JPL

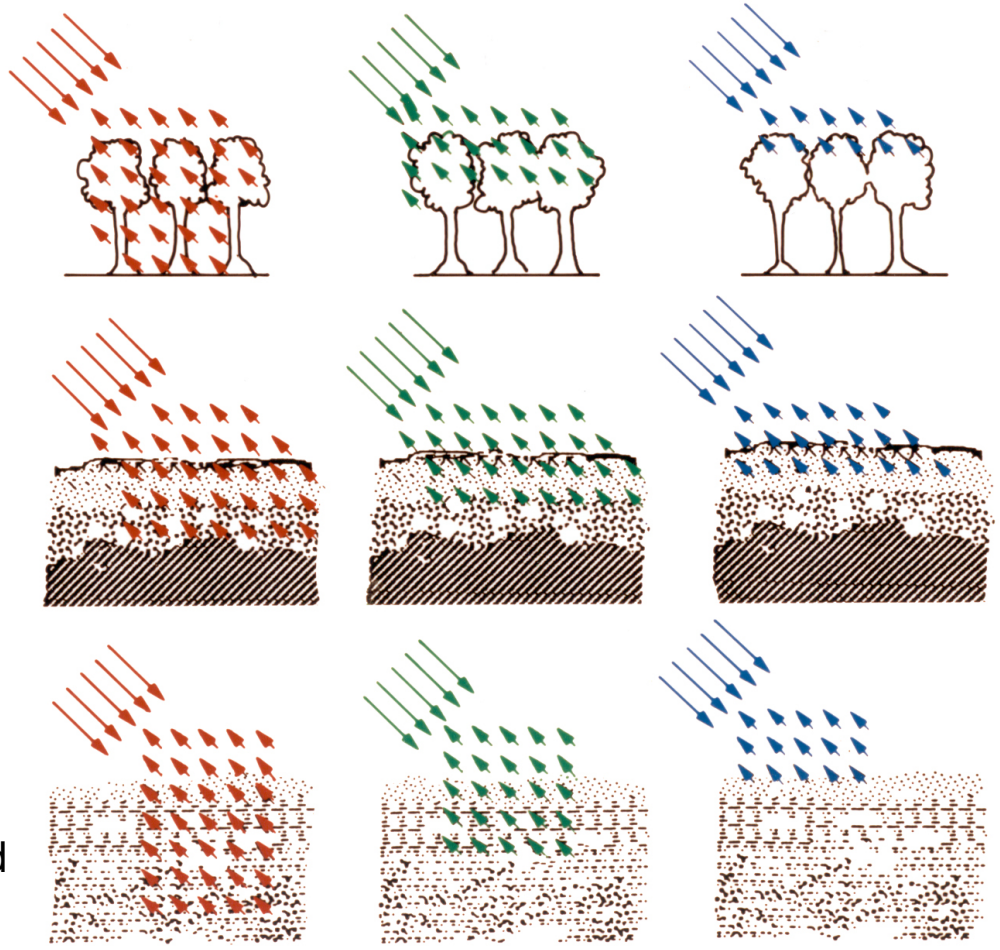
What Radar Can Tell Us

- Transmitted radar signals have known characteristics
  - Amplitude
  - Polarization
  - Phase and Time Reference
  - Wavelength, or Frequency
- A distant object that scatters the radar signal back toward the receiver alters the amplitude, polarization, and phase, differently for different wavelengths
- Comparison of the received signal characteristics to the transmitted signal allows us to understand the properties of the object.
- This is the principle of active remote sensing.

Wavelengths - A Measure of Surface Scale Sizes

Light interacts most strongly with objects on the size of the wavelength

L (24 cm) C (6 cm) X (3 cm)



