Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Reminders:

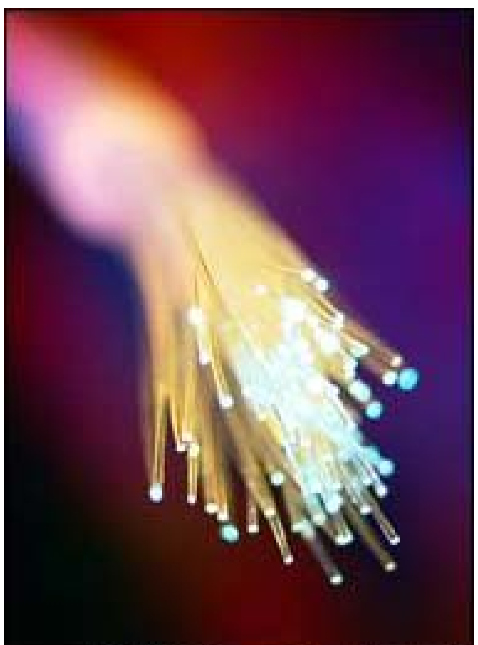
1) Assignment #12 → due Monday

2) Start Optics (Chapter 33)

3) Last HW (#13 posted) → due Monday, May 3rd

Reflection

$$\boxed{\theta_i = \theta_r}$$



Lawrence Lawry / Getty Images file

Refraction

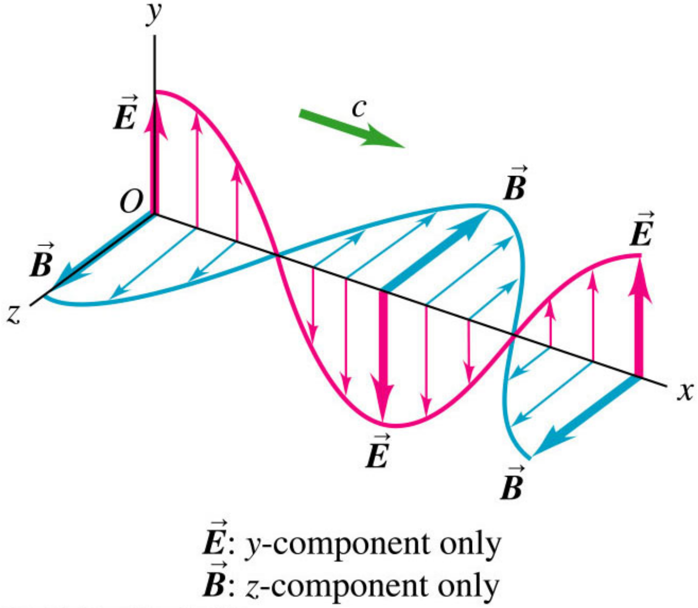
$$\boxed{n_1 \sin\theta_1 = n_2 \sin\theta_2}$$

Index of Refraction

- Speed of light, c, in vacuum is 3×10^8 m/s
- Speed of light, v, in different medium can be $v < c$.
- index of refraction, $n = c/v$.
- frequency, f, does not change in wave eqn. of $v = f\lambda$,
- wavelength, λ, depends on medium, $\lambda = v/f = c/nf = \lambda_0/n$
- In some media, *n*, depends on f, this is called dispersion.

Waves, wave front, rays (Y&F section 33.2)

Plane waves moving in +x direction

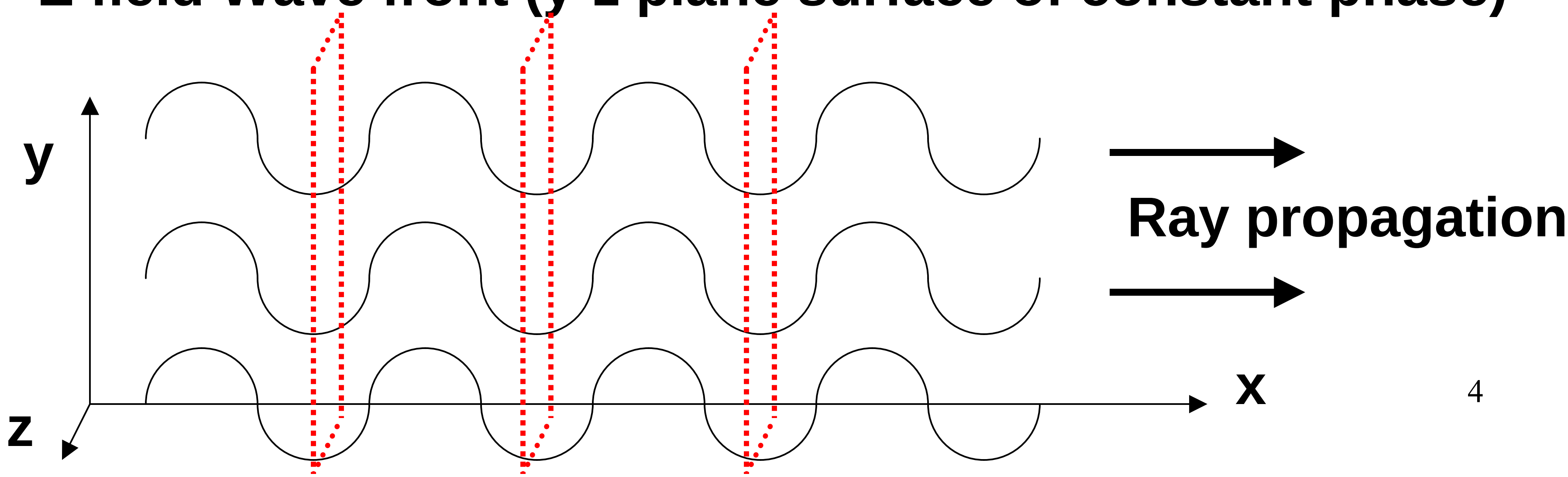


$$\vec{E}(x,y,z,t) = E_0\hat{y}\cos(kx-\omega t)$$

$$\vec{B}(x,y,z,t) = B_0\hat{z}\cos(kx-\omega t)$$

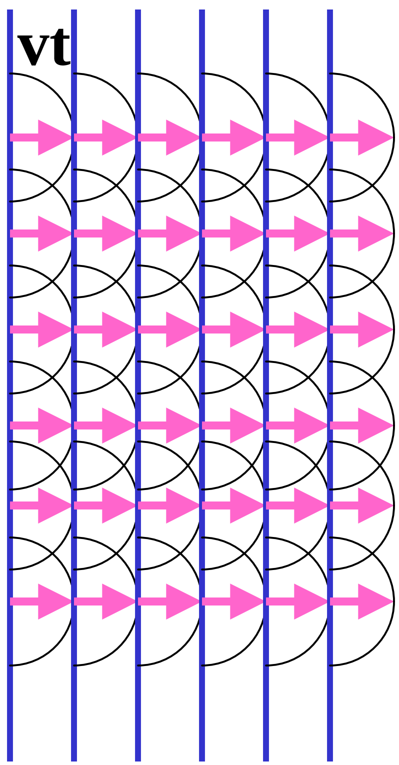
Wave front is a surface of constant phase

E field Wave front (y-z plane surface of constant phase)



Huygen's Principle (Y&F section 33.7)

- Huygen's principle; a wave front can be a source of secondary wavelets the spread out in all directions at the speed of propagation in the medium. The envelope of leading edges forms a wave front.
- This principle was stated by Huygen in 1678, it is derivable from Maxwell's eqn. It is a geometrical description of ray propagation.

