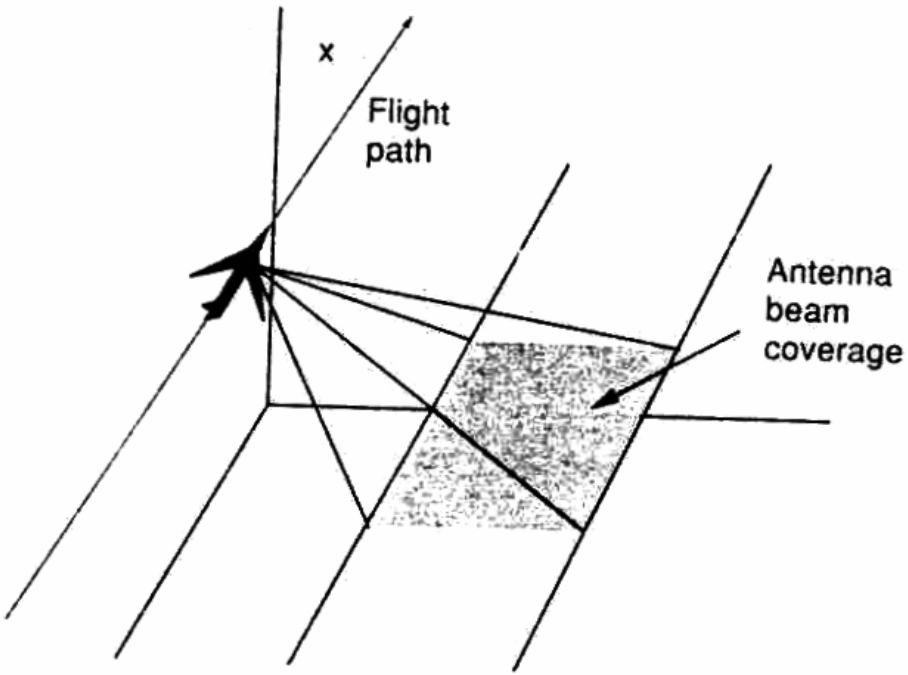
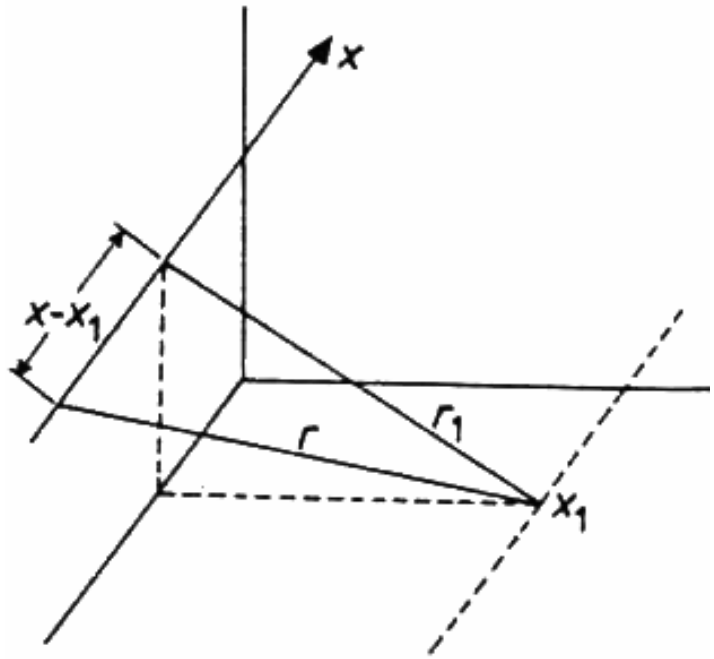
Applications of Optical Signal Processing

Synthetic-Aperture Radar (SAR) (I)





Synthetic-Aperture Radar (SAR) (II)

$$S_1(t) = A_1 \exp\left[- j\omega\left(t - \frac{2r}{c} \right) \right]$$

$$r = \sqrt{r_1^2 + (x - x_1)^2} \approx r_1 + \frac{(x - x_1)^2}{2r_1}$$

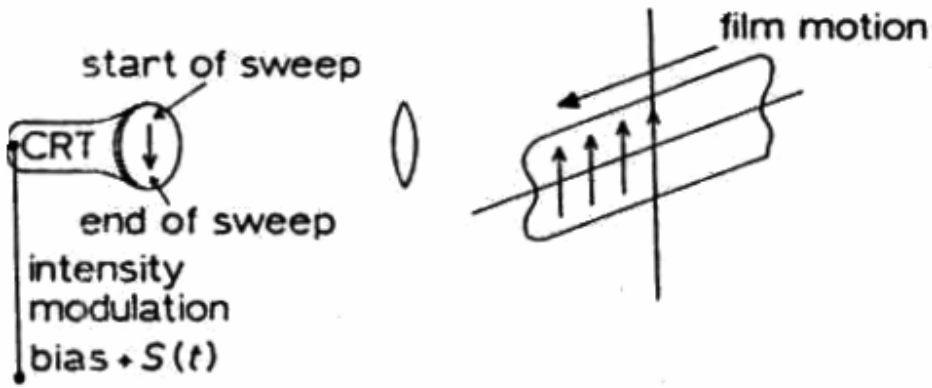
$$S_1(t) = A_1(x_1, r_1) \exp\left\{ - j\left[\omega t - 2kr_1 - \frac{k}{r_1}(x - x_1)^2 \right] \right\}$$

