Demo #3: 4F Spatial Filtering

2.71/2.710 - Optics

Mechanical Engineering
MIT

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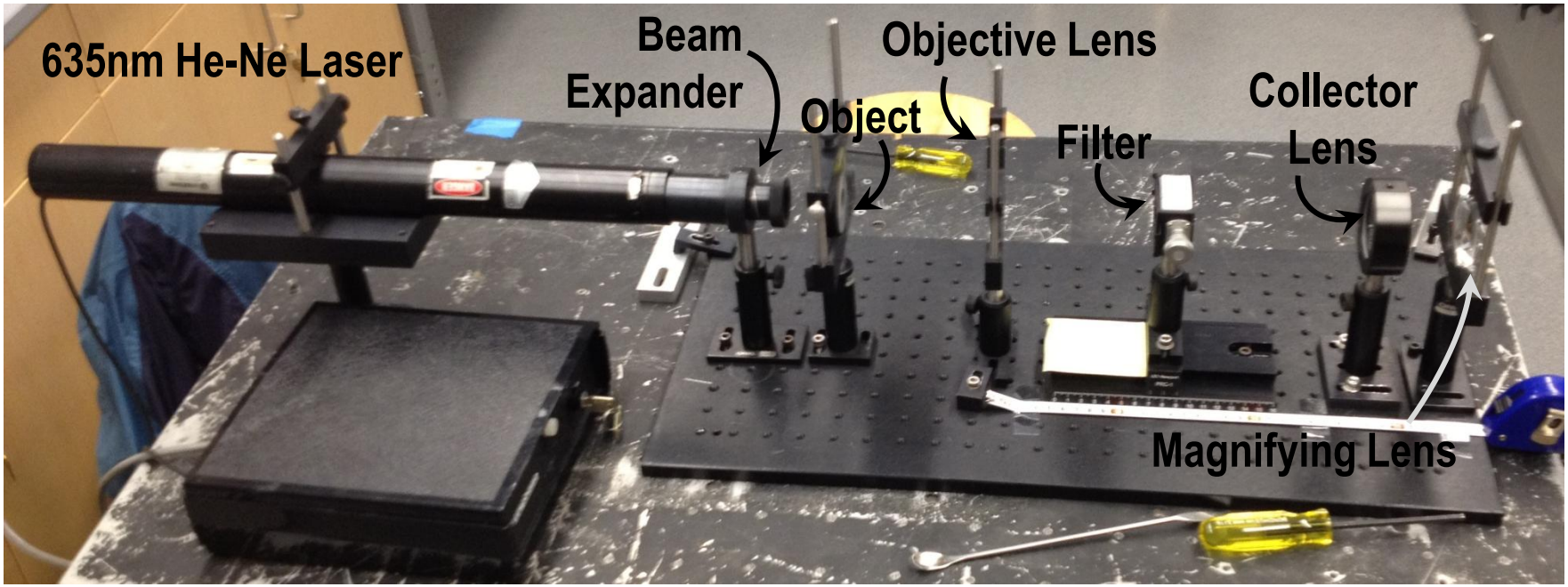
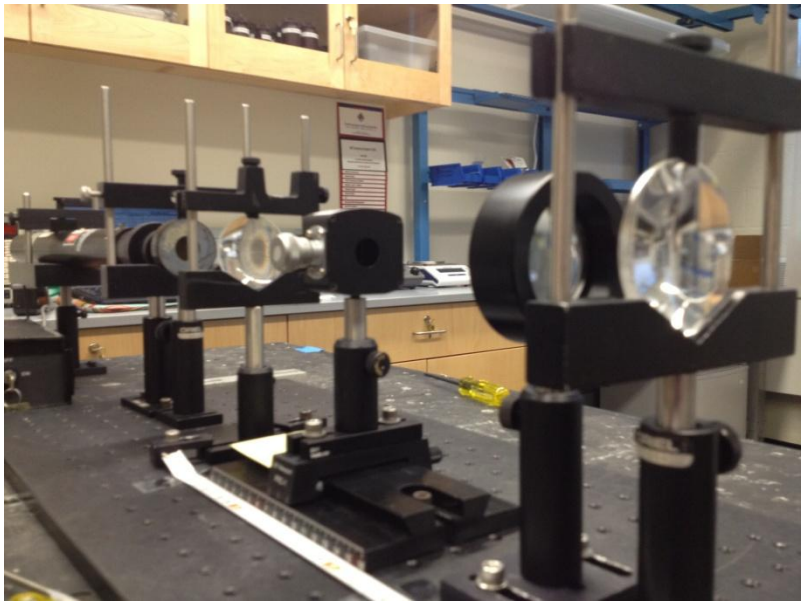
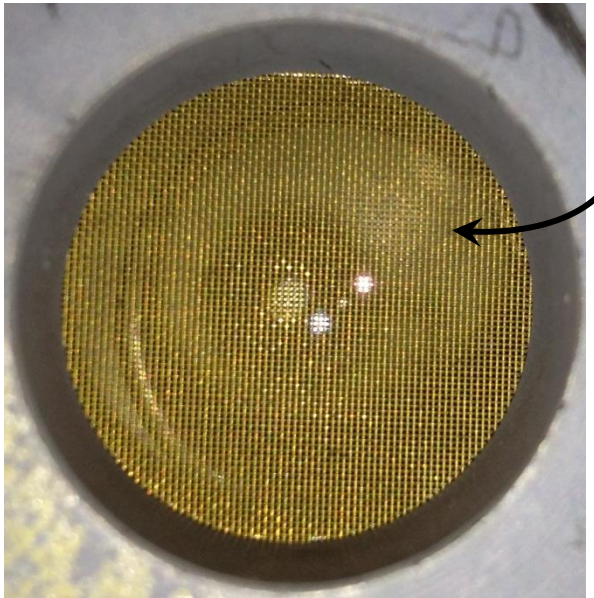
Demo #3: 4F Spatial Filtering Setup