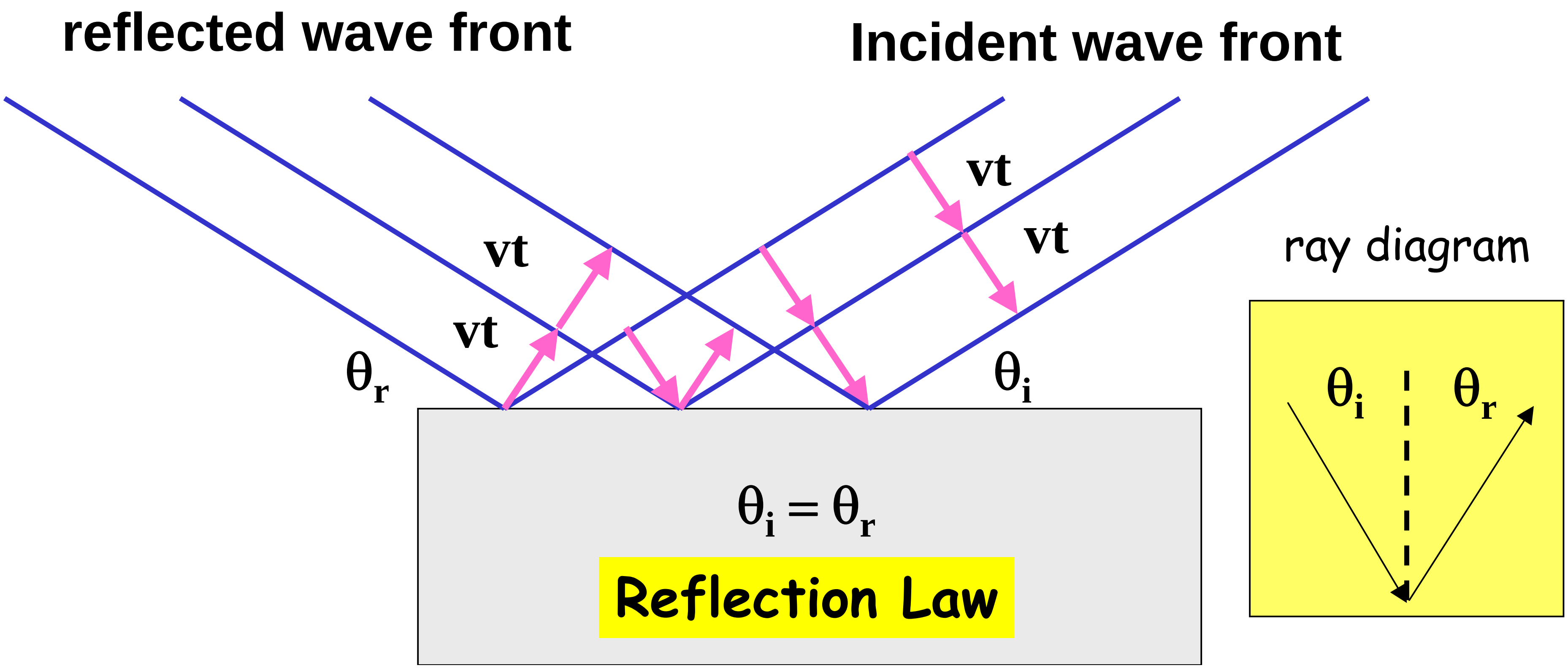


Plane wave example;

Secondary wavelets create another wave front (plane)

Reflection from Huygen's Principle

Consider wave fronts, separated by vt, the incident wave fronts in contact with the surface will create a wavelets according to Huygen's Principle and leads to another "reflected" wave front.
The result is $\theta_i = \theta_r$



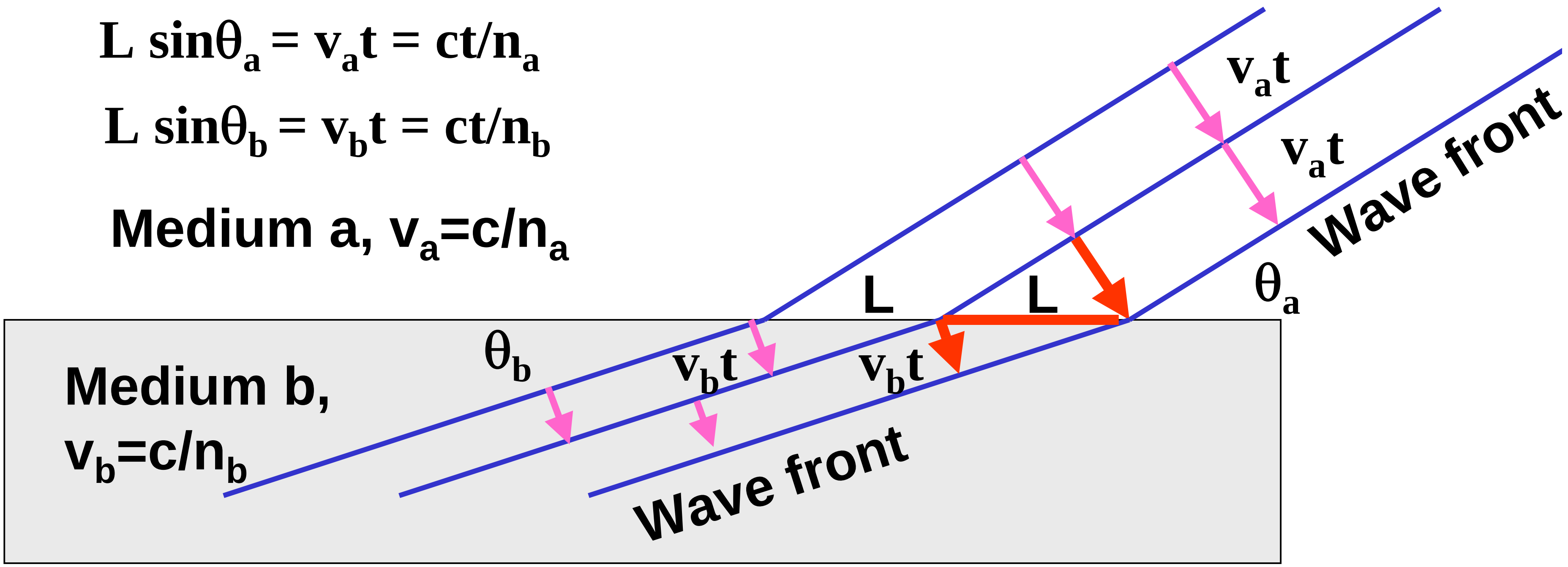
Refraction from Huygen's Principle

Now the speed changes, from medium a to medium b, so the Speed may change and the wavefront spacing differs.

