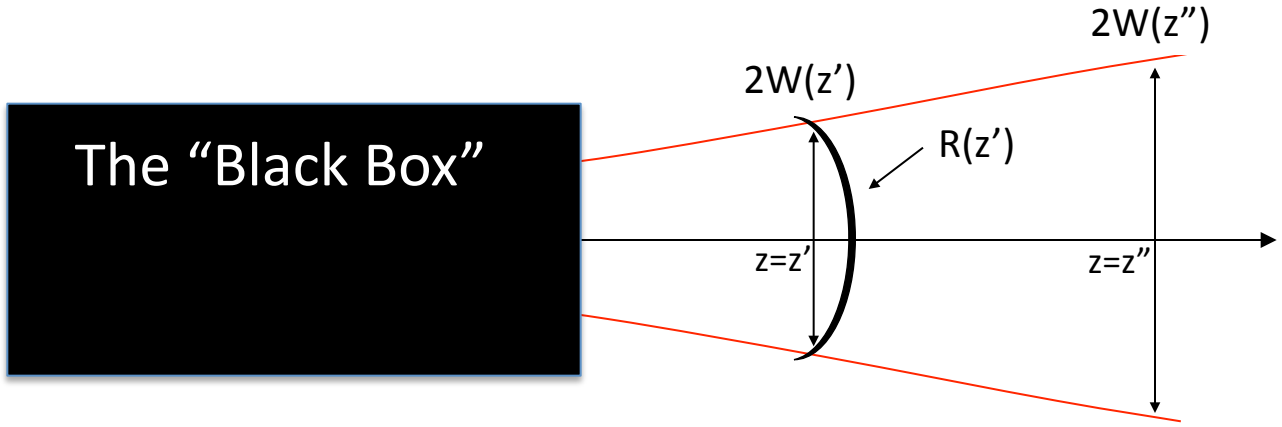
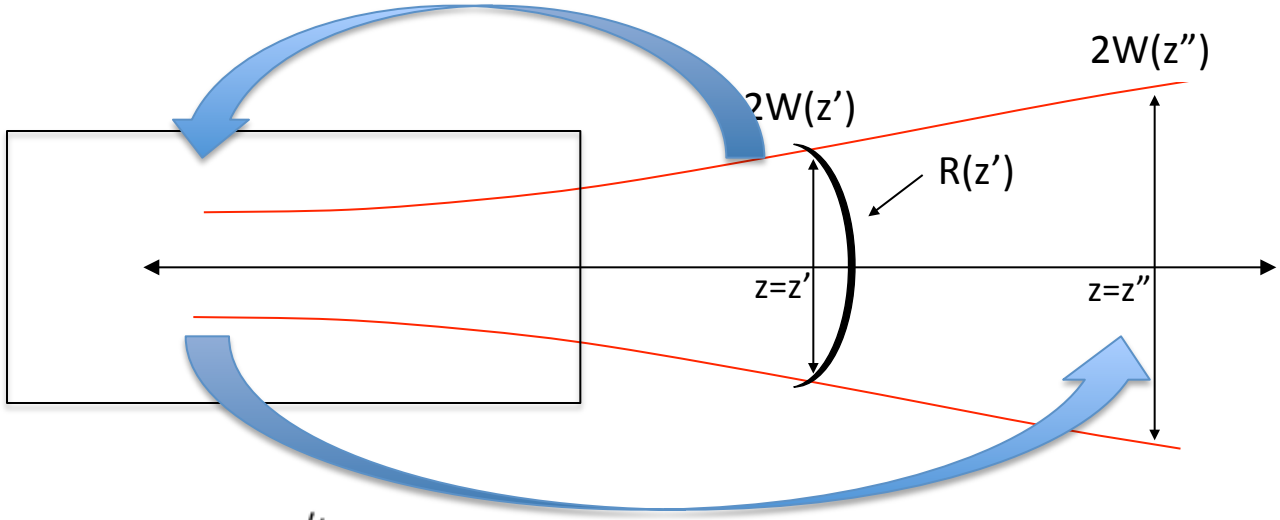
PHYS 408 Group Activities for Feb 3 2011

