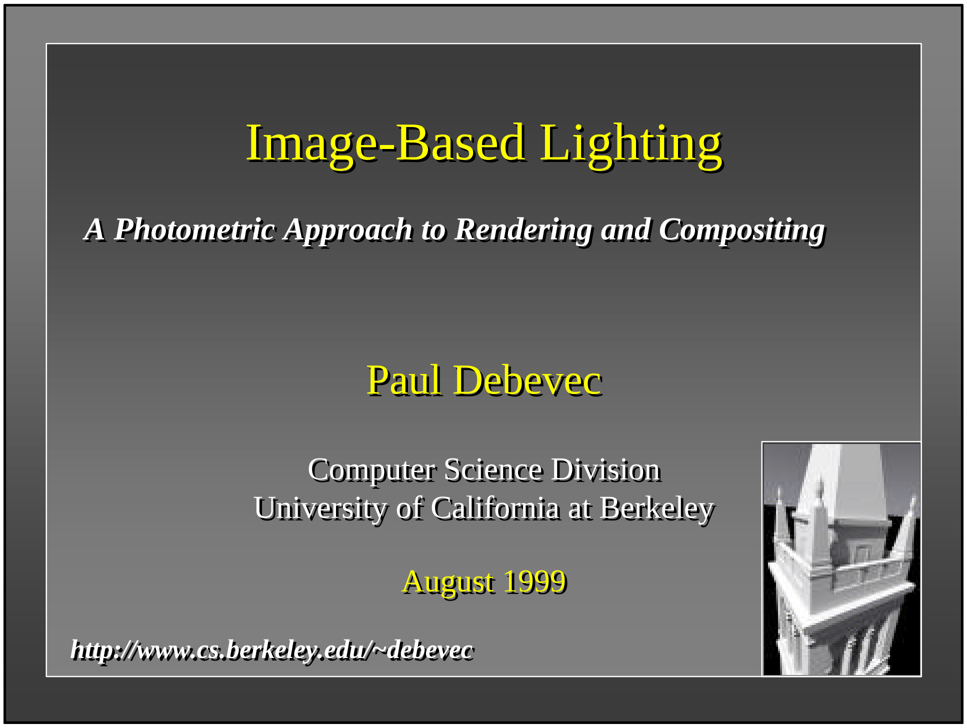
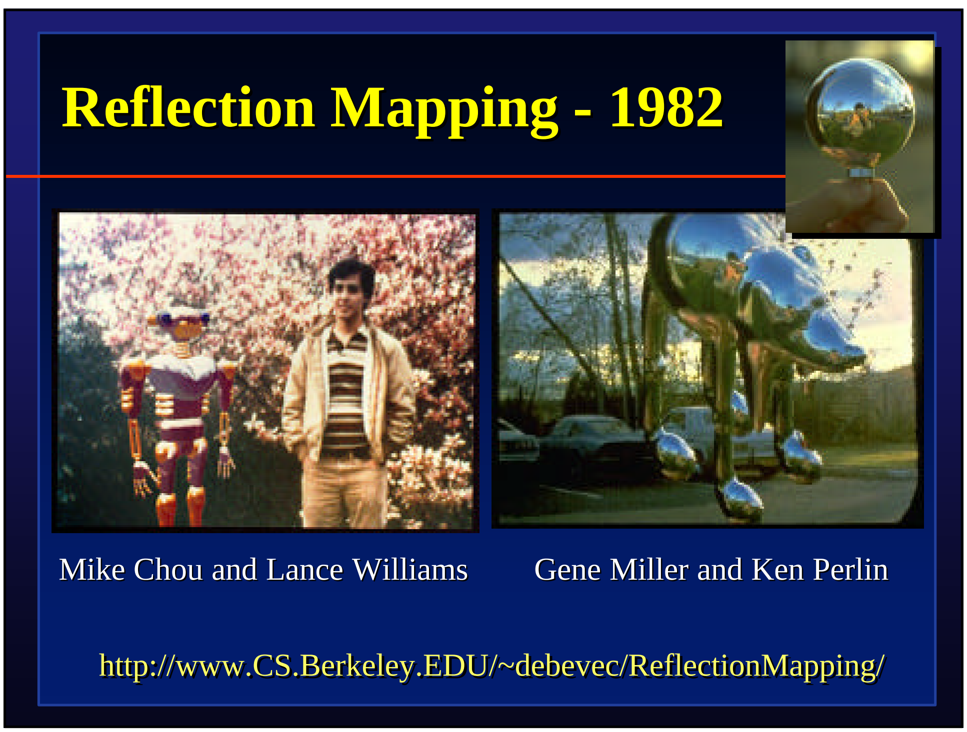


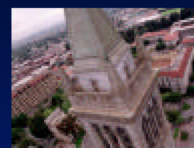
Image-Based Lighting
A Photometric Approach to Rendering and Compositing
Paul Debevec
Computer Science Division
University of California at Berkeley
August 1999
http://www.cs.berkeley.edu/~debevec


Reflection Mapping - 1982
Mike Chou and Lance Williams
Gene Miller and Ken Perlin
http://www.CS.Berkeley.EDU/~debevec/ReflectionMapping/

Motivations

Image-Based Modeling and Rendering

- IBMR allows us to model and render real scenes
- We want to add new objects
  - buildings, furniture, people
- We want the lighting to be correct



CGI / Background Plate Compositing

- Want to add synthetic actors, creatures, props to film and video
- Must be photorealistic
- Current techniques are challenging

CGI / Background Plate Compositing

Need to match:

- Camera Parameters
  - Pose, Focal length, Distortion, Focus
- Film Response
  - Contrast, Toe & Shoulder, Color Balance
- MTF / Film Grain
  - Modulation Transfer Function, Ag Particles
- Illumination
  - Highlights, Reflections, and Shadows

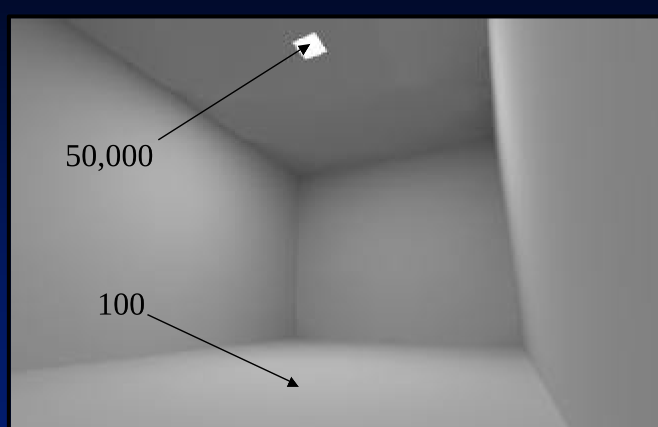
Photometric Approach:

Illuminate Synthetic Objects
with Measurements of
Real Light

How can we measure the light?

