Wave Phenomena

Interference, Diffraction, Refraction, etc.

Electromagnetic Radiation and Telescopes

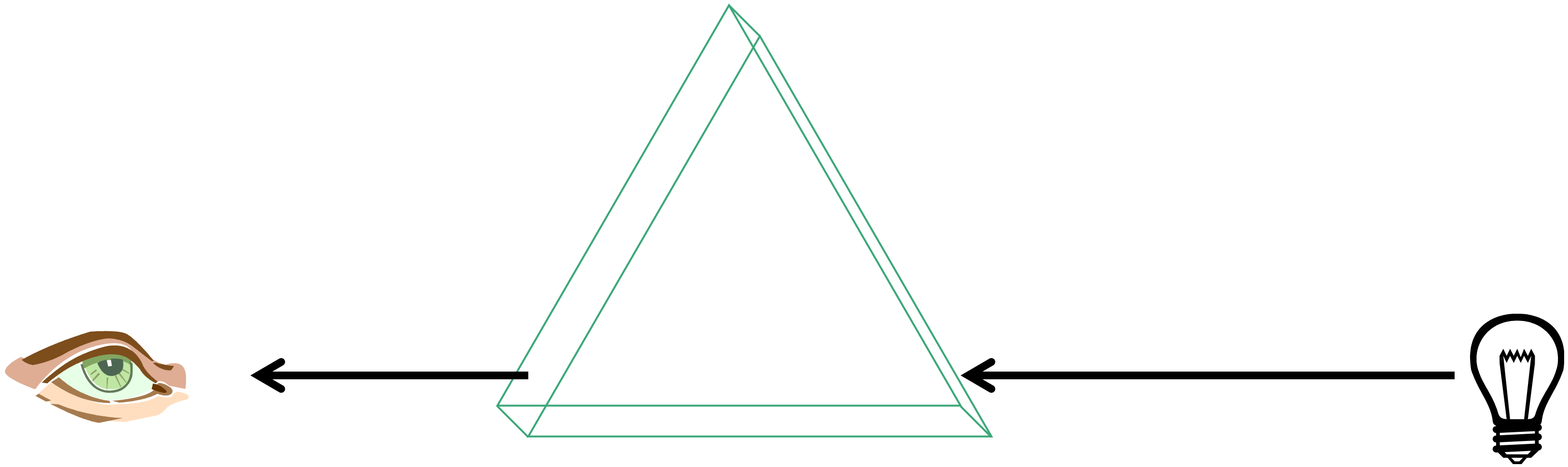
I. Waves (chpt. 3)
Speed, frequency, wavelength, light, EMR etc.

II. Spectroscopy (chpt. 4)
Wein's Law, Doppler effect, spectral lines, etc.

III. Telescopes (chpt. 5)
Refractors, reflectors, resolution, magnification, etc.

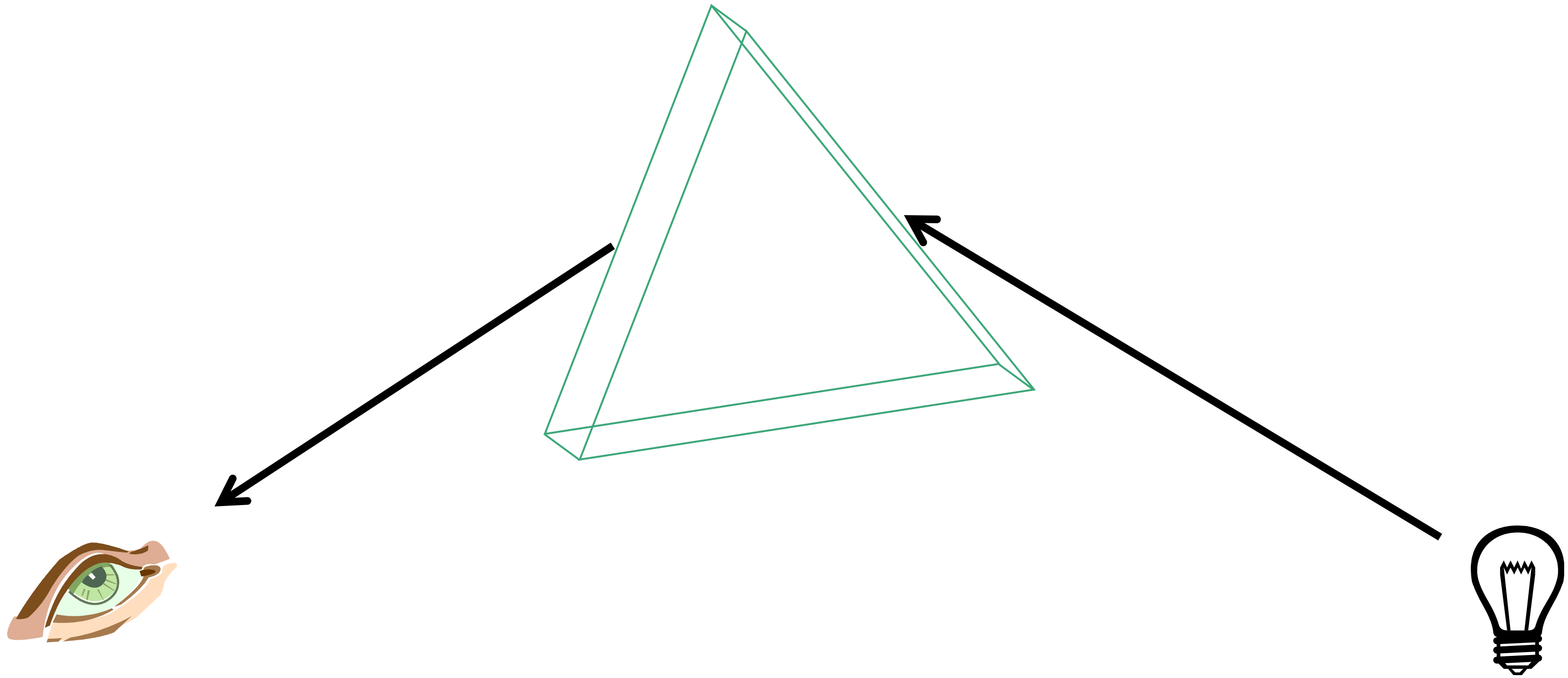
	The student will be able to:	HW:
1	Define, illustrate, and apply the basic wave concepts of frequency, wavelength, and speed and relate these to source and medium.	1
2	Solve mathematical problems involving speed, frequency, and wavelength.	2 – 4
3	Describe and illustrate the nature of electromagnetic radiation.	5
4	State the six major regions of the electromagnetic spectrum in order of frequency and/or wavelength.	6 – 8
5	State the colors of the visible spectrum in order of frequency and/or wavelength.	
6	Define, illustrate, and apply the concepts of diffraction, interference, opacity and transparency.	9 – 10
7	Explain, illustrate, and apply the basic concepts of blackbody radiation.	11 – 12
8	Solve mathematical problems using Wein’ s law.	13 – 15
9	Explain, illustrate, and apply the concept of the Doppler effect and the astronomical terms of redshift and blueshift.	16 – 17
10	State and apply Kirchoff’s Laws of continuous, emission, and absorption spectra and describe the components and operation of a spectroscope.	18 – 21
11	Explain how spectral lines and the width and intensity of those lines are related to properties of atoms and or molecules.	22 – 25
12	Describe and illustrate the two main types of optical telescopes – refracting and reflecting and contrast in terms of resolution, light gathering, and aberrations.	26 – 32
13	Describe how the Earth’ s atmosphere affects astronomical observations and current efforts to improve ground-based astronomy.	
14	Compare and contrast telescopes that create images using nonvisible radiation.	
15	Solve mathematical problems relating magnification to focal lengths of objective and ocular.	33 – 34
16	Solve mathematical problems relating angular resolution to wavelength and diameter.	35 – 38
17	Solve mathematical problems involving light gathering capacities.	39 – 42

Experiments With a Prism



1. Hold the prism *upright*. Line up the bottom side of the prism with the light bulb.
2. Now move the prism just a little bit downward without rotating it.
3. Look into the prism and see the bulb inside!

Experiments With a Prism



4. Now move the prism to the up and rotate it slightly back.

5. Look into the prism and see the bulb inside! How does it look different than before?

Reflection, Transparency

- Reflection occurs when a wave “bounces off” a surface or boundary between two different materials or media.
- Absorption occurs when the energy of the wave is absorbed or transferred into a material. The wave ceases to exist.
- The degree of absorption determines the degree of transparency or opacity.
  Transparent = wave passes through
  Opaque = wave cannot pass through

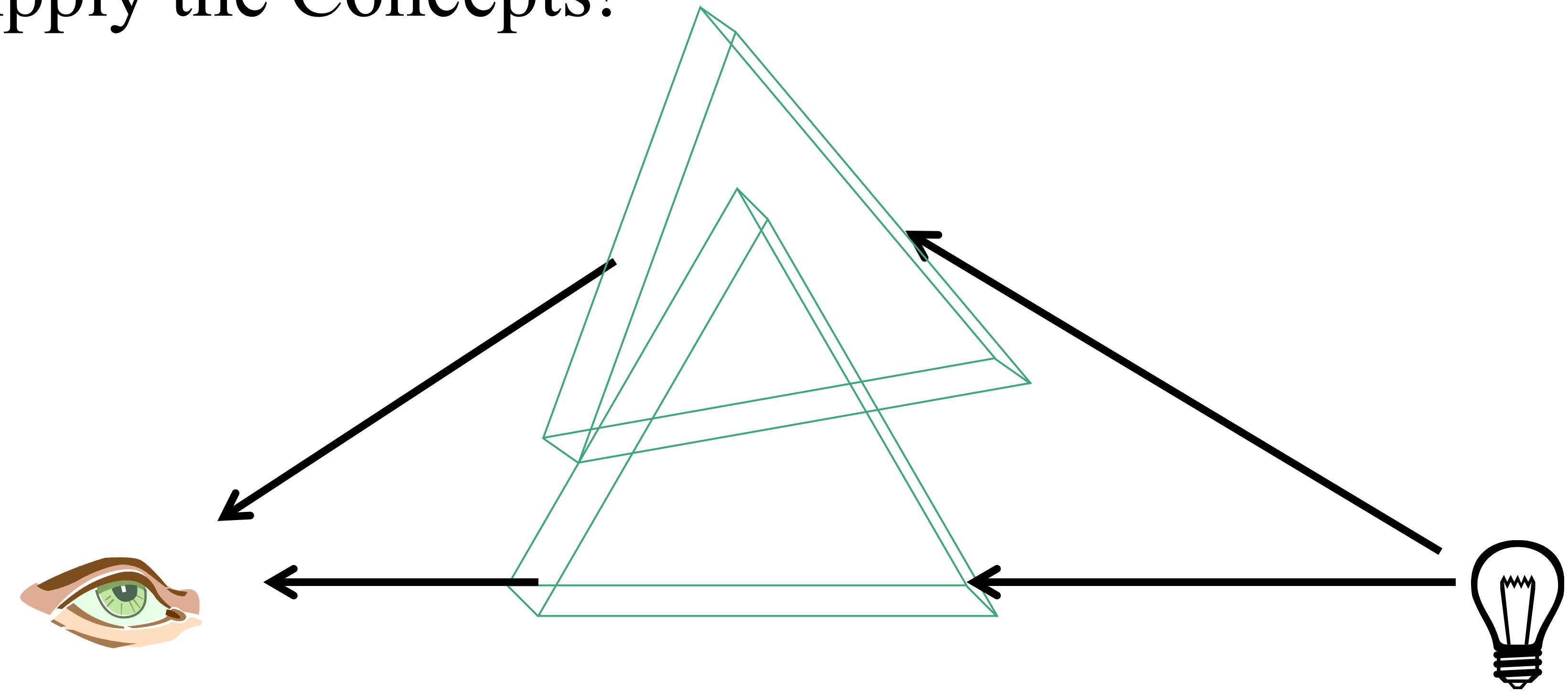
Refraction

- Refraction is when a wave bends due to transition into a different medium.
- In other words, the wave is redirected or turned when it passes into a new material.
- Refraction is related to the change in speed of the wave.

