



# Capturing Spatially Varying Anisotropic Reflectance Parameters using Fourier Analysis

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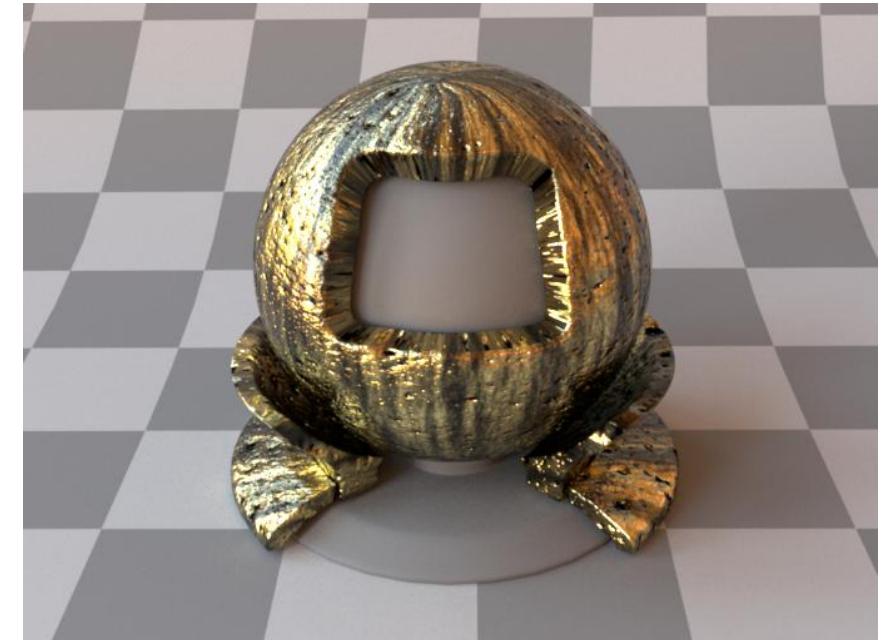
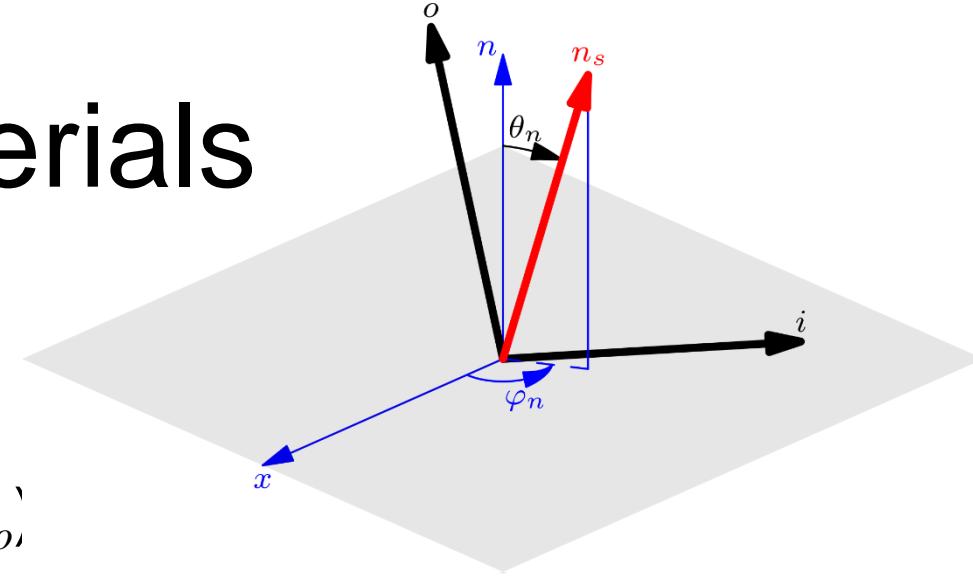
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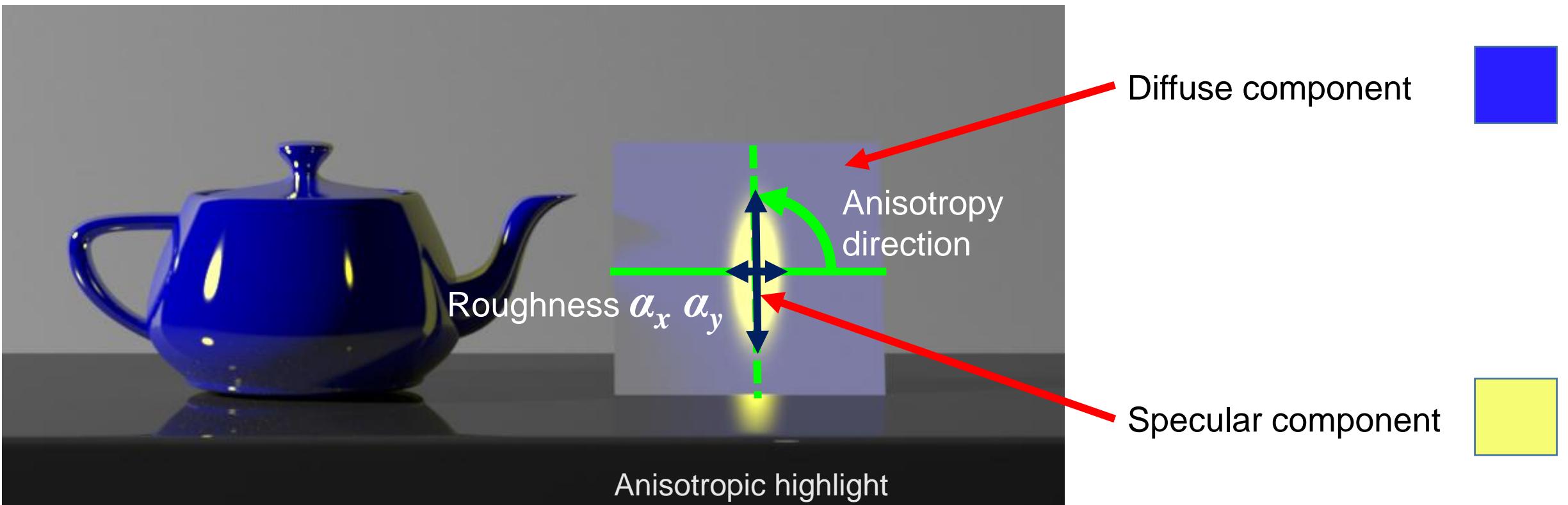
# Representing opaque materials

