Calculating Haze Parameter of Textured Transparent Conductive Oxides

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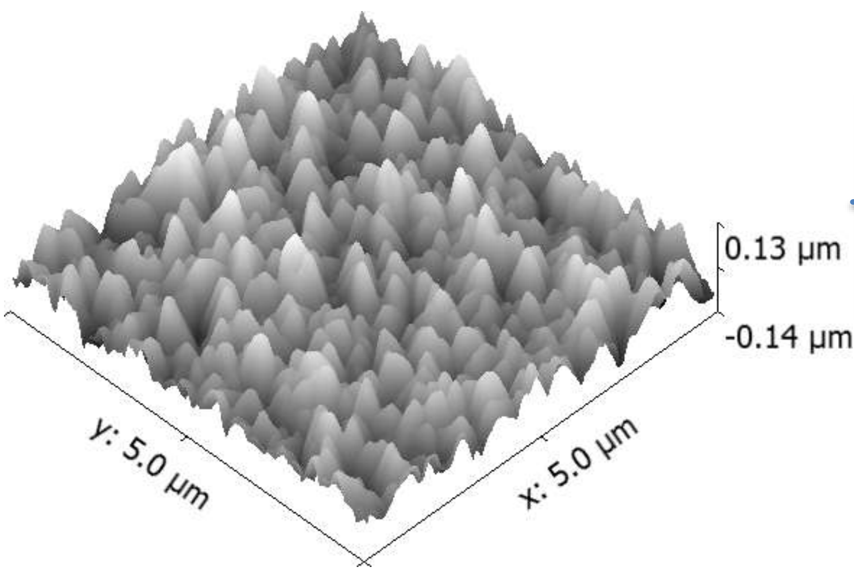
Outline

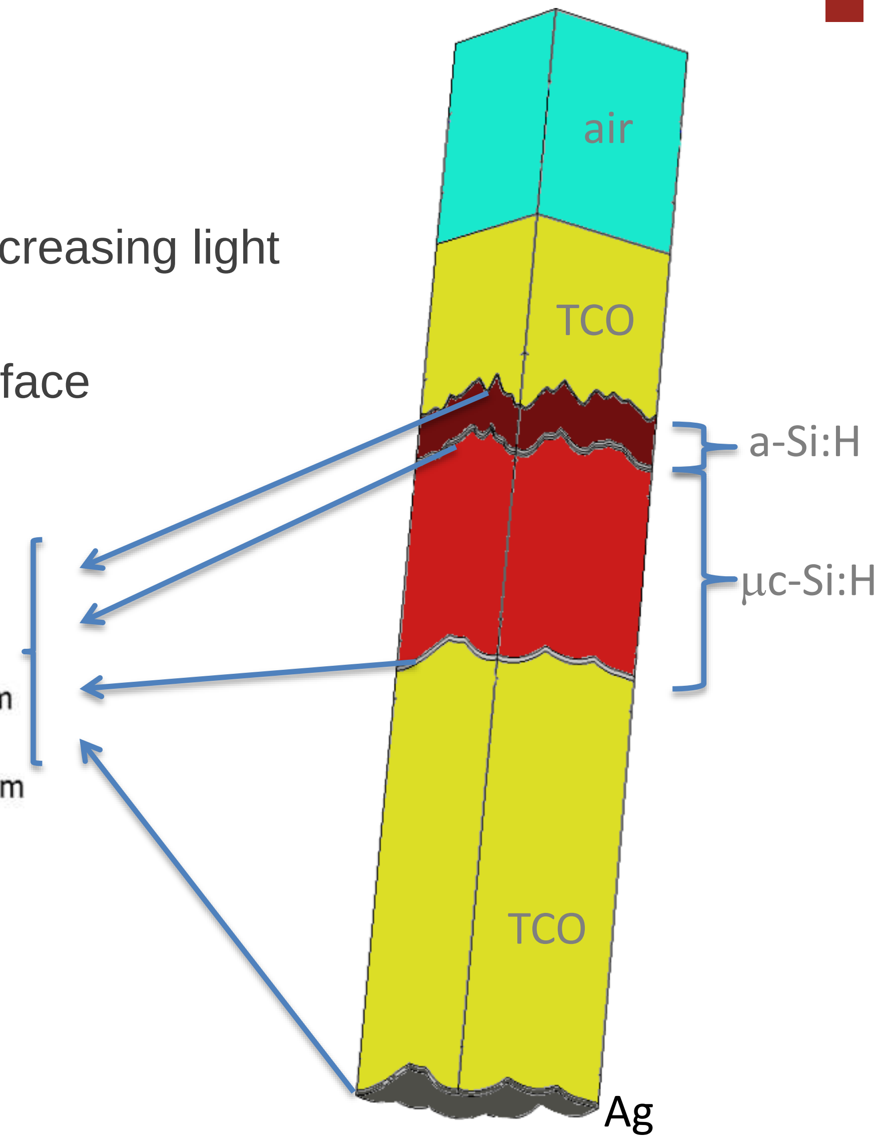
- Introduction
- Optical models (RF module)
  - air/perfect electric conductor (PEC) interface
  - realistic interface between two custom materials
- Results
- Conclusions