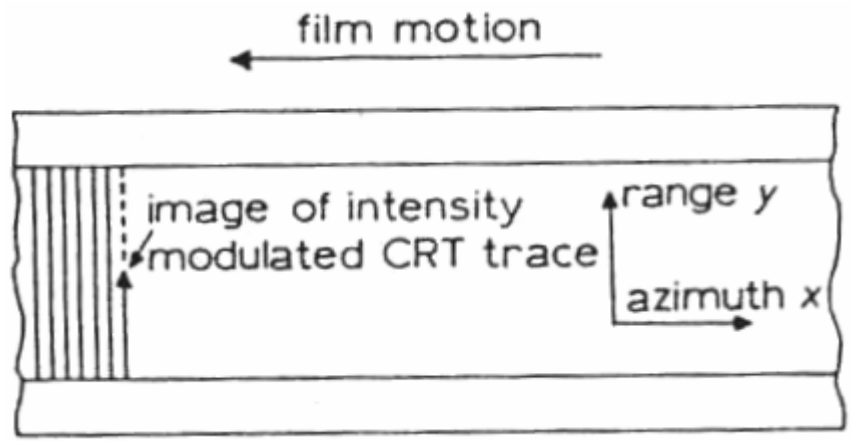
$$x = vt$$

Synthetic-Aperture Radar (SAR) (III)

$$S(t)=\sum_{n=1}^{N} S_n(t)=\sum_{n=1}^{N} A_n(x_n, r_1)\exp\left\{-j\left[\omega t-2kr_1-\frac{k}{r_1}(vt-x_n)^2\right]\right\}$$

$$S(t)=\sum_{n=1}^{N}\left|A_n(x_n,r_1)\right|\cos\left[\omega_c t-2kr_1-\frac{k}{r_1}(vt-x_n)^2+\phi_n\right]$$





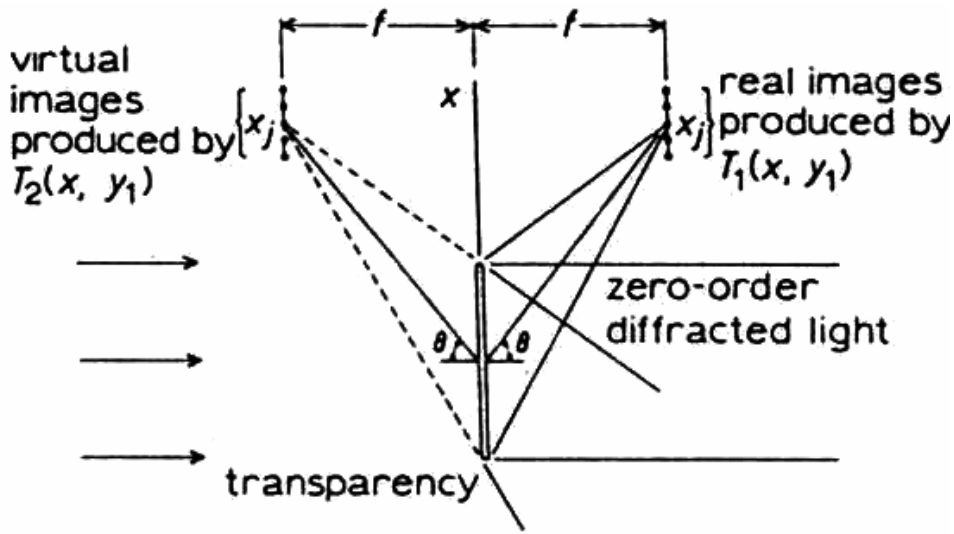
Synthetic-Aperture Radar (SAR) (IV)

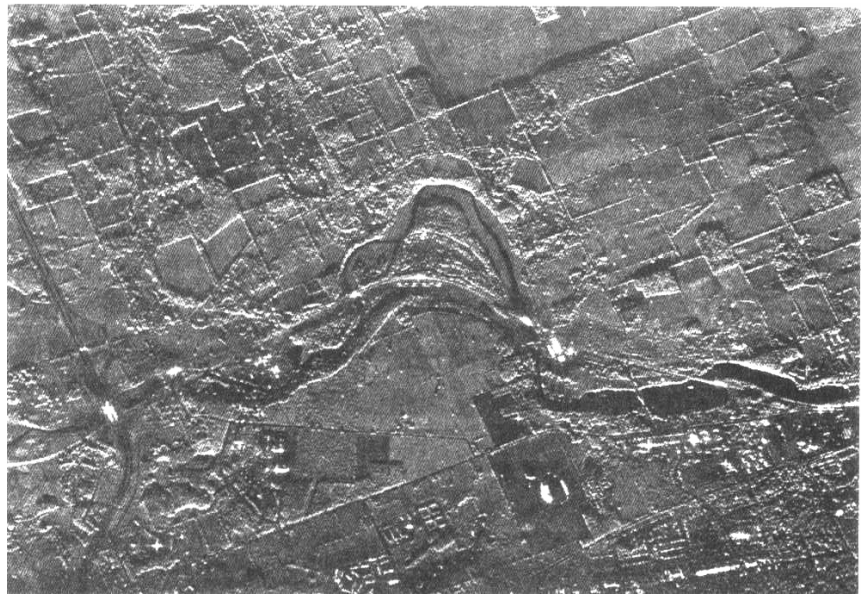
$$T(x,y_1)=K_1+K_2\sum_{n=1}^{N}\left|A_n(x_n,r_1)\right|\cos\left[\omega_x x-2kr_1-\frac{k}{r_1}\left(\frac{v}{v_f}x-x_n\right)^2+\phi_n\right]$$