- BRDF - 4D function:
  - Incoming light (elevation  $\theta_i$  & azimuth  $\varphi_i$ )
  - Observation point (elevation  $\theta_o$  & azimuth  $\varphi_o$ )

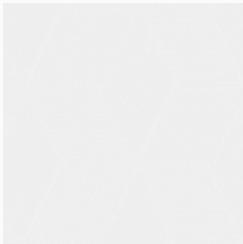
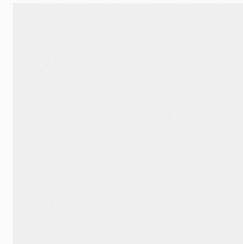
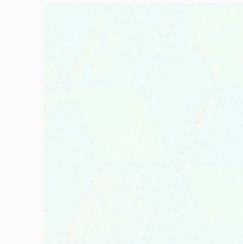


- Spatially varying material SVBRDF:
  - + 2 dimensions: u, v

# Representing opaque materials



# Representing opaque materials

Diffuse	Specular	Shading normal	Anisotropy direction	Roughness
				 $\alpha_x/\alpha_y$
3 dimensions: • Red • Green • Blue	3 dimensions: • Red • Green • Blue	2 dimensions: • Elevation $\theta_n$ • Azimuth $\varphi_n$	1 dimension: • Direction $\varphi_a$	2 dimensions: • Horizontal $\alpha_x$ • Vertical $\alpha_y$

# Related work

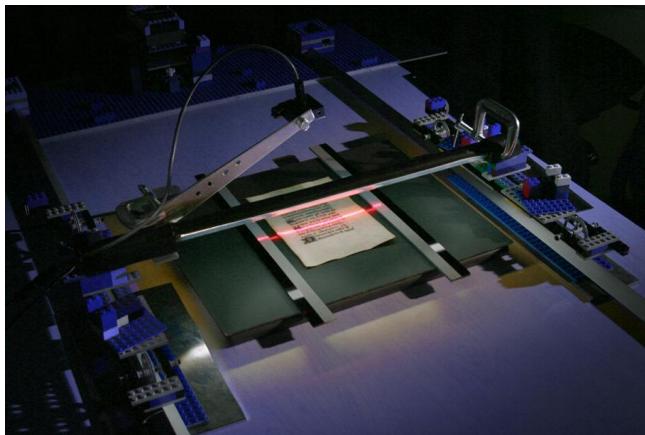
	BRDF acquisition	Spatially Varying BRDF
		Capture under varying illumination
<b>Isotropic</b>	[Matusik <i>et al</i> – 2003]	[Gardner <i>et al</i> – 2003] ★ [Holroyd <i>et al</i> – 2010] ★★
<b>Anisotropic</b>	[Ngan <i>et al</i> – 2005] [Filip <i>et al</i> – 2014]	[Tunwattanapong <i>et al</i> – 2013] ★★★ [Aittala <i>et al</i> – 2015] ★

## Lighting system complexity

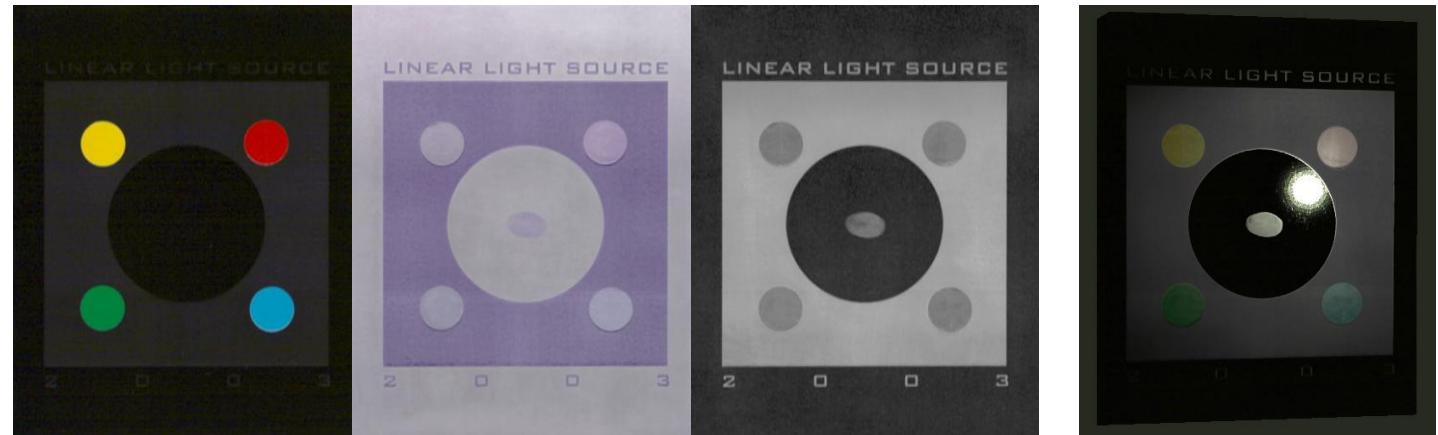


# Related work

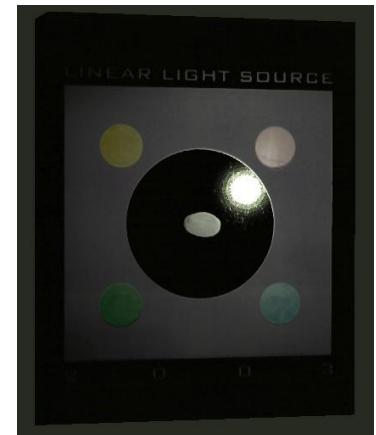
[Gardner *et al* – 2003] Linear Light Source Reflectometry