Forest: Leaves reflect X-band wavelengths but not L-band

Dry soils: Surface looks rough to X-band but not L-band

Ice: Surface and layering look rough to X-band but not L-band

Radar Images in Different Bands

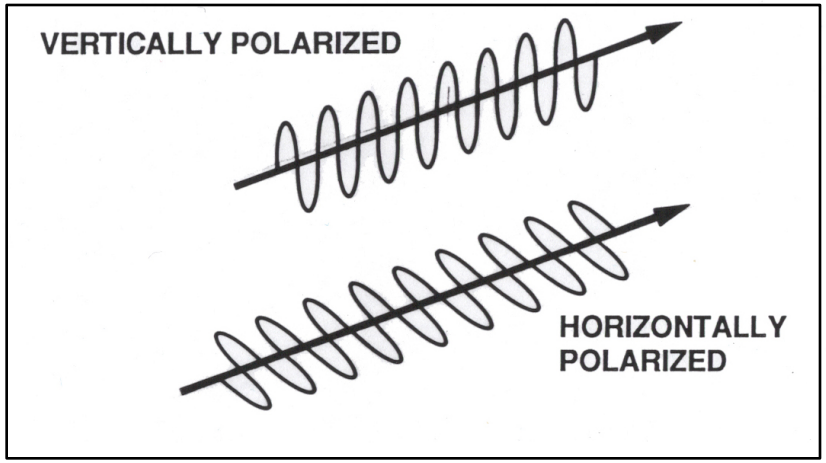
X-band

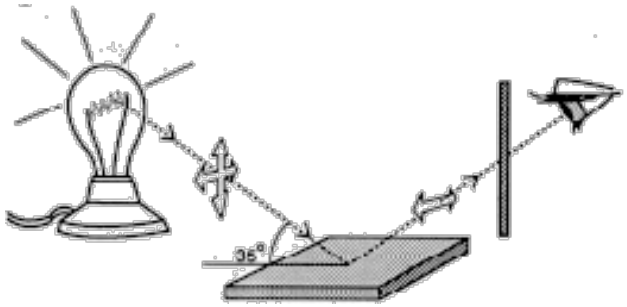
L-band

P-band

Polarization - A Measure of Surface Orientations and Properties

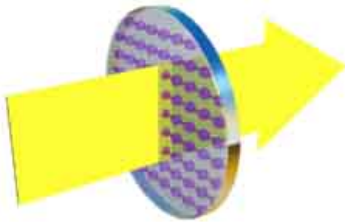
Wave Polarization



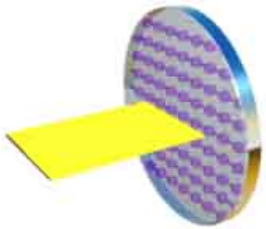


Mostly horizontal polarization is reflected from a flat surface

Polarization Filters



Vertical polarization passes through horizontally arranged absorbers.



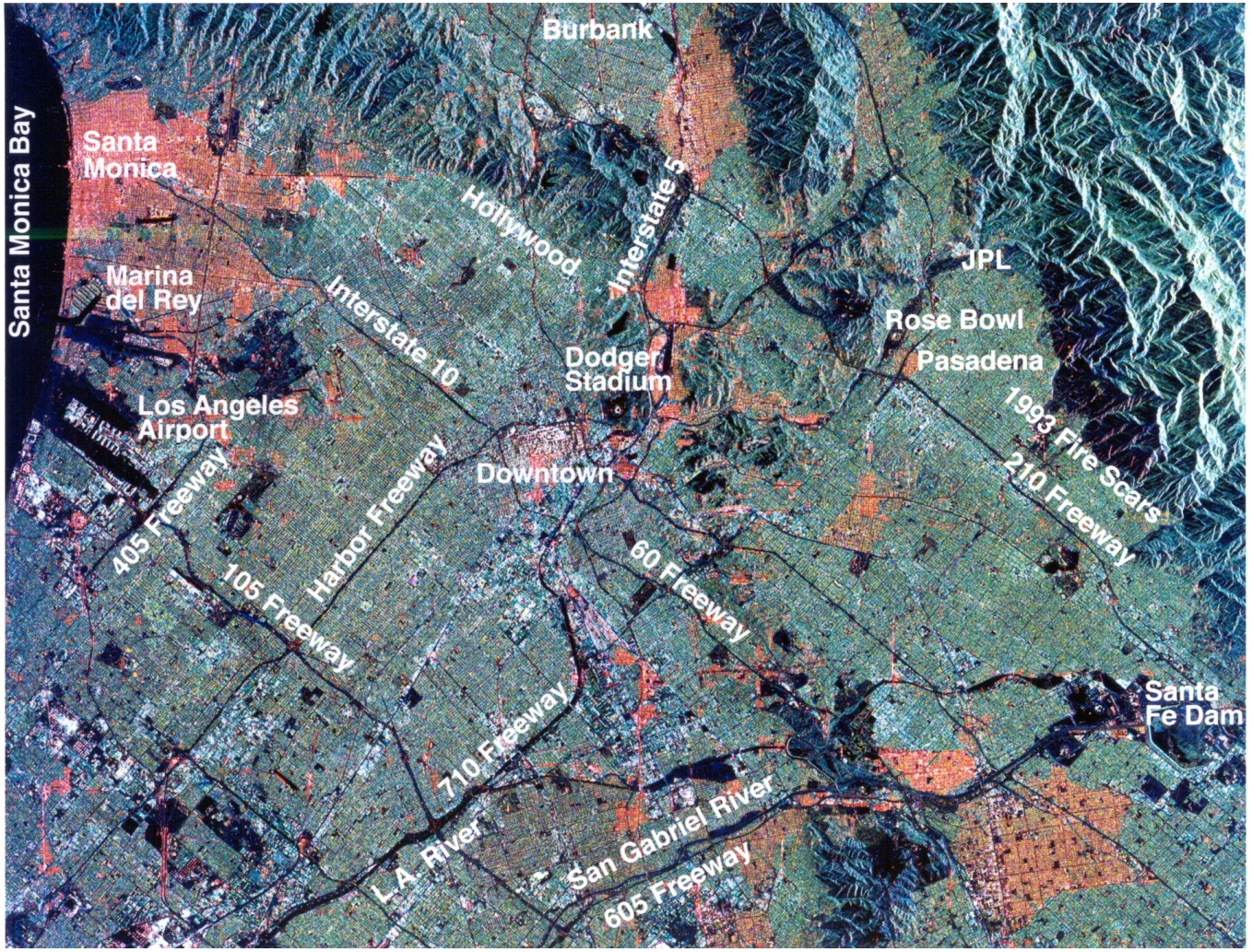
Horizontal polarization does not pass through horizontally arranged absorbers.