Light is difficult to measure

Concentrated Light Sources => High Dynamic Range



10’ x 15’ x 9’ room, 9” by 9” light, 50% reflective walls

Mirrored Ball - Records light in all directions

Brightest regions are saturated

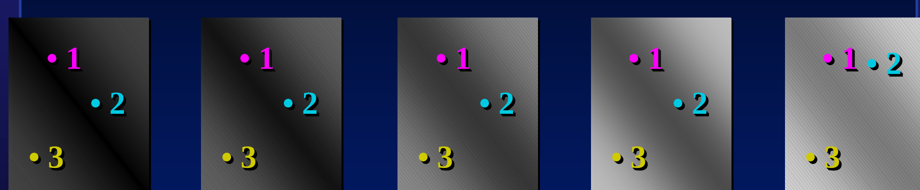
⬇

Intensity and color information lost

High Dynamic Range Photography

Debevec and Malik, SIGGRAPH 97

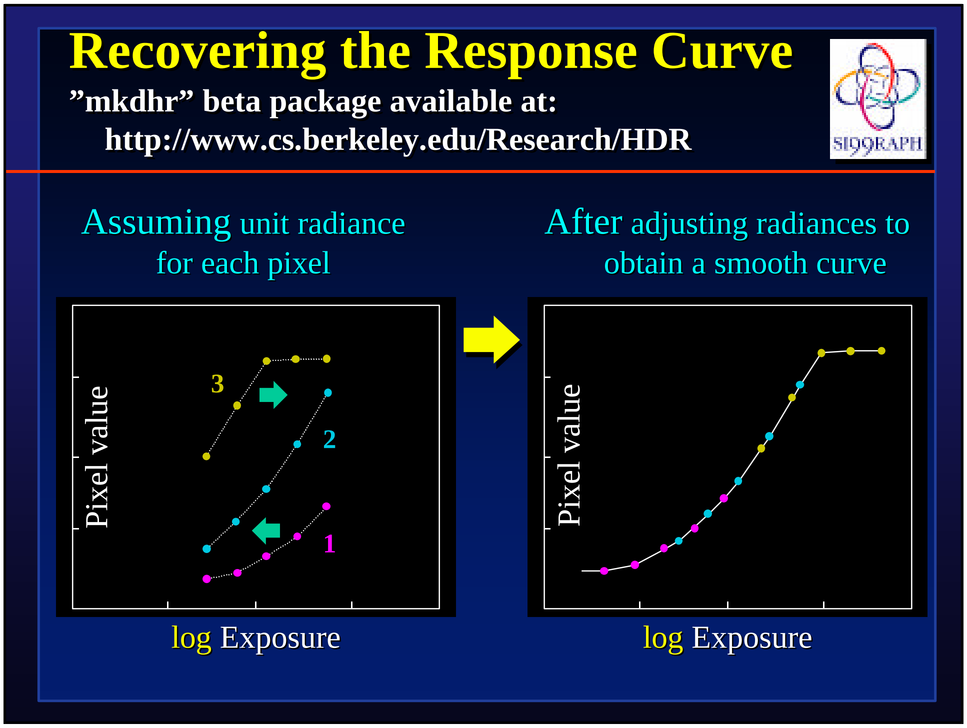
Image series

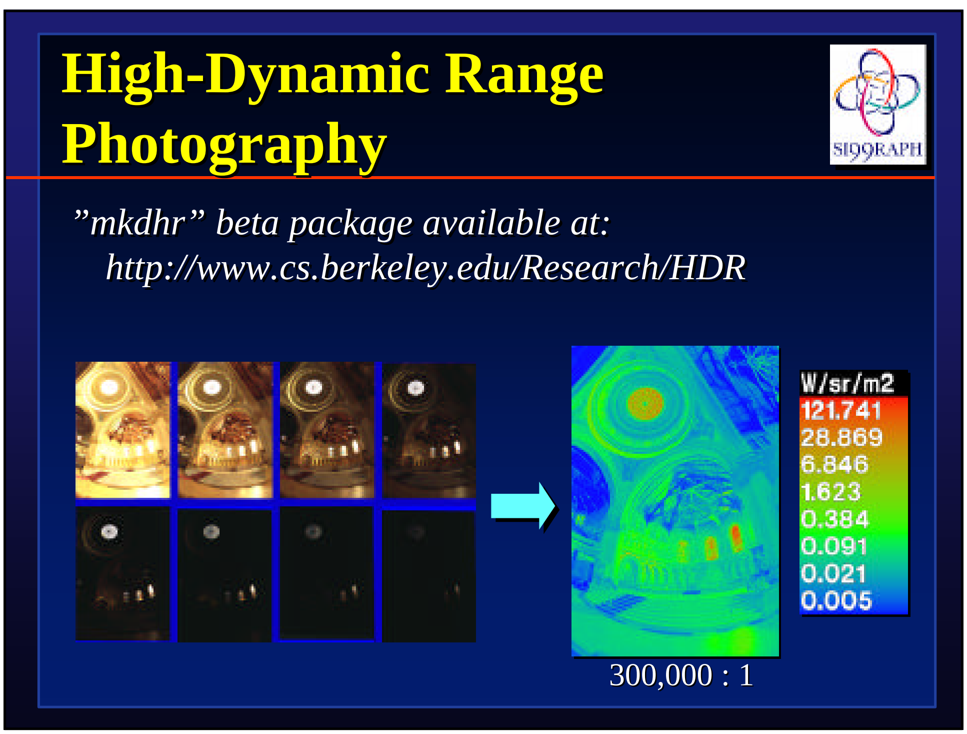


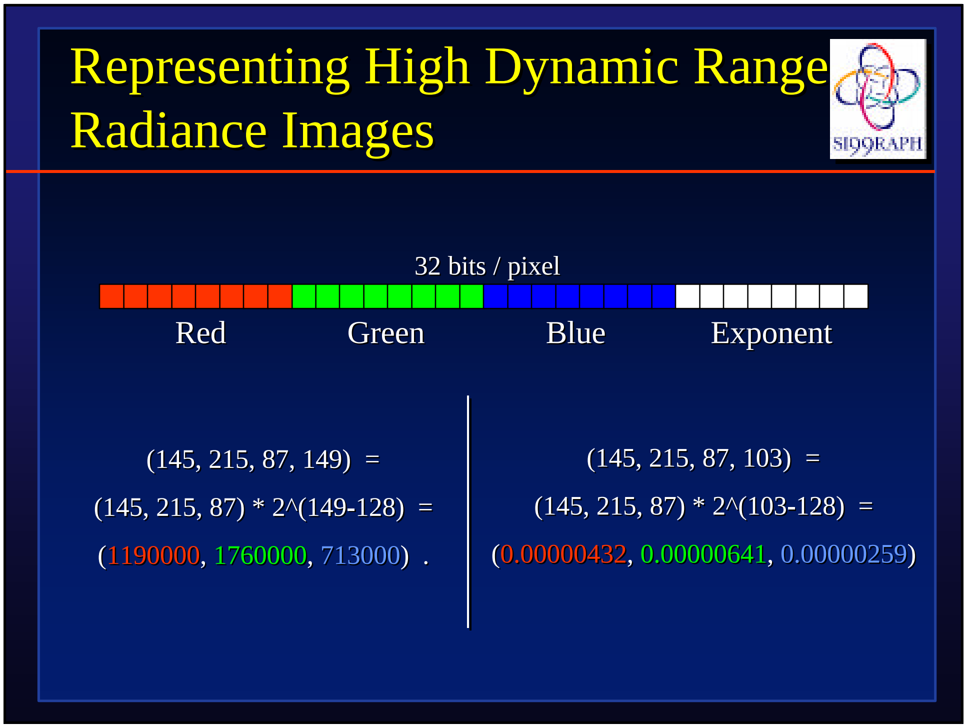
Δt = 1/64 sec	Δt = 1/16 sec	Δt = 1/4 sec	Δt = 1 sec	Δt = 4 sec

