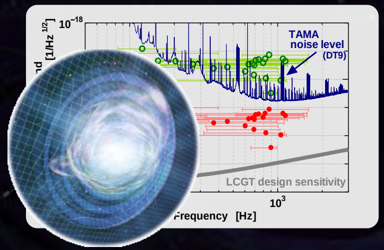
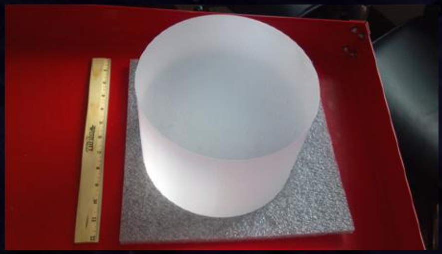


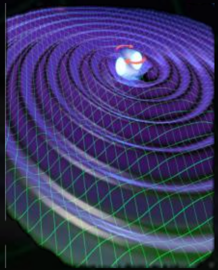



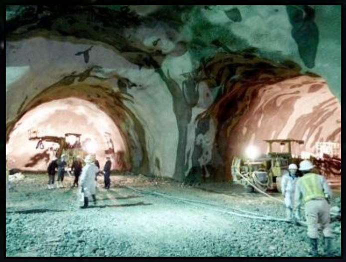



Stray-Light Control in Interferometers

Masaki Ando (National Astronomical Observatory of Japan)
Most materials by T. Akutsu, a leader of AOS subsystem







Stray-Light Noise

- Stray light noise (SLN) is like a ghost in an interferometer.
  - Most of interferometric GW antennas suffered from it in the final stage of commissioning. Sensitivities are often limited by SLN.
  - It is hard to identify the origin, and to mitigate SLN.
  - In TAMA, several set-ups were replaced or re-installed during noise-hunting process, hoping to reduce SLN.

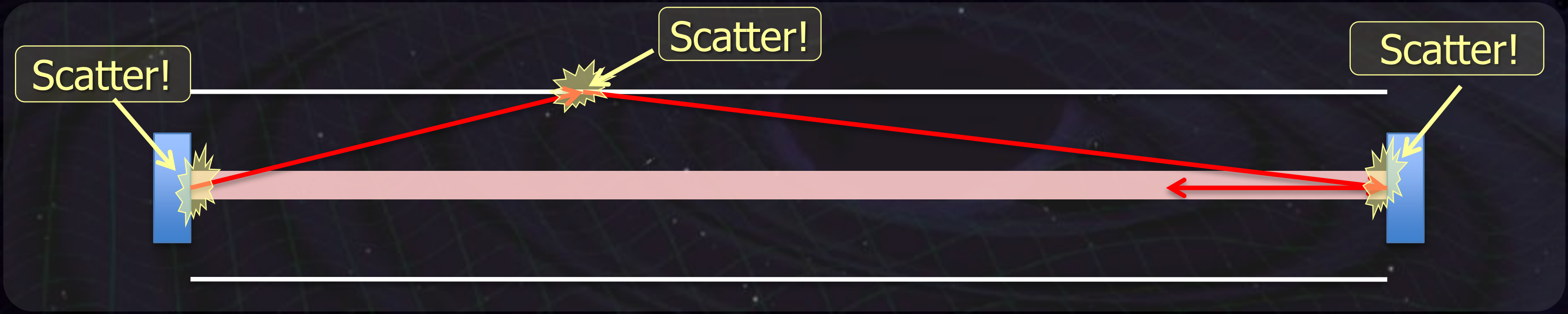
⇩

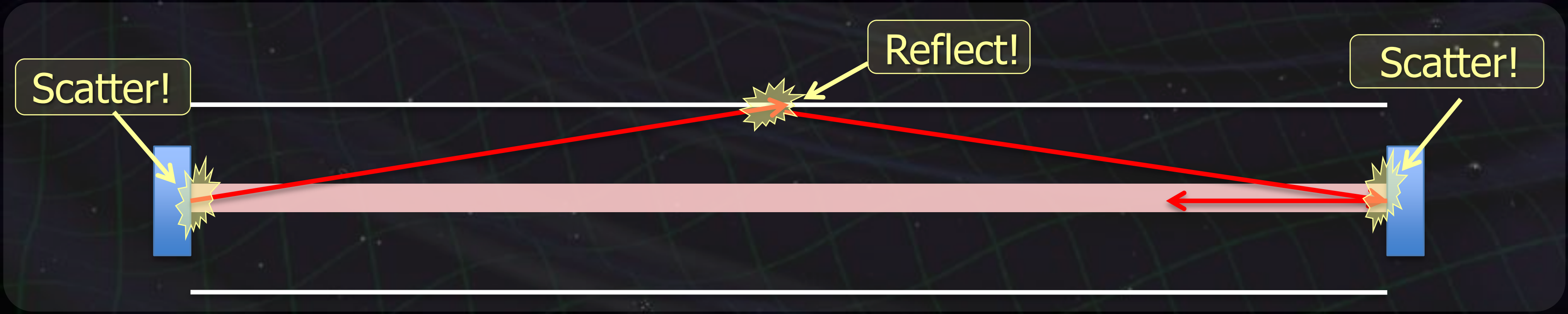
In large-scale interferometer, like KAGRA,
we should consider about SLN from the design phase.

