Distributed Ray Tracing

Anti-Aliasing

- Graphics as signal processing
  - Scene description: continuous signal
  - Sample
  - digital representation
  - Reconstruction by monitor

Anti-Aliasing

- Represent any function as sum of sinusoidals
- Sampling
  - Spatial: multiply function by comb function
  - Frequency: convolve function by comb function
- Nyquist limit
- Reconstruction
  - Spatial: convolve with filter
  - Frequency: multiply by filter

Typical anti-aliasing

- Increase sampling frequency
  - Doesn’t solve problem
  - Increases frequencies handled (Nyquist limit)
- Average values after sampling
  - Doesn’t address problem
  - Blurs bad results

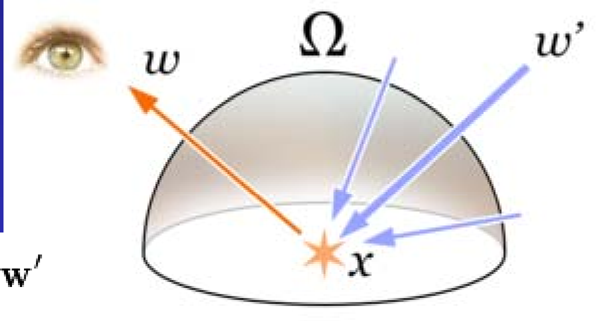
Ideal sampling and reconstruction

- Sample at greater than Nyquist frequency
- Reconstruct using sinc (box) filter
- Given sampling frequency, remove all frequencies higher than Nyquist limit
- Filter first, then sample
  - or do both at the same time

Illumination is Integration

Outgoing intensity of reflected light at a point on a surface in a certain direction is

- The point's emission ,
- An integral over the hemisphere above the surface of an illumination function L and a bidirectional reflectance function (BDRF).



$$L_o(x, \mathbf{w}, \lambda, t) = L_e(x, \mathbf{w}, \lambda, t) + \int_\Omega f_r(x, \mathbf{w}', \mathbf{w}, \lambda, t) L_i(x, \mathbf{w}', \lambda, t)(-\mathbf{w}' \cdot \mathbf{n}) d\mathbf{w}'$$

Usually referred to as "Kajia's Rendering Equation"

The shading function may be too complex to compute analytically

Distributed Ray Tracing

Sampling to approximate integral

- Anti-Aliasing
- Gloss
- Translucency
- Soft Shadows (Penumbra)
- Motion Blur
- Depth of field

Importance Sampling

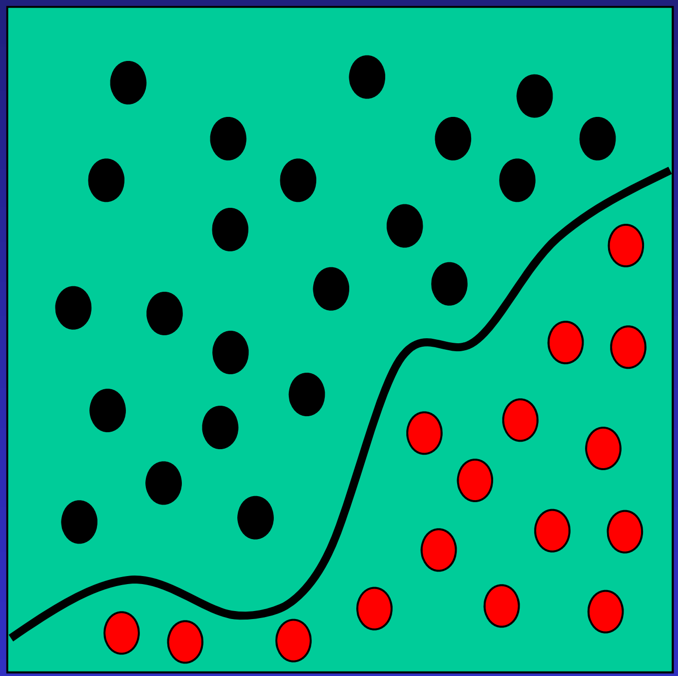
- Sample uniformly and average samples according to distribution function

OR

- Sample according to distribution function and average samples uniformly

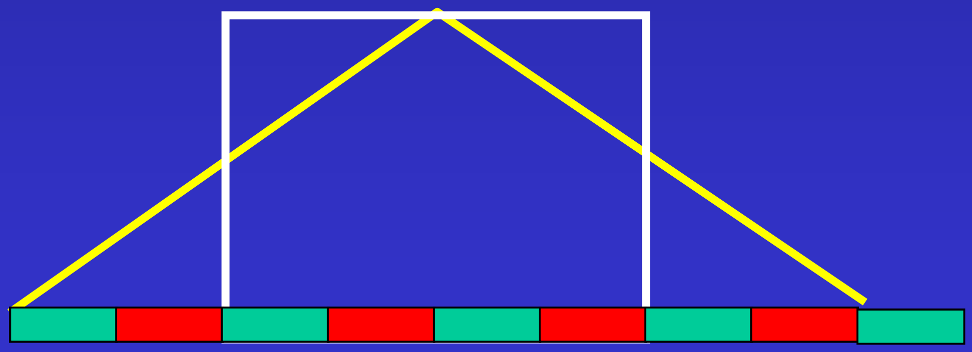
Monte Carlo Integration

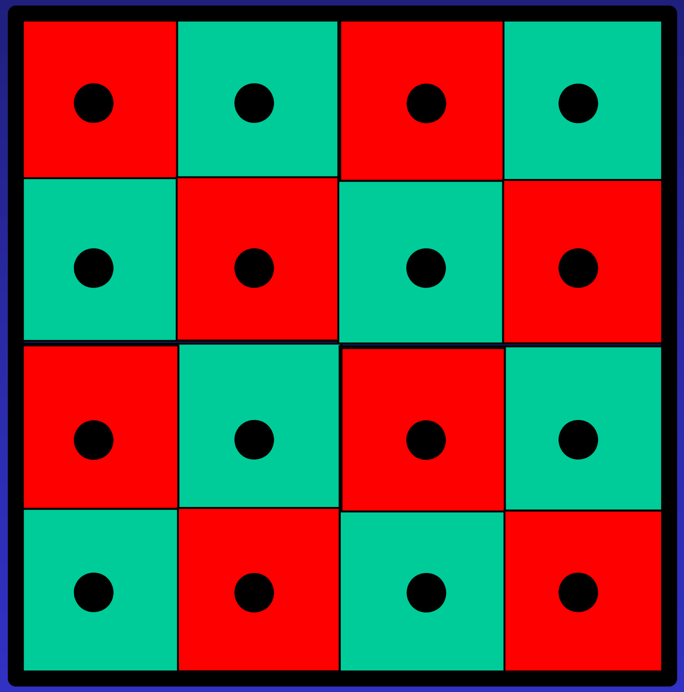
- Determine area under the curve
- Non analytic function so can't integrate
- Can tell if point is above or below curve
- Generate random samples
- Count fraction below curve
- Accurate in the limit



Supersampling

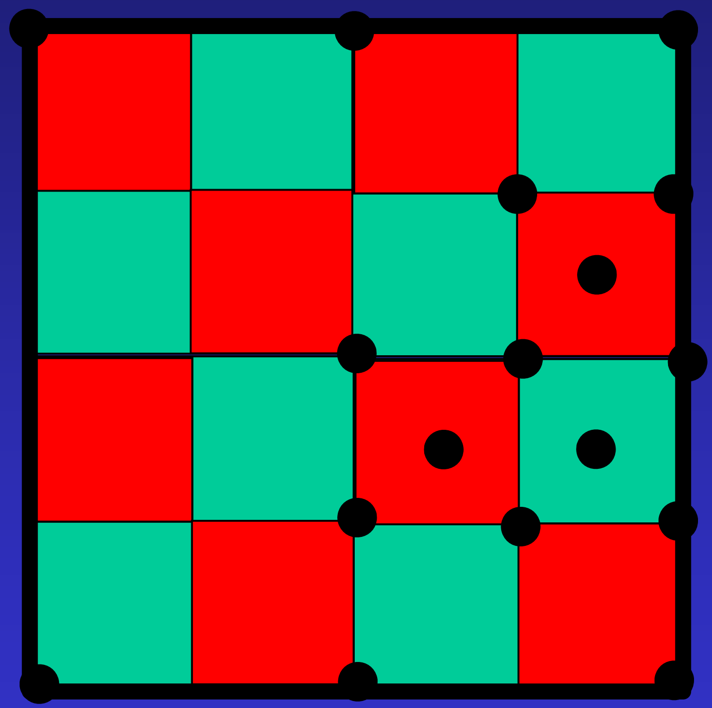
- Multiple samples per pixel
- Average together using uniform weights (box filter)
- Average together using a pyrimid filter or a truncated Gaussian filter





