

# Evaluation of reflectivity of metal parts by a thermo-camera

## Abstract

Assessment of specular reflectivity of metallic surfaces with different roughness in the MWIR (Medium Wave InfraRed) spectrum by a thermo camera, and comparison against a theoretical model.

## Reflection model from Bennett and Porteus

$$\sigma = \sigma_s + \sigma_d = \sigma_0 \exp\left(\frac{-(4\pi R_q)^2}{\lambda^2}\right) + \sigma_0 \frac{2^5 \pi^4}{R_{\Delta q}^2} \left(\frac{R_q}{\lambda}\right)^4 (\Delta\theta)^2$$

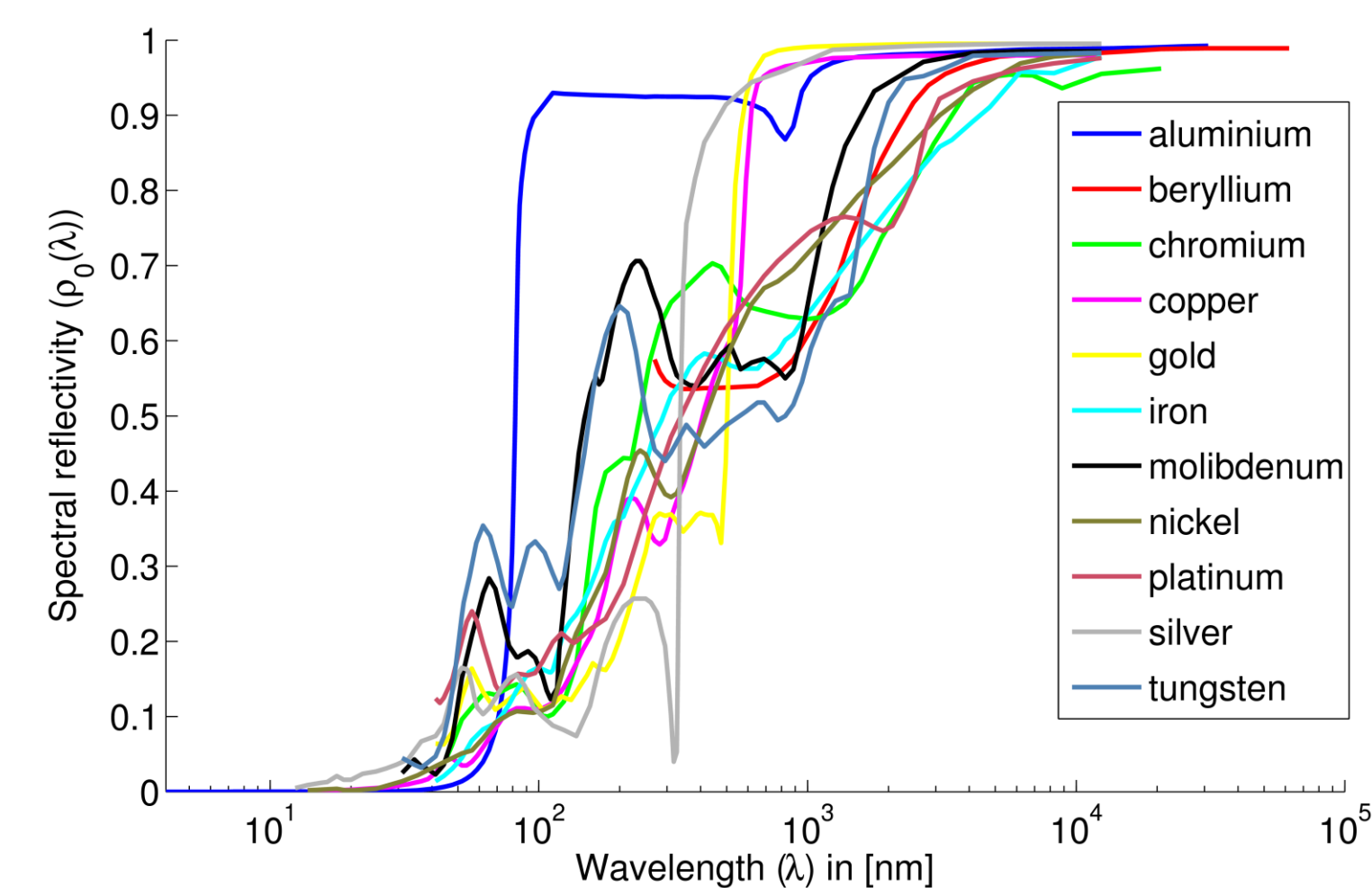
$\sigma_s$ : specular component     $\sigma_d$ : diffuse component

