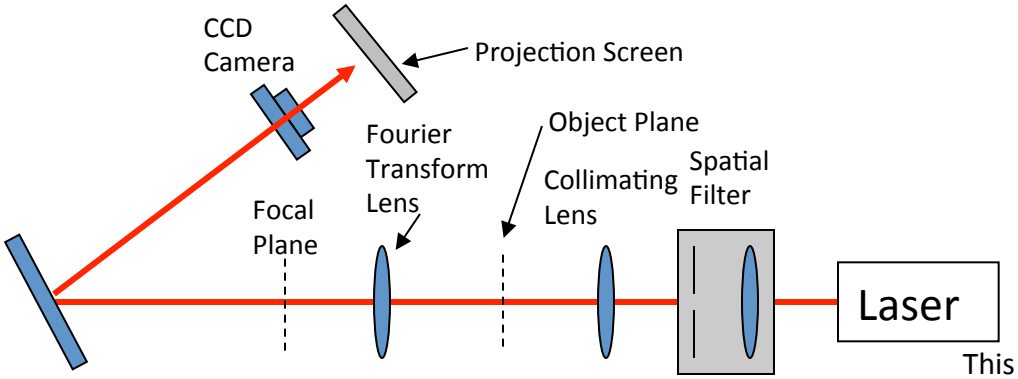
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THIS IS AN OLD EXAM QUESTION

Consider your favorite experiment we did this term: the Fourier Optics lab. A diagram of the setup is shown below.

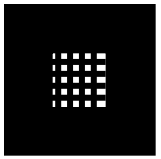


•If then

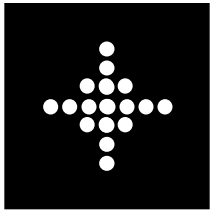
•If then

$rect[x/w]$ $w\frac{sin[kw/2]}{kw/2}$

This mesh grid is inserted in the object plane



Which produces this image in the focal plane

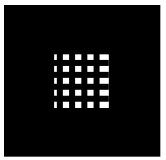


a) In the focal plane, the dots appear brightest in the center and then decrease in amplitude as you move off center. Why? *HINT: express the mesh as a square wave multiplied by a rect*

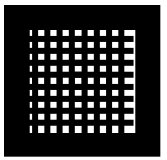
b) Now a new mesh grid is inserted in the object plane. It is almost identical to the old mesh grid (same wire spacing, same wire diameter), however the area of the mesh has increased. As more light makes it through the object plane, the image in the focal plane will change. Name two of the changes and justify your answer. Do not give the trivial answer that the focal plane image appears "brighter"

Hint: You could use the convolution theorem and the Hint above

Old Mesh Grid



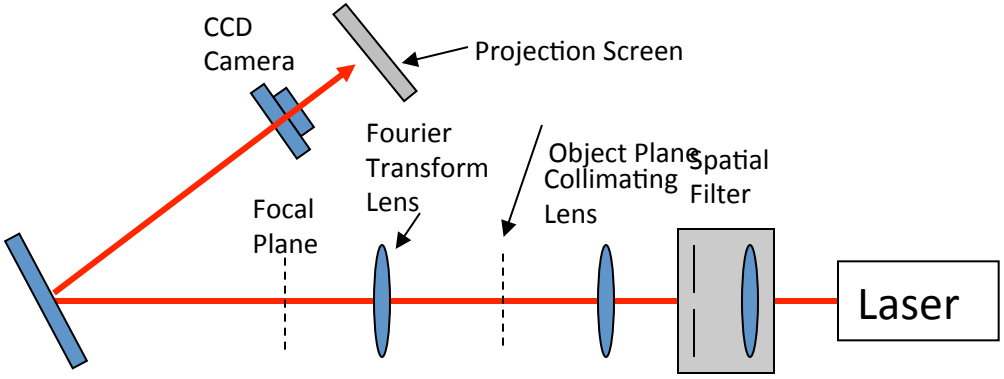
New Mesh Grid



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THIS IS AN OLD EXAM QUESTION

Consider your favorite experiment we did this term: the Fourier Optics lab. A diagram of the setup is shown below.