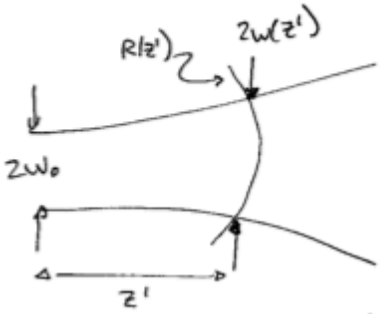
Please complete these exercises without opening the textbook. If you have questions talk with your group mates or raise your hand and Kirk or Ellen will come to help



A laser located somewhere in a black box shines a beam out. Say you have measured the beam width W(z') and radius R(z') at z=z' (note that you don't know what z' is).

write a step by step recipe for your lab partner to calculate the (new) beam diameter at z=z". I'm looking for a qualitative recipe here.





$$\begin{cases} w(z') = w_0\left[1 + \left(\frac{z'}{z_0}\right)^2\right]^{1/2} & (1) \\ R(z') = z'\left[1 + \left(\frac{z_0}{z'}\right)^2\right] & (2) \end{cases}$$

Two equations, 2 unknowns [z' & w_0 or z_0]

1.) Plan is to calculate $2w_0$ & z'

$2w_0$ → minimum waist; z' → location of

2-) Calculate $w(z'')$ via (1)

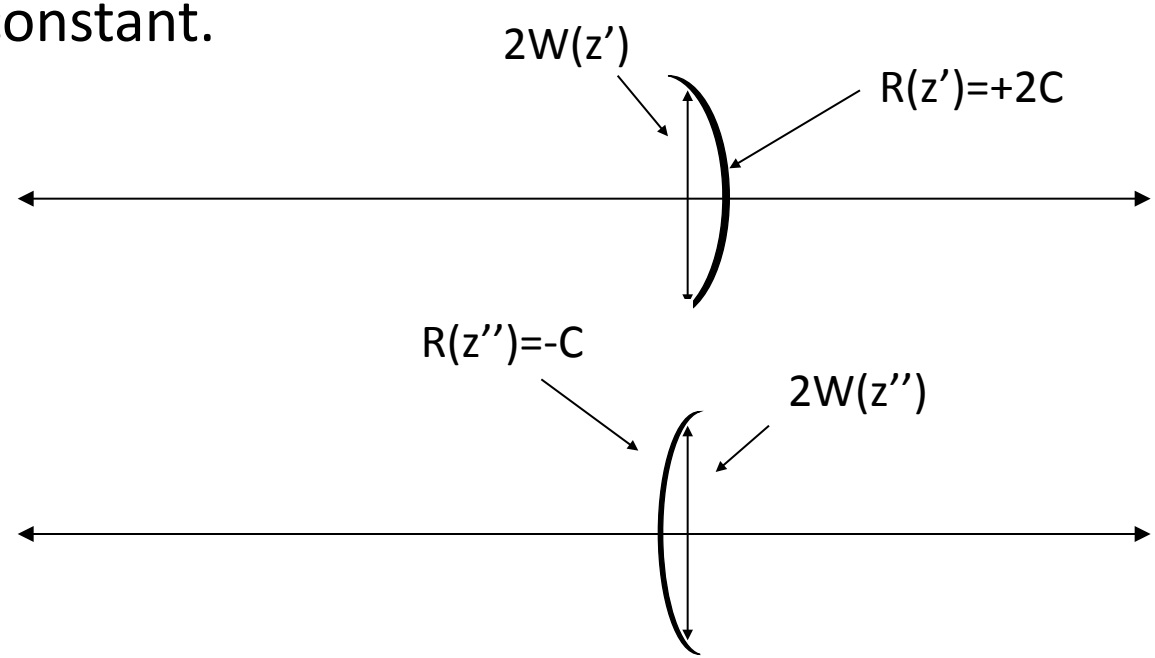
do it by inverting (1) & (2)

$$\Rightarrow \quad z' = \frac{R(z')}{1 + \left[\frac{\lambda R(z')}{\pi w(z')^2}\right]^2} \qquad w_0 = \frac{w(z')}{\left[1 + \left[\frac{\pi w(z')^2}{\lambda R(z')}\right]^2\right]^{1/2}}$$

given $R(z')$ & $w(z')$ find w_0 & its location z'

PHYS 408 Group Activities for Feb 10 2011

1- Sketch the two beams below with the following parameters at the position z' and z'' and label the origin in your drawings with C as a positive constant.