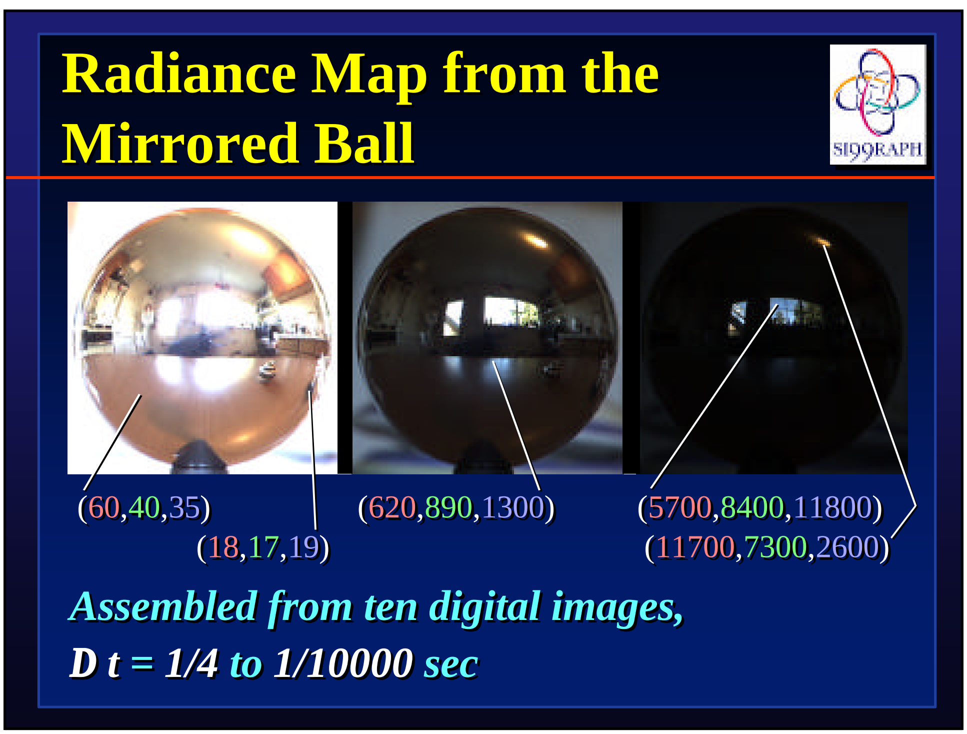
$$\text{Exposure} = \text{Radiance} \times \Delta t$$

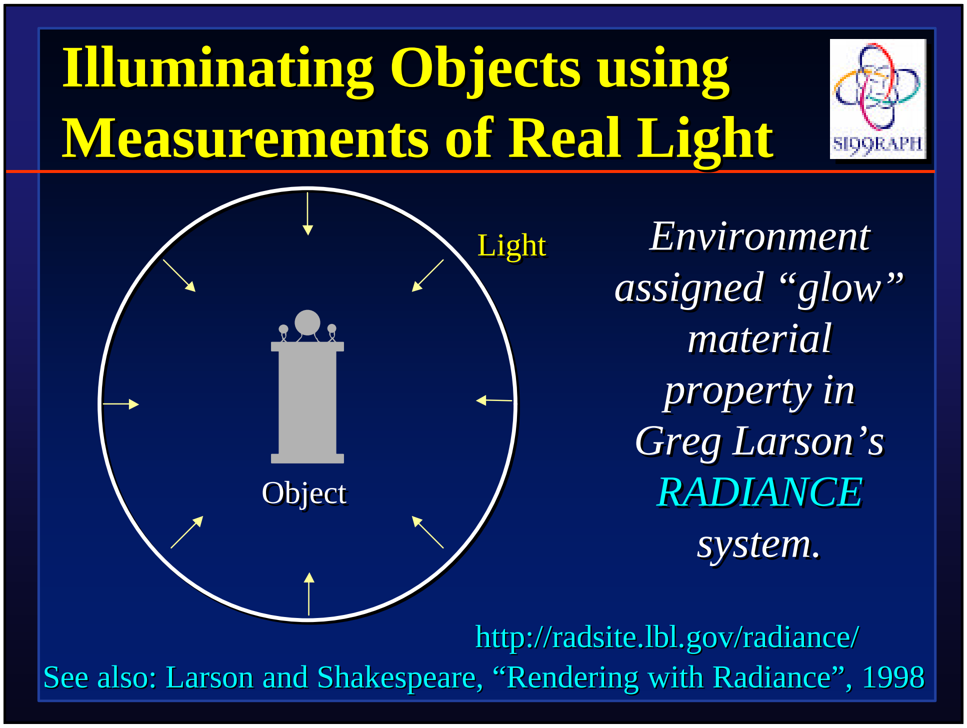
$$\log \text{Exposure} = \log \text{Radiance} + \log \Delta t$$

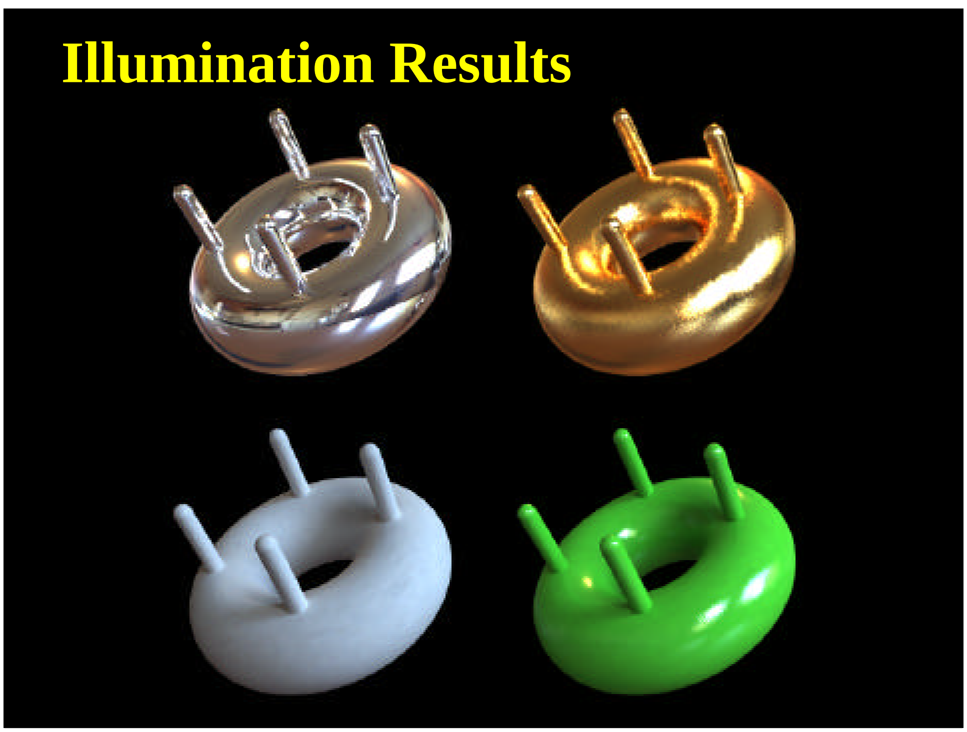

Recovering the Response Curve
"mkdhr" beta package available at:
http://www.cs.berkeley.edu/Research/HDR
SIGGRAPH
Assuming unit radiance for each pixel
After adjusting radiances to obtain a smooth curve
Pixel value
3
2
1
log Exposure
Pixel value
log Exposure