$$T_1(x,y_1)=\frac{K_2}{2}\sum_{n=1}^{N}\left|A_n(x_n,r_1)\right|\exp\left\{j\left[\omega_x x-2kr_1-\frac{k}{r_1}\left(\frac{v}{v_f}\right)^2\left(x-\frac{v_f}{v}x_n\right)^2+\phi_n\right]\right\}$$

$$T_2(x,y_1)=\frac{K_2}{2}\sum_{n=1}^{N}\left|A_n(x_n,r_1)\right|\exp\left\{-j\left[\omega_x x-2kr_1-\frac{k}{r_1}\left(\frac{v}{v_f}\right)^2\left(x-\frac{v_f}{v}x_n\right)^2+\phi_n\right]\right\}$$

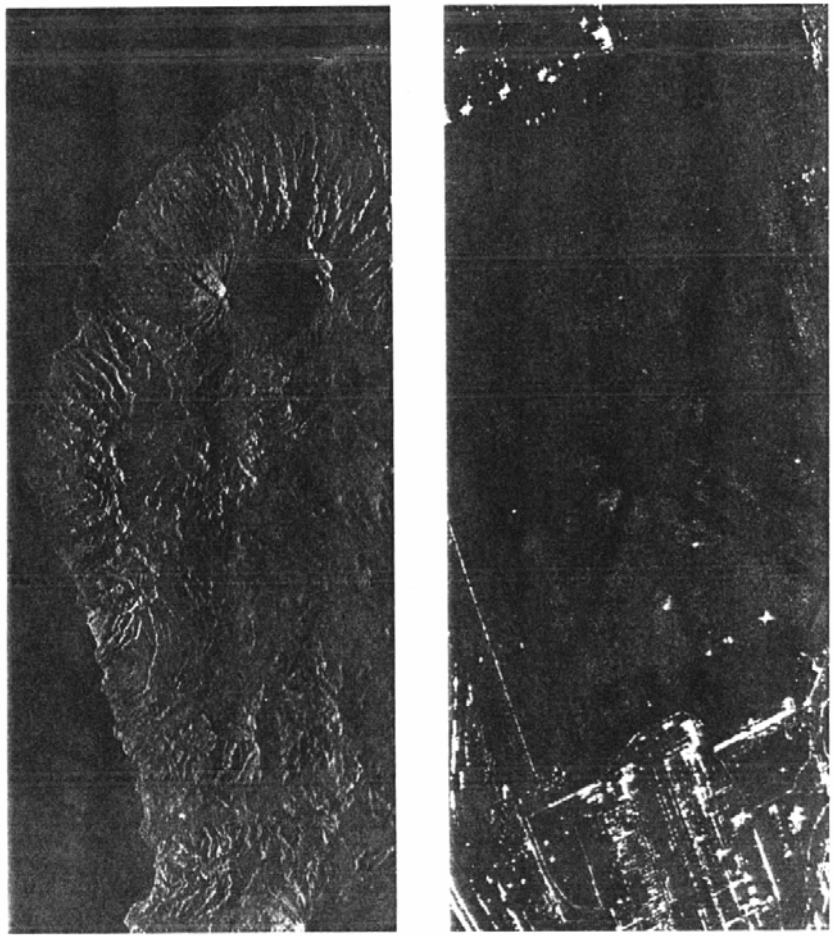
Synthetic-Aperture Radar (SAR) (V)





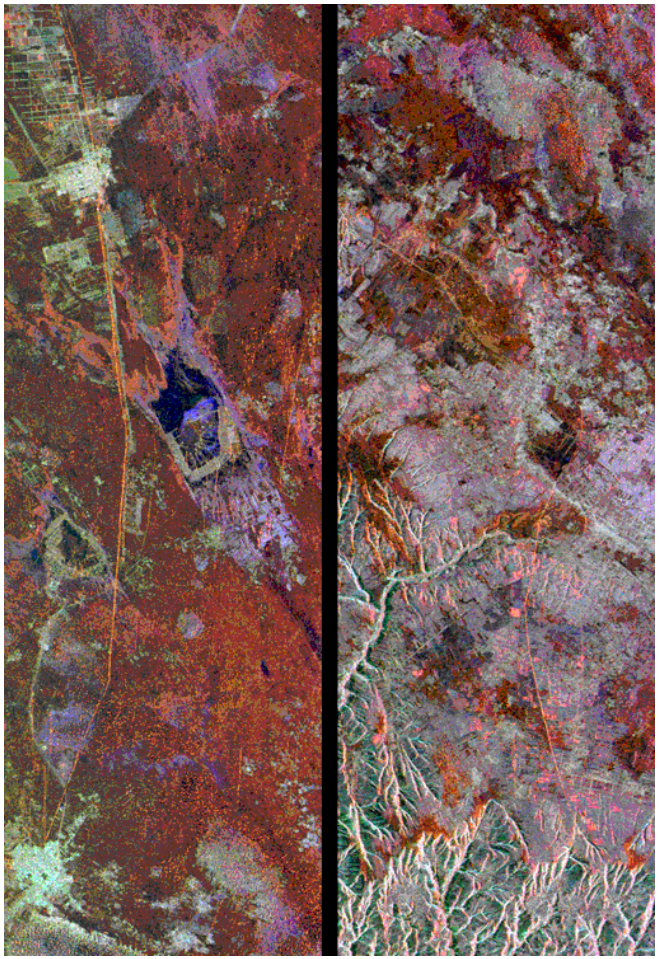
Synthetic-Aperture Radar (SAR) (VI)

(a)



(b)

Synthetic-Aperture Radar (SAR) (VII)



The images were acquired by the Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) onboard the space shuttle Endeavour on April 10, 1994. SIR-C/X-SAR, a joint mission of the German, Italian and the United States space agencies, is part of NASA's Mission to Planet Earth.

