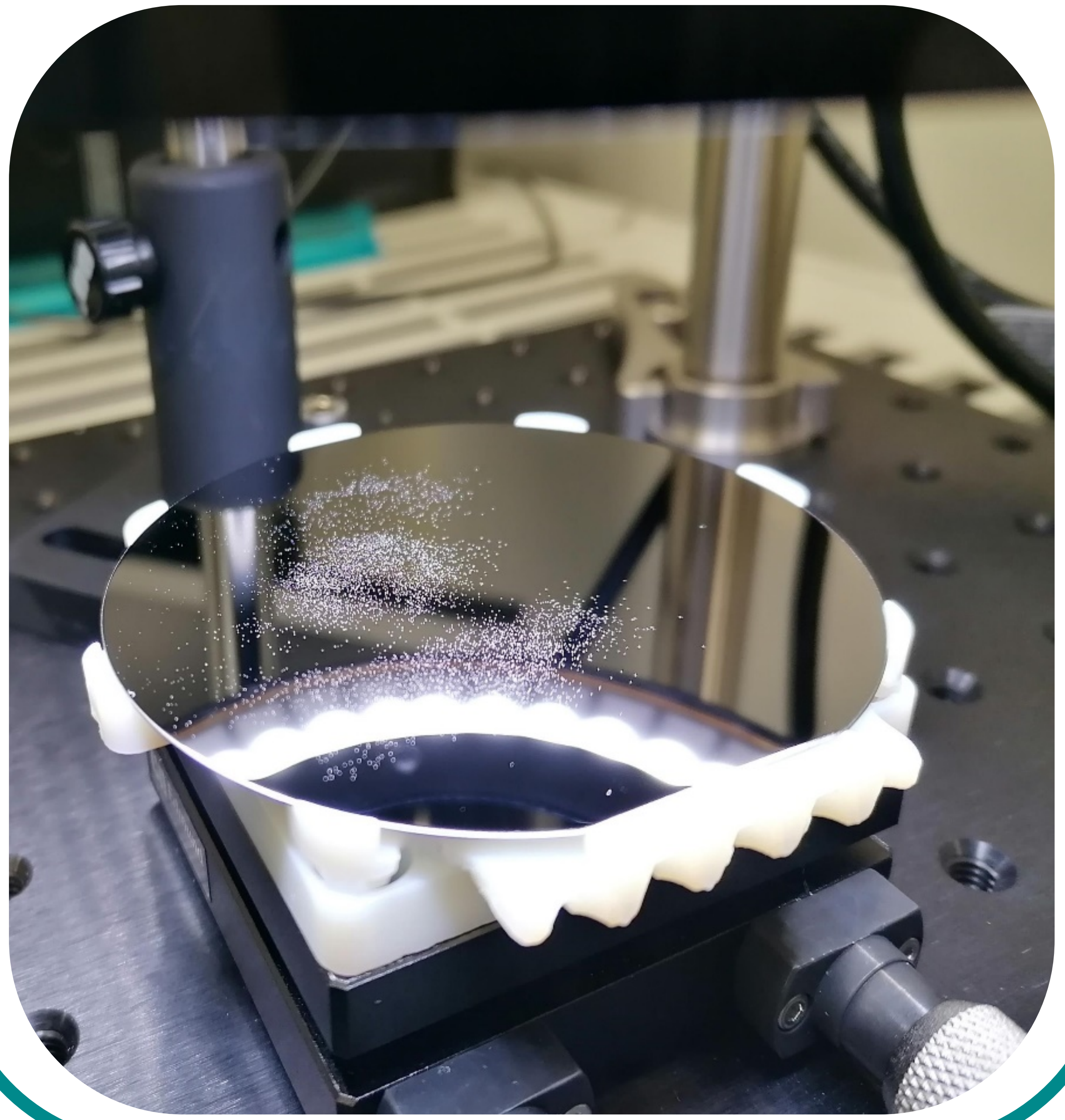
ANALYSIS PROCESS

Imaging setup

Dust samples photographed
in **ISO3 clean room**

$8\mu m$ **particles (1px)**

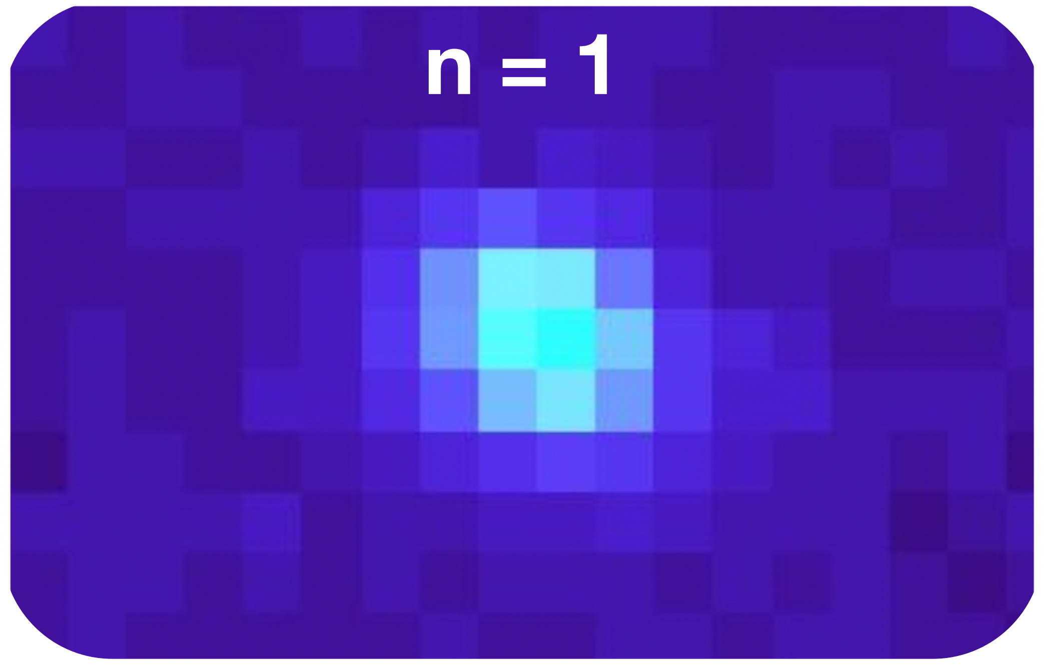