The linear light source apparatus



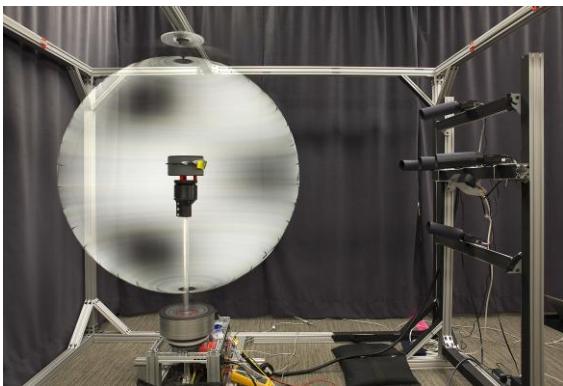
Diffuse, Specular intensity, Specular roughness



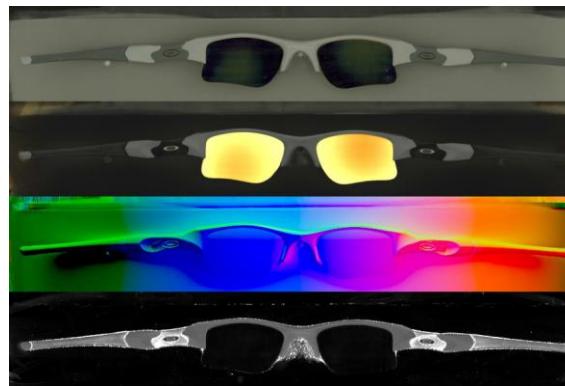
Rendering

# Related work

[Tunwattanapong *et al* – 2013] Acquiring Reflectance and Shape from Continuous Spherical Harmonics Illumination



Acquisition Setup



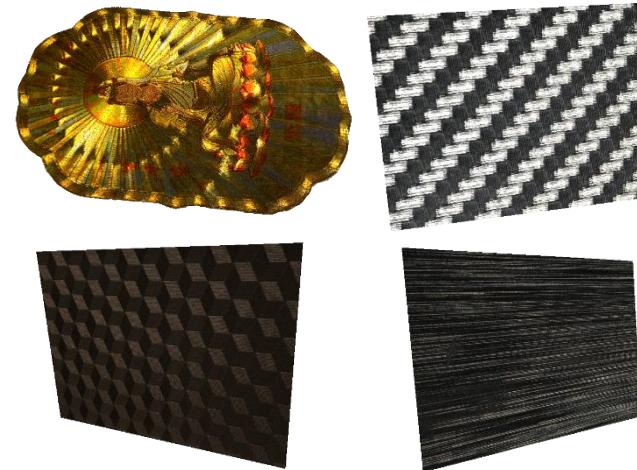
Reflectance Maps



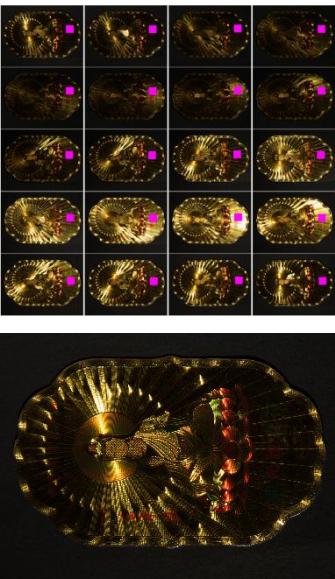
Rendered 3D Model

# Contribution

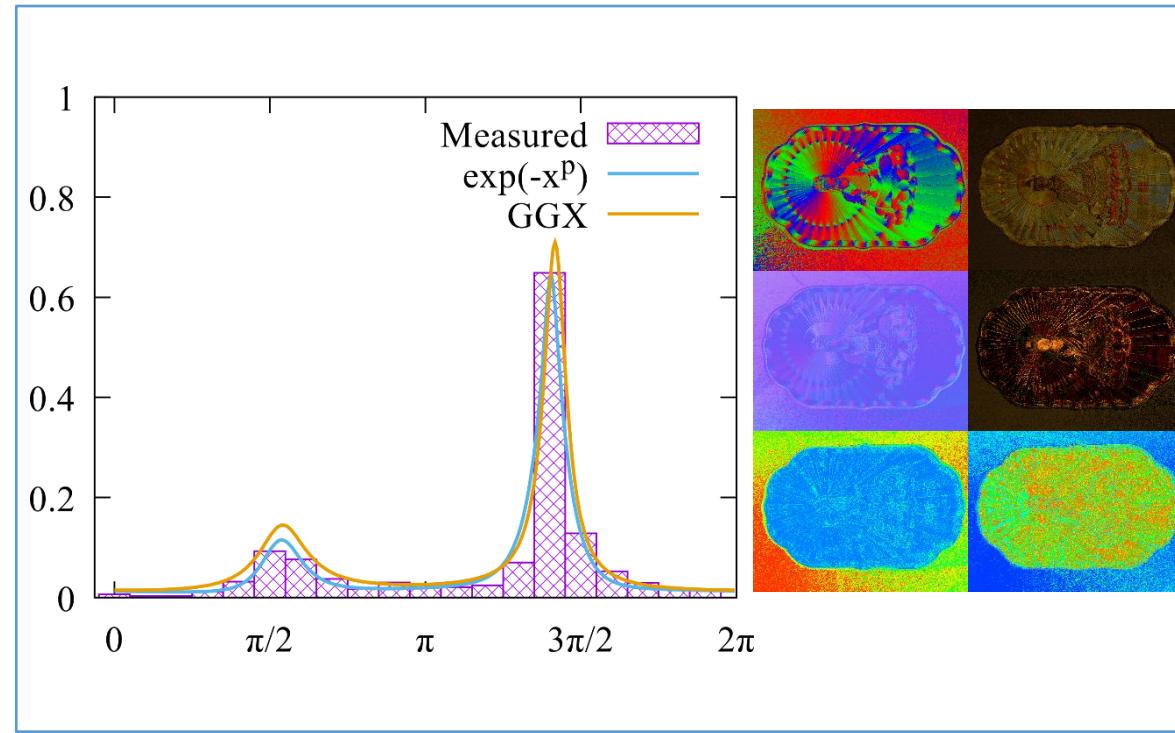
- Capturing material with a simple setup
  - **Easy** and **cheap** to reproduce setup
  - **Fast** acquisition time
  - Few samples needed (*20 used in our example*)
  - Simple and flexible
- Dealing with anisotropic Spatially-Varying material
  - No assumption on surrounding pixels
  - Works with **high frequency patterns** (amulet dataset)



