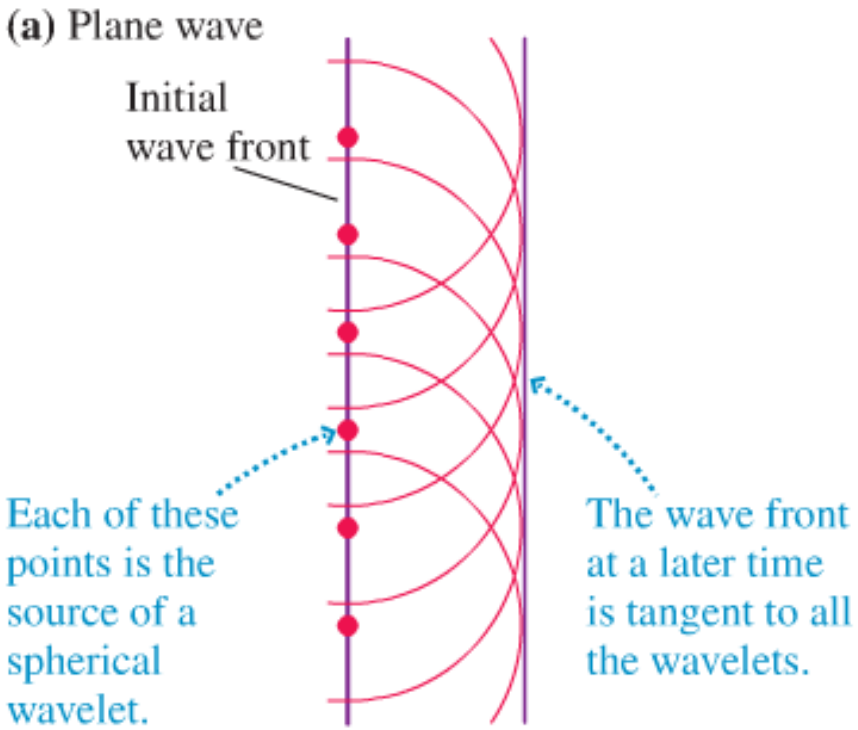
Chapter 22: Wave Optics

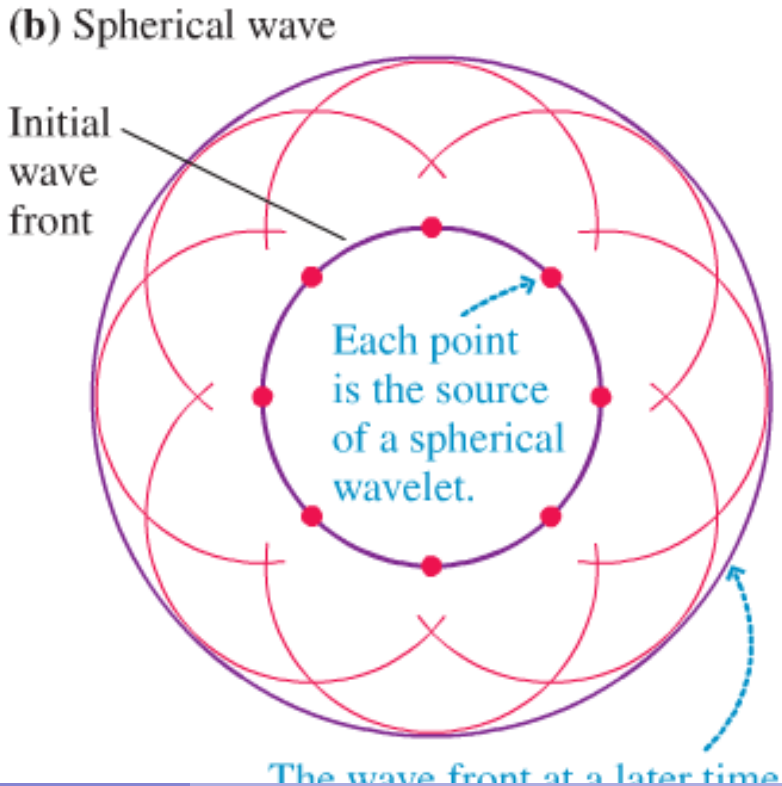
Now we go from general properties of waves to specifically studying the properties of light: optics. This chapter begins with an historical introduction to the particle and wave models of light (which we have covered already). Then we get to do all of the neat wave-like properties of light.

