Sensing Increased Image Resolution Using Aperture Masks

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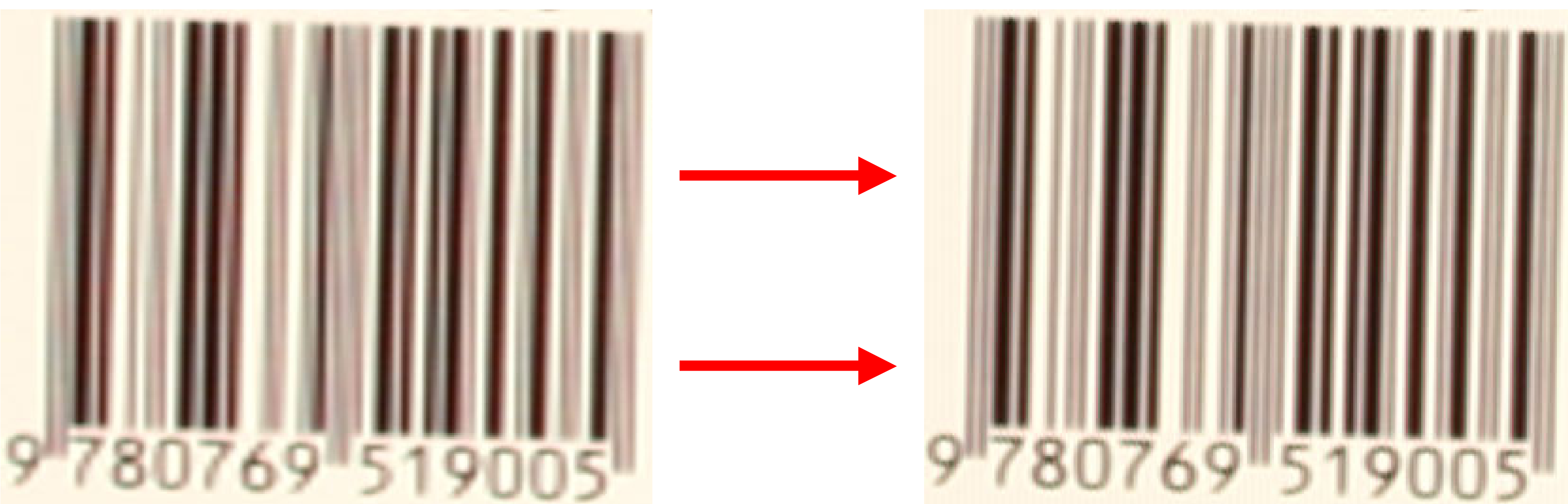
CVPR 2008