Restoring Blurred Image (I)

$$G(p) = S(p)D(p)$$

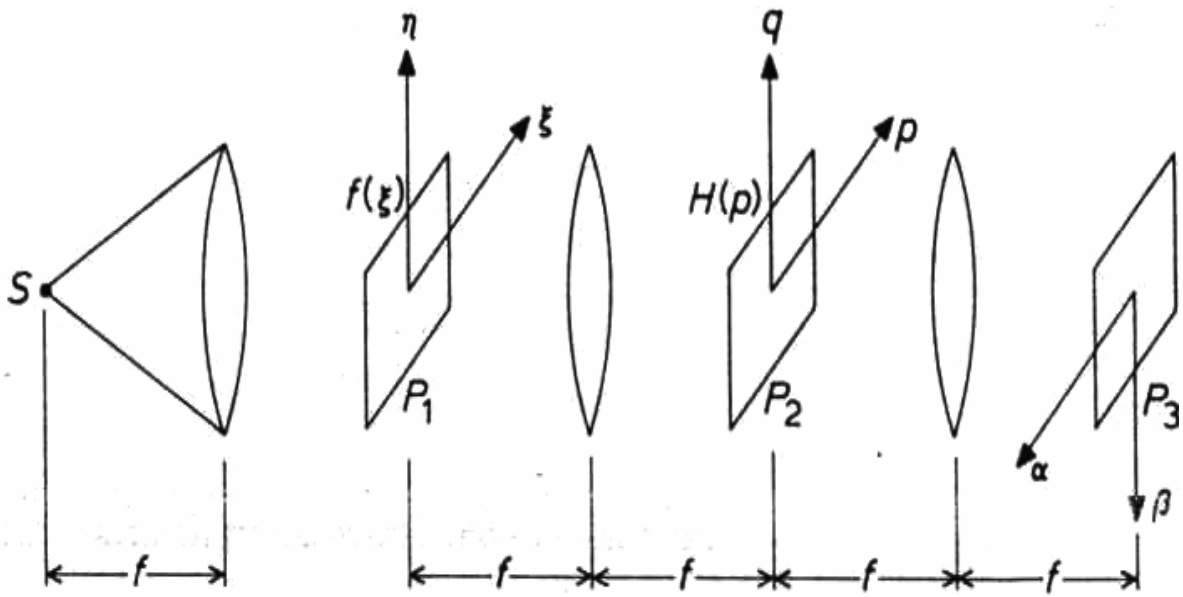
$$H(p) = \frac{1}{D(p)}$$

Restoring Blurred Image (II)

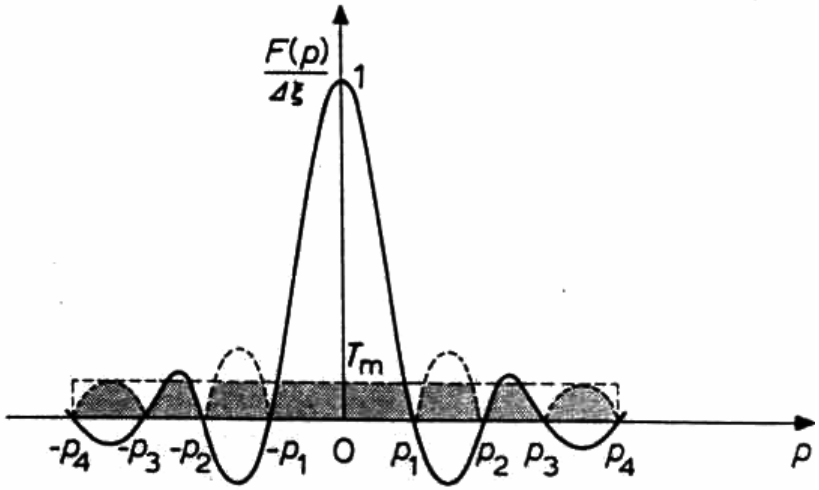
$$f(\xi)=\begin{cases}1, & -1/2\Delta\xi \le \xi \le 1/2\Delta\xi \\ 0, & \text{otherwise}\end{cases}$$

