Image-Based Reflectometry

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Why Measure Reflectance?

- Faithfully represent real materials
- Avoid manual parameter tuning
- Discover how real surfaces behave
- Develop new reflectance models

BRDF

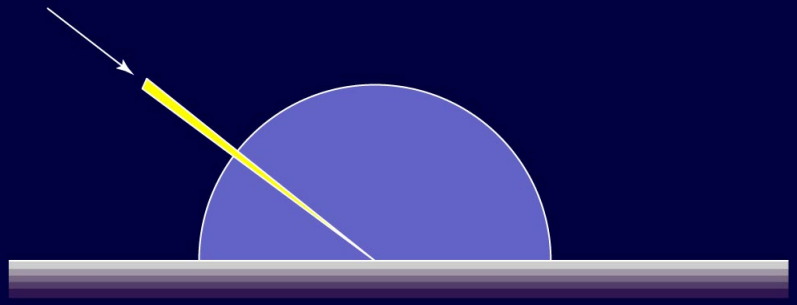
$$\rho(\omega_i, \omega_e) = \frac{dL_e}{dI_i} = \frac{\text{exitant radiance}}{\text{incident irradiance}}$$

"Bidirectional Reflectance Distribution Function"

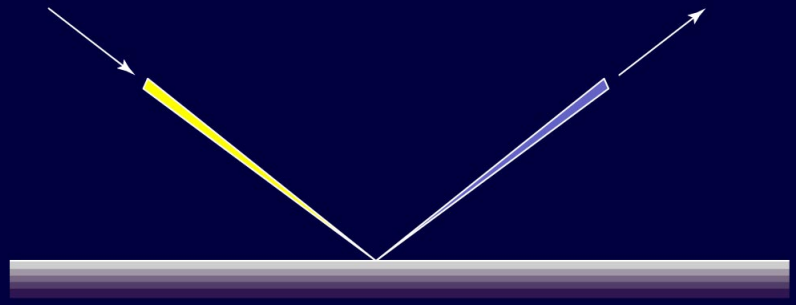
BRDF Properties

- Reciprocity
- Energy conservation
- Isotropy

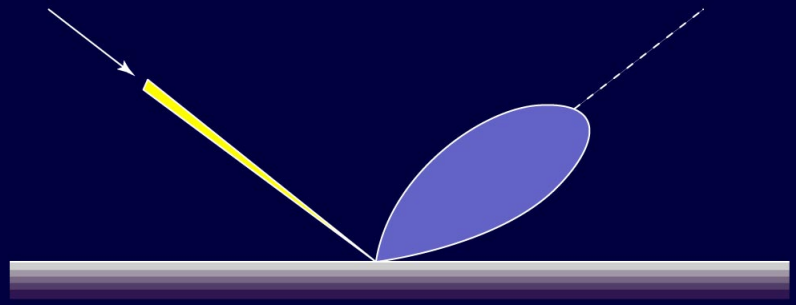
Modes of Reflection



Lambertian

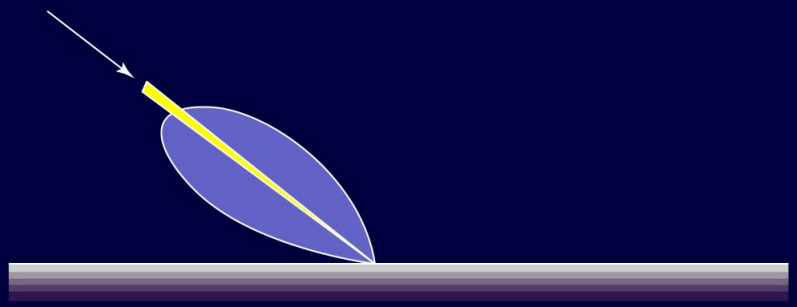


Specular

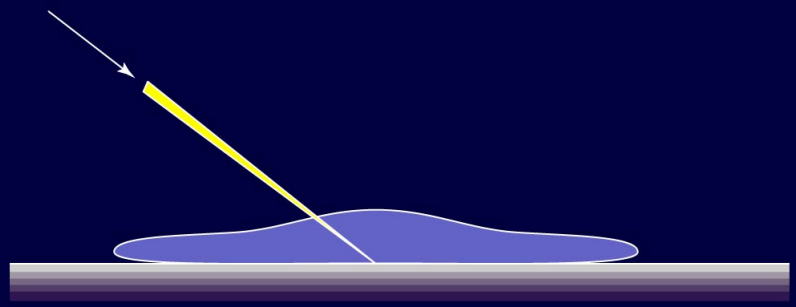


Off-Specular

Modes of Reflection



Retroreflection



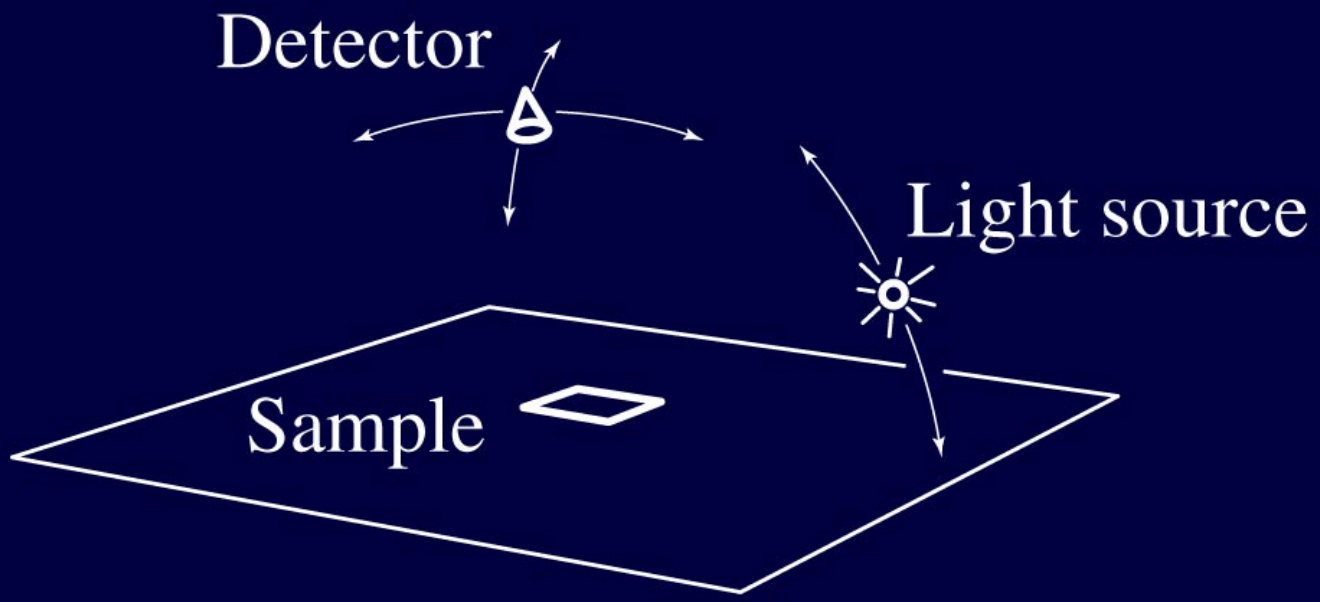
Near Horizon

Measurement Challenges

- High-dimensional domain
  - 4 dimensions of angle; 5 with wavelength
  - Many samples required; slow measurements
- Confounding reflectance and geometry
- Dynamic range