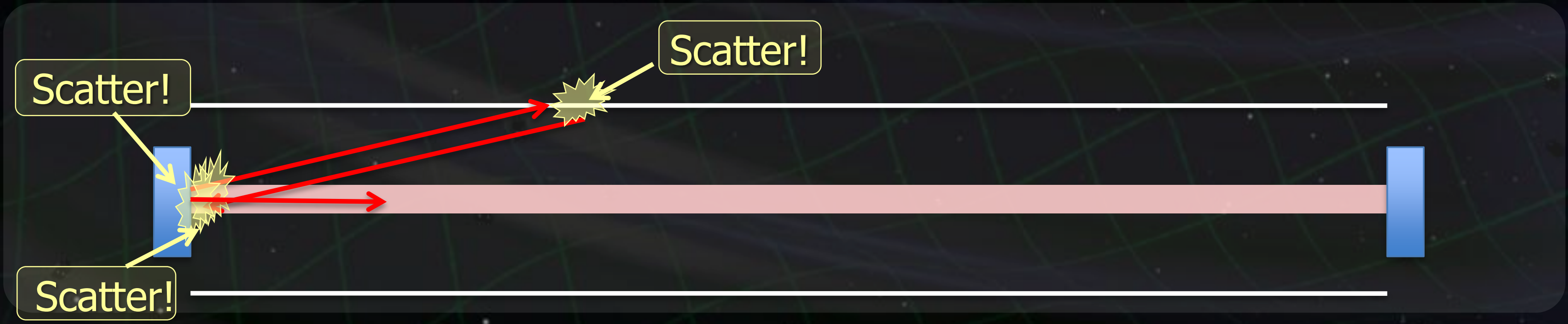
Mechanism of Stray-Light Noises

- Stray light occurs at various place in an interferometer.
  - Laser beam diffraction
  - Scattering on the surfaces and in substrate of optics
  - Small reflection on AR surfaces of optics
- Stray light hits something with vibration, such as wall of vacuum duct, and re-enter to the main laser beam.
- Changes in the optical-path length difference of the stray light cause phase noises on the main beam, which cannot be distinguished from GW signal.

