# Modeling Anisotropic Surface Reflectance with Example-Based Microfacet Synthesis

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# Surface Reflectance

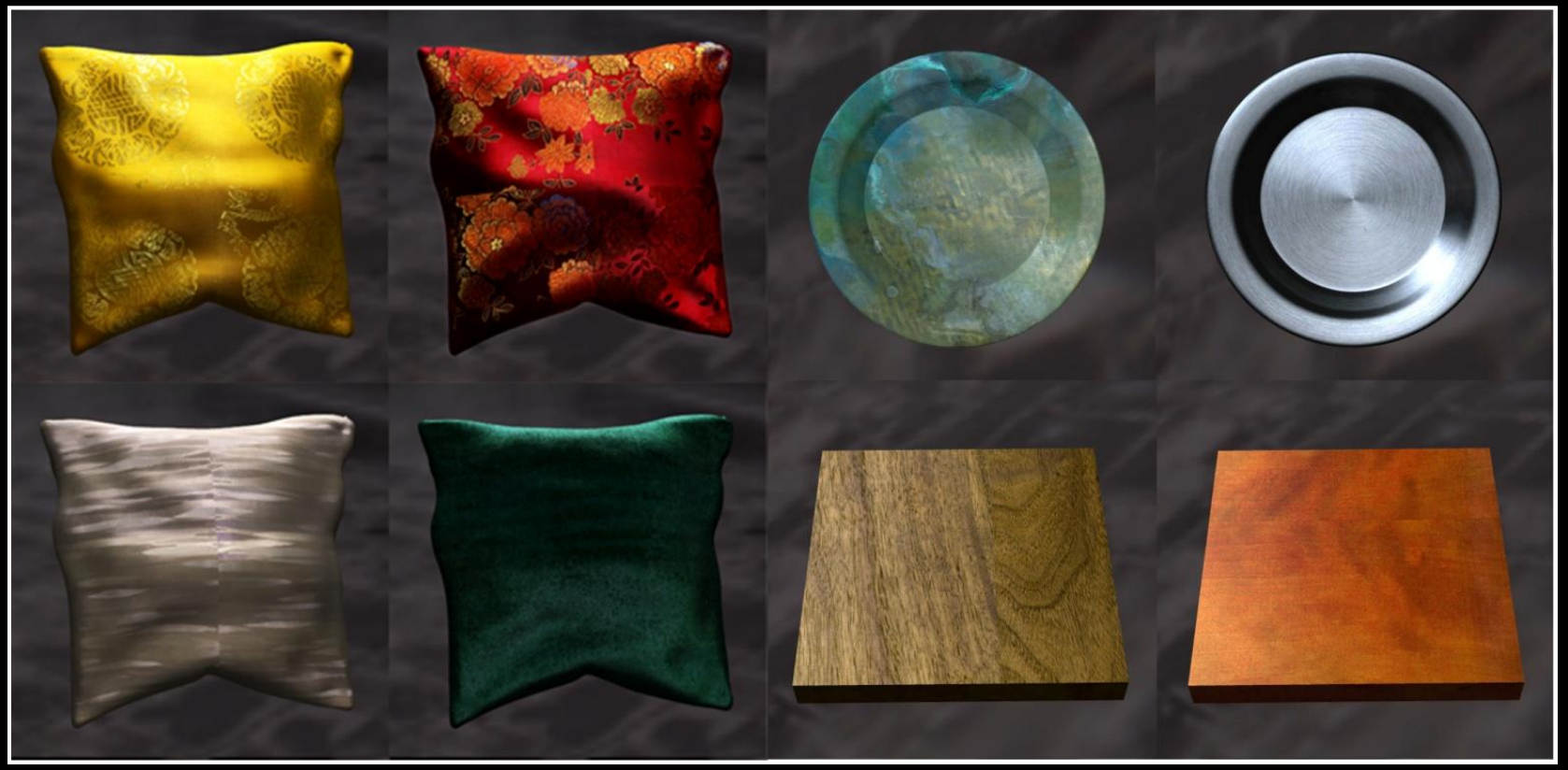
satin metal wood

# Anisotropic Surface Reflectance


anisotropic

isotropic

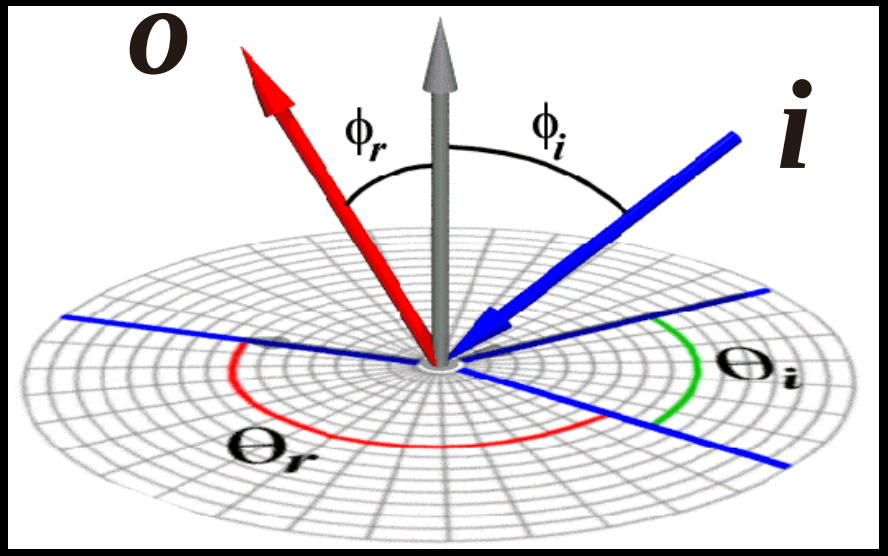
# Our Goal



*modeling spatially-varying anisotropic reflectance*

# Surface Reflectance in CG

- 4D BRDF $\rho(o,i)$
  - Bidirectional Reflectance Distribution Function