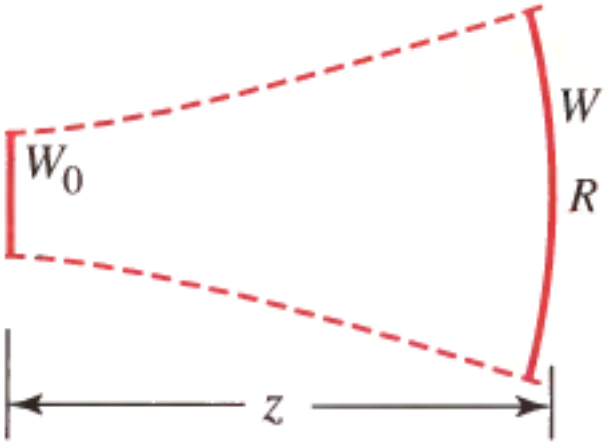


2- In our sign convention, is $z'' > 0$ or $z'' < 0$

3- is $|z''| < |z'|$ or vice versa?

Bonus-In the lab how can you change R(z') without changing W(z')?

Given W and R, determine z and W_0

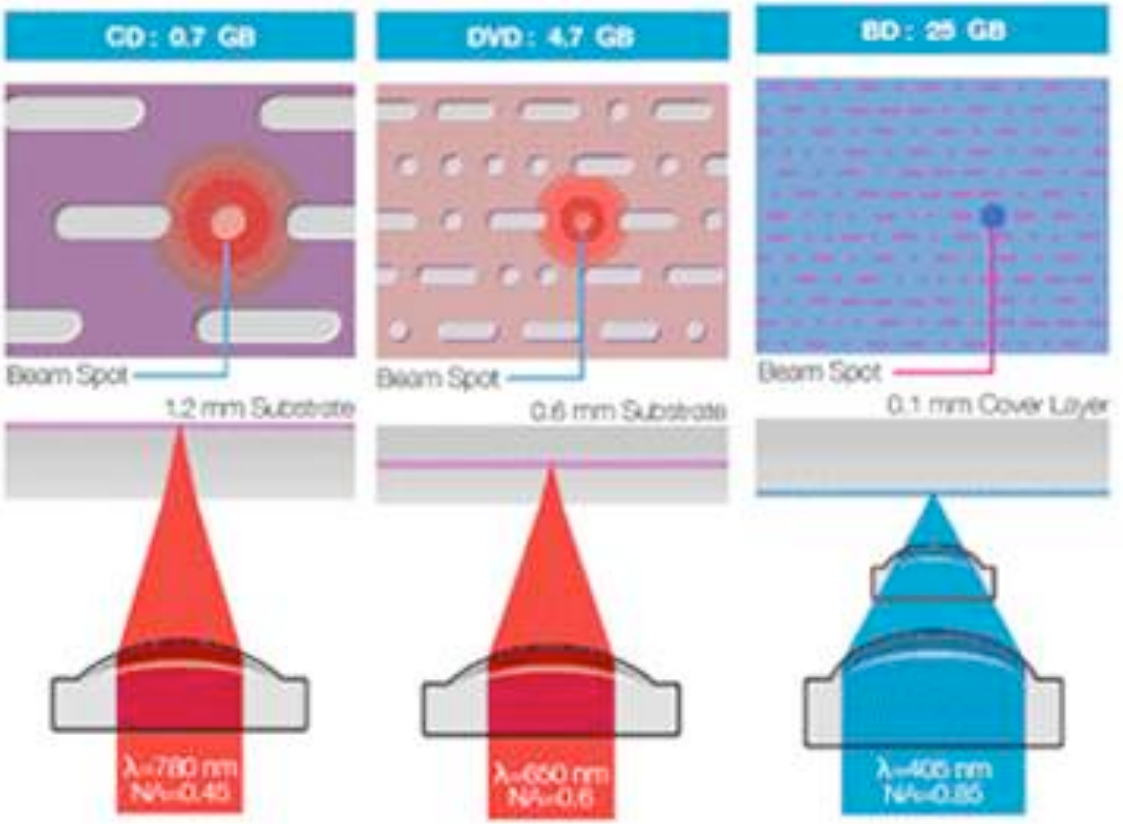


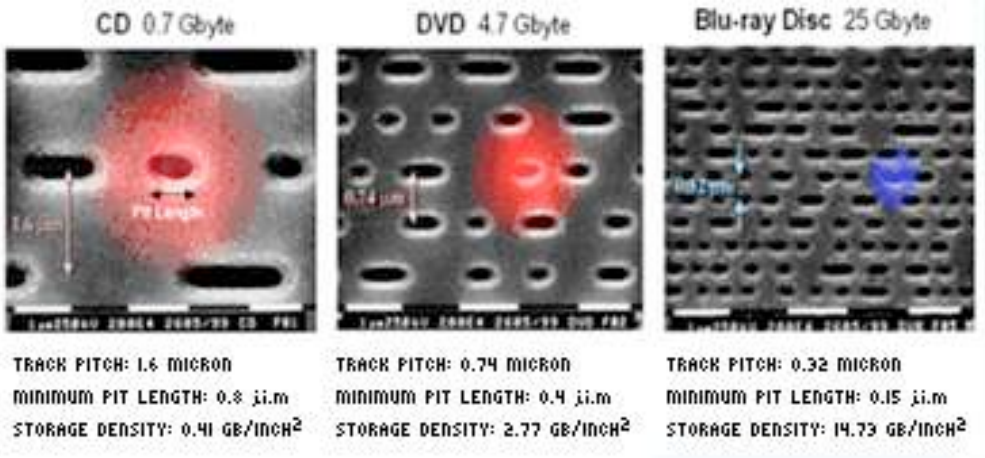
$$z = \frac{R}{1 + (\lambda R/\pi W^2)^2}$$

$$W_0 = \frac{W}{\sqrt{1 + (\pi W^2/\lambda R)^2}}$$

Images from B. Saleh and M Teich, Fundamentals of Photonics, 2nd Edition. (2007) Wiley and Sons

Gaussian Beams through Optical Components…why would we care?