A Simple Gonioreflectometer

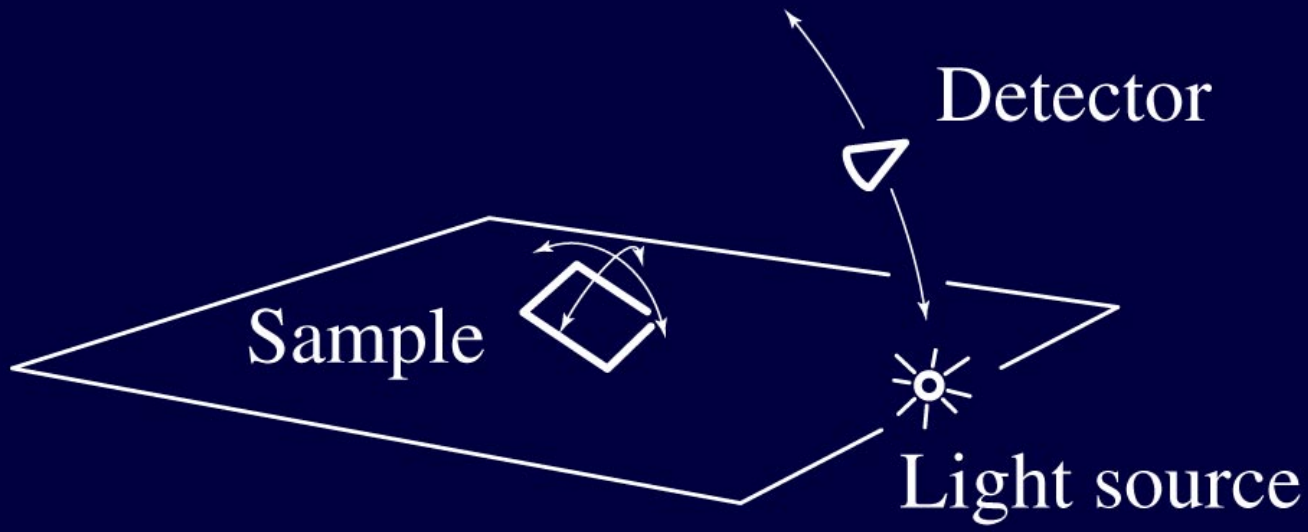
3 DOF: 2 detector, 1 source



Nicodemus et al. 77

Another Gonioreflectometer

3 DOF: 2 sample, 1 detector



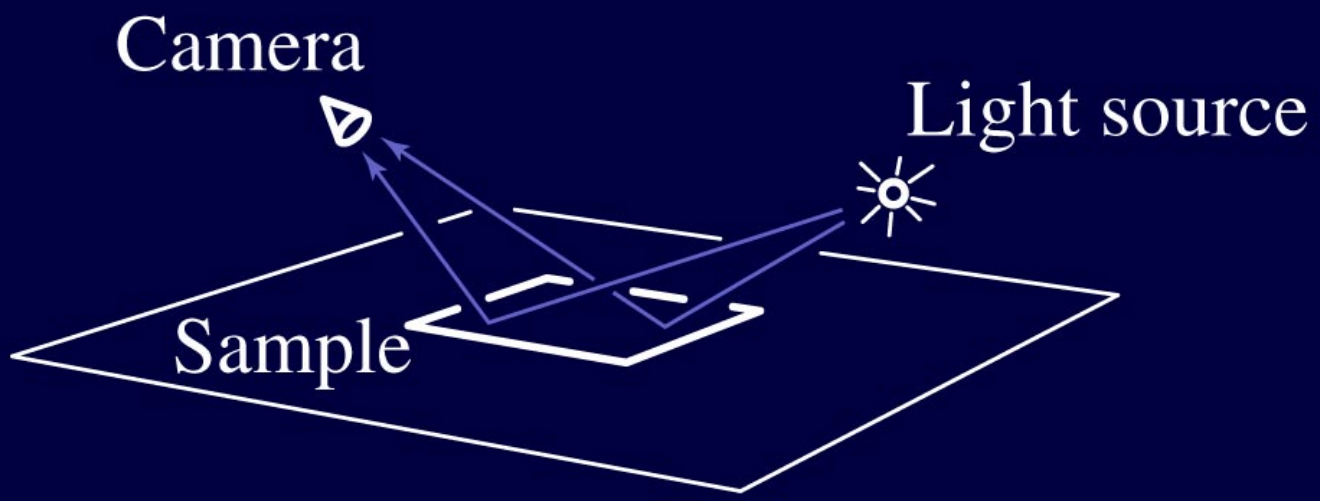
Torrance & Sparrow 65; Dana et al. 96

Image-Based Measurement

- Image sensor replaces mechanical DOFs
- Advantages
  - speed
  - simplicity of apparatus
  - use of off-the-shelf parts

