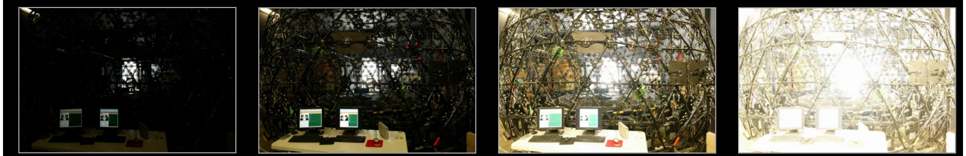
Radiometry and HDR Basics



70001 – Advanced Computer Graphics: Photographic Image Synthesis

Abhijeet Ghosh

Lecture 02, Jan. 16th 2024

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Radiometry & Geometric Optics

- Light transport modeled using geometric or ray optics
  - light as particle, not wave!
  - some exceptions, i.e., polarization
- Basic properties of geometric optics:
  - Linearity
  - Energy conservation

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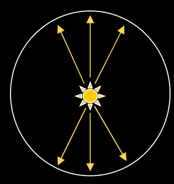
Basic Quantities

- Radiant Flux or Power Φ : Energy flowing through a surface per unit time. Units - Joules/second (J/s) or Watts (W).
  - Emission from light sources typically described with flux



- Irradiance E : area density of incoming flux (W/m^2)
  - for a sphere of radius r, $E = \Phi / 4\pi r^2$
  - energy received from an isotropic source falls off with squared distance!

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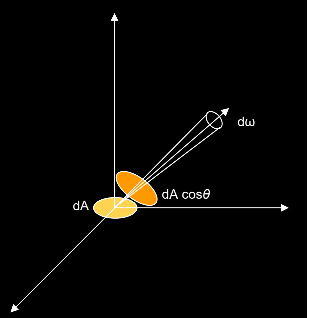
Basic Quantities



- Intensity I : flux density per solid angle [W/sr]
  - $I = d\Phi/d\omega$
  - useful for describing point light sources, with zero area!
- Radiance L : radiant flux density per unit area, per unit solid angle [W/m^2sr]
  - $L = d^2\Phi/(dA \cos\theta \, d\omega)$
  - radiance remains constant along a direction!

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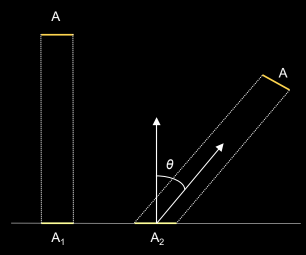
Lambert's Law

- Irradiance E proportional to cosine of the angle between light direction l and surface normal n

$$E = d\Phi/dA,$$

hence $E_1 = \Phi/A,$

and $E_2 = \Phi\cos\theta/A.$



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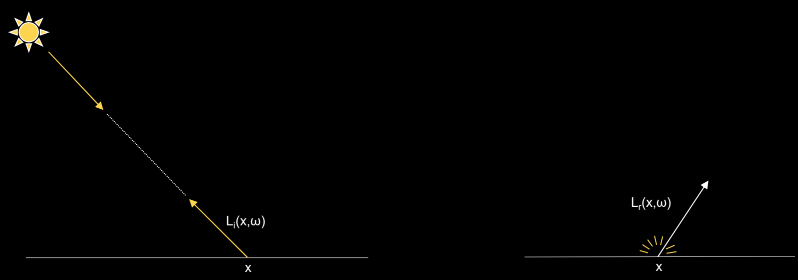
Incident and Exitant Radiance



- Incident radiance $L_i(x,\omega)$, due to light arriving from a source
- Exitant radiance $L_r(x,\omega)$, due to reflection from a surface

In general $L_i(x,\omega) \neq L_r(x,\omega)$

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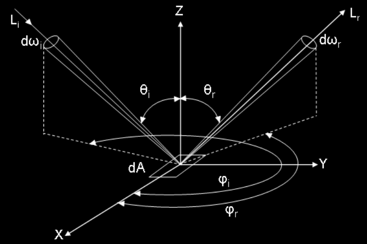
BRDF



- Bidirectional Reflectance Distribution Function [Nicodemus et al. 77]
  - formalizes the reflection of light at a surface!

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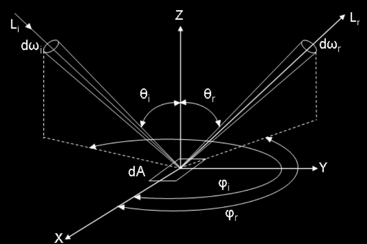
BRDF



- Defined as the ratio of reflected radiance to incident irradiance:

$$f_r(x, \omega_r, \omega_i) = dL_r(x, \omega_r)/dE_i(x, \omega_i)$$
$$= dL_r(x, \omega_r)/(L_i(x, \omega_i) \cos\theta \, d\omega_i).$$

  - the units of a BRDF are inverse steradian [1/sr].

