

- 3a) Explain what this second expression means:
- 3b) What is the meaning of the terms U_n and U_{n+1} ?
- 3c) What is U_0 in terms of r_1, r_2, t_1 , and U_{laser} ?
- 3d) What is r in terms of r_1 and r_2 ?
- 3e) Suppose there was a loss inducing optical element inside the cavity with a field transmission coefficient of t_{loss} . What would r be in terms of t_{loss}, r_1 and r_2 ? What if t_{loss} were complex?
- 3e) What is the effect of changing the index of refraction of the material between the mirrors? Is this equivalent to changing the distance between the mirrors? Why or why not?
- 3f) What is the effect of changing the wavelength of the input laser field? Is this equivalent to changing the distance between the mirrors? Why or why not?

- 3g) Evaluate the infinite sum for the field and derive an expression for the intensity

Hint $1 + a + a^2 + a^3 \dots = \frac{1}{1-a}$

FIG. 2. An in-class derivation for the field inside an optical resonator.

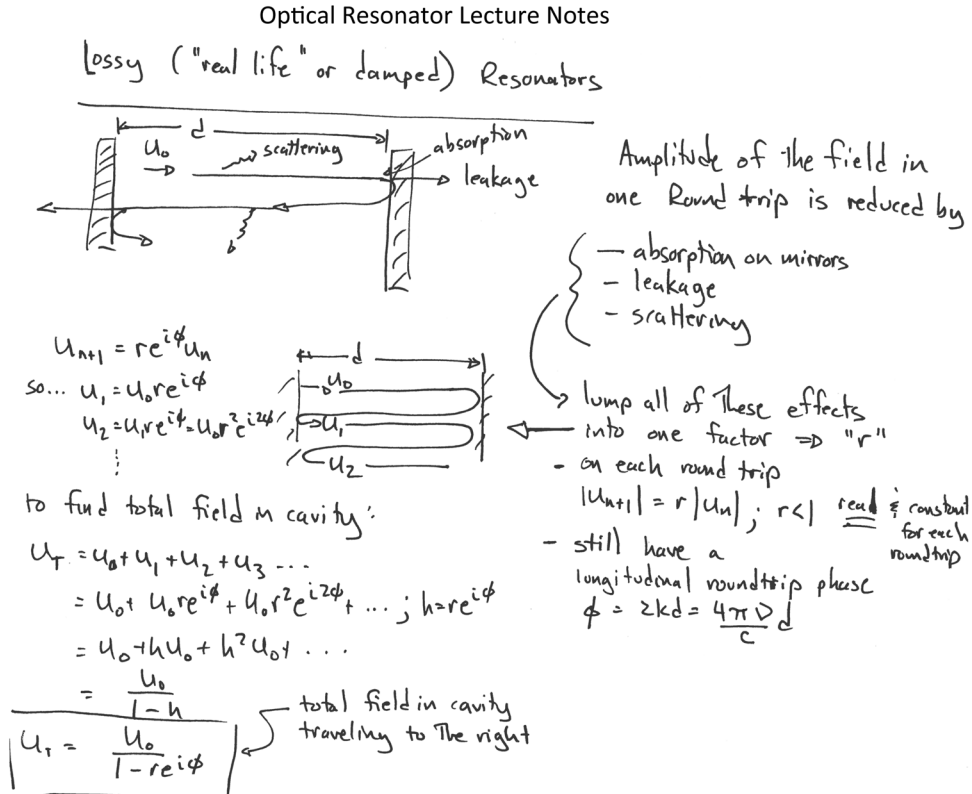
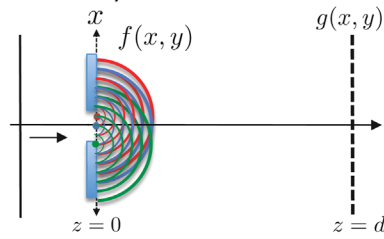


FIG. 3. The corresponding lecture notes for the in-class activities as shown in Fig. 2.