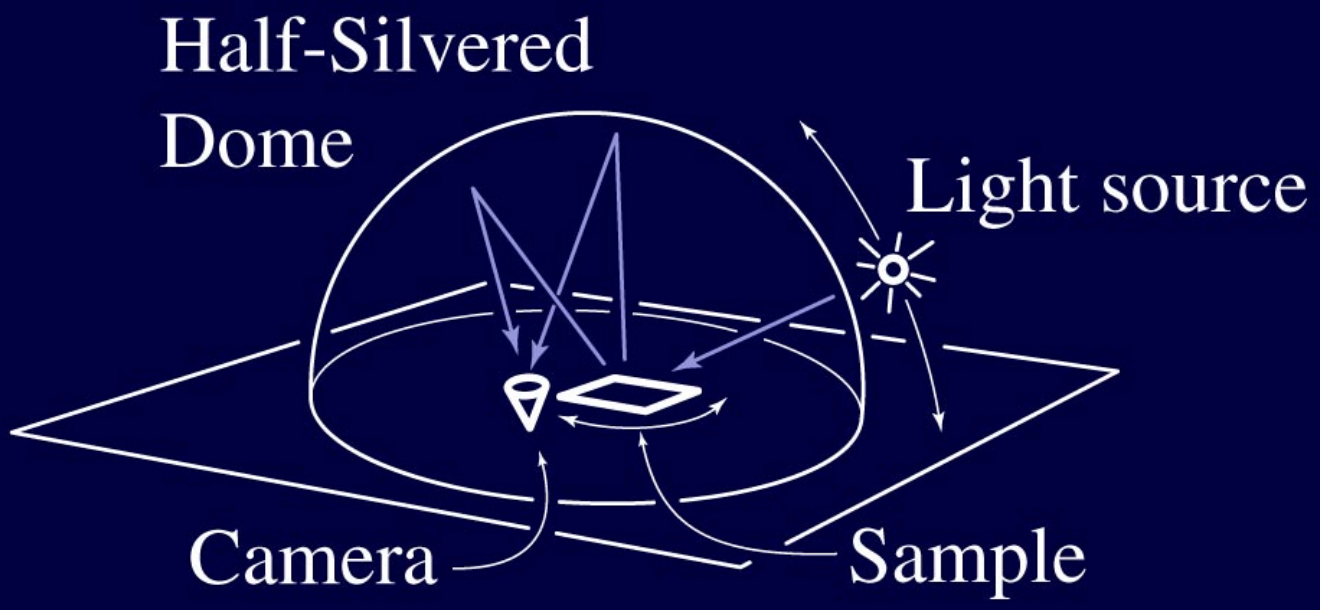
Karner, Mayer, & Gervautz 96

2 DOF: 2 sample



Ward 92

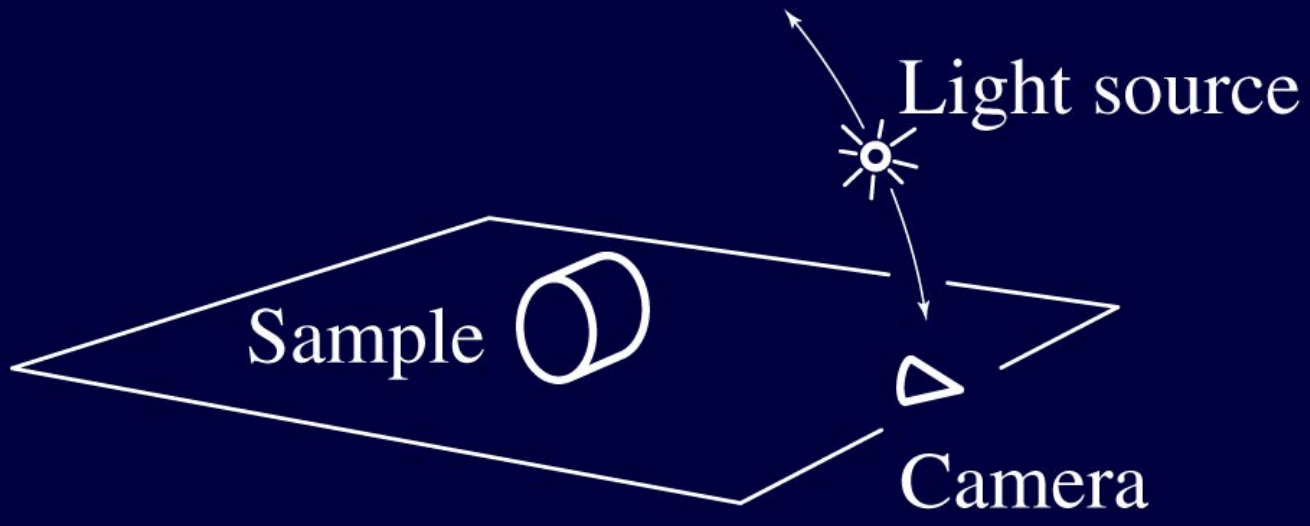
4 DOF: 2 image, 1 source, 1 sample



Castonguay 93

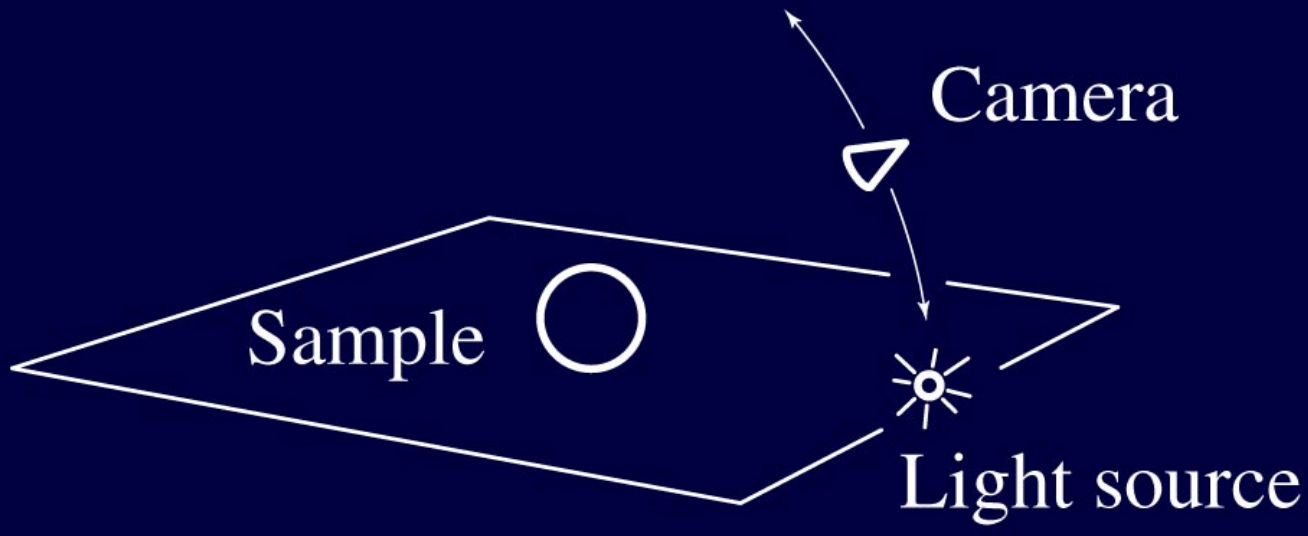
Lu, Koenderink, & Kappers 98

2+ DOF: 1 image, 1 source (plus 1 sample)