Sample area **A=4.8cm²**

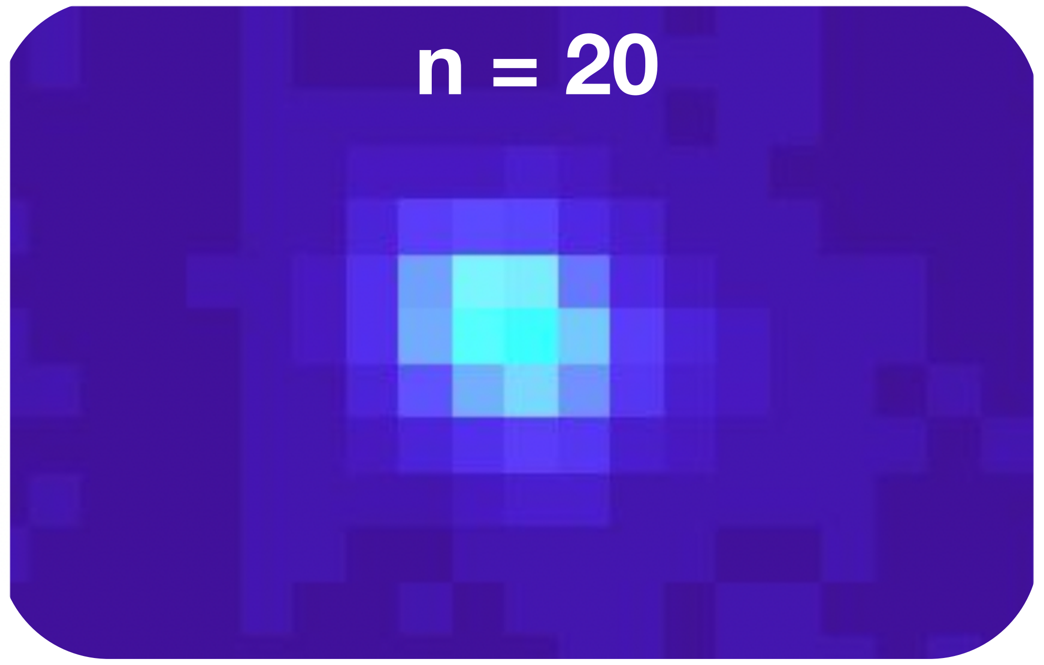


Acquisition

Parameter optimization:
Illumination e focusing

Pixel noise reduction:
averaging of **n** images