Dispersion

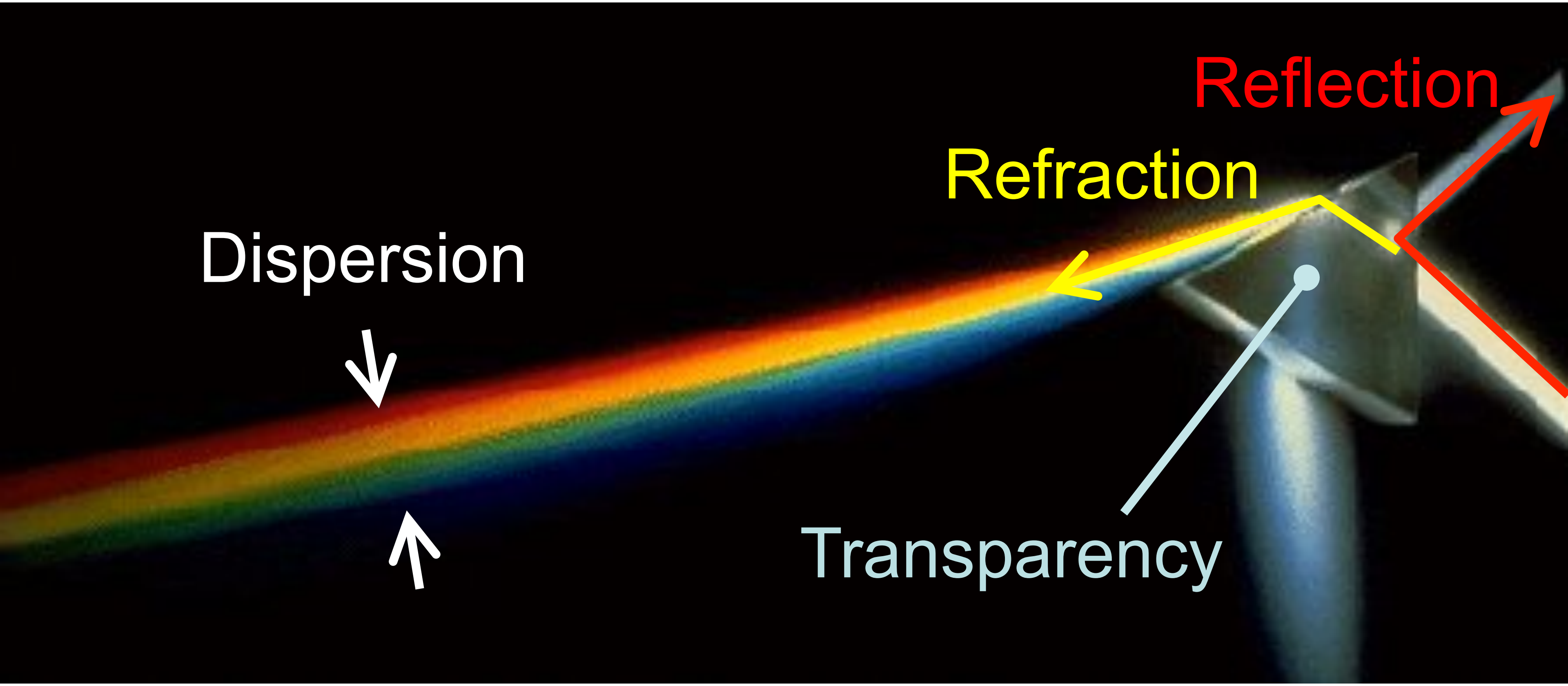
- The separation of white light into colors when passing through a prism is an example of dispersion.
- Dispersion results from a very slight dependence of speed on wavelength within a given medium.

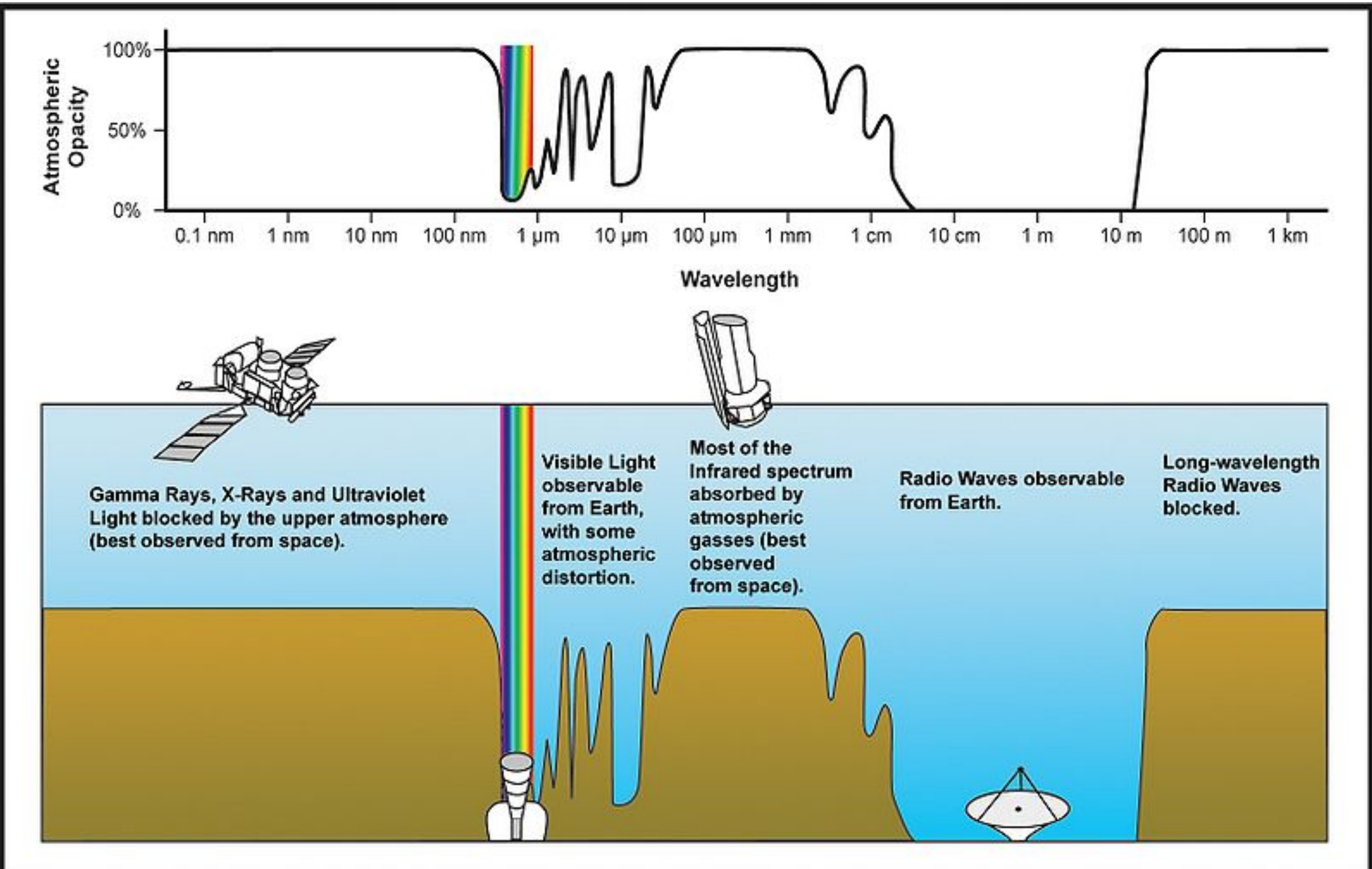
Apply the Concepts!



1. How do the experiments with the prism illustrate transparency, opacity, reflection, refraction, and/or dispersion?

2. Draw the path that you think the light must follow through the prism in each experiment.


Reflection
Refraction
Dispersion
Transparency

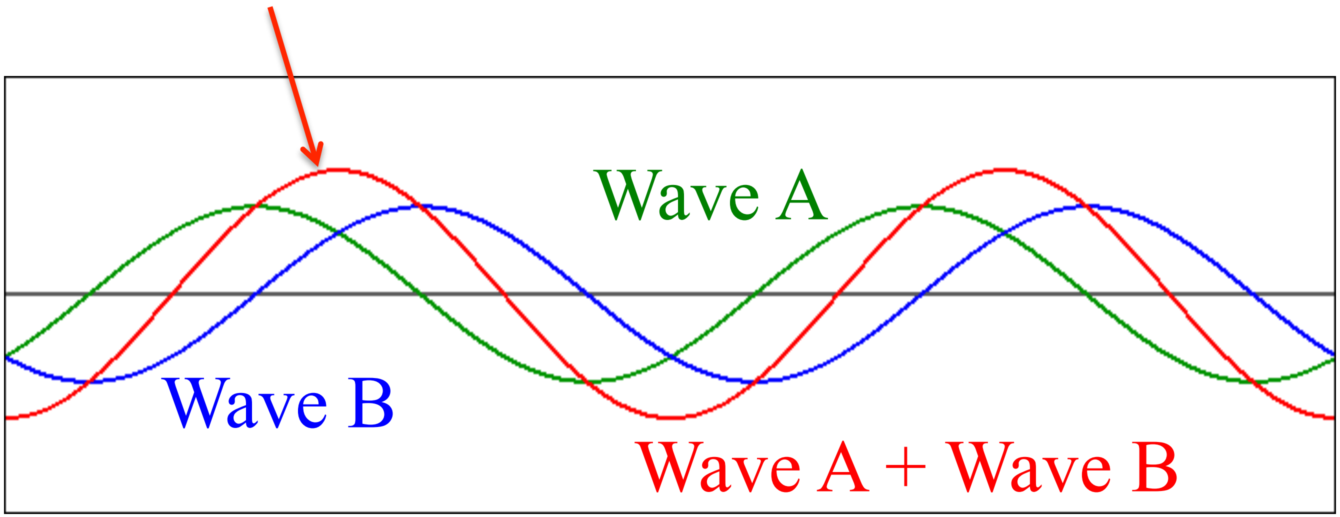


Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.