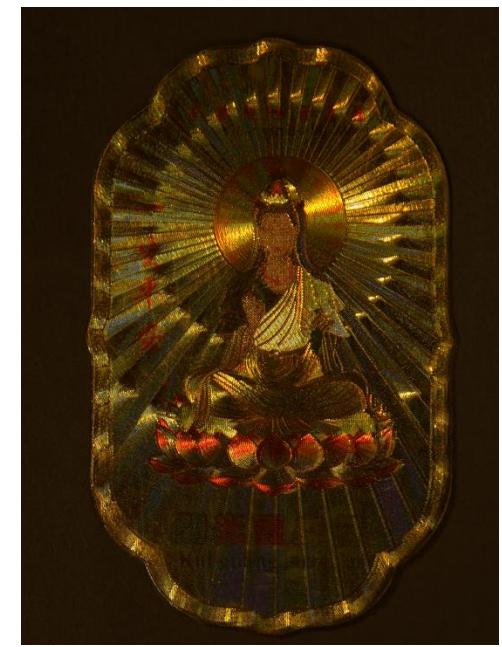
# Overview of our technique



Capture



Analysis

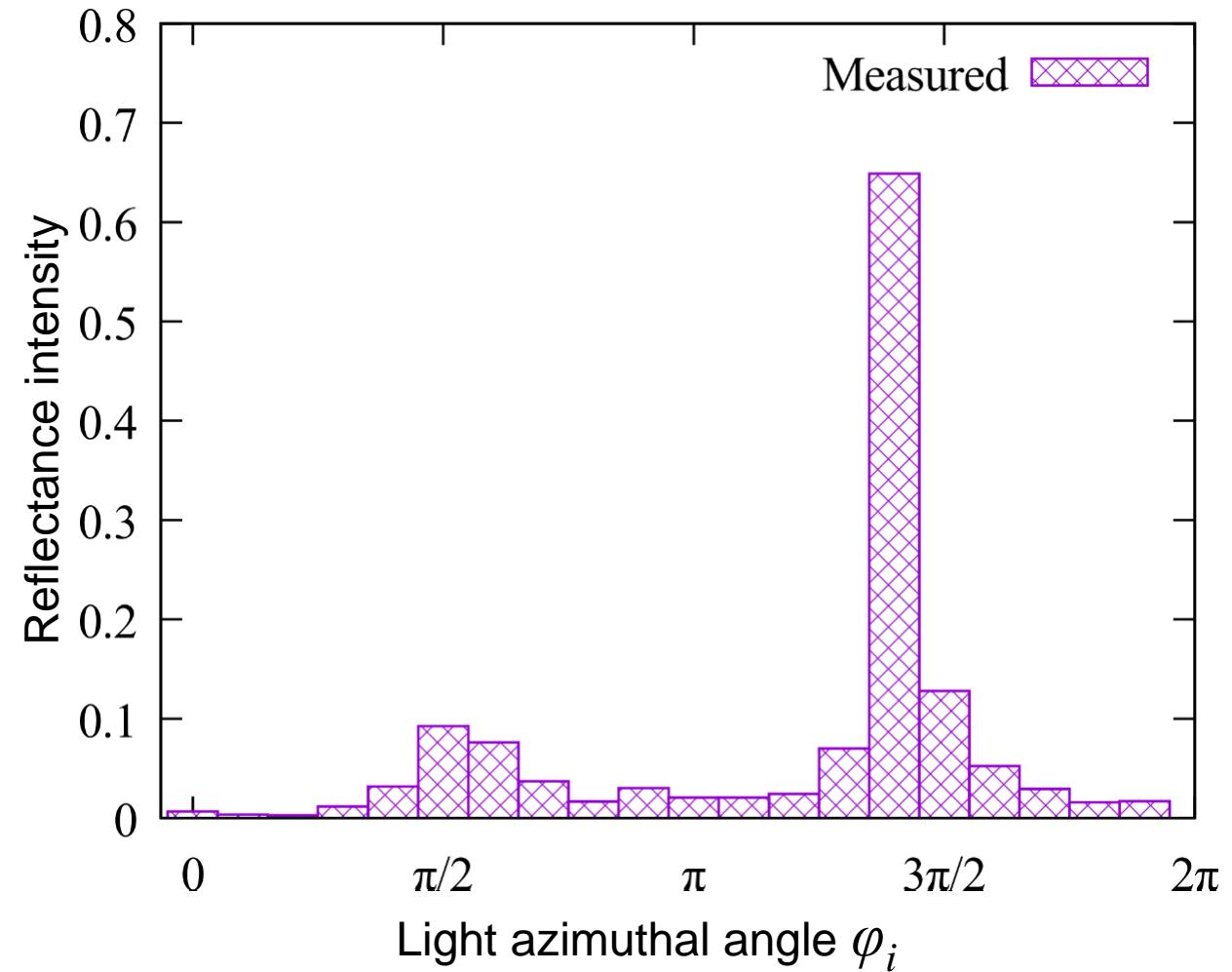
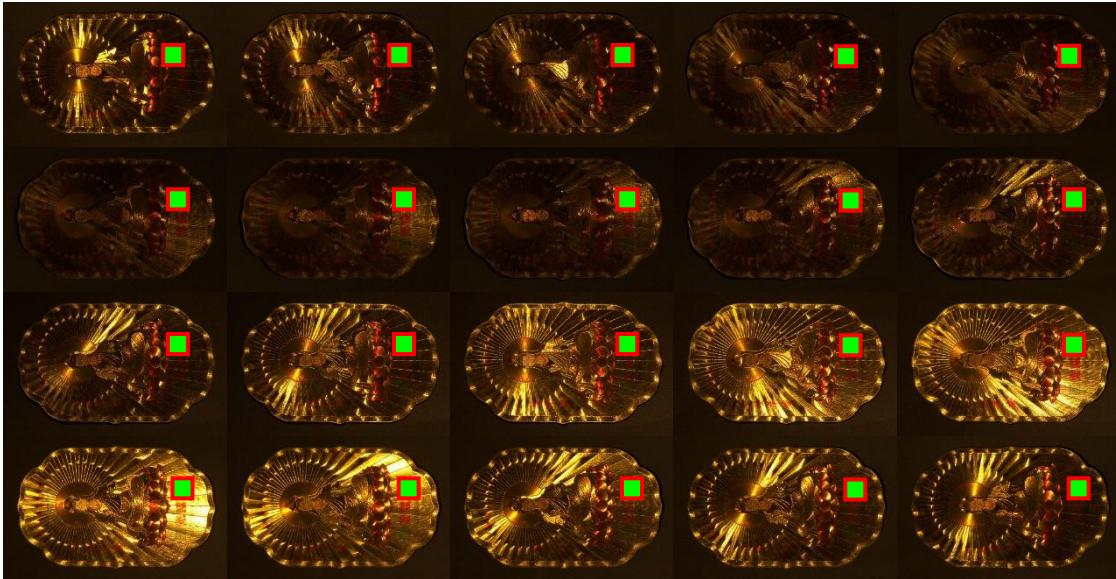