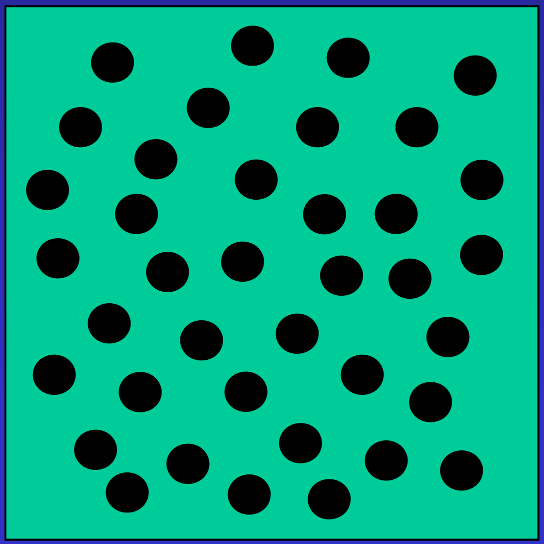
Adaptive Supersampling

- Trace rays at corner of pixels: initial area
- Trace ray (sample) at center of area
- If center is ‘different’ from corners,
  - Subdivide area into 4 sub-areas
  - Recurse on sub-areas



Poison Distribution

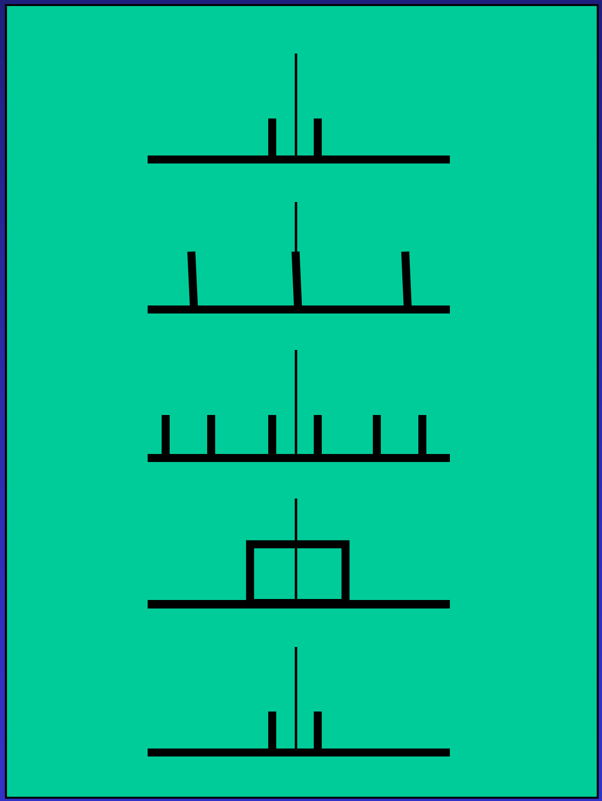
- Similar to distribution of vision receptors
- Random with minimum distance between samples



Spectrum analysis of regular sampling

low frequency signal

high frequency signal



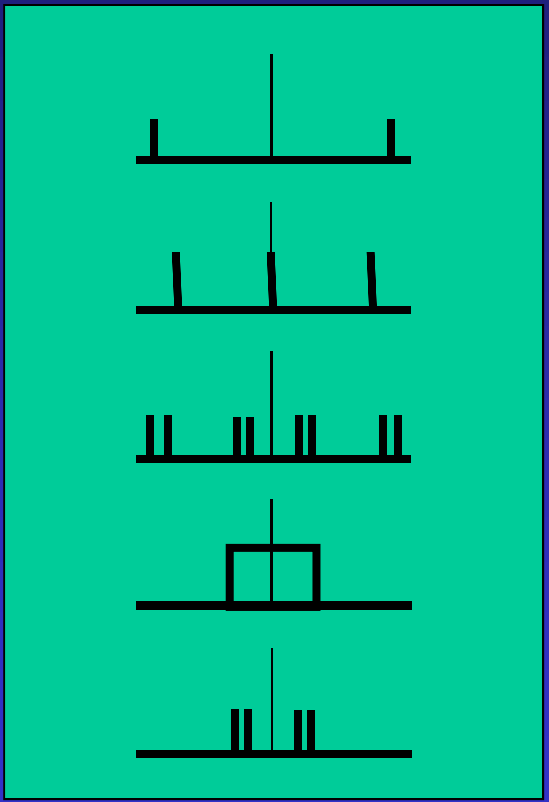
Original signal

Sampling filter

Sampled signal

Ideal reconstruction filter

Reconstructed signal



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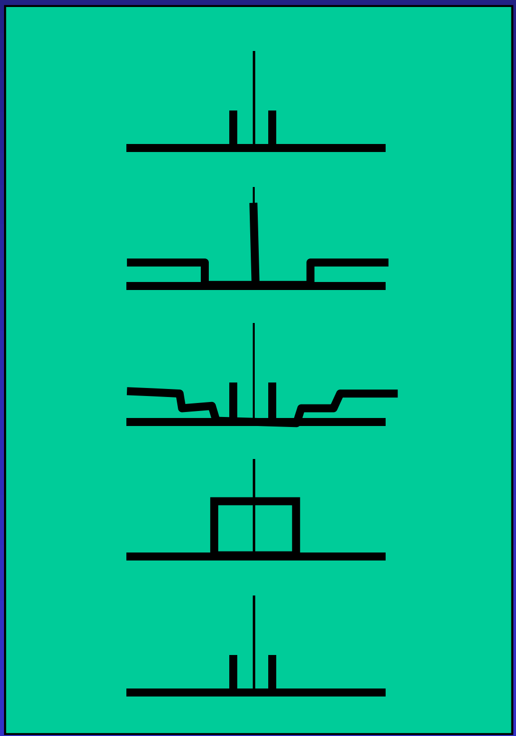

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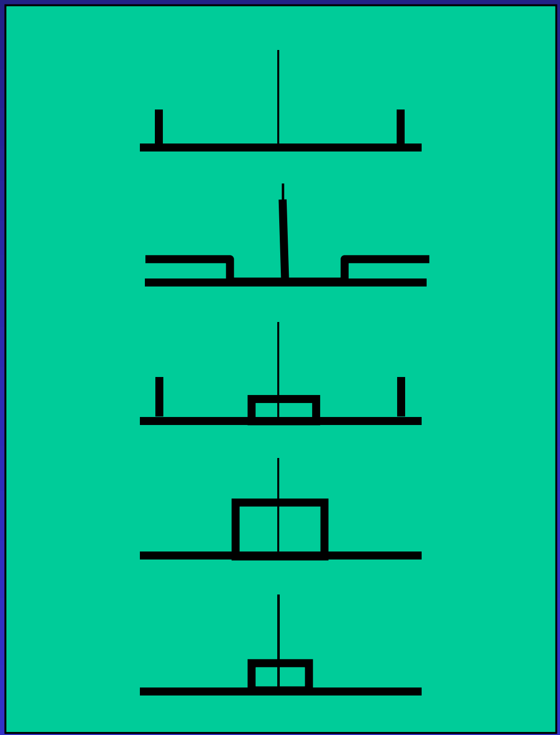
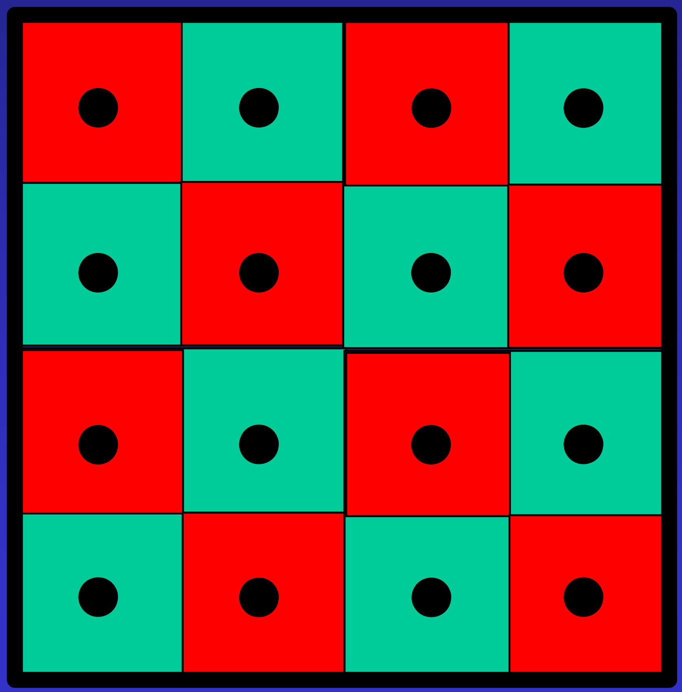
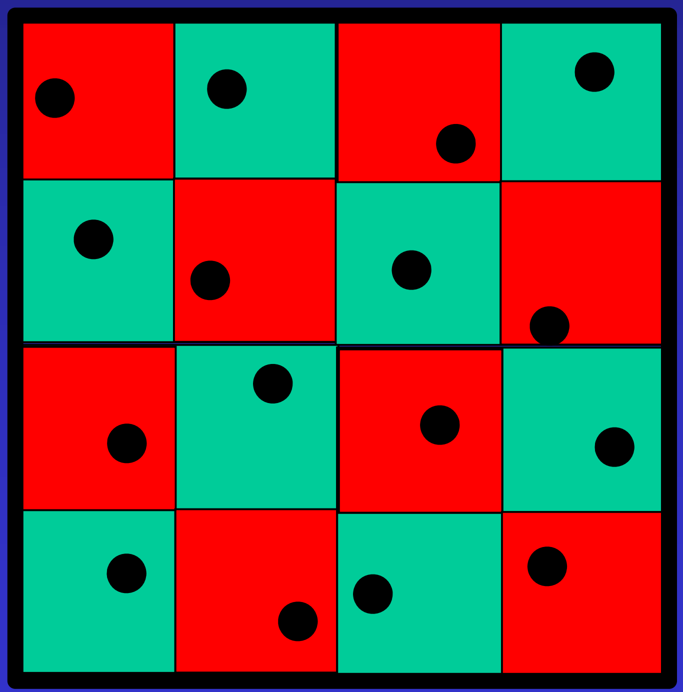