$\sigma_0$  specular reflectance of a perfectly smooth surface (Figure 1)  
 $R_q$  RMS-roughness (Root Mean Square) of the surface  
 $\lambda$  wavelength of the light  
 $R_{\Delta q}$  RMS-slope of the surface  
 $\Delta\theta$  Instrumental acceptance angle

If  $\lambda$  is sufficiently long:  $R_q < \frac{\lambda}{8 \cos \theta}$  (Rayleigh criterion)

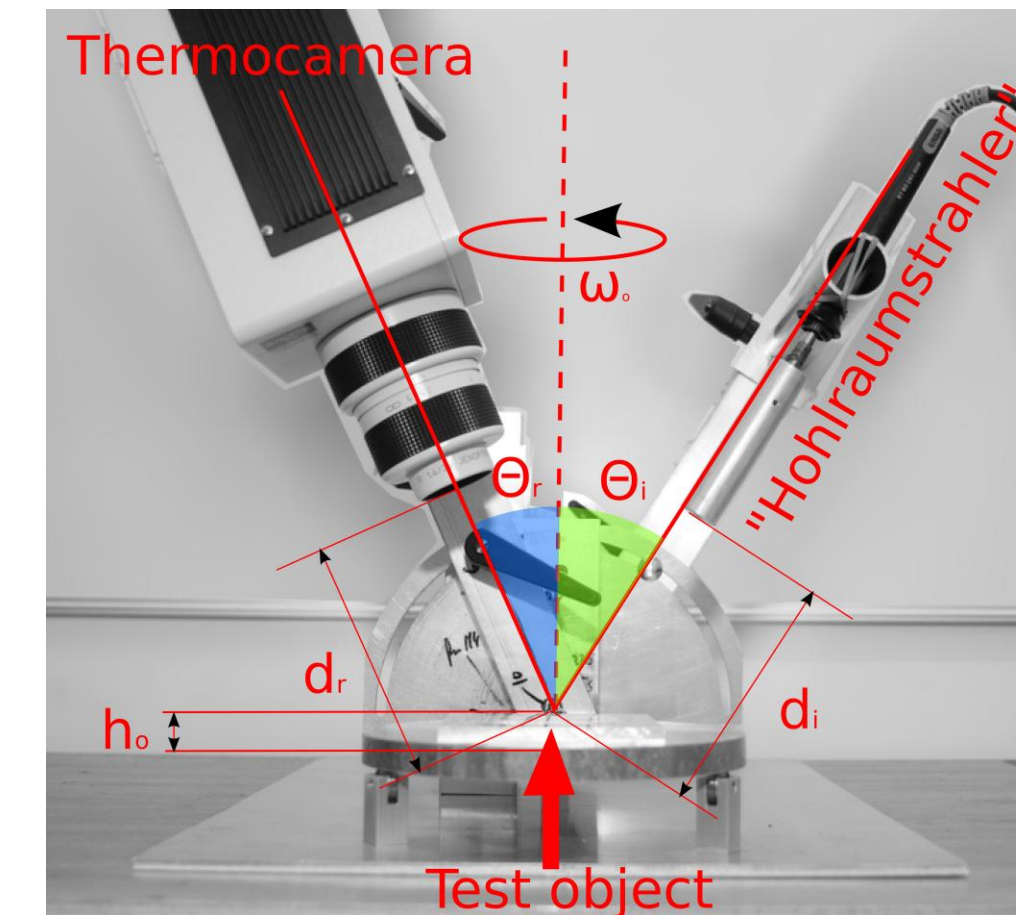
$\theta$  Incident angle

$$\sigma = \sigma_s = \sigma_0 \exp\left(\frac{-(4\pi R_q)^2}{\lambda^2}\right)$$



