# Low Straylight Diffraction Grating (LSG)

## Final Presentation

30.01.2023, ESTEC Noordwijk

# Agenda

| | |
|---|---|
| 13:00 – 13:50 | Welcome at ESTEC and Lunch |
| 14:00 – 14:15 | Introductory talk |
| 14:15 – 14:45 | **Measurement and Characterization** |
| 14:45 – 15:15 | Final Presentation for binary Littrow gratings (SFT2) |
| 15:15 – 15:45 | Final Presentation for Echelle gratings (SFT1) |
| 15:45 – 16:00 | Coffee break |
| 16:00 – 16:30 | Final Presentation for SPDT blaze grating (SFT3) |
| 16:30 – 17:00 | Perspectives |
| 17:00 – 17:30 | Conclusion and Discussion |

# Scope of the project

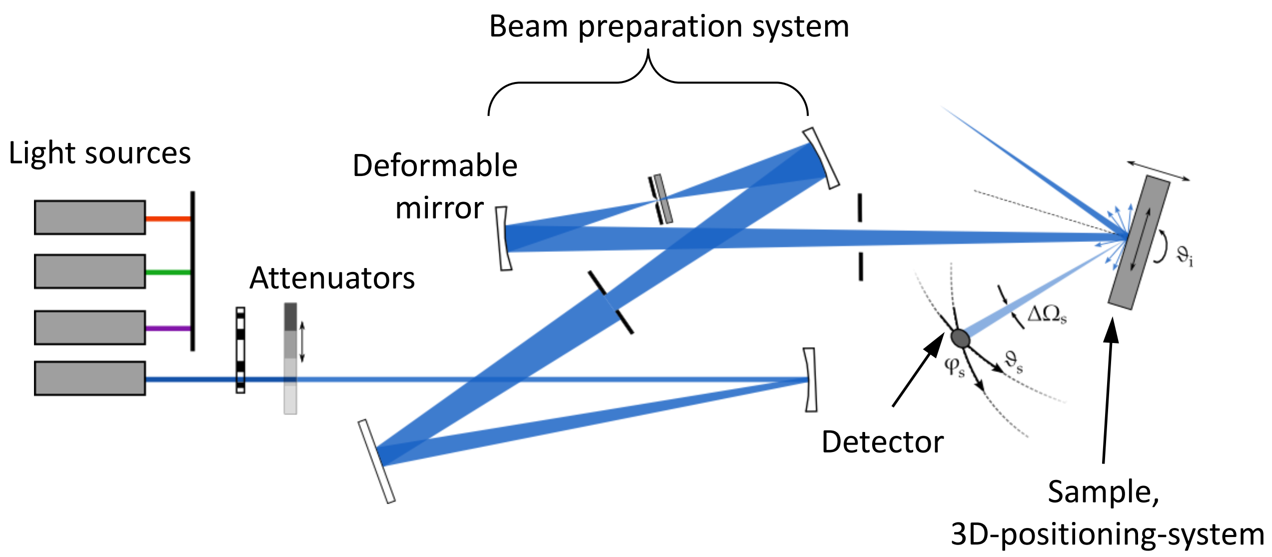
## Context

- In spectrometric instruments gratings are a **main contributor of straylight**
- Straylight in gratings is **poorly understood** and astonishing straylight phenomena were observed (level and distribution of straylight)
- Origins are **manifold** and strongly depent on **fabrication technology**
- Grating design plays an important role and **suitable modelling and analysis** of straylight is welcomed