$$L \sin\theta_a = v_a t = ct/n_a$$

$$L \sin\theta_b = v_b t = ct/n_b$$

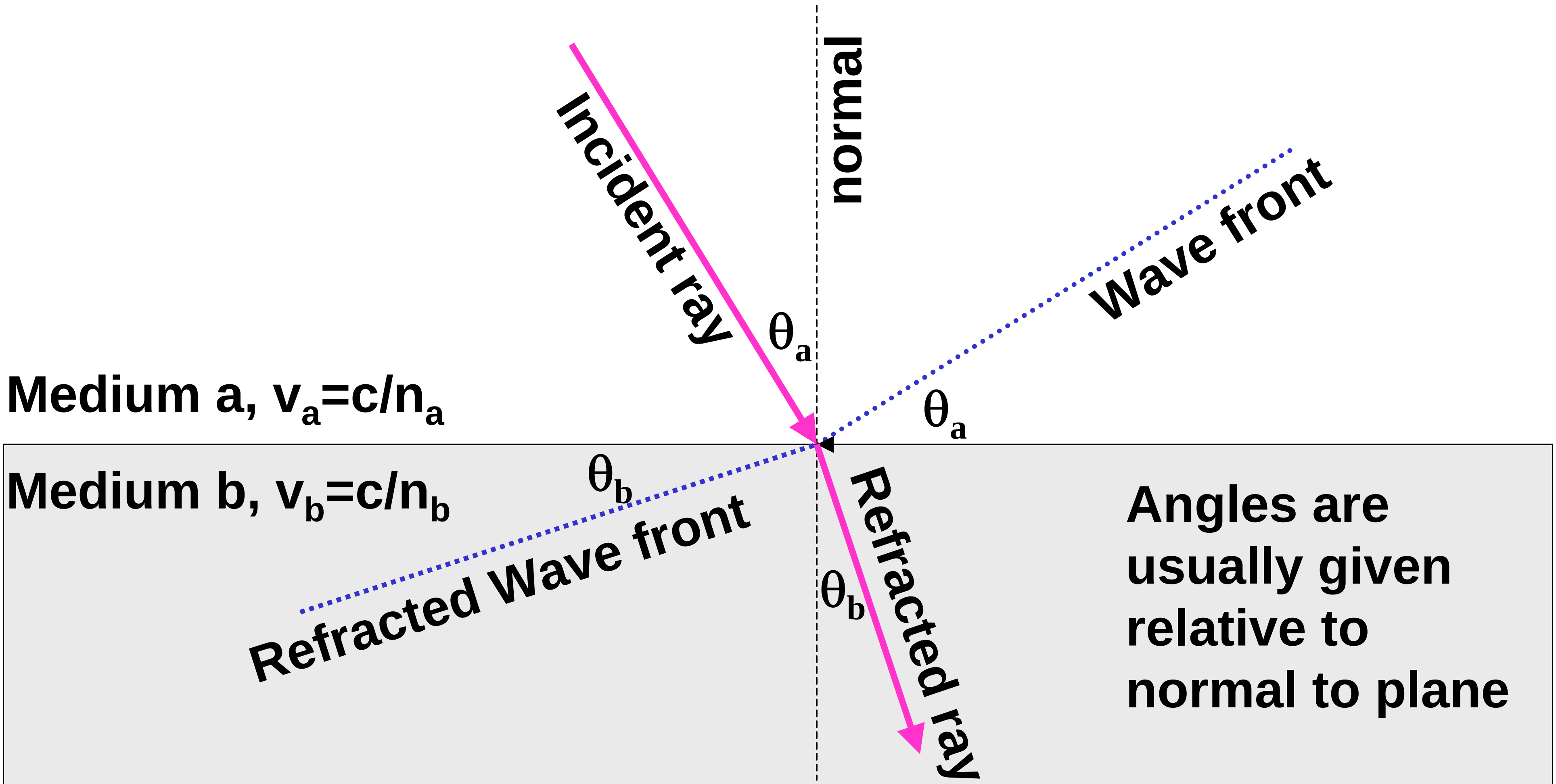
Medium a, $v_a = c/n_a$



$$\boxed{n_a \sin\theta_a = n_b \sin\theta_b}$$

Snell's Law

Snell's Law (law of refraction)

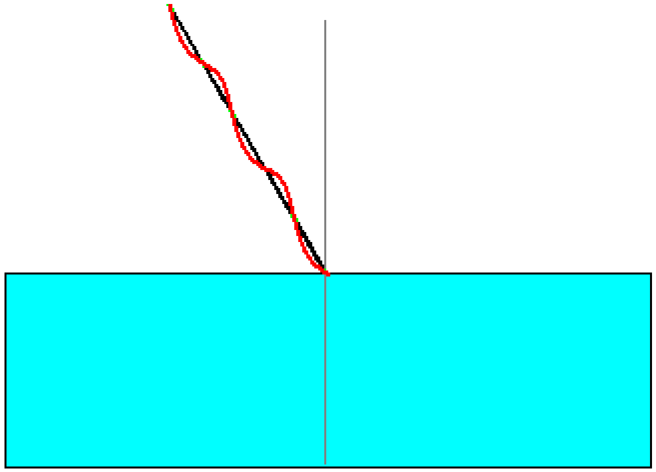


$$n_a \sin\theta_a = n_b \sin\theta_b$$

Snell's Law

Question 1

A ray of light passes from air into water with an angle of incidence of 30^o. Which of the following quantities does **<u>not</u>** change as the light enters the water.



a) Wavelength

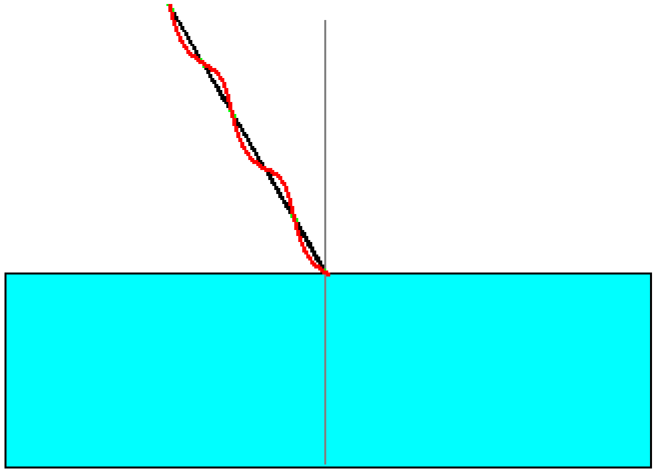
b) frequency

c) speed of propagation

d) direction of propagation.

Question 1

A ray of light passes from air into water with an angle of incidence of 30°. Which of the following quantities does **not** change as the light enters the water.



a) Wavelength

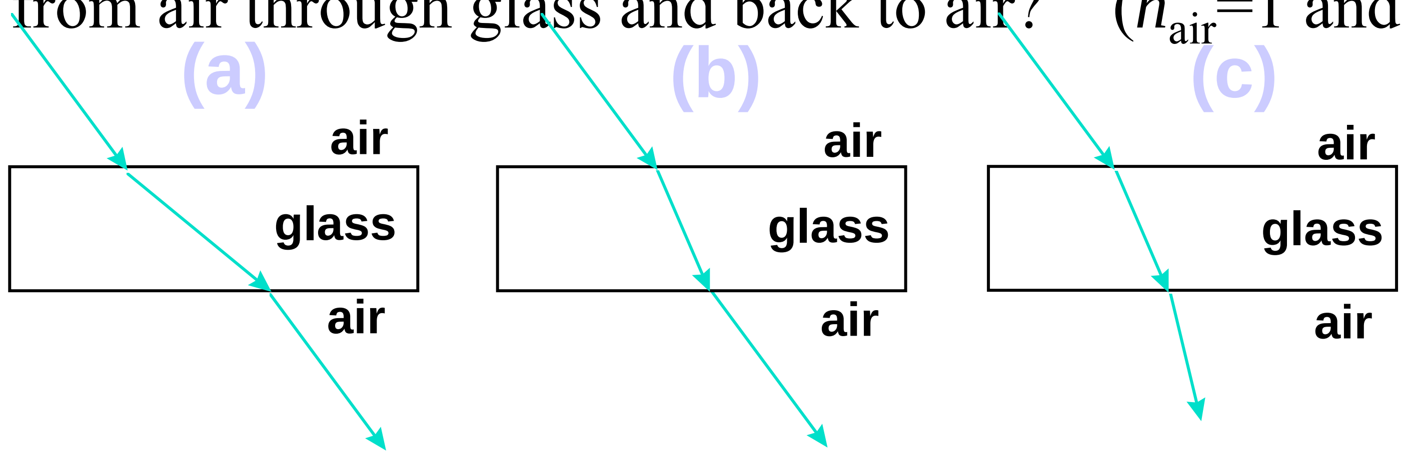
b) frequency

c) speed of propagation

d) direction of propagation.

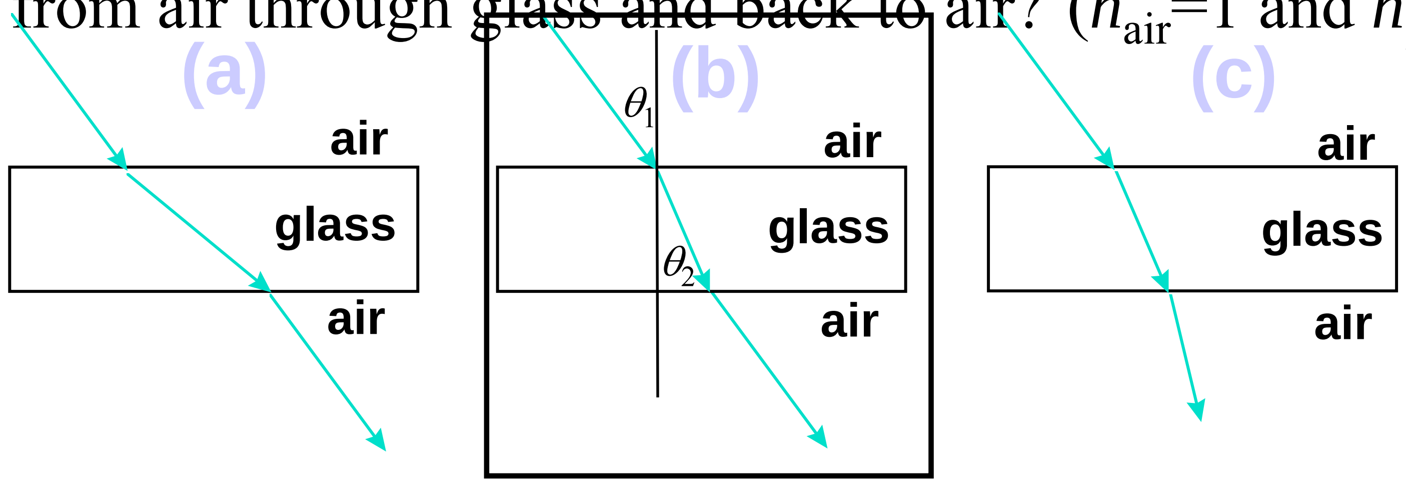
Question 2

- Which of the following ray diagrams could represent the passage of light from air through glass and back to air? (n_{air}=1 and n_{glass}=1.5)



Question 2

- Which of the following ray diagrams could represent the passage of light from air through glass and back to air? (n_{air}=1 and n_{glass}=1.5)