Color figures from www.colorado.edu/physics/2000

Polarimetry from SIR-C/X-SAR

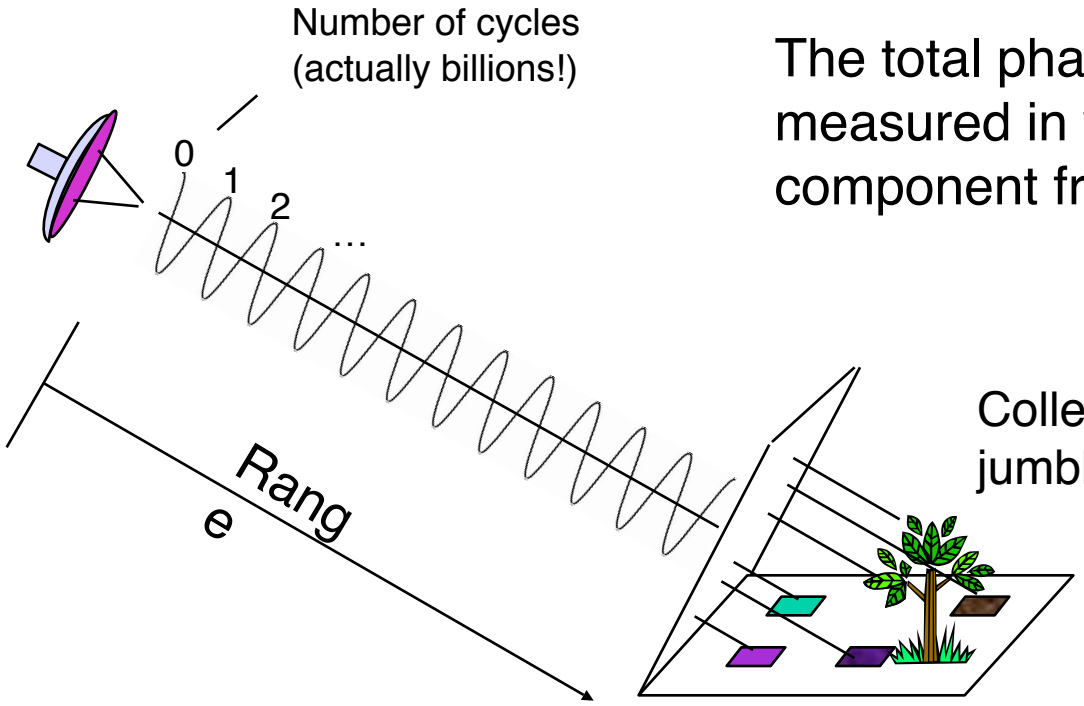
In red areas, streets are oriented along the shuttle track.

The geometry of the surface is captured in the polarization



Phase - A Measure of the Range and Surface Complexity

The phase of the radar signal is the number of *cycles of oscillation* that the wave executes between the radar and the surface and back again.