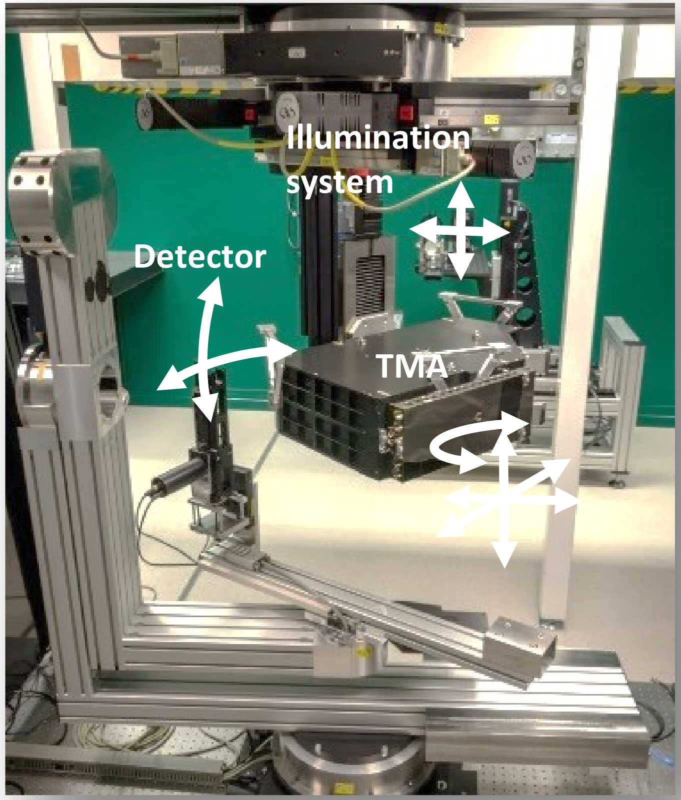
→ The individual **causes of straylight** shall be investigated and **appropriate changes of the manufacturing process(es) for lower straylight** shall be derived

→ **Short Introduction on straylight measurement**

# ALBATROSS: 3D-Arrangement for Laser Based Transmittance, Reflectance, and Optical Scatter MeaSurement




**Light scattering characterization of Three-Mirror Anastigmat, TMA**




- High dynamic range and linearity (> 15 orders of magnitude)
- Sample curvature compensation
- Spectral range: 193 nm – 10.6 µm
- 18 motorized axis / degrees of freedom
- Measurements at 633 nm and 10.6 µm



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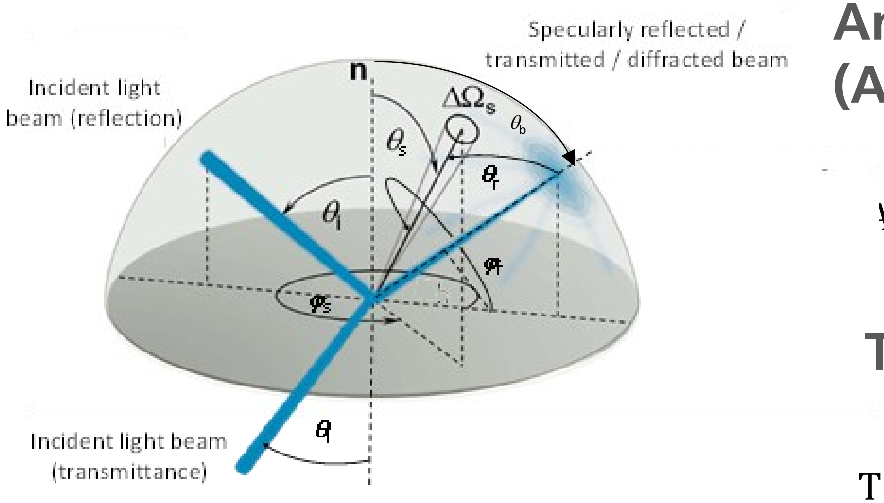
# Light scattering quantities




$\theta_{s/r}$ … polar scattering angle
$\varphi_{s/r}$ … azimuthal scatter angle
$P_s$ … scattered light power
$P_i$ … incident light power
$P_r$ … specularly reflected light power
$P_n$ … diffracted light power
$P_t$ … specularly transmitted light power
$\Delta\Omega_s$ … detector solid angle

## Angle Resolved Scattering (ASTM E2387, ISO19986)

$$\mathrm{ARS}(\theta_i, \theta_s, \varphi_s) = \frac{\Delta P_s(\theta_i, \theta_s, \varphi_s)}{\Delta\Omega_s P_i}$$

## Angle Resolved Efficiency

$$\mathrm{ARE}(\theta_i, \theta_s) = \frac{P_\mathrm{n}(\theta_i, \theta_s)}{P_i}$$