Spectral reflectivity of perfectly smooth metal surfaces

## Measurement setup

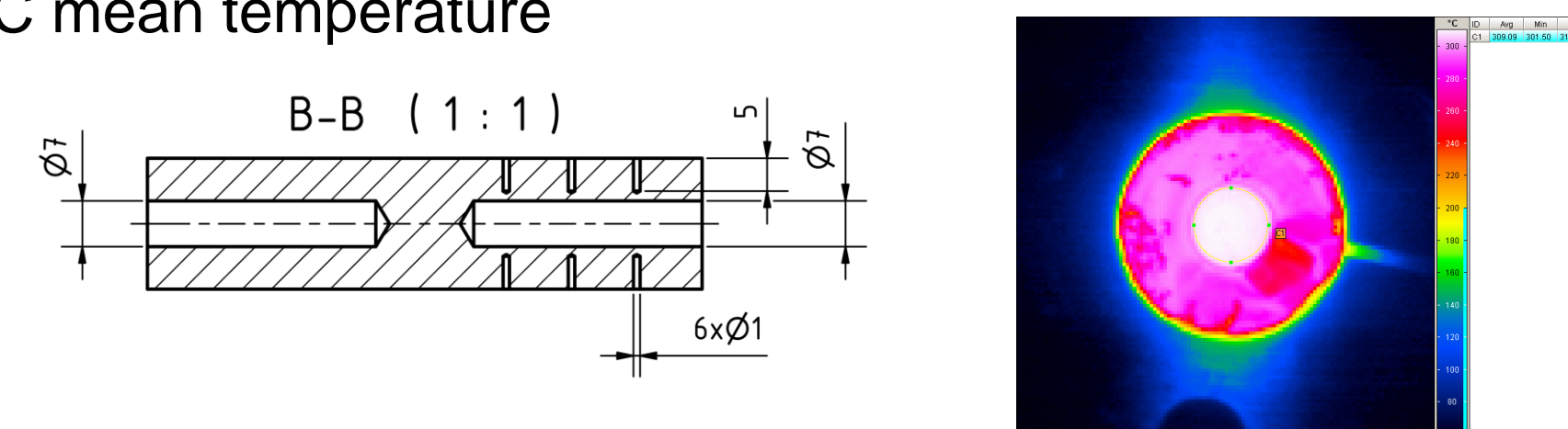


### Thermocamera: VarioThermo Head II

- PtSi-sensor
- MWIR (340nm – 5000nm)
- 256x256 resolution
- 25mm lens

### Radiation source: „Hohlraumstrahler“ – quasi black body

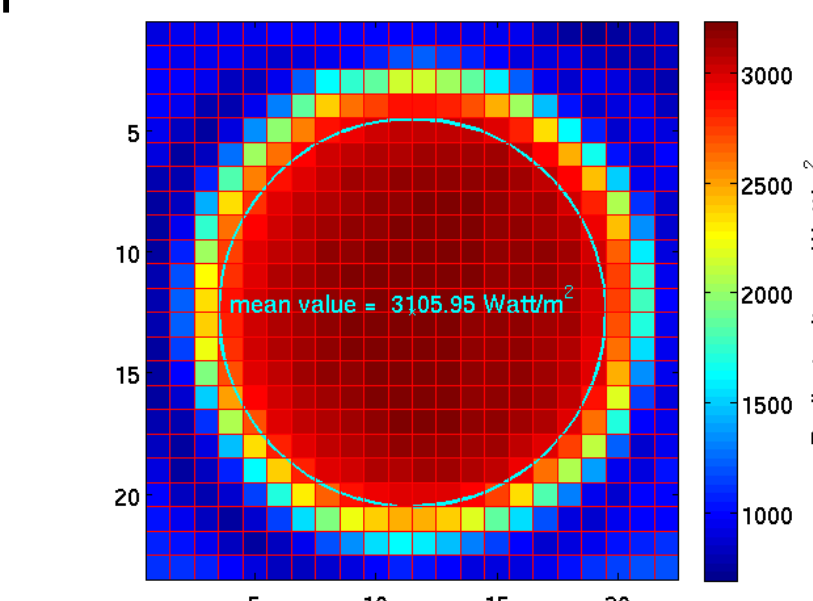
- low reflection - high emission ( $\epsilon=0.91$ )
- temperature monitored near the cavity by temperature probes
- 300°C mean temperature