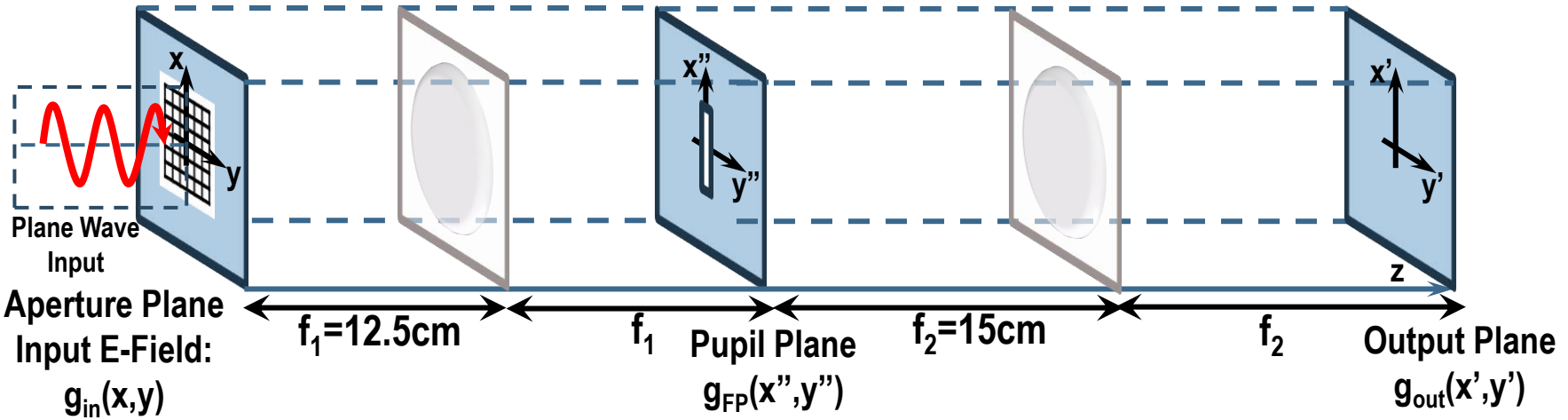






Object is a Wire Mesh

Demo #3: 4F Spatial Filtering Scheme



Input Field: $g_{in}(x,y) = g_{illum} g_t$

Objective Lens Performs Fourier Transform

Field Before Pupil Plane: $g_{pp-}(x'',y'') \propto G_{in}\left(\frac{x''}{\lambda f_1}, \frac{y''}{\lambda f_1}\right)$