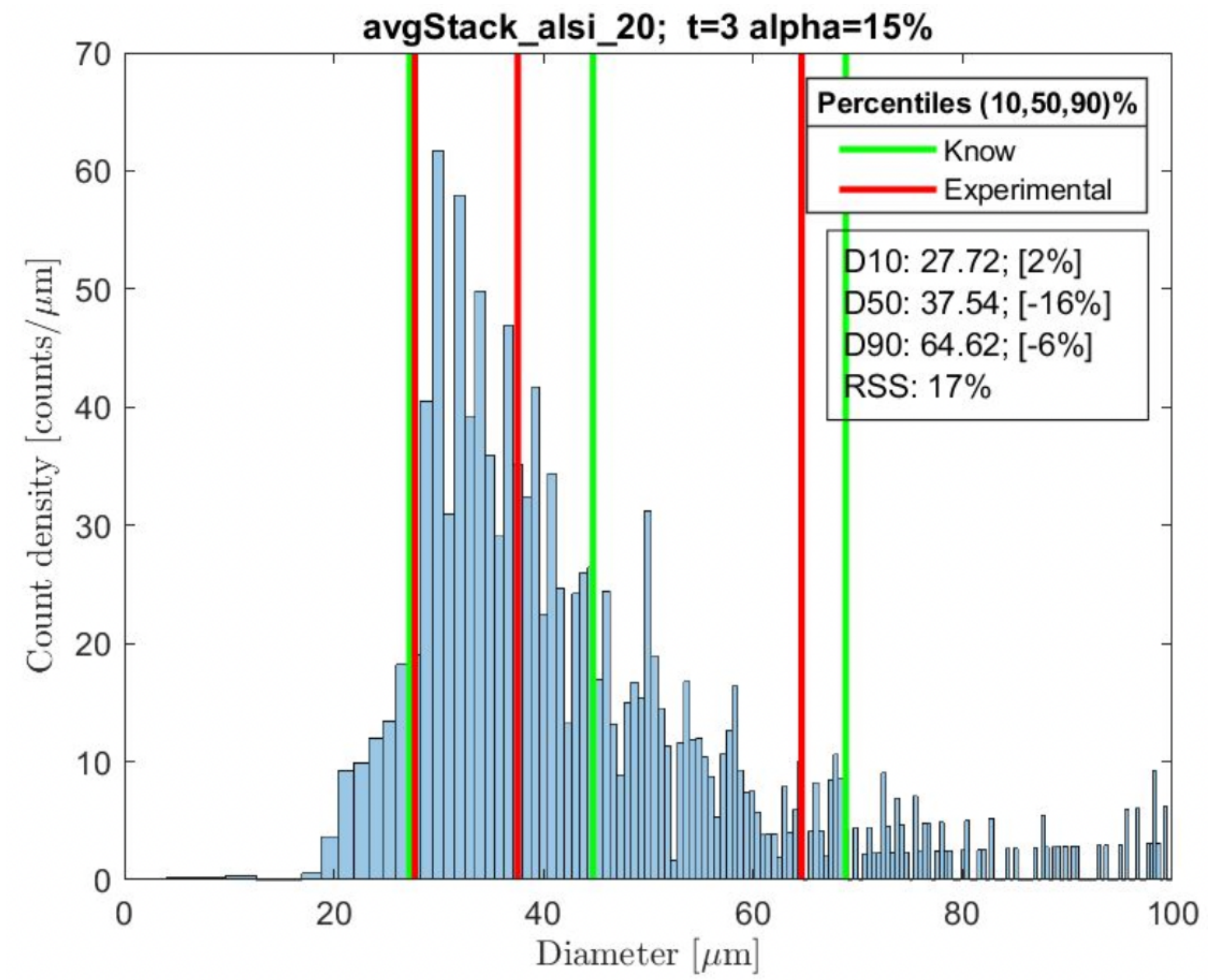


Algorithm

Background light removal

Anti-clustering search strategy

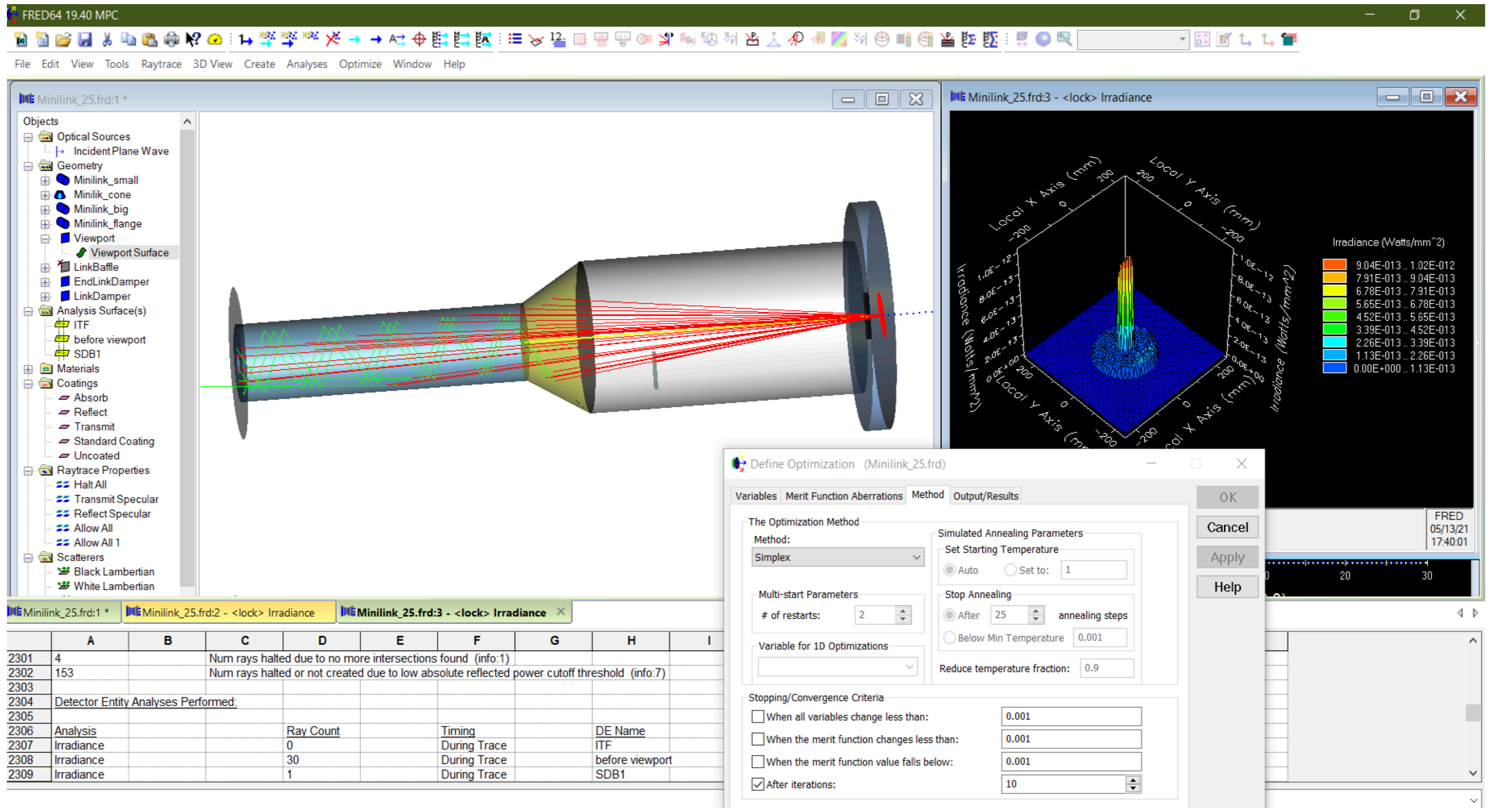
Distribution reconstruction