Huygens-Fresnel In-Class Activity

- 1) Using the figure to the left, state in your own words the Huygens-Fresnel principle
- 2) Explain the meaning of each term in the expression below and how it relates to 1)

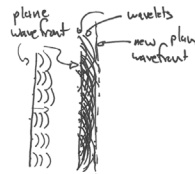


$$g(x, y) = \frac{i}{\lambda d} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x', y') e^{ikd} e^{ik \frac{(x-x')^2 + (y-y')^2}{2d}} dx' dy'$$

Huygens-Fresnel Lecture Notes

First, need to remind you of Huygen-Fresnel

⇒ states that each point on a wave front generates a spherical wavelet. The envelope of these "secondary" wavelets constitutes the overall "next" wavefront



Physical interp. of $g(x, y) = \iint_{-\infty}^{\infty} f(x', y') h(x-x', y-y') dx' dy' \quad (1)$

• ~~suppose~~ suppose that you have a spherical wave centered @ the origin $(x, y, z=0)$ in the input plane... what would $F(x, y) = ?$
 ⇒ $f(x, y) = \delta(x)\delta(y)$ under paraxial approx.

• what is $g(x, y)$? from (1)
 $g(x, y) = \iint_{-\infty}^{\infty} \delta(x')\delta(y') h(x-x', y-y') dx' dy'$
 only true for $F(x, y) = \delta(x)\delta(y)$ ⇒ $h(x, y)$ ← hence name "impulse response"
 we can find an explicit expression for $h(x, y)$. Under the paraxial approx, what does a spherical wave look like @ $z=d$?
 ⇒ a paraboloidal wave or w/ $f(x, y) = \delta(x)\delta(y)$
 $g(x, y) = h(x, y) = \frac{1}{i\lambda z} e^{ikz} e^{ik \frac{x^2 + y^2}{2z}}$
 $z=d$

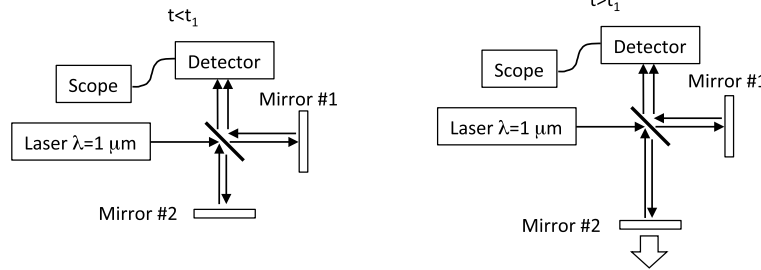
now what if impulse is located @ (x', y') ? ⇒ $f(x, y) = \delta(x-x')\delta(y-y')$
 ⇒ $g(x, y) = h(x-x', y-y')$ from (1)

Apply Huygen-Fresnel principle
 • each point on the wavefront as it passes through the input plane @ $(x', y', z=0)$ generates a spherical wave w/ amplitude $f(x', y')$ that contributes to the
 ⇒ must sum over all x', y' @ $z=0$ to get total field @ $z=d$
 ⇒ $g(x, y) = \iint_{-\infty}^{\infty} f(x', y') h(x-x', y-y') dx' dy'$
 amplitude of wavelet @ x', y' response or illuminate @ $x, y, z=d$ due to wavelet @ $x', y', z=0$

FIG. 4. An in-class activity on the Huygens-Fresnel principle and the corresponding lecture notes.

Interferometer Application Activity

You and your lab partner are using the interferometer below to measure the acceleration of gravity (g). Mirror #1 is held fixed and mirror #2 is dropped at $t=t_1$ and the scope records the output of the photo-detector. The entire interferometer is located in a vacuum chamber to minimize any effects of air.



1a) Qualitatively in your own words describe how this setup can measure g . How does the mirror in time?

1b) Sketch the output voltage measured by the scope

1c) Find an expression for g based on the measurements from the scope

Bonus- An interferometer can be used as a gyroscope to measure rotation. Describe how it could work and estimate if a hand sized device could measure the rotation of the earth

Gaussian Beam Application Activity

The ongoing Lunar Laser Ranging Experiment measures the distance between Earth and Moon using laser ranging. Lasers on Earth are aimed at retro-reflectors previously planted on the Moon (Apollo 11) and via the reflected signal the distance is measured.

3-As an optical design engineer on the project you must model the laser beam propagation as a Gaussian Beam and you need to optimize the return signal as measured on earth. The laser ($\lambda=532$ nm, 10 Watt) is pointed to the moon through a telescope and you are offered three different telescopes with varying apertures. Via calculations of Gaussian beams, discuss the advantages and disadvantages of each.

Bonus-If the retroreflector is 1m^2 how much total power is reflector to earth?

Gran Telescopio Canarias (10.4 m)



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Hale Telescope (5.1 m)



[Hale Telescope](#)
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Hooker Telescope (2.5 m)



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FIG. 5. In-class activities on the applications of optics to measure the acceleration due to gravity and for lunar ranging.