•If [illegible] then [illegible]

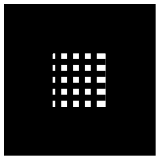
•If [illegible] then [illegible]

[illegible]

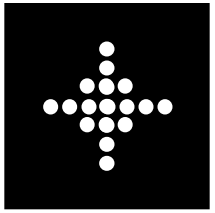
$rect[x/w]$ $\quad w\frac{sin[kw/2]}{kw/2}$

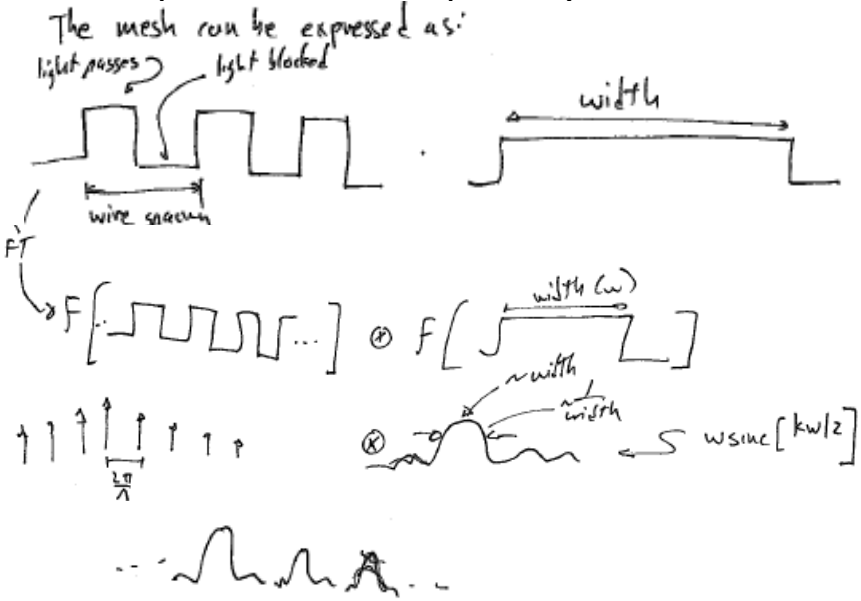
a) In the focal plane, the dots appear brightest in the center and then decrease in amplitude as you move off center. Why? *HINT: express the mesh as a square wave multiplied by a rect*

This mesh grid is inserted in the object plane



Which produces this image in the focal plane



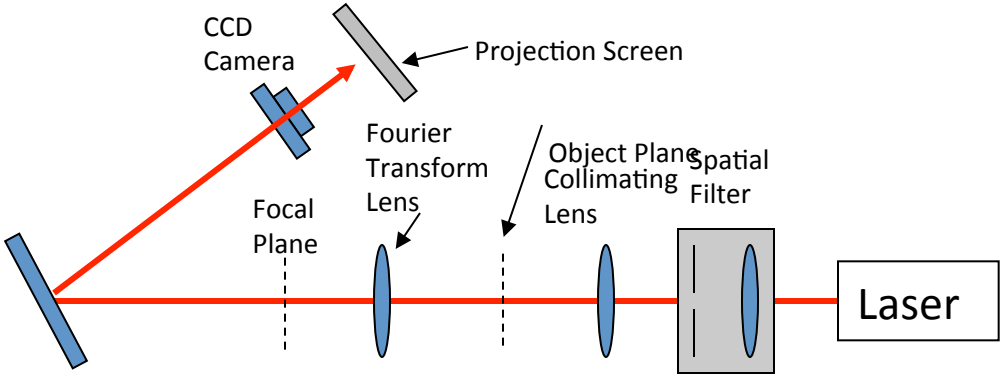


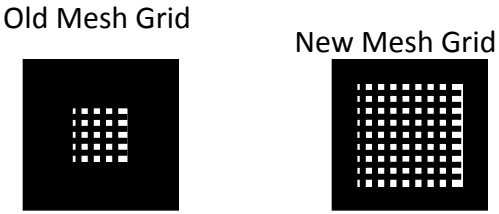
so you need less & less high harmonics to build square wave... so that is why amplitude decreases.