Some Examples

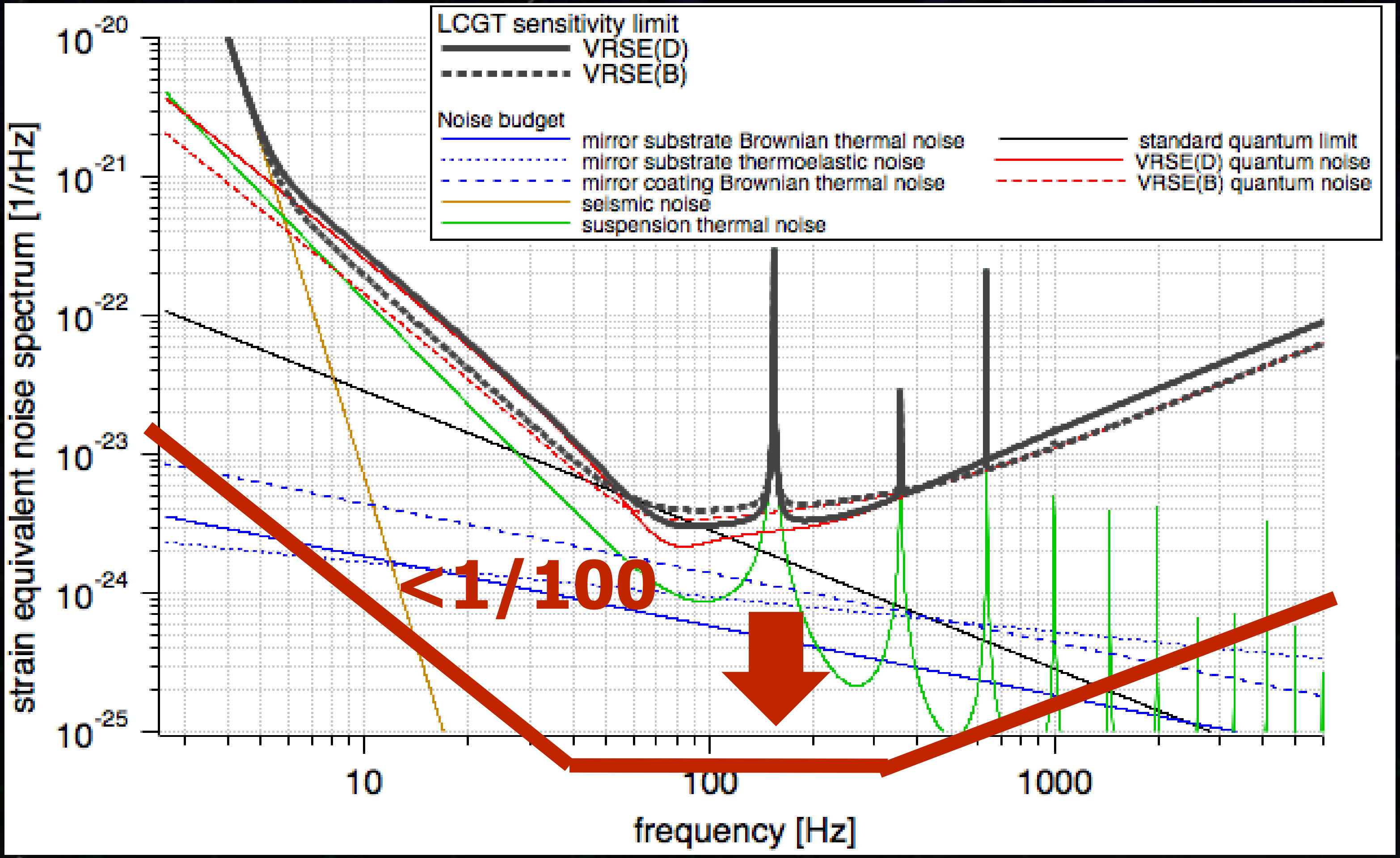






Requirement for SLN Level

- Safety margin of 2-orders are set, compared with KAGRA sensitivity curve



Quantitative Estimation

KAGRA

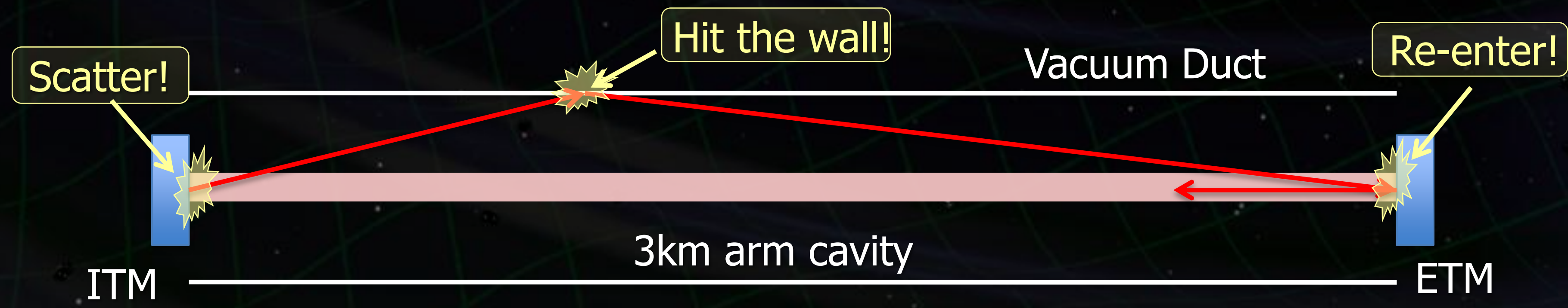
- SLN contribution to strain sensitivity.

$$\delta h_{\mathrm{SLN}} = \frac{G}{L_{\mathrm{arm}}} \sqrt{\frac{P_{\mathrm{scatter}}}{P_{\mathrm{main}}}} \delta\phi_{\mathrm{scatter}}$$

Transfer function for re-entrance to the main beam [m/rad]

Amplitude ratio of produced stray light to the main beam

Phase fluctuation of stray light [Unit : rad/Hz$^{1/2}$]



Quantitative Estimation

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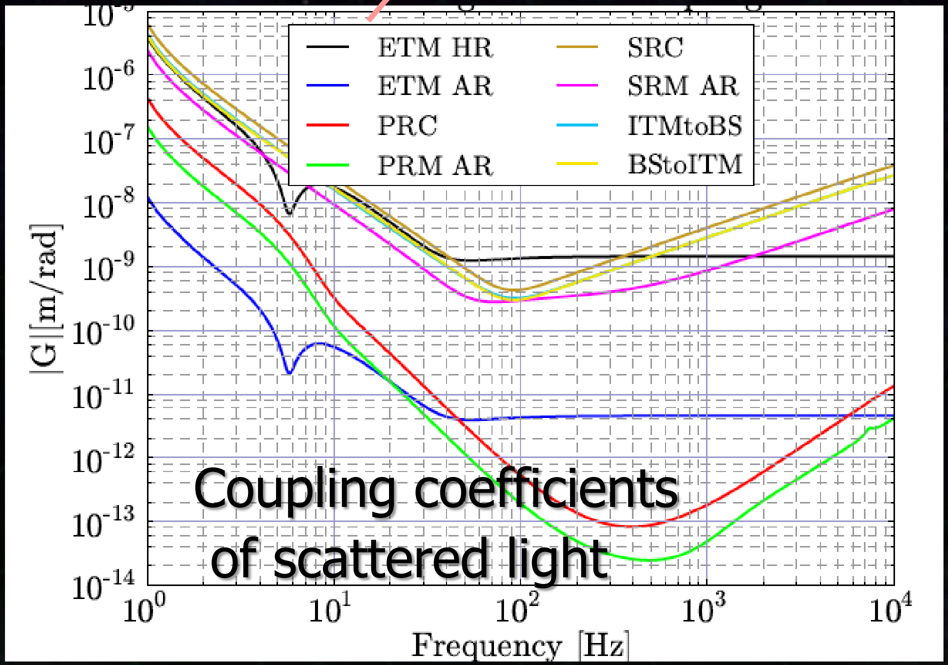


Requirements on
- Amount of scattered light
- Vibration isolation for mid-path components