## Total scattering (ISO13696)

$$\mathrm{TS} = \int_0^{2\pi} \int_{2°}^{85°} \mathrm{ARS} \sin\theta_s \, \mathrm{d}\theta_s \mathrm{d}\varphi_s$$

- Scattering loss
- Energy balance: 100% = R + T + A + $\mathrm{TS_b}$ + $\mathrm{TS_f}$

## Encircled energy

$$S(\theta_r) = \int_0^{2\pi} \int_{0°}^{85°} \mathrm{ARS}(\theta_s, \varphi_s) H\left(\theta_r - \arccos\left[\cos\theta_s \cos\theta_b + \sin\theta_s \sin\theta_i \cos\varphi_s\right]\right) \sin\theta_s \mathrm{d}\theta_s \mathrm{d}\varphi_s$$

*H*… Heavisside function

- Scattering in a cone with opening angle $\theta_r$ around the different diffraction orders



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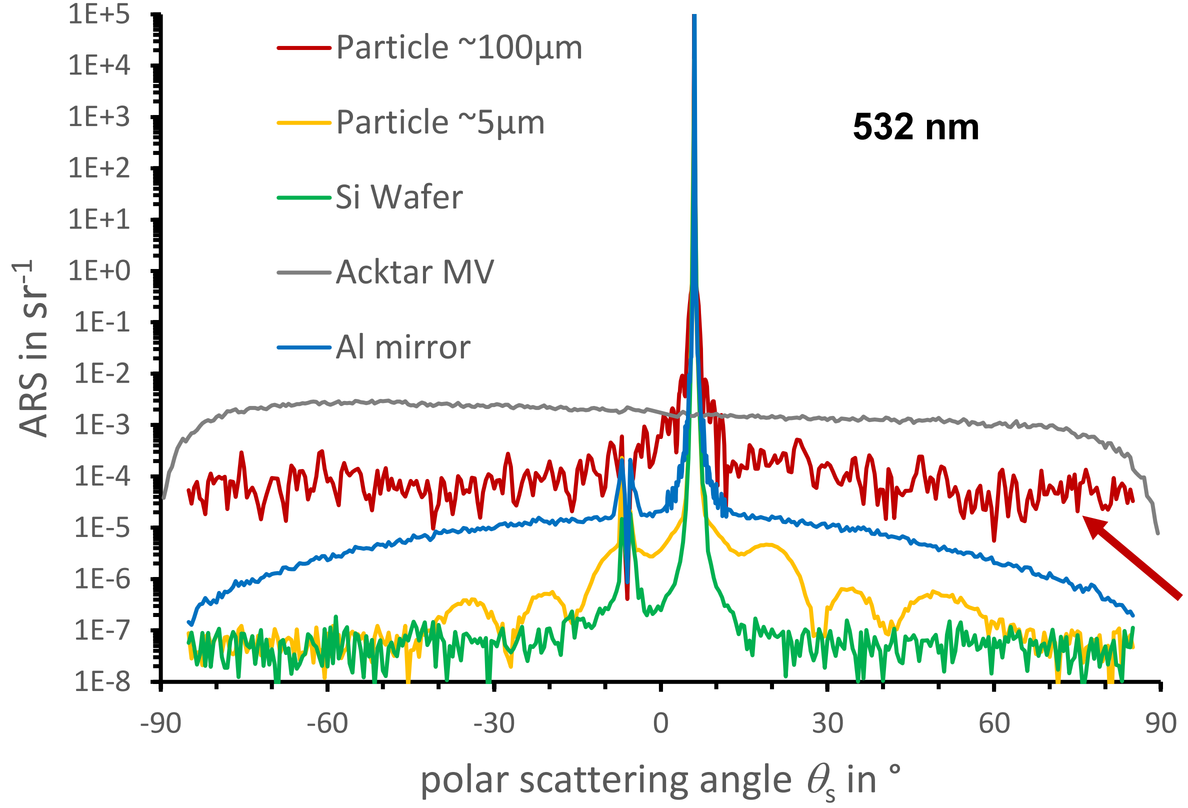
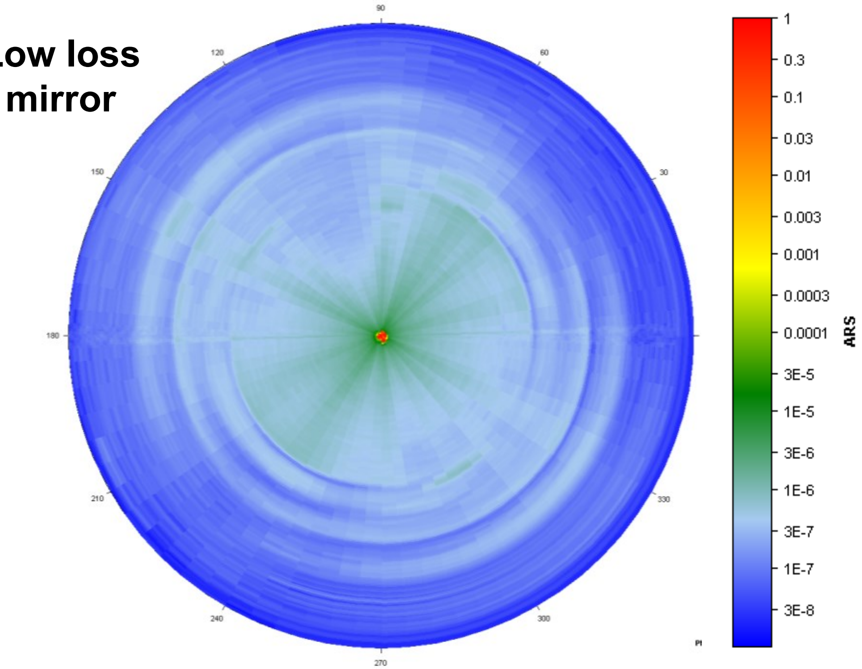
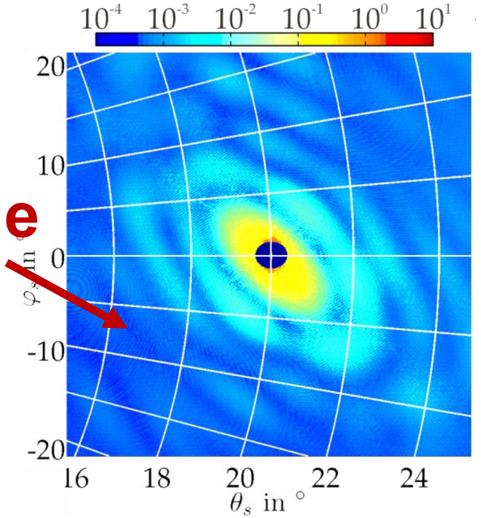
# Typical scattering distributions