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Radiance imaging with cameras

Camera settings:

Shutter speed – 1 sec

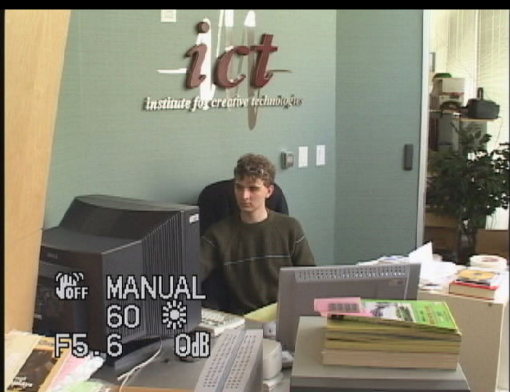
Aperture - f/8

gain – ISO 100

ND filters

9

Radiance in the Real World – Dynamic Range



Sony VX2000 video camera

Office interior

Indirect light from window

1/60th sec shutter

f/5.6 aperture

0 ND filters

0dB gain

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Dynamic Range in the Real World

Outside in the shade

$1/1000^{th}$ sec shutter

f/5.6 aperture

0 ND filters

0dB gain

16 times the light as inside

11

Dynamic Range in the Real World

Outside in the sun

$1/1000^{th}$ sec shutter

f/11 aperture

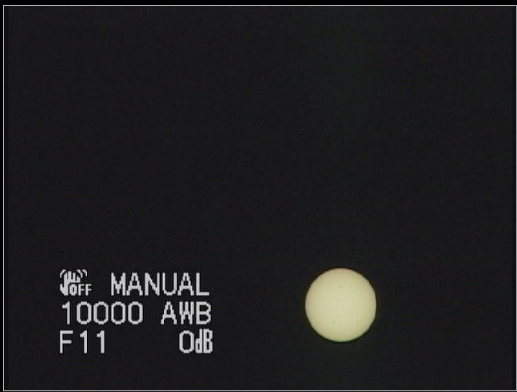
0 ND filters

0dB gain

64 times the light as inside

12

Dynamic Range in the Real World



Straight at the sun

1/10,000th sec shutter

f/11 aperture

13 stops ND filters

0dB gain

5,000,000 times the light as inside

13

Dynamic Range in the Real World

Very dim room

1/4th sec shutter

f/1.6 aperture

0 stops ND filters

18dB gain

1/1500th the light than inside

14

Dynamic Range in the Real World

1

1500

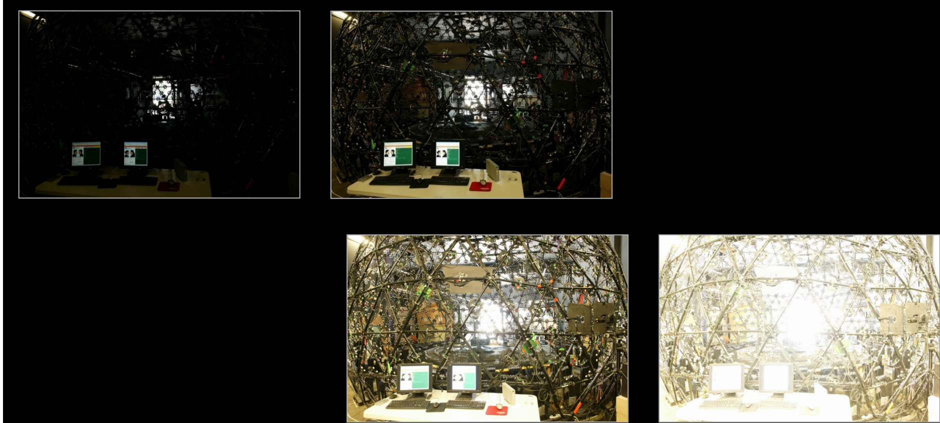
25,000

400,000

2,000,000,000

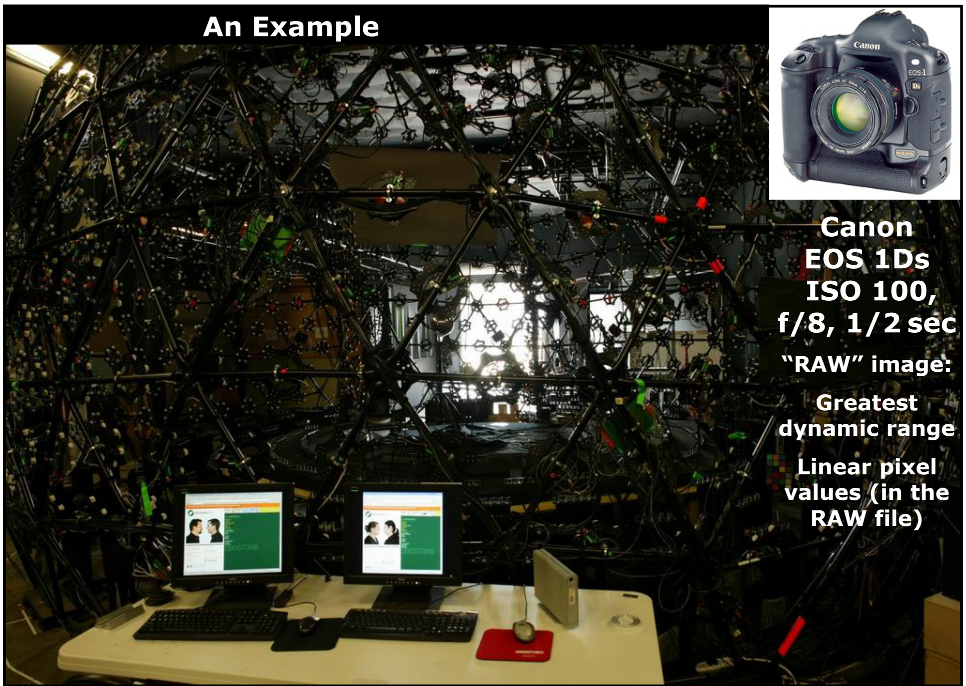
The real world is
high dynamic range.