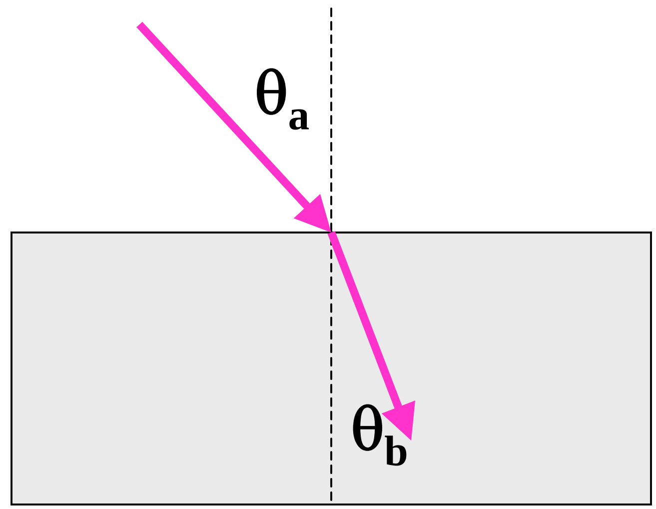
- **The behavior of these rays is determined from Snell's Law:**

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

- Since **n(glass) > n(air)**, **$\sin\theta$(glass) < $\sin\theta$(air)** .
- **Therefore, moving from air to glass, ray will bend toward normal.**
  - **this eliminates (a).**
- **Moving from glass to air, ray will bend away from normal.**
  - **this eliminates (c).**
- **As a matter of fact, the final angle in air must be equal to the initial angle in air!!**

EXAMPLE, from air into glass;

Suppose we have light in air (n=1) incidence on glass (n=1.55) at an angle θ_a=45 deg. What is the angle of the refracted light, θ_b?



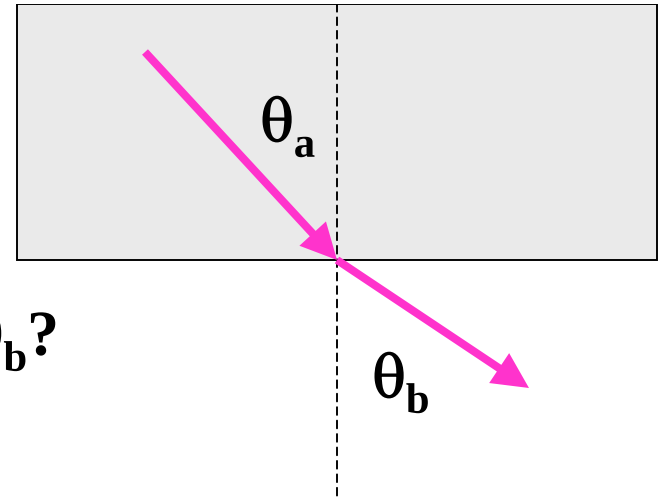
$$n_{air} \sin\theta_a = n_{glass} \sin\theta_b$$

$$(1)\sin(45°) = (1.55)\sin\theta_b$$

$$\sin\theta_b = \frac{(1)\sin(45°)}{1.55} = \frac{1}{1.55\sqrt{2}}$$

$$\theta_b = 27°$$

EXAMPLE, from glass into air;
Suppose we have light in glass (n=1.55) incident into air at an angle θ_a=30 deg.
What is the angle of the refracted light, θ_b?



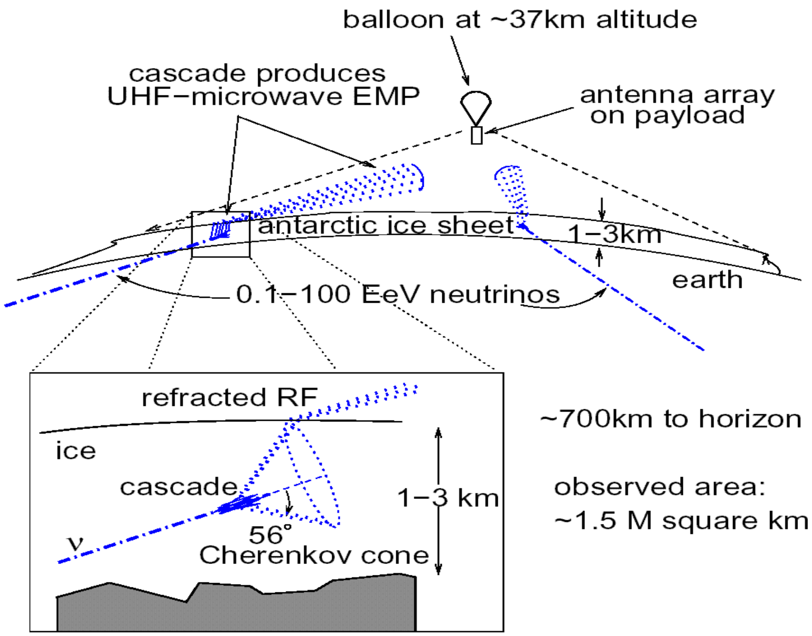
$$n_{glass}\sin\theta_a = n_{air}\sin\theta_b$$