  - how much light reflected wrt in/out directions

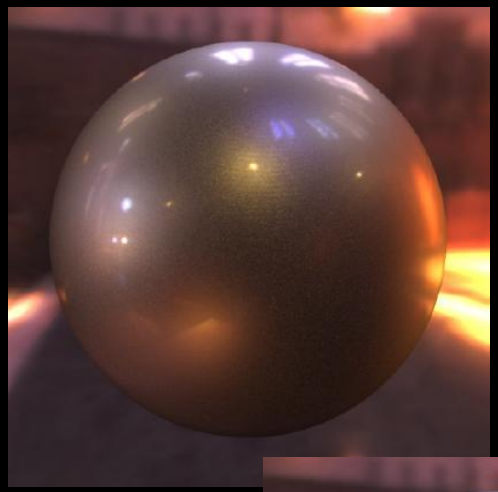


# Surface Reflectance in CG

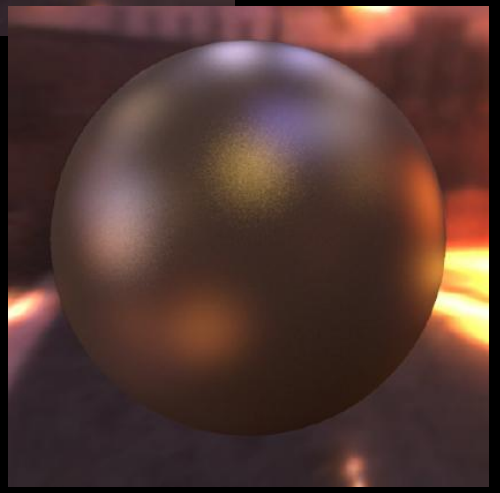
- 4D BRDF $\rho(o,i)$
  - Bidirectional Reflectance Distribution Function
  - how much light reflected wrt in/out directions
- 6D Spatially-Varying BRDF: SVBRDF $\rho(x,o,i)$
  - BRDF at each surface point $x$

# Related Work I

- parametric BRDF models
  - compact representation
  - easy acquisition and fitting
  - lack realistic details