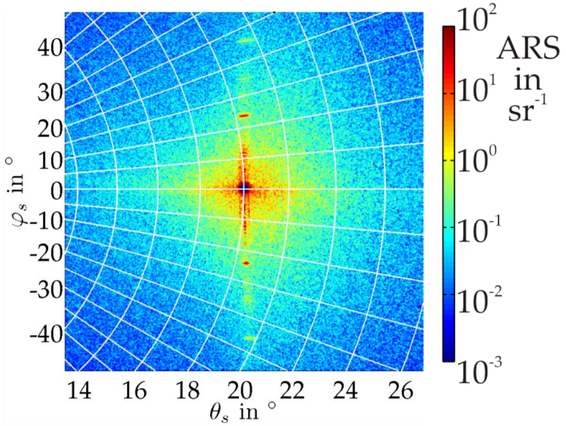



Particle




Diamond turned Al



# Project approach to address SOW – structural feature types (SFT)

**SFT1**
Binary transmission grating in fused silica

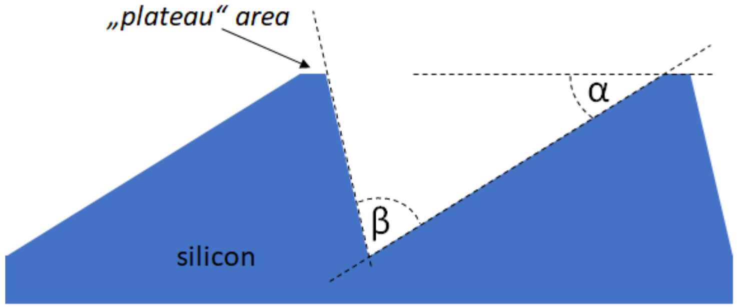
- EBL
- Dry etching

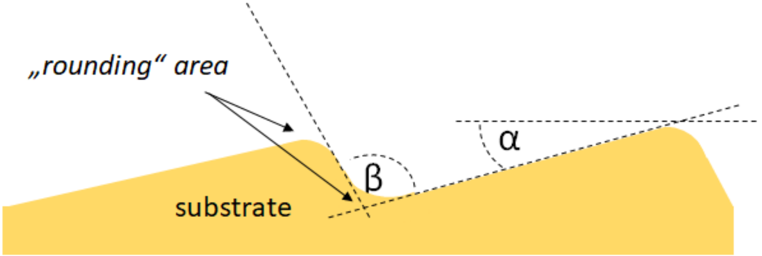
**SFT2**
Echelle type reflection grating in silicon

- EBL or Mask aligner lithography
- Wet-chemical etching

**SFT3**
Blazed wideband grating (transmission or reflection)

- Diamond machining


- EBL process
- Etching process
- Post-processing

- Benefits from EBL optimization @ SFT1
- Compare to Phase Mask fabricated gratings from SRON