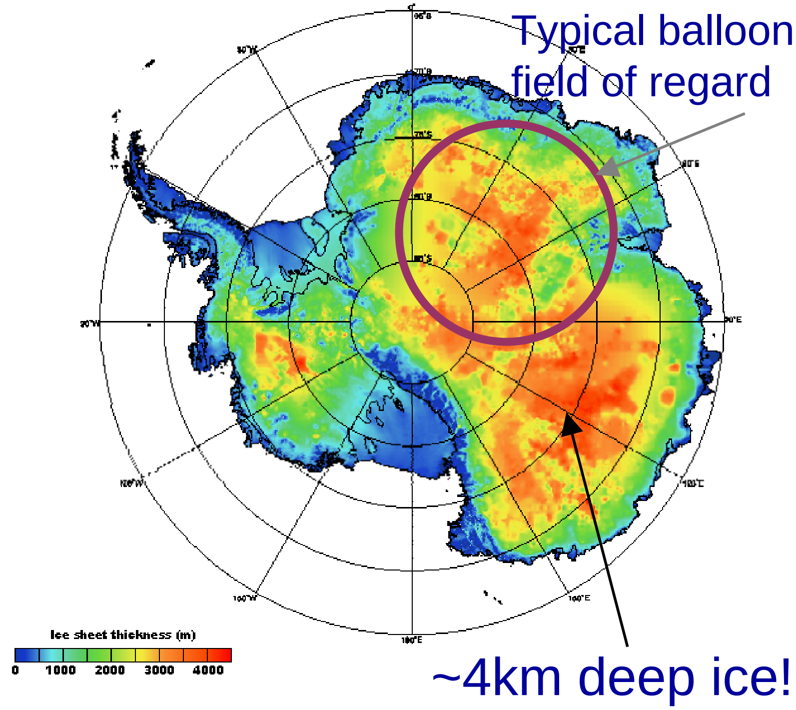
$$(1.55)\sin(30°) = (1)\sin\theta_b$$

$$\sin\theta_b = (1.55)\sin(45°) = \frac{1.55}{2}$$

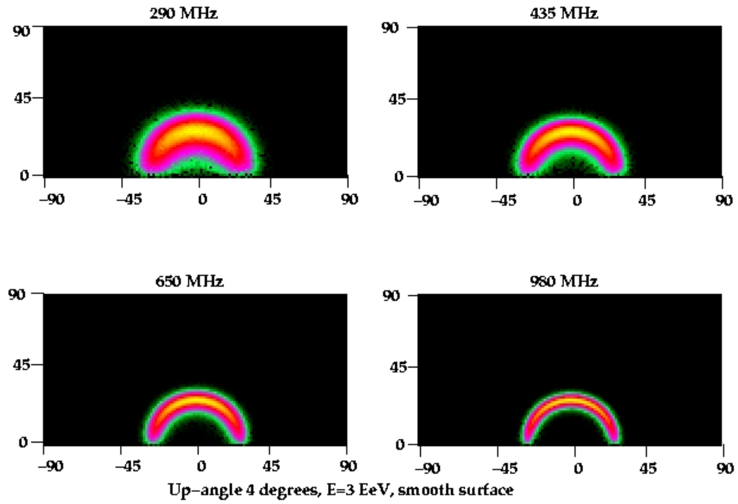
$$\theta_b = 51°$$

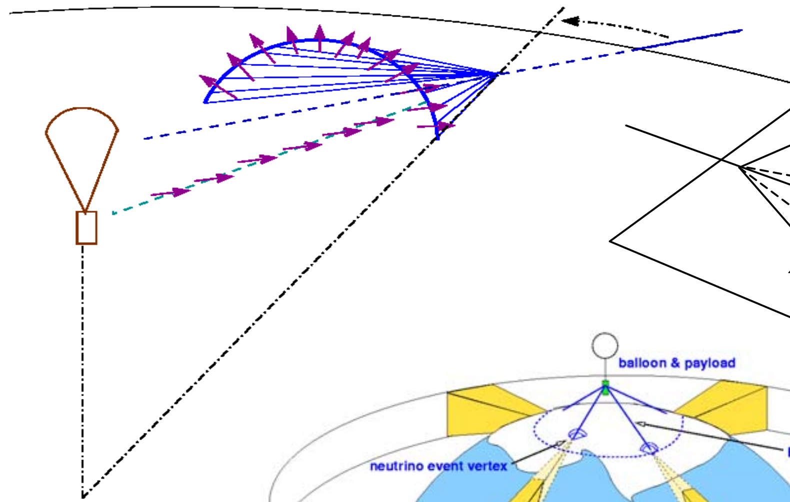
The ANITA Concept

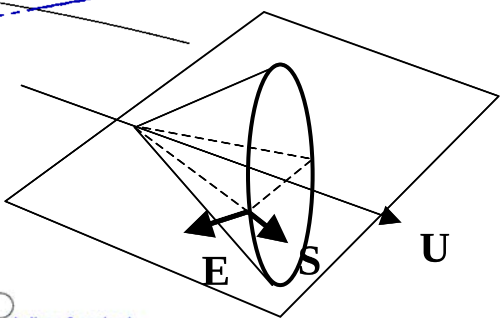


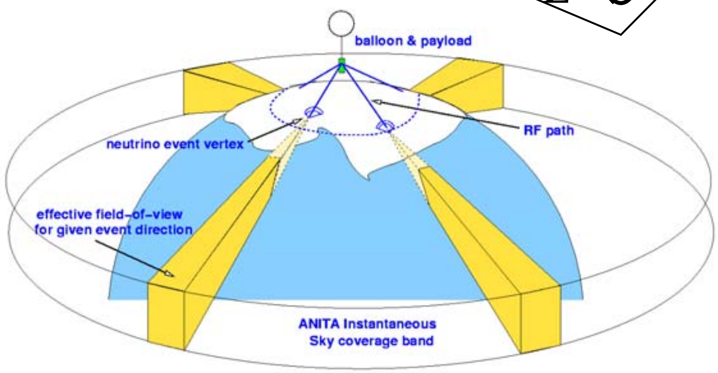


Refraction limits ANITA !





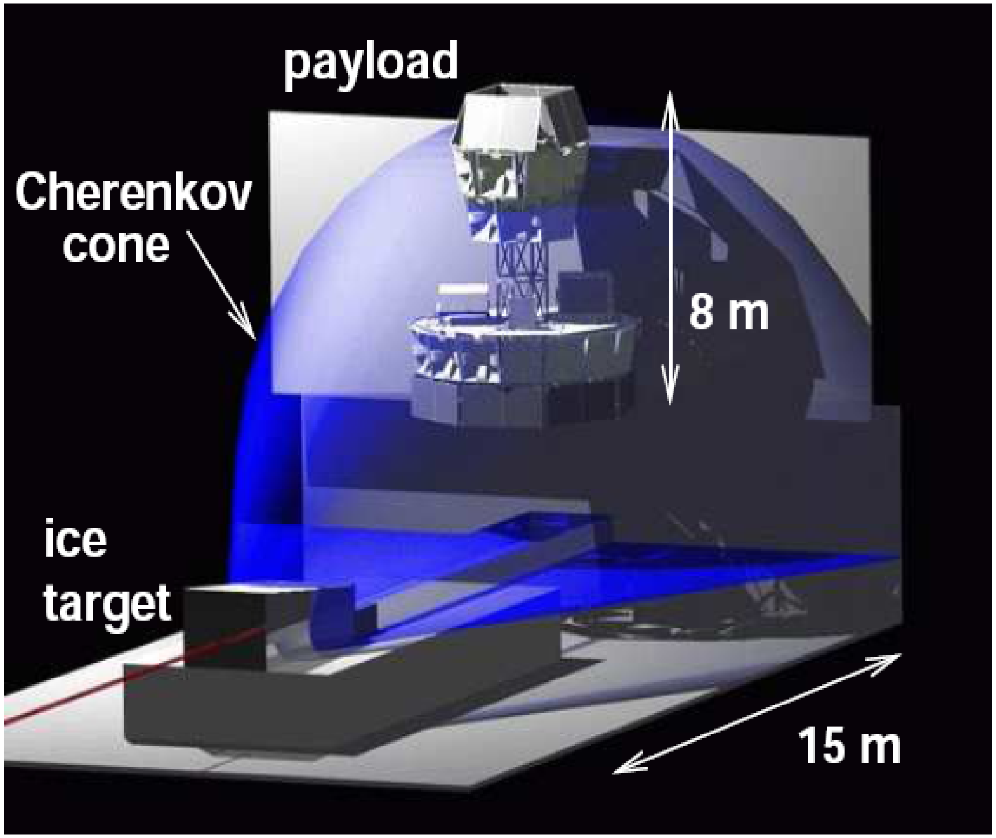


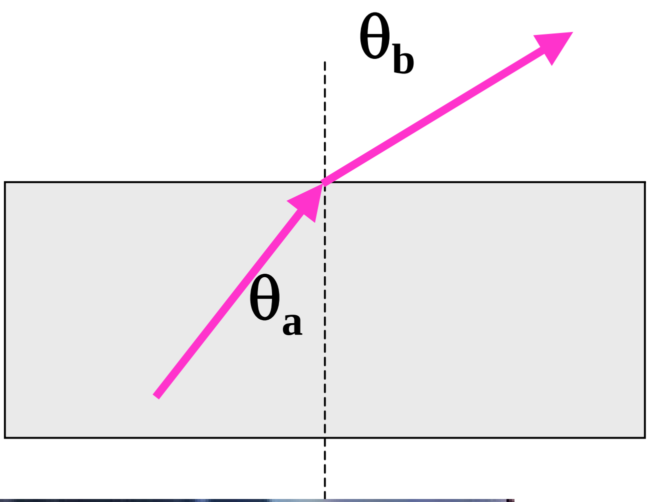


- ANITA at float (123Kft)
  - Seen through amateur telescope from the South Pole
  - Size of the Rose Bowl!
  - (thanks to James Roth)

“Mini-Antarctica” at Stanford Linear Accelerator

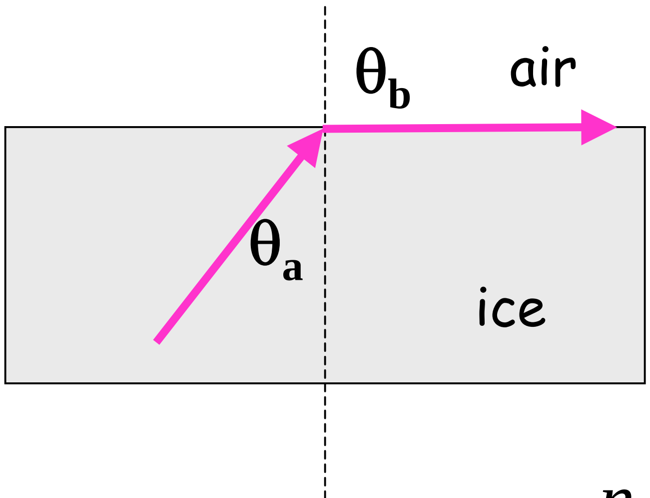
SLAC T486





- 2 mile long accelerator
- 28 Billion electron Volts
- If you've driven I-280 between San Francisco and San Jose →

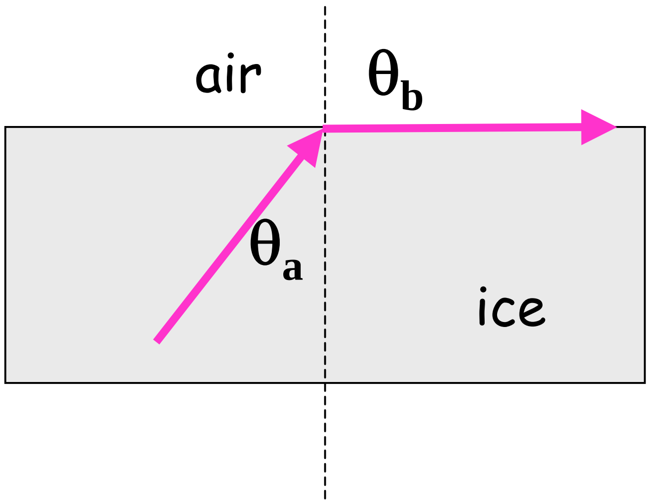
- Problem!!!