Rendering



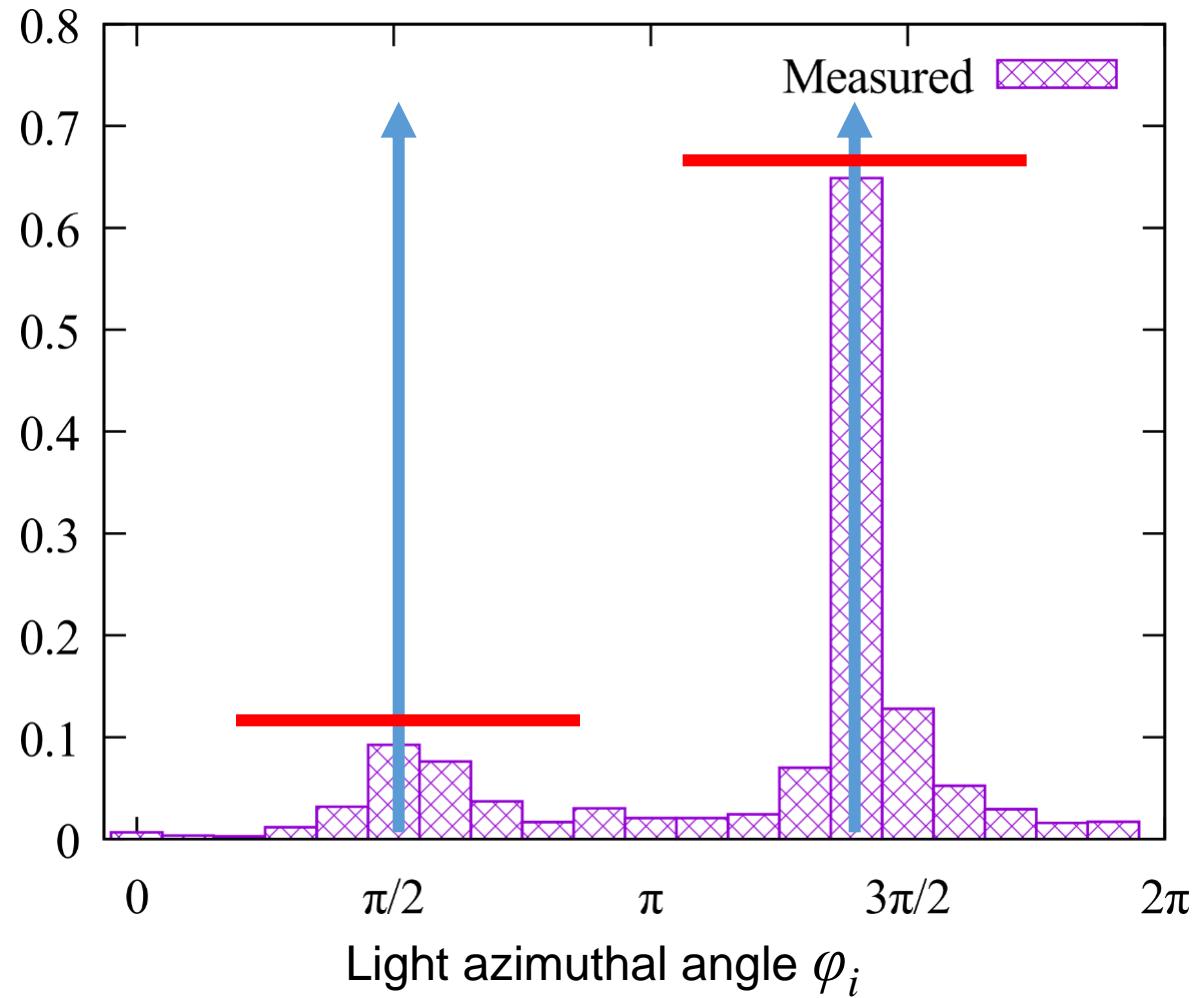
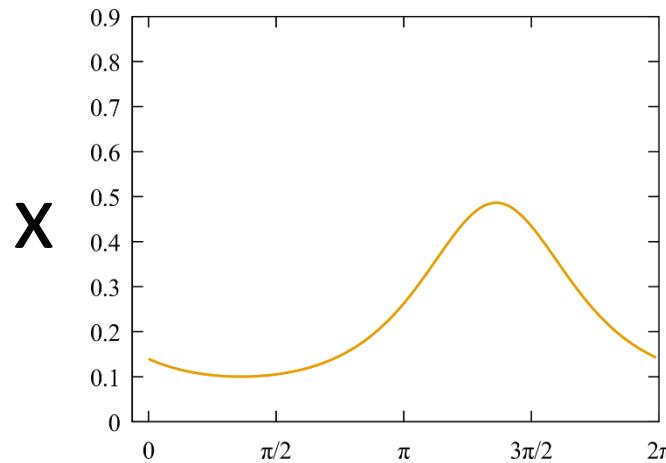
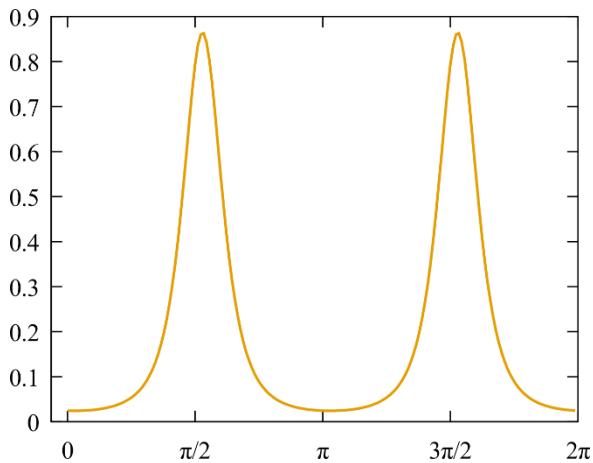
# Analysis