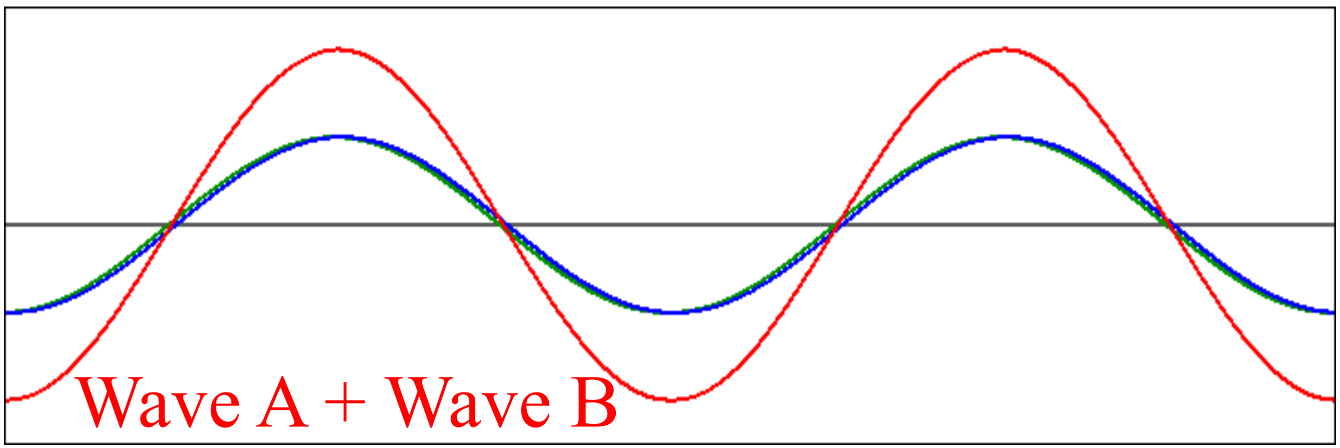
Interference

- Interference occurs when two or more waves meet in the same medium.
- If the combined effect results in greater amplitude it is called constructive interference.
- If the combined effect results in lesser amplitude it is called destructive interference.

The red wave is simply the sum of the two individual waves – this sum is called the superposition of waves A and B.

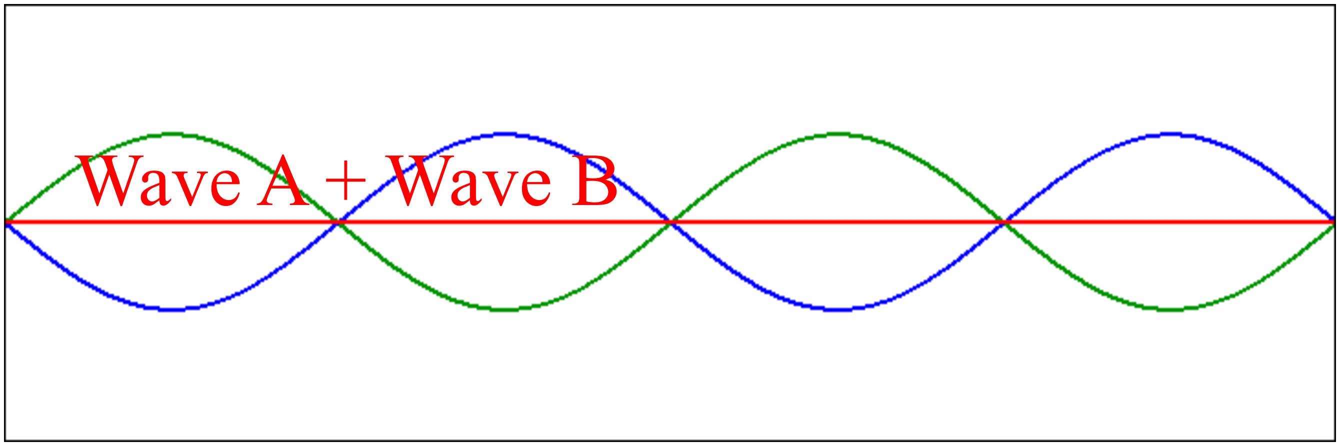


Constructive Interference!



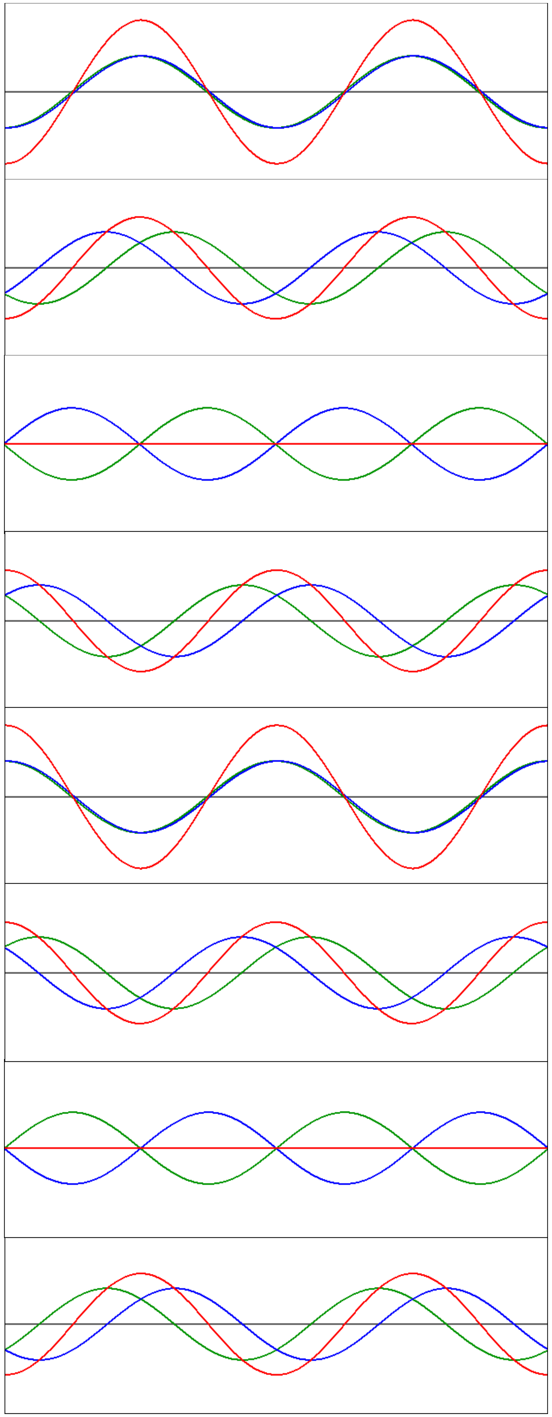
If two waves meet in the same medium and are exactly *in phase* then crest meets crest, trough meets trough and the result is twice the level of disturbance caused by either wave alone!

Destructive Interference!



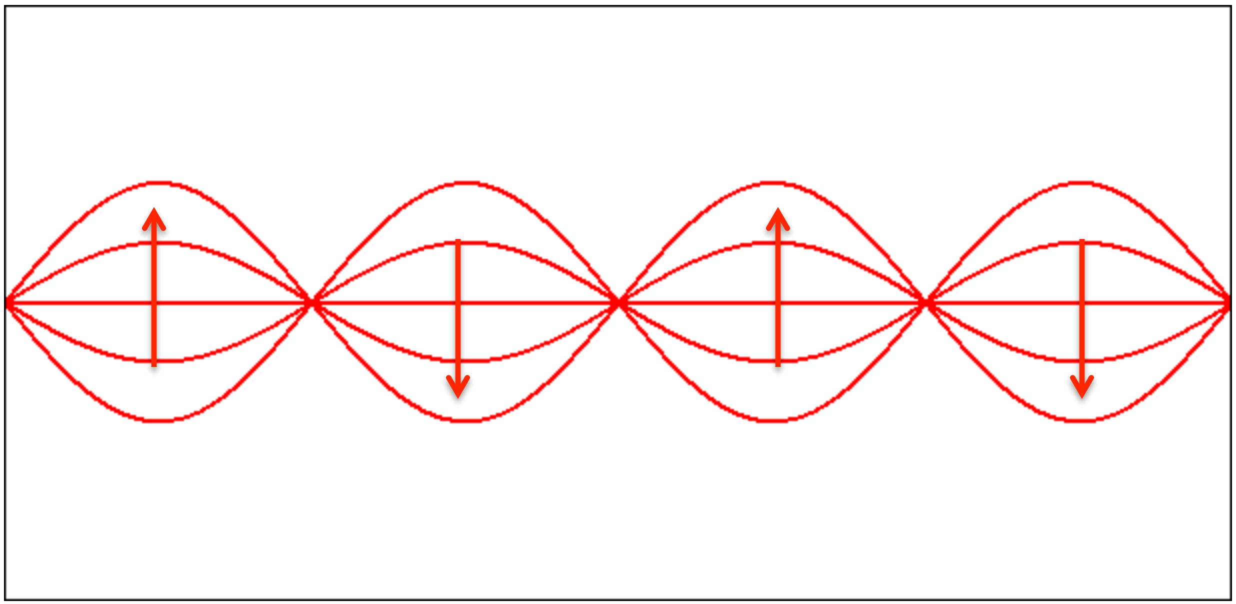
If two waves meet in the same medium and are exactly *opposite phase* then crest meets trough, trough meets crest and the result is zero disturbance!