Taking HDR Images



www.debevec.org

An Example



F5AT8487.CRW

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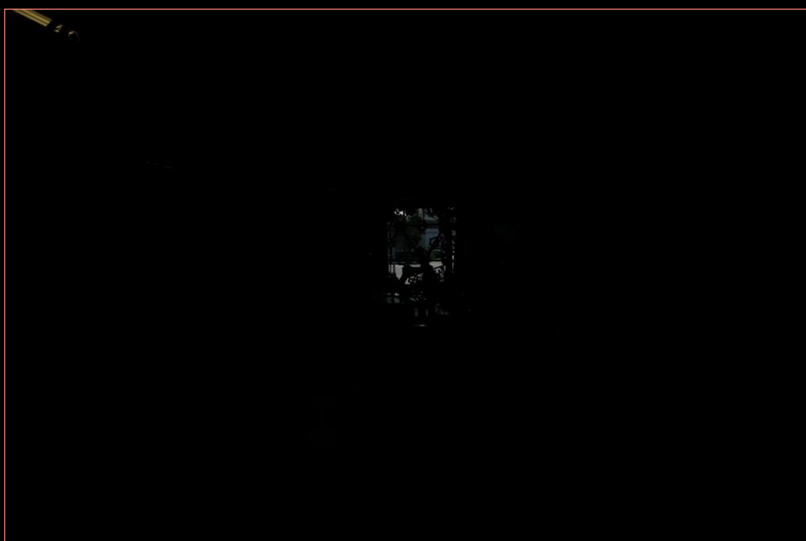
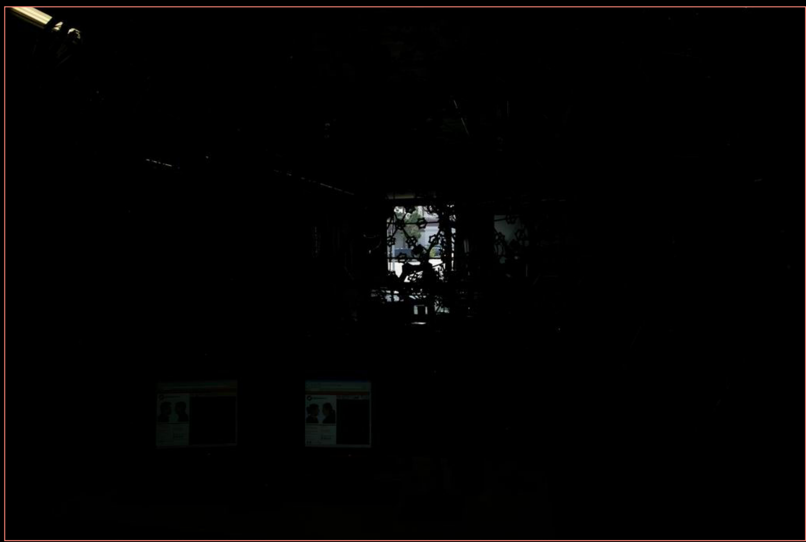
High Dynamic Range Imaging