- Each pixel treated independently



# Analysis

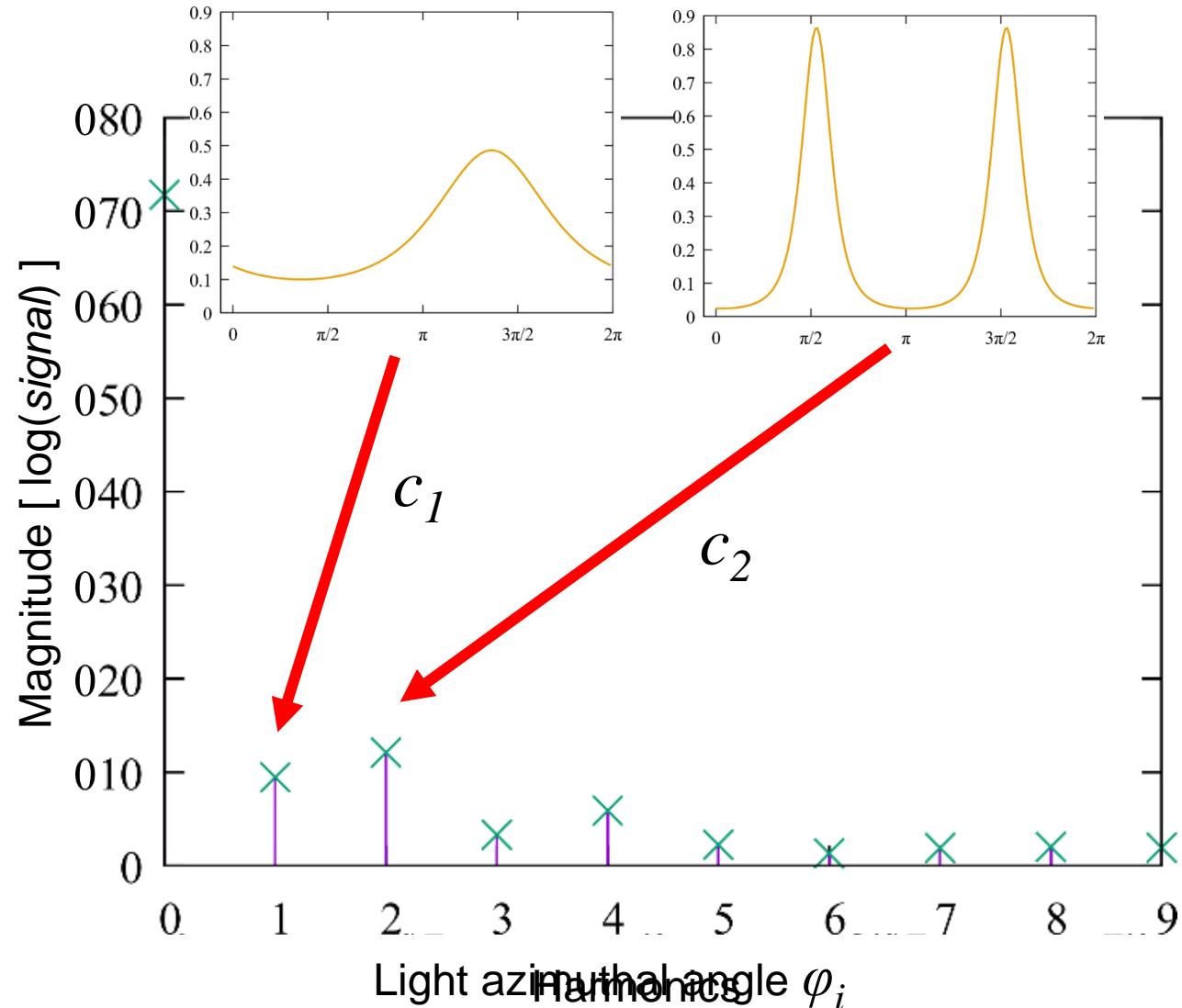
- Anisotropy  
→ **Two** peaks
- Shading normal  
→ **Maximum** difference