Diffraction - Huygen's Principle

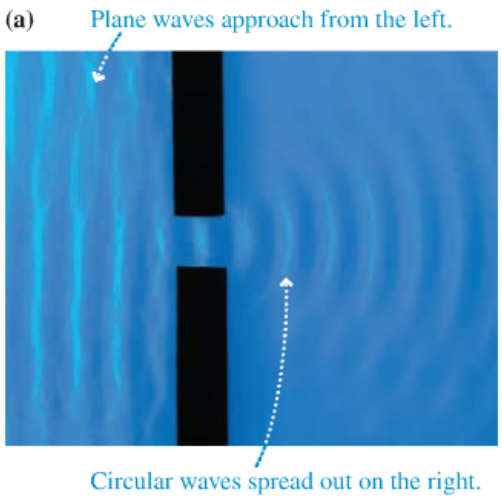
Huygen's Principle

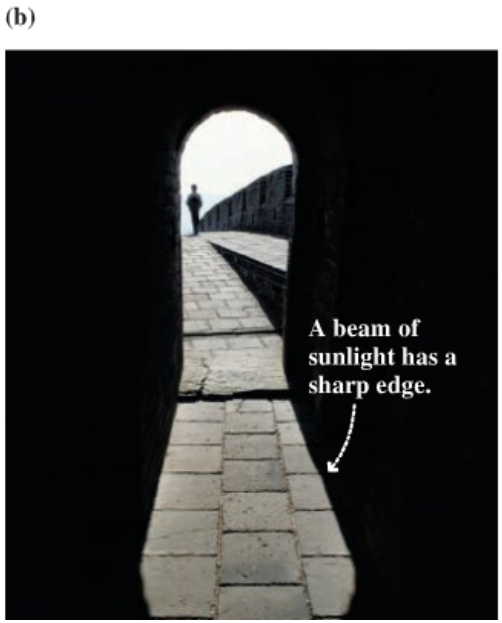
1. Each point on a wave front is the source of a spherical wavelet that spreads out at the wave speed.
2. At a later time, the shape of the wavefront is the tangent line to all of the wavelets.