ISO 100, f/8, 1/1000 sec

18

High Dynamic Range Imaging



ISO 100, f/8, 1/125 sec

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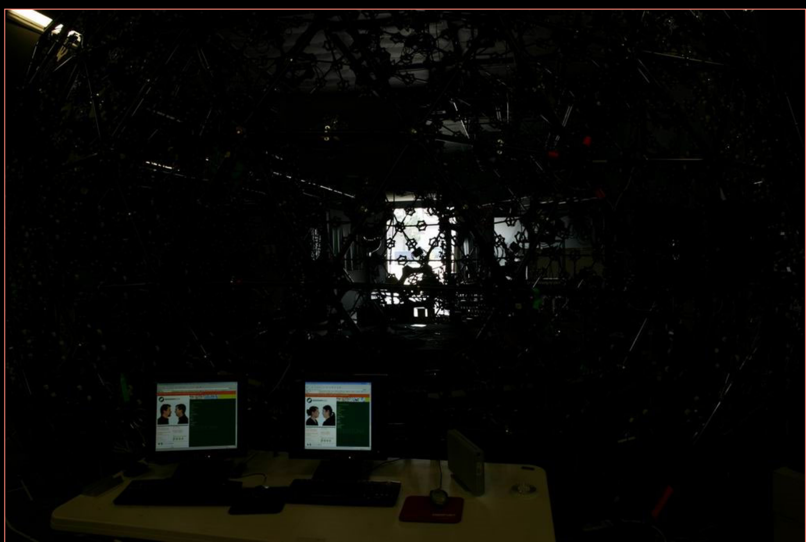
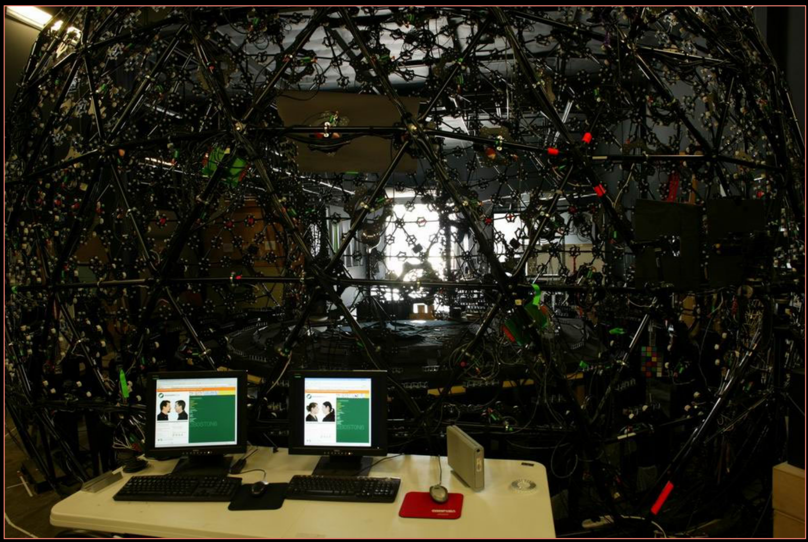
High Dynamic Range Imaging



ISO 100, f/8, 1/15 sec

20

High Dynamic Range Imaging



ISO 100, f/8, ½ sec

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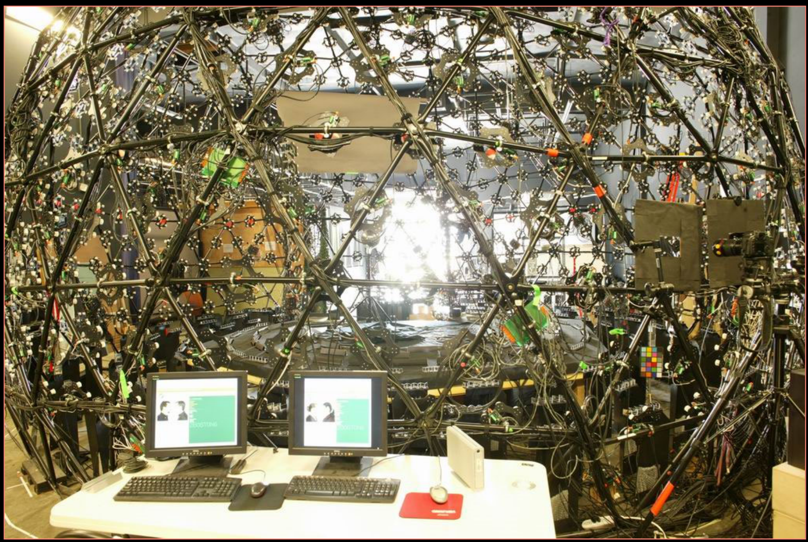
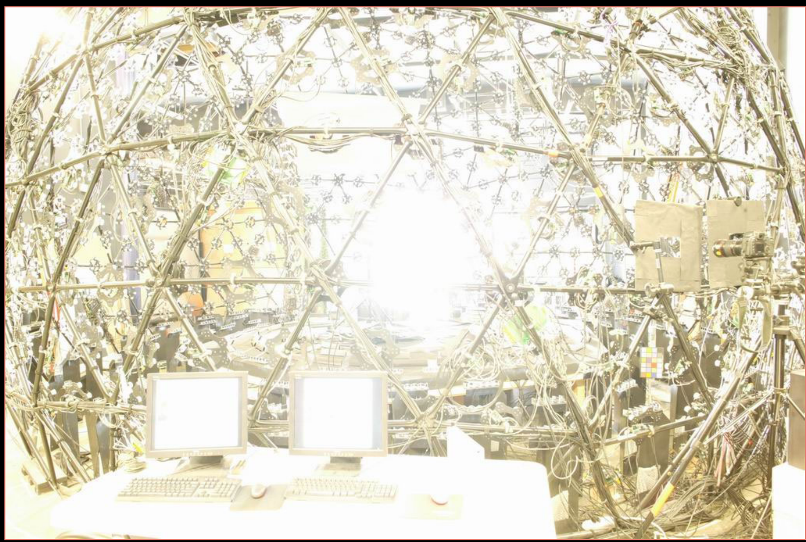
High Dynamic Range Imaging