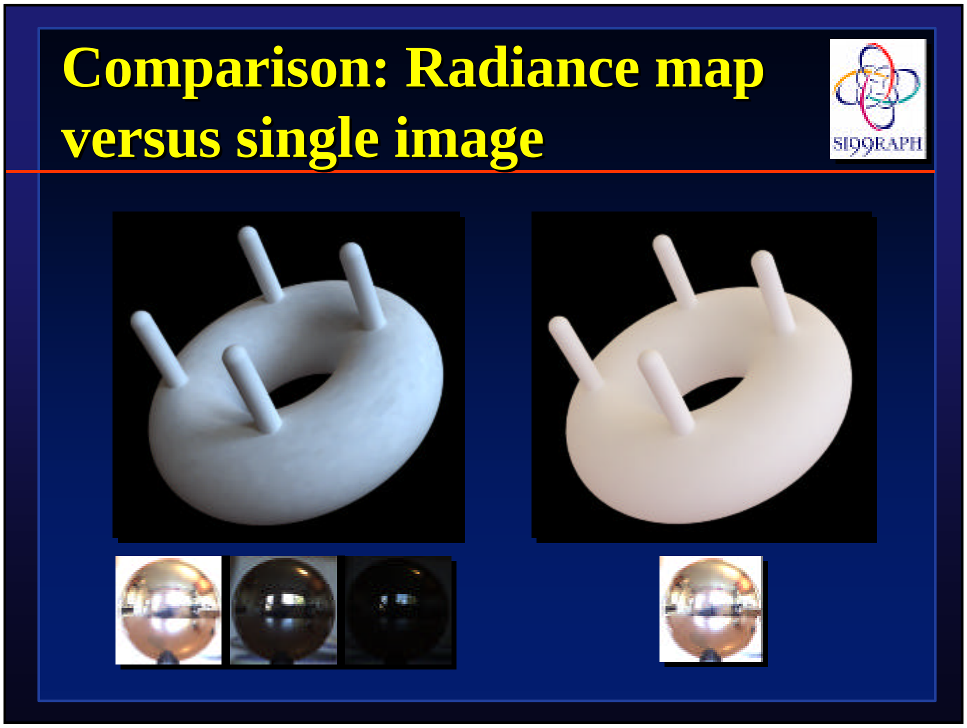

High-Dynamic Range Photography
SIGGRAPH
"mkdhr" beta package available at:
http://www.cs.berkeley.edu/Research/HDR
W/sr/m2
121.741
28.869
6.846
1.623
0.384
0.091
0.021
0.005
300,000 : 1

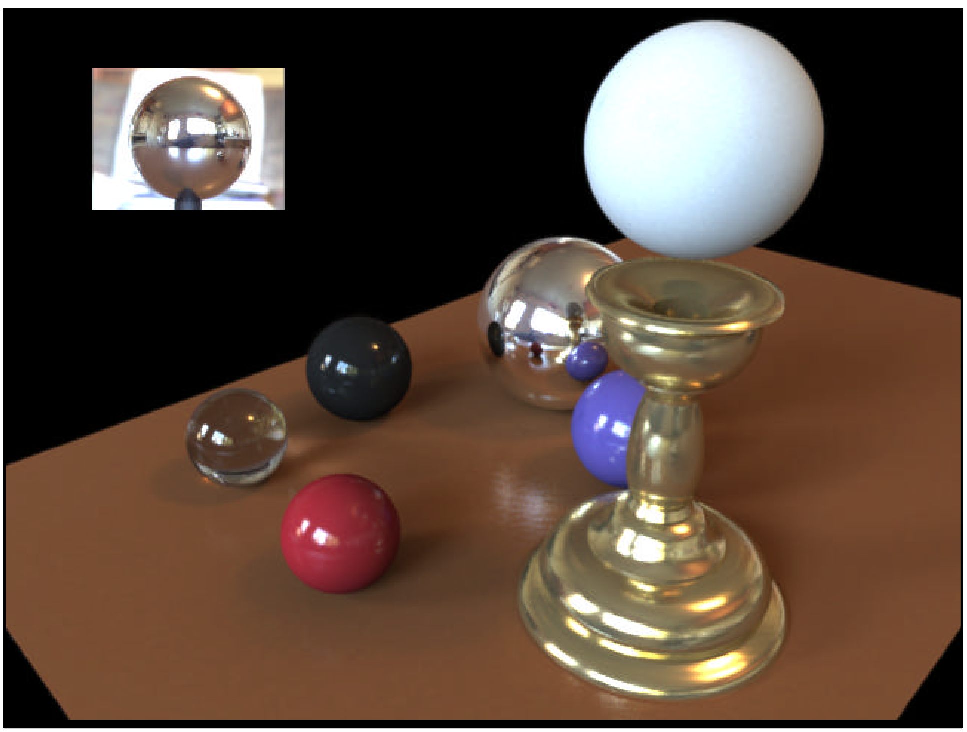

Representing High Dynamic Range Radiance Images
SI99RAPH
32 bits / pixel
Red
Green
Blue
Exponent
(145, 215, 87, 149) =
(145, 215, 87) * 2^(149-128) =
(1190000, 1760000, 713000) .
(145, 215, 87, 103) =
(145, 215, 87) * 2^(103-128) =
(0.00000432, 0.00000641, 0.00000259)

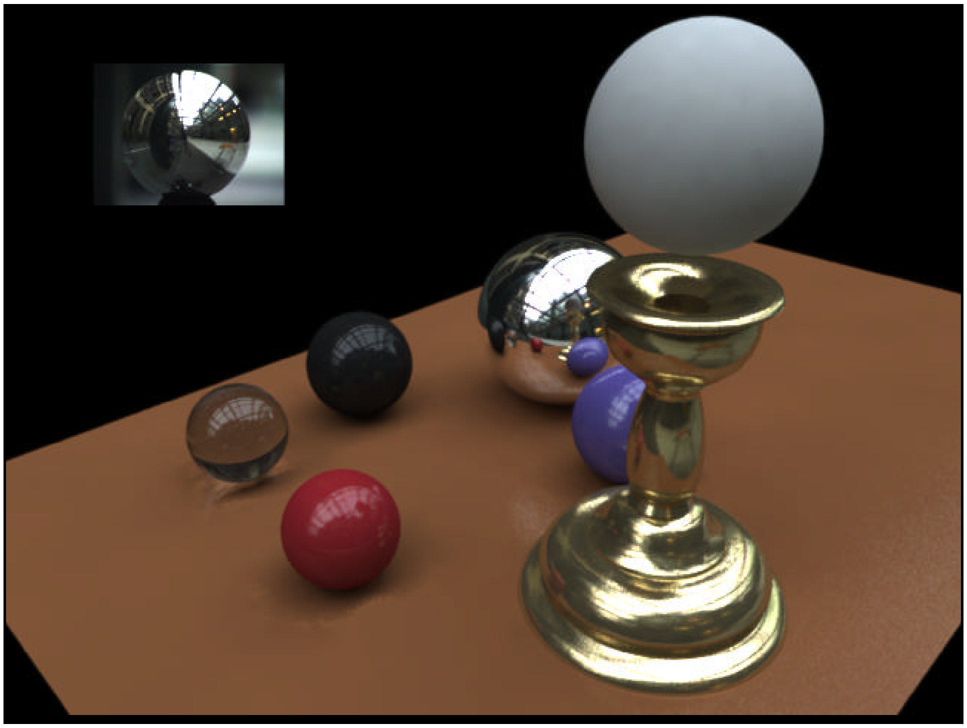

Radiance Map from the Mirrored Ball
SI99RAPH
(60,40,35)
(18,17,19)
(620,890,1300)
(5700,8400,11800)
(11700,7300,2600)
Assembled from ten digital images,
D t = 1/4 to 1/10000 sec


Illuminating Objects using Measurements of Real Light
SI99RAPH
Light
Object
Environment assigned "glow" material property in Greg Larson's RADIANCE system.
http://radsite.lbl.gov/radiance/
See also: Larson and Shakespeare, "Rendering with Radiance", 1998