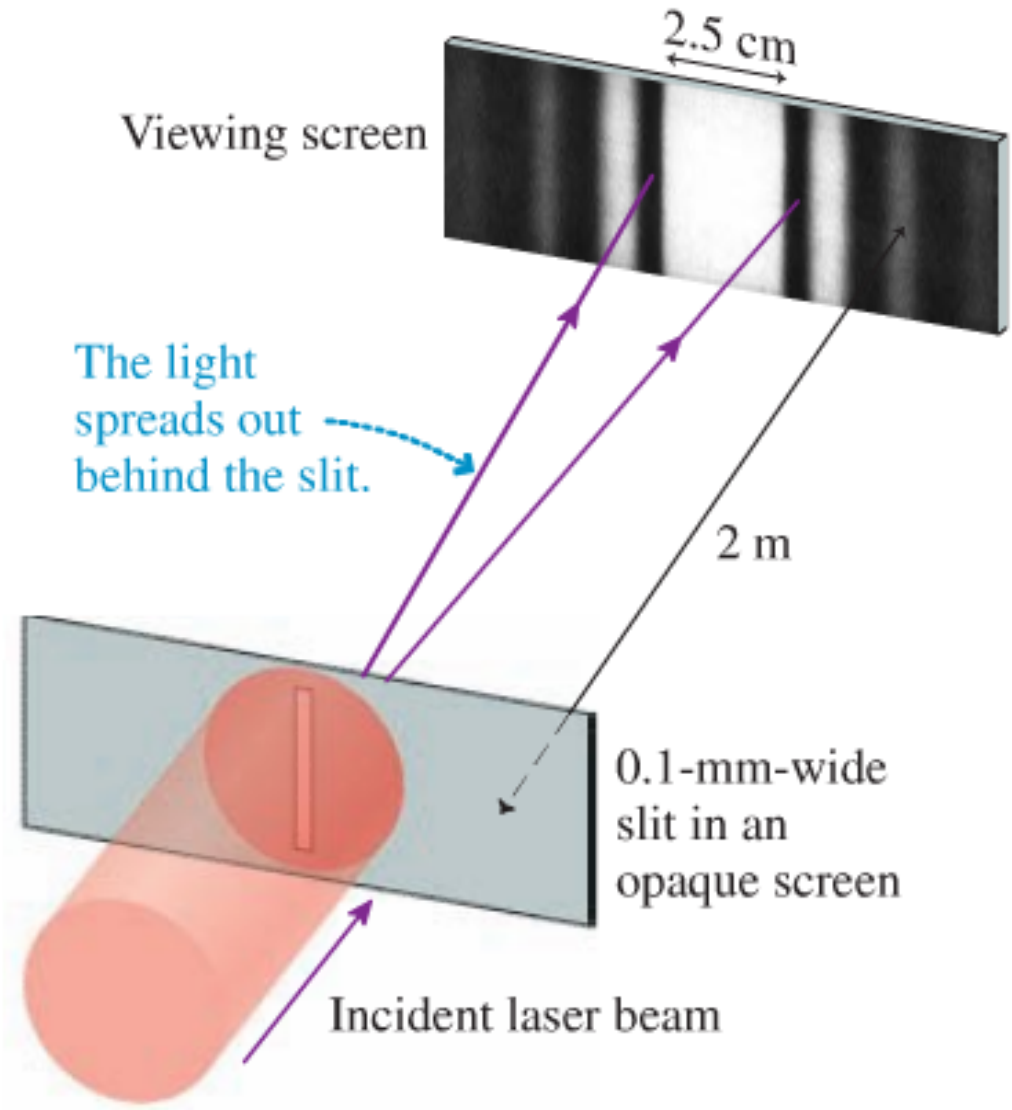




Diffraction - Single Slit



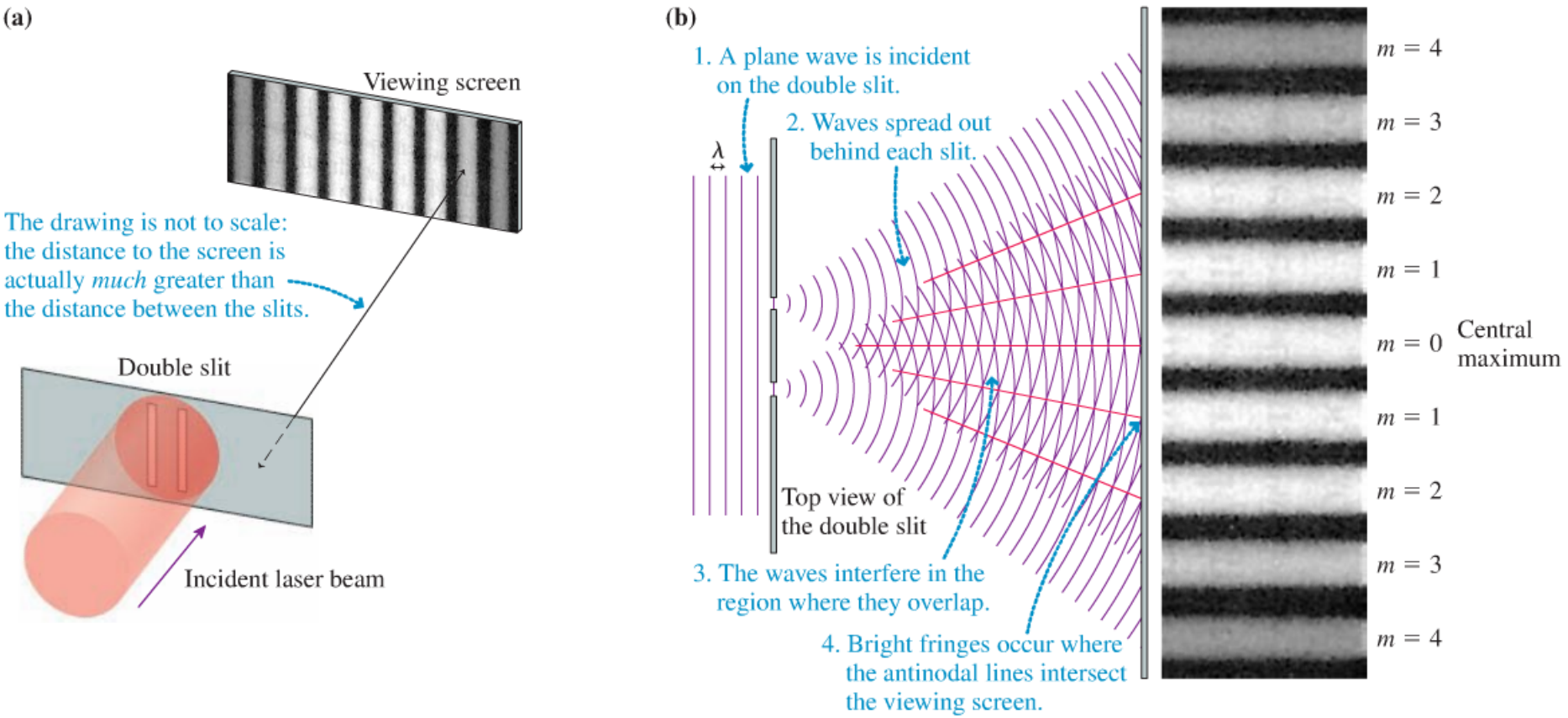




Note on shadows

The last slide stated that shadows cast by sunlight are sharp. That's not true. It is true that diffraction is not a significant effect on the shadow of the doorway shown. However, the disc of the sun subtends and angle of about 0.5 degree. Such an extended source causes the shadows of edges to be blurred. At 1 metre from a sharp edge, the shadow of the edge would be blurred over about 1 cm.
Neverthless the point is that point light sources can produce shadows that appear sharp when the object's size is much larger than the wavelength of light.