# Analysis

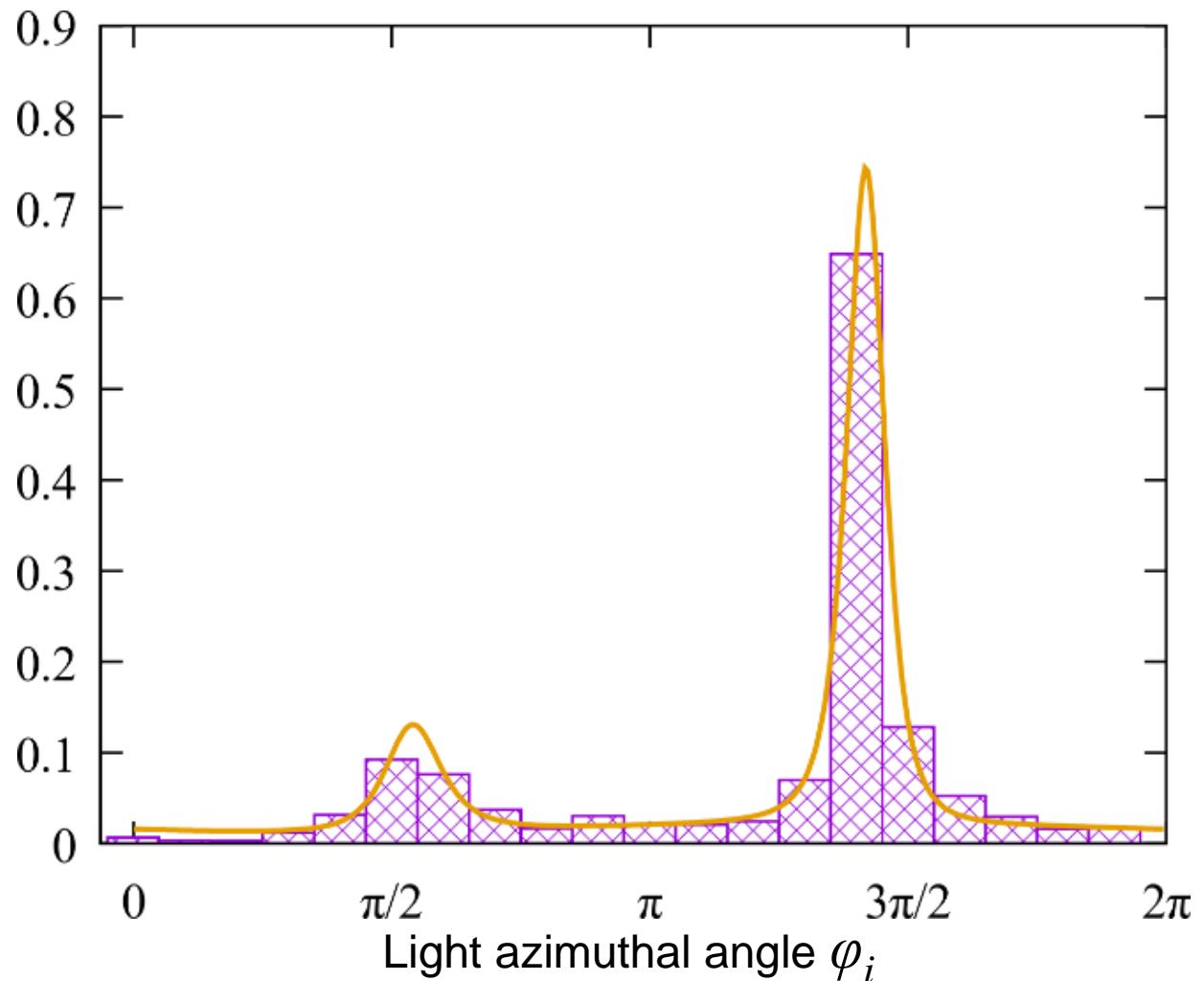
- Fourier transform
  - Fundamental – **average**
  - Harmonics – **complex numbers**
- Frequency domain
  - Argument – **offset**
  - Magnitude – **contribution**

$$c_n = \int_0^{2\pi} s(\phi_h) e^{ni\phi_h} d\phi_h$$



# Analysis

- Initial estimation of
  - Anisotropy direction  $\varphi_a$
  - Normal azimuth  $\varphi_n$
- 3-step minimization process
  1. Even rank harmonics  
– **Anisotropy / Specular**
  2. First harmonic & fundamental  
– **Normal / Diffuse**
  3. Fit on signal itself
- Loop back











# Limitations

- Constrained to almost planar surfaces
  - Shading normal in a **limited range variation**
- Miss of high specularity or diffuse details
  - 20 samples used – **Nyquist-Shannon sampling theorem**
  - **Single exposure images @14bits**
- Fresnel term ignored
  - **Gazing angles** issues



# Conclusion & Future work

- Technique for **retrieving anisotropic SVBRDF**
- Based on **Fourier analysis**
- **Simple** capture setup and modular analysis
  
- Application to **non-planar objects**
- Extension to more **advanced anisotropy patterns**
- Gathering **similar pixels** to improve accuracy