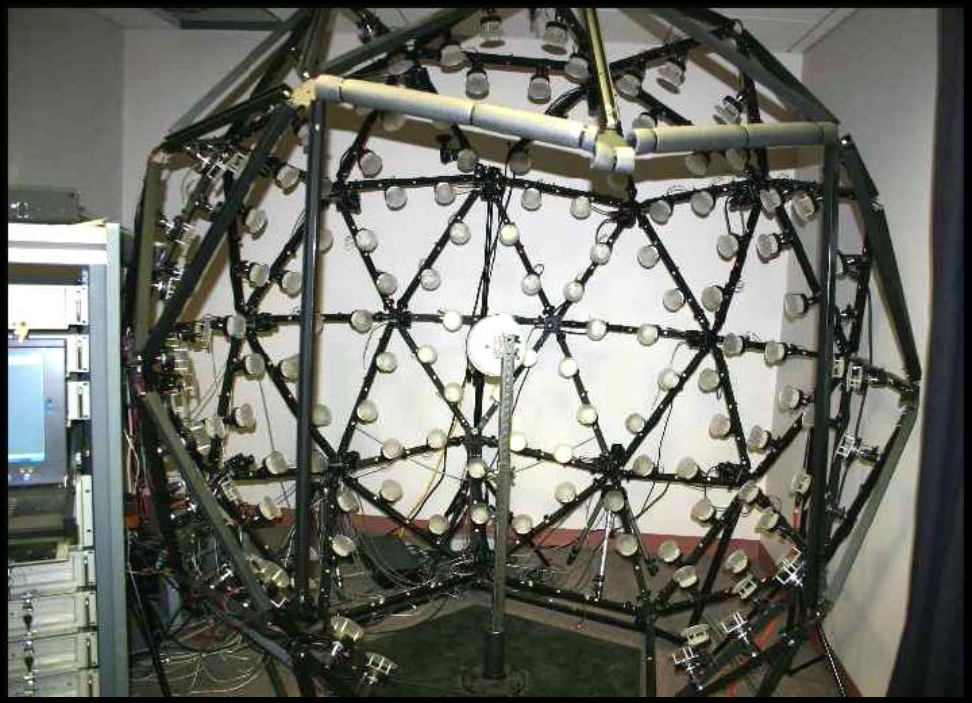
ground truth



parametric model
[Ward 92]

# Related Work II

- tabulated SVBRDF
  - realistic
  - large data set
  - difficult to capture
    - lengthy process
    - expensive hardware
    - image registration



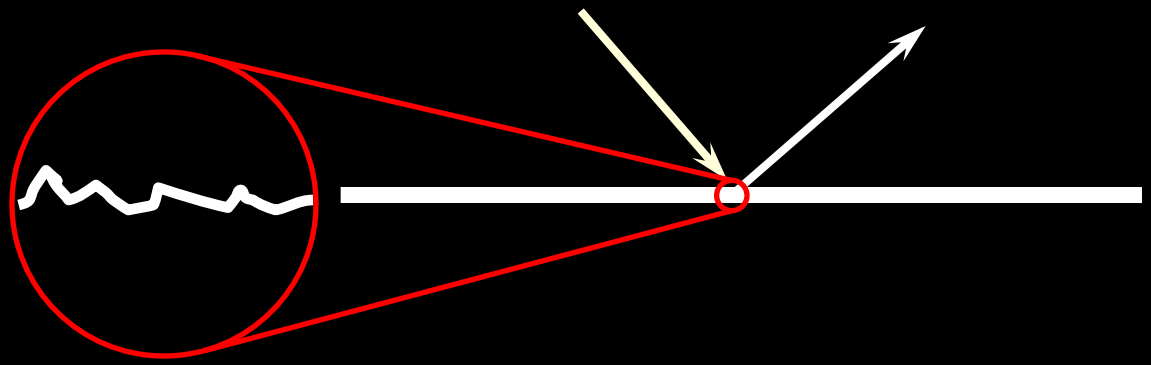
light dome [Gu et al 2006]

# Microfacet BRDF Model

- surface modeled by tiny mirror facets

$$\rho_s(x,o,i) = \frac{D(x,h)S(x,o)S(x,i)F(x,o,i)}{4(i\cdot n)(o\cdot n)}$$

[Cook 82]



# Microfacet BRDF Model

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[Cook 82]

# Microfacet BRDF Model

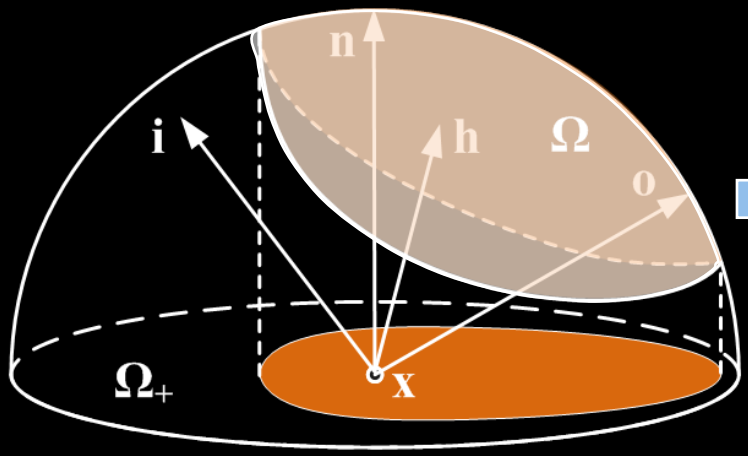
- Normal Distribution Function (NDF)

$$\rho_s(x,i,o) \backsim D(x,h) \qquad h = \frac{i+o}{\|i+o\|}$$

  - 2D function of the half-way vector $h$
  - term dominates surface appearance

# Challenge: Partial Domains

- samples from a single viewing direction
  - cover only a sub-region Ω of NDF
  - How to obtain the full NDF?