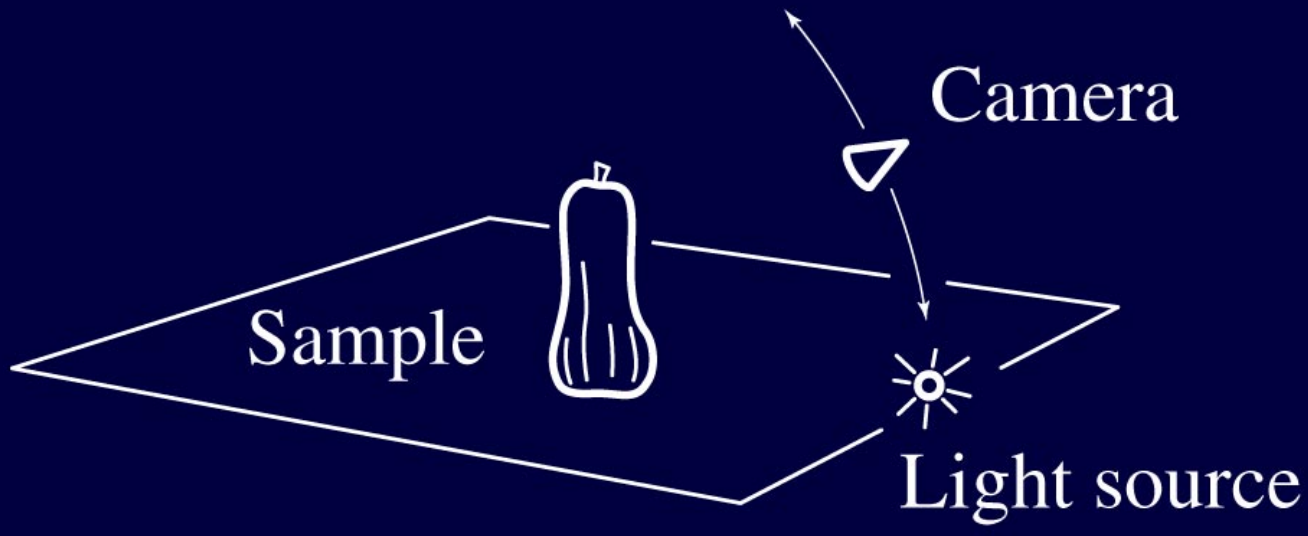
Our Technique

3 DOF: 2 image, 1 camera



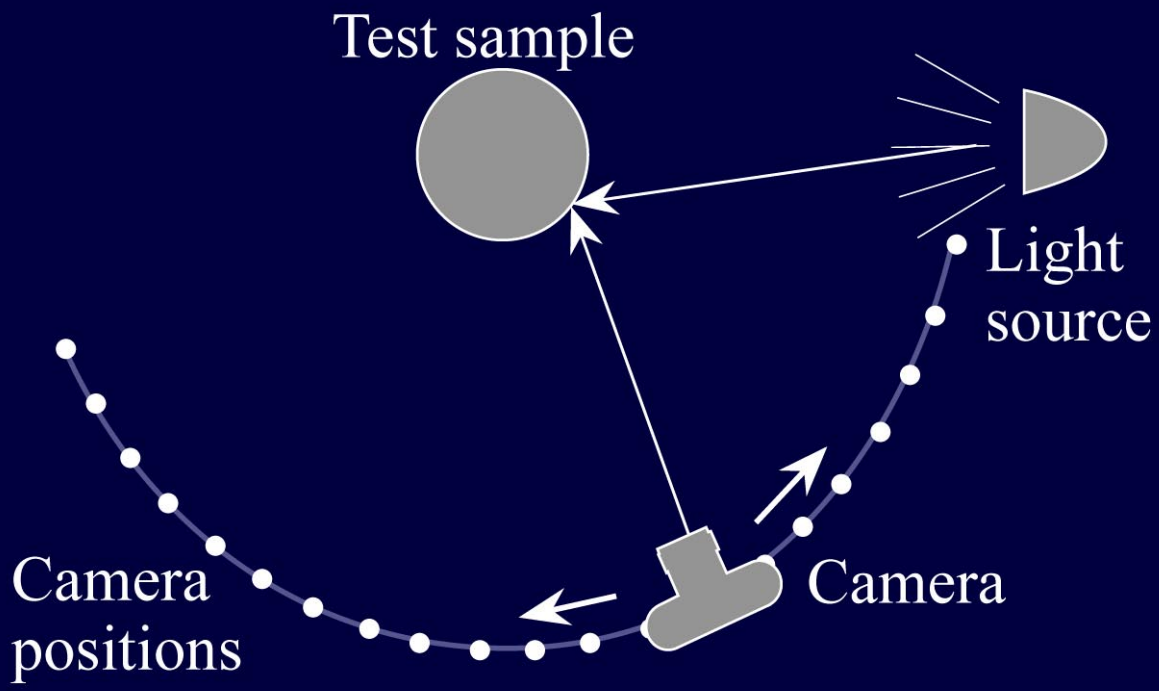
Our Generalized Technique

3 DOF: 2 image, 1 camera



Ikeuchi & Sato 91; Sato, Wheeler, & Ikeuchi 97

BRDF Measurement Setup



BRDF Measurement Setup

Calibration

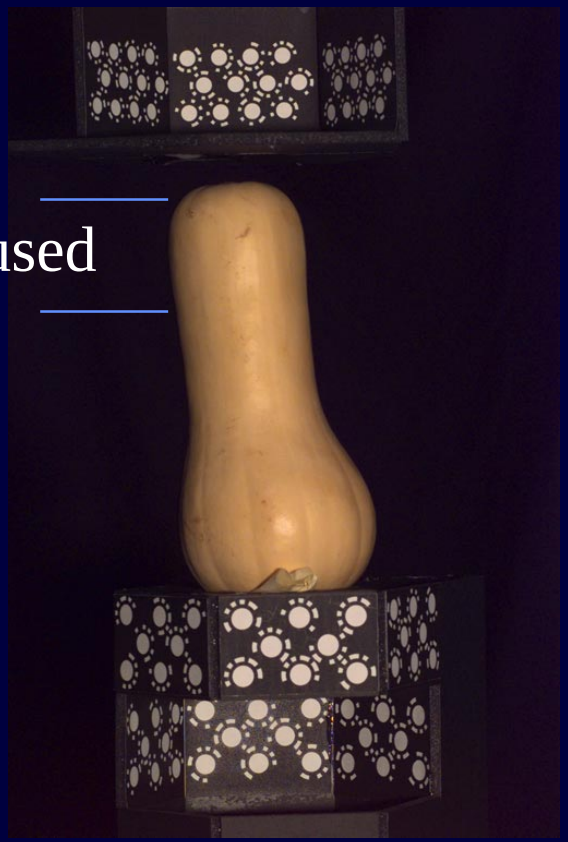