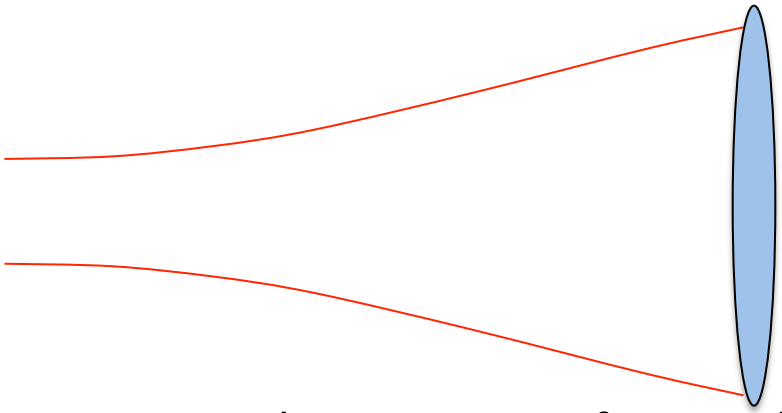


Images Source: www.blu-raydisc.com

PHYS 408 Group Activities for Feb 10 2011

Thin lens with focal length *f*

$$z = \frac{R}{1 + (\lambda R/\pi W^2)^2}$$



?

$$W_0 = \frac{W}{\sqrt{1 + (\pi W^2/\lambda R)^2}}$$

4-Write a step by step recipe for your lab partner to calculate the new beam parameters after the lens. Now I want a quantitative result. *Hint: it will be helpful to explicitly write down the electric field immediately after the lens. Don't use q(z) here.*

5- Given the new beam parameters, write an expression for the new minimum waist and its location.