The total phase is two-way range measured in wave cycles + random component from the surface

Collection of random path lengths jumbles the phase of the echo

Only *interferometry* can sort it out!

Interference Concept

- Interference occurs when the phase of two different waves is not aligned. The observed intensity, I, is the time average of the sum of the wave fields

$$E(z,t)=E_0 \cos(2\pi(f\,t - z / \lambda))$$

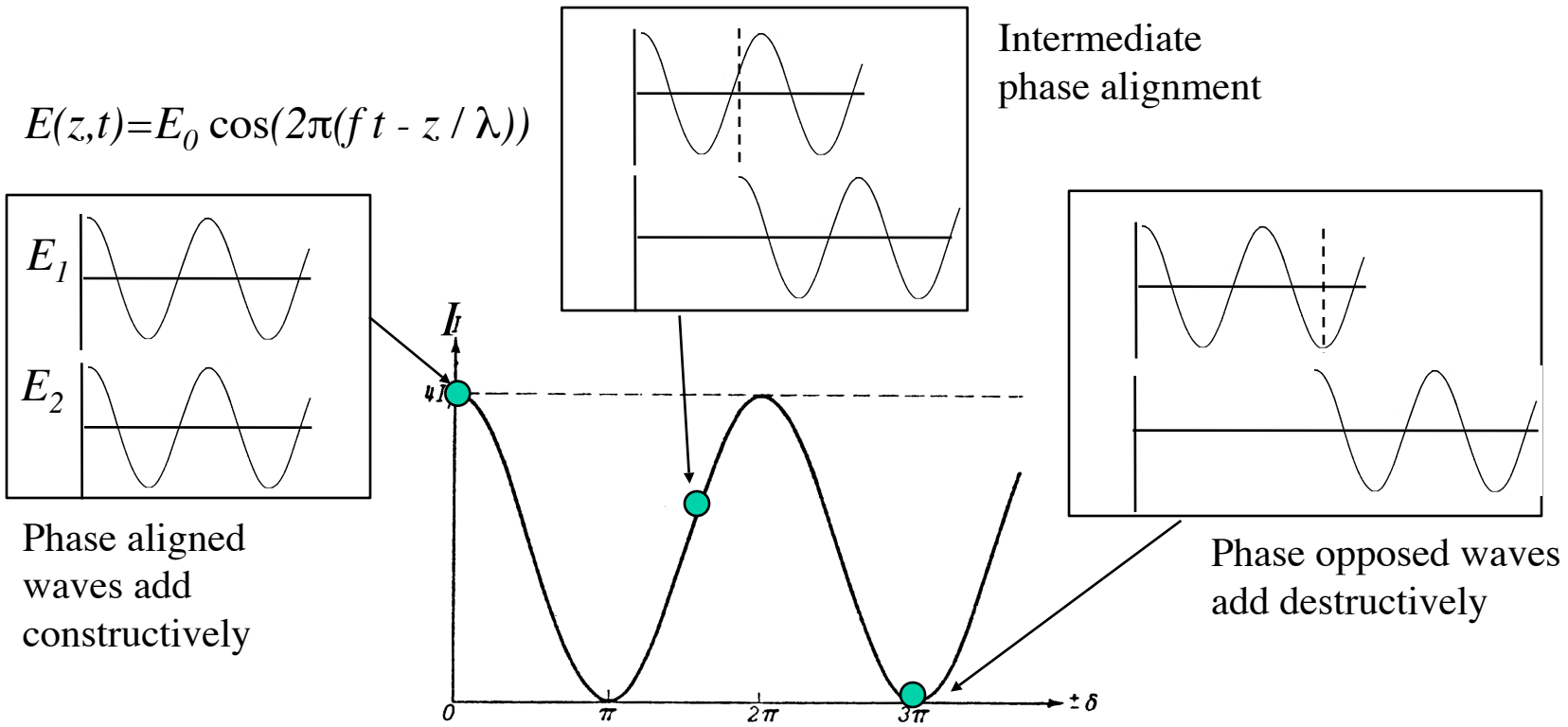


Fig. 7.1. Interference of two beams of equal intensity; variation of intensity with phase difference.

Young's Interferometer

- In Young's experiment, a point source illuminates two separated vertical slits in an opaque screen. The slits are very narrow and act as line sources. For this case, the pattern of intensity variations on the observing screen is bright/dark banding.