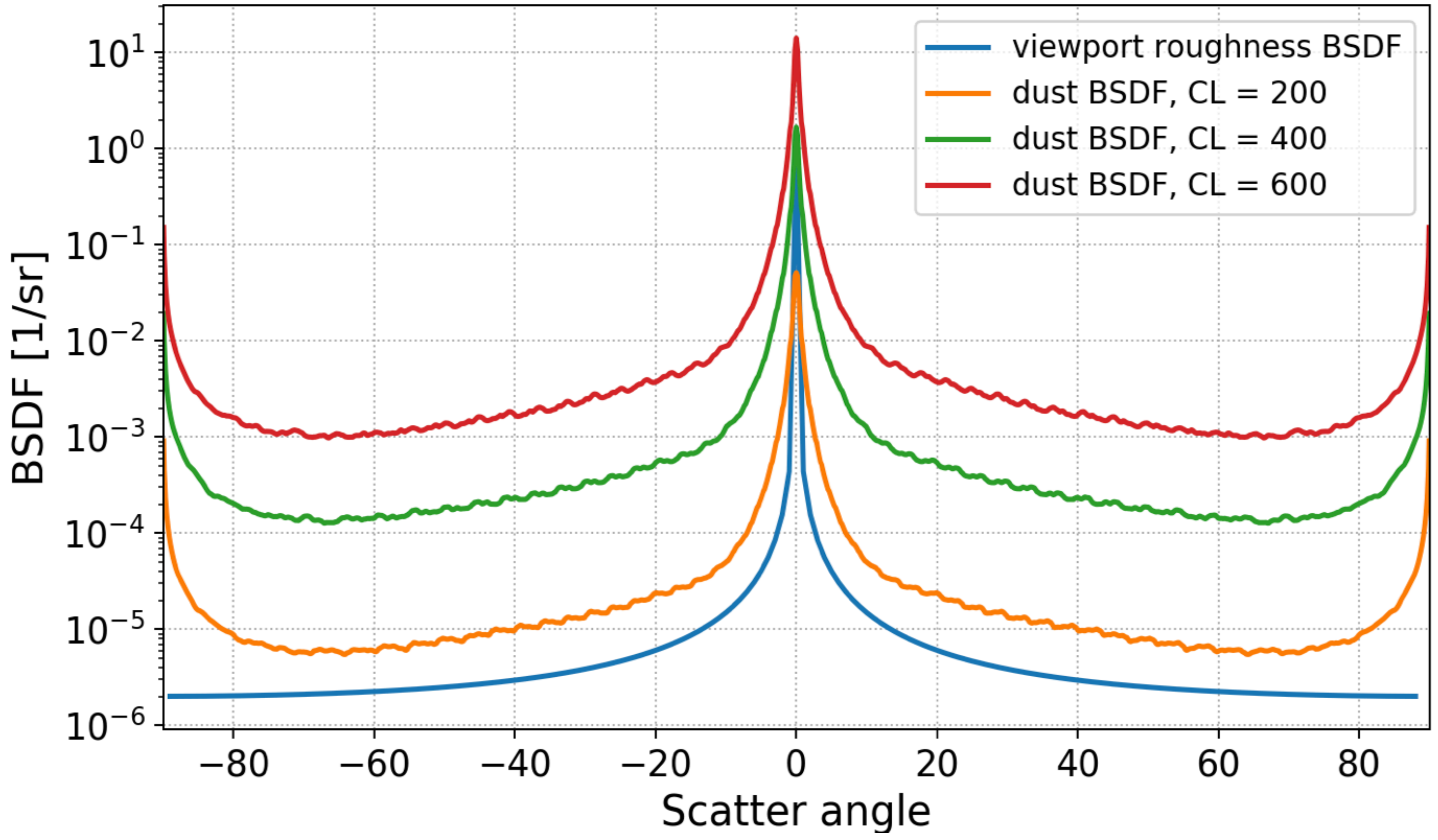
FRED SIMULATIONS

With **FRED** we can simulate the impact of a scattering model

INPUT: roughness/dust distribution