Bonus- Will a lens always produce a focus downstream for any input beam?

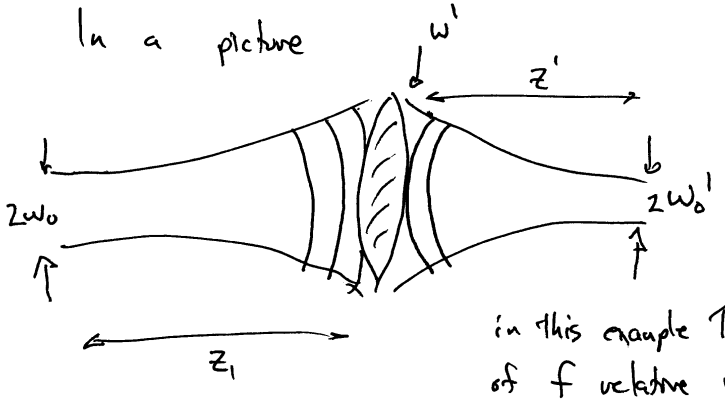
what is produced?

→ a new gaussian beam w/ the same waist (@ lens)

but a new radial phase

$$\frac{1}{R'} = \frac{1}{R} - \frac{1}{f}$$

In a picture



in this example the sign & magnitude of f relative R causes new radial phase (R') to flip sign

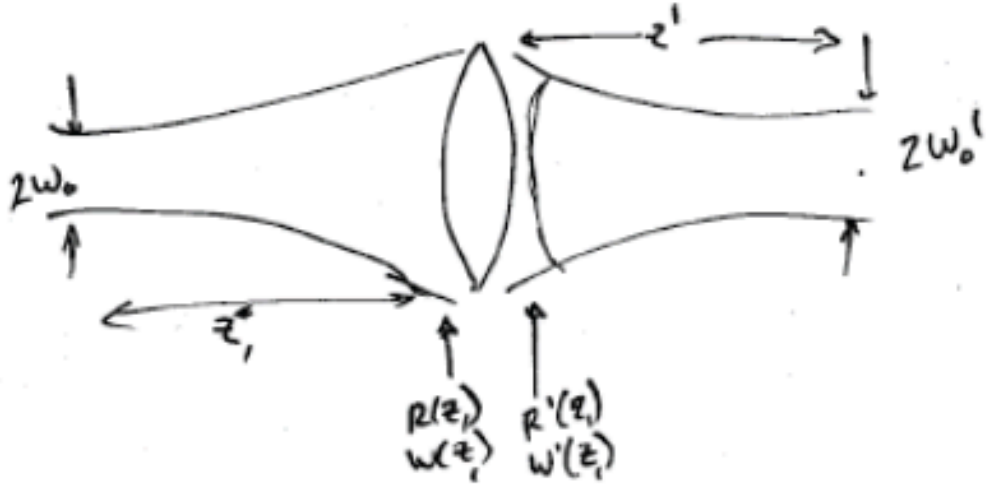
so to find the new w_0' & z' (new minimum waist & it location)

(1) $$w_0' = \frac{w(z)}{\left[1 + \left[\frac{\pi w(z)^2}{\lambda R'(z)}\right]^2\right]^{1/2}}$$

(2) $$-z' = \frac{R'}{1 + \left[\frac{\lambda R'}{\pi w'^2}\right]^2} \quad \text{w/} \quad \frac{1}{R'} = \frac{1}{R} - \frac{1}{f}$$

[for sign convention when you specify R(z) to the left of w_0 location

Propagating a Gaussian Beam through a lens



so to find new w_0' & z' use R', w' via

(3) $$w_0' = \frac{w'(z)}{\left[1 + \left(\frac{\pi w'(z)}{\lambda R'(z)}\right)^2\right]^{1/2}}$$