Superposition of identical waves moving in opposite directions:



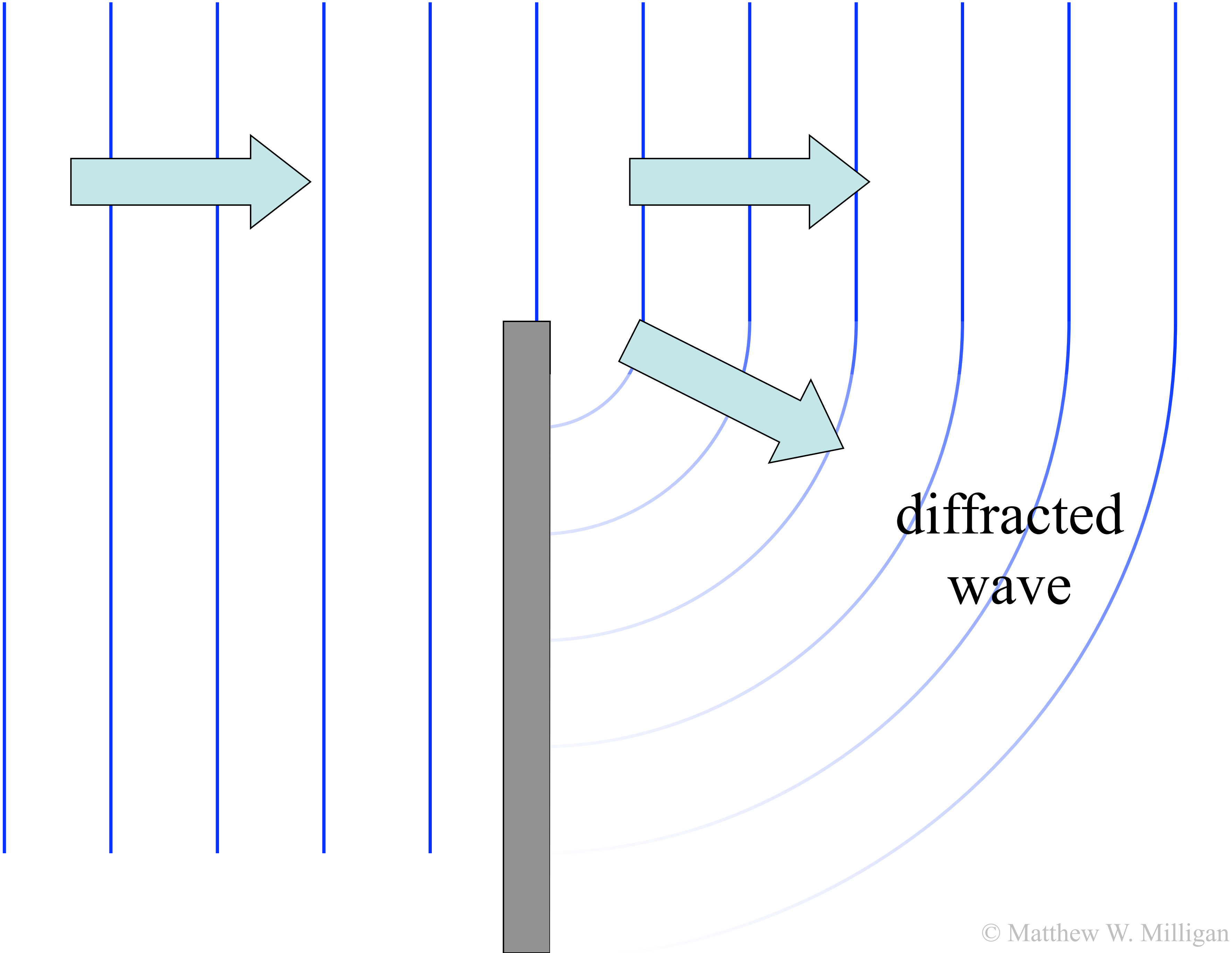
These are "frames of a movie" – notice that the green wave moves to the right as the blue wave moves to the left. The superposition of the two waves does not move left OR right!

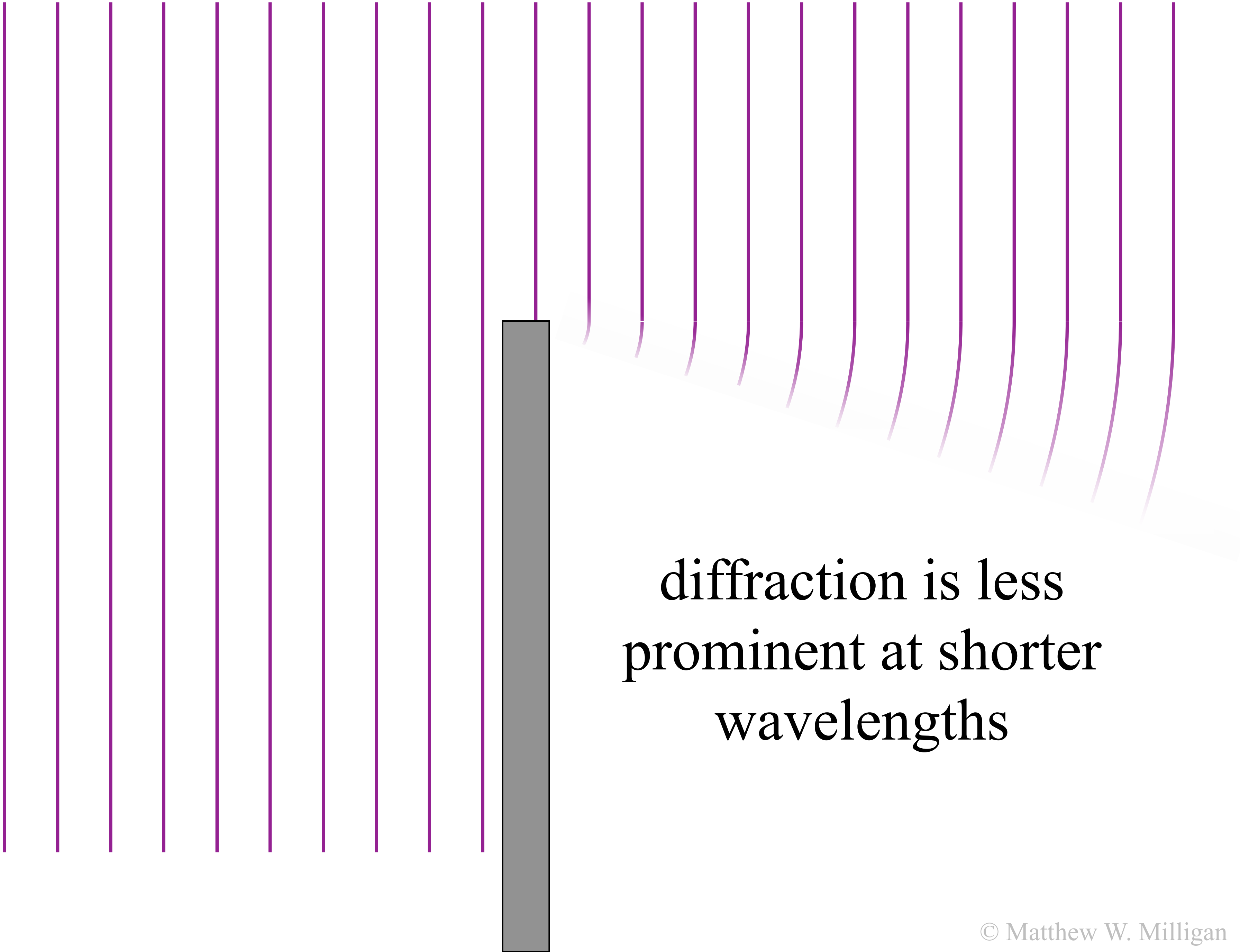
The result is called a standing wave:



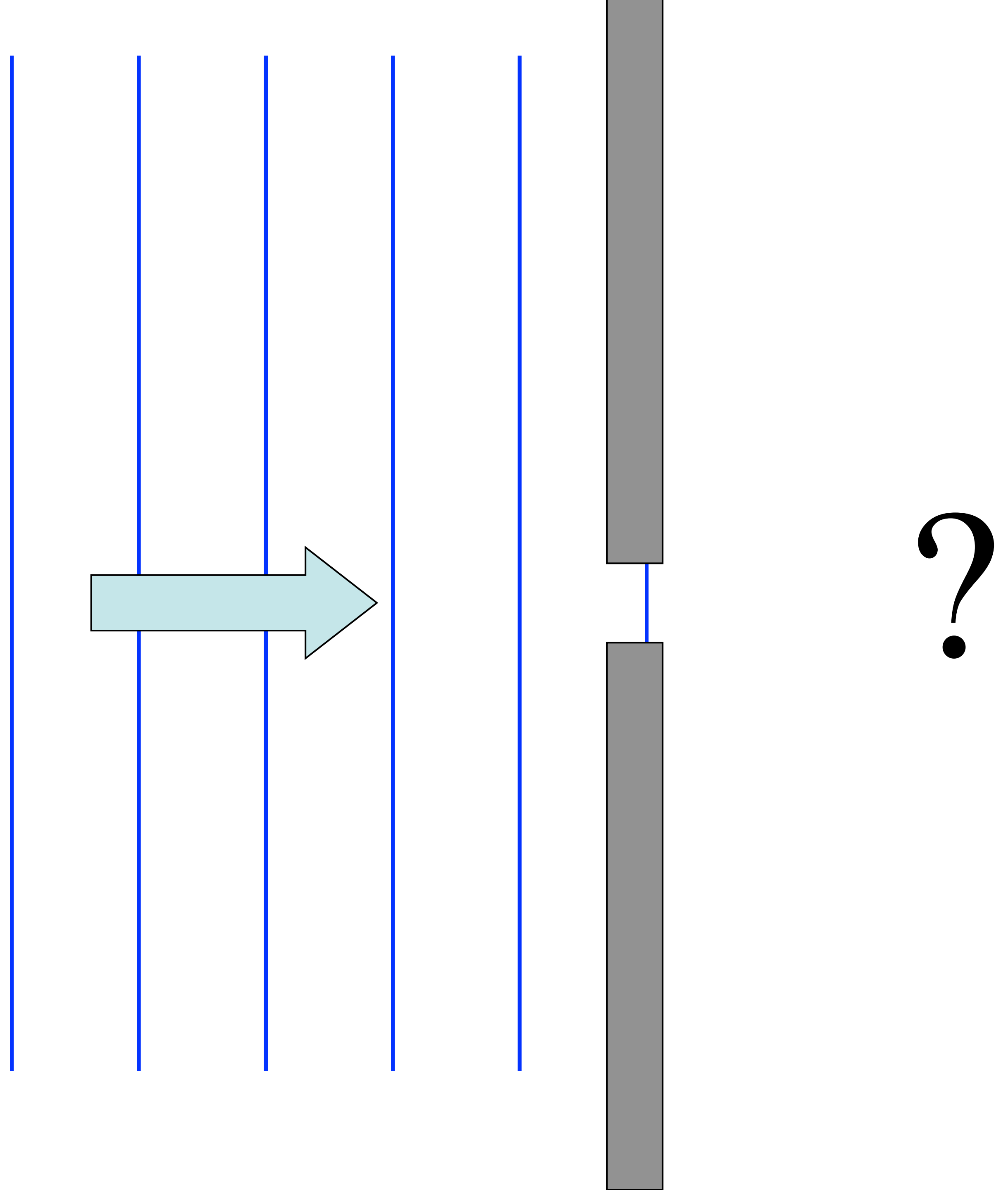
Diffraction

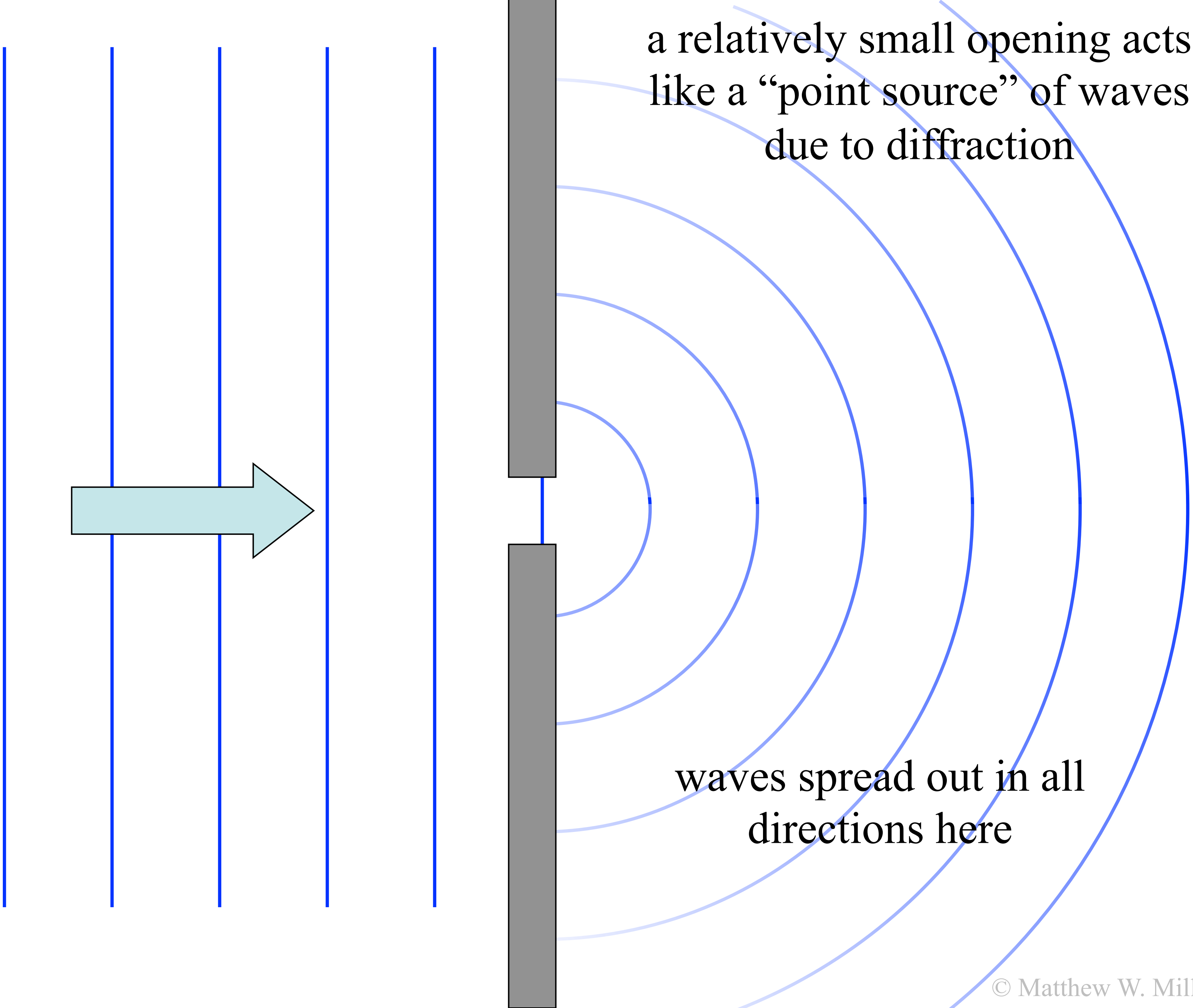
- Diffraction is when a wave bends around the edge of an obstacle.
- In other words, the wave is redirected or "turned" by interaction with a barrier.
- The extent of diffraction is less pronounced the smaller the wavelength relative to the size of the obstacle.

