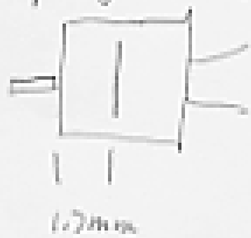
Mat 288S Homework #4 Solutions

Bare laser up against photodiode window



Feasible, but inconvenient. Move laser back 1 mm, (as in packaged laser)

How much of 2D gaussian does this circular PD collect?

A. Can we assume PD is in the far field?

worst case half angles

$\theta_{\parallel} = 13°$ $\theta_{\perp} = 27°$

$= .23$ rad $= .47$ rad

$$\theta = \frac{\lambda}{\pi w_0} \Rightarrow w_0 = \frac{\lambda}{\pi \theta}$$

$$w_{0\parallel} = \frac{(405\,nm)}{\pi(0.23\,rad)} = 0.56\,\mu$$

$$w_{0\perp} = \frac{(405)}{\pi(0.47)} = 0.27\,\mu$$

The longest Rayleigh range

$$z_r = \frac{\pi w_0^2}{\lambda} = 2.4\,\mu$$ tiny compared to detector dist,

∴ Far field approximation is valid

Worst case estimate: assume the beam is circular, and diverges at the $\theta_\perp$ angle:

$$w(z) = \frac{\lambda z}{\pi w_0} = \frac{(.4\mu)(2.7\times10^3\mu)}{\pi\ (0.27\mu)} = 1.3\ mm$$

cf. pure geometrical case $\quad w(z) = z\tan\theta = 2.7mm\tan(27°) = 1.37mm$

The fraction collected by the PD, radius $r = 1.5\ mm$

$$\frac{P(r)}{P(r\to\infty)} = 1-\exp\left[-\frac{2r^2}{W^2}\right] = 1-\exp\left[-\frac{2(1.5mm)^2}{(1.3mm)^2}\right] = 0.93$$

$$\boxed{\text{Worst case collection efficiency} = 0.93}$$

cf. the result of numerical calculation over an elliptical beam $\propto \int_0^{2\pi}\int_0^r r\,d\theta\,dr\left[\exp\left(-2r^2\frac{(w_\perp^2\cos^2\theta + w_\parallel^2\sin^2\theta)}{w_\perp^2 w_\parallel^2}\right)\right]$

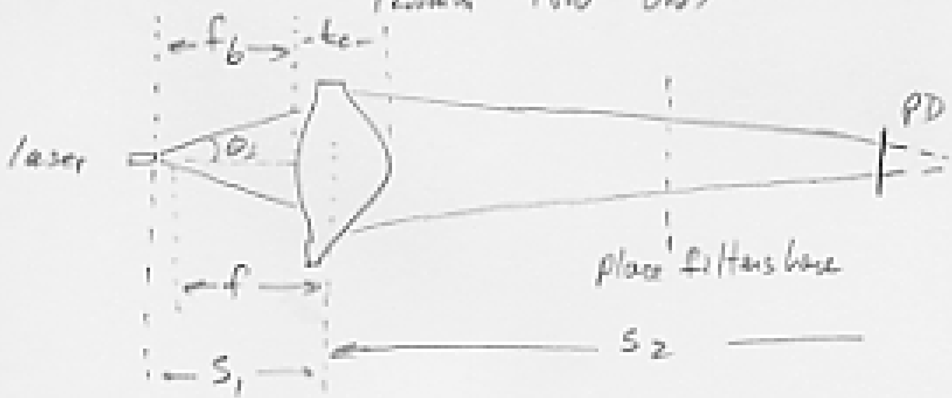
(S. Srinivasan + others)

$\rightarrow 0.96$

Thus, this photodetector can collect almost all the light. However, there is no room for filters, and probing can be difficult. Can we maintain the efficiency with a more convenient system?

2. Consider the Melles Griot glass asphere, AR coated 400–700 nm;

	f	ϕ	$f/\#$ ⇒ NA		f_b	t_c
LAG-18.0-12.0-C	12.0mm	18.0	0.67	0.75	6.9	8.8



For convenience, use $S_2 = 100$ mm

$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$ In far field, geometrical optics valid

$\frac{1}{S_1} = \frac{1}{f} - \frac{1}{S_2} = \frac{S_2 - f}{f S_2}$ $S_1 = \frac{f S_2}{S_2 - f} = \frac{(100\,mm)(12\,mm)}{(100-12)\,mm} = 13.6$ mm

only slightly longer than f!

Note the lens surface is f_b = 6.9 mm from laser.

Worst case (by geometrical optics): $W(@\,lens) = (S_1 - \frac{t_c}{2}) \tan\theta_\perp$

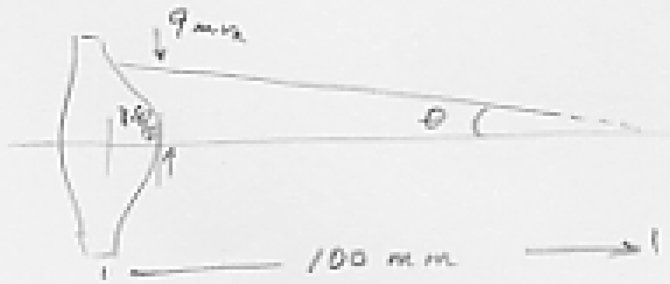
$= 9.2\,mm \tan(27°)$

$= 4.7$ mm

$\frac{P(lens)}{P(\infty)} = 1 - \exp\left(-\frac{2r^2}{W^2}\right) = 1 - \exp\left(-2\left(\frac{9.0}{4.7}\right)^2\right) = 0.999$

∴ This collects all the light. What about at detector?

At the 3 mm ϕ detector, the maximum incident angle is



$$\theta_{det} \le \tan^{-1}\left(\frac{9}{100-4.4}\right) = 5.4^{\circ}$$

$\therefore$ There is no worry about AR coating performance at large angles, or angular acceptance of package.

The asphere eliminates spherical aberration, which would be $<<$ 3 mm ϕ anyway, and the diffraction limit $\sim \frac{\lambda}{NA} = \frac{.4\mu}{\sin(5.4^{\circ})} \approx 4\mu$ is also of no concern.