partial region

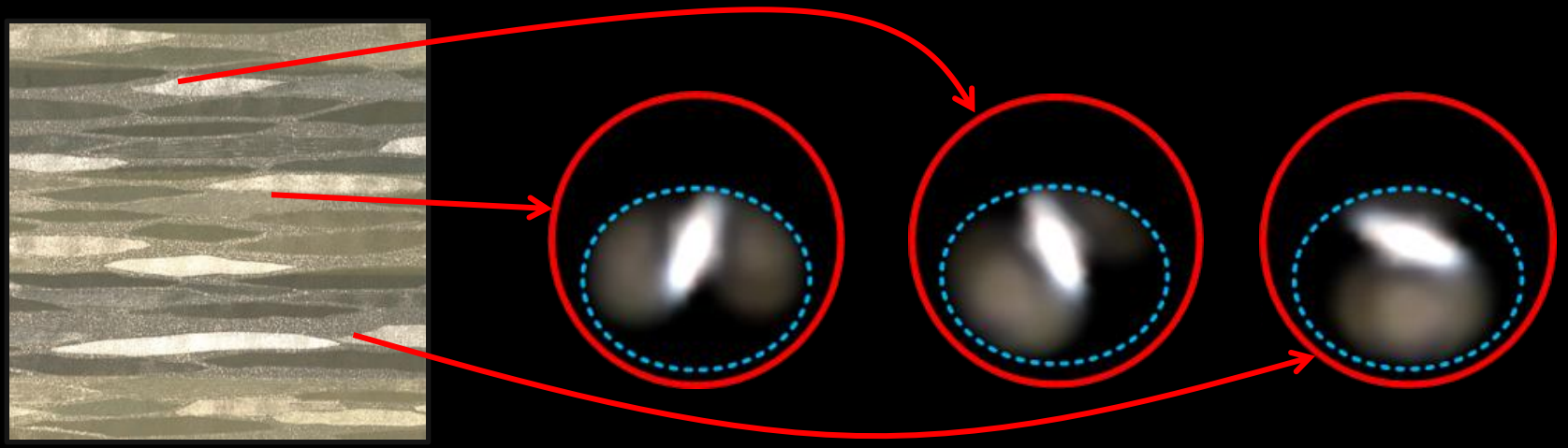
partial NDF

?

complete NDF

# Key Observation: Exploit Spatial Redundancy

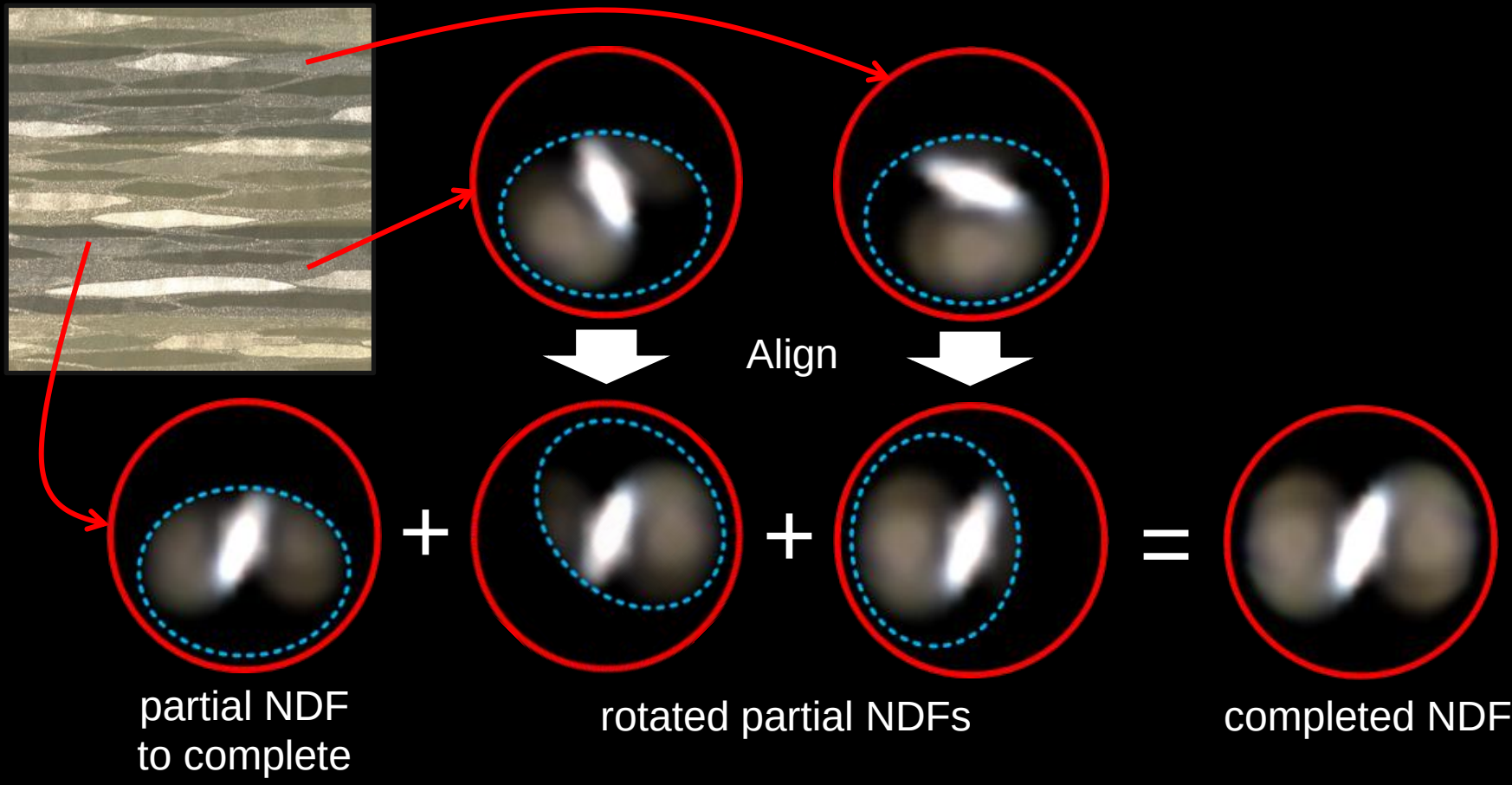
- find surface points with ***similar but differently rotated*** NDFs