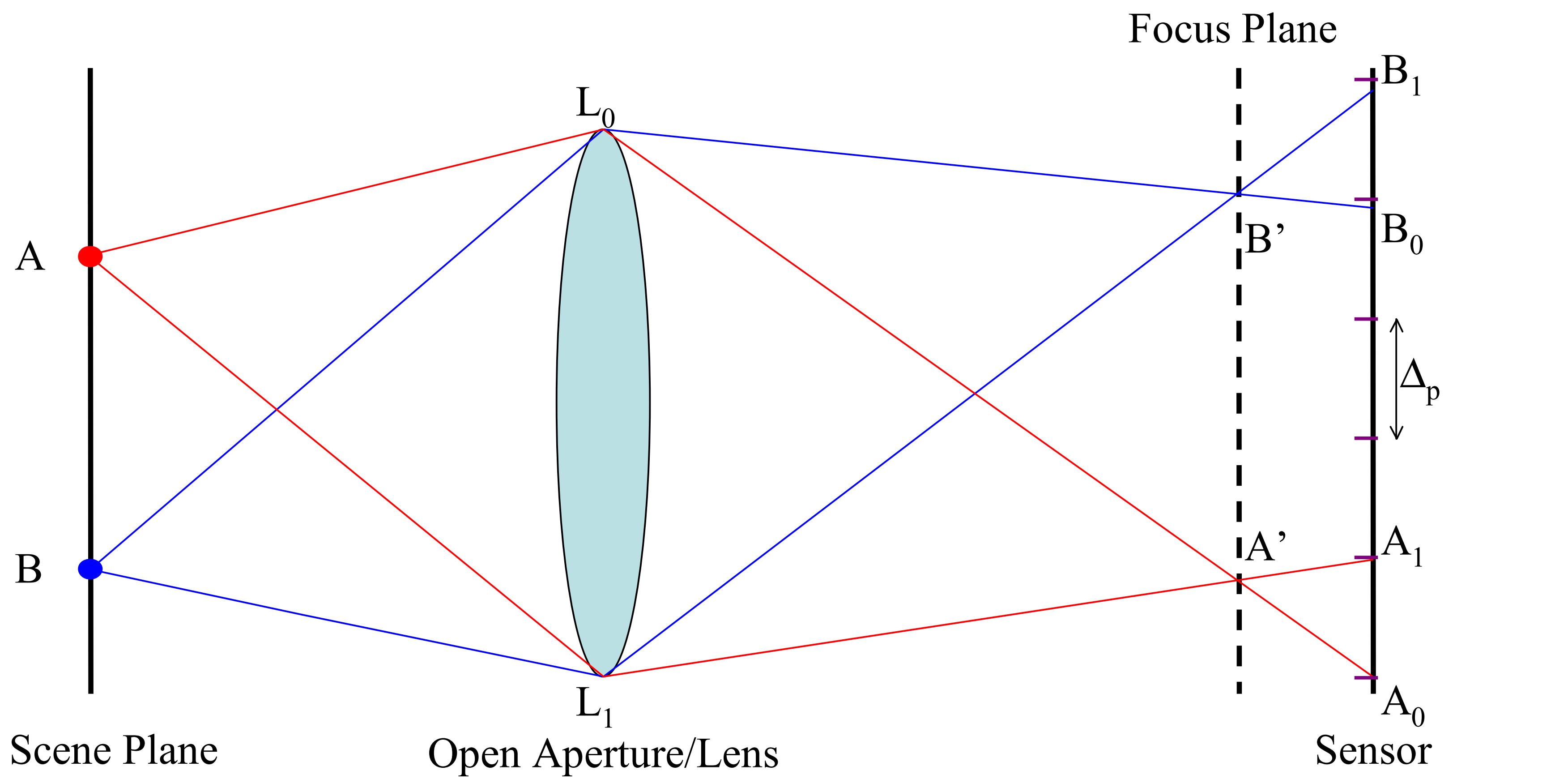
Supplemental Material



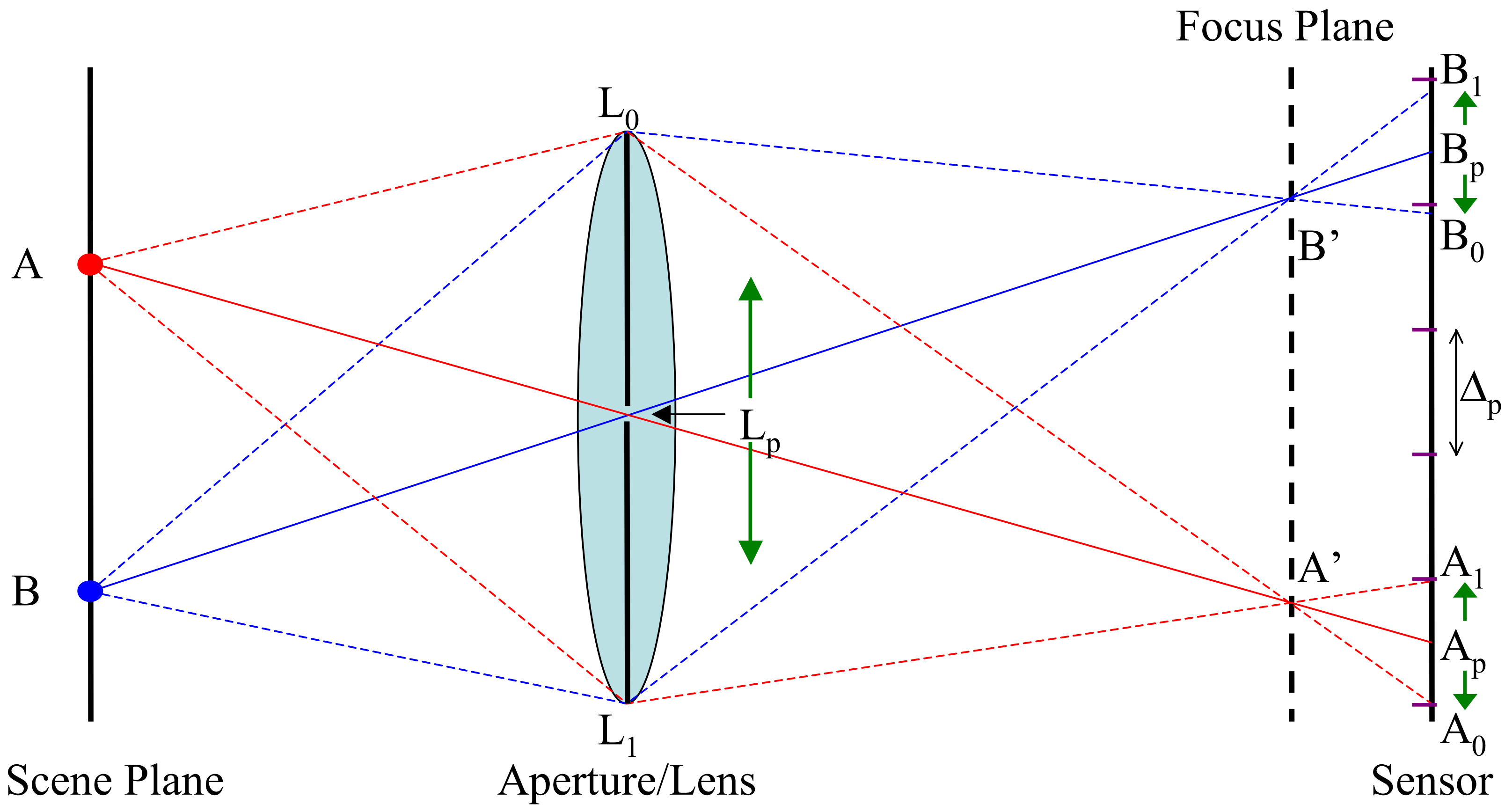
Contributions

- Achieve sub-pixel image shift using a mask in front of the lens
- Enhance effective sensor resolution without moving the camera or sensor.