ISO 100, f/8, 4 sec

22

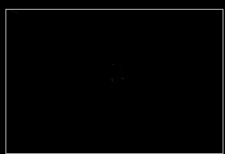
High Dynamic Range Imaging



ISO 100, f/8, 30 sec

23

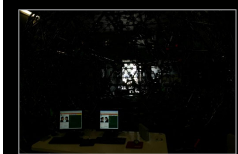
High Dynamic Range Imaging



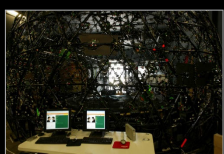
f/8, 1/8000th sec

f/8, 1/1000th sec

f/8, 1/125th sec

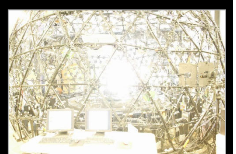


f/8, 1/15th sec



f/8, 1/2 sec

f/8, 4 sec



f/8, 30 sec

- Set of images referred to as an HDR stack
- In this case, acquired at 3-stops apart
  - Each successive image is 2^3 = 8x brighter!

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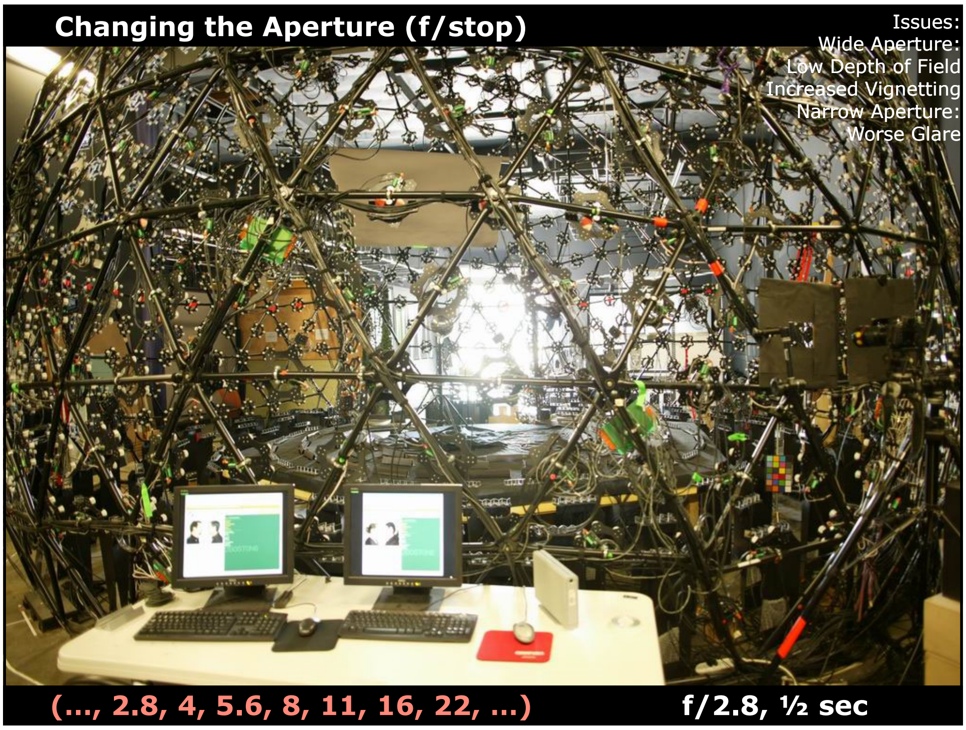
Changing the Aperture (f/stop)
Issues:
Wide Aperture:
Low Depth of Field
Increased Vignetting
Narrow Aperture:
Worse Glare
(…, 2.8, 4, 5.6, 8, 11, 16, 22, …)
f/2.8, ½ sec