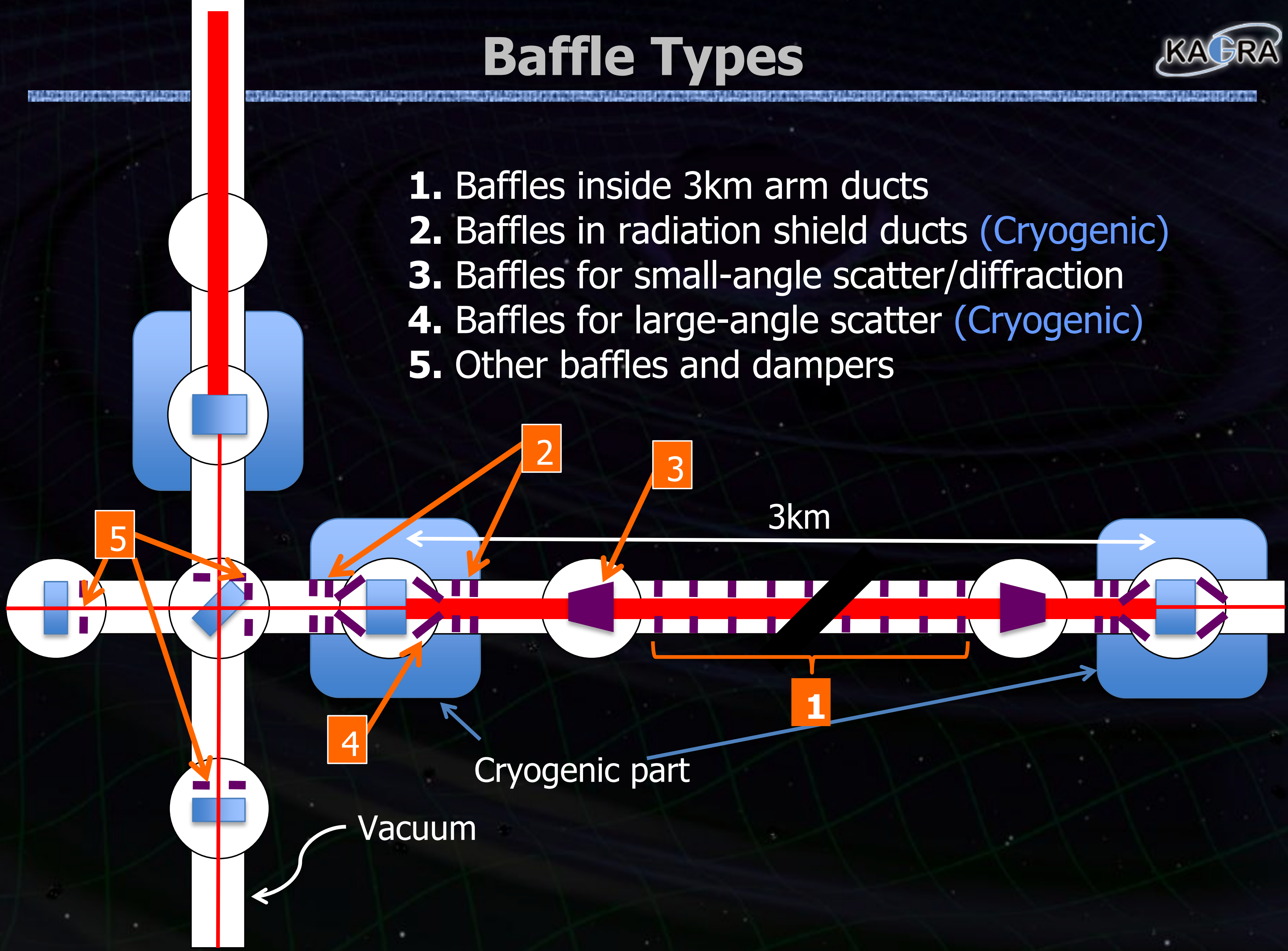
Stray-Light Control

- Strategy : Absorb most of the stray light by baffles.

- What we should consider about are …
  - Quality of optics
    Amount and angular dependence of stray light
    (Scatter on mirror surface, AR surface, Diffraction)
  - Optical design of baffles and installation positions
    Ray-tracing and shape design
    Surface treatment for better absorption
  - Vibration isolation of baffles.

Baffle Types

1. Baffles inside 3km arm ducts
2. Baffles in radiation shield ducts (Cryogenic)
3. Baffles for small-angle scatter/diffraction
4. Baffles for large-angle scatter (Cryogenic)
5. Other baffles and dampers