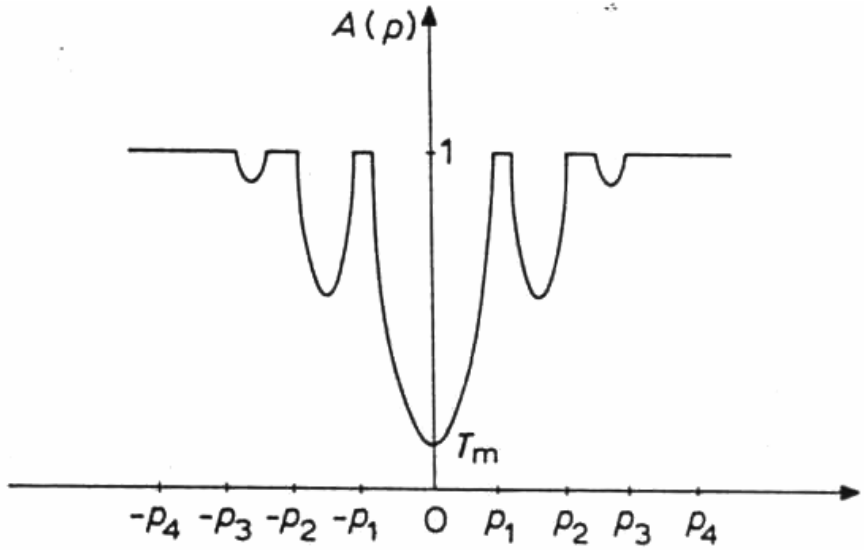
$$F(p)=\Delta\xi\frac{\sin(p\Delta\xi/2)}{p\Delta\xi/2}$$

$$H(p)=\frac{p\Delta\xi/2}{\sin(p\Delta\xi/2)}$$

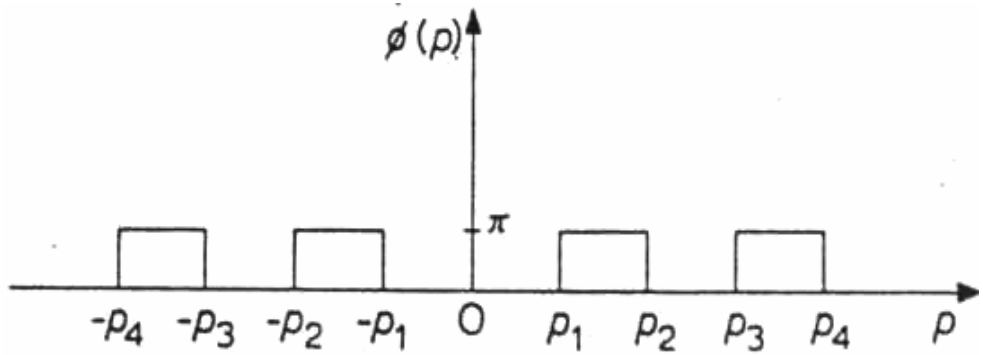


Restoring Blurred Image (III)



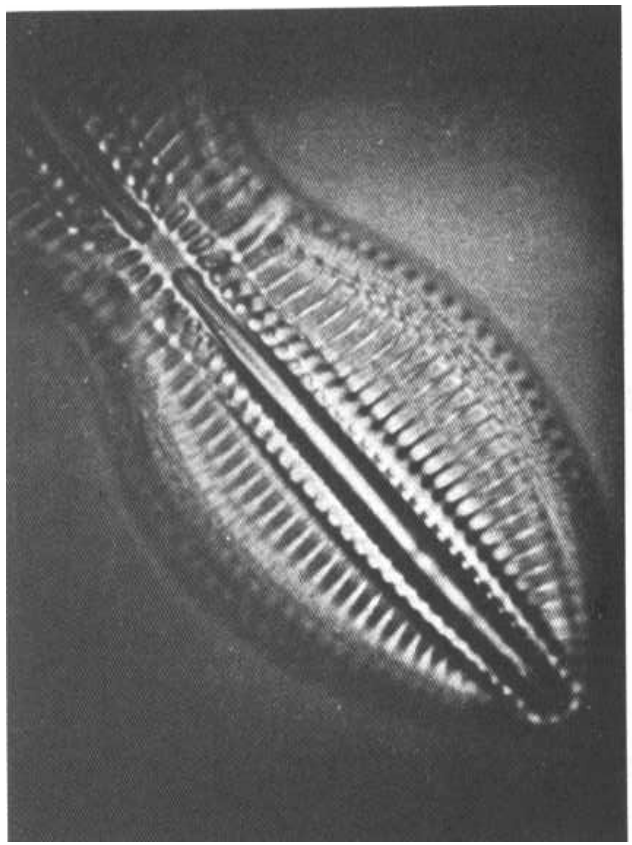


$$H(p) = A(p)e^{j\phi(p)}$$

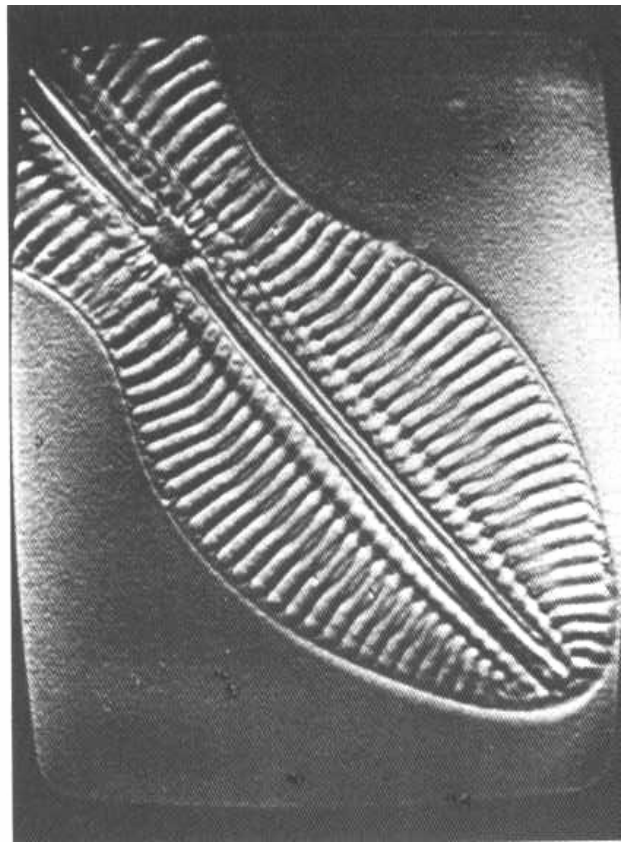


Restoring Blurred Image (IV)

