## The Limits of Sight

The Ikonos satellite was the first commercial satellite to take surveillance photographs for sale and was active until 2015. The cost for photos from the satellite archive is \$10 per sq kilometer. The aperture of the camera on the satellite is a = 0.7 m and the satellite operates L = 681 km above the Earth. What is the size of the smallest object visible to the camera? The range of wavelengths of visible light is about  $\lambda = 400 - 700 nm$ . What is the size of the smallest object visible to human eyes?





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### Waves



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# **Electromagnetic Waves**



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### **Electromagnetic Spectrum**



### The Electric Field of Sunlight

The intensity of sunlight reaching the Earth is called the solar constant (which is not really constant) and has a value of  $I_s = 1366 J/s - m^2$ . What is the size of the electric field in sunlight? How does this compare with the typical fields we use in lab ( $|\vec{E}| \approx 10 N/C$ )?



### Lab Results





The videos are here and here. The simulation is here.





(b)

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Limits of Sight







# **X-Ray Interference**

A beam of X-rays with a wavelength  $\lambda = 2.10 \times 10^{-11} m$  is incident on a thin slab of NaCl, a crystalline solid. A detector is located on a track D = 1.70 m downstream from the target and the first peak in the interference pattern is at a perpendicular distance  $y_1 = 0.12 m$  from the

central axis. What is the interatomic spacing of NaCl?



## **Rapidly Time-Varying Intensity Pattern**



## **Rapidly Time-Varying Intensity Pattern**



# Predicted Double Slit Interference Intensity Pattern



### Measured Double Slit Interference Intensity Pattern



A laser beam is passed through two narrow slits and an interference pattern is thrown on a screen a distance D = 1.7 m away from the slits. The bright spots are  $\Delta y = 0.1 m$  apart. What is the separation d of the slits? The light has a wavelength  $\lambda = 6.5 \times 10^{-7} m$ .







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Jerry Gilfoyle
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A laser beam of wavelength  $\lambda = 6328$  Å is shone on a single slit of width a = 1.0 mm. If a screen is placed a distance L = 0.40 m away, then how far from the central maximum are the first two dark spots on each side of the central maximum?



### **Diffraction Equation**

$$I = I_m \left(\frac{\sin \alpha}{\alpha}\right)^2 = I_m \left(\frac{\sin \left(\frac{\pi a}{\lambda} \sin \theta\right)}{\frac{\pi a}{\lambda} \sin \theta}\right)^2$$
$$\alpha = \frac{\pi a}{\lambda} \sin \theta \qquad \theta \equiv \text{angular position}$$



# L'Hopital's Rule

f(a)=g(a)=0

#### and

lf

$$\lim_{x\to a^+}\frac{f'(x)}{g'(x)}=A$$

then

$$\lim_{x \to a^+} \frac{f(x)}{g(x)} = A$$

### **The Diffraction Function**



Jerry Gilfoyle



### **Interference and Diffraction**



### **Defining the Limits of Sight-1**



Limits of Sight

### **Defining the Limits of Sight-2**



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# Diffraction



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Limits of Sight

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### **Electromagnetic Spectrum**



Jerry Gilfoyle

#### The Limits of Sight



#### The Limits of Sight







Jerry Gilfoyle

Limits of Sight





Double-slit Interference, a = 0.04mm, d = 0.125 mm 14  $\theta = \arctan\left(\frac{y}{L}\right)$ 12 10 Intensity 8 6 2 0 -2 2 -4 ٥ θ (deg) Single-slit Diffraction, a = 0.04 mm  $\theta = \arctan\left(\frac{y}{I}\right)$ 14 12 10 Intensity 8 6 2 0 -2 -4 0 2 θ (deg)

Jerry Gilfoyle

Double-slit Interference, a = 0.04mm, d = 0.125 mm 14  $\theta = \arctan\left(\frac{y}{L}\right)$ 12 10 Intensity 8 Blue - double-slit interference 14 Green - single-slit diffraction 12 d = 0.125 mm a = 0.04 mm 10 0 -2 Intensity -4 n 2 θ (deg) Single-slit Diffraction, a = 0.04 mm 14  $\theta = \arctan\left(\frac{y}{t}\right)$ 12 2 10 0 Intensity -4 -2 0 8  $\theta$  (dea) 6 0 -2 -4 0 2 θ (deg)

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# Atomic Spectroscopy -1

Light of wavelength  $\lambda = 600 \ nm$  is incident normally on a diffraction grating in a spectrometer. Two adjacent maxima occur at angles given by  $\sin \theta_1 = 0.2$  and  $\sin \theta_2 = 0.3$ . The fourth-order maxima are missing. What is the separation between adjacent slits?



#### The Diffraction Grating





Visible emission spectrum of helium.