Baffle Design

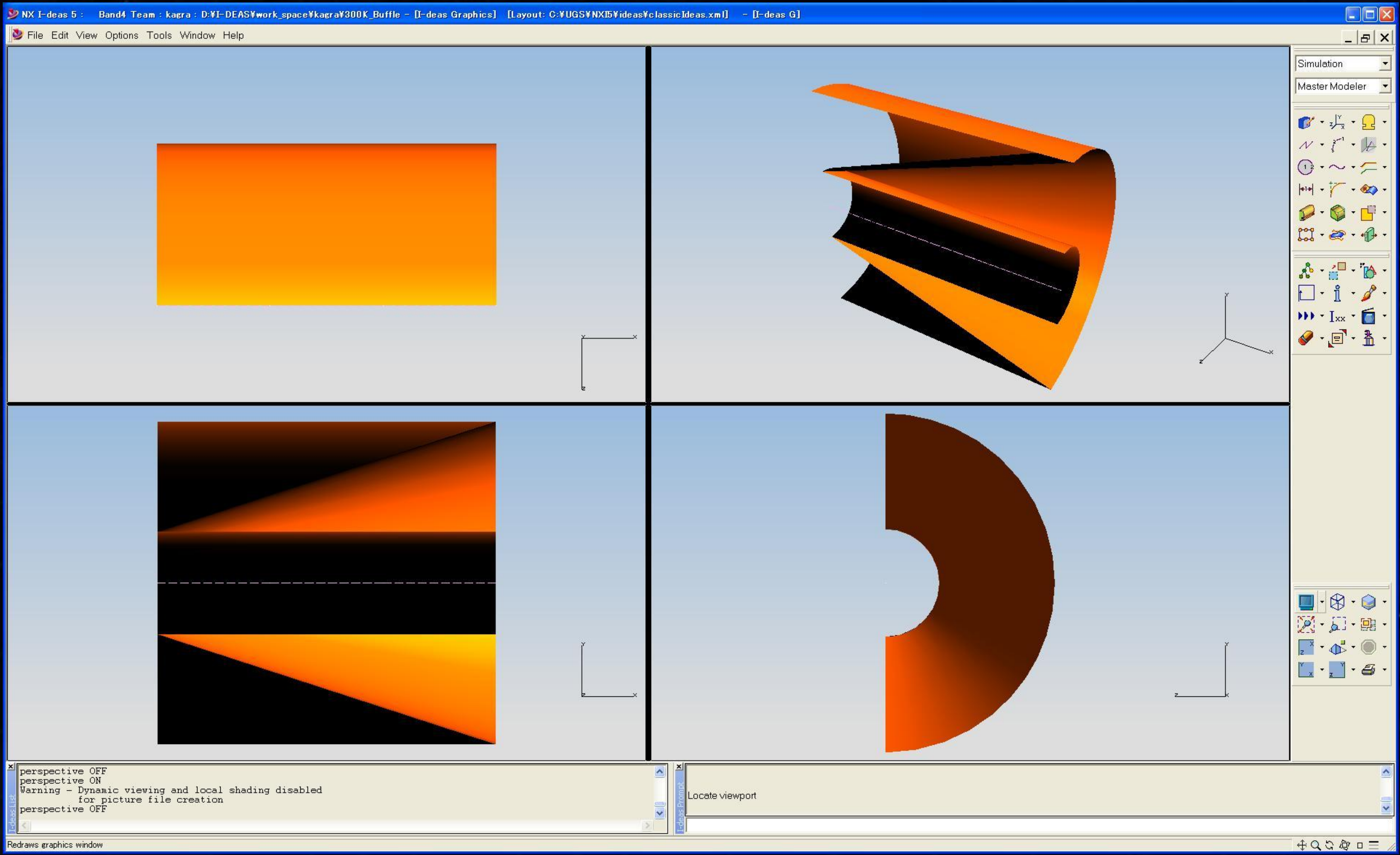
- Basic concept : absorption by multiple reflection

Specifications

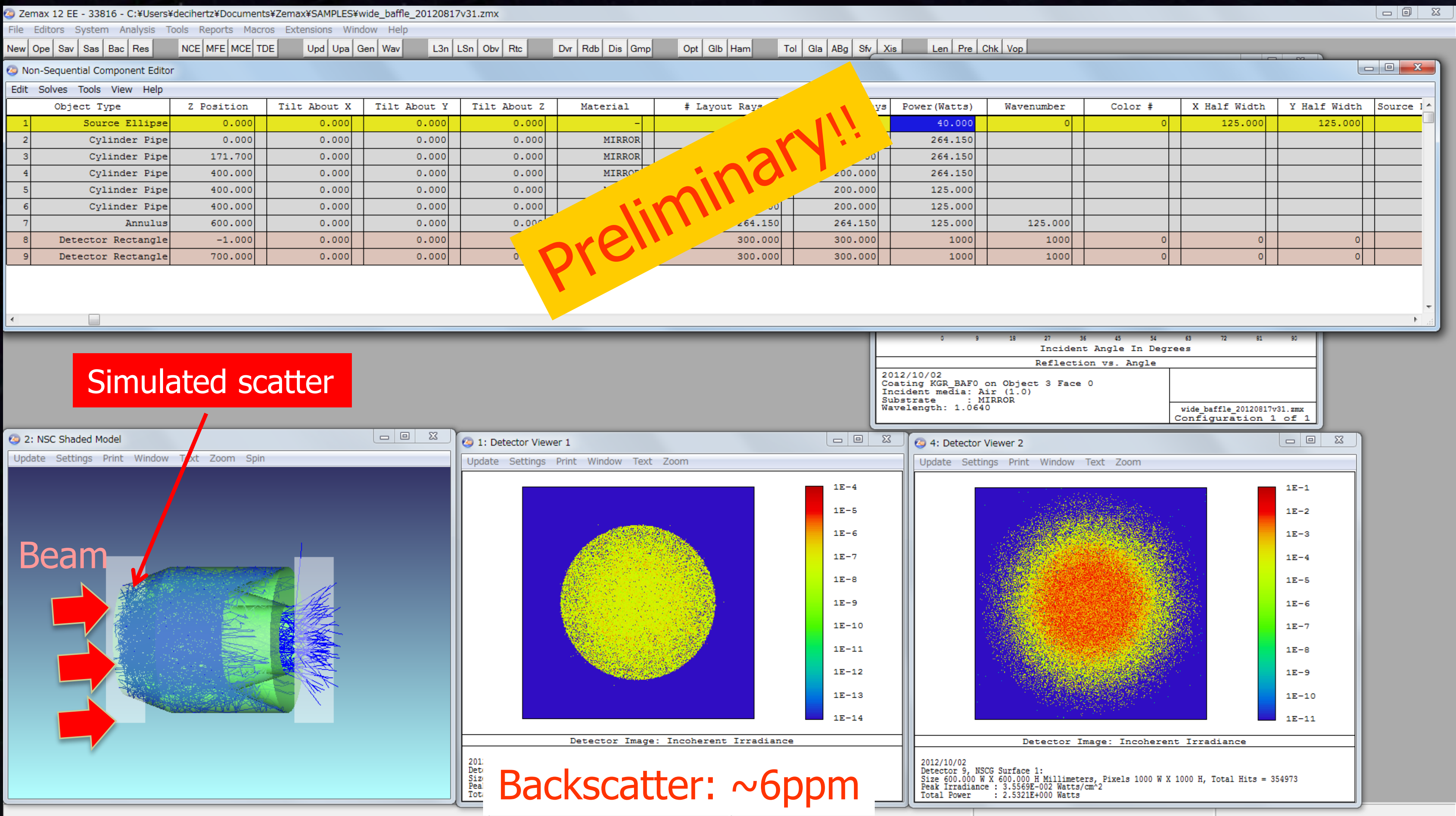
- Back reflection → Shape, Surface treatment
- Vibration isolation
- Production procedure, Cost, Size, Weight
- Vacuum and Cryogenic compatibilities,
  and Thermal conductivity