Increase of Death of Field (Using Spatial Filtering)



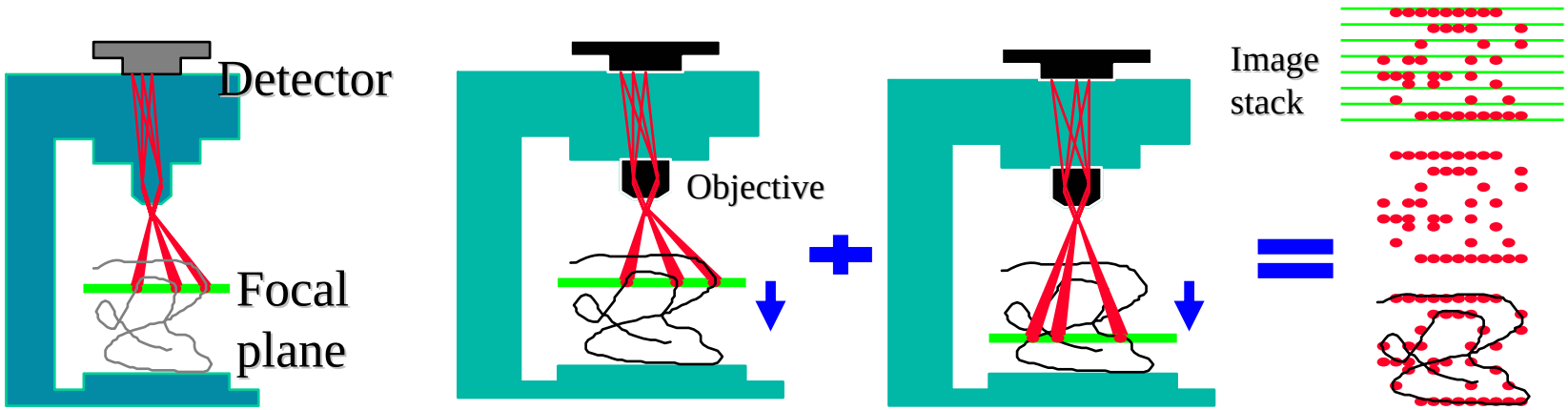
(a)



(b)

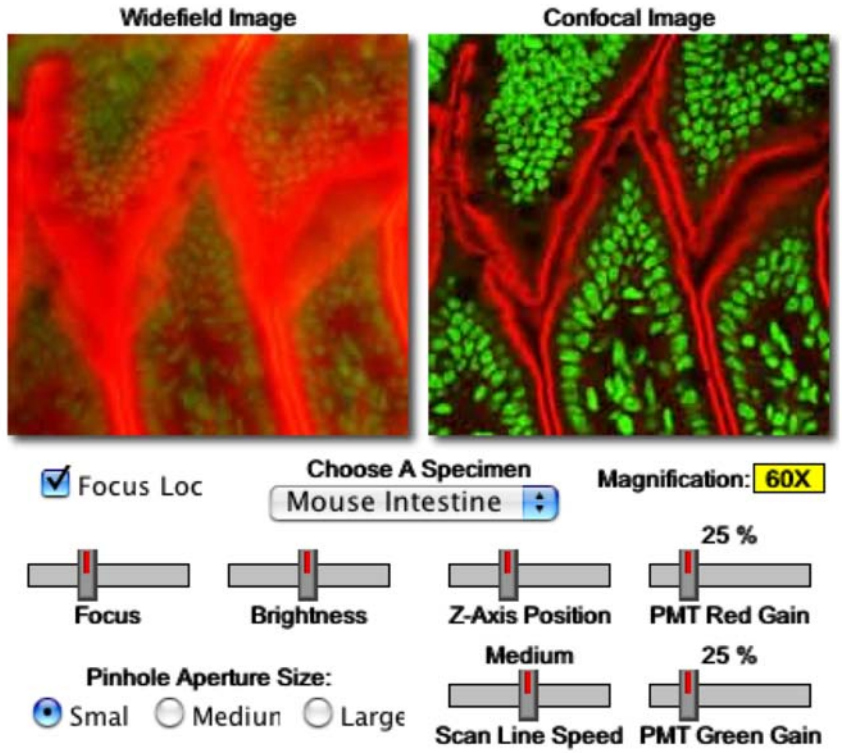
3D Microscopy

- Introduction to 3D Microscopy
  - ✓ 3D Microscopy
    - The spreading of light from a point source actually occurs in three dimensions.
    - When a microscope is focused on a specimen, the detector records an image from a plane.
      - This is the focal plane.
      - Parts of the specimen in the best focus.
    - 3D data is acquired by combining data from several different focal planes into a stack of images.
    - This is accomplished by changing the distance between the specimen and the microscope's objective lens from one image acquisition to the next.