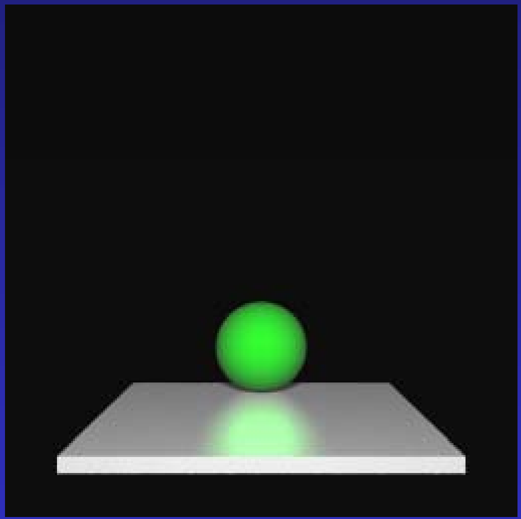
Jittered Sampling

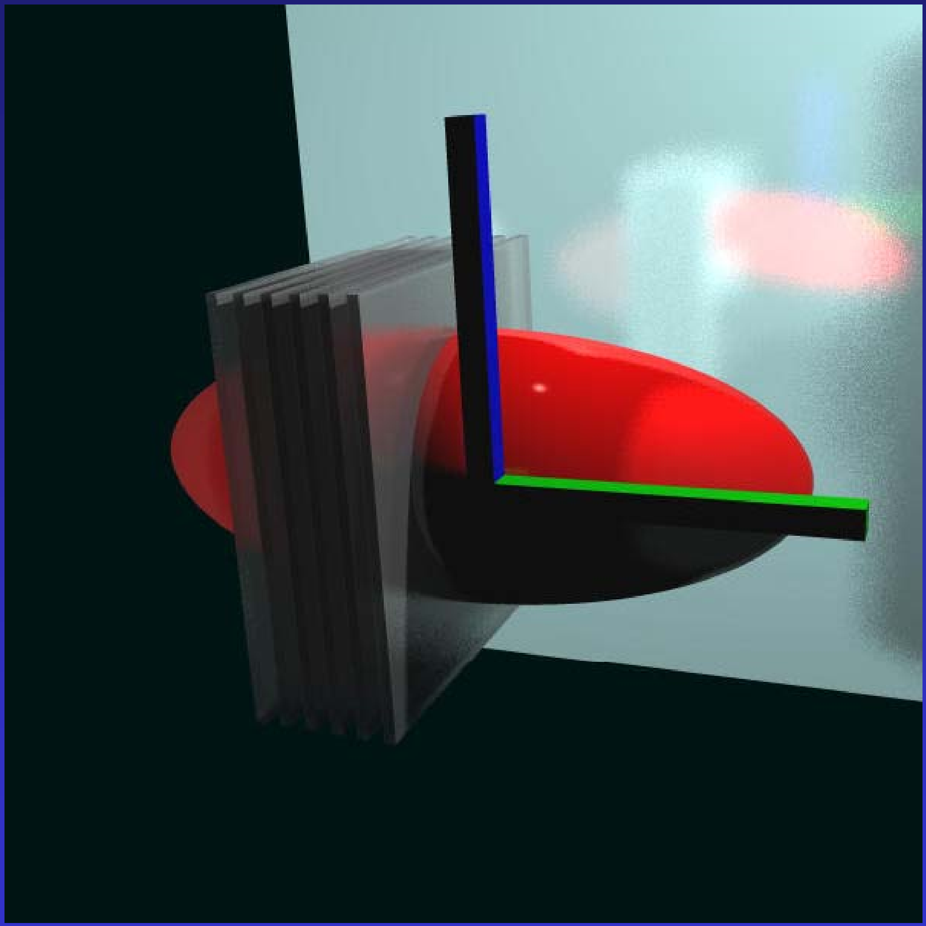
Frequencies above Nyquist limit are converted to noise instead of incorrect patterns