Introduction

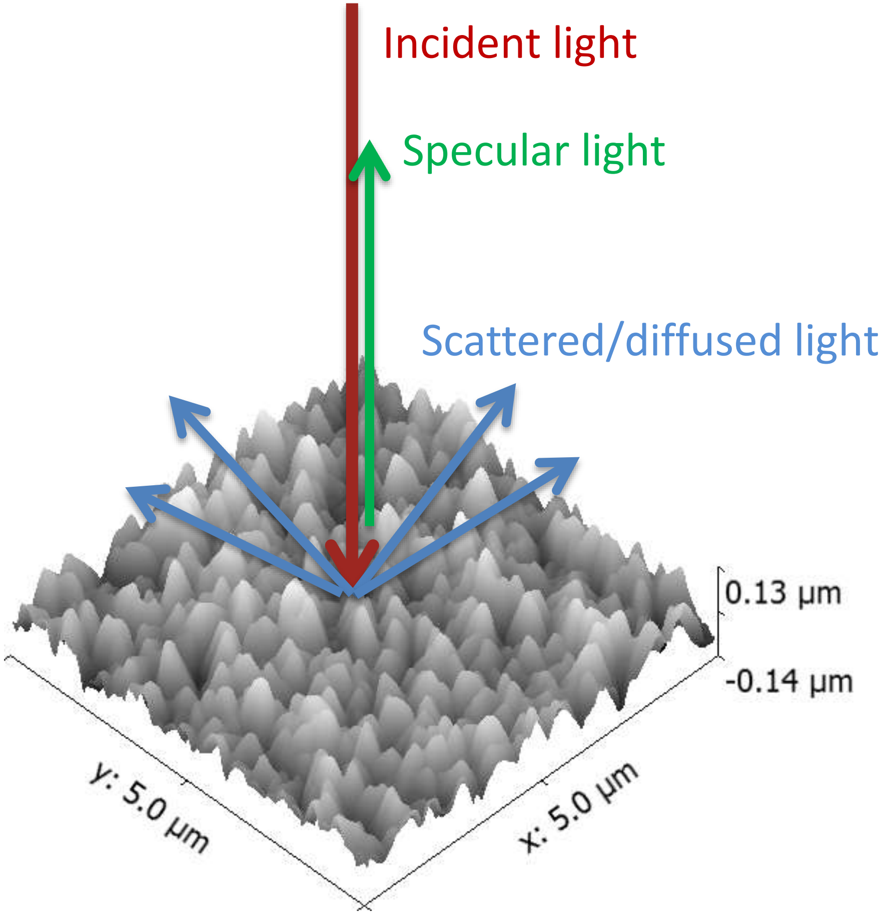
- Rough interfaces:
  - To increase scattering of light, thus increasing light path in active layers
  - To reduce reflectance at specific interface



SnO_2:F, Asahi U TCO



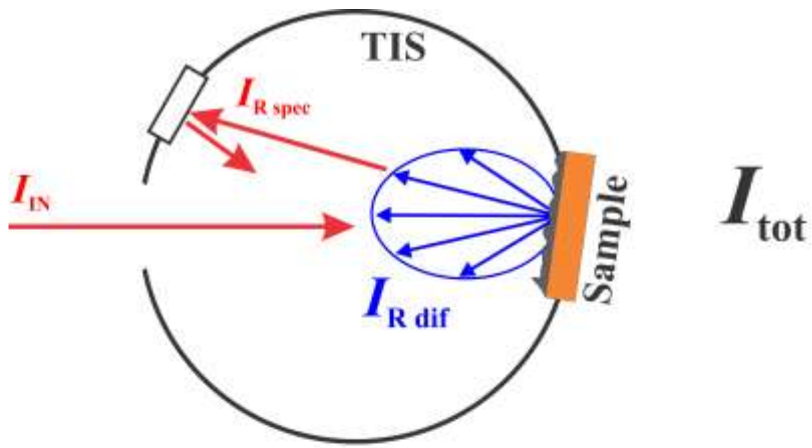
Introduction

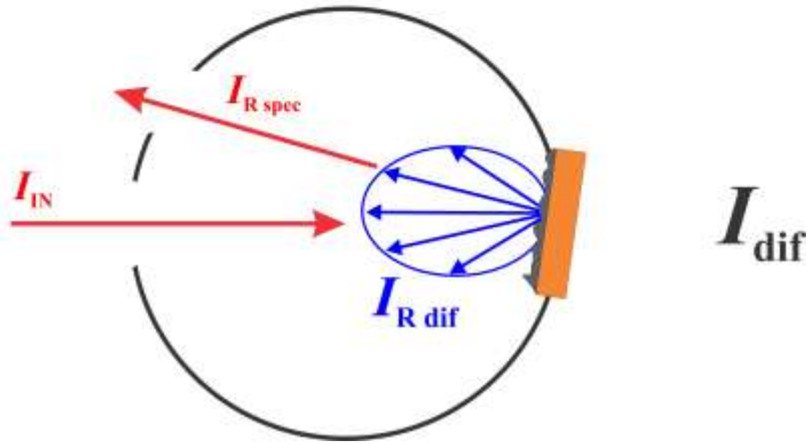


To improve absorption of light in a layer:

1. Increase scattered light, I_{dif} ↗
2. Decrease specular light, I_{spec} ↘

Introduction





Measured with Lambda 950 spectrophotometer

Haze is wavelength dependent!