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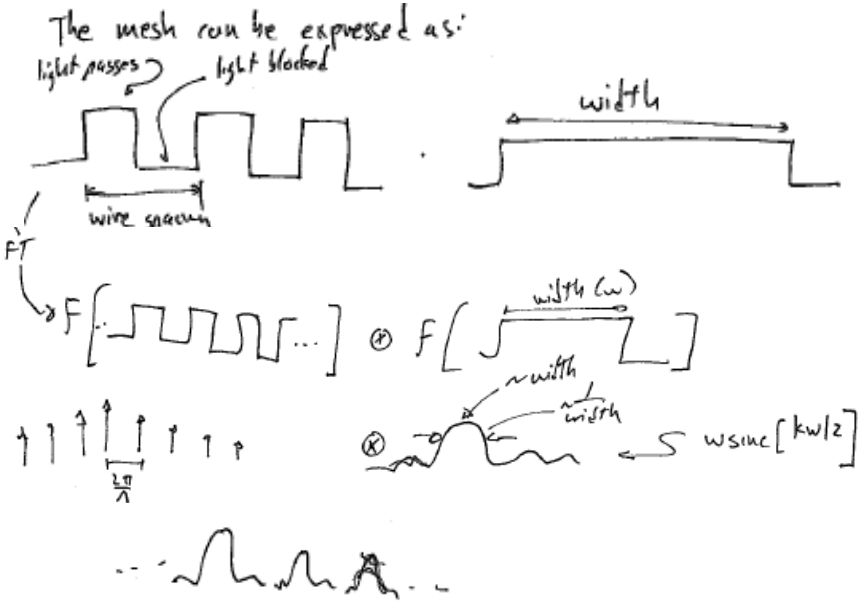
THIS IS AN OLD EXAM QUESTION

Consider your favorite experiment we did this term: the Fourier Optics lab. A diagram of the setup is shown below.





b) Now a new mesh grid is inserted in the object plane. It is almost identical to the old mesh grid (same wire spacing, same wire diameter), however the area of the mesh has increased. As more light makes it through the object plane, the image in the focal plane will change. Name two of the changes and justify your answer. Do not give the trivial answer that the focal plane image appears "brighter"



A bigger width (w) means sinc gets smaller & higher @ x=0

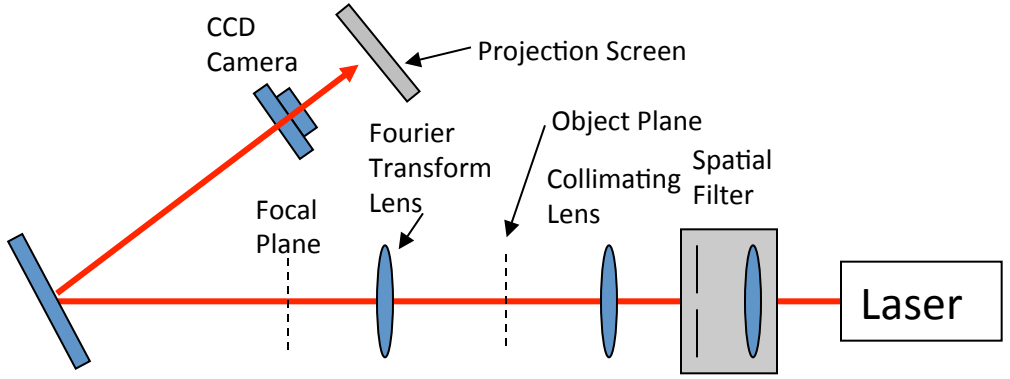
so ① dots will get narrower (smaller)

② dots will get higher (more intense)