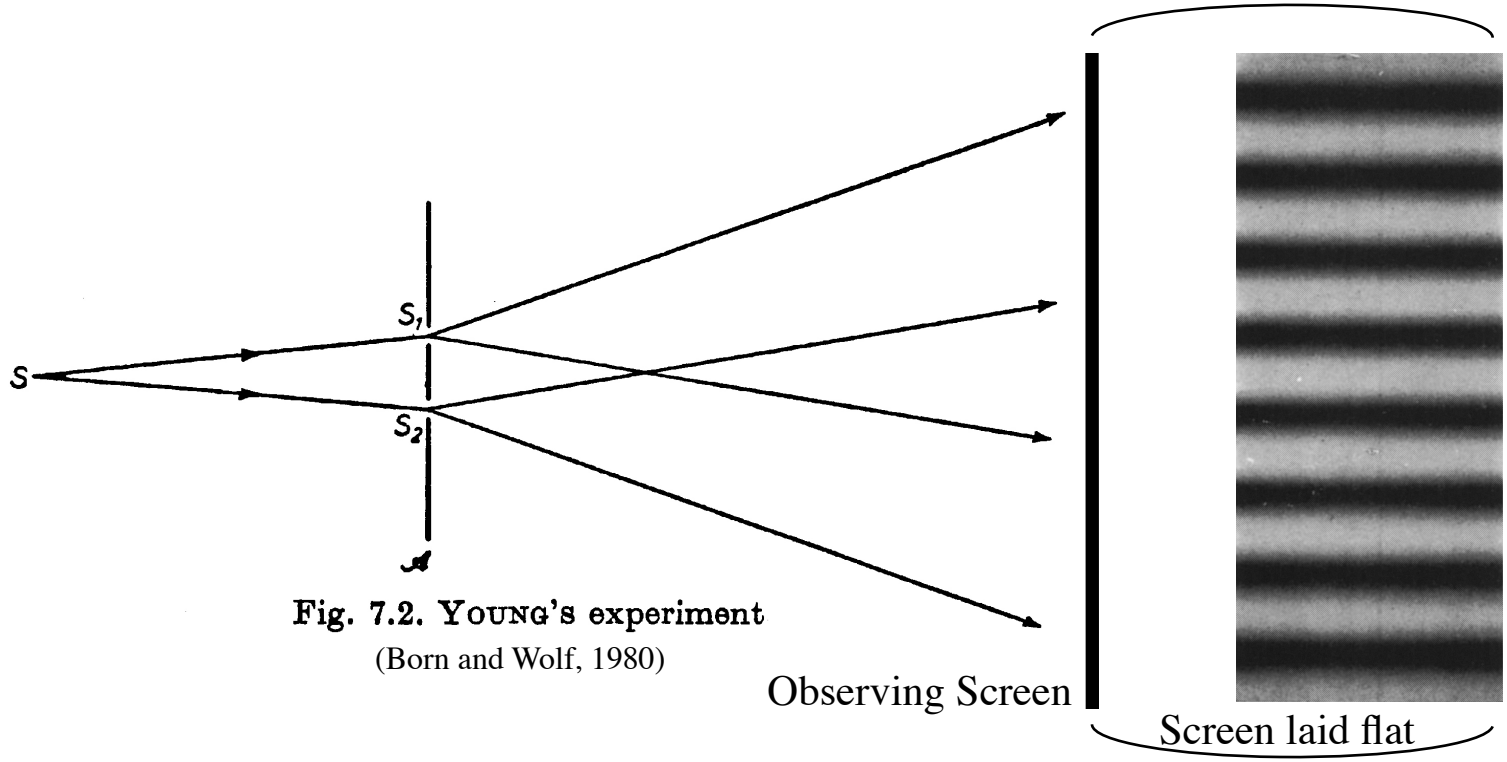


Fig. 7.2. YOUNG's experiment
(Born and Wolf, 1980)

Young's Interferometer Geometry

- The brightness variations can be understood in terms of the relative phase of the interfering waves at the observing screen
- The spacing of fringes is set by the slit separation
- Phase = $2 \pi x d / a \lambda$
- $x_{max} = m a \lambda / d$, m = 0, 1, 2 , ...