OUTPUT: ray-tracing, BSDF

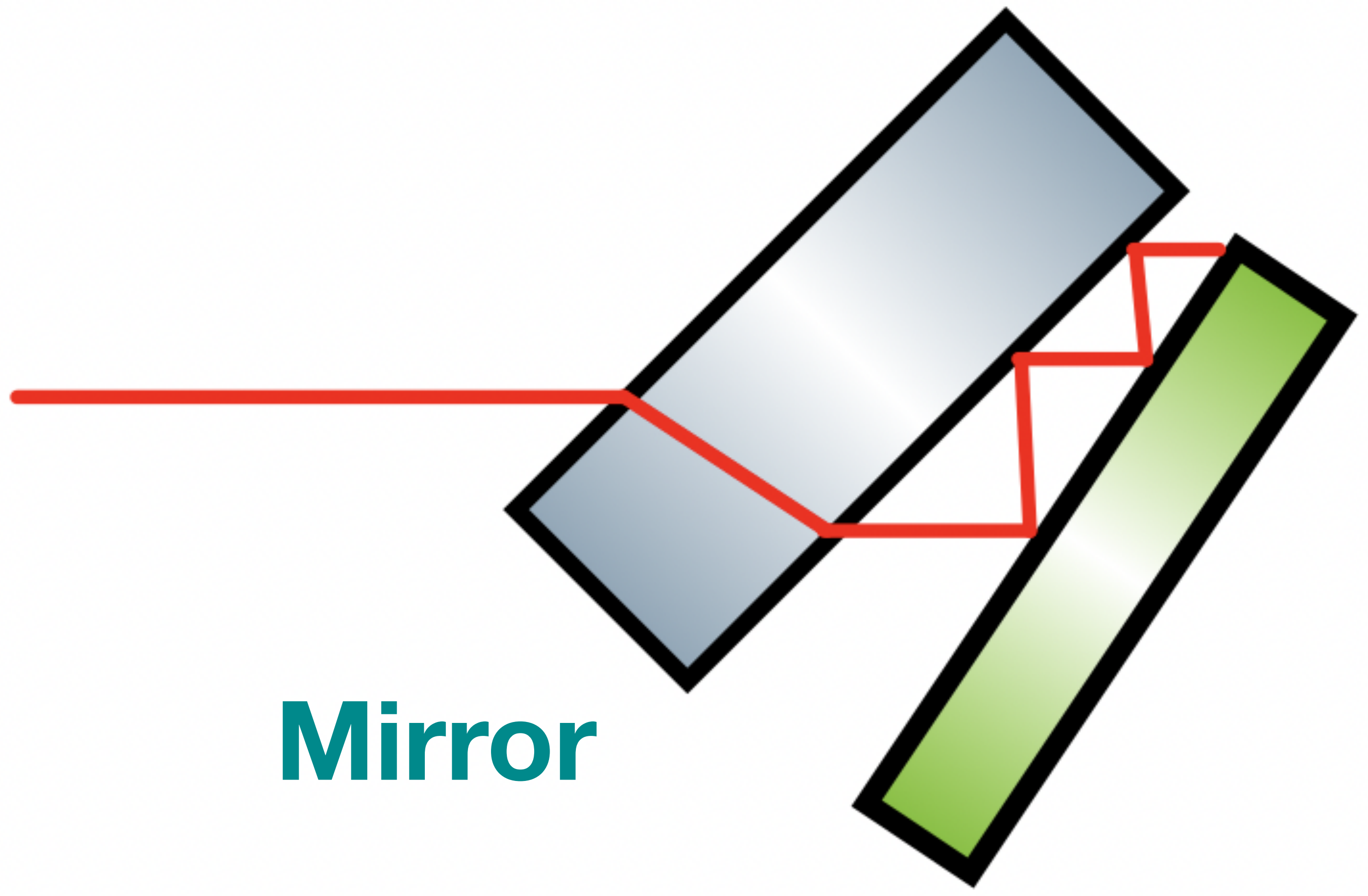


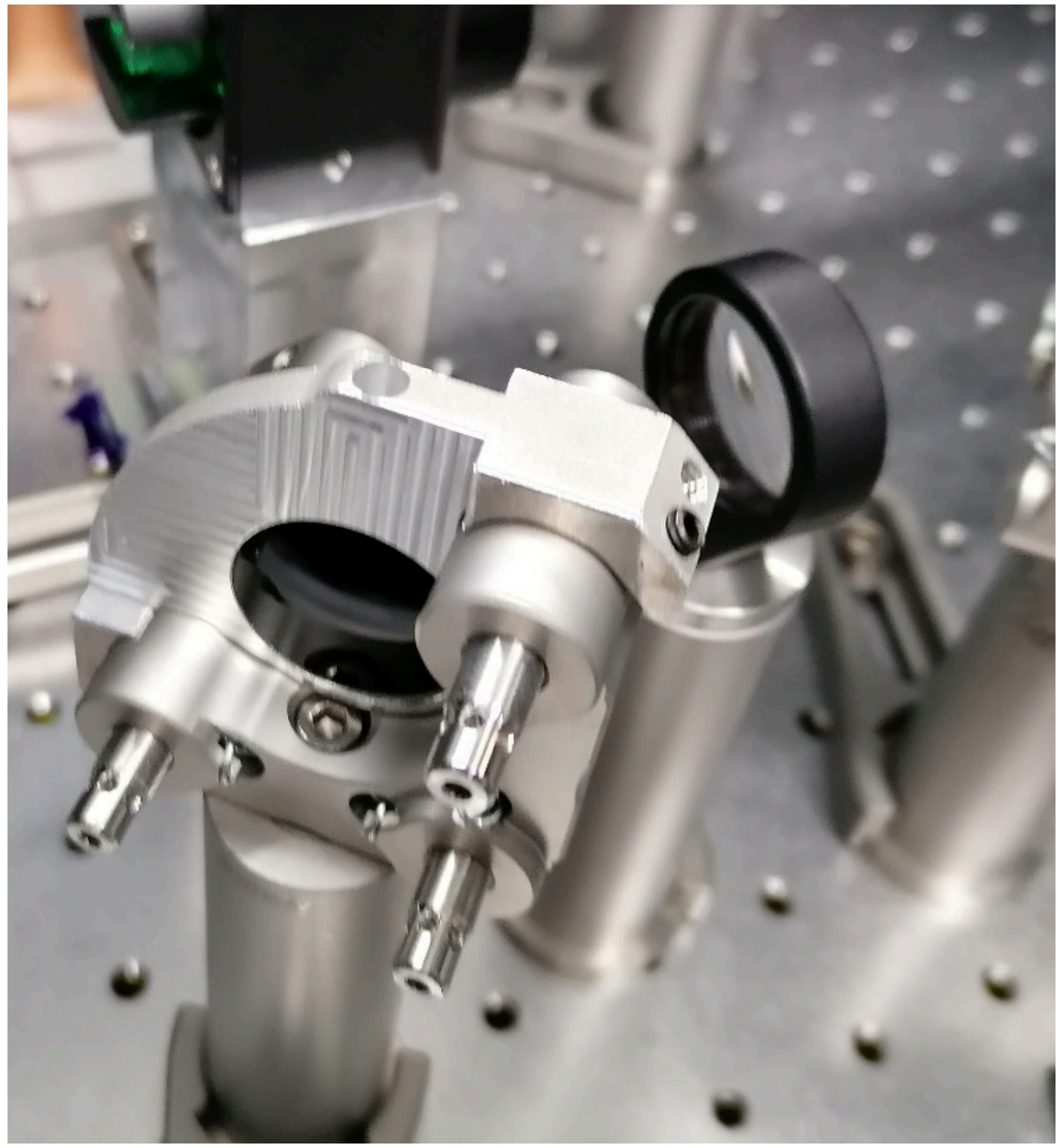
GHOST BEAMS DUMPING

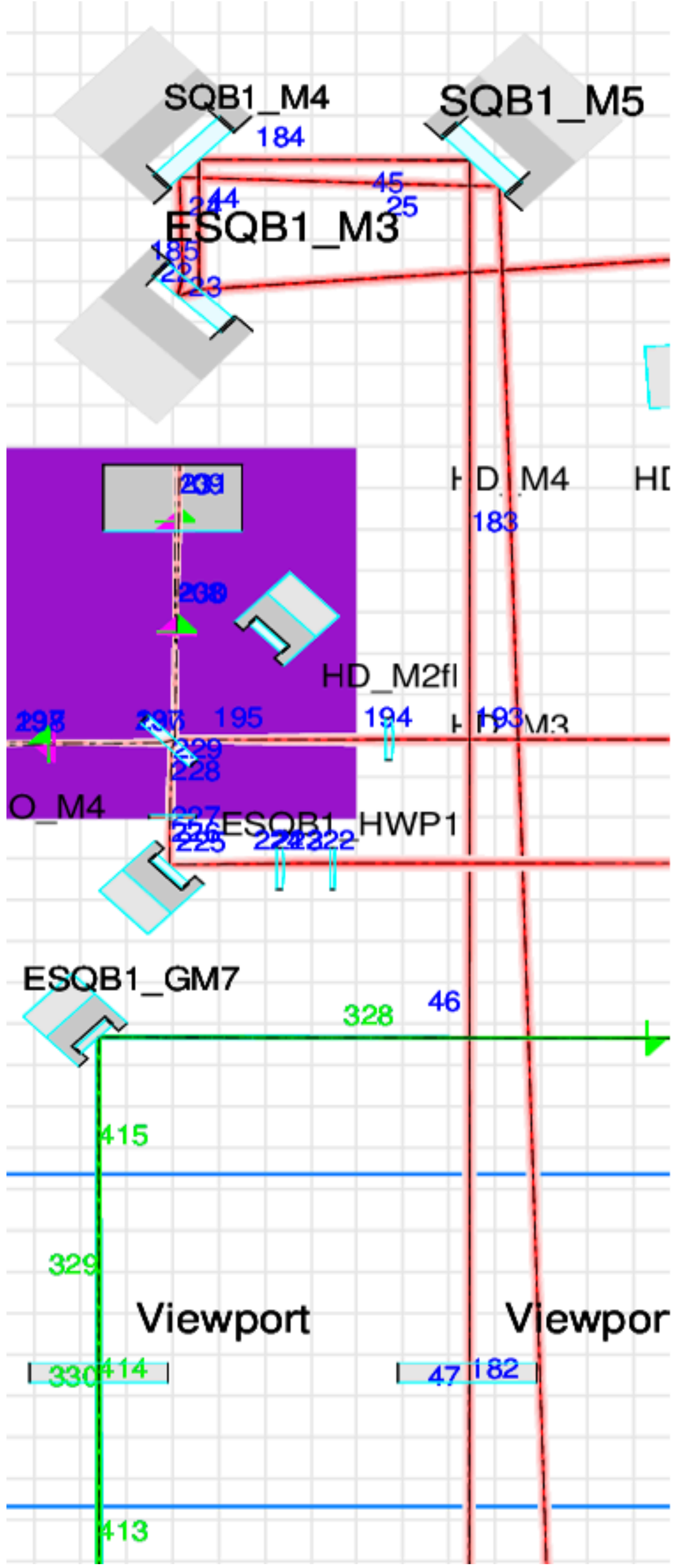
Ghost beams: unwanted reflection/transmissions due to imperfect coatings

- **Reflected** ghost beams:
  wedge on the rear face to separate the main and the ghost beams in order to absorb the last one