- There is no escape!!!

$$n_{ice} \sin\theta_a = n_{air} \sin\theta_b$$
$$(1.8)\sin(34°) = (1)\sin\theta_b$$
$$\sin\theta_b = (1.8)\sin(34°) = 1.0$$
$$\theta_b = 90°$$

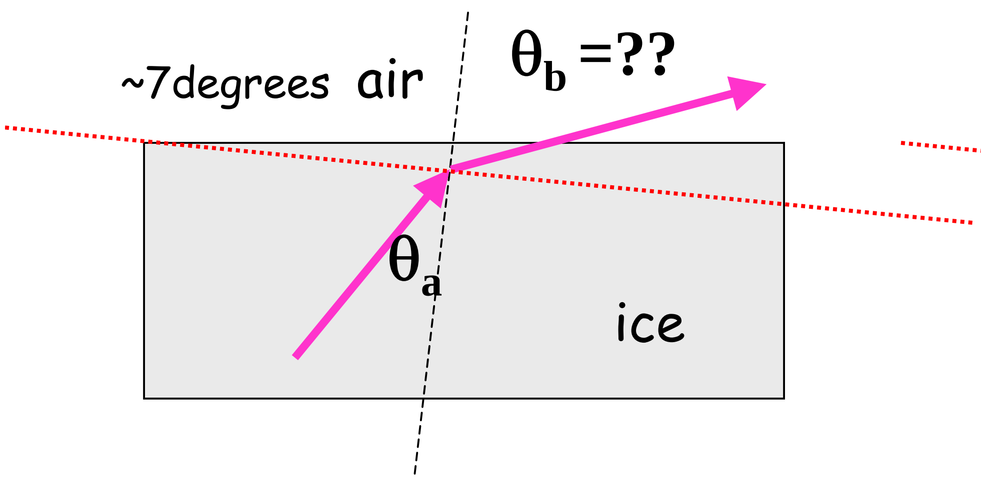
- Problem

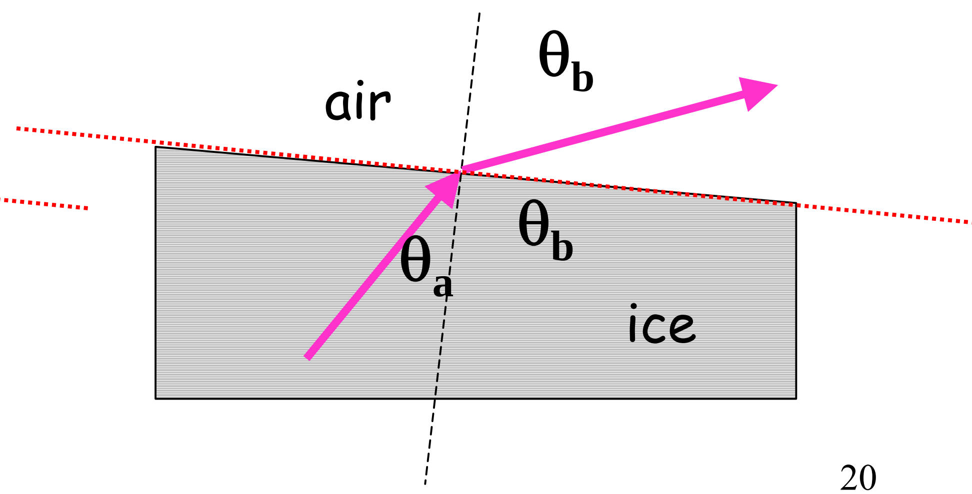


$$n_{ice} \sin\theta_a = n_{air} \sin\theta_b$$
$$(1.8)\sin(34°) = (1)\sin\theta_b$$
$$\sin\theta_b = (1.8)\sin(34°) = 1.0$$
$$\theta_b = 90°$$

$$n_{ice} \sin\theta_a = n_{air} \sin\theta_b$$
$$(1.8)\sin(27°) = (1)\sin\theta_b$$
$$\sin\theta_b = (1.8)\sin(27°) = 0.82$$
$$\theta_b = 54.8°$$

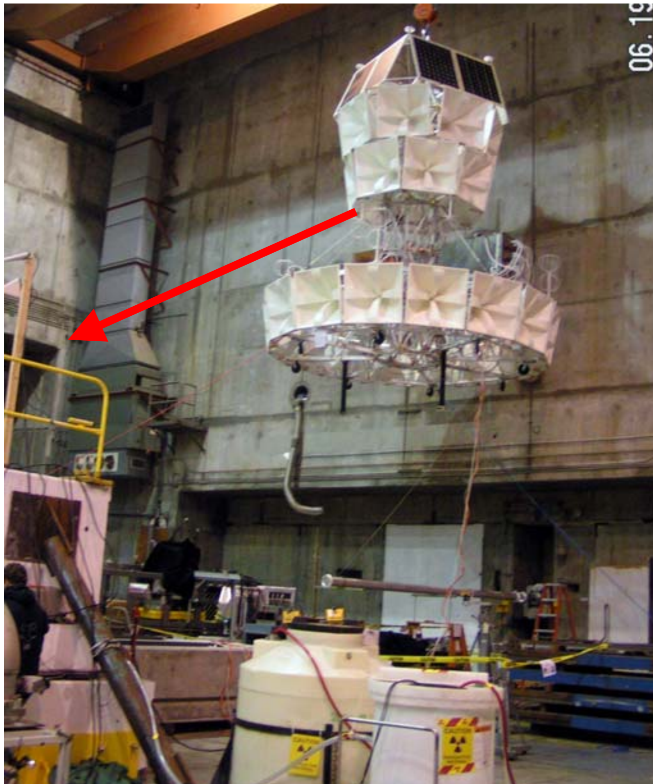
- Solution = cut!