CAD drawing of the source and its thermo image

## Evaluation of measurement data

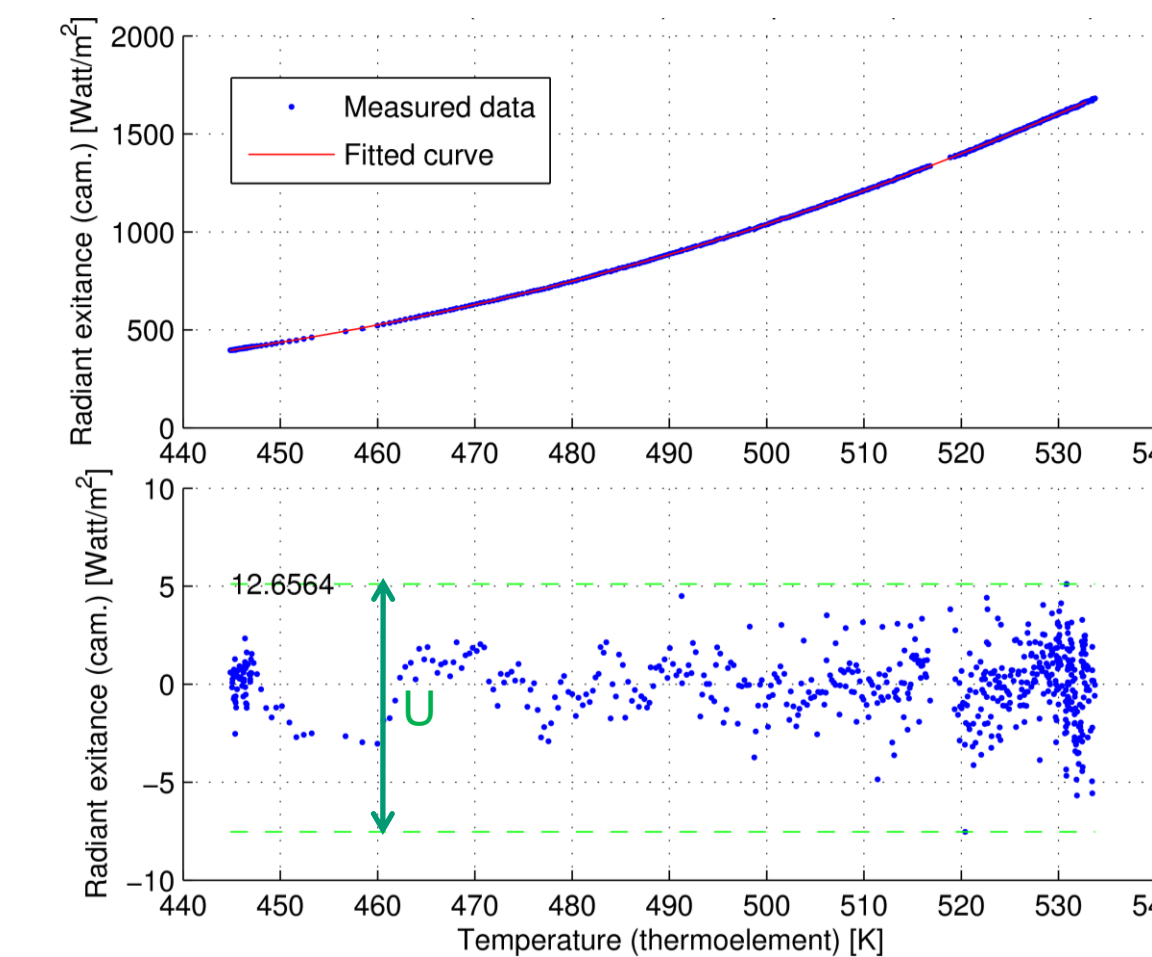
- synchronization of data from camera and probes
- camera image processing
- dropping of out-of-range data
- segmentation of source in the images
- calculation of mean radiant exitance