Gloss

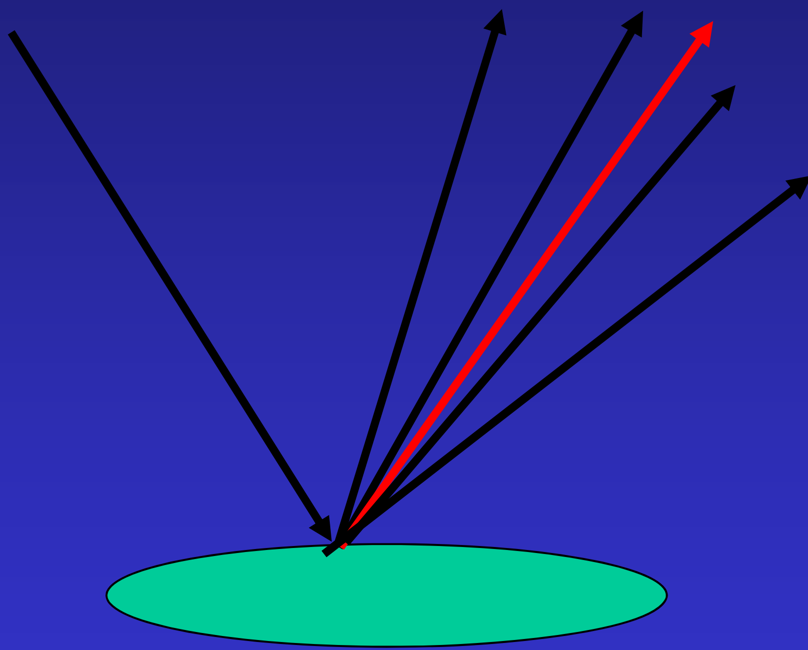




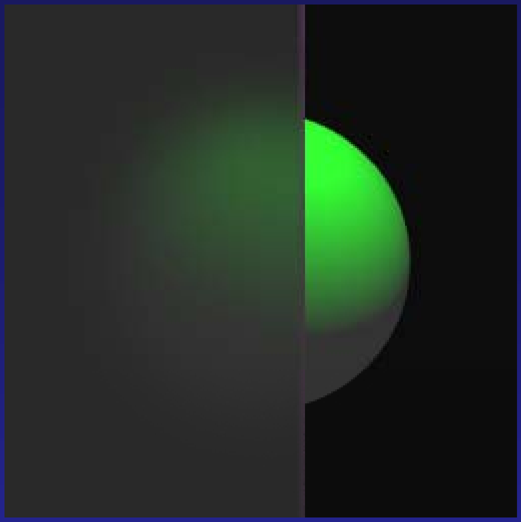
Gloss

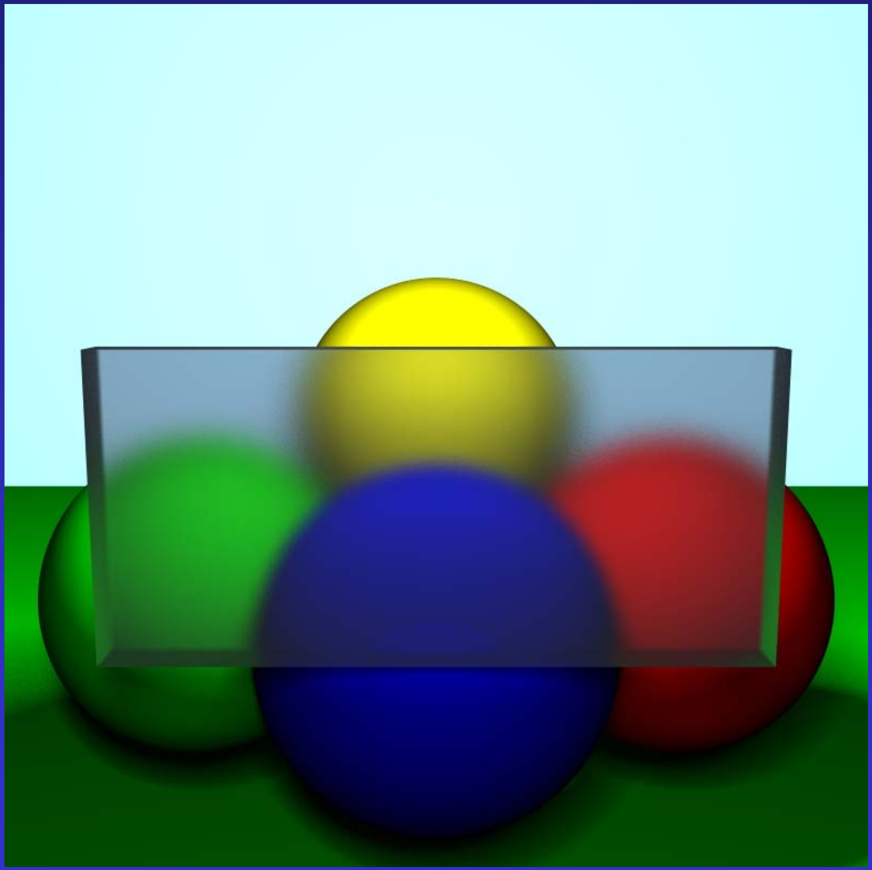
- Mirror reflections calculated by tracing rays in the direction of reflection
- Gloss is calculated by distributing these rays about the mirror direction
  - The distribution is weighted according to the same distribution function that determines highlights.

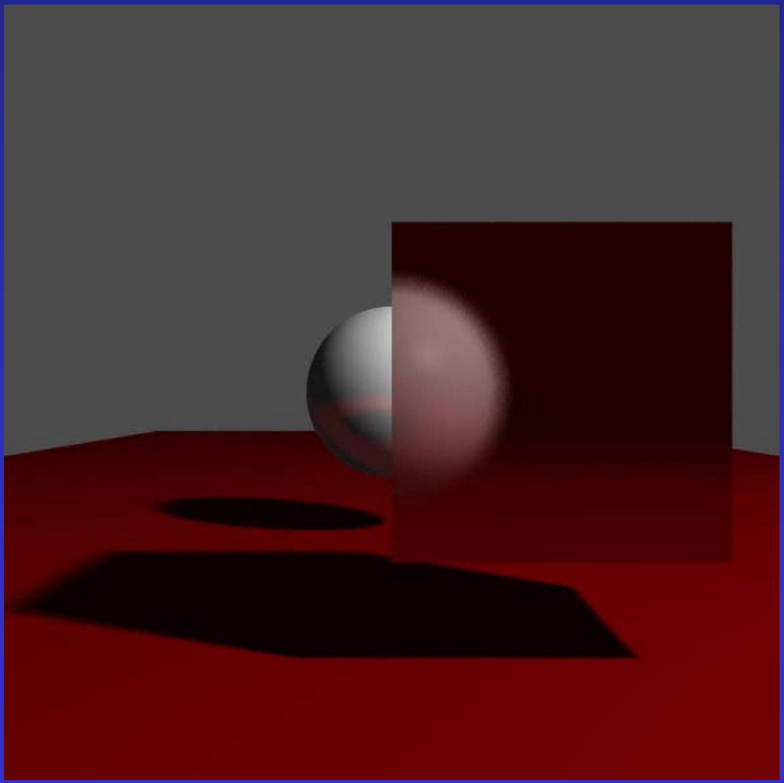
Gloss



Translucency



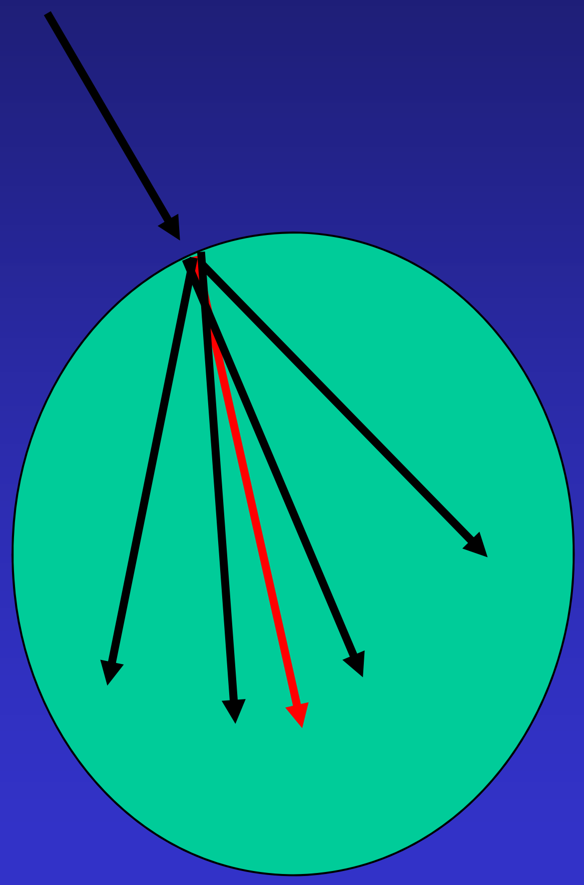




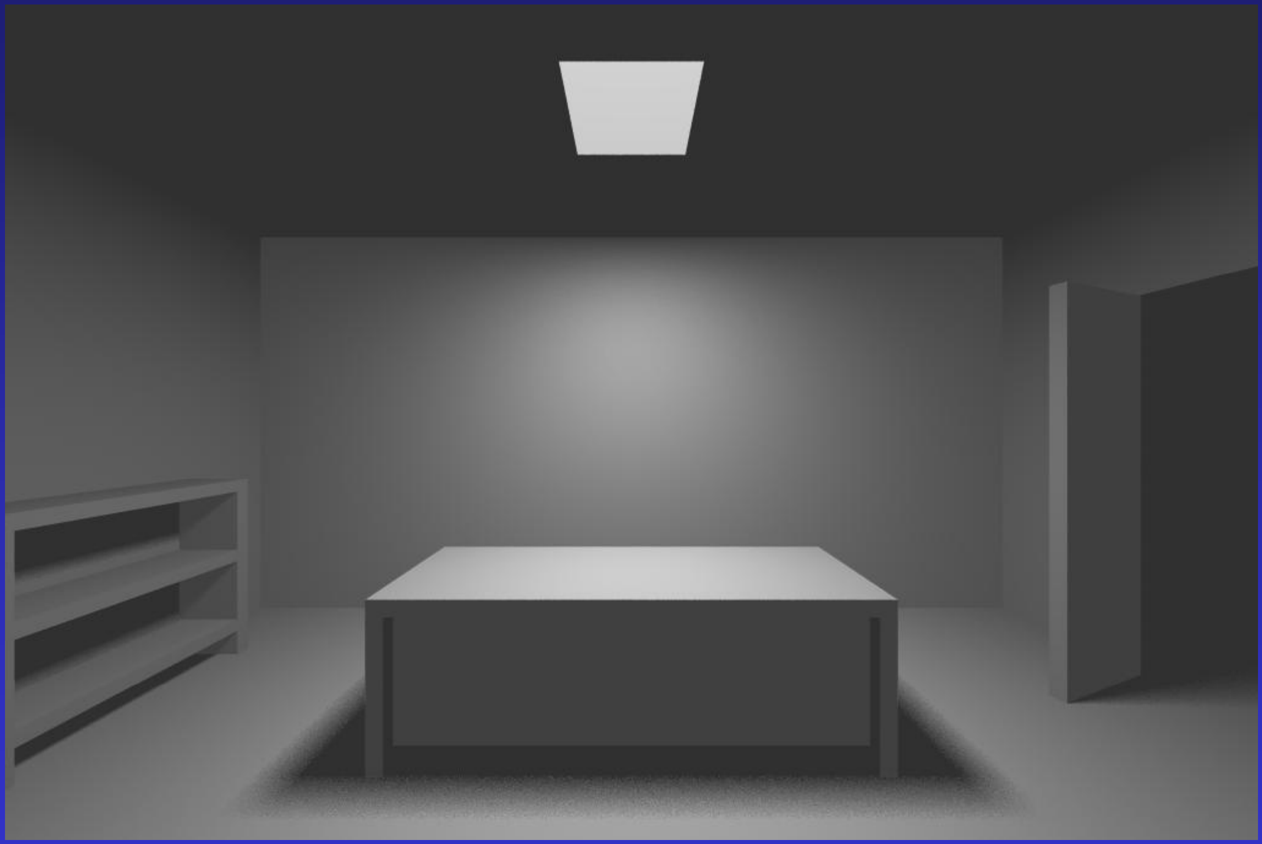
Translucency

- Analogous to the problem of gloss
- Distribute the secondary rays about the main direction of the transmitted rays
  - The distribution of transmitted rays is defined by a specular transmittance function