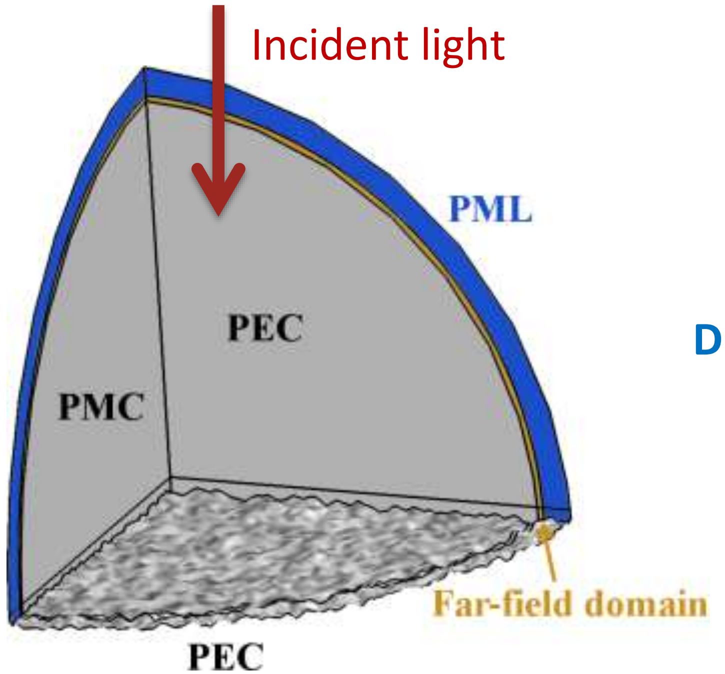
λ = 500 ... 1000 nm

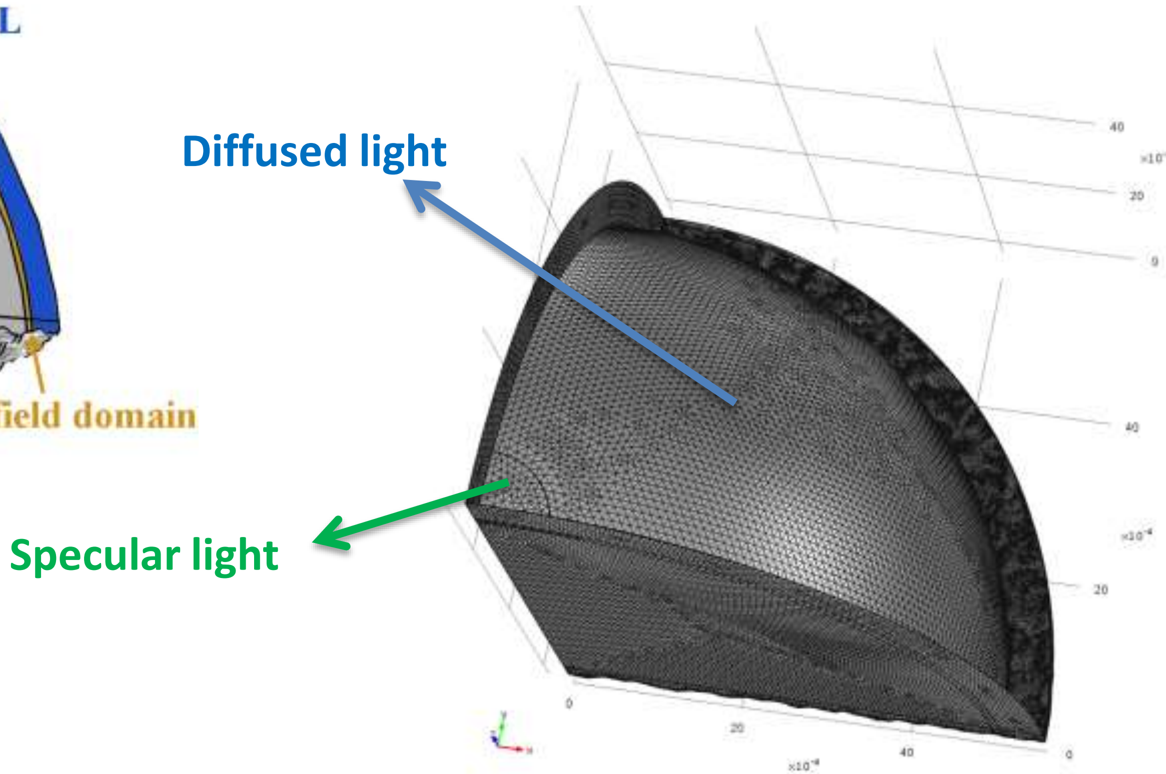
$$H = \frac{I_{dif}}{I_{tot}} = \frac{I_{dif}}{I_{spec} + I_{dif}}$$