- Process parameters and tools
- Grating material
- Surface finishing



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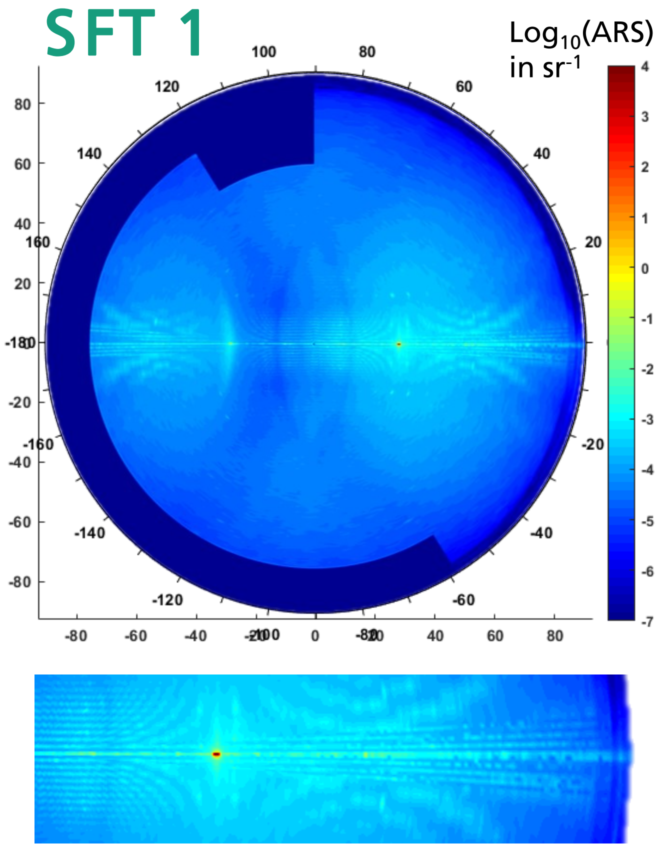
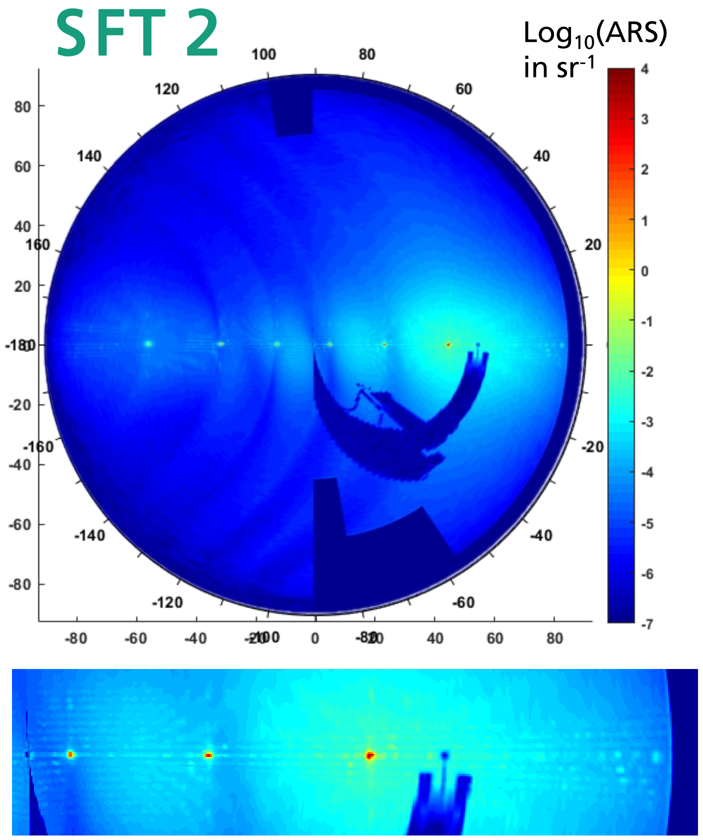
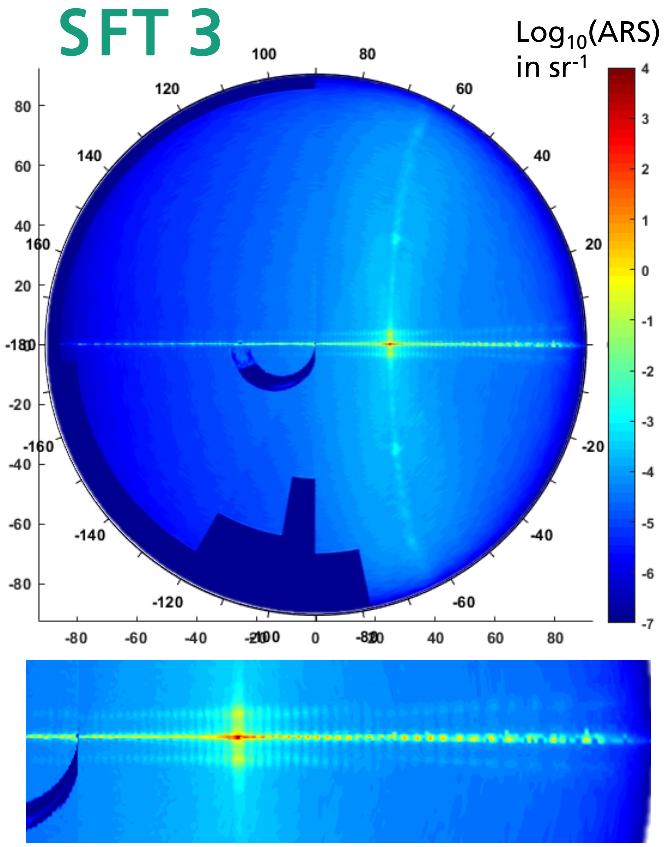
# Scattering Footprints of SFTs




- Diffraction efficiency, Scattering loss, Ghost efficiency, analysis of diffraction plane
- Characteristic footprint + topography cross correlation → fabrication optimization