Segmentation of the source and calculation of the mean value

## Calibration

- evaluation of correspondence between camera- and probe-data
- scanning temperature range
- best fit of 4<sup>th</sup> grade polynomial

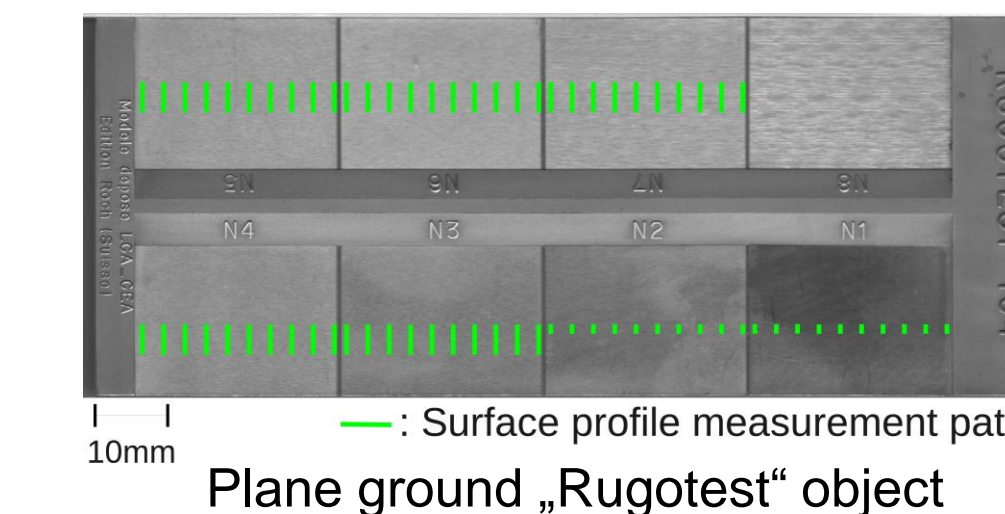


Calibration curve: radiant exitance measured by the camera vs. temperature of the probe

Evaluation of the measurement uncertainty (U): difference between the measured values and the calibration curve