Illumination Results


Comparison: Radiance map versus single image
SI99RAPH





Video

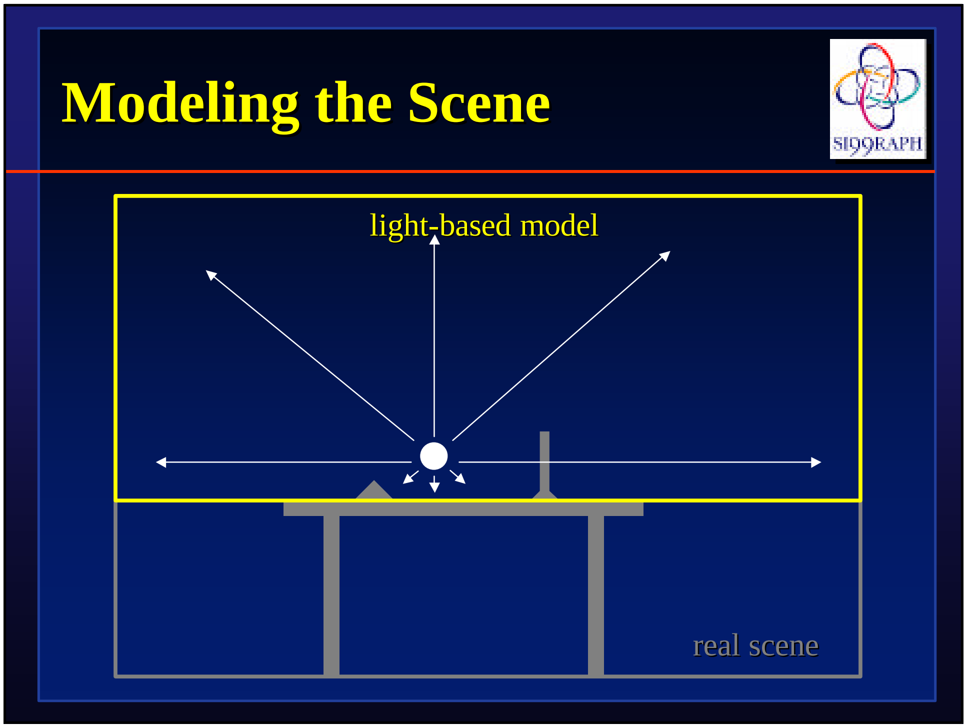
We can now illuminate synthetic objects with real light.

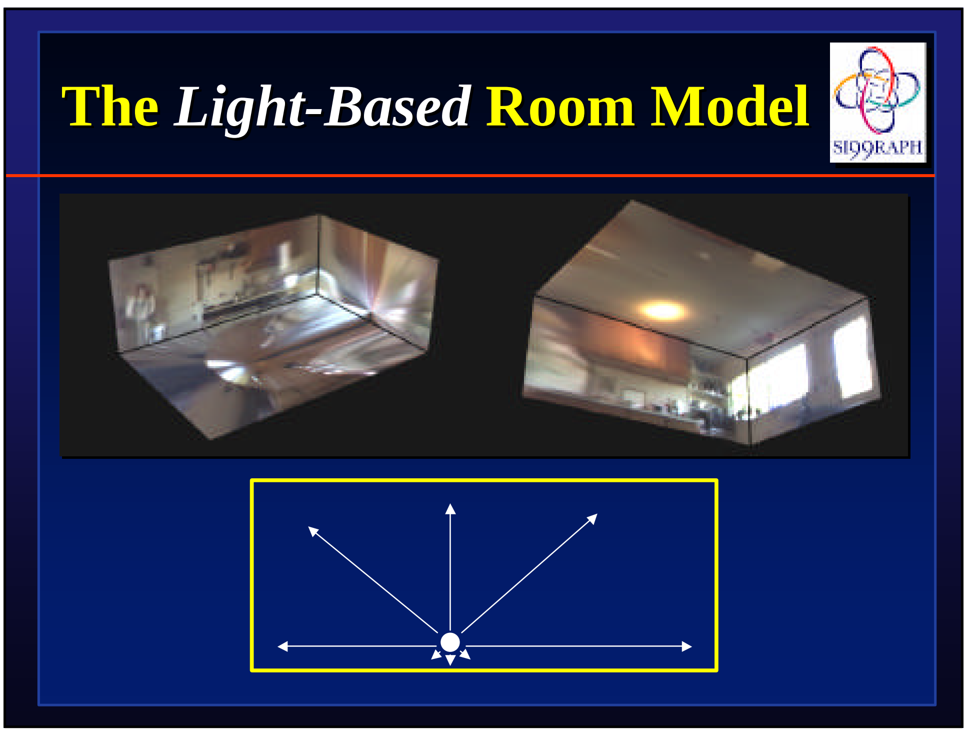
How do we add synthetic objects to a real scene?

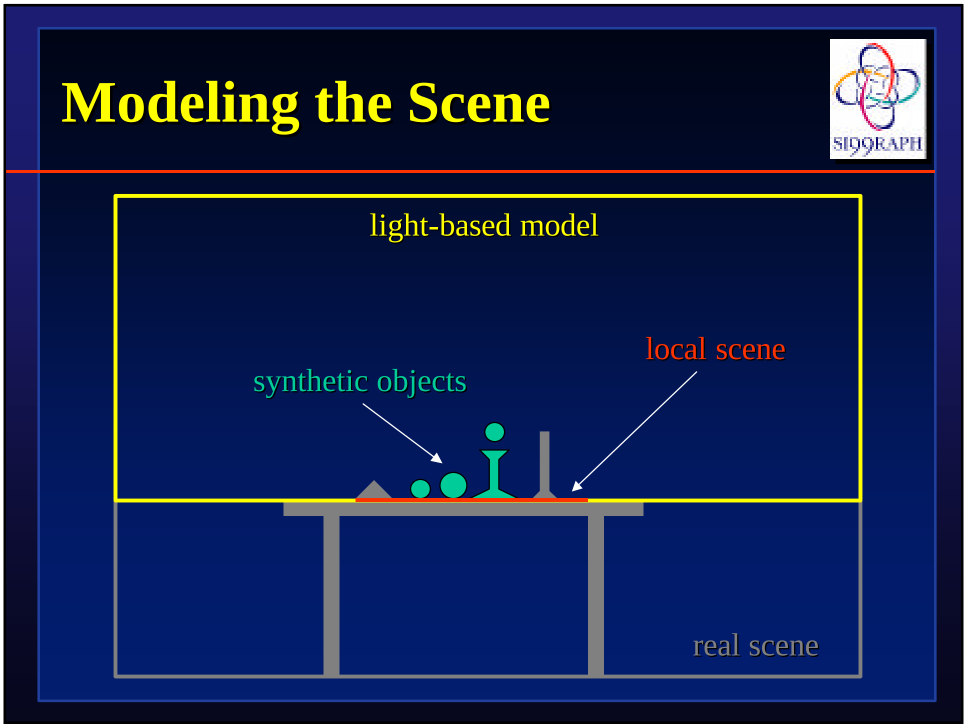
Real Scene Example

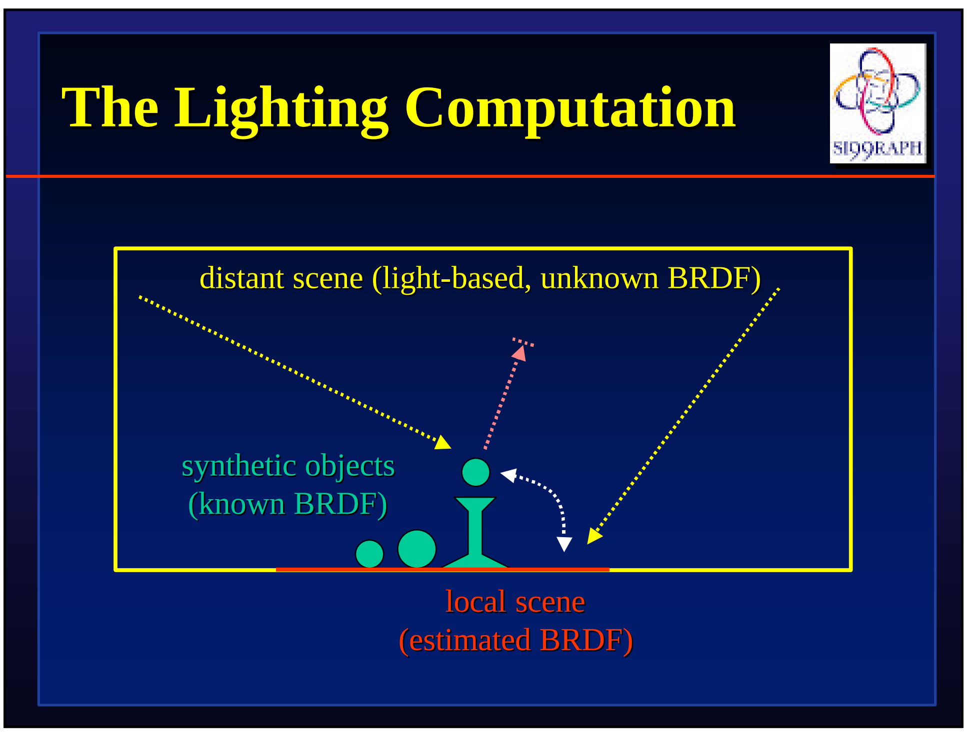
Goal: place synthetic objects on table

Light Probe / Calibration Grid


Modeling the Scene
SIGGRAPH
light-based model
real scene


The Light-Based Room Model
SIGGRAPH


Modeling the Scene
SI99RAPH
light-based model
local scene
synthetic objects
real scene