Optical model

air-perfect electric conductor (PEC) interface

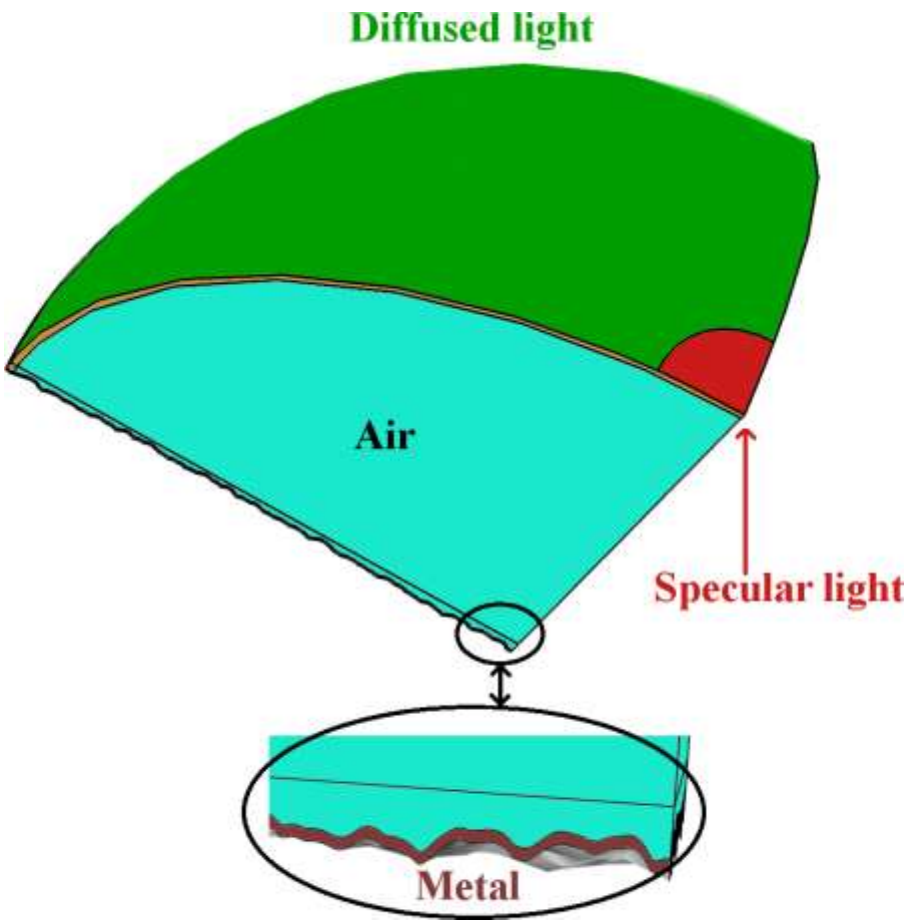
r = 6500 nm
DOF ≈ 2.2M for λ = 500 nm
DOF ≈ 0.7M for λ = 1000 nm