## Test objects

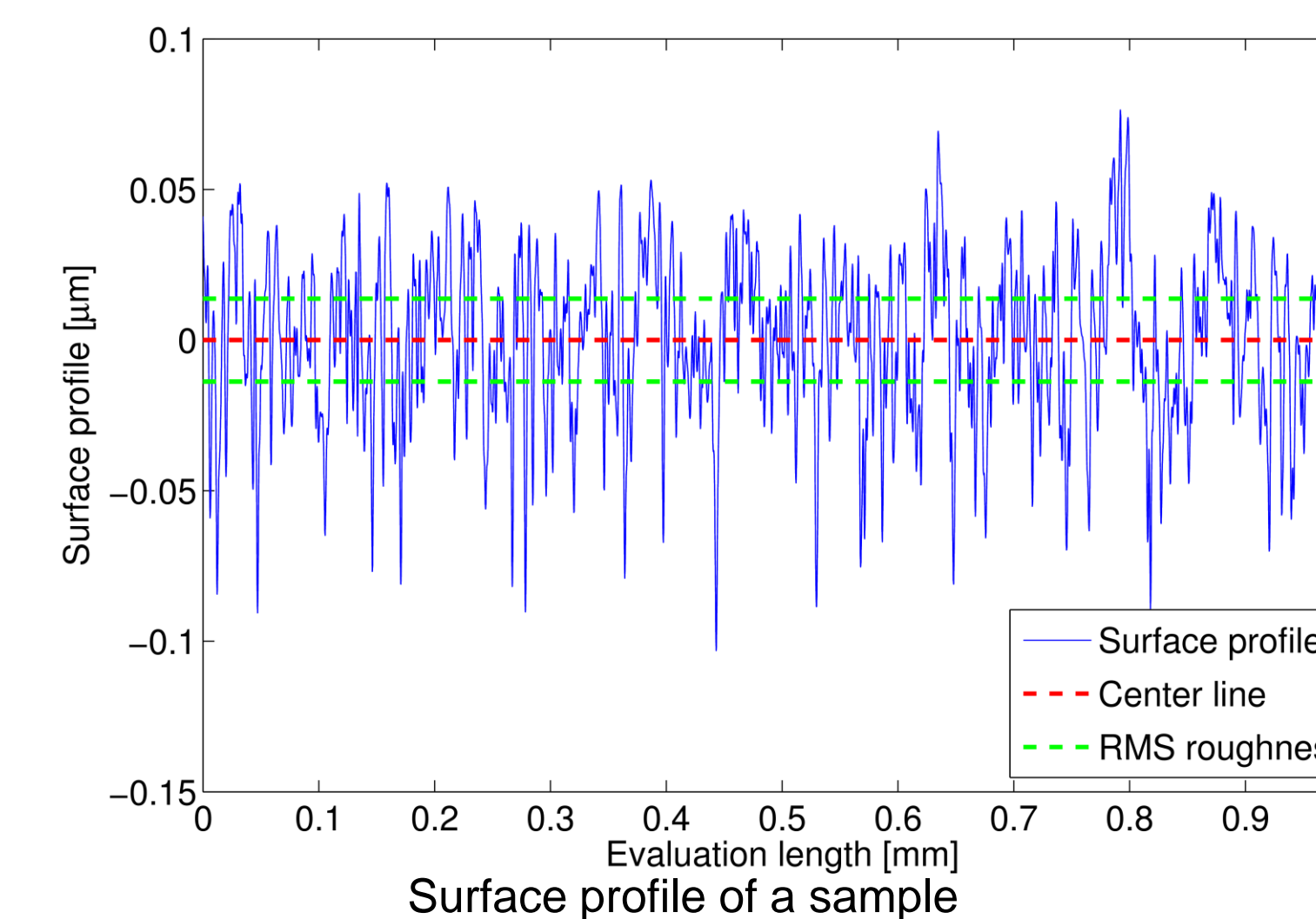
- Sheet metal
- Machined surfaces
- Different roughnesses



Plane ground „Rugotest“ object

## Surface roughness measurements

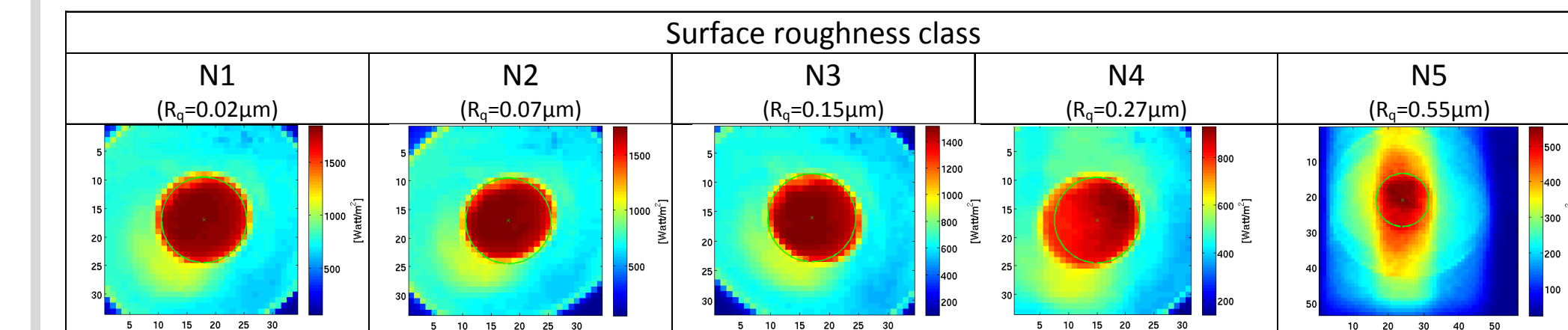
- Measurement of surface profile at 10 different positions
- Evaluation of  $R_q$ ,  $R_a$ ,  $R_{\Delta q}$ , autocovariance, distribution of height and autocovariance