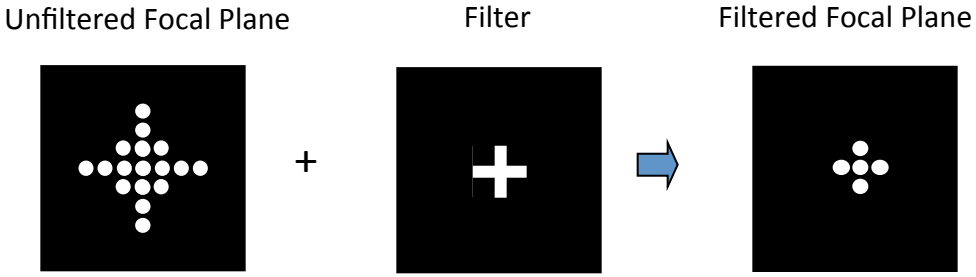
③ you will see more dots in the wings (as amplitude i

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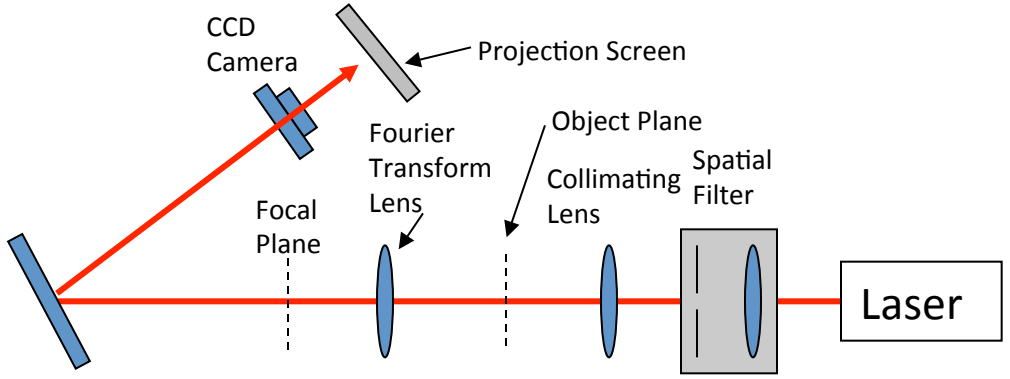


c) The original mesh is now placed back in the object plane. If nothing is placed at the focal plane, an image of the mesh appears on the projection screen. However, if some filters are placed at the focal plane then the image on the projection screen changes. Describe the resulting image on the screen when the focal plane is filtered as shown below. It would be best to use words plus a mathematical expression in your answer.

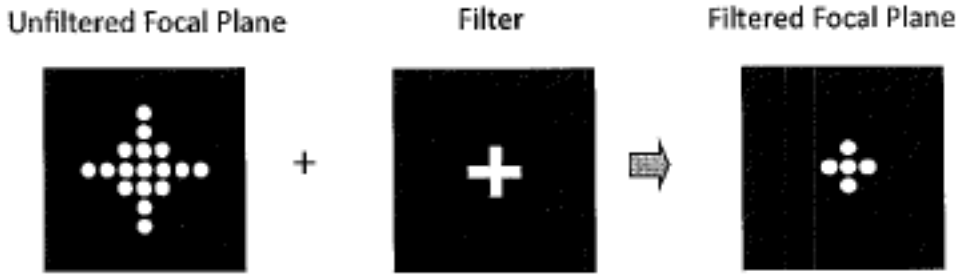


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THIS IS AN OLD EXAM QUESTION



c) The original mesh is now placed back in the object plane. If nothing is placed at the focal plane, an image of the mesh appears on the projection screen. However, if some filters are placed at the focal plane then the image on the projection screen changes. Describe the resulting image on the screen when the focal plane is filtered as shown below. It would be best to use words plus a mathematical expression in your answer.