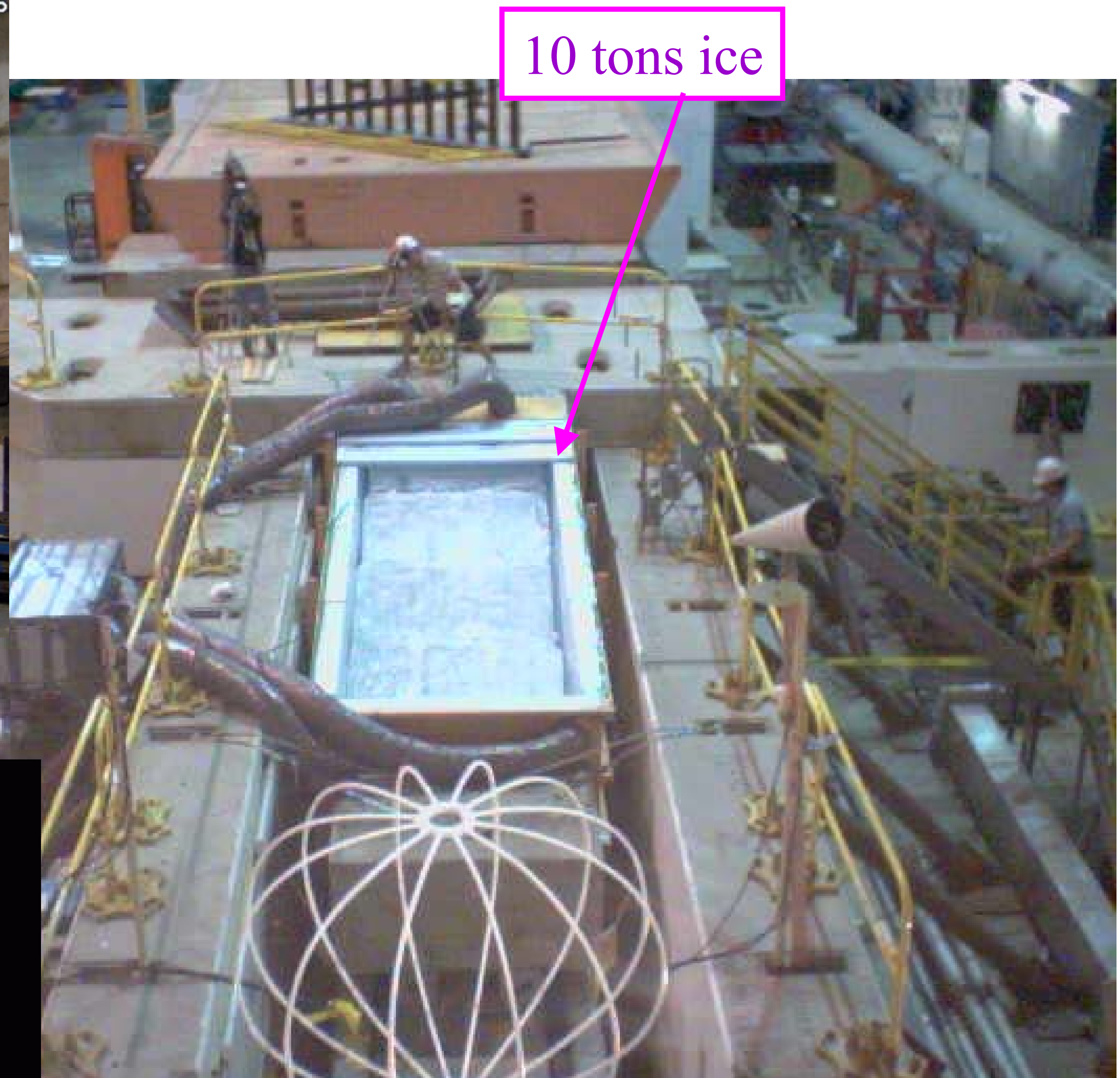


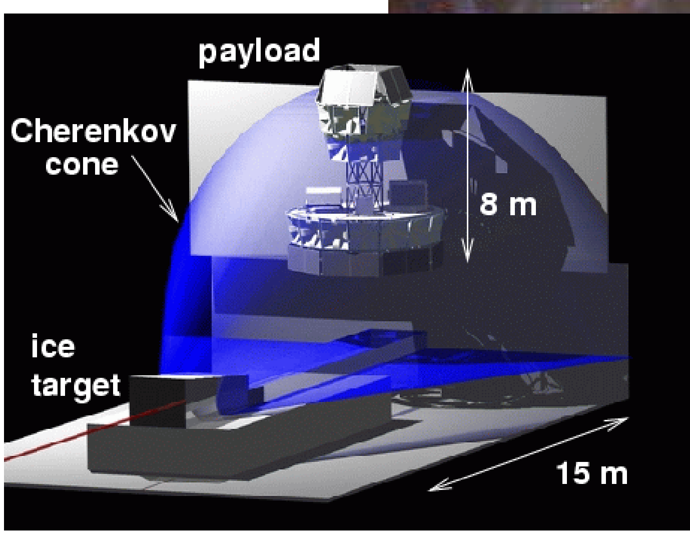


Mini-Antarctica at Stanford Linear Accelerator

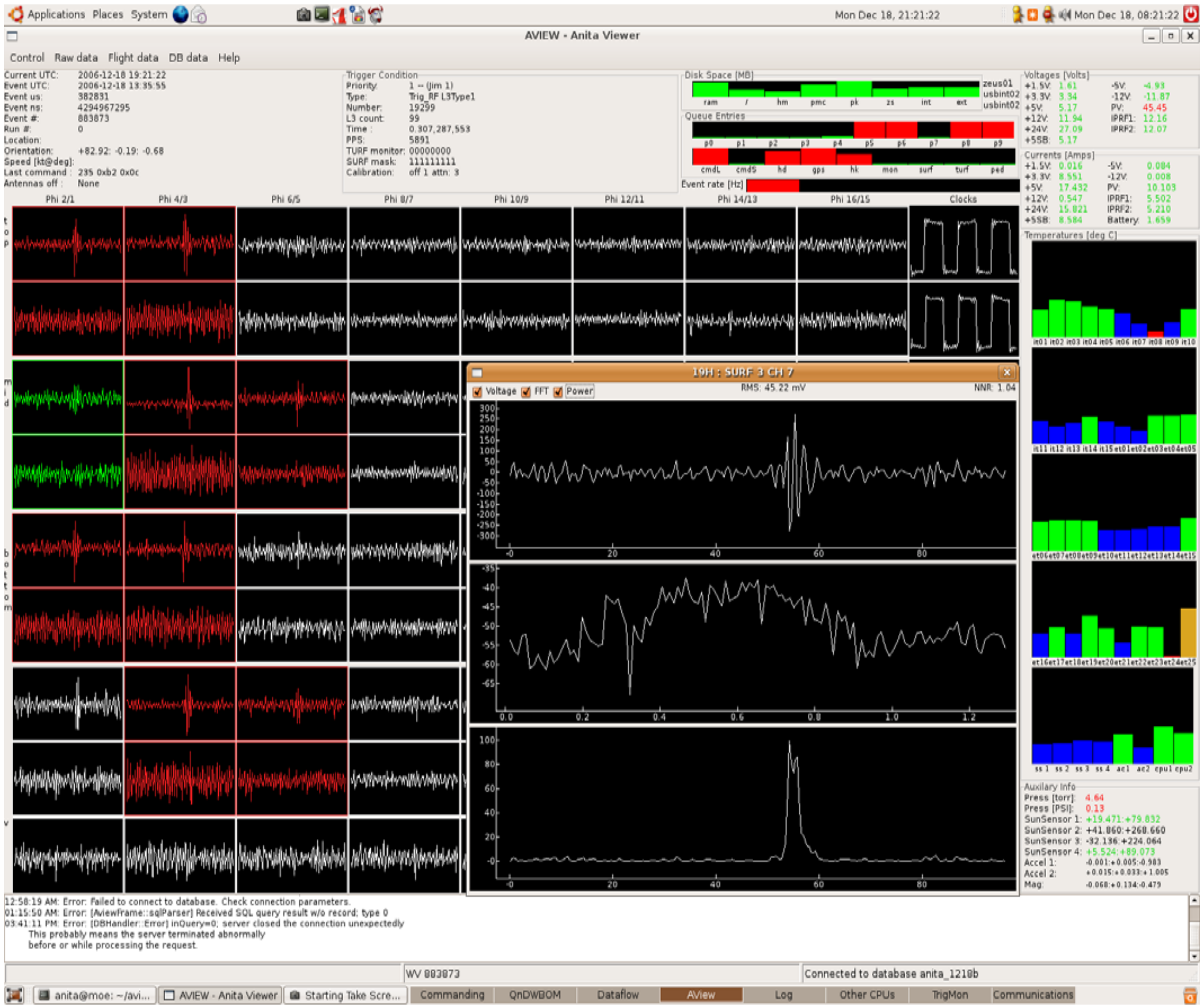
Cut ~7degrees! (jackhammers, chainsaws, mauls not shown)