3D Microscopy

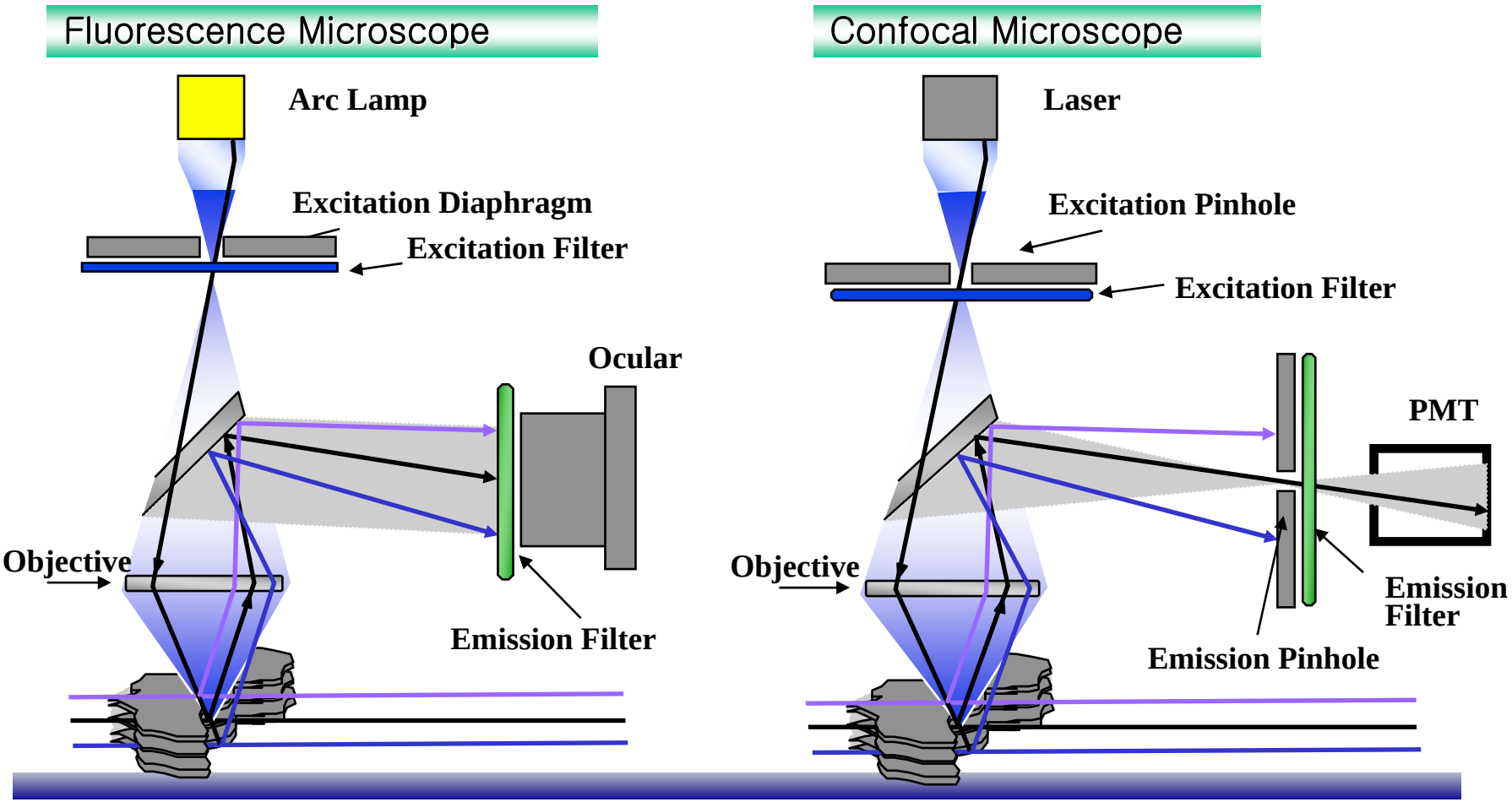
- Fluorescence & Confocal Microscopy
  - ✓ Fluorescence Microscopy
    - – Fluorescence microscope collects light emitted from all points in the specimen (with varying efficiencies depending on position relative to focal plane).
    - – The result for specimens that are thick relative to the depth of focus of the objective is a blurred image.
  - ✓ Confocal Microscopy
    - – One way to obtain images that better represent the fluorescence distribution just in the focal plane is to use a confocal microscope.



http://micro.magnet.fsu.edu/primer/techniques/confocal/index.html

3D Microscopy

❑ Principles of Fluorescence & Confocal Microscopy



3D Microscopy

- Characteristics of Confocal Microscopy
  - ✓ Benefits
    - Reduced blurring of the image from light scattering and increased effective resolution.
    - Improved signal to noise ratio and clear examination of thick specimens.
    - Z-axis scanning and depth perception in z-sectioned images.
    - Magnification can be adjusted electronically.
  - ✓ Drawbacks
    - Slower data acquisition - need to collect one pixel at a time.
    - Increased photo-damage (photo-bleaching) due to longer exposure to exciting light.
  - ✓ Spinning disk Confocal Microscopy
    - To allow faster acquisition, do confocal imaging "in parallel"