The filtered portion only includes the DC term & the harmonics $\pm \frac{2\pi}{\Lambda_x}, \pm \frac{2\pi}{\Lambda_y}$

so the output

$g(x,y) \sim A + B\cos\left(\frac{2\pi}{\Lambda_x}x\right) + C\cos\left(\frac{2\pi}{\Lambda_y}y\right)$

no sharp edges just a sinusoidal variation

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The 4-f optical system

-used for optical image processing
-also used for other devices

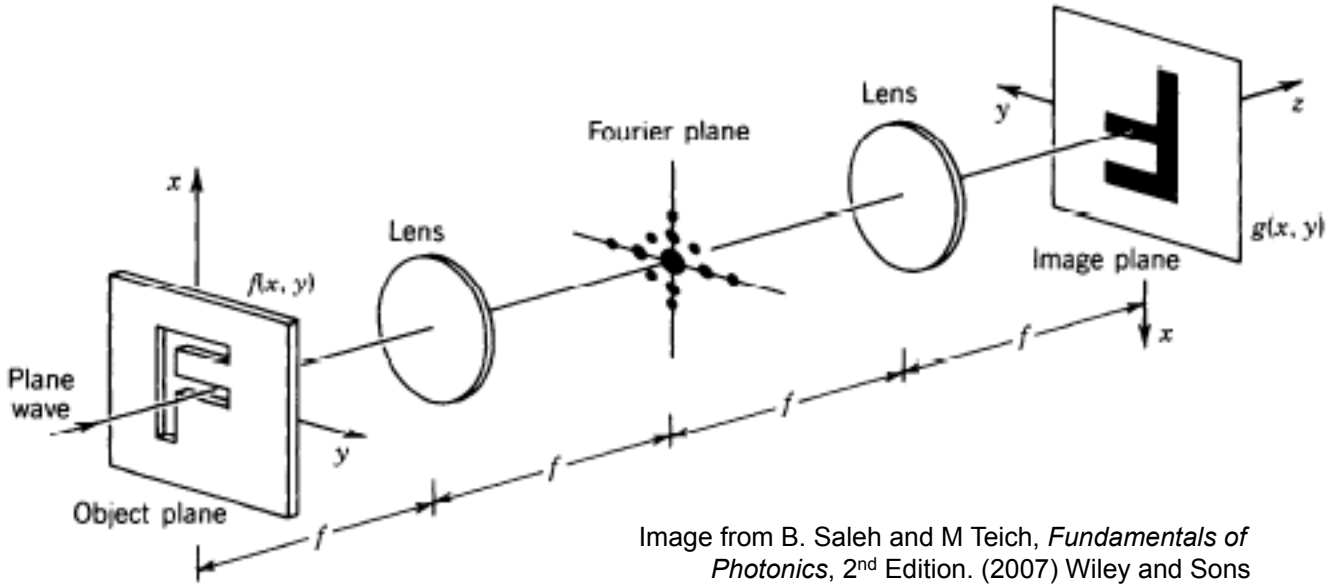
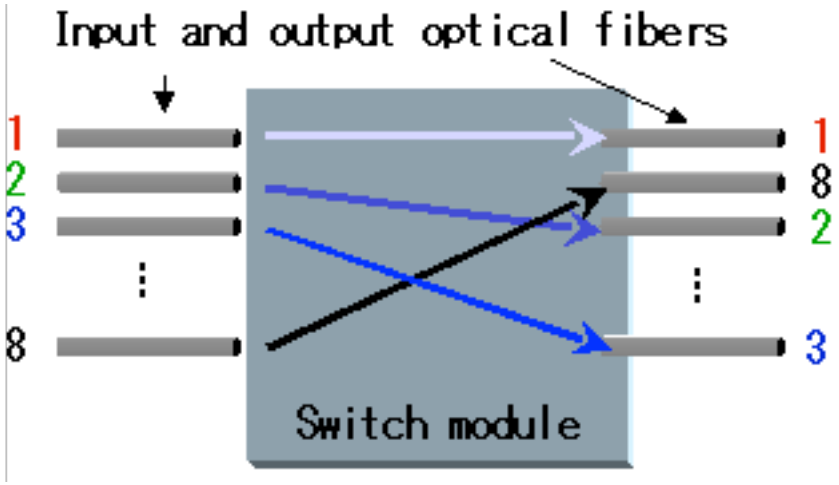


Image from B. Saleh and M Teich, *Fundamentals of Photonics*, 2nd Edition. (2007) Wiley and Sons