- Geometric
  - photogrammetric targets
  - image locations give transformations
  - 3 sets: sample, source, stationary
  - result: automatic, totally flexible calibration

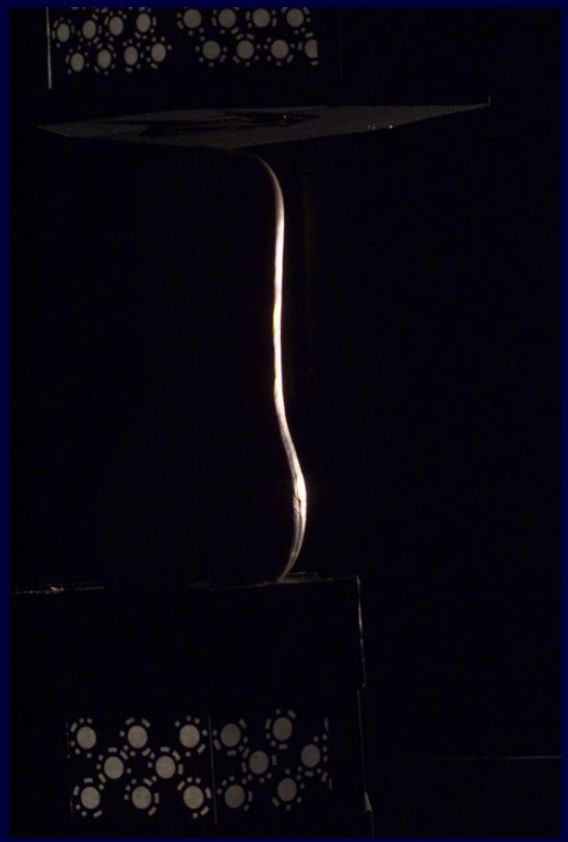
Calibration

- Radiometric
  - camera flat field
  - camera linearity
  - source flat field
  - absolute reflectance