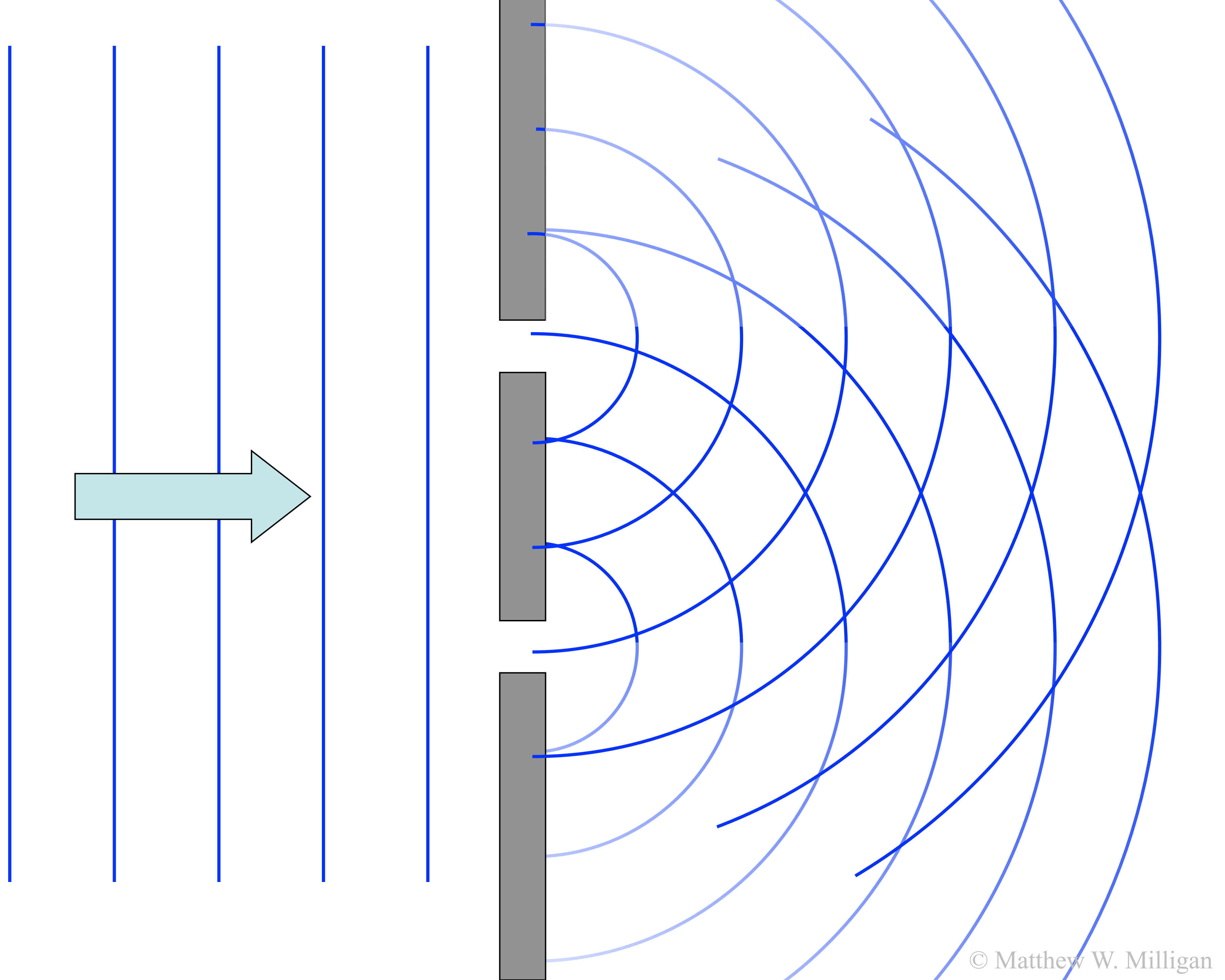

diffracted
wave

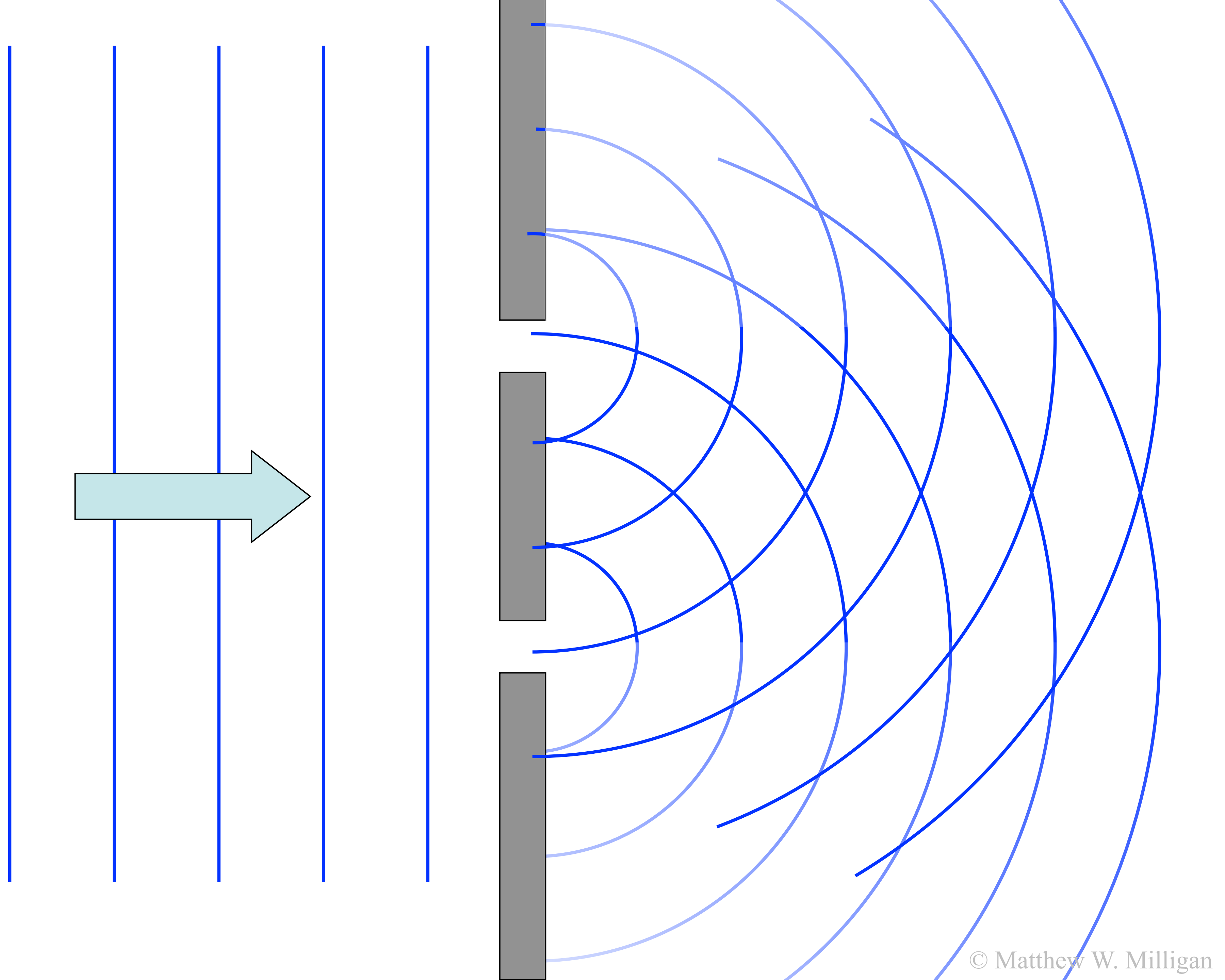


diffraction is less prominent at shorter wavelengths

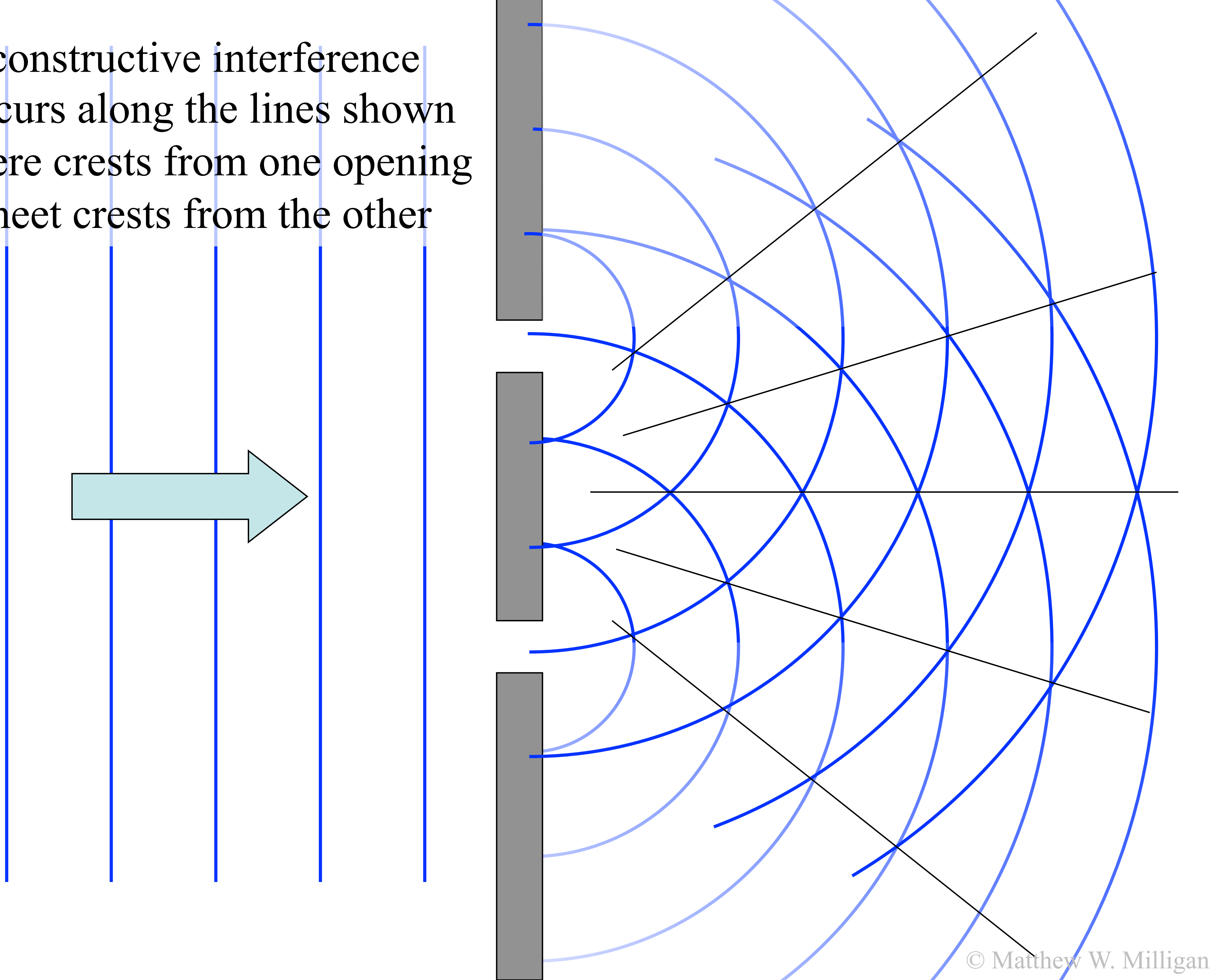



a relatively small opening acts like a "point source" of waves due to diffraction
waves spread out in all directions here

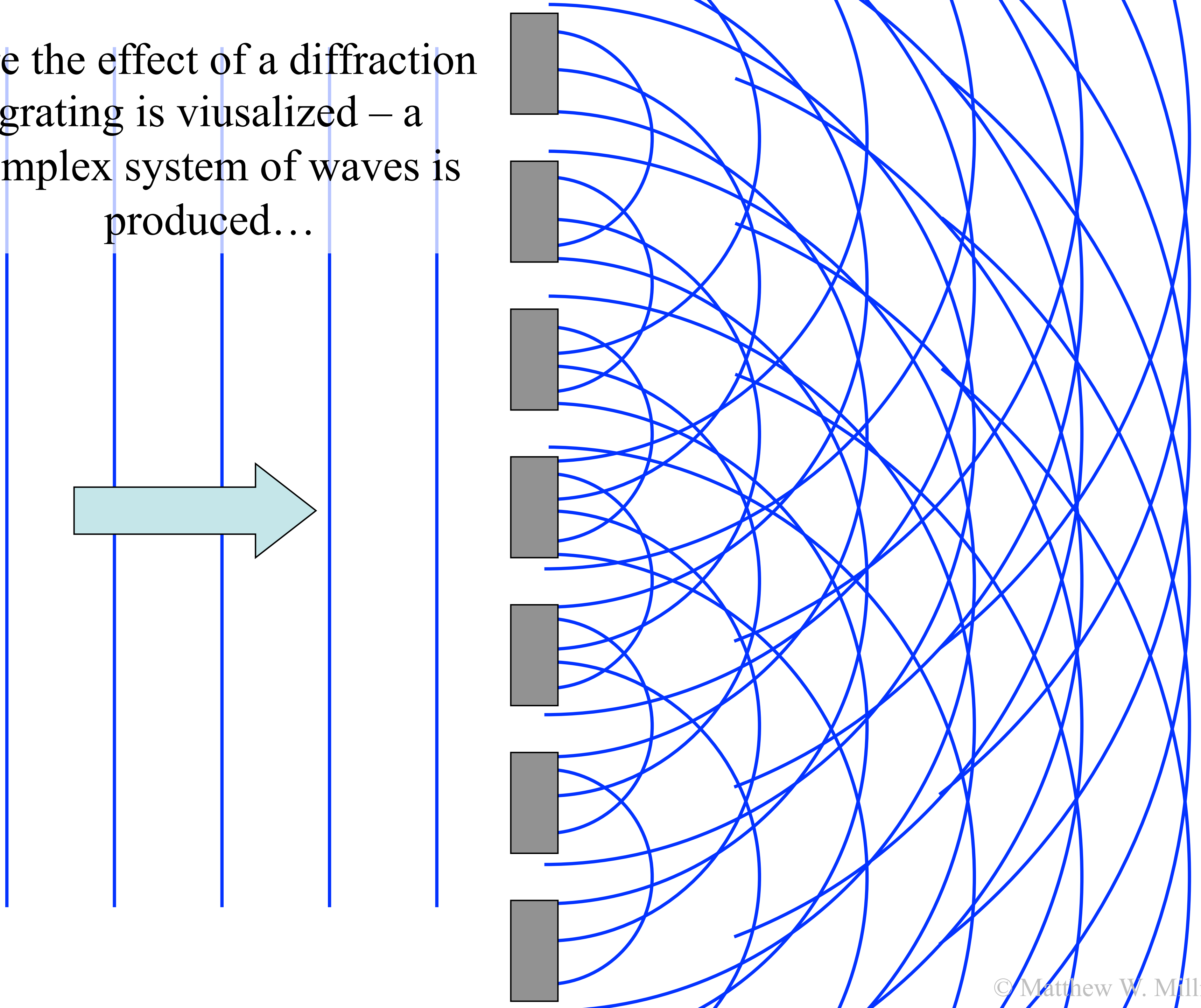




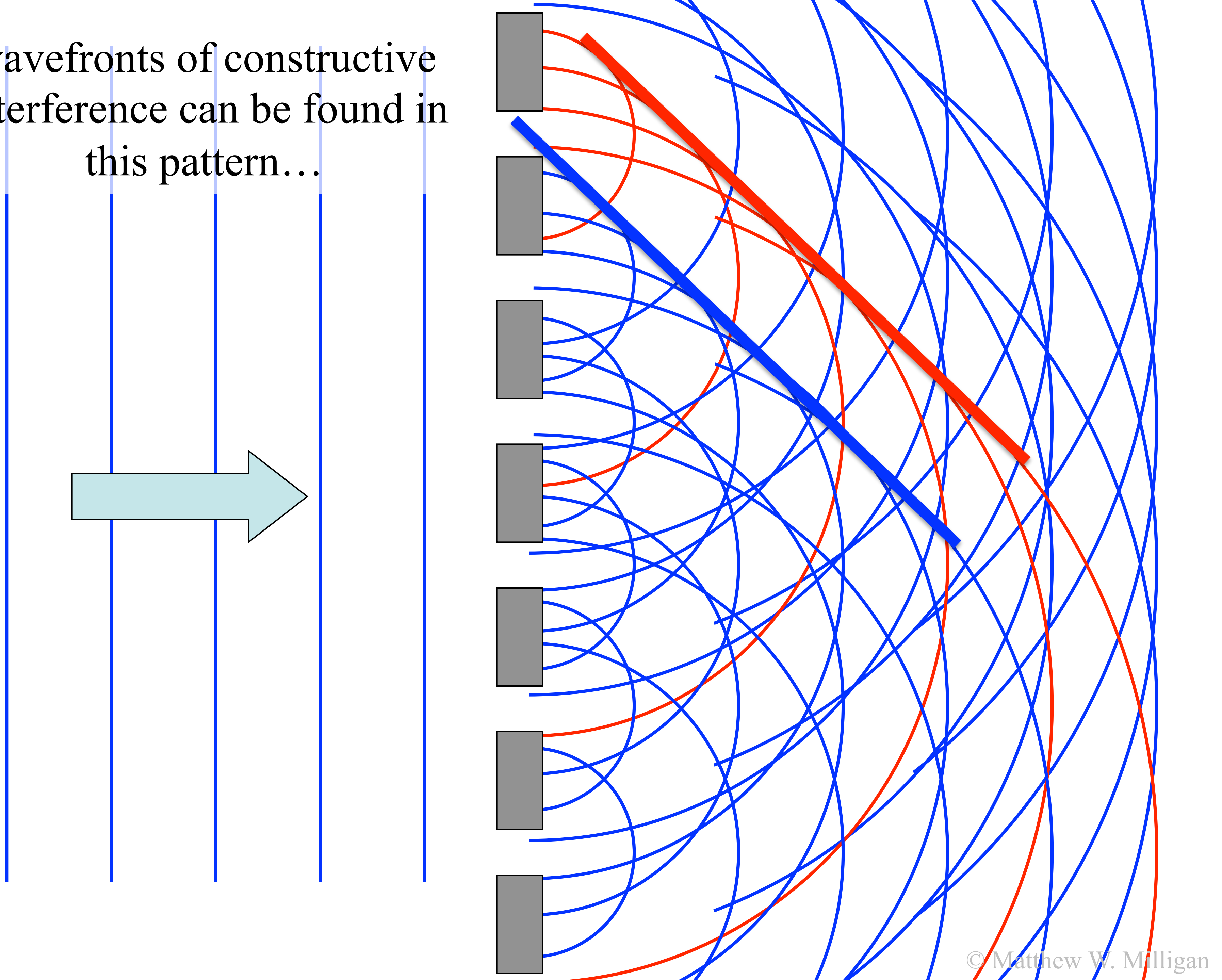
constructive interference
occurs along the lines shown
where crests from one opening
meet crests from the other