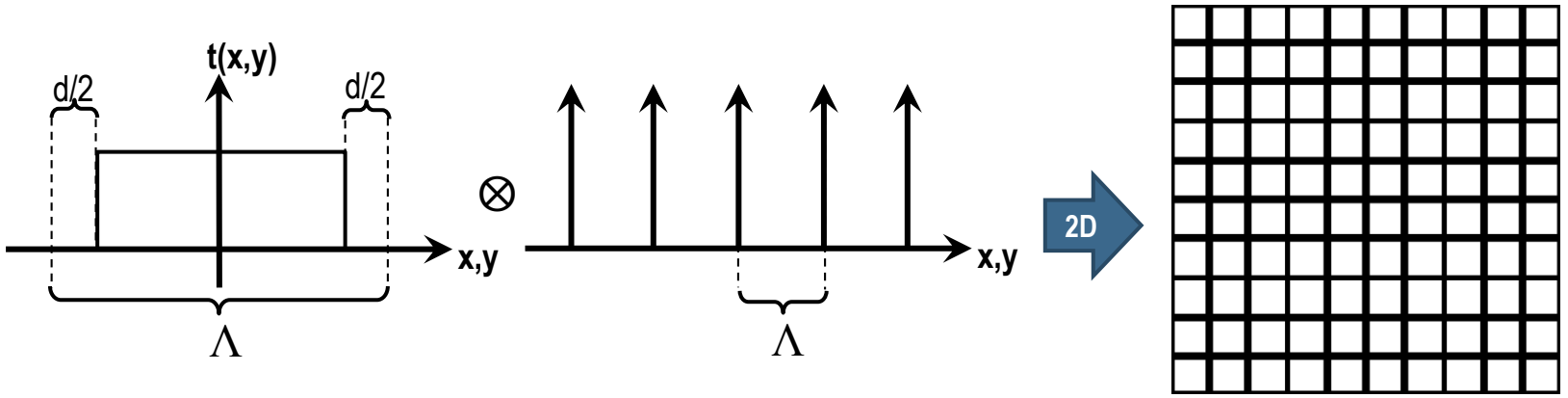
Spatial Filtering at Pupil Plane. Remove frequencies.

Field After Pupil Plane: $g_{pp+}(x'',y'') = g_{pp-}(x'',y'') g_{FP}(x'',y'')$

Collector Lens Performs Fourier Transform

Field at Output Plane: $g_{out}(x',y') \propto G_{pp+}\left(\frac{x'}{\lambda f_2}, \frac{y'}{\lambda f_2}\right)$

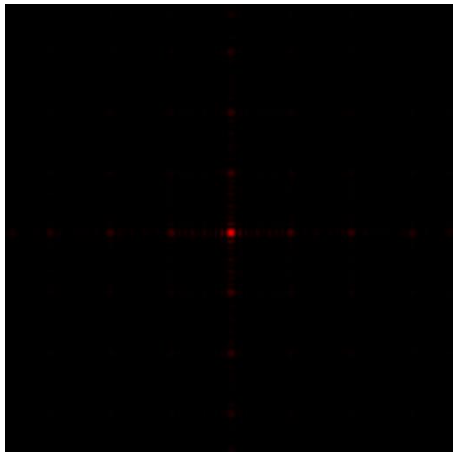
Demo #3: Field Through Objective Lens



Input Field: $g_{in}(x,y) = \left[\text{rect}\left(\frac{x}{\Lambda - d}\right)\text{rect}\left(\frac{y}{\Lambda - d}\right)\right] \otimes \left[\text{comb}\left(\frac{x}{\Lambda}\right)\text{comb}\left(\frac{y}{\Lambda}\right)\right]$