Optical model

realistic interface between two custom materials



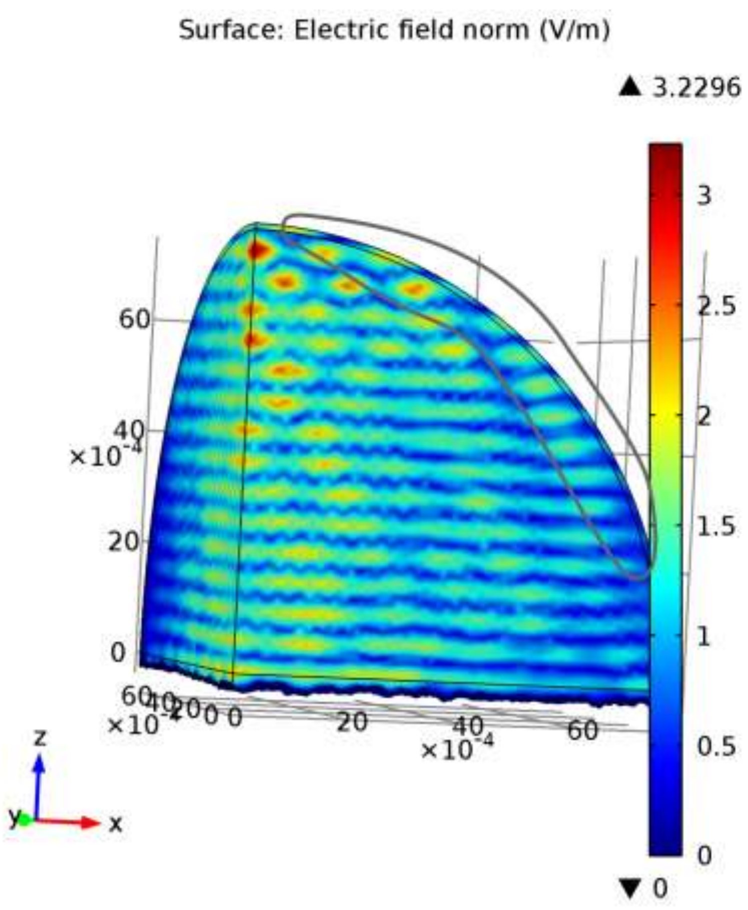
Gaussian beam

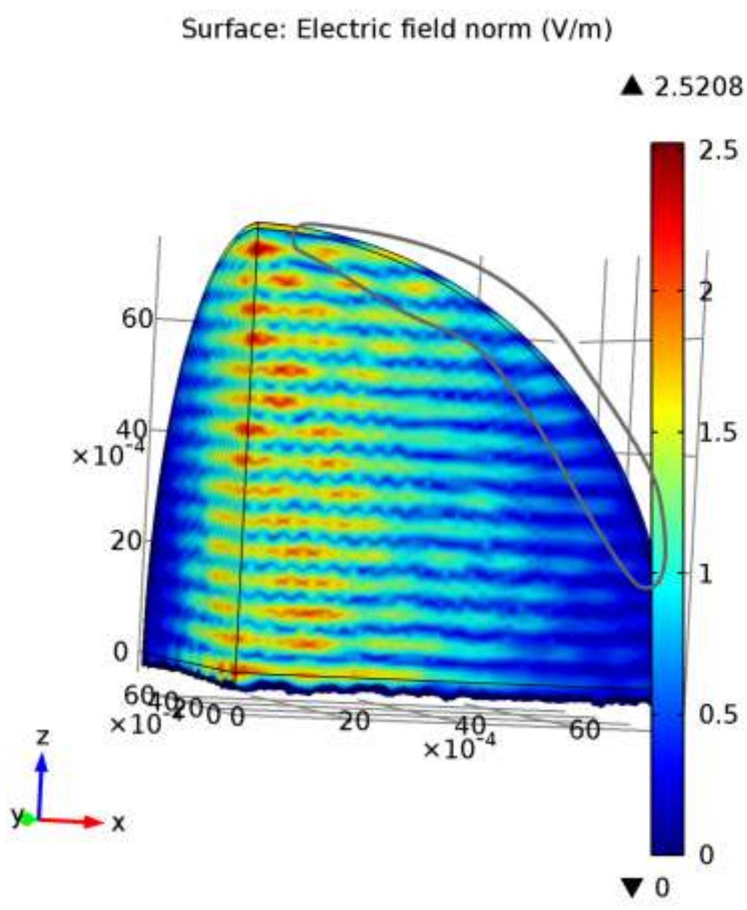
- To reduce the reflection from ABC
- Wide enough to incorporate enough of the surface statistics into the simulation
- Wide enough to obtain collimated beam