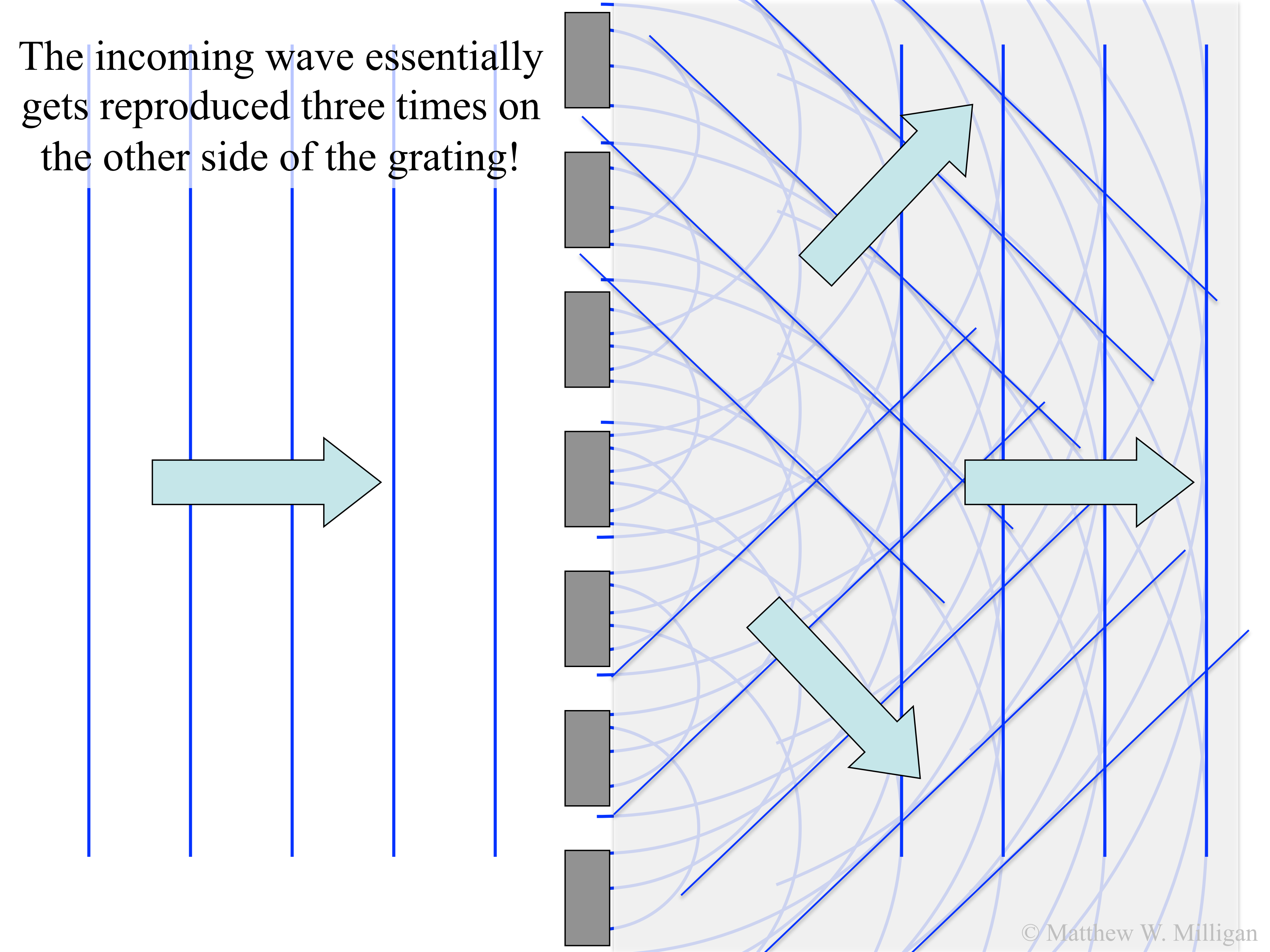
here the effect of a diffraction grating is viusalized – a complex system of waves is produced…



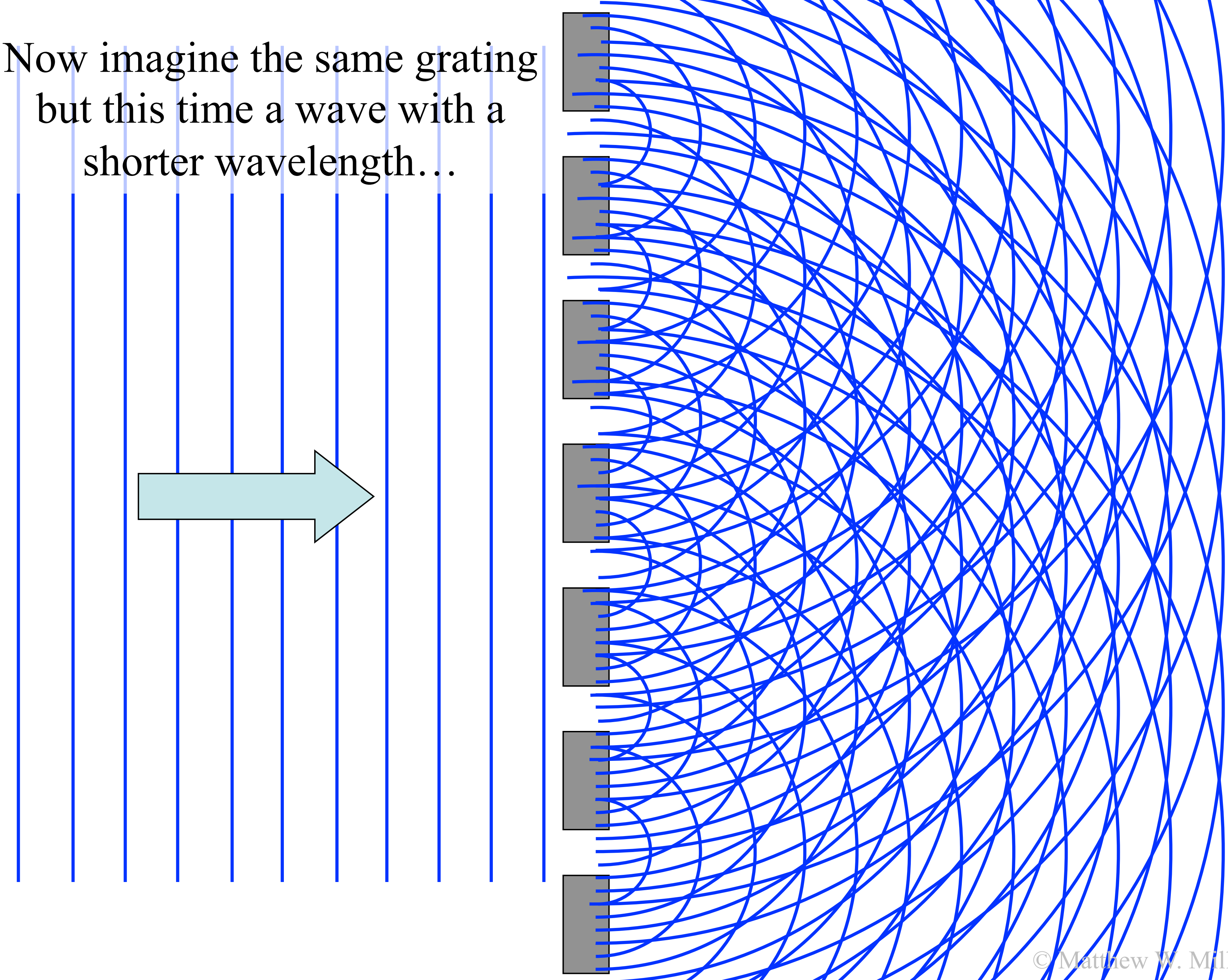
wavefronts of constructive interference can be found in this pattern…



The incoming wave essentially gets reproduced three times on the other side of the grating!