material sample

partial NDF at each surface point

# Example-Based Microfacet Synthesis



# Comparison

- appearance under novel viewing/lighting

ground truth

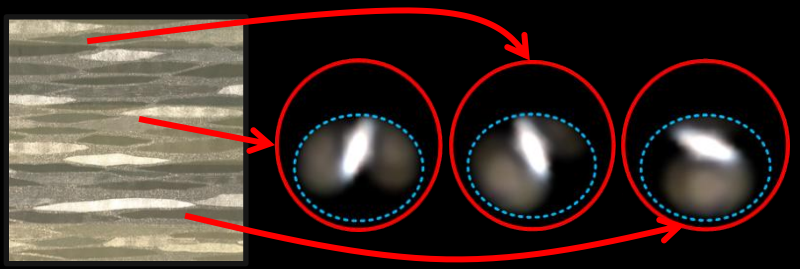
our model

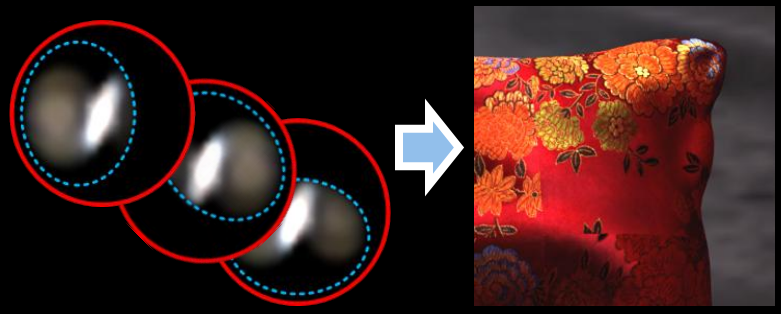
isotropic Ward model

anisotropic Ward model

# Overall Pipeline

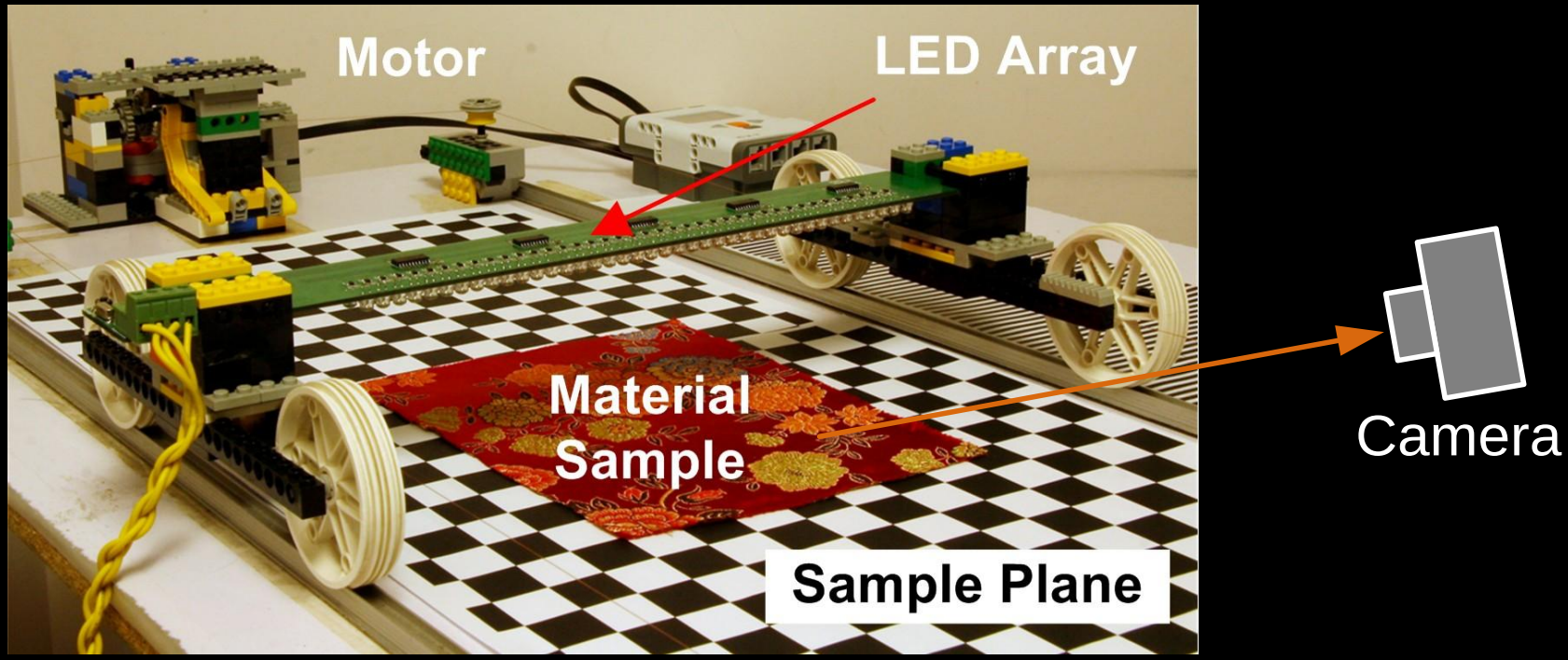
- Capture BRDF slice
- Partial NDF Recovery
- Microfacet Synthesis