Baffle Design

- Basic concept : absorption by multiple reflection



Ray-Tracing Simulation



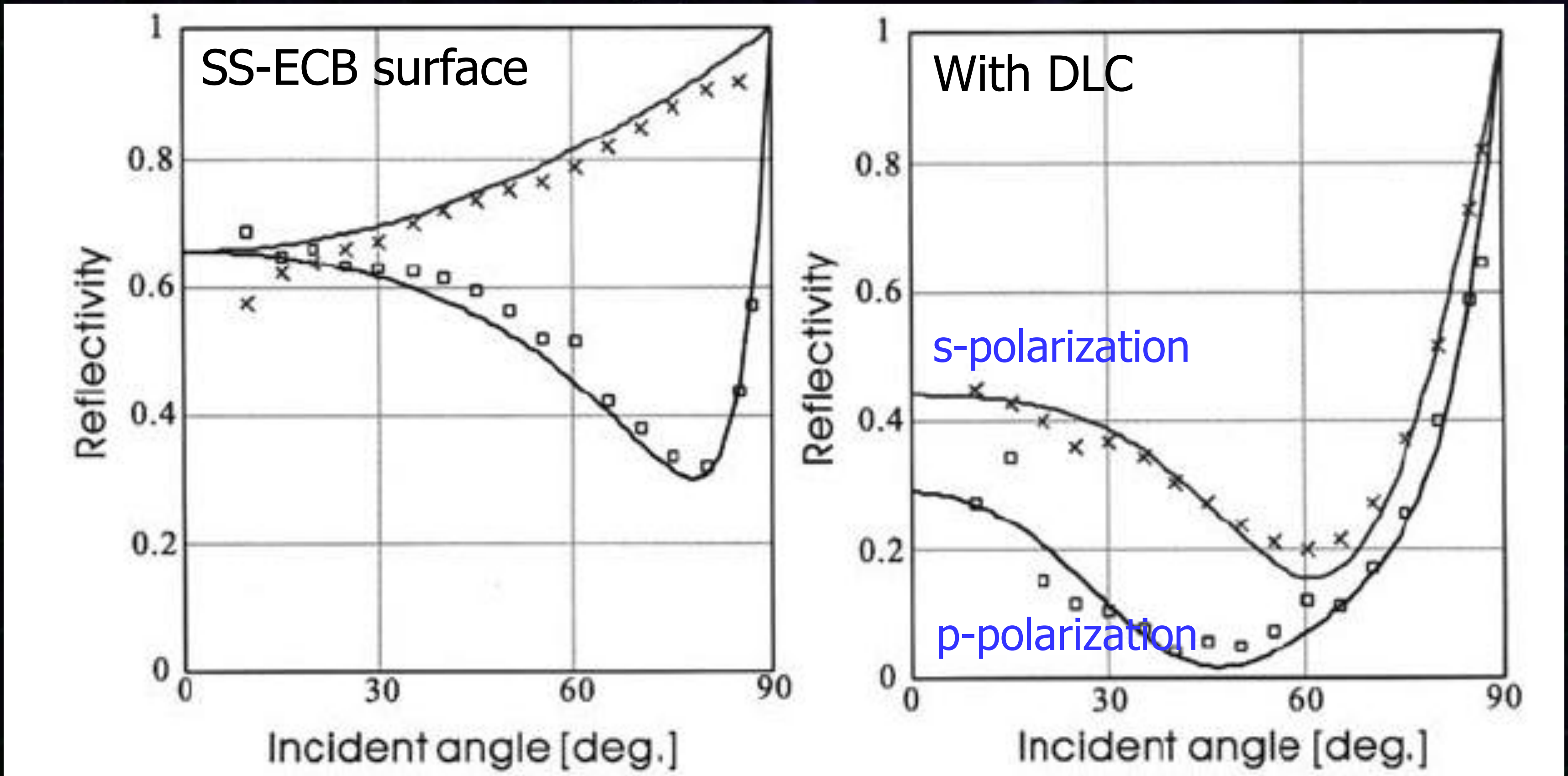
Surface Coating

- Under investigation

- Candidate : Diamond-like Carbone (DLC)
  - Heritages in TAMA300
    * Vacuum and cryogenic compatibilities
    * Small scatter (peculiar reflection)
  - Difficulties : Rather high reflectivity (~40%)