Young's Double-Slit Experiment

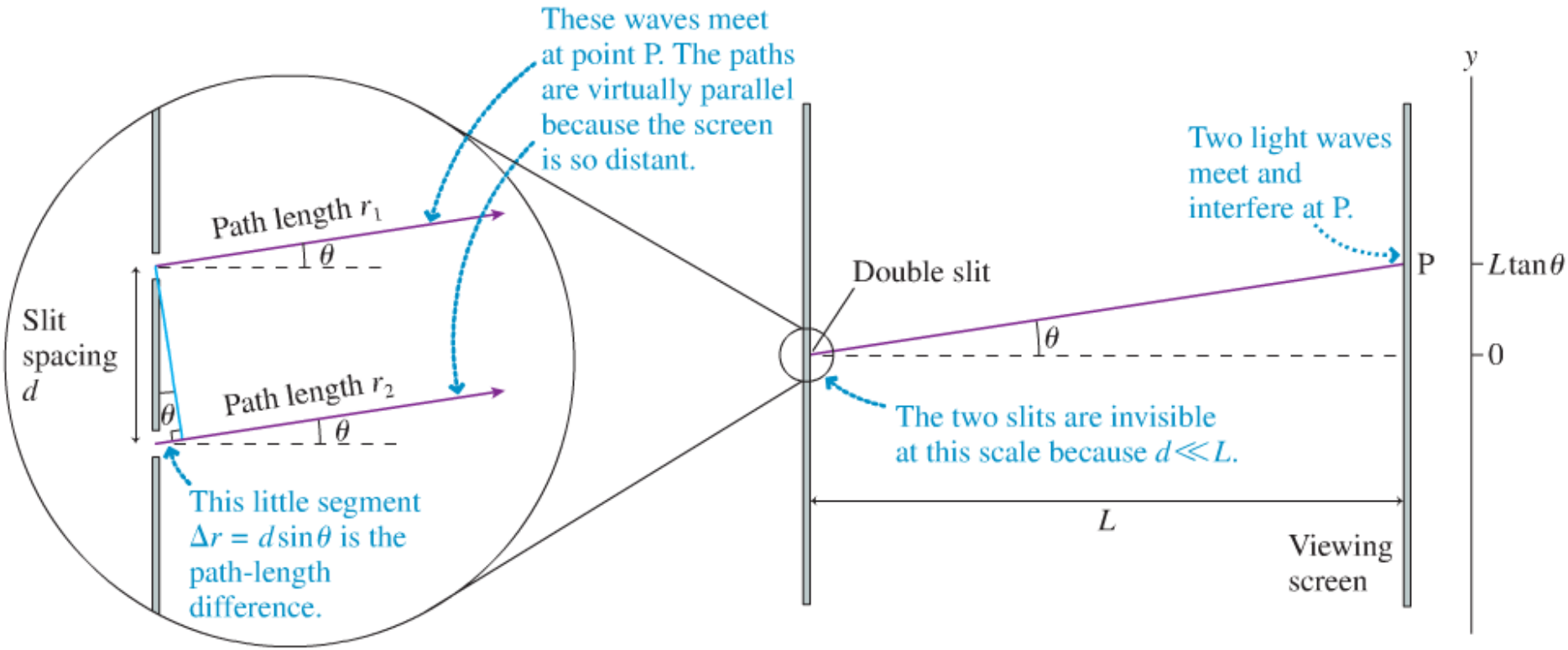


Young's Double-Slit Experiment

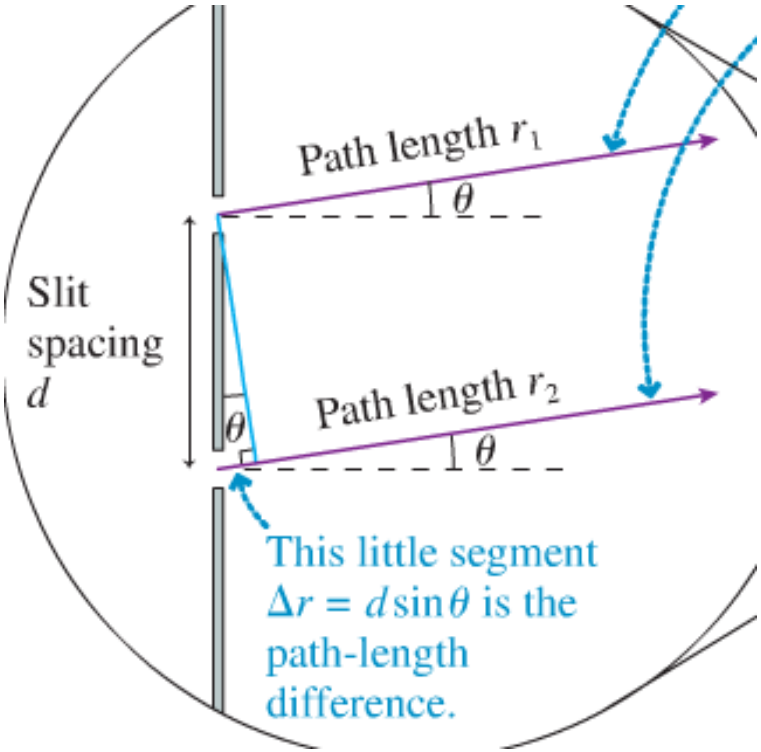
Notes

- The slit-width (a) and slit-separation (d) are similar in size to the wavelength of light (λ)
- The wave fronts arrive at the two slits from the same source in about the same time - they are in phase ($\Delta\phi = 0$).
- Each slit acts like a point-source by Huygen's principle.

Analyzing Young's Double-Slit Experiment



Analyzing Young's Double-Slit Experiment



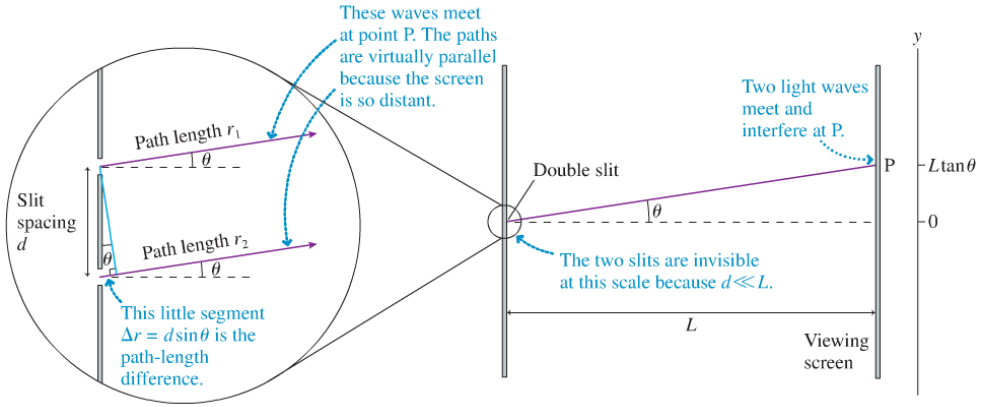
- Constructive interference occurs when

$$\Delta r = d \sin\theta_m = m\lambda, m = 0, 1, 2, 3, \ldots$$

- In practice, the angle is small and $\sin\theta \approx \theta$

$$\theta_m = m\frac{\lambda}{d}$$

Analyzing Young's Double-Slit Experiment



- Using some simple trigonometry:

$$y_m = \frac{m\lambda L}{d}, m = 0, 1, 2, 3, \ldots$$

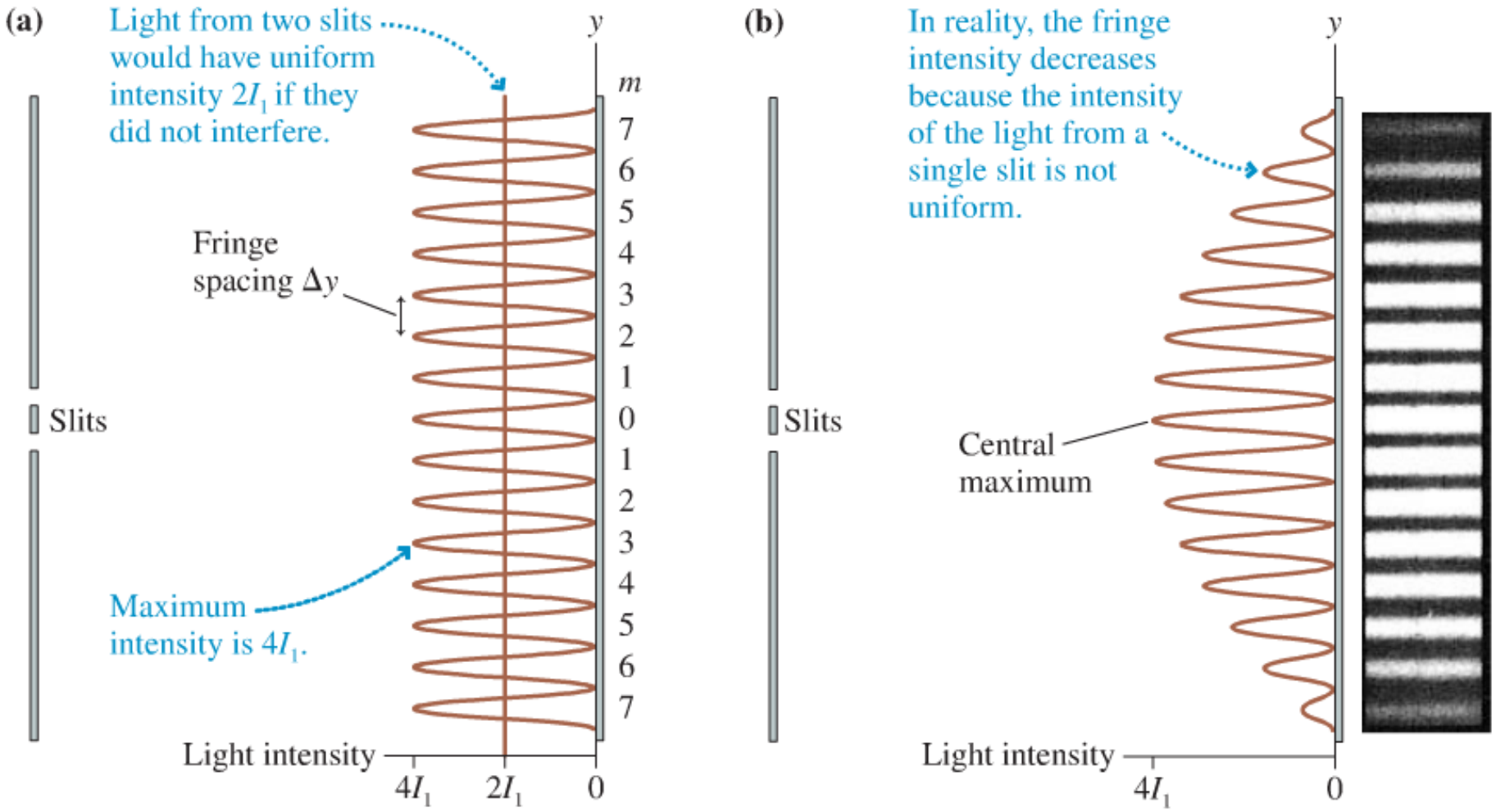
- Similarly, we can get the dark fringe positions:

$$y'_m = \left(m + \frac{1}{2}\right)\frac{\lambda L}{d}, m = 0, 1, 2, \ldots$$

- And we can get the fringe spacing

$$\Delta y = y_{m+1} - y_m = \frac{(m+1)\lambda L}{d} - \frac{m\lambda L}{d} = \frac{\lambda L}{d}$$

Young's Double-Slit Fringe Intensity



$$I_{double} = 4I_1 \cos^2\left(\frac{\pi d}{\lambda L} y\right)$$