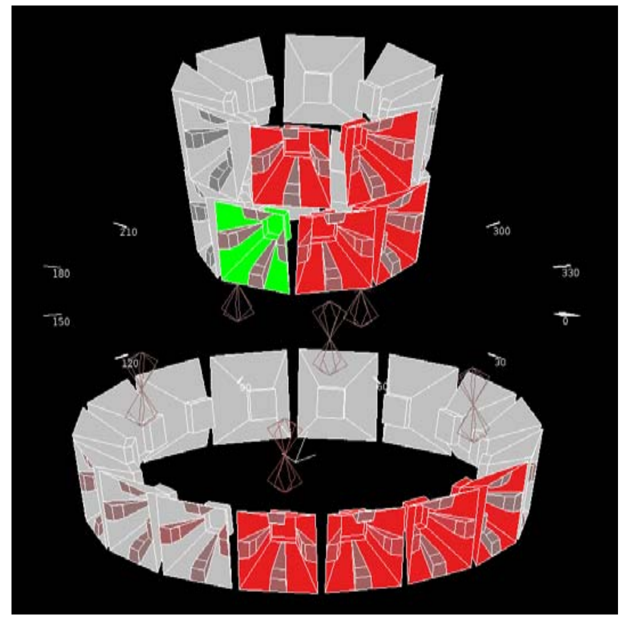



10 tons ice


payload
Cherenkov cone
8 m
ice target
15 m

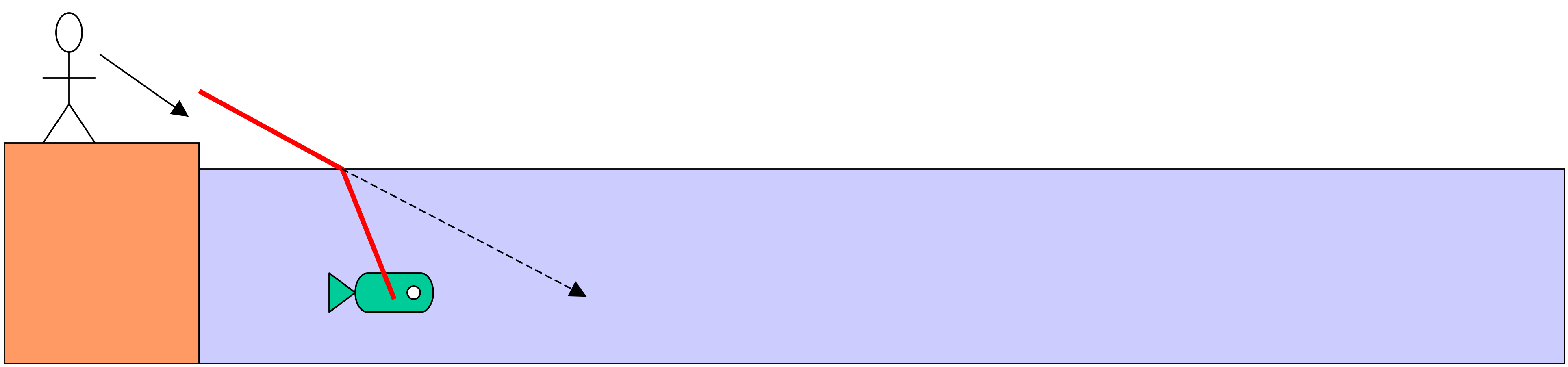
Let there be light! (OK, radio)





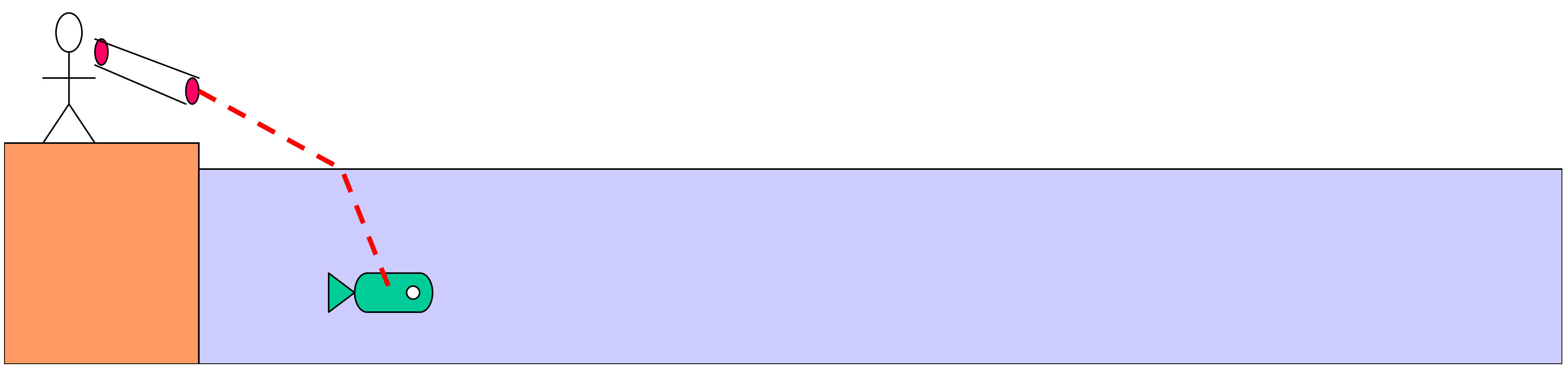
Suppose you are stranded on an island with no food. You see a fish in the water. Where should you aim your spear to hit the fish?

ANSWER; do not aim directly at the apparent position of the fish. Aim at the inside of the fish.



Suppose in the previous question instead of a spear you had a high power laser to simultaneously kill and cook the fish (in the water). Where should you aim the laser??

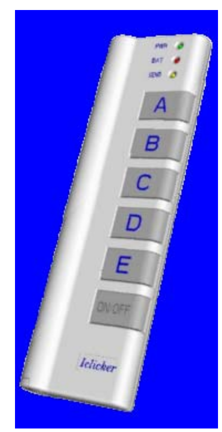
ANSWER; aim directly at apparent fish position as the laser beam will refract to the correct fish position.



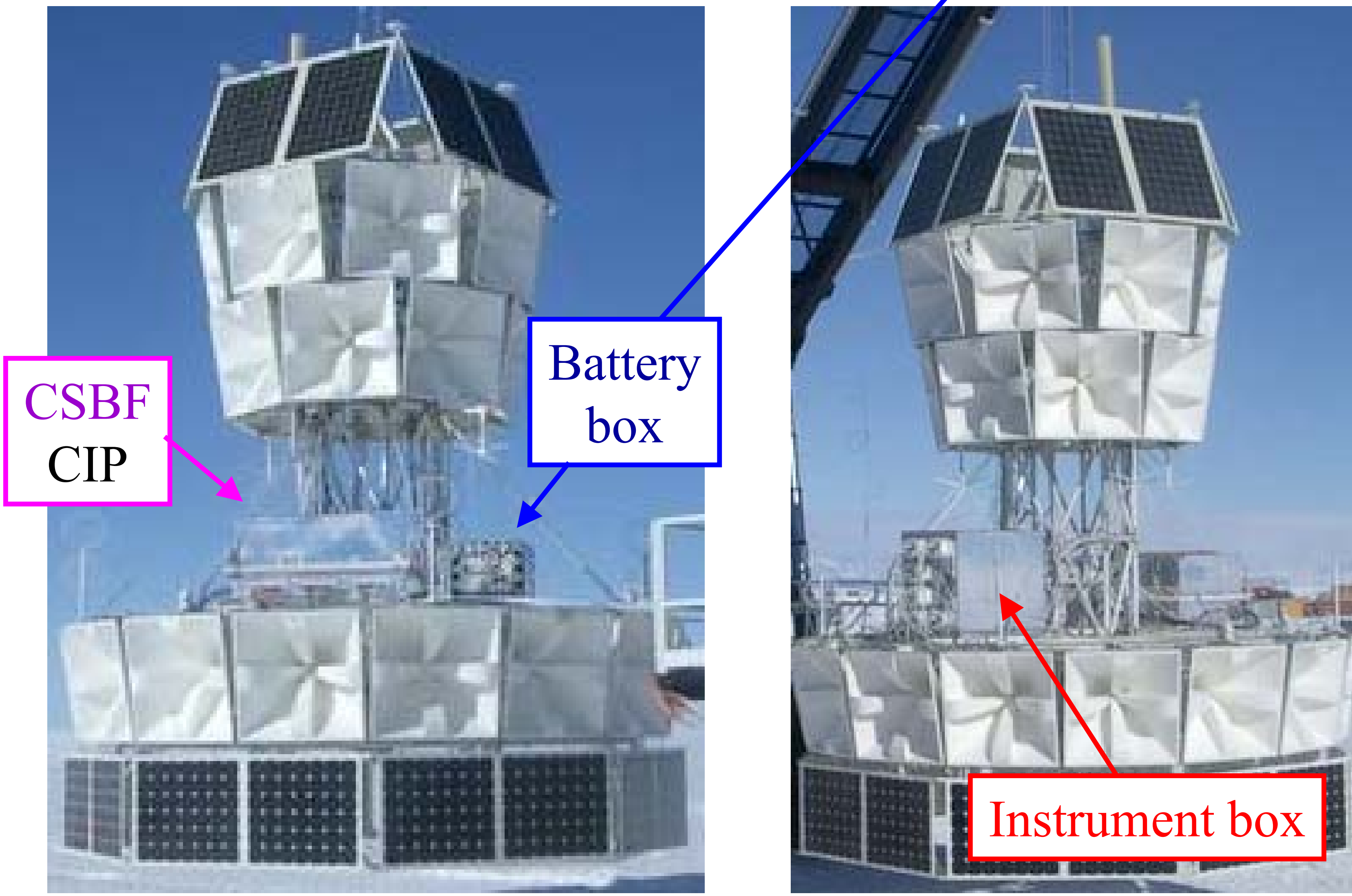
For next time

- Homework #12 posted → due <u>Monday</u>

- The home stretch: optics/optical phenomenon



Key Instrument pieces



Launch: December 15, 2007
(after almost 2 agonizing weeks of waiting)

Courtesy Kim Palladino

- A flawless launch
  - CSBF truly professional
  - After day after day after day of false starts, we were really ready to go