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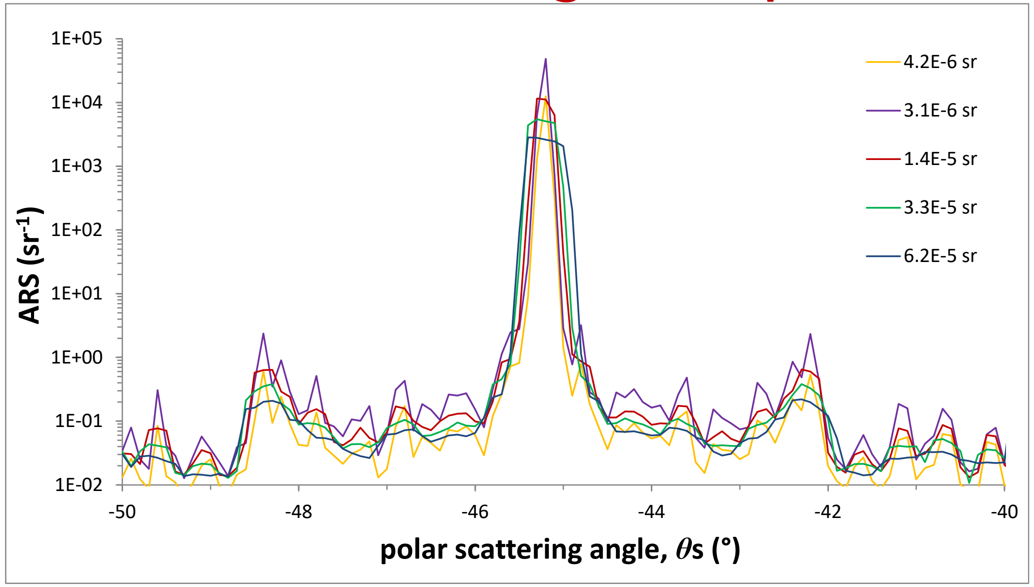
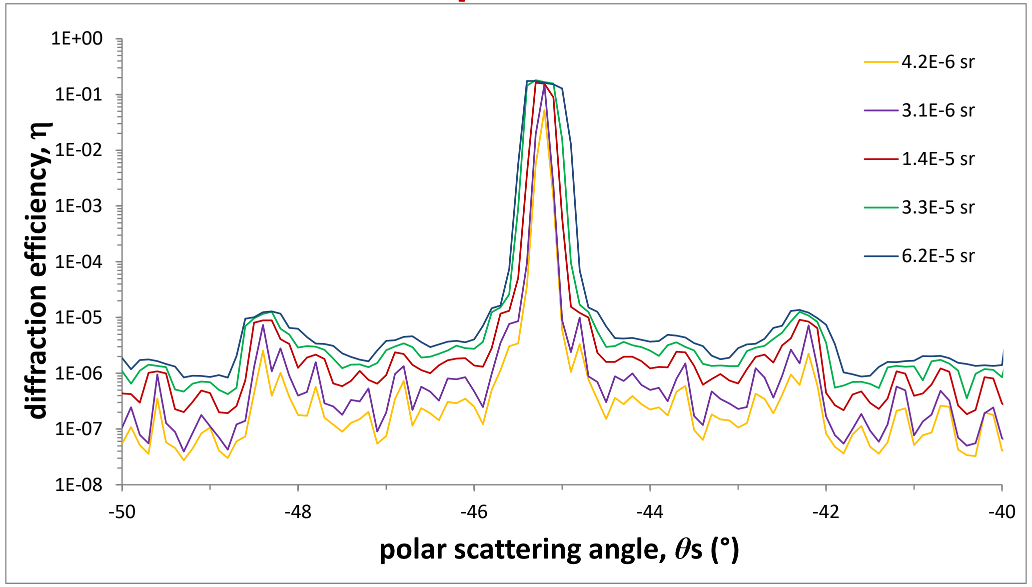
# Difference between ARS and ARE

## Scattering description




+ Diffuse contributions are ideally described with the help of the ARS in order to circumvent the impact of the actual detector geometry /ray-set density in straylight simulations
- Description of isolated peaks (regular and ghost diffraction orders) critically depends on detector geometry

## Ghost description (1-2 orders above background)




+ Peak intensities do not depend on detector geometry

→ Important: detector aperture needs to be larger than diffraction peak + oversampling

- Background scattering is not well described

# Topography analysis

**Interferometry**


**Bright field microscopy**

**White Light Interferometer**

**Atomic Force Microscope**


**Raster-Electron microscopy**

- Analysis of long ranging waviness to small lateral features
- For correlation between fabrication imperfections and light scattering

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