- **Transmitted** ghost beams:
  Tilted absorbers (2.5°) to trap the ghost beam





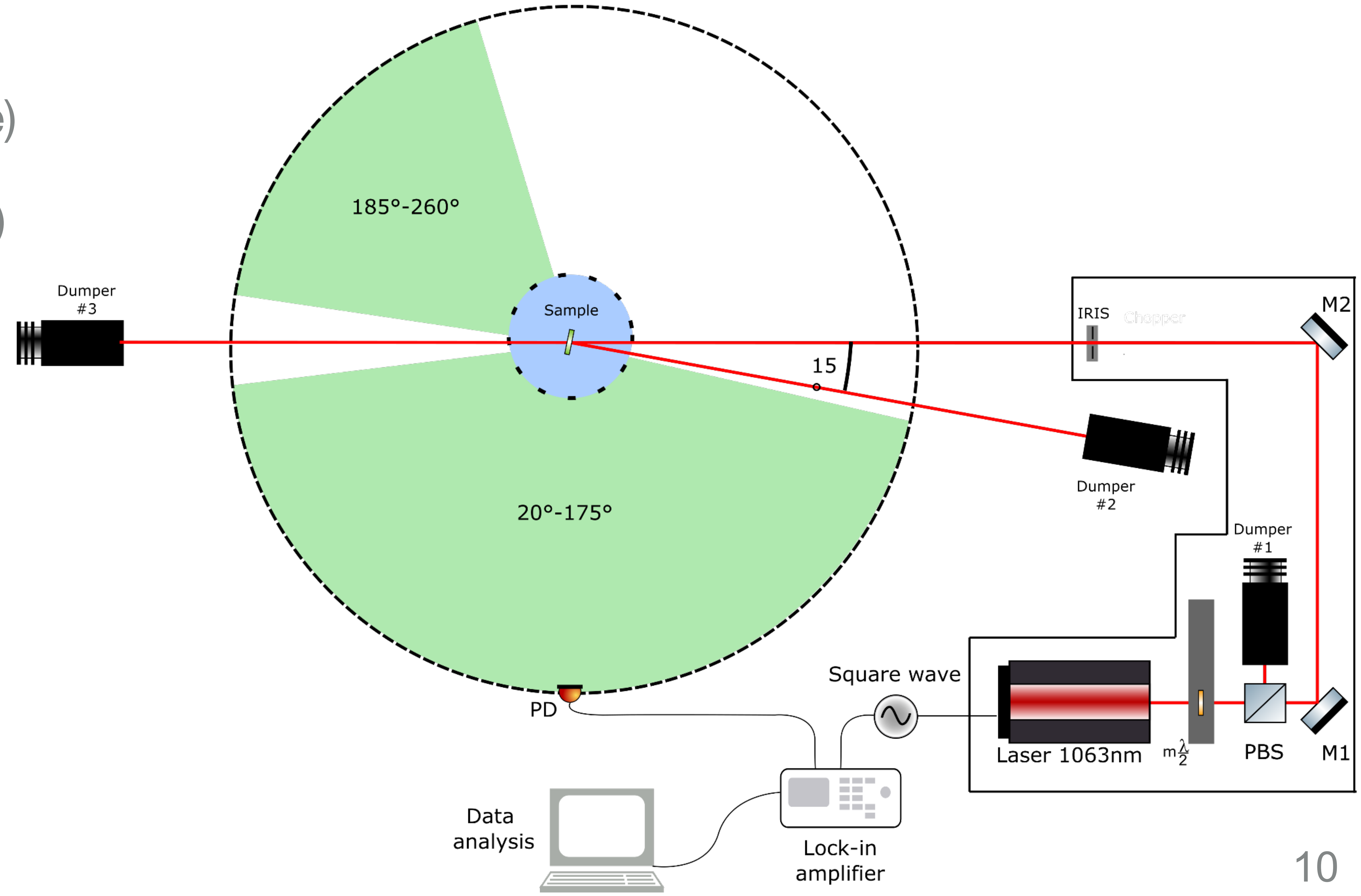


SCATTEROMETER FACILITY

Optical setup to measure the **BSDF**:

- Two motorized goniometer:
  - **DETECTOR** (scattering angle)
  - **SAMPLE** (angle of incidence)
- Modulated measurement to reduce extra noise
- Final Goal: high sensitivity

$$BSDF \sim 10^{-7} sr^{-1}$$



INTEGRATING SPHERE

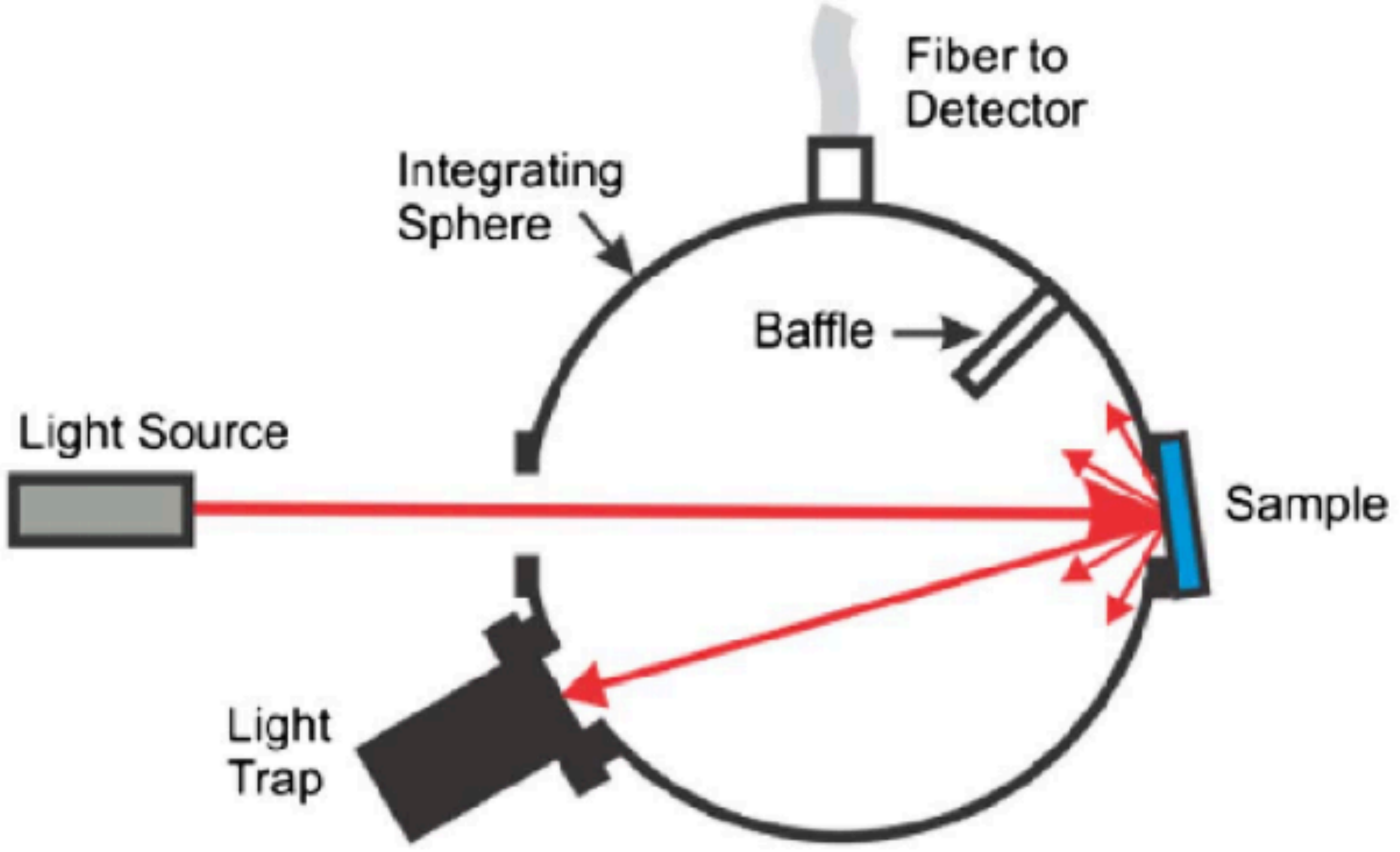
Optical component consisting of a hollow spherical cavity