Translucency



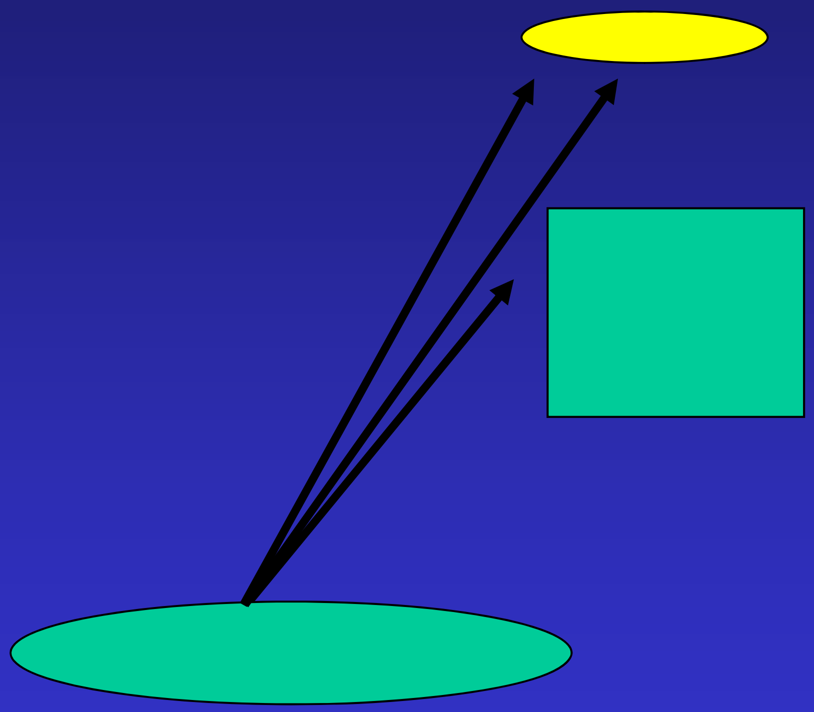
Penumbras



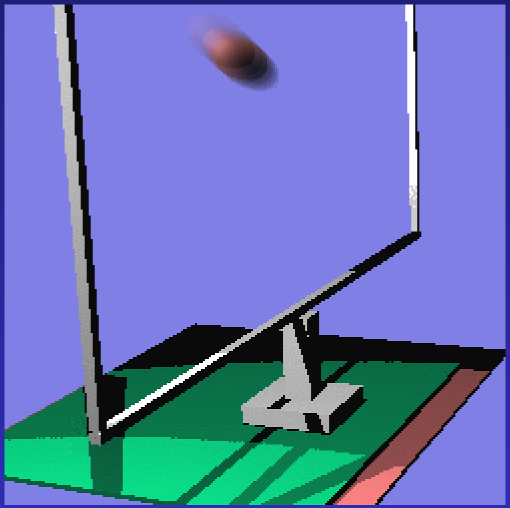
Penumbras

- Consider the light source to be an area, not a point
- Trace rays to random areas on the surface of the light source
- distribute rays according to areas of varying intensity of light source (if any)
- Use the fraction of the light intensity equal to the fraction of rays which indicate an unobscured light source

Penumbras



Motion Blur

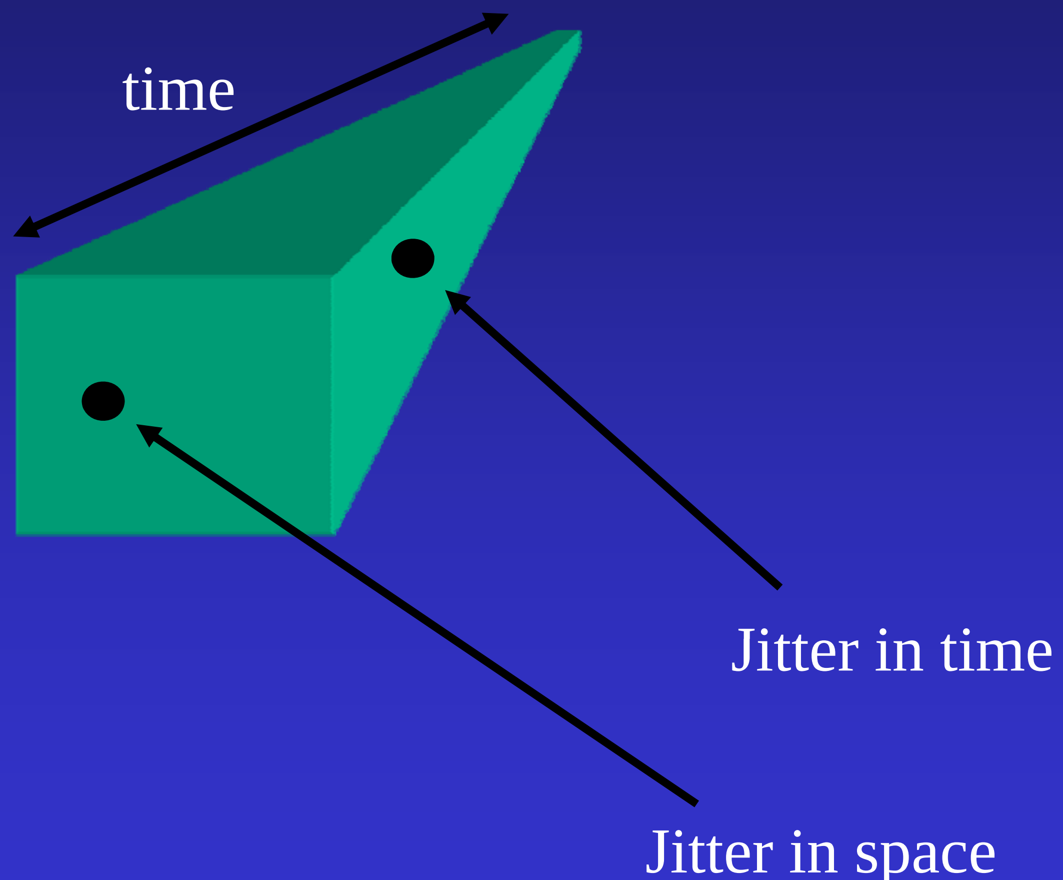


Motion Blur

Post-process blurring can get some effects, but consider:

- Two objects moving so that one always obscures the other
  - Can’t render and blur objects separately
- A spinning top with texture blurred but highlights sharp
  - Can’t post-process blur a rendered object
- The blades of a fan creating a blurred shadow
  - Must consider the movement of other objects