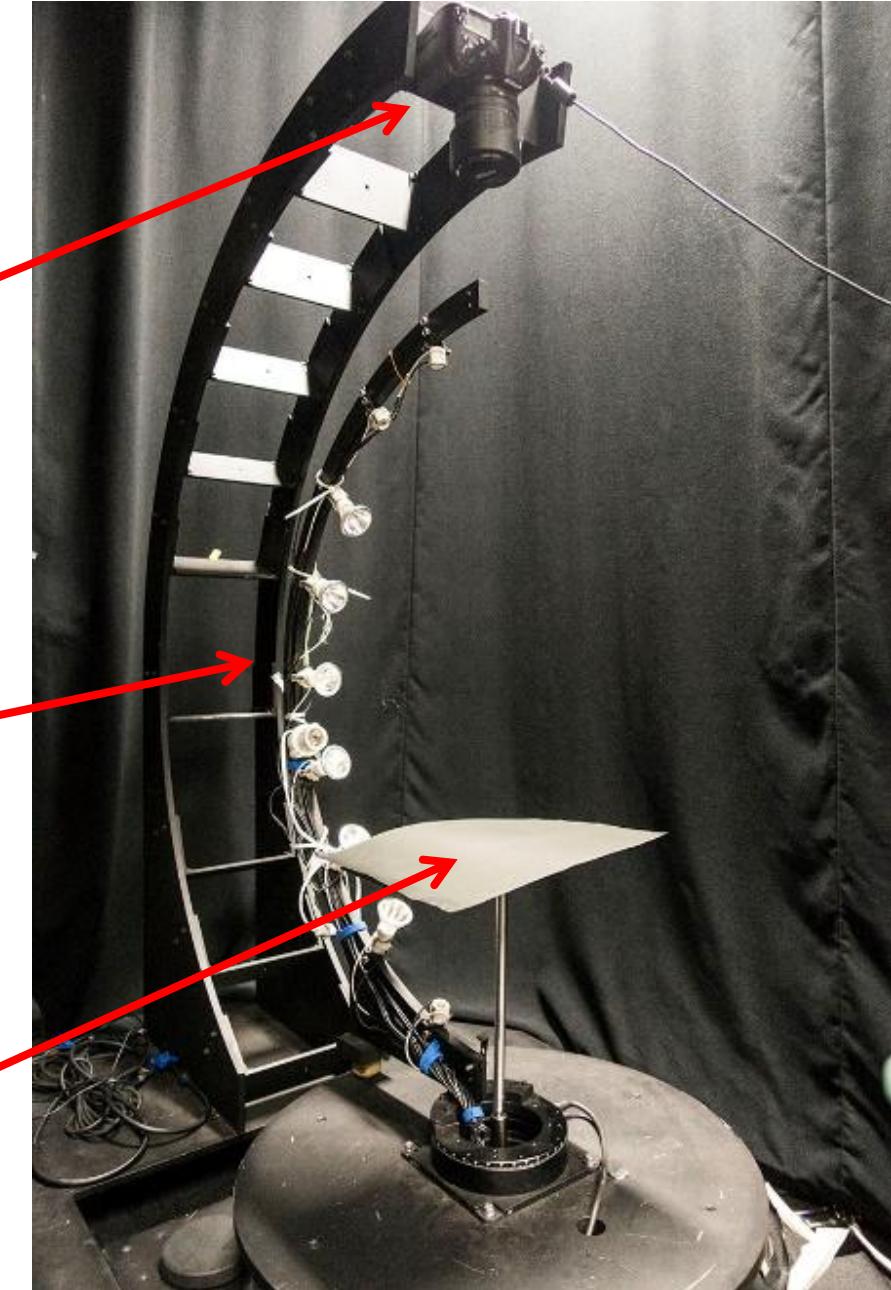
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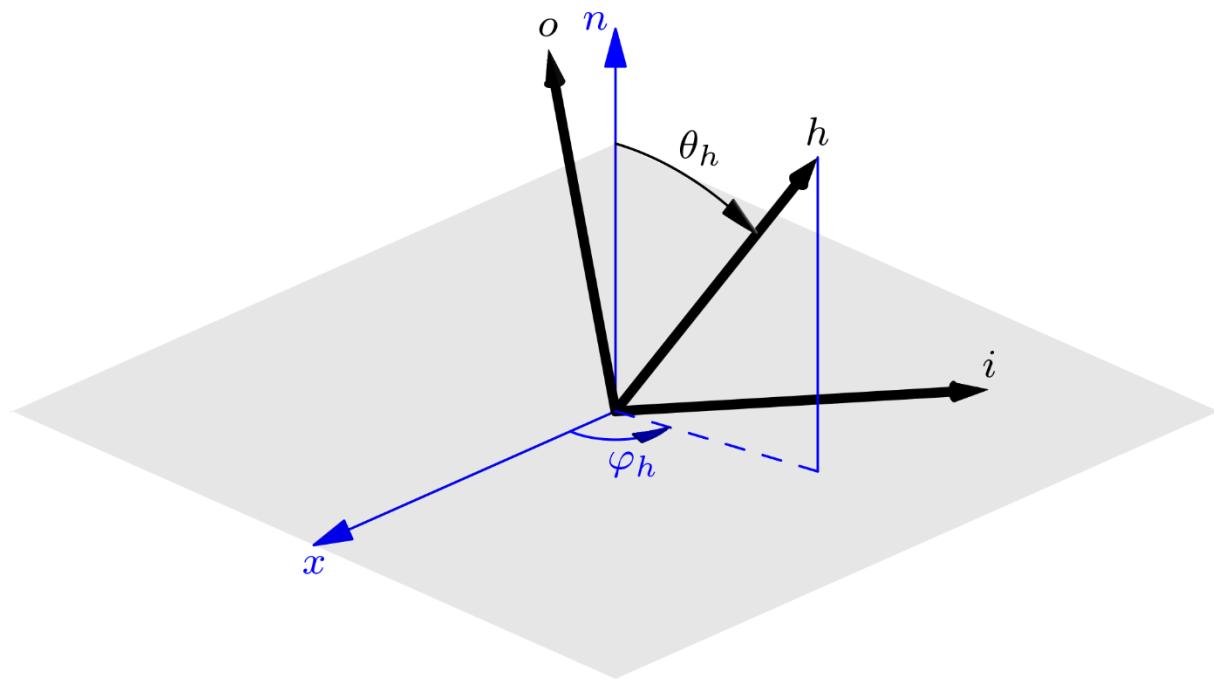
**Nicolas Holzschuch**  
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# Capture setup

- Nikon D7100 camera
  - AF-S Nikkor 18-105mm 1:3.5-5.6G lens
  - Captured in NEF 14 bits
- Rotating arm with light
  - Computer controlled synchronized with camera shoot
- Sample stage



# Representation



- Incoming light vector  $i$
- Outgoing light vector  $o$
- Half vector  $h = \frac{i + o}{\|i + o\|}$
- Anisotropy direction  $x$

# BRDF model

- Cook-Torrance

$$r(i, o) = \frac{k_d}{p} + \frac{k_s}{a_x a_y} \frac{F(\cos q_d) G(i, o)}{4 \cos q_i \cos q_o} D\left(\tan^2 q_h \left( \frac{\cos^2 j_h}{a_x^2} + \frac{\sin^2 j_h}{a_y^2} \right)\right)$$

- GGX Isotropic NDF

$$D(i, o) = \frac{a_g^2 C^+(m \times n)}{p \cos^4 q_h (a_g^2 + \tan^2 q_h)^2}$$

- GGX Anisotropic NDF

$$D(i, o) = \frac{C^+(m \cdot n)}{p \cos^4 q_h a_x a_y \left( 1 + \tan^2 q_h \left( \frac{\cos^2 j_h}{a_x^2} + \frac{\sin^2 j_h}{a_y^2} \right) \right)^2}$$