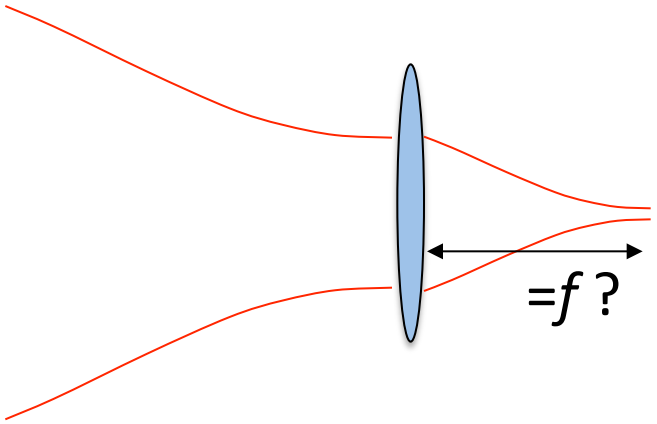
(4) $$-z' = \frac{R'}{1 + \left[\frac{\lambda R'}{\pi w'^2}\right]^2}$$ w/ $\frac{1}{R'} = \frac{1}{R} - \frac{1}{f}$

$w'(z) = w(z)$

[for sign convention if the $R'(z)$ is specified to the left of w_0 location then distance is negative

PHYS 408 Group Activities for Feb 10 2011

Thin lens with focal length *f*



(1) $w_0' = \dfrac{w'(z)}{\left[1 + \left[\dfrac{\pi w(z)}{\lambda R'(z)}\right]^2\right]^{1/2}}$

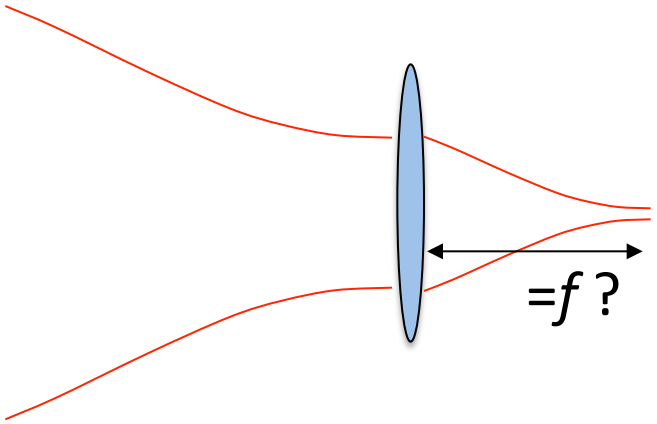
(2) $-z' = \dfrac{R'}{1 + \left[\dfrac{\lambda R'}{\pi w'^2}\right]^2}$ w/ $\dfrac{1}{R'} = \dfrac{1}{R} - \dfrac{1}{f}$

[for sign convention when you specify R(z) to the left of w_0 location

6-Take the specific case of the lens located at the input beam's minimum waist. Where does it focussed? Does this match the ray optics limit?

PHYS 408 Group Activities for Feb 10 2011

Thin lens with focal length *f*



(1) $w_0' = \dfrac{w'(z)}{\left[1 + \left[\dfrac{\pi w(z)^2}{\lambda R'(z)}\right]^2\right]^{1/2}}$

(2) $-z' = \dfrac{R'}{1 + \left[\dfrac{\lambda R'}{\pi w'^2}\right]^2}$ w/ $\dfrac{1}{R'} = \dfrac{1}{R} - \dfrac{1}{f}$

