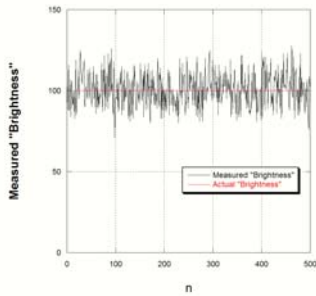


## Example:



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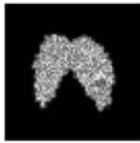
## How to "Add" More Photons

### 1. Make Pinhole Larger

⇒ "Fuzzy" Image



Input Object  
(Radioactive Thyroid  
w/ "Hot" and "Cold" Spots)



"Noisy" Output Image  
(because of small number  
of detected photons)



"Fuzzy" Image  
Through Large Pinhole  
(but less noise)

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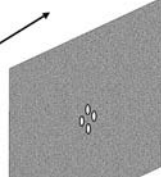
## How to "Add" More Photons

### 2. Add More Pinholes

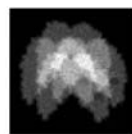
■ BUT: Images "Overlap"



Input Object  
 $f[x, y, z, t, \lambda]$



Absorber with  
Four Pinhole Apertures



Output Image  
 $g[x, y]$

In

IT

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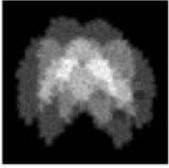
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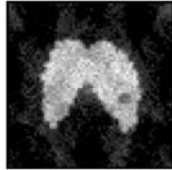
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## How to "Add" More Photons 2. Add More Pinholes

- Process in Computer to Combine "Overlapping" Images



Before Postprocessing



After Postprocessing

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## Improvements to "Ray Selection"

1. Select more rays with more pinholes
2. Combine features of pinhole and mirror

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## Alternatives to "Ray Selection"

- Find an element that BOTH "selects" and "redirects" rays
- Combine a Pinhole and a Mirror

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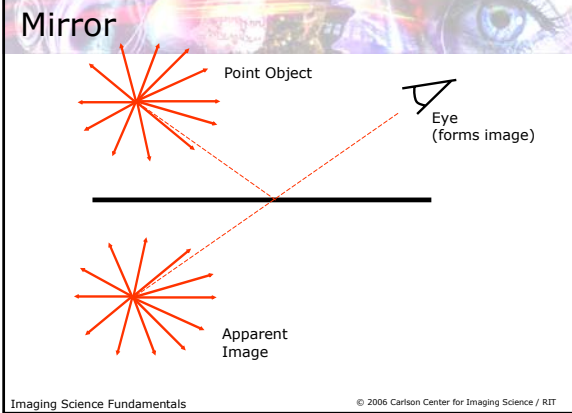
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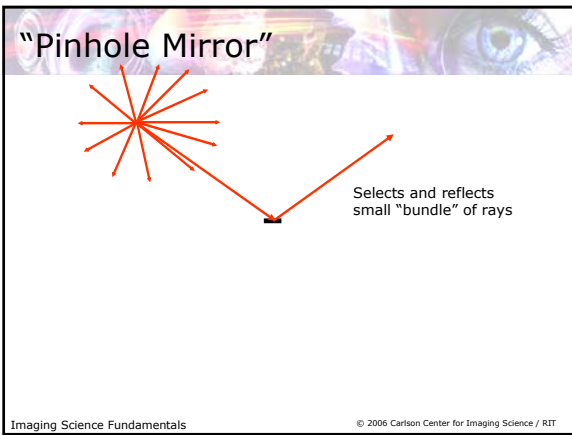
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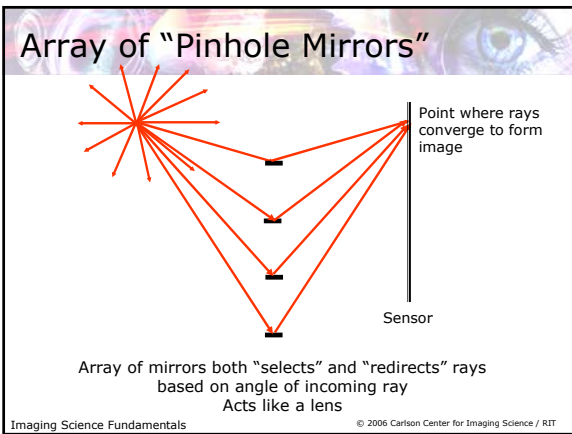
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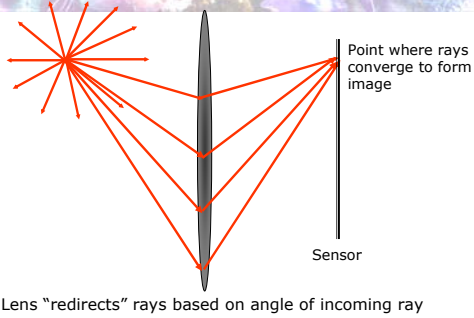
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## Array of "Pinhole Mirrors"



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## Need for Collection Element

- A crucial component in most imaging systems collects the energy emerging from a single point on the object and *redirects* it to a *single* point in the image
  - Lens
  - Mirror
  - Diffractive element

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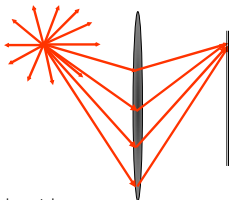
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## Light Collection

- "Redirection" of rays based on incoming angle allows you to make a "brighter" image, since more rays reach the sensor



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## Transparent Optical Elements

- Speed of light is *slower* in medium

$$v < c \approx 3 \times 10^8 \frac{\text{meters}}{\text{sec}}$$

- Medium described by *refractive index*  $n$

$$n_{\text{medium}} \equiv \frac{c}{v_{\text{medium}}} \geq 1$$

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## Index of Refraction $n$

- Vacuum:  $n = 1.0$
- Air at Standard Temperature and Pressure (STP):  $n \approx 1.00027$
- Water:  $n \approx 1.33 \approx 4/3$
- Glass:  $1.4 \leq n \leq 1.65$ , often  $n \approx 1.5$
- Diamond:  $n \approx 2.42$
- Germanium:  $n \approx 4.0$  (but only for thermal infrared light)

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