# Device Setup

- Camera-LED system



# Capturing Process

# Modeling Process

- Partial NDF Recovery
- Example-Based Microfacet Synthesis

# NDF Recovery

- invert the microfacet BRDF model

$$\rho_s(x,o,i) = \frac{D(x,h)S(x,o)S(x,i)F(x,o,i)}{4(i\cdot n)(o\cdot n)}$$

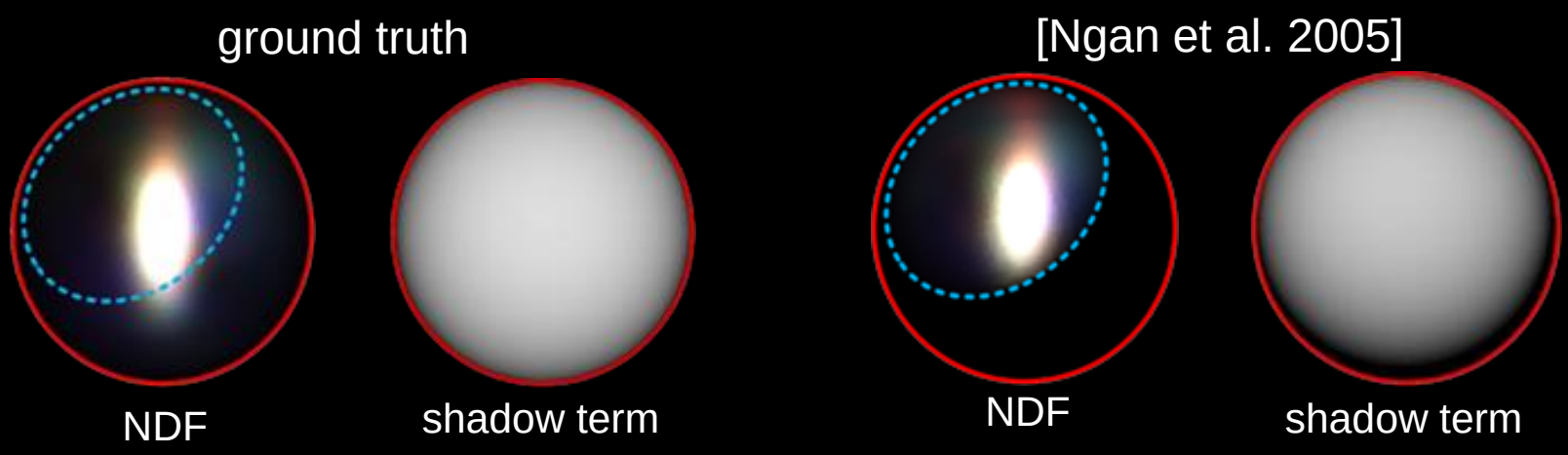
rearrange terms

$$D(x,h) = \frac{4\rho_s(x,o,i)(i\cdot n)(o\cdot n)}{S(x,o)S(x,i)F(x,o,i)}$$

with fixed $\boldsymbol{o}$

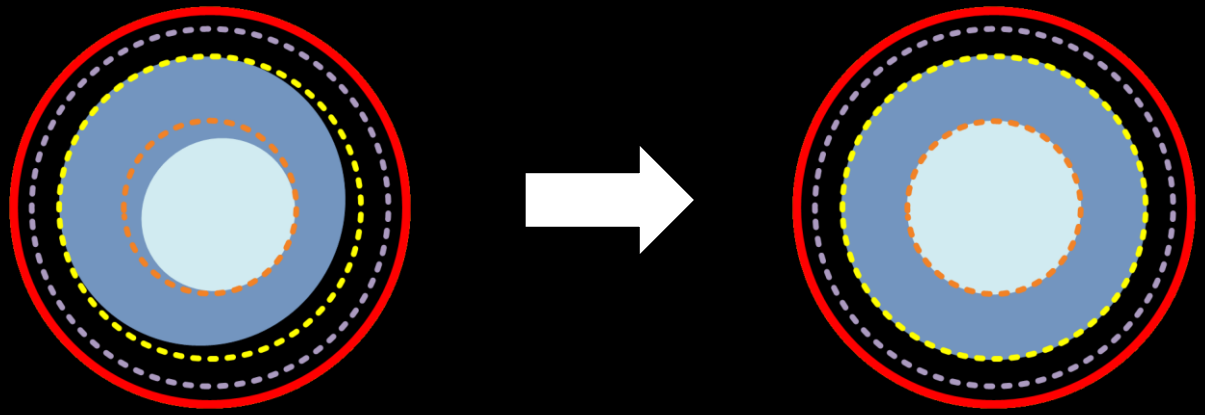