Temporal Jittered Sampling



Temporal Jittered Sampling

7	11	3	14
4	15	13	9
16	1	8	12
6	10	5	2

Pinhole Camera

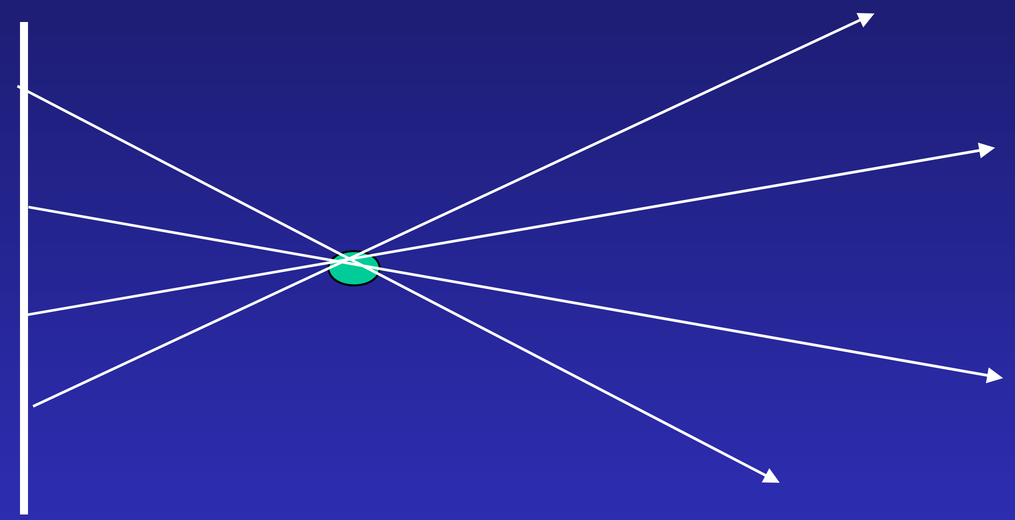
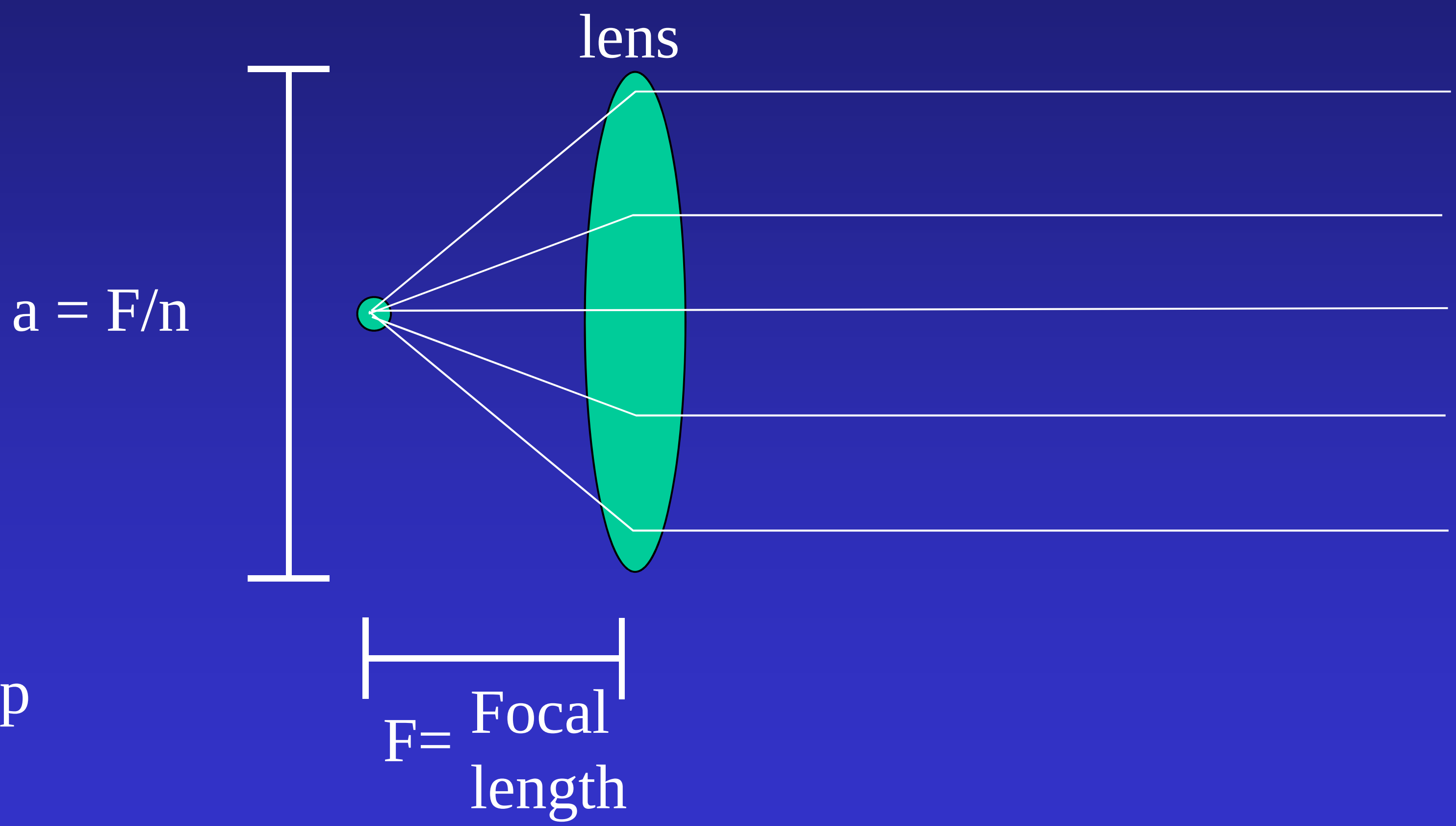