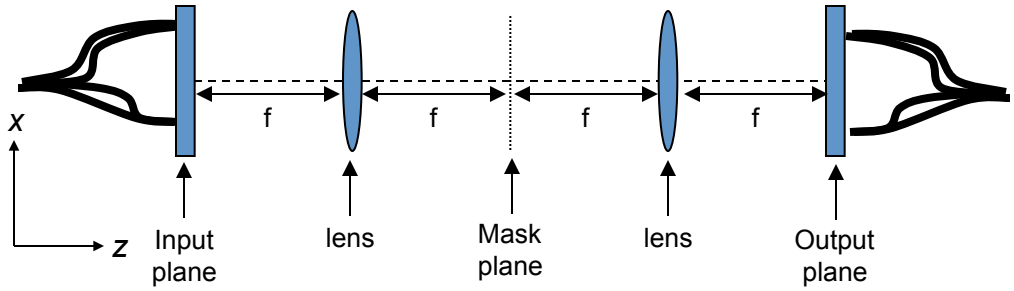
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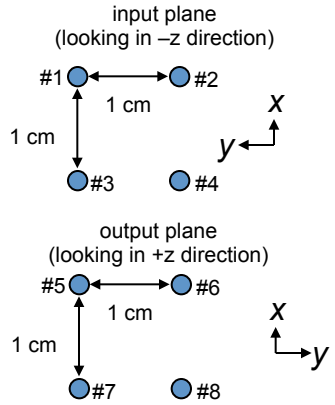
Optical Cross-connects: NxN optical switch



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Optical Cross-connects: 4x4 optical switch





Four optical fibers are located at the input and output planes. If the wavelength is 1550 nm, f=10 cm and you approximate the input and output of the optical fibers in their respective planes as delta functions, design a mask that would switch light from fiber #1 in the input plane to fiber #6 in the output plane. In both the input and output plane, the optical fibers are arranged in a 1cm x 1cm square centered on the optical axis of the lenses

1a) give a mathematical description of the mask you need.

b) specify how you would make such a mask (not just the mathematical description of the mask).

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The optical setup in this question is a "4-f system" (see section 4.4 B, page 136 of Fundamentals of Photonics 1st Ed.). Without any mask the input from fibre 1 will end up in fibre 7 due to the inverting nature of the system. Centering the x and y axes on the optical axis, we have for an input function

$$f(x,y) = \delta(x-\alpha)\delta(y-\alpha)$$

with $\alpha = 0.5$ cm. At the mask plane, the complex amplitude will be the Fourier transform (see question 3, homework 5):

$$g_1(x,y) = e^{i\frac{\alpha k x}{f}} e^{i\frac{\alpha k y}{f}}.$$

We know that at the output plane we want the complex amplitude to be the same as the input so we take the inverse Fourier transform of $f(x,y)$ (or the FT with $x \to -x$ and $y \to -y$, see exercise 4.2-2):

$$g_2(x,y) = IFT[f(x,y)] = e^{-i\frac{\alpha k x}{f}} e^{-i\frac{\alpha k y}{f}}.$$

We require

$$\begin{aligned} g_2(x,y) &= g_1(x,y)m(x,y) \\ m(x,y) &= e^{-i\frac{2\alpha k x}{f}} e^{-i\frac{2\alpha k y}{f}} \end{aligned}$$

where $m(x,y)$ is the complex amplitude transmittance of the mask. We recognise this as two linear phase delays. We could construct an appropriate mask using two prisms, one oriented for the x-direction and one oriented for the y-direction, both with slopes $-\frac{2\alpha}{f(n-1)}$ where n is the index of the prism. You could also use one appropriately shaped prism.

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2-You are told told that an image has spatial frequencies of $\Lambda_x = \pm 2 \times 10^{-6}\ m$, $\Lambda_y = \pm 1 \times 10^{-6}\ m$

a) If this image goes through a 2-f lens system (the first half of a 4-f system), plot and label what appears at the focal plane of the first lens.
b) Say you want to only have spatial frequencies in the y-direction at the output of the 4-f system. What would the mask function m(x,y) need to be so that when inserted at the focal plane of the first lens it would result in this desired output.
c) Plot the output image when your mask is used.