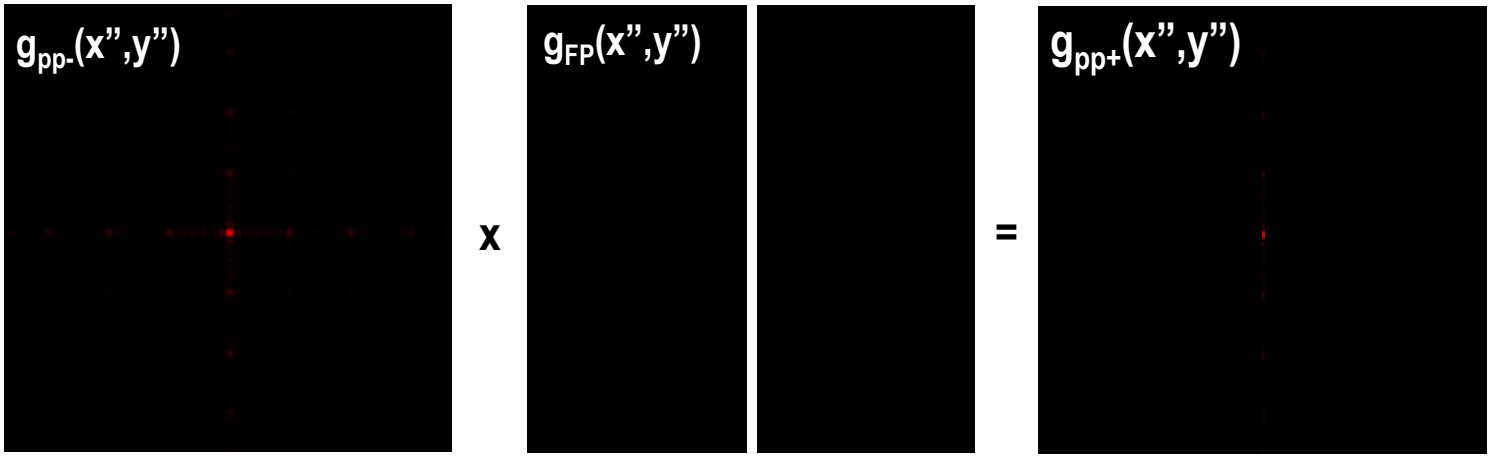
Field Before Pupil Plane: $g_{pp-} \propto \text{sinc}\big((\Lambda - d)u\big)\text{sinc}\big((\Lambda - d)v\big)\text{comb}(\Lambda u)\text{comb}(\Lambda v)$

$$g_{pp-} \propto \text{sinc}\left((\Lambda - d)\frac{x''}{\lambda f_1}\right)\text{sinc}\left((\Lambda - d)\frac{y''}{\lambda f_1}\right)\text{comb}\left(\Lambda\frac{x''}{\lambda f_1}\right)\text{comb}\left(\Lambda\frac{y''}{\lambda f_1}\right)$$



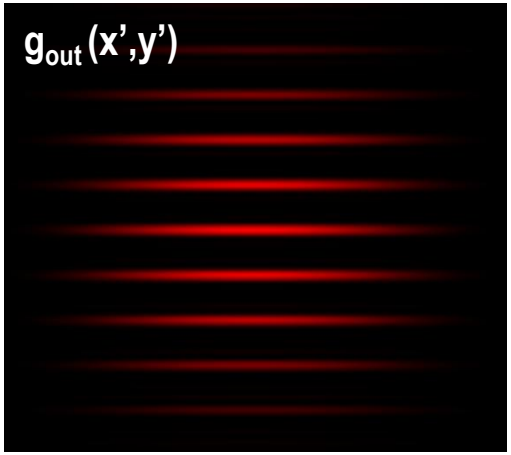
Comb functions in the x and y-directions. Sinc functions superimposed in x and y directions produce a cross pattern.

Demo #3: 4F Spatial Filtering and Output Field



Field After Pupil Plane: $g_{pp+} \propto \text{rect}\left(\frac{v}{a}\right) comb(\Lambda v) = \text{rect}\left(\frac{y''}{a\lambda f_1}\right) comb\left(\Lambda \frac{y''}{\lambda f_1}\right)$

Field at Output Plane: $g_{out} \propto \text{sinc}(a\lambda f_1 v)\text{comb}(\Lambda\lambda f_1 v) = \underbrace{\text{sinc}\left(a\frac{f_1}{f_2}y'\right)}_{\text{Since } a \text{ is small, sinc pattern has a large central lobe}} \underbrace{\text{comb}\left(\frac{1}{\Lambda}\frac{f_1}{f_2}y'\right)}_{\text{Recover near original comb period that has been magnified by } f_2/f_1}$



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