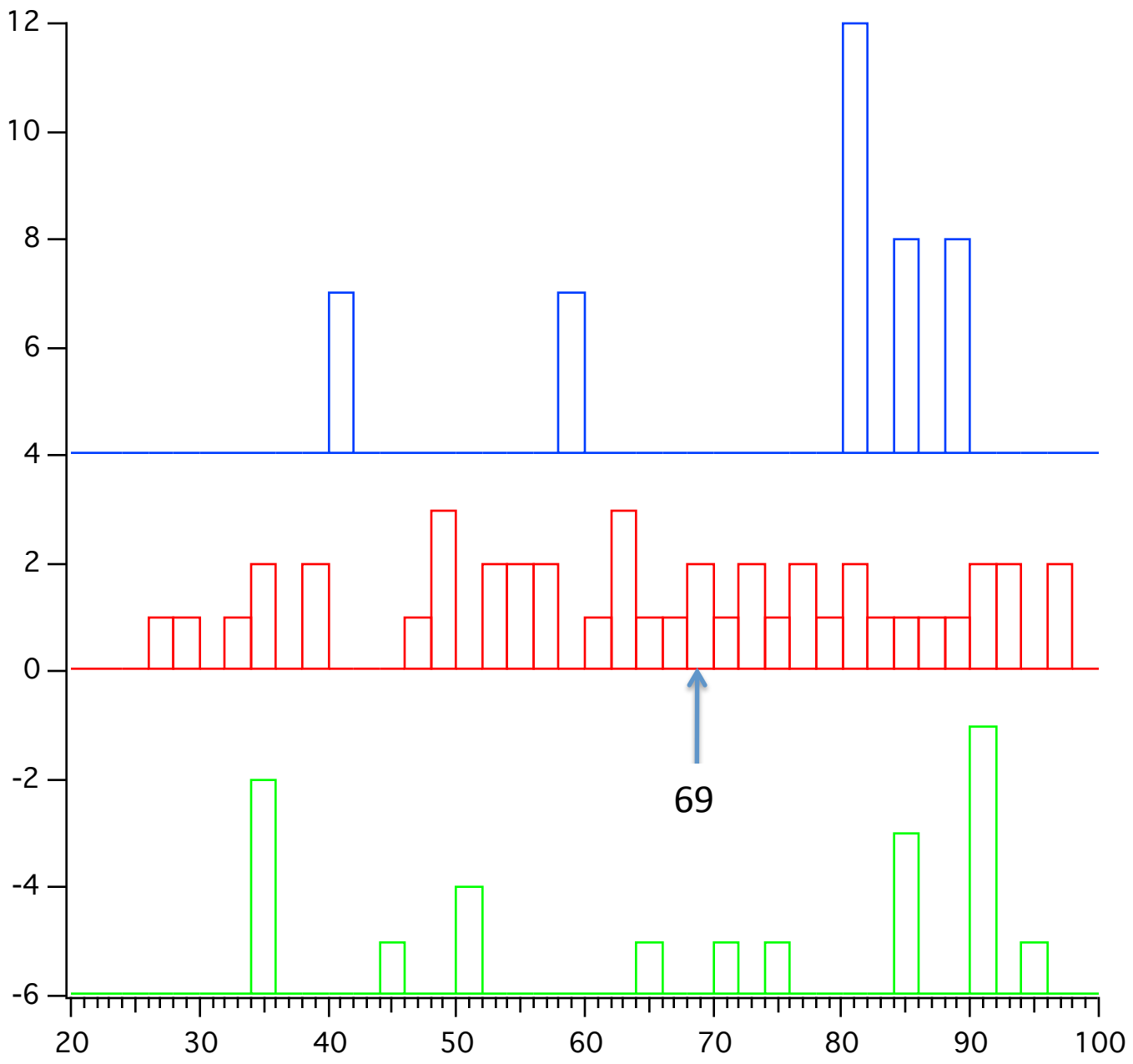
[for sign convention when you specify R(z) to the left of w_0 location

so @ $z=0$ $w'(z) = w_0$ $\dfrac{1}{R} = 0$ $\Rightarrow$ $\dfrac{1}{R'} = -\dfrac{1}{f}$

$\Rightarrow w_0' = \dfrac{w_0}{\left[1 + \left(\dfrac{\pi w_0^2}{\lambda f}\right)^2\right]^{1/2}}$

$z' = \dfrac{f}{1 + \left(\dfrac{\lambda f}{\pi w_0^2}\right)}$

does this ...


12
10
8
6
4
2
0
-2
-4
-6
20
30
40
50
60
70
80
90
100
69