Interior covered with a diffuse white reflective coating:

- **Multiple reflections**
- **Uniform diffusion**
- **Backward and forward scattering**

⬇

Total **I**ntegrated **S**cattering

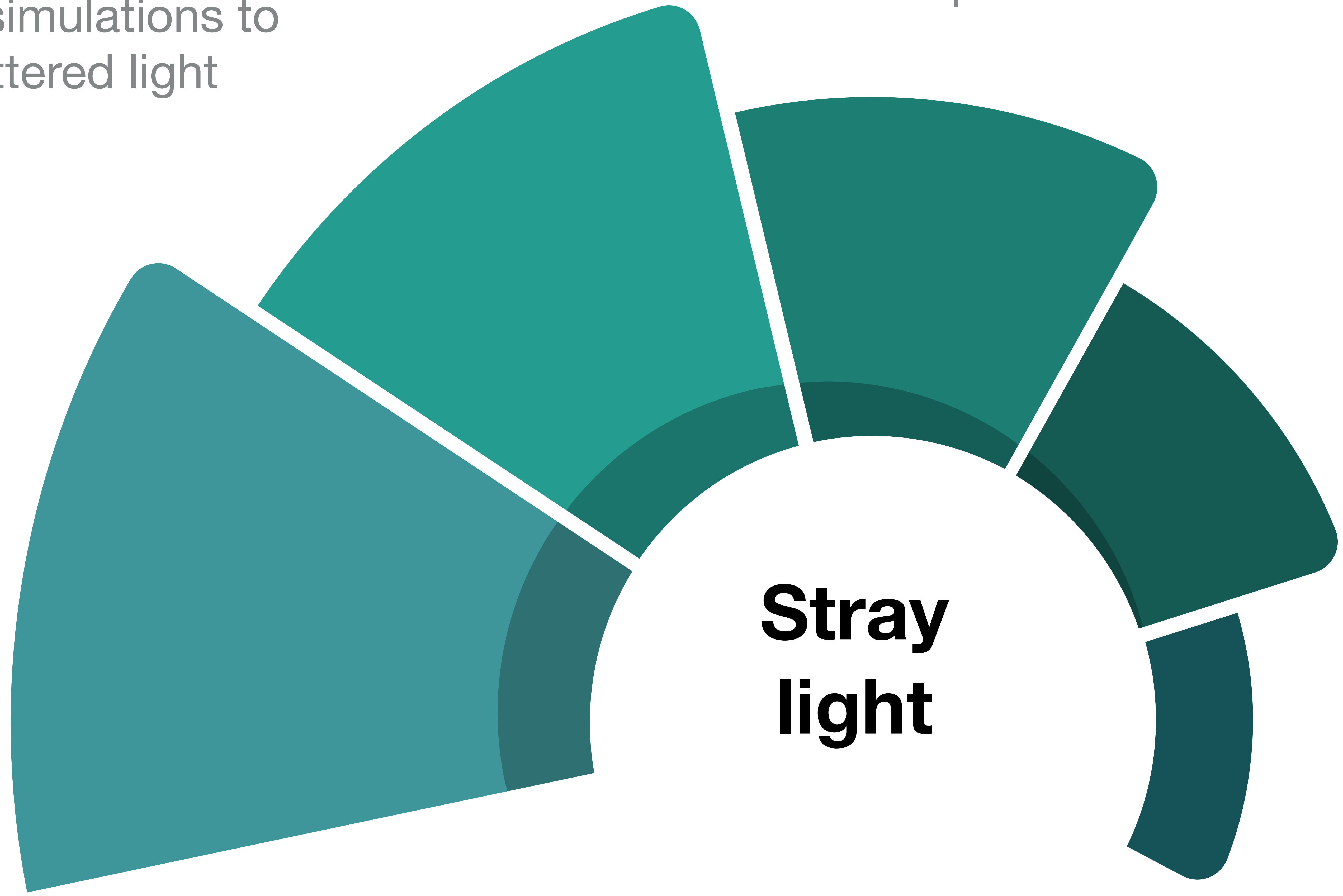


$$TIS = \frac{P_{scat}}{P_{tot}}$$

P_{tot}=*total power incident radiation*

P_{scat}=*scattered light*

GLOBAL APPROACH



Simulations

Padova/Genova - Numerical simulations to predict scattered light

Stray light mitigation

Virgo - Investigation and dumping of ghost beams on optical bench.

Direct BSDF measurement

Padova - Optical elements characterization used in Virgo

Dust monitoring

Virgo - Estimation of scattering from dust distributed on the optical elements

Direct TIS measurement

Padova - TIS measurement of optical elements used in Virgo

THANK YOU FOR YOUR ATTENTION!