Image plane

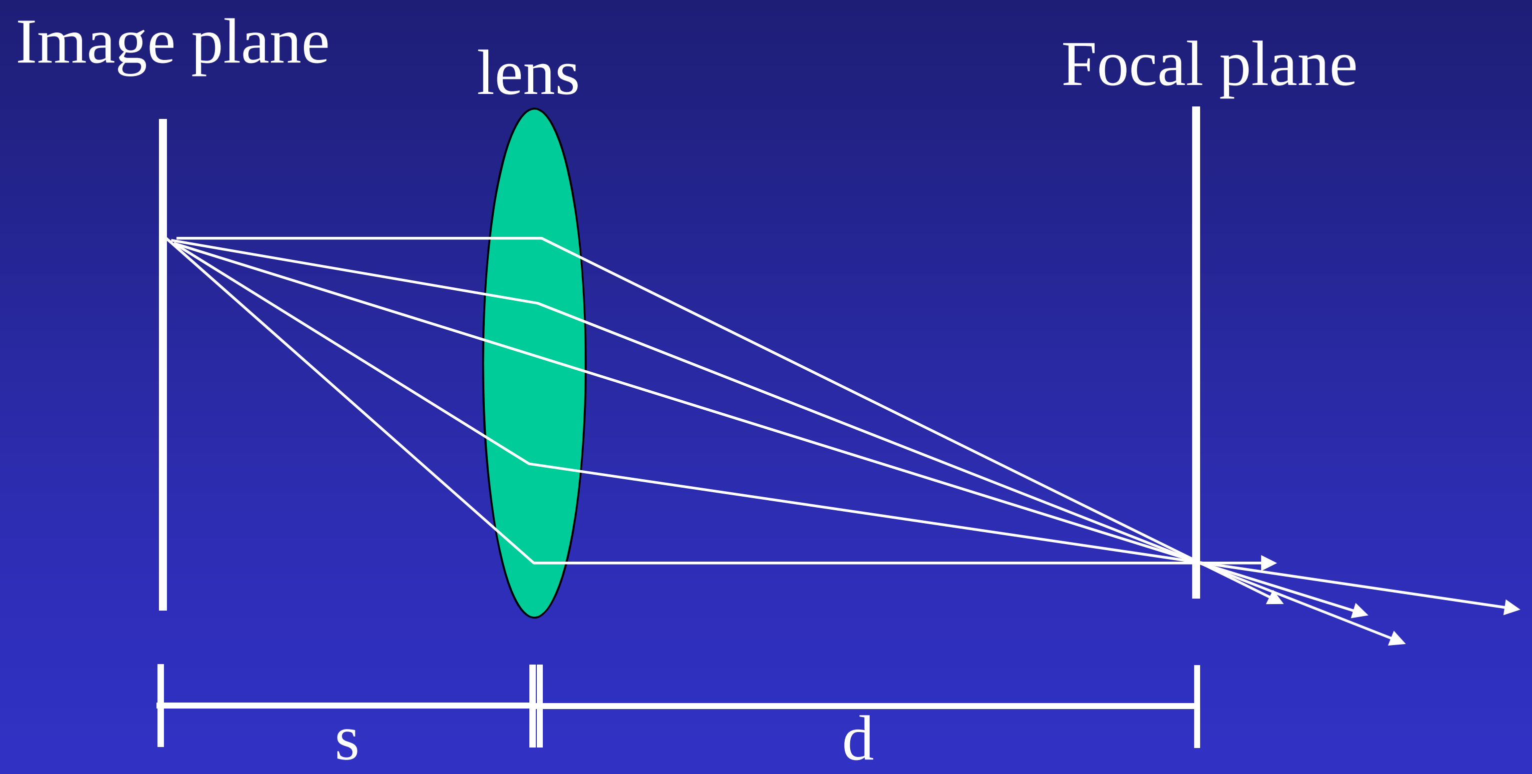
Perfect focus - low light

Use of lens - more light



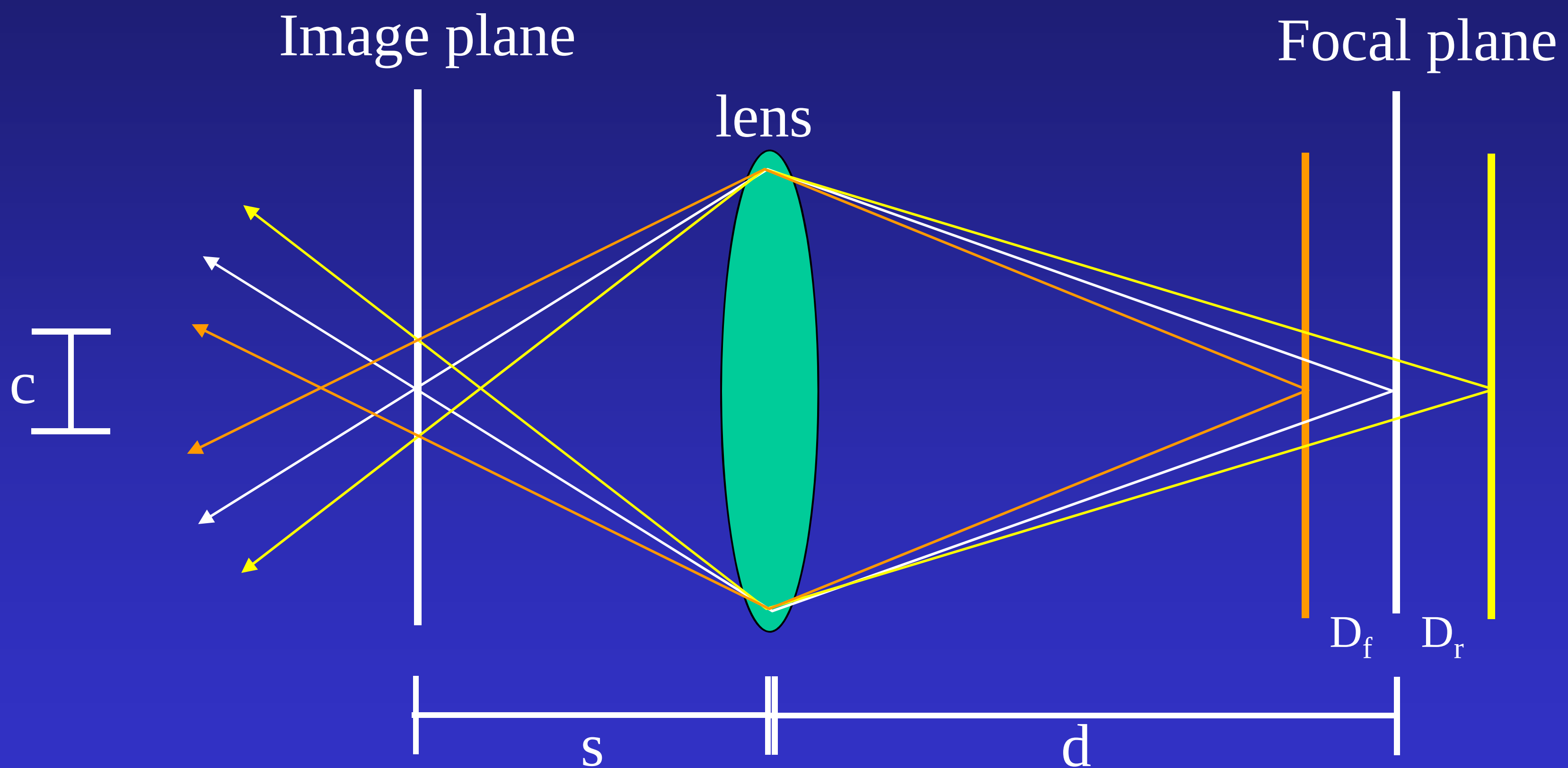
n = f-stop

Use of lens - more light



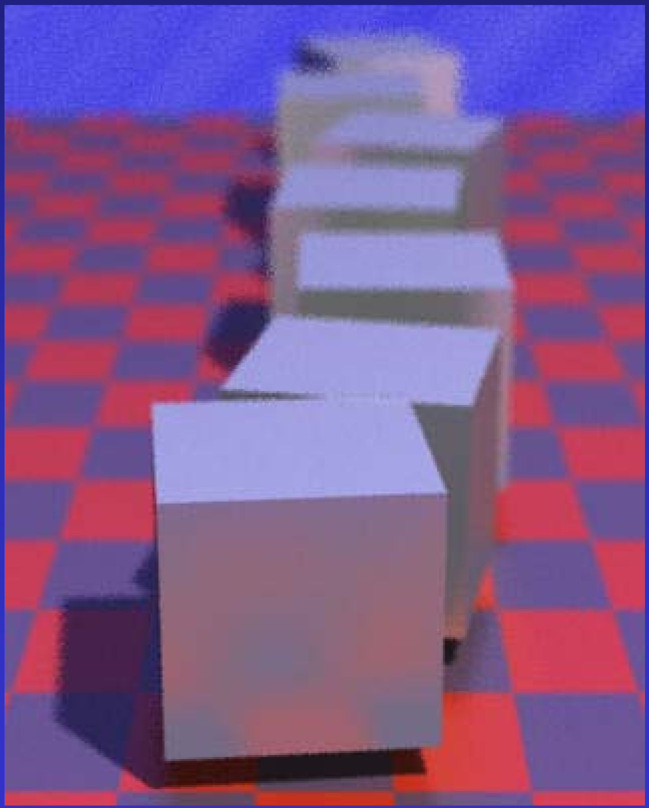
$$\frac{1}{s}+\frac{1}{d}=\frac{1}{f}$$

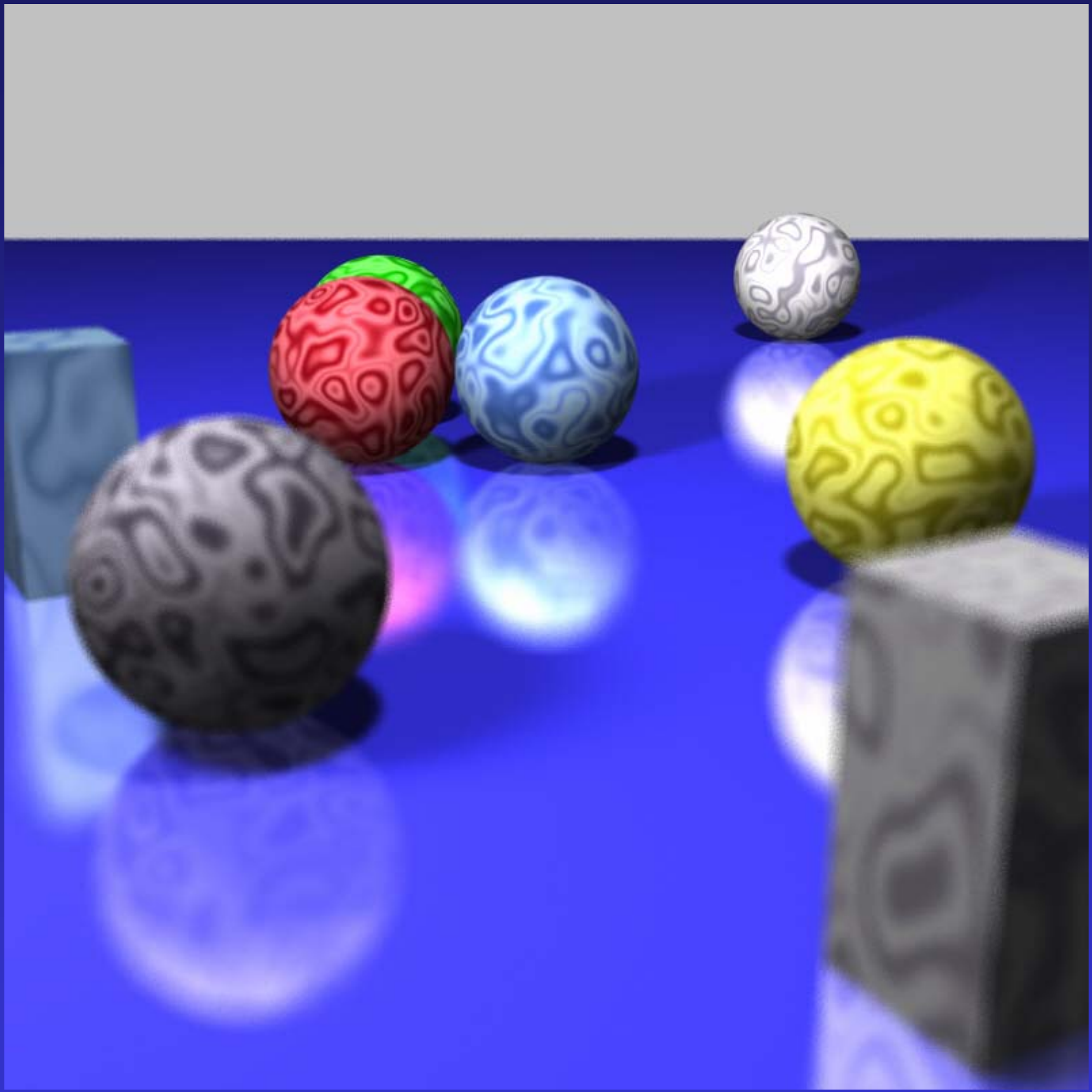
Circle of Confusion



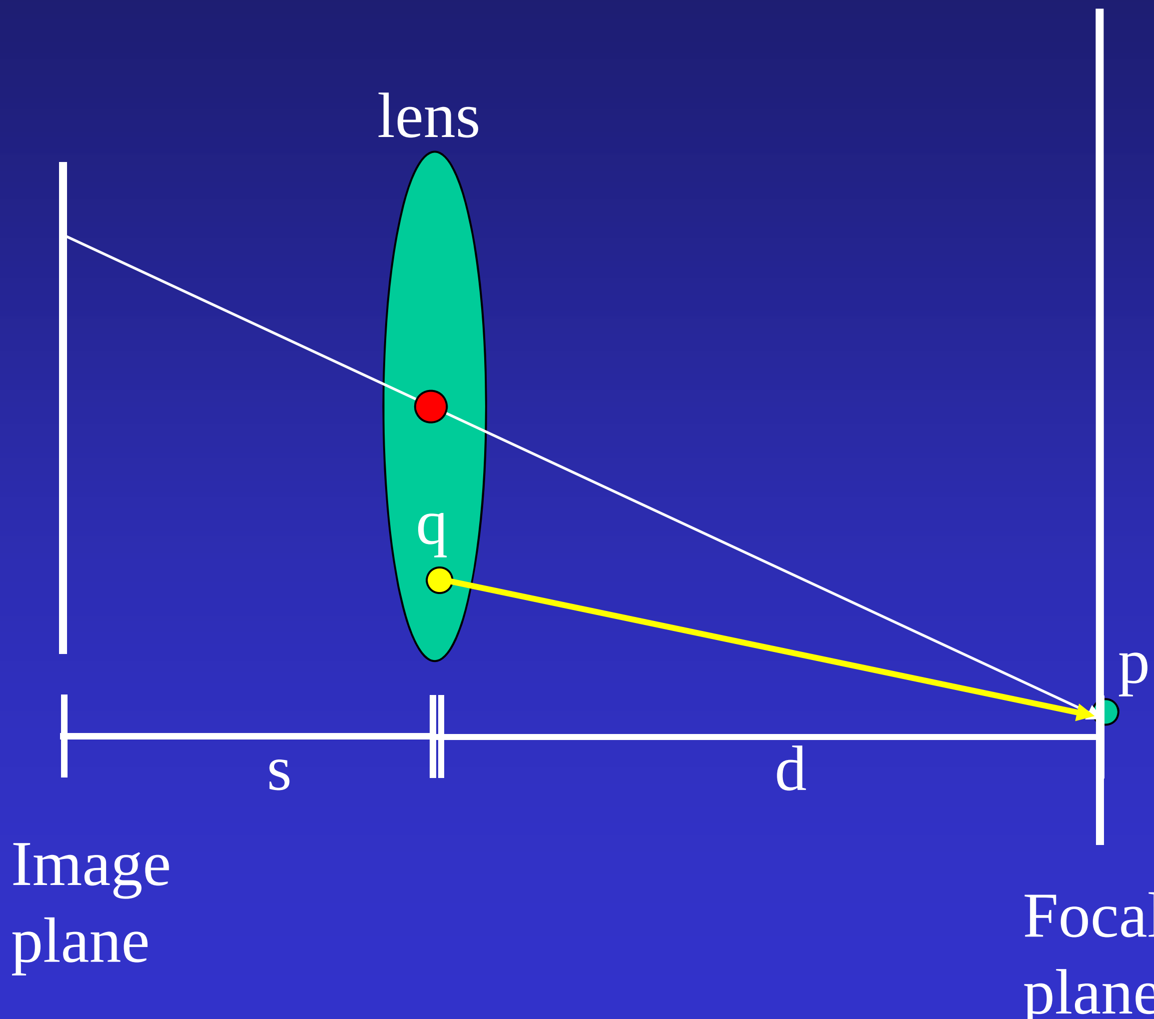
c = circle of confusion ~= 0.33mm