# Partial NDF Recovery

- straightforward solution leads to biased result
  - iteratively solve for NDF and shadow term
  - cross-talk between two terms for incomplete data



# Partial NDF Recovery (con’t)

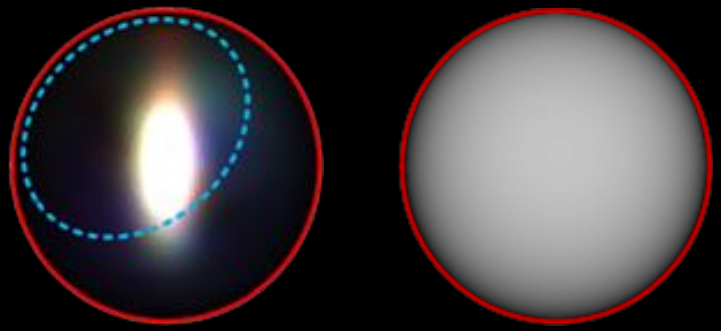
- minimize the cross-talk
  - isotropically constrain shadow term in each iteration



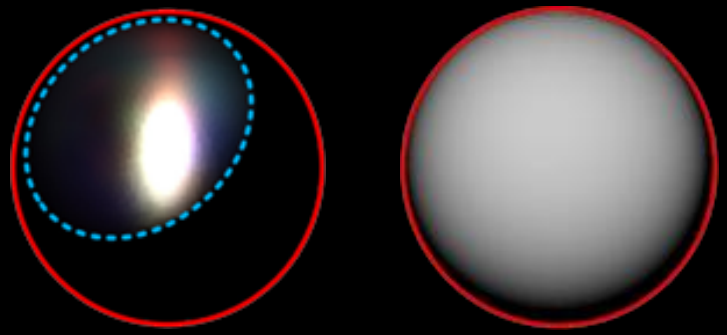
before constraint

after constraint

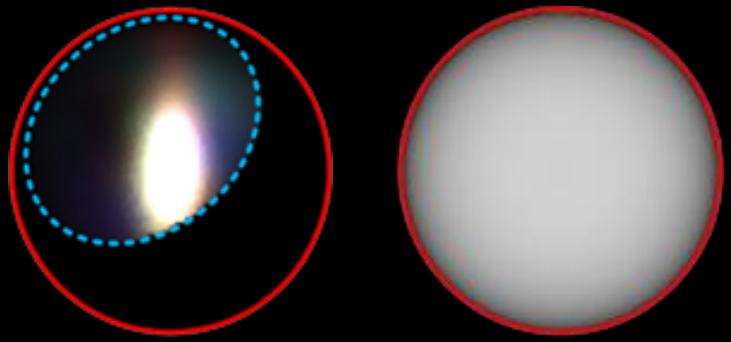
# Recovered Partial NDF



ground truth



[Ngan et al. 2005]