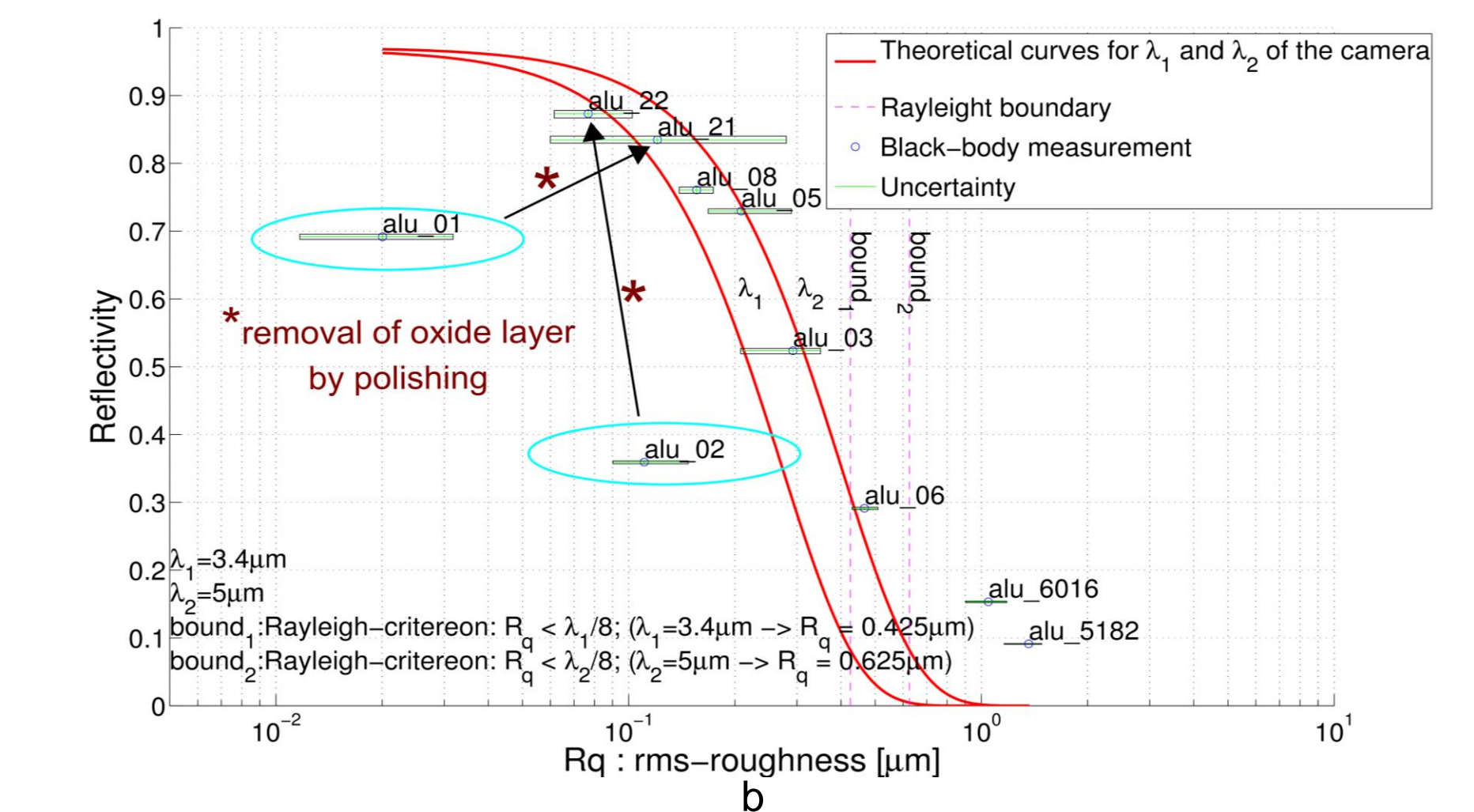
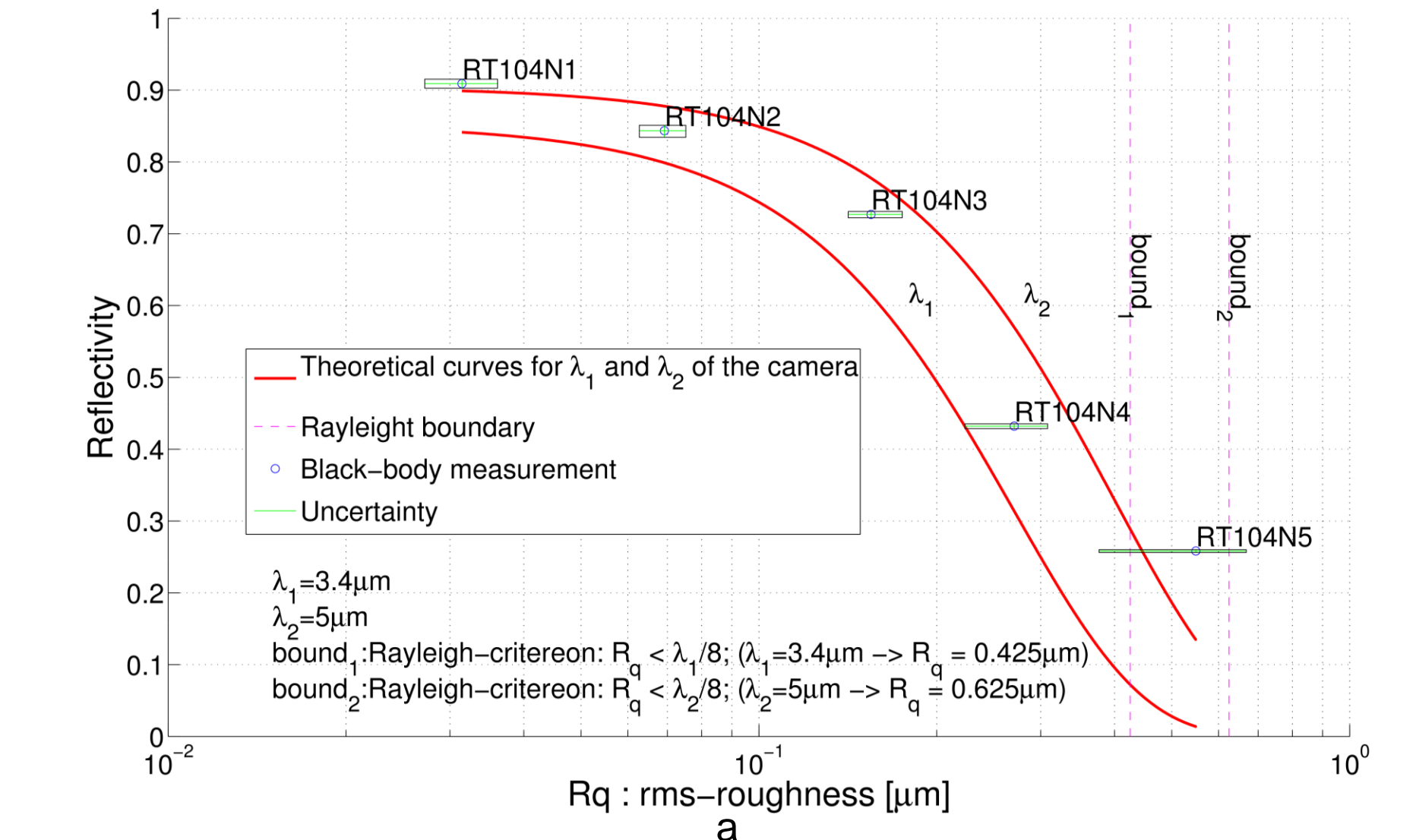
Surface profile of a sample

## Reflectivity measurement

- measurements at small (5°) incident angle
- mean value from 60 measurements



Reflected images of the radiation source on different surfaces



Measured reflectivity from (a) plane ground parts, (b) aluminum sheets compared to the theoretical model of Bennett and Porteus