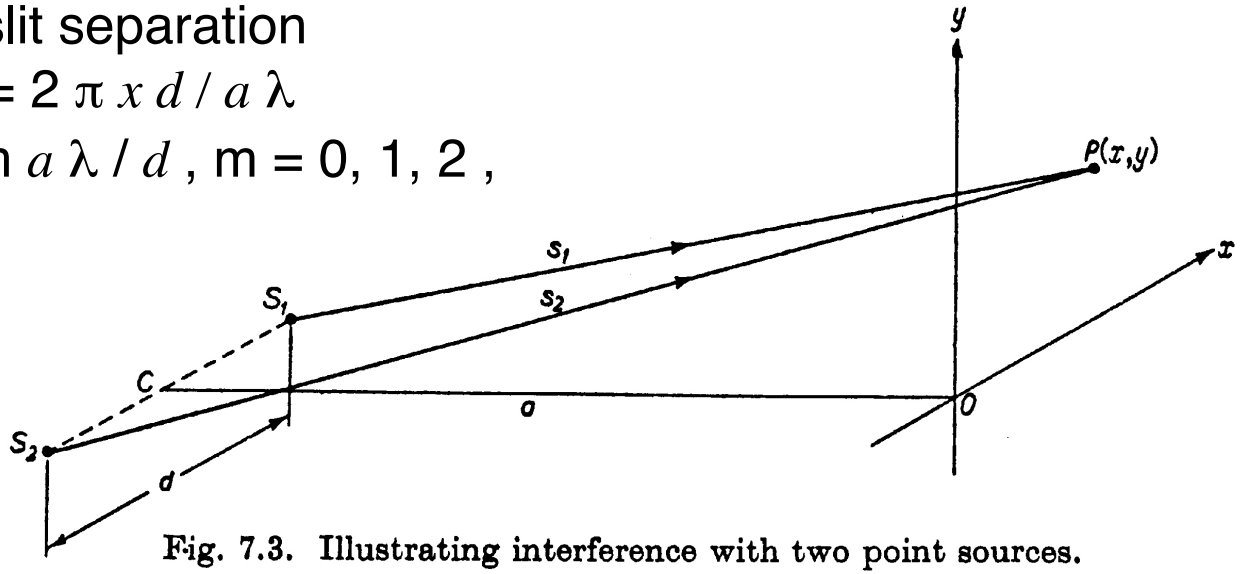
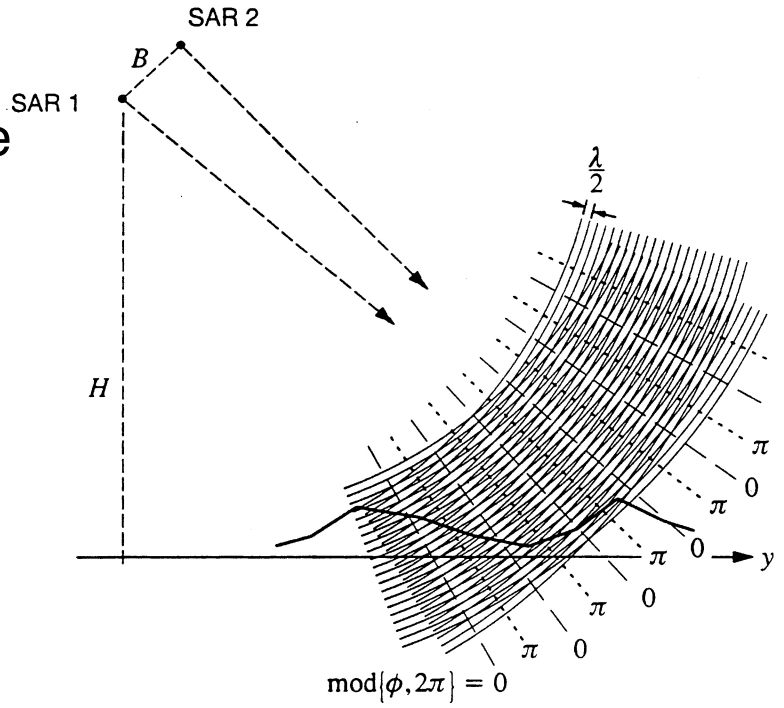


Fig. 7.3. Illustrating interference with two point sources.
(Born and Wolf, 1980)

Radar Interferometry

- Radar Interferometry is a simple extension of the Young's interferometry concept
- Radar has a coherent source much like a laser
- The two radar (SAR) antennas act as coherent point sources

- Because the wavelengths are so long, the signal can easily be digitized and processed coherently, measuring the phase information directly.
- When imaging a surface, the phase fronts from the two sources interfere.
- The surface topography slices the interference pattern.



- The measured phase differences record the topographic information.