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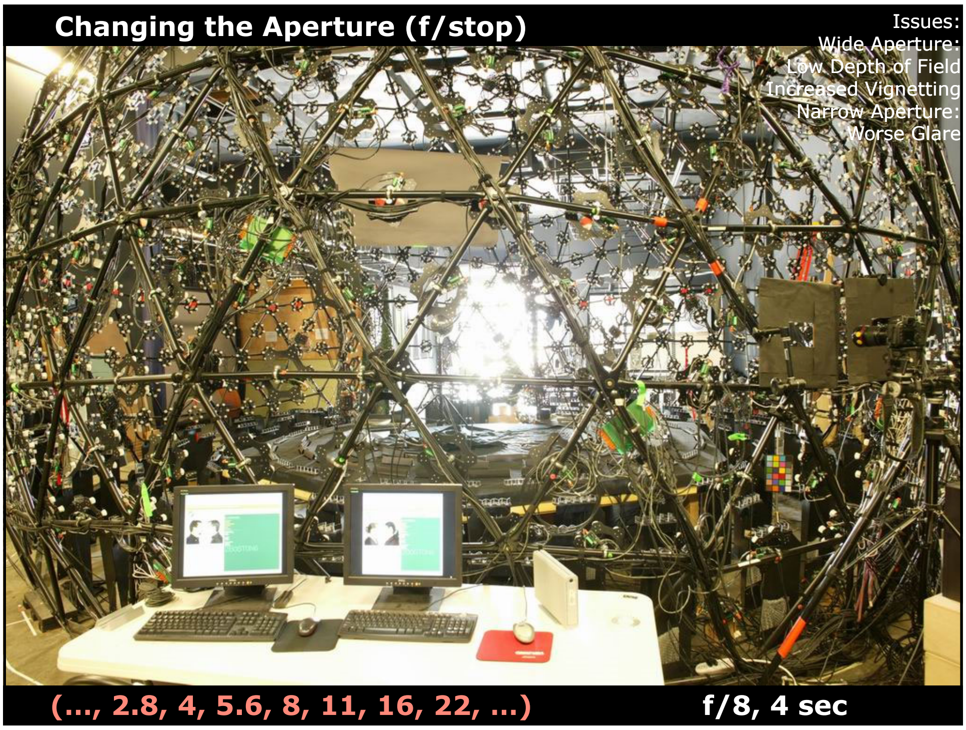
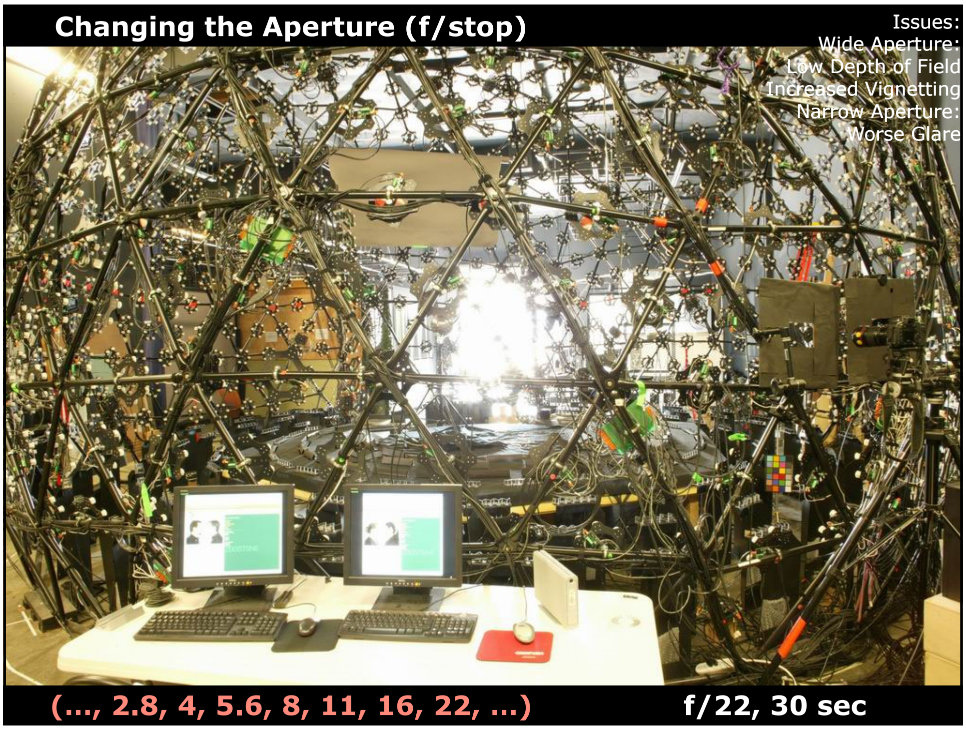

Changing the Aperture (f/stop)
Issues:
Wide Aperture:
Low Depth of Field
Increased Vignetting
Narrow Aperture:
Worse Glare
(…, 2.8, 4, 5.6, 8, 11, 16, 22, …)
f/8, 4 sec

26


Changing the Aperture (f/stop)
Issues:
Wide Aperture:
Low Depth of Field
Increased Vignetting
Narrow Aperture:
Worse Glare
(…, 2.8, 4, 5.6, 8, 11, 16, 22, …)
f/22, 30 sec