BRDF Measurement Data

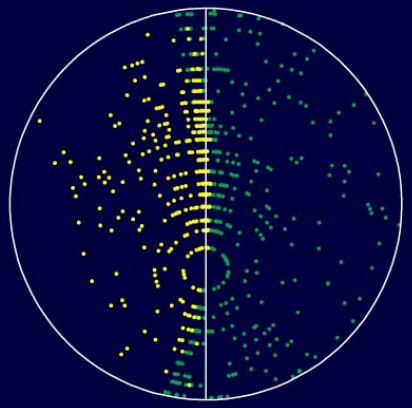
Geometry used

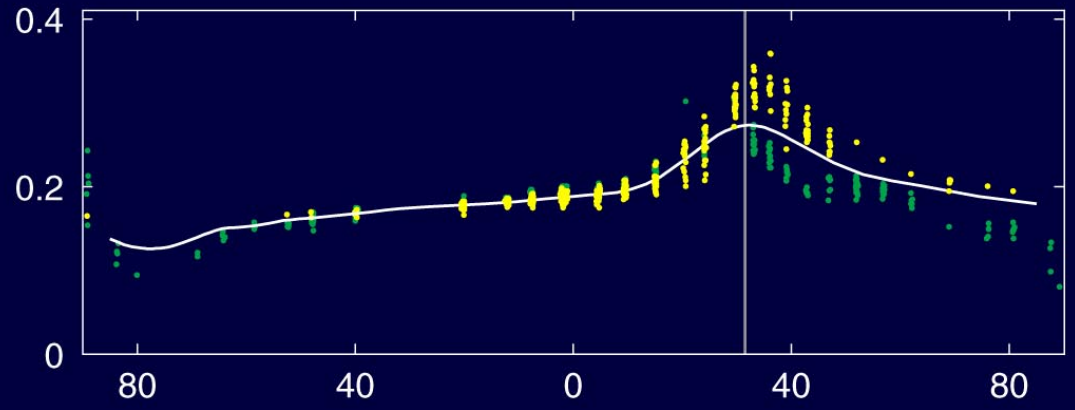




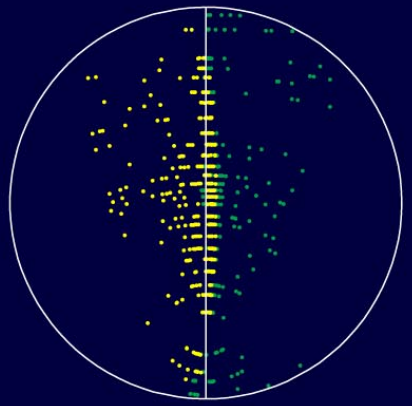
Measurement Results: Squash

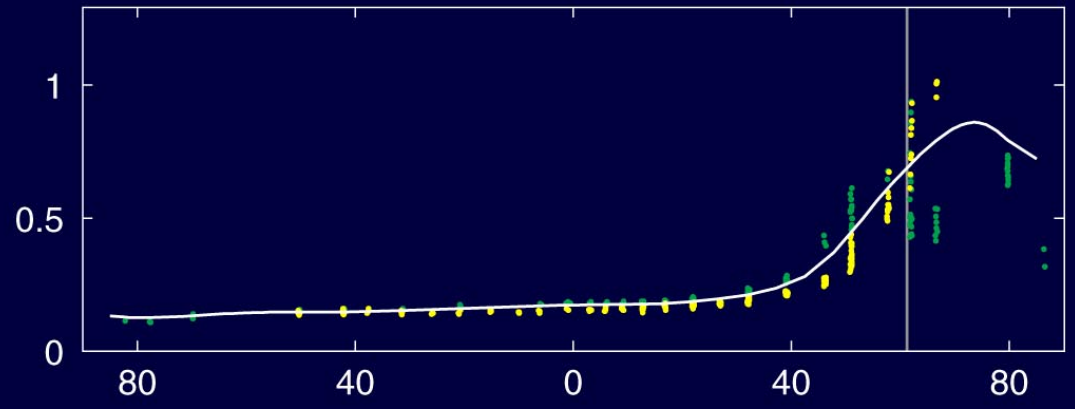
30˚



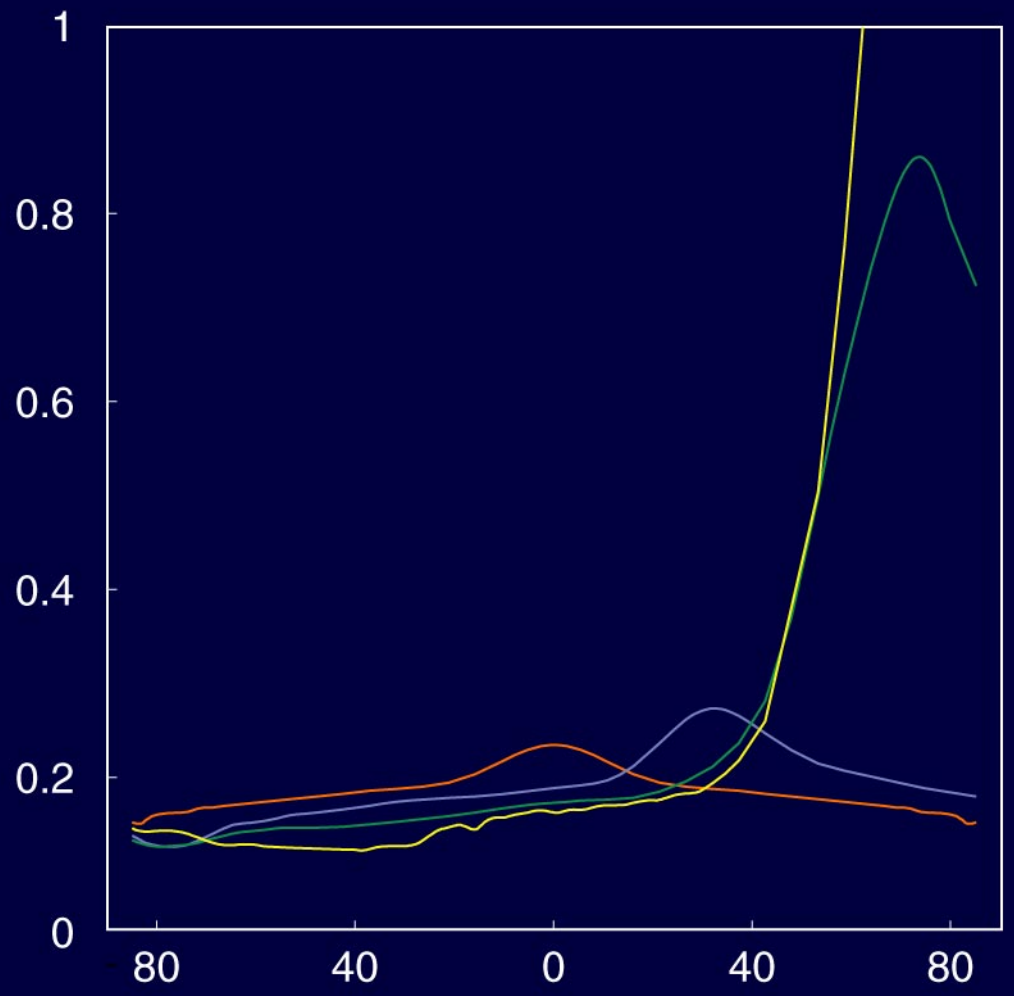


60˚

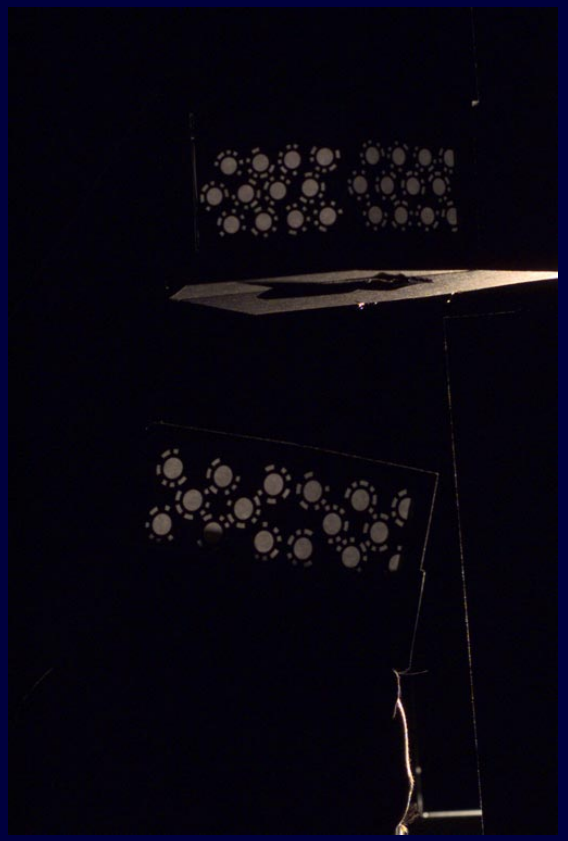




Measurement Results: Squash