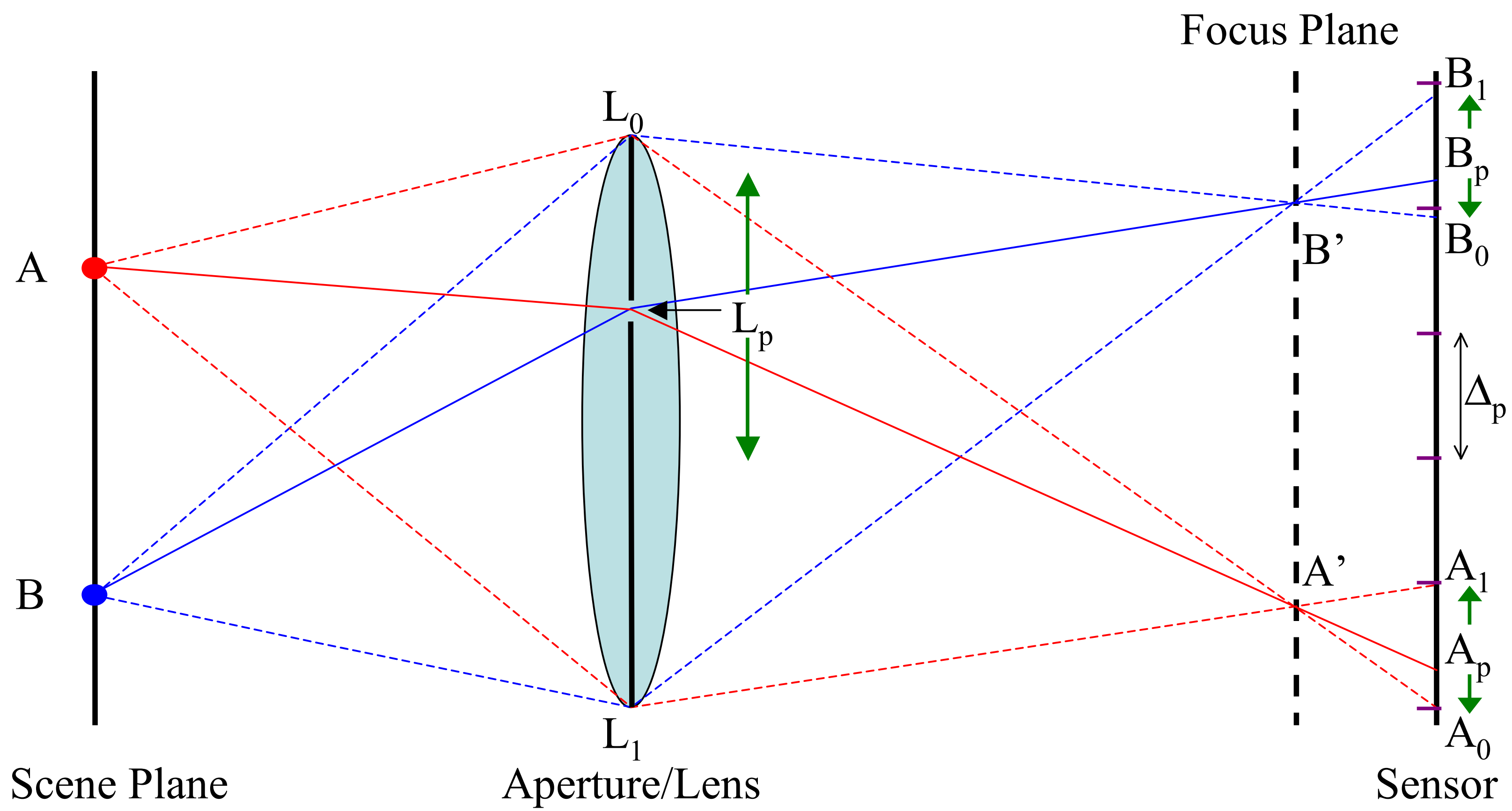
We intentionally blur the image so that when the aperture is open, the blur is less than one pixel, Δ_p