our result

# Microfacet Synthesis

partial NDFs from
other surface points

align

partial NDF
to complete

rotated partial NDFs

completed NDF

# Microfacet Synthesis (con’t)

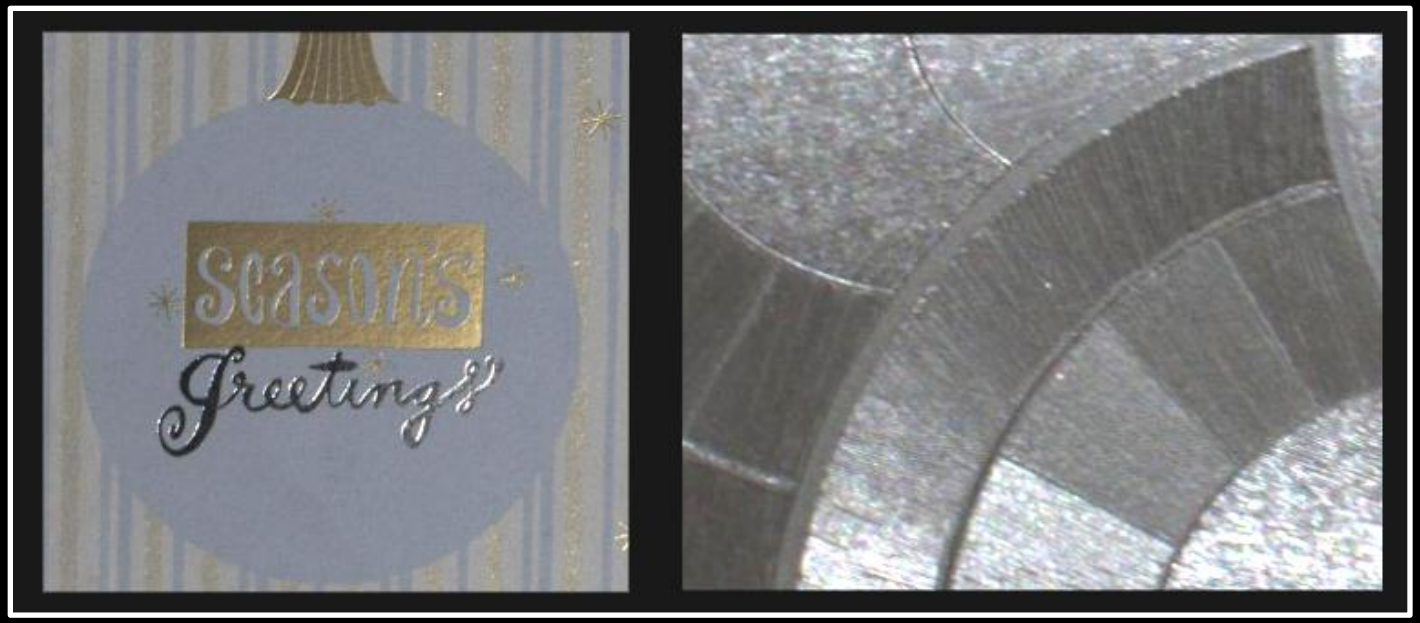
- straightforward impl. is too slow:
  - expensive distance calculation
  - huge number of surface points (search)
  - hundreds of rotation angles (alignment)

# Accelerating Synthesis

- NDF Clustering
  - complete NDFs on a smaller set of representatives (1%)
  - search candidates from representatives only
- Search Pruning
  - approximate nearest neighbor acceleration [Mount 97]
  - key = histogram

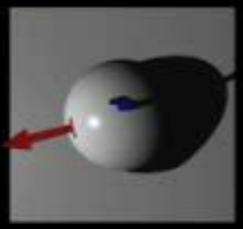
# Model Validation

- full SVBRDF dataset [Lawrence et al. 2006]
  - data from one view for training
  - data from other views for validation



# Validation Result


Ground Truth from IST Data Set



Our Synthesized Result

# Rendering Result: Satin

# Rendering Result: Wood

# Rendering Result: Brushed Metal

# Conclusion

- model surface reflectance via microfacet synthesis
  - general and compact representation
  - high resolution (spatial & angular), realistic result
  - easier to acquire from real world material samples
    - singe-view capture
    - cheap device
    - shorter capturing time

# Thank You!