$$E_b = e^{(i2\pi z/\lambda)} e^{-(x/w)^2} e^{-(y/w)^2} \hat{y}$$

Gaussian beam

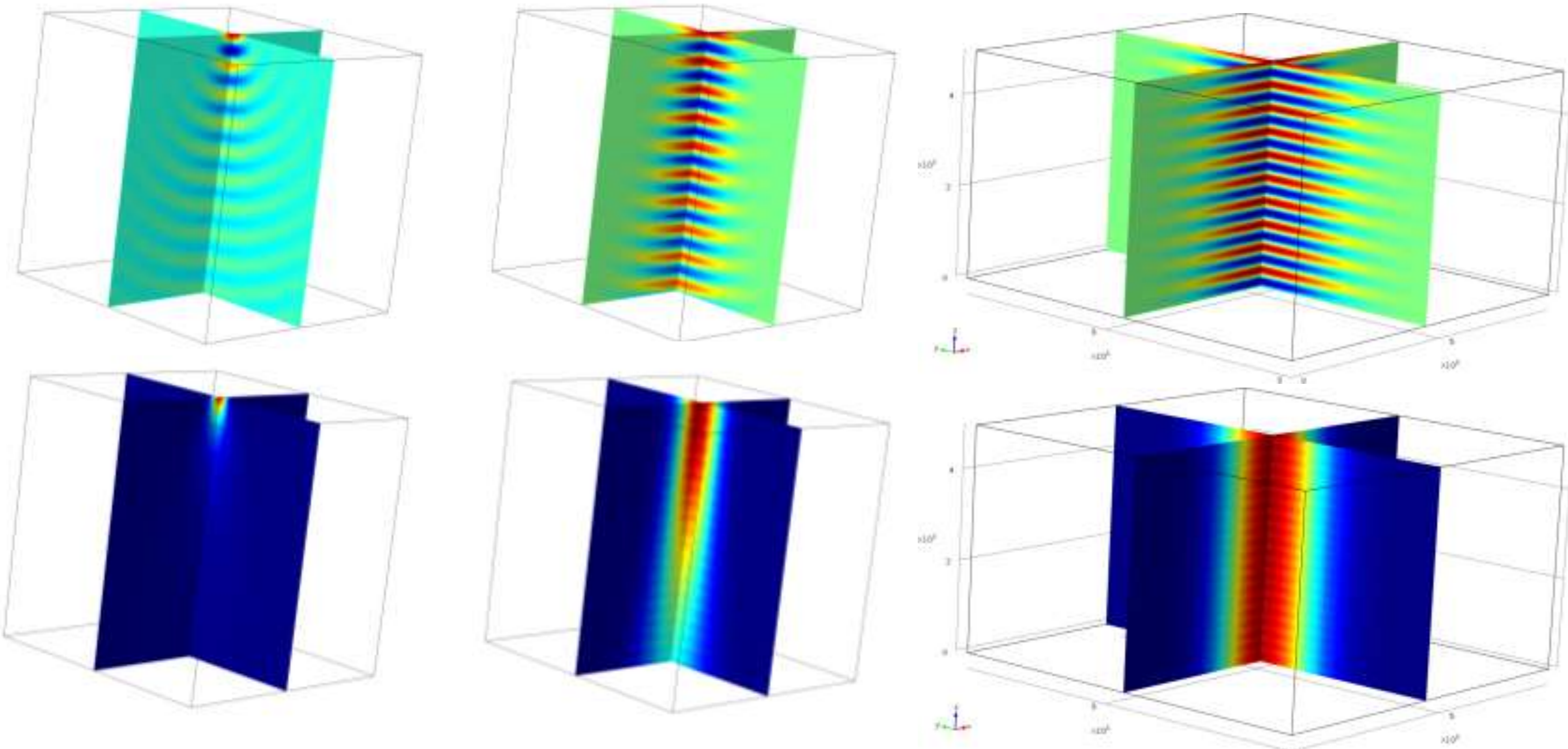
Laser beam – bending of the field





Gaussian beam

Evolution of Gaussian beam



E

W

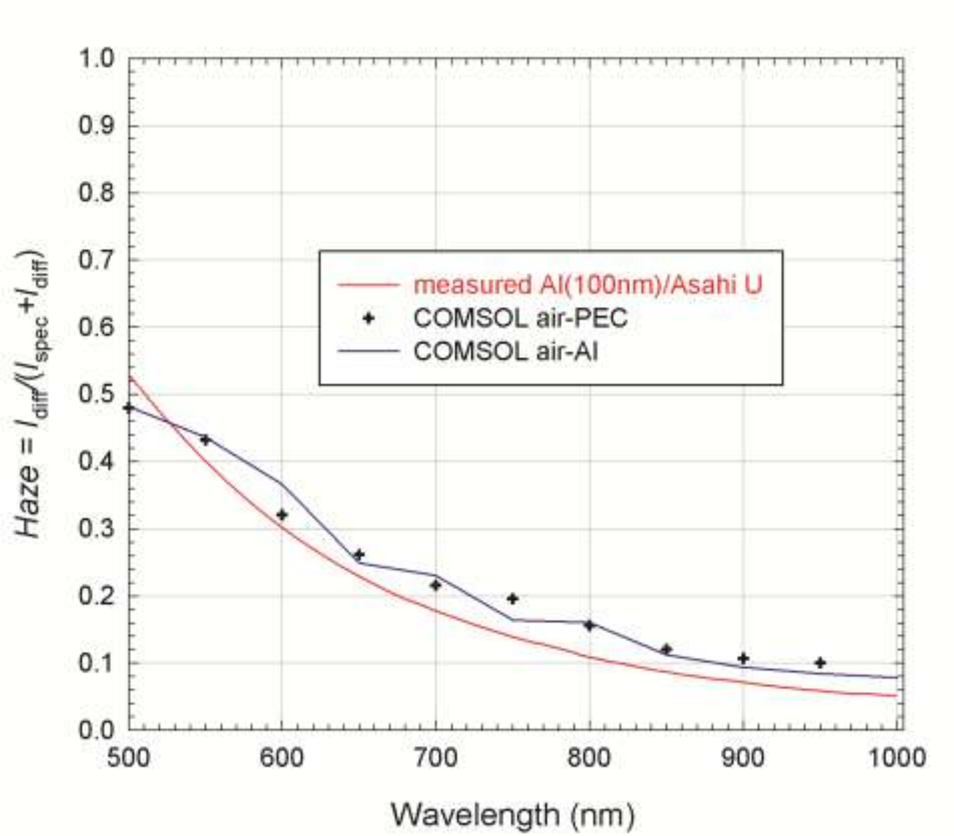
$w = \lambda$ — $\theta \approx 18^{o}$

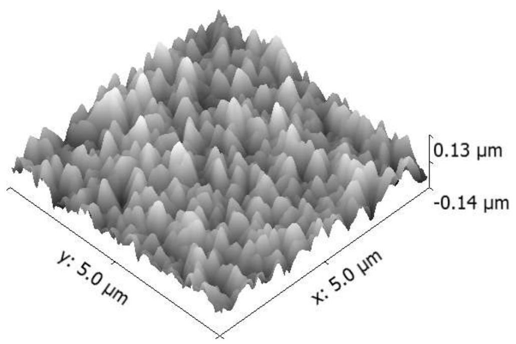
$w = 3\lambda$ — $\theta \approx 6^{o}$

$w = 8\lambda$ — $\theta \approx 2.2^{o}$

Beam divergence

Results

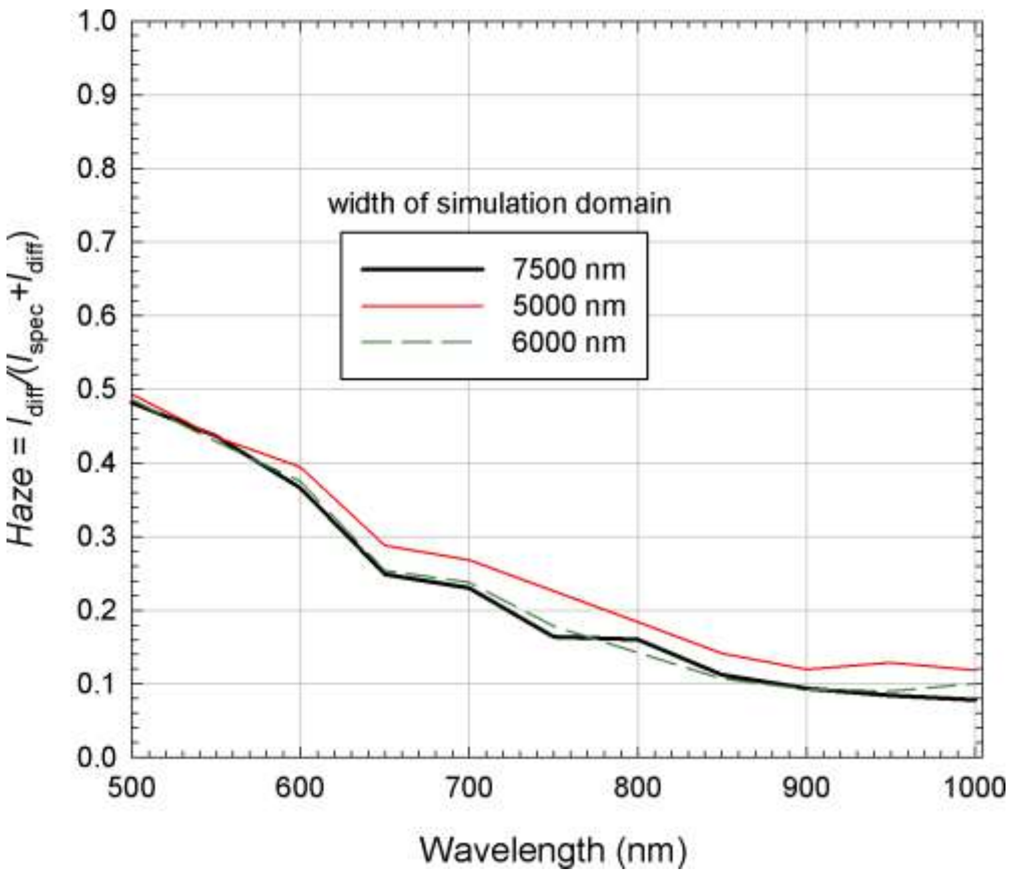


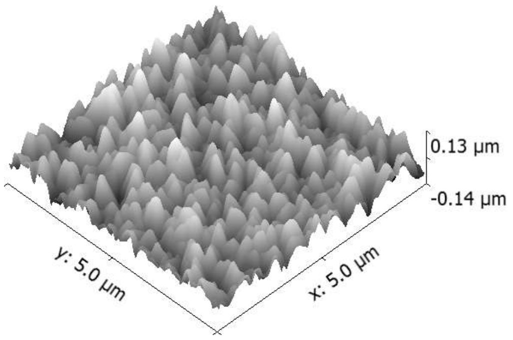