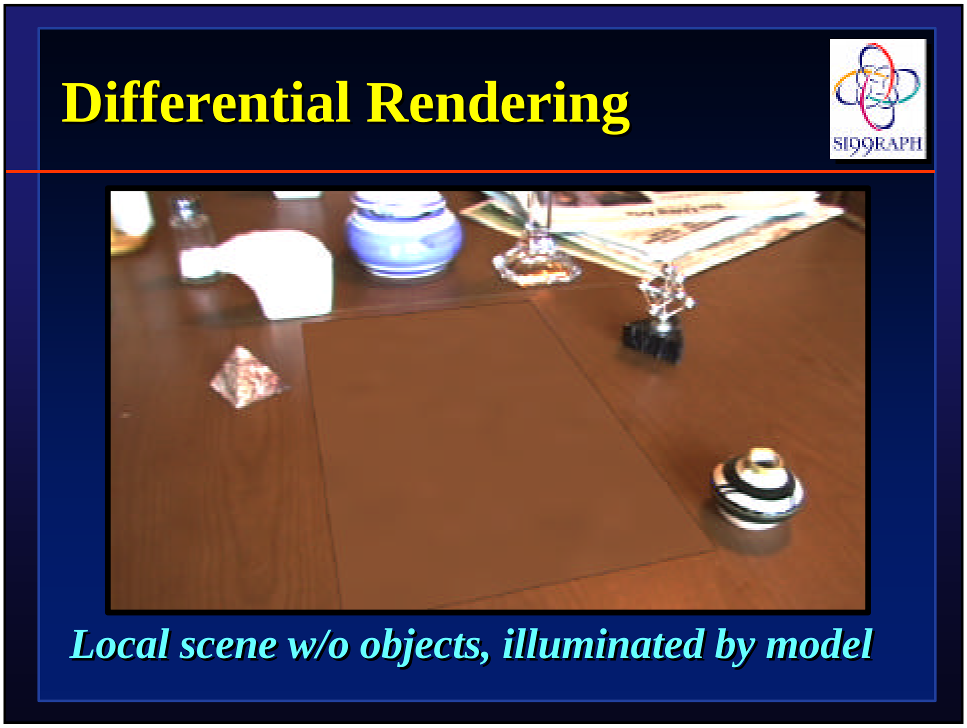

The Lighting Computation
SI99RAPH
distant scene (light-based, unknown BRDF)
synthetic objects
(known BRDF)
local scene
(estimated BRDF)

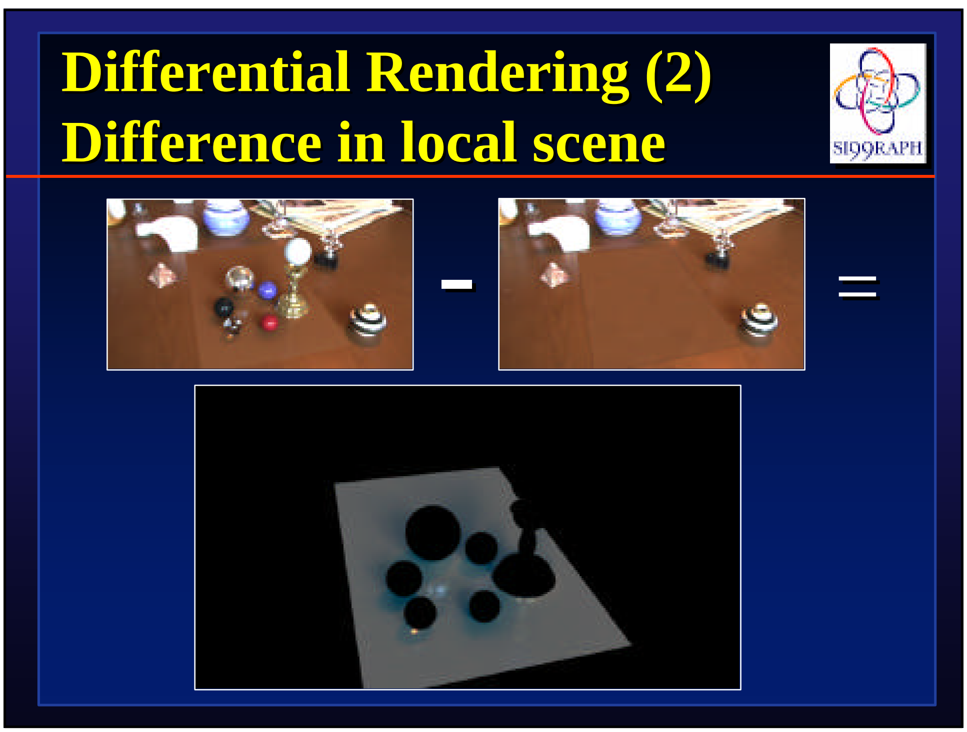
Rendering into the Scene

Background Plate

Rendering into the Scene

Objects and Local Scene matched to Scene


Differential Rendering
SIGGRAPH
Local scene w/o objects, illuminated by model


Differential Rendering (2)
Difference in local scene
SIGGRAPH
-
=


Differential Rendering (3)
SIGGRAPH
Final Result

Video

Domino animation rendered by Son Chang and Christine Waggoner

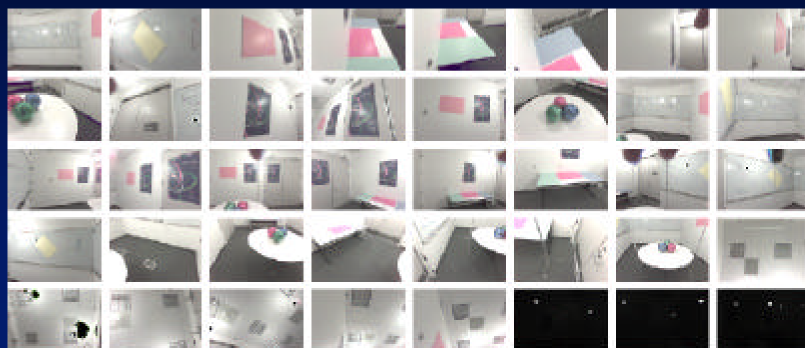
Estimating the local scene material properties

- Necessary for correct *shadows* and *reflections*
- For each part of the local scene, we know its *irradiance* from the light-based model
- If the material is *diffuse*, its albedo is its *radiance* divided by its *irradiance*
- *Non-diffuse* properties can be estimated by *iterative methods* or specified by hand
- See: Ward92, Karner20, Dana97, Sato97, Yu98, Debevec98, Yu99

