7.45 $\Delta f \Delta t \sim 1$ (Eq. 7.63) implies

and at is time required to emit waveform (phon)

with $L = c \Delta t$  
$L = \text{length of waveform} = 20 \lambda_0$

$\lambda_0 = 500 \text{ nm}$  
here

$\Delta f = \frac{c}{\lambda_0}$

$20 \left( \frac{c}{\lambda_0} \right) = c \left( \frac{1}{\lambda} \right)$

$\Delta f = \frac{c}{\lambda_0} = \frac{3 \times 10^8 \text{ m/s}}{20 \times 500 \text{ nm}} = \frac{3 \times 10^8 \text{ m/s}}{2 \times 10^{-7} \text{ m}}$

$\Delta f = 3 \times 10^{13} \text{ Hz}$  
Bandwidth

vs $f = \frac{c}{\lambda_0} = \frac{3 \times 10^8 \text{ m/s}}{5 \times 10^{-7} \text{ m}} = 6 \times 10^{14} \text{ Hz}$

or with $\left| \frac{\Delta f}{f} \right| = \left| \frac{\Delta f}{f} \right| = \frac{3 \times 10^{13} \text{ Hz}}{6 \times 10^{14} \text{ Hz}} = 0.05$

$\frac{\Delta f}{f} = 0.05 \Rightarrow \Delta f = (0.05) (500 \text{ nm})$

$= 25 \text{ nm}$

a pretty broad line

from spectrometer viewpoint

at here $\frac{20 \lambda_0}{c} = 3 \times 10^{-15}$

very short time
\[ I_i = \frac{1}{2} I_i \quad I_{mid} = I_i \cos^2 25^\circ \]

and

\[ I_{final} = I_{mid} \cos^2 (50^\circ - 25^\circ) = I_{mid} \cos^2 (25^\circ) \]

\[ I_{final} = \frac{1}{2} I_i \cos^4 (25^\circ) = \frac{1}{2} \times 1000 \text{ W/m}^2 \times \cos^4 (25^\circ) \]

\[ = 500 \text{ W/m}^2 \times 0.675 \]

\[ I_{final} = 337 \text{ W/m}^2 \]

Without middle polarizer

\[ I_{final} = \frac{1}{2} I_i \cos^2 (50^\circ) = 500 \text{ W/m}^2 \times 0.413 \]

\[ = 207 \text{ W/m}^2 \text{ less than with middle polarizer} \]
Reflected beams are each of one particular polarization as split by the calcite crystal and re-enter and re-trace their paths, re-uniting when they exit the left side of calcite. An observer will not see a double image from the mirror.
\[ \frac{1}{s_0} + \frac{1}{s_c} = \frac{1}{f} \quad \text{for mirrors } f = -\frac{R}{2} \quad \text{with } (R < 0) = \text{concave mirror} \]

\[ \Rightarrow \frac{1}{s_i} = \frac{1 - \frac{1}{s_0}}{\frac{s_0 - f}{s_0}} \]

\[ s_0 \quad \text{and concave mirror } f > 0 \quad \text{so } s_i \to \infty \text{ when } s_0 = f \]

Also, \( M = -\frac{s_i}{s_0} = \frac{f}{s_0 - f} \quad \text{so } M \to \infty \quad (\text{flips sign}) \quad \text{at } s_0 = f \)

With just the bottom mirror pig reflection blows up when \( s_0 \approx 9 \text{ cm} \) if you slowly lift pig.

So mirrors have \( f = 9 \text{ cm} \Rightarrow |R| = 2f = 18 \text{ cm} \)

And \( 4.5 \text{ cm} \)

Thickness of assembly is also \( 9 \text{ cm} \) or \( \approx f \)

So when pig is on bottom mirror it's near the focal point of upper mirror:

\[ \Rightarrow s_i = \infty \]

\( f \text{ behind top (above) mirror} \)

This serves as a virtual object for the lower mirror

\( s_0 \approx \infty \Rightarrow s_i = \frac{1}{f} \)

Bottom mirror takes 11 rays from top mirror & refocuses them at \( f \) in the opening of the top mirror.
beam profile

plain laser beam plotted in Fig X.6.1
flat top suggests beam diameter is less than diameter of fiber optic detector

beam expander made from \( f_1 = 48 \text{ mm} \) \( f_2 = 152 \text{ mm} \)

\[ \frac{D_2}{D_1} = \frac{f_2}{f_1} = \frac{48 + 152}{48} = 5.25 \]

expanded beam width is wider and exhibits a reduced peak intensity. It fits a gaussian profile pretty well No. 2 (normalized plot at both) while the original beam does not. Expanded beam is not 5x as wide (based on spread at half-max I)

expanded beam has width (full width at half max FWHM) of \( \frac{\pi}{4} \times 45 \text{ cm} \). With 5.25x expansion original beam is probably \( \approx 0.85 \text{ mm diameter} > \) diameter of fiber optic

x.7 polaroids

source \( I_0 = 3.0 \)

w/ 1 polarizer \( I_1 = 0.97 = \frac{1}{2} f I_0 \) \( f = 0.5 \)

w/ 2 polarizers \( I_2 = 0.59 = \frac{1}{4} f^2 I_0 \) \( f = 0.78 \)

w/ 3 polarizers \( I_3 = 0.38 = \left(\frac{1}{2} f f f\right) I_0 \) \( f = 0.89 \)

so about 60-65% of energy sent through 35-40% is absorbed even when polarizers are all aligned parallel.

\( \frac{I(\theta)}{I(0)} \) vs \( \cos^2 \theta \) plotted in Figs. X.7.1 gives a pretty good straight line as expected from Malus's law

\( I(\theta) = I(0) \cos^2 \theta \)
Normalized Profile

\[ \frac{I(x)}{I_{\text{max}}} \]

Laser beam profile with w/o expander

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