Now imagine the same grating but this time a wave with a shorter wavelength…



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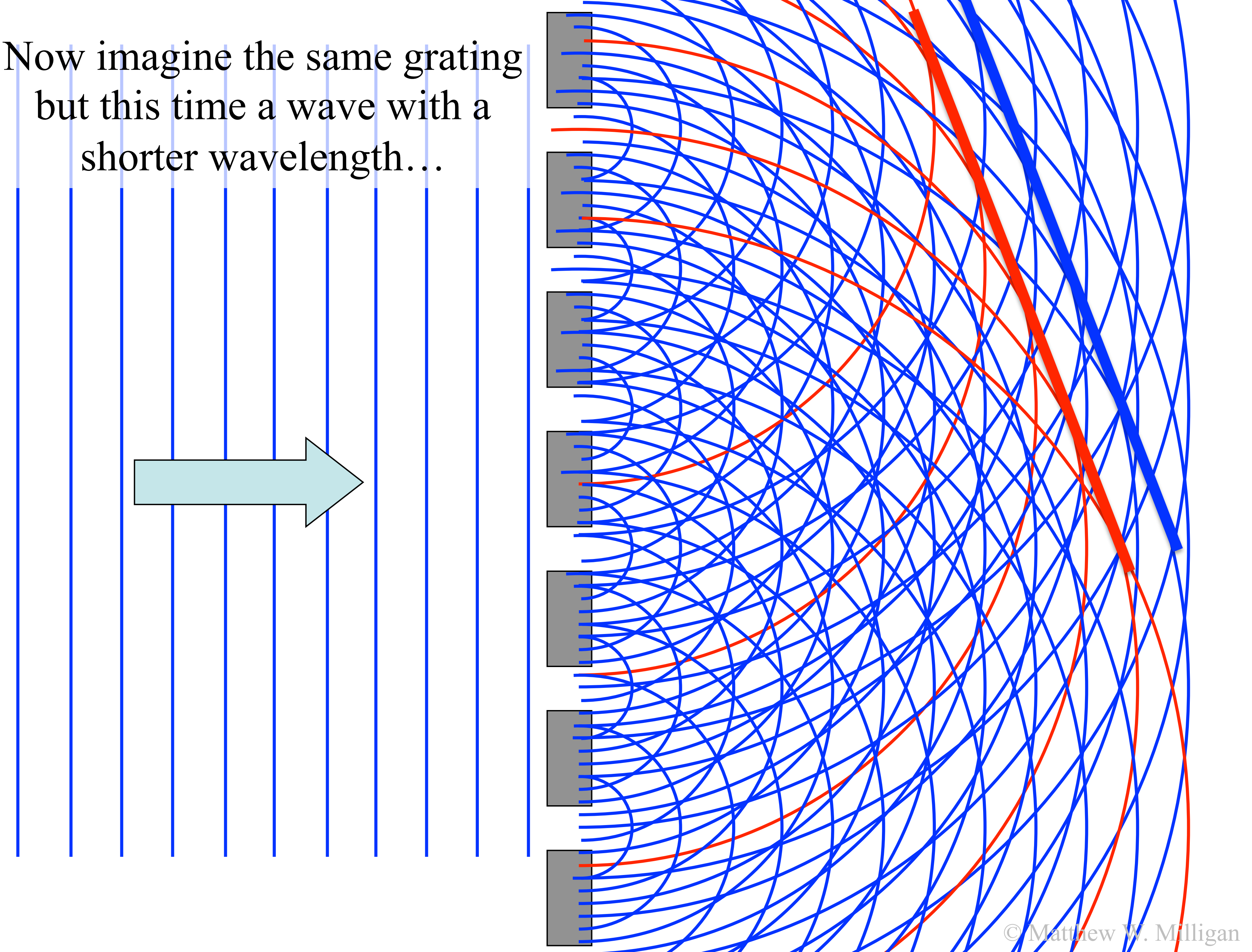

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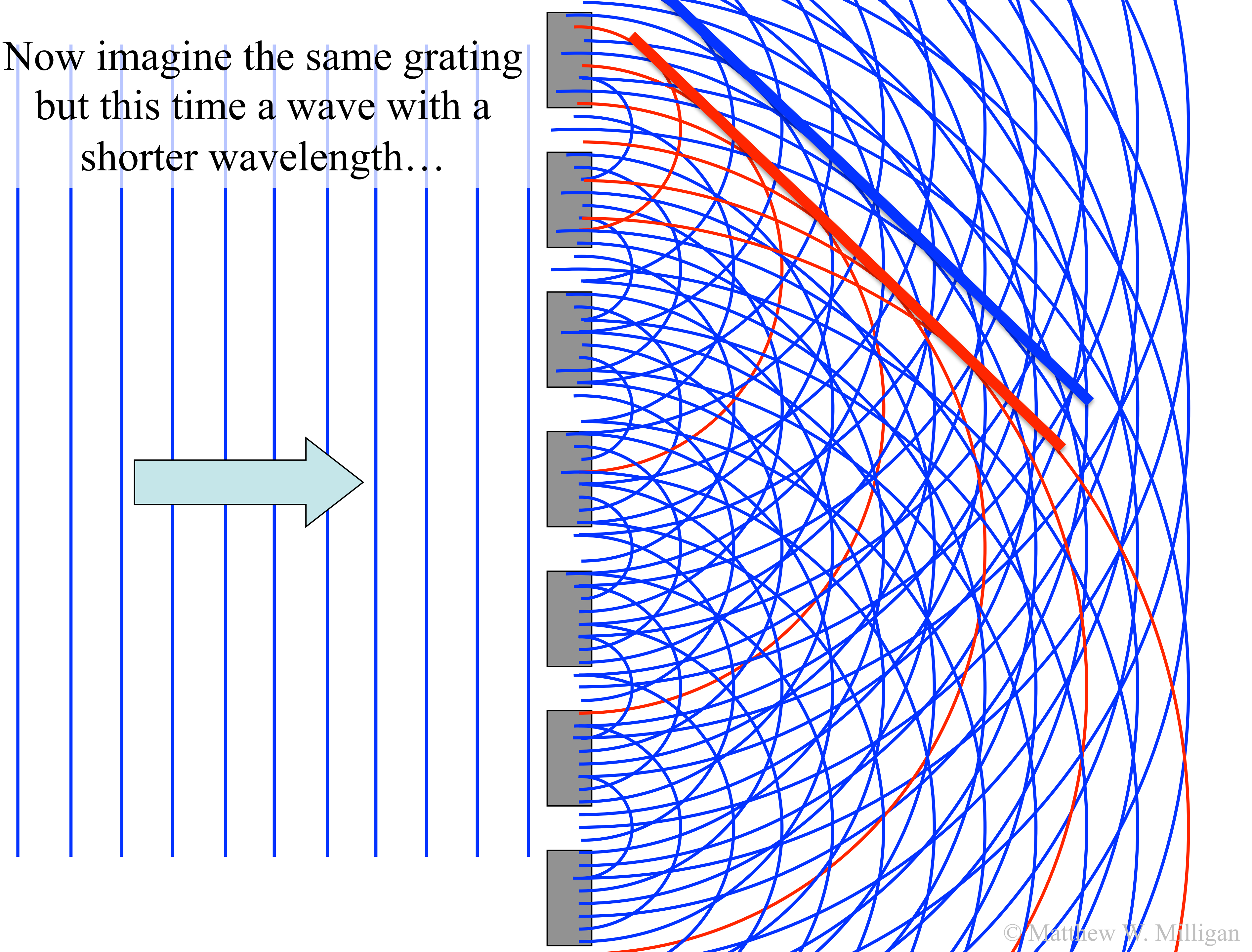
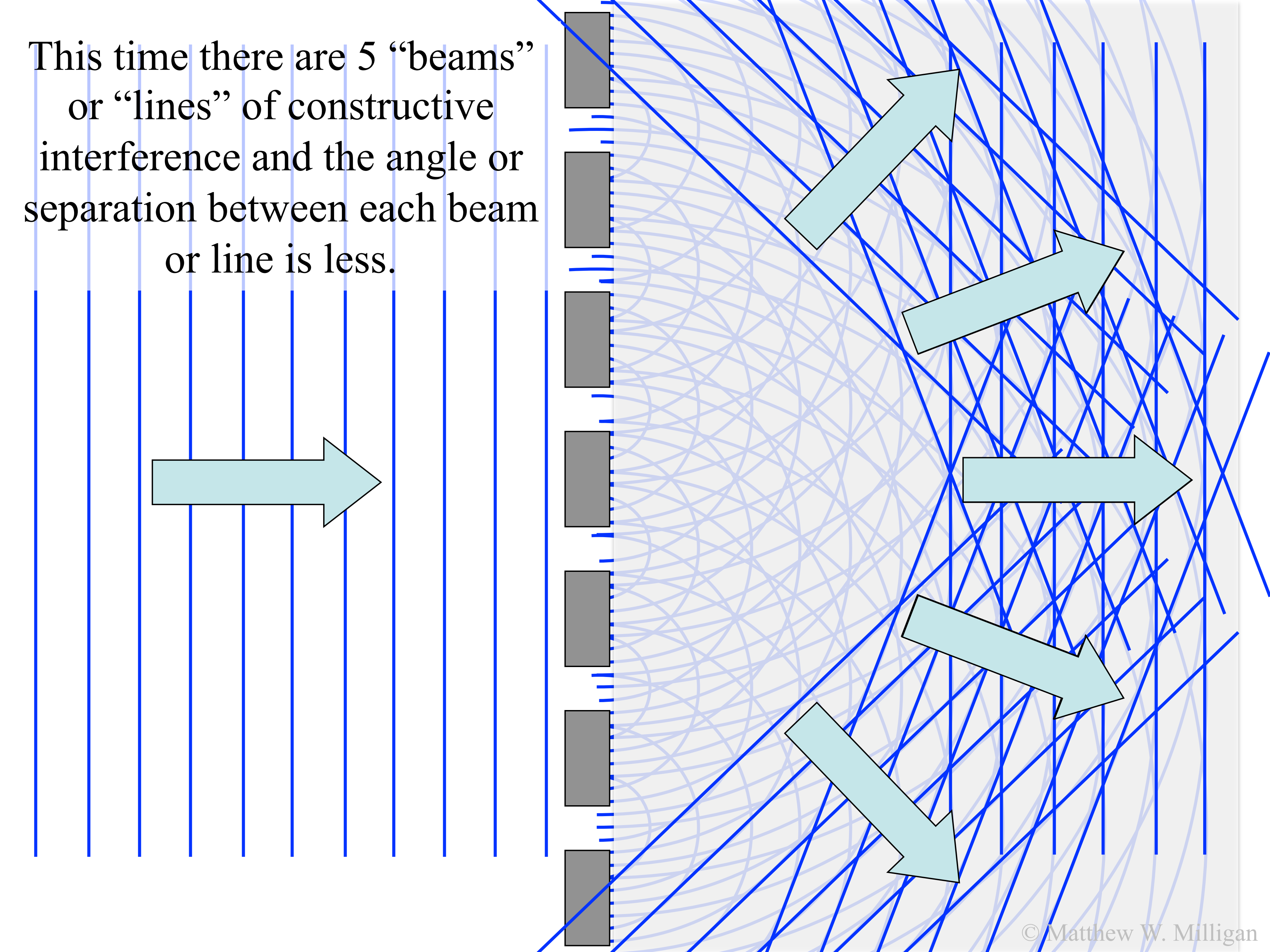


This time there are 5 “beams” or “lines” of constructive interference and the angle or separation between each beam or line is less.



Polarization

- Polarization refers to the orientation of oscillations in a transverse wave, such as light.
- Light is said to be polarized if its oscillations share a certain orientation.