27


Changing ISO (Gain)
ISO 100, ½ sec (+3 stops)
ISO 800, ½ sec
ISO 100, 4 sec

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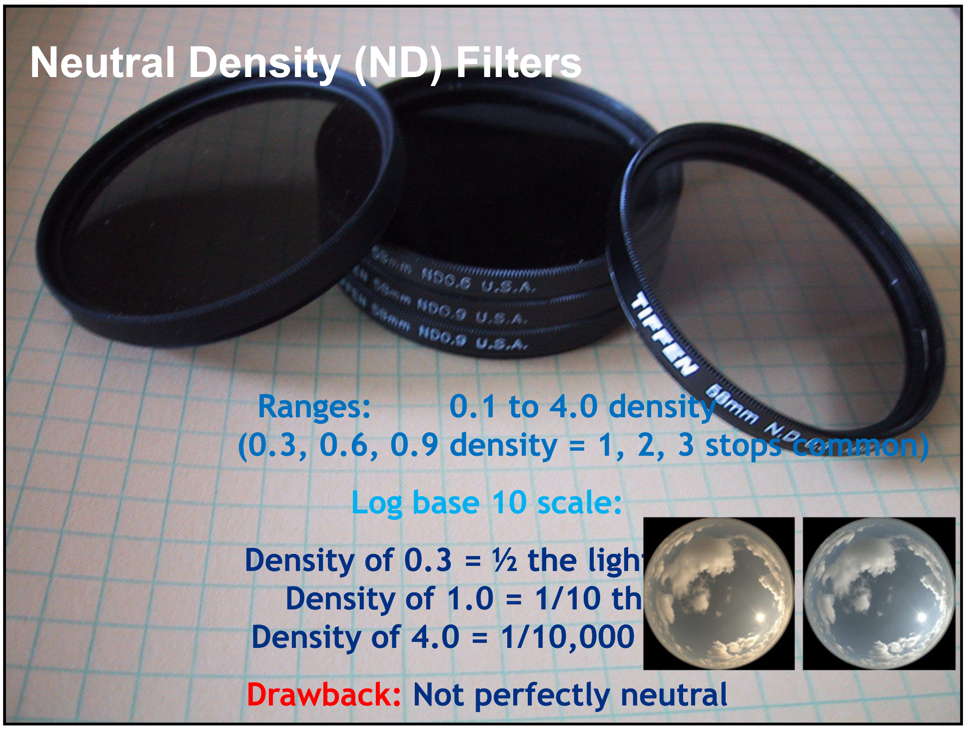
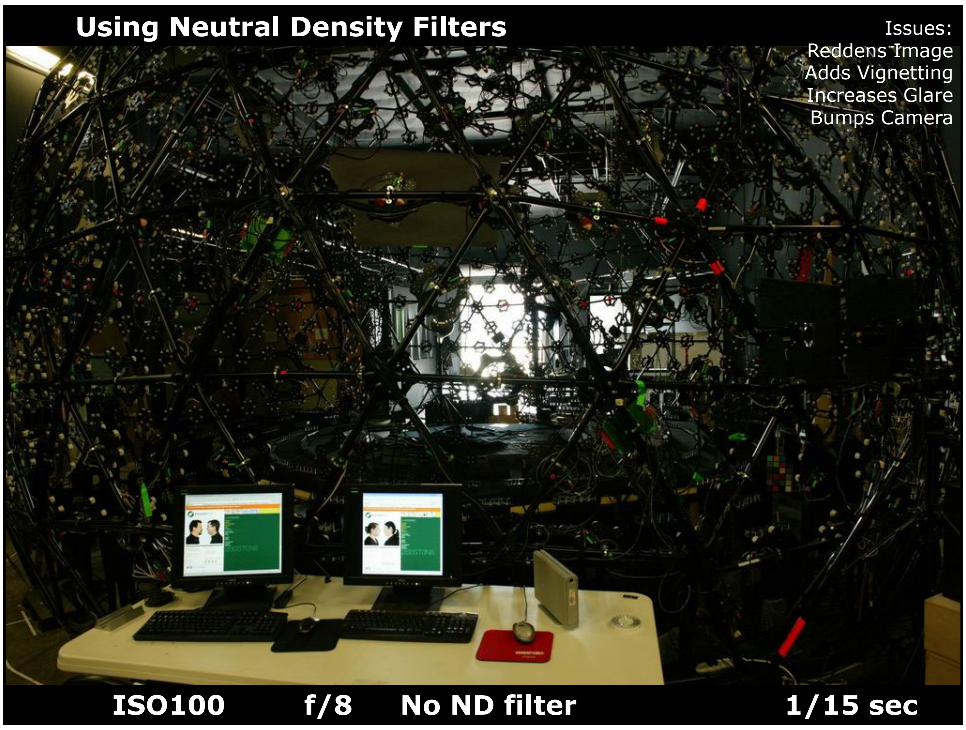
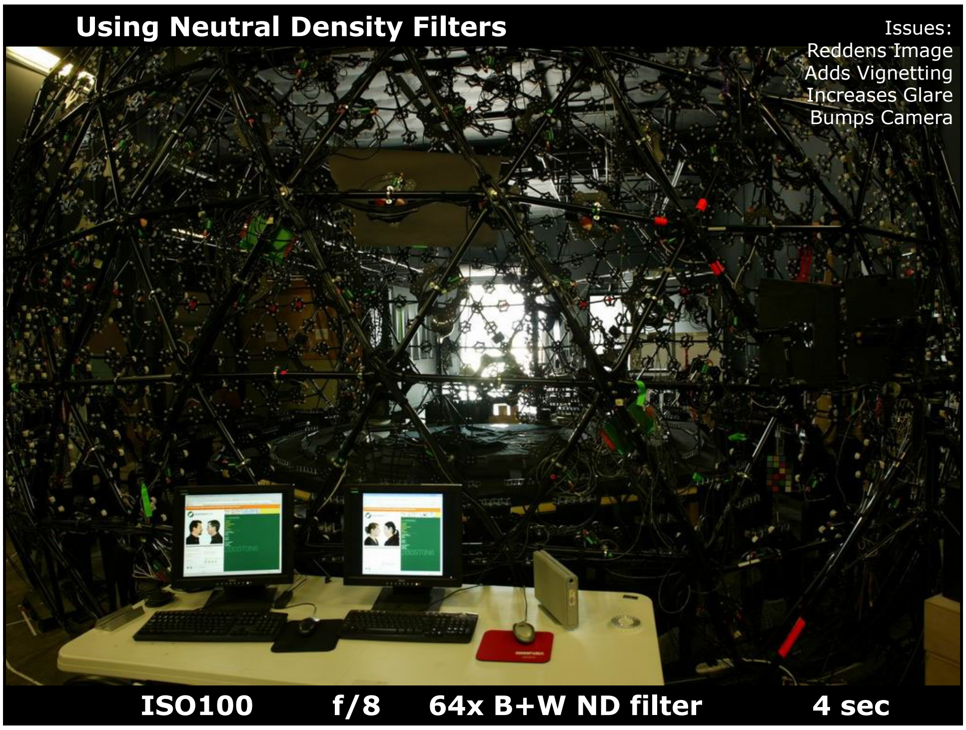