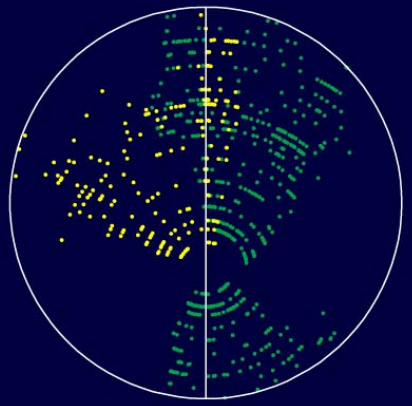


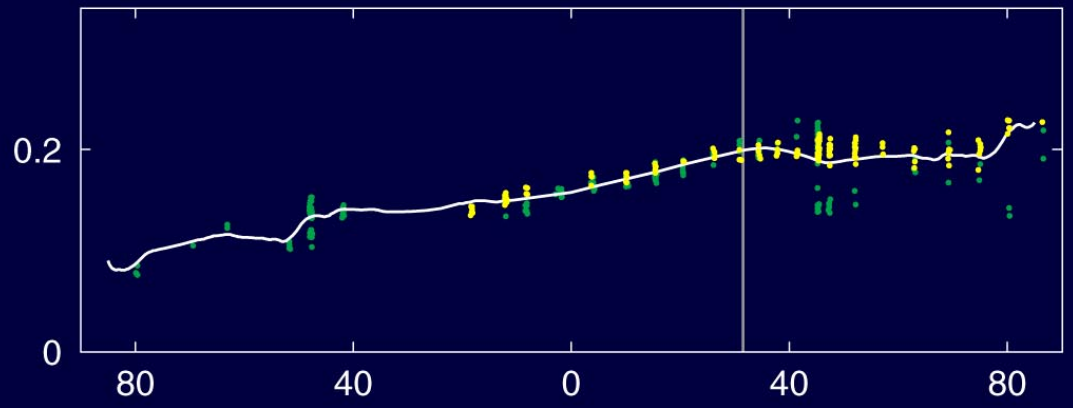
BRDF Measurement Data



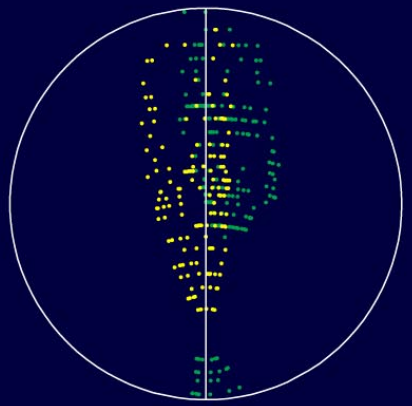
Measurement Results: Skin

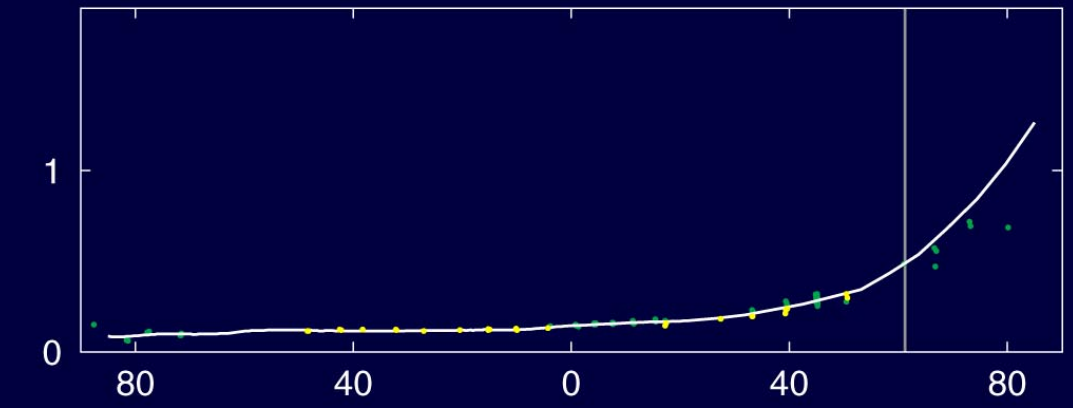
30˚



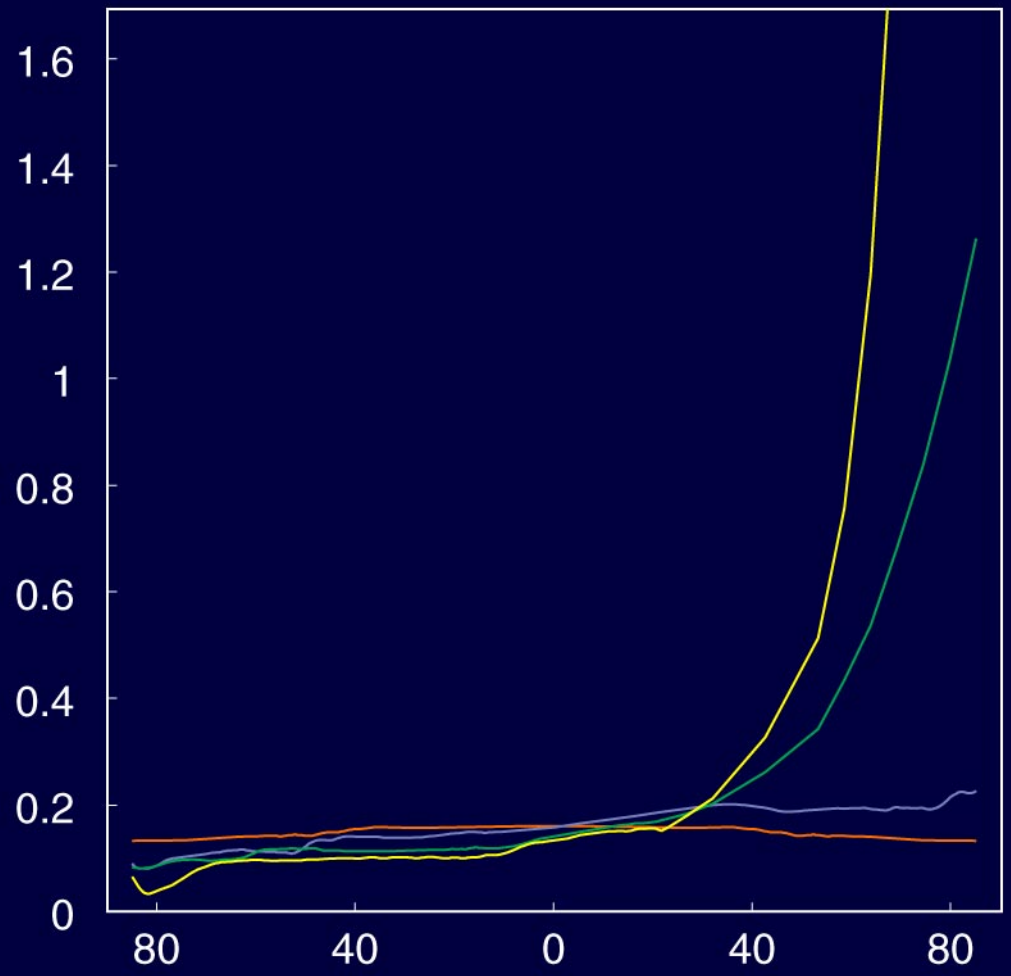


60˚





Measurement Results: Skin



Advantages & Limitations

- Advantages
  - measures curved samples
  - requires little time
  - requires little equipment w/o scanner
- Limitations
  - measures curved samples
  - measures homogeneous samples
  - requires scanner for arbitrary shapes

Future work

- Get rid of scanner: visual hull
- Video for more frames
- Higher dynamic range Debevec & Malik 97

Future Directions

- Integrated approach to surface appearance
  - BRDF
  - milligeometry
  - reflectance variation