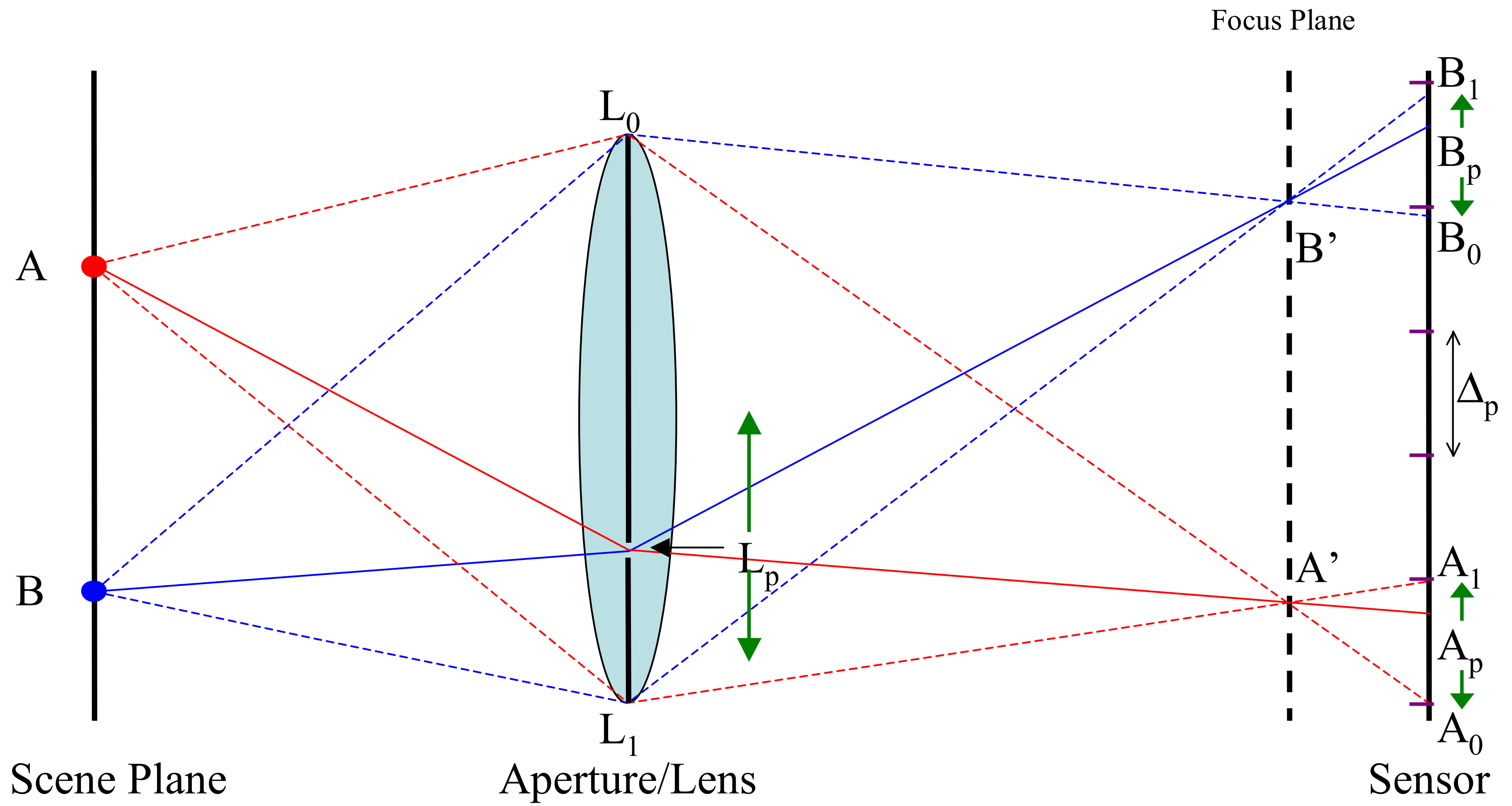
Moving a pinhole in along the lens effectively moves the image in an out-of-focus sensor plane.



Moving a pinhole in along the lens is same moving the sensor by sub-pixel distances.



Moving a pinhole in along the lens is same *moving the sensor* by sub-pixel distances.



Moving the pinhole aperture with a slightly out of focus sensor…

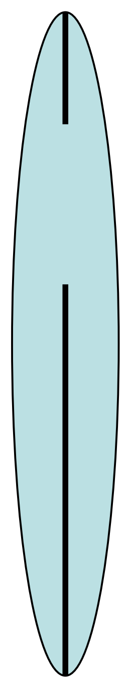
…is equivalent to…

…translation based superresolution

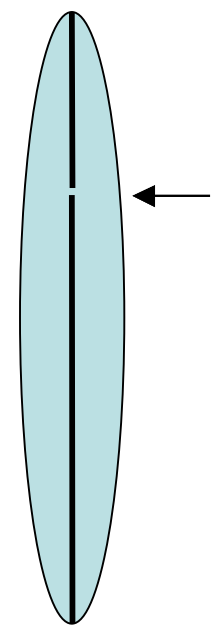
But, aperture movement is in mm instead of μm

Pin holes are inefficient, collect little light, thus increasing exposure time. Instead, we use wider carefully chosen apertures.