    Large-area coating
- Other candidates : black platings
  - Low reflectivity (~a few % @1064nm)
  - Large-area coating

Diamond-like Carbon (DLC)

Results of surface reflectivity measurements



R. Takahashi, Y. Saito et al., Vacuum 73, 145 (2004)

Vacuum Compatibility

Results of
out-gassing measurement

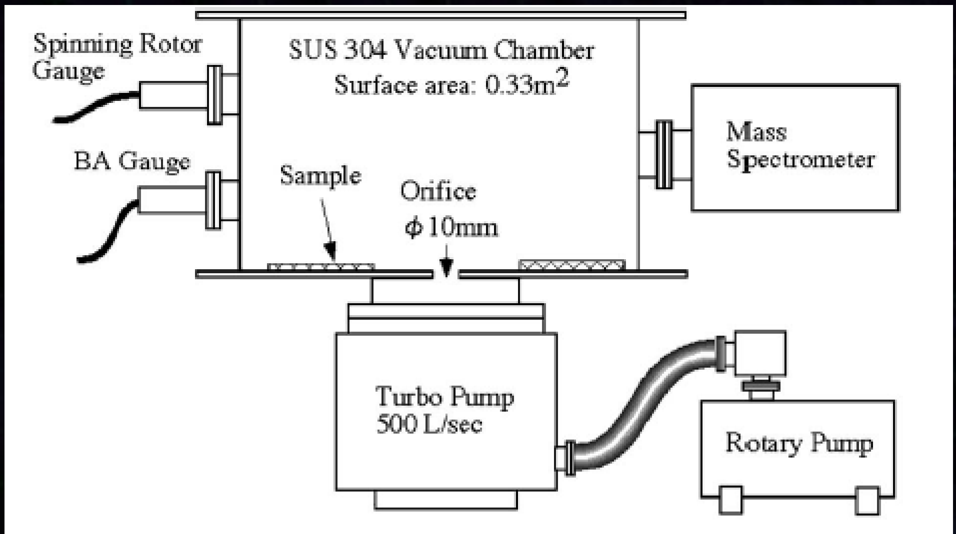
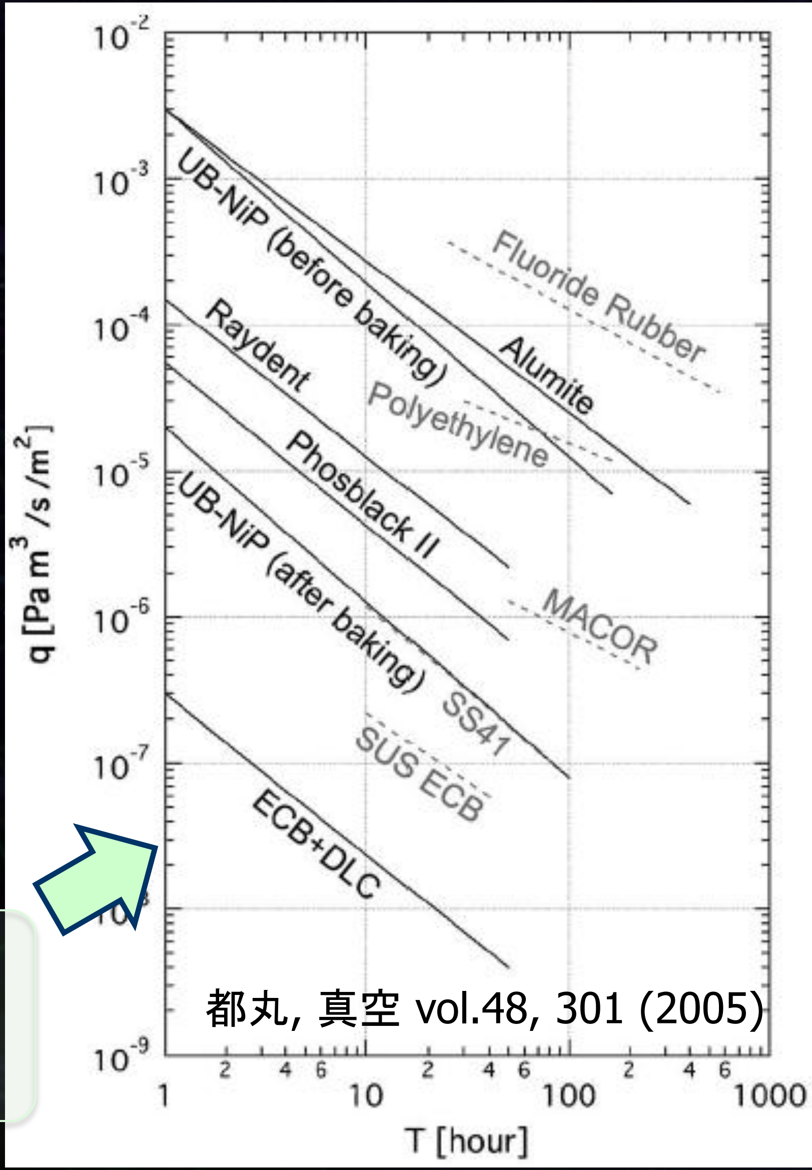