Depth of Field





Depth of Field



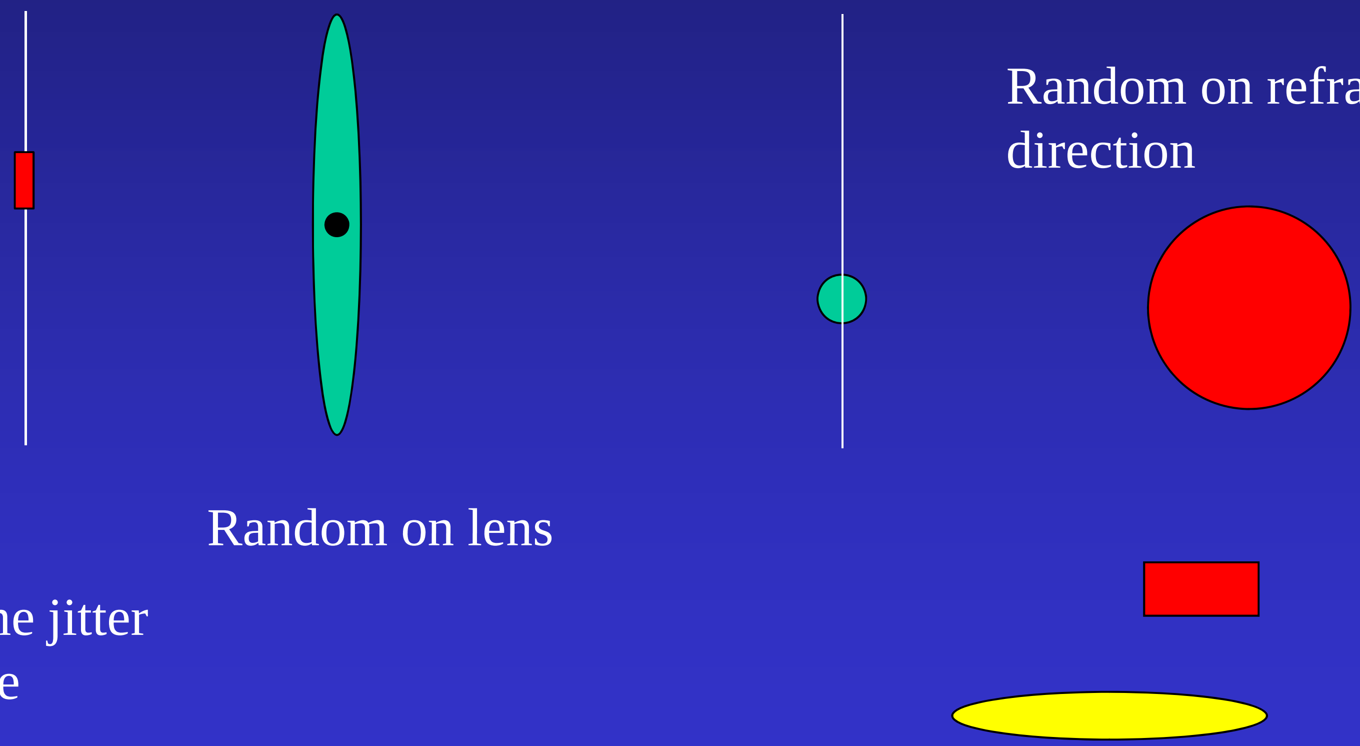
Given pixel, s, d

1. Construct ray from pixel through lens center to point p on focal plane

2. Randomly generate point q on 2D lens

3. Trace ray from q through p

Summary


Random on refraction direction
Random on refraction direction
Random on lens
Space-time jitter subsample
Random on area light source