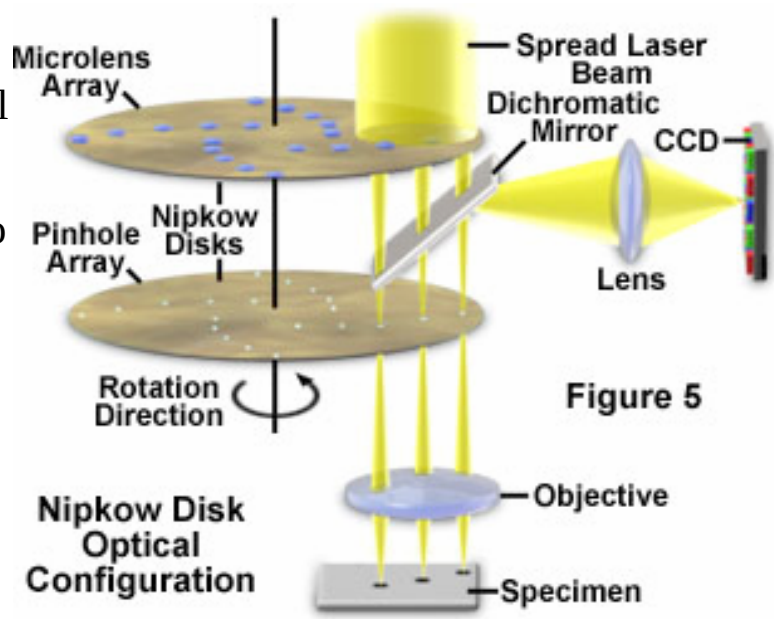
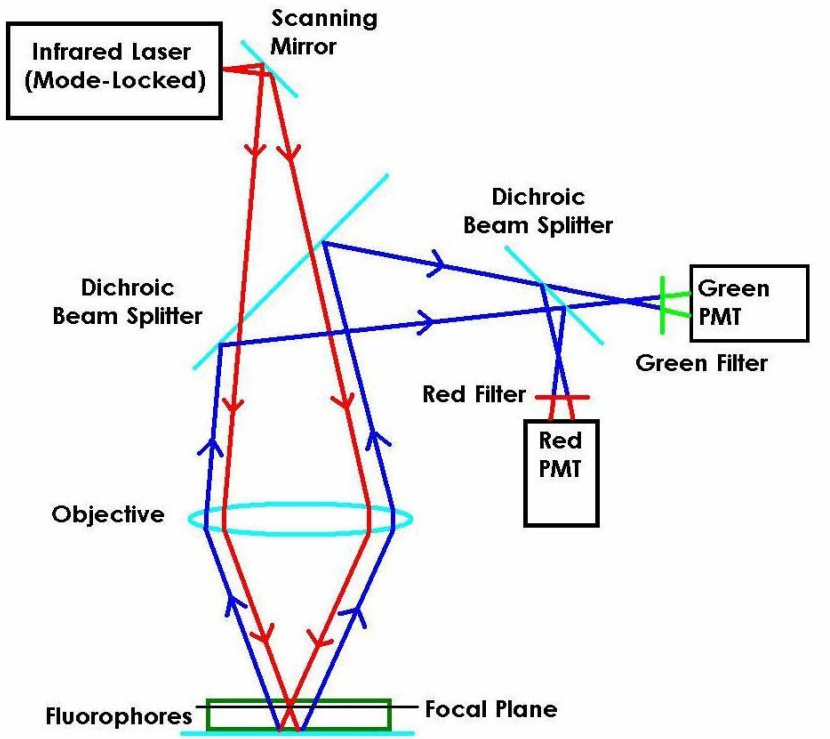
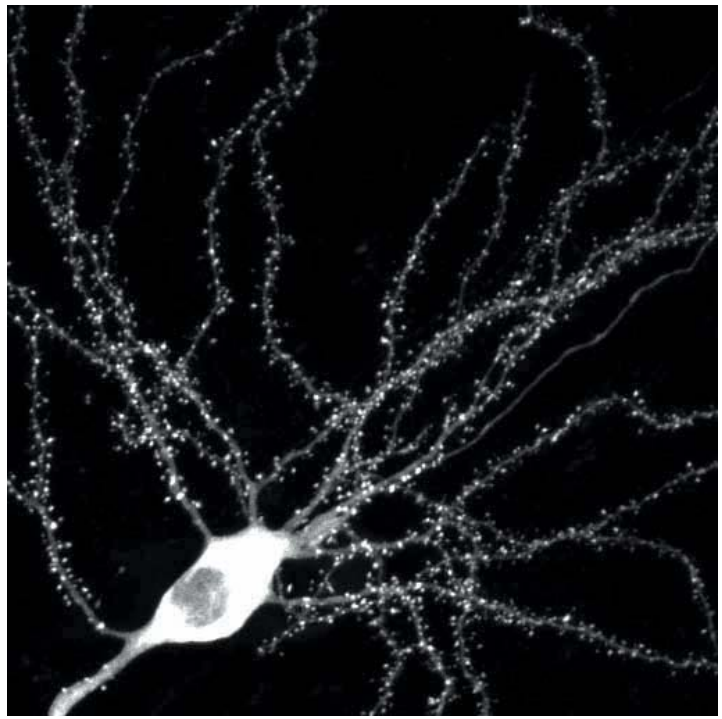


Figure 5

Two-Photon Scanning Microscopy





A live neuron visualized with two-photon microscope.
This neuron is expressing a recombinant protein that makes fluorescence.
http://www.brain.riken.go.jp/english/b_rear/b7/figures/y_hayashi.html