Reflectance Properties for a Whole Scene: Inverse Global Illumination

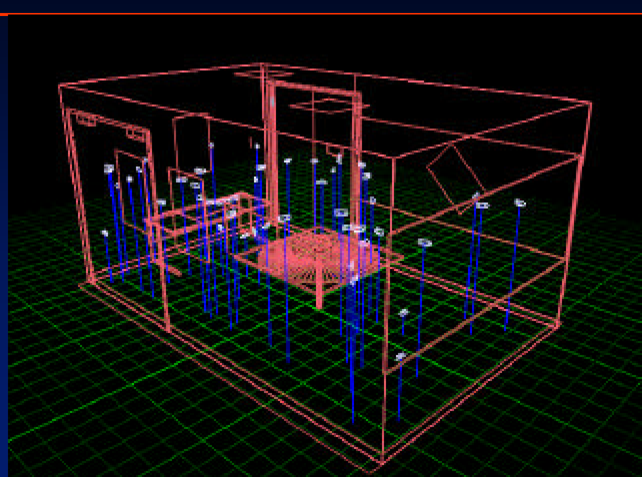
Yizhou Yu, Paul Debevec, Jitendra Malik, Tim Hawkins

SIGGRAPH 99, Thursday, 11:50-12:15pm, West Hall A

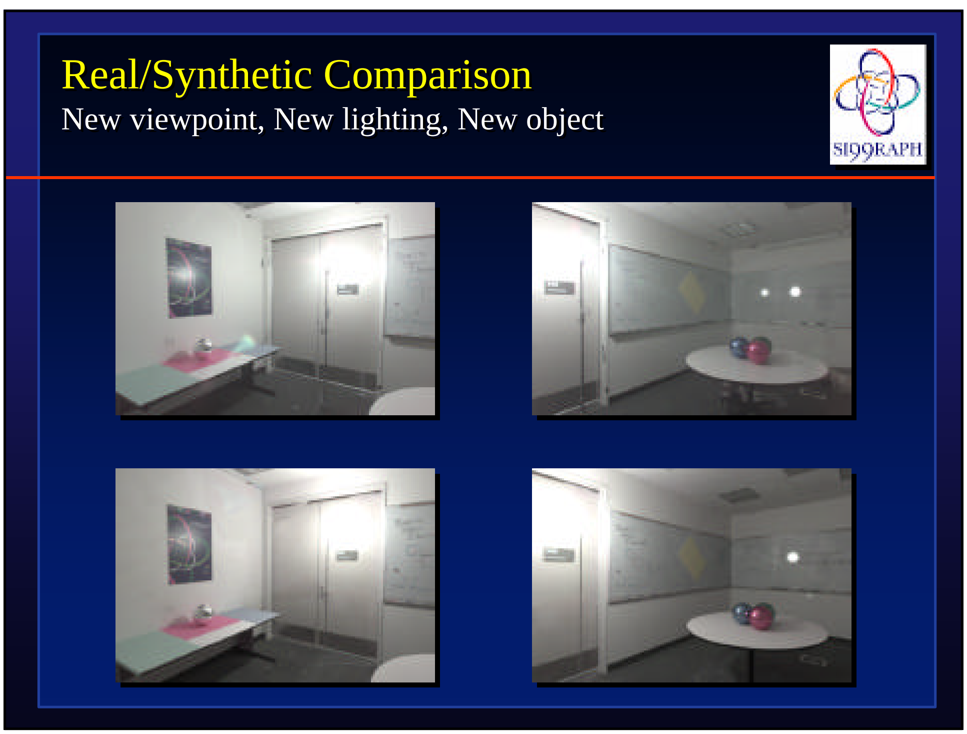


40 radiance maps of a room

Recovered Geometry and Viewpoints




Real/Synthetic Comparison
Same viewpoints, Same lighting, Same objects


Real/Synthetic Comparison
New viewpoint, New lighting, New object

Communicating the sense of Brightness

- **Fade In / Fade Out**
  - Bright areas appear first / fade last
- **Motion Blur**
  - Bright areas leave streaks
- **Blur / Glare / Soft Focus**
  - Bright areas blossom
- **Radial Light Falloff (Vignetting)**
  - Bright areas sear through corners
- **Color tinting**
  - Bright areas still ramp to white

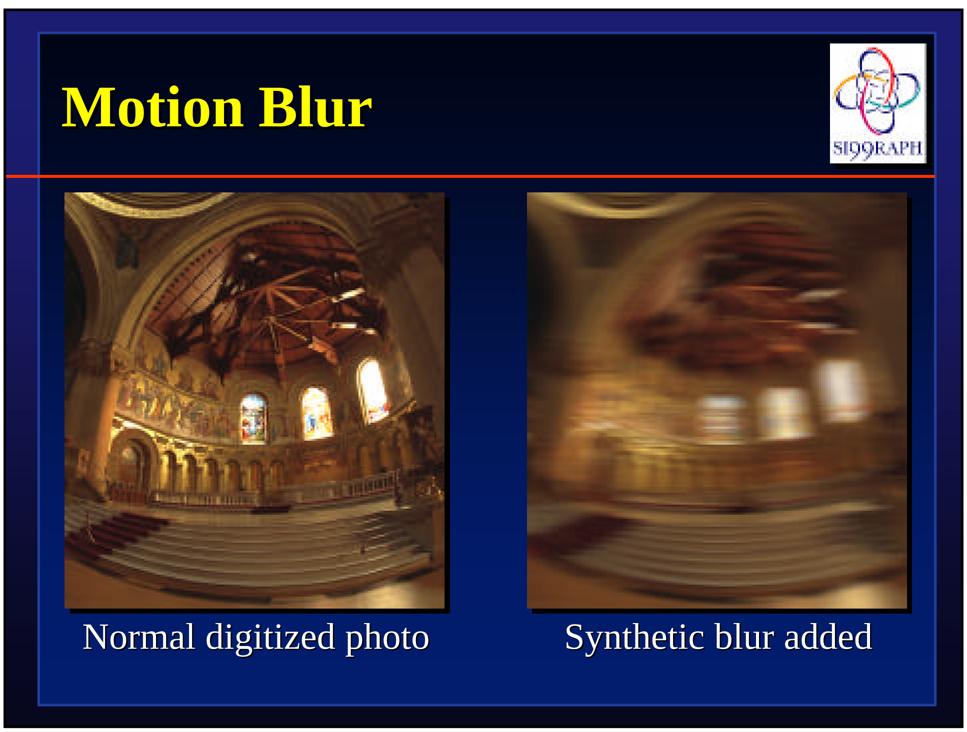
RNL Example

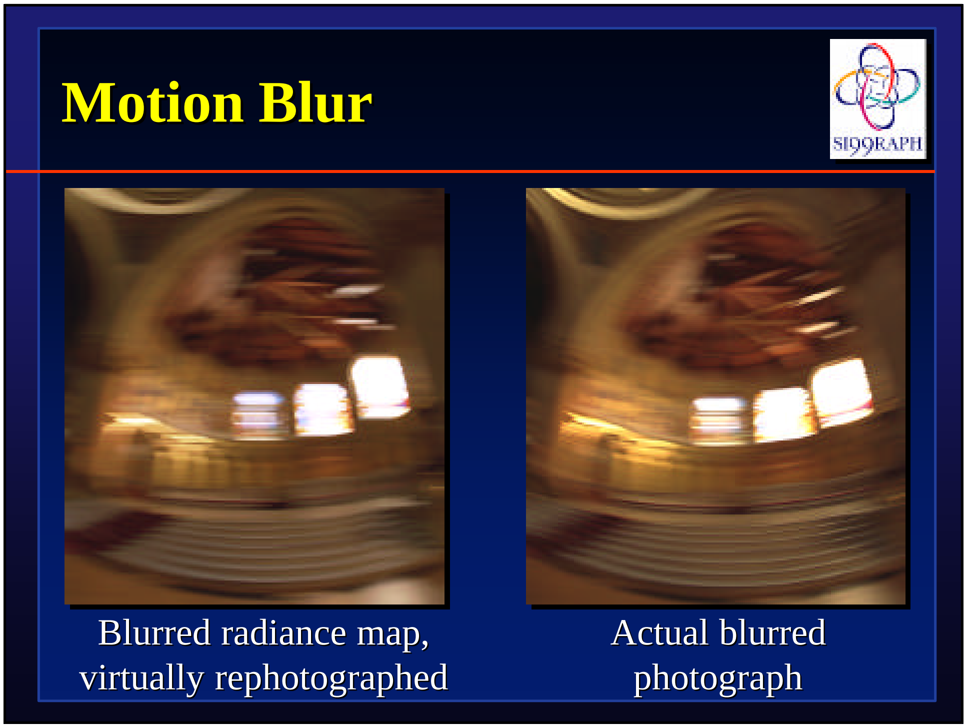
Renderer Output

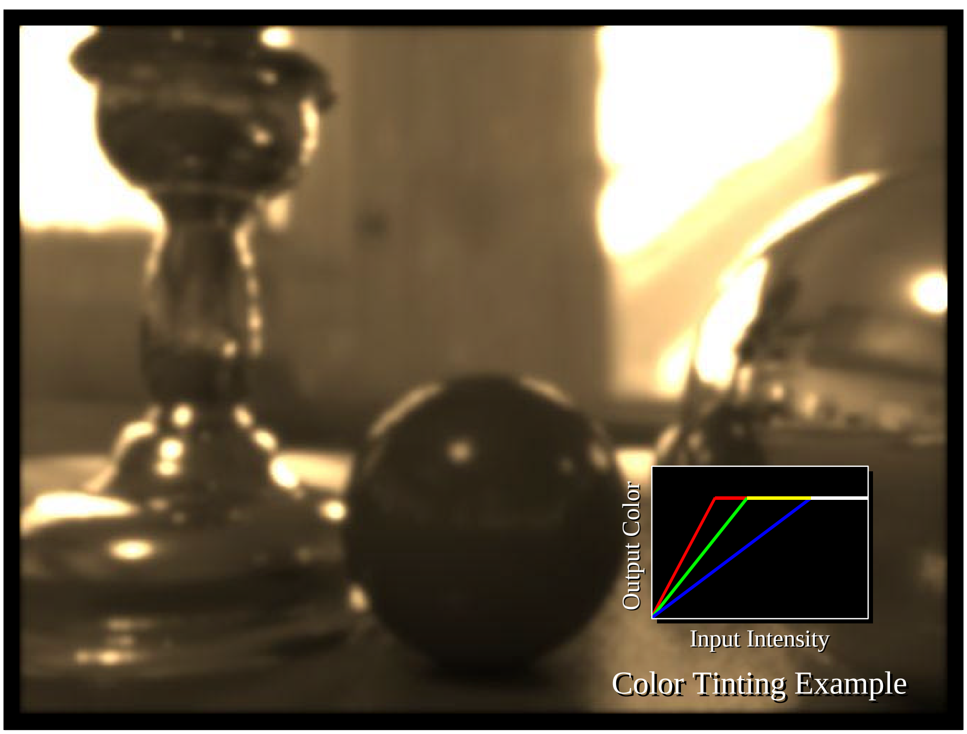

RNL Example
Defocus & Glare Added


RNL Example
Soft Focus Added


RNL Example
Light Falloff (Vignetting) Added


Motion Blur
Normal digitized photo
Synthetic blur added


Motion Blur
Blurred radiance map,
virtually rephotographed
Actual blurred
photograph

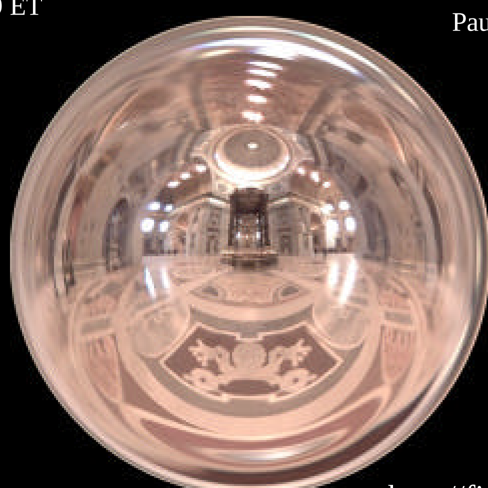

Output Color
Input Intensity
Color Tinting Example

Video

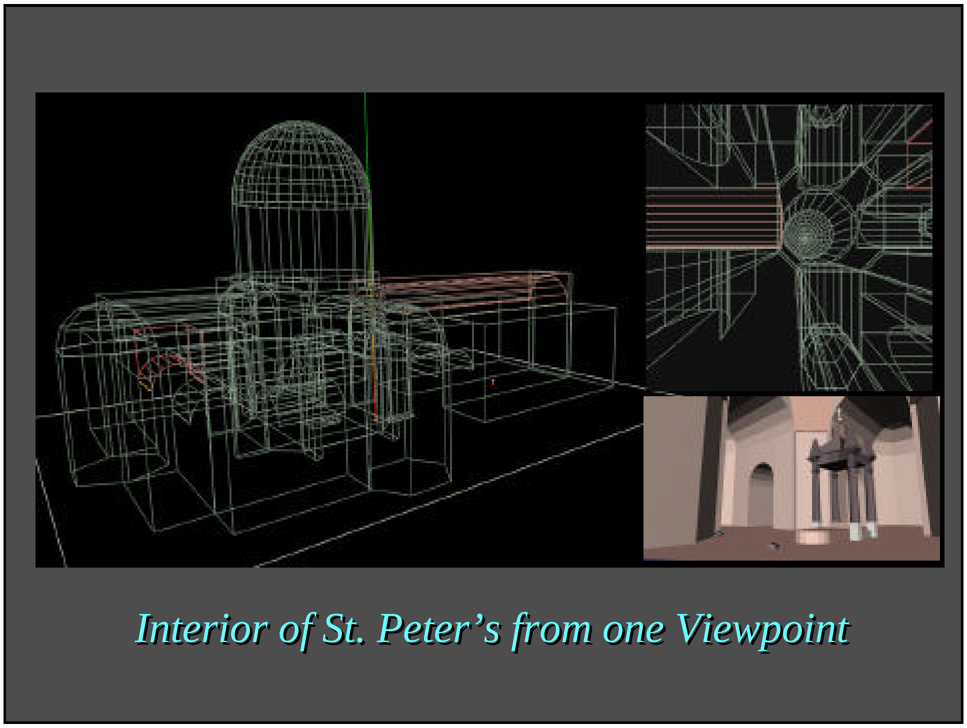
Interior Illumination Model
St. Peter's Basilica for "Fiat Lux"

SIGGRAPH 99 ET

Christine Cheng, H.P. Duiker, Tal Garfinkel, Tim Hawkins, Jenny Huang, Westley Sarokin, Paul Debevec



http://fiatlux.berkeley.edu/


Interior of St. Peter's from one Viewpoint


http://fiatlux.berkeley.edu/
Related Sketches
The Making of "Fiat Lux"
Wednesday 11 August, 5:25pm - 6:00pm, Room 151 / 152
Image-Based Modeling, Rendering, and Lighting in "Fiat Lux"
Friday 13 August, 11:40am - 12:15pm, Room 408AB


Gregory Ward Larson, Chris Bregler, Jianbo Shi, Thomas Leung, Kevin Deus, David Metzger, Hal Wasserman, Greg Chew, Charles Ying, Steve Chenney, Tim Hawkins, Andrean Kalemis, Jitendra Malik
Serge Belongie, Michael Naimark, Steve Saunders, Rick Bukowski, David Forsyth, Chris Healey, Golan Levin, Carlo Sequin, Keeble and Shuchat Photography, Stanford Memorial Church
Science Foundation, ONR MURI Program, Interv
Research Corporation Silicon Graphics, Inc.