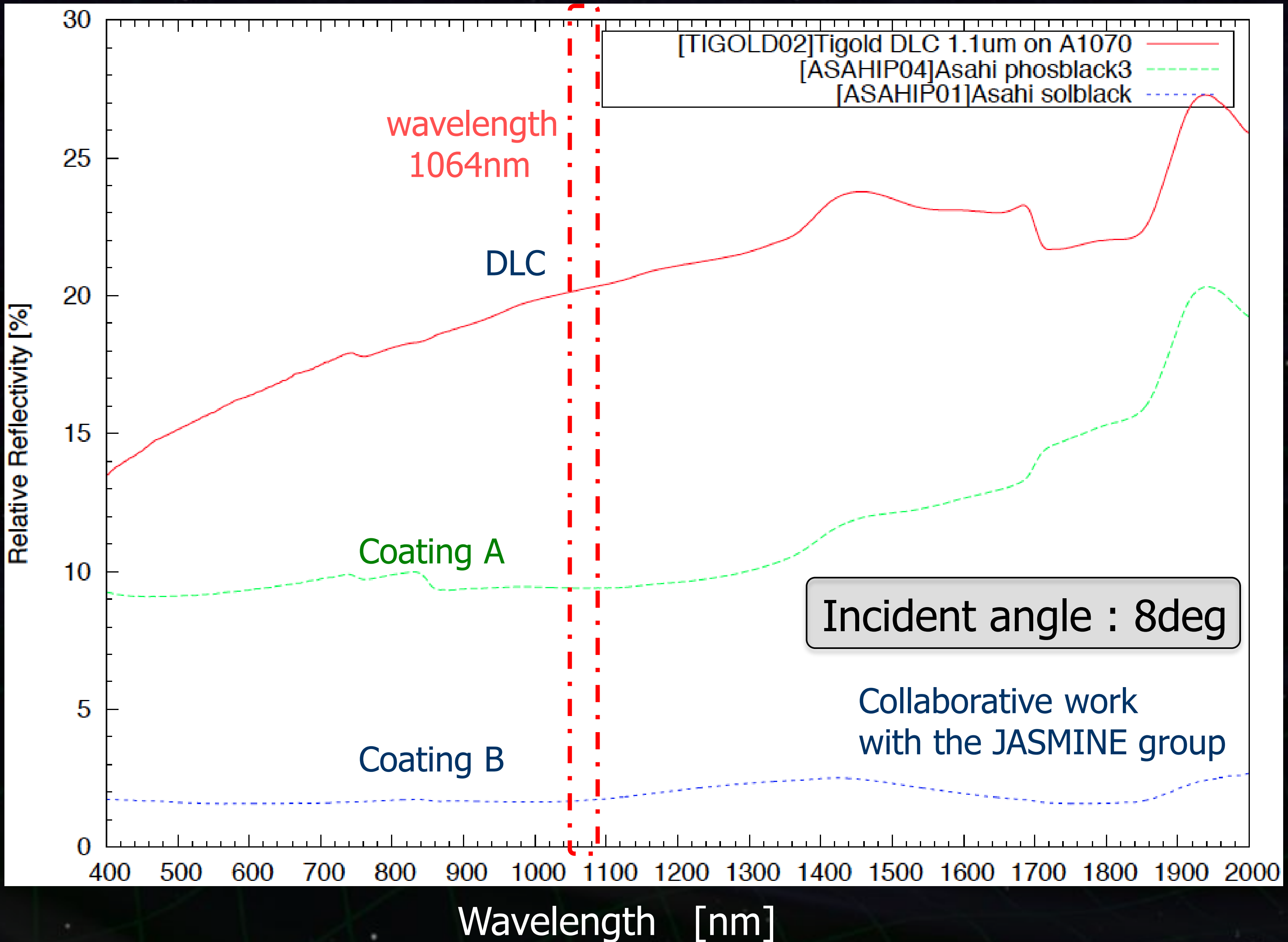
Fig. 2 Measurement apparatus of outgassing rate using orifice method.



都丸, 真空 vol.48, 301 (2005)

DLC has lower out gasses
(Depends on surface polish)

Other Coating Candidates



Current Activities

- Mechanical design and prototype tests
  - FEM modeling for distortion
  - Construction procedure

- Optical design
  - Ray-tracing simulation
  - Systematic survey measurements
    for surface properties of various coatings
    and their vacuum compatibilities.