Simulation domain:
$r \approx 7.5$ µm
$w/2 = 5$ µm

Results

Uncertainty of results related to domain width at fixed size of Gaussian beam

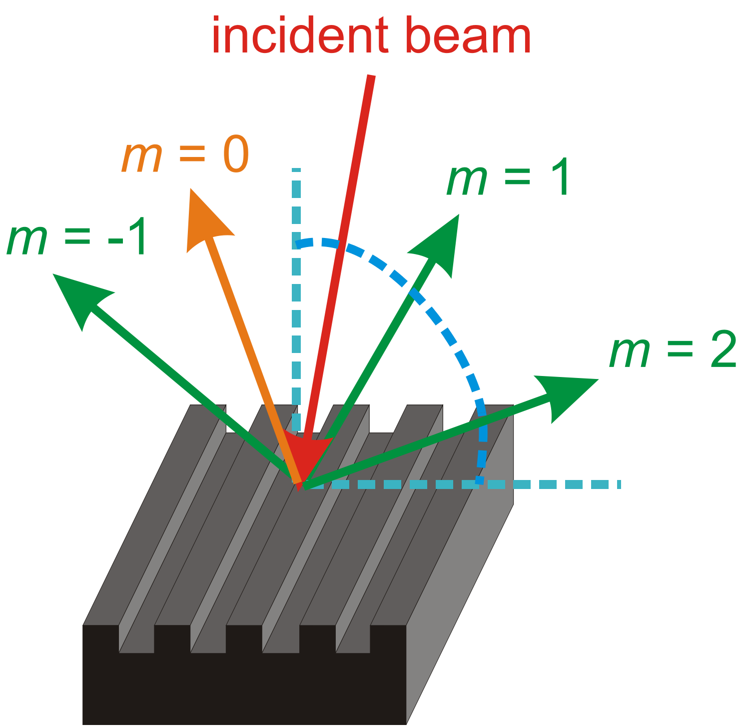




Gaussian beam:
$w/2 = 5\ \mu m$

Results

Anisotropic surface

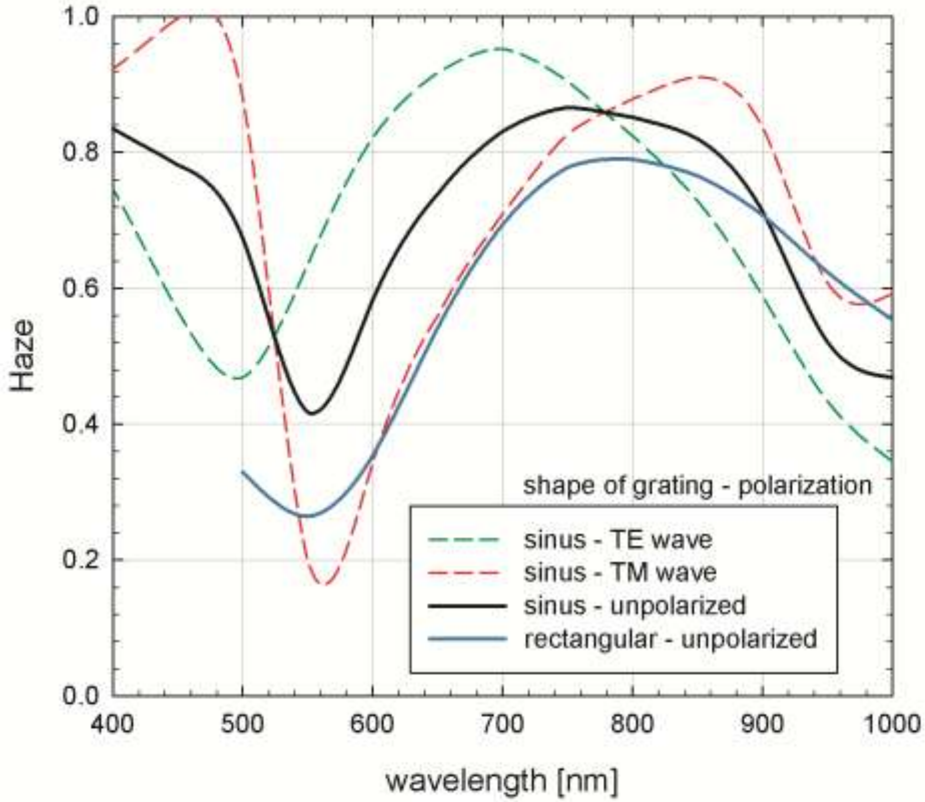


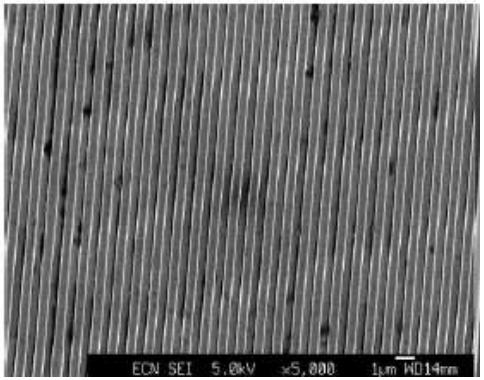
grating equation:

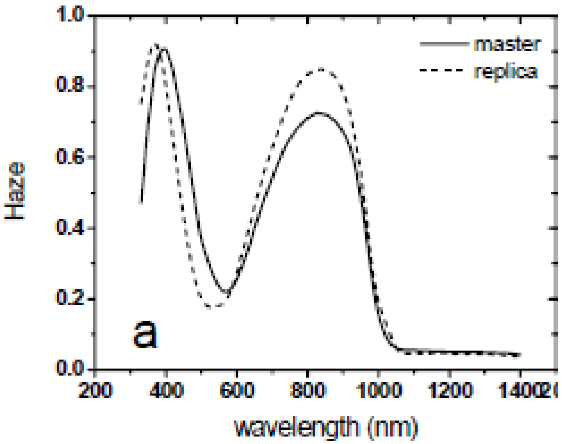
$$\varphi_m = \arcsin(\frac{m\lambda}{NP} - \sin(\varphi_{inc}$$

Haze:
50% TE wave
50% TM wave

Results







*M.C.R. Heijna, et al., Nanoimprint lithography of light trapping patterns in sol-gel coatings for thin film silicon solar cells, *Proceedings of SPIE* 7002, Strasbourg (2008)

Conclusions

- Two different optical models were presented to calculate Haze function
- Models were verified on isotropic and anisotropic surface
- The bottleneck of the program is far field calculation (support for multicore paralization of far field calculation, far field points are not dependent on each other)

The end

Thank you for your attention