Neutral Density (ND) Filters
Ranges: 0.1 to 4.0 density
(0.3, 0.6, 0.9 density = 1, 2, 3 stops common)
Log base 10 scale:
Density of 0.3 = ½ the ligh
Density of 1.0 = 1/10 th
Density of 4.0 = 1/10,000
Drawback: Not perfectly neutral
58mm NDO.6 U.S.A.
58mm NDO.9 U.S.A.
58mm NDO.9 U.S.A.
TIFFEN

29


Using Neutral Density Filters
Issues:
Reddens Image
Adds Vignetting
Increases Glare
Bumps Camera
ISO100 f/8 No ND filter 1/15 sec

30


Using Neutral Density Filters
Issues:
Reddens Image
Adds Vignetting
Increases Glare
Bumps Camera
ISO100
f/8
64x B+W ND filter
4 sec

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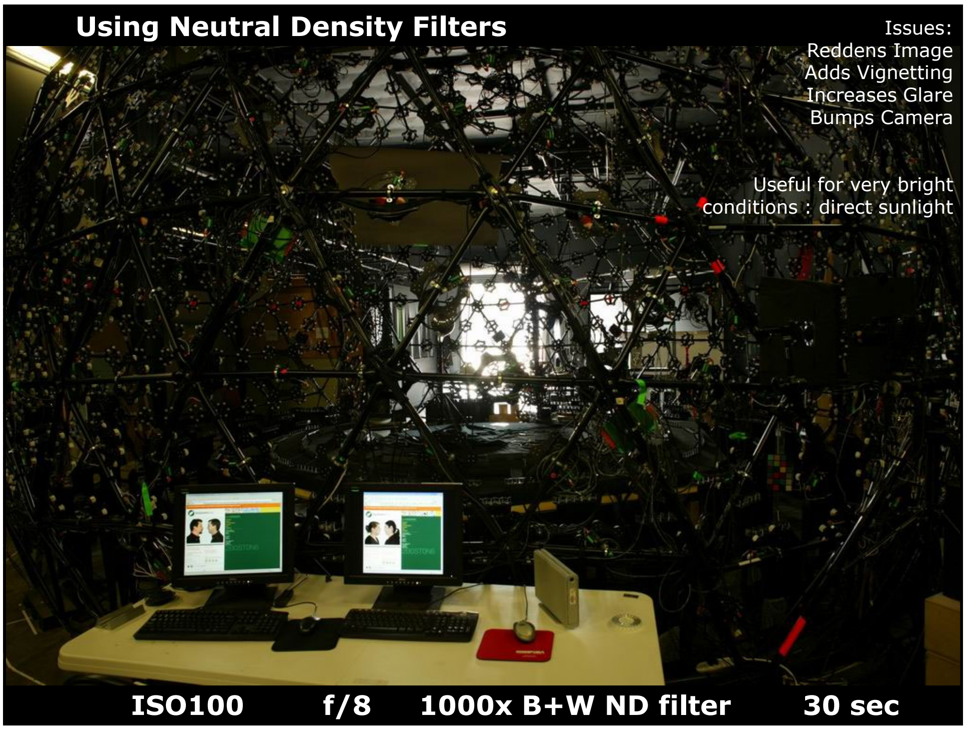
Using Neutral Density Filters
Issues:
Reddens Image
Adds Vignetting
Increases Glare
Bumps Camera
Useful for very bright
conditions : direct sunlight
ISO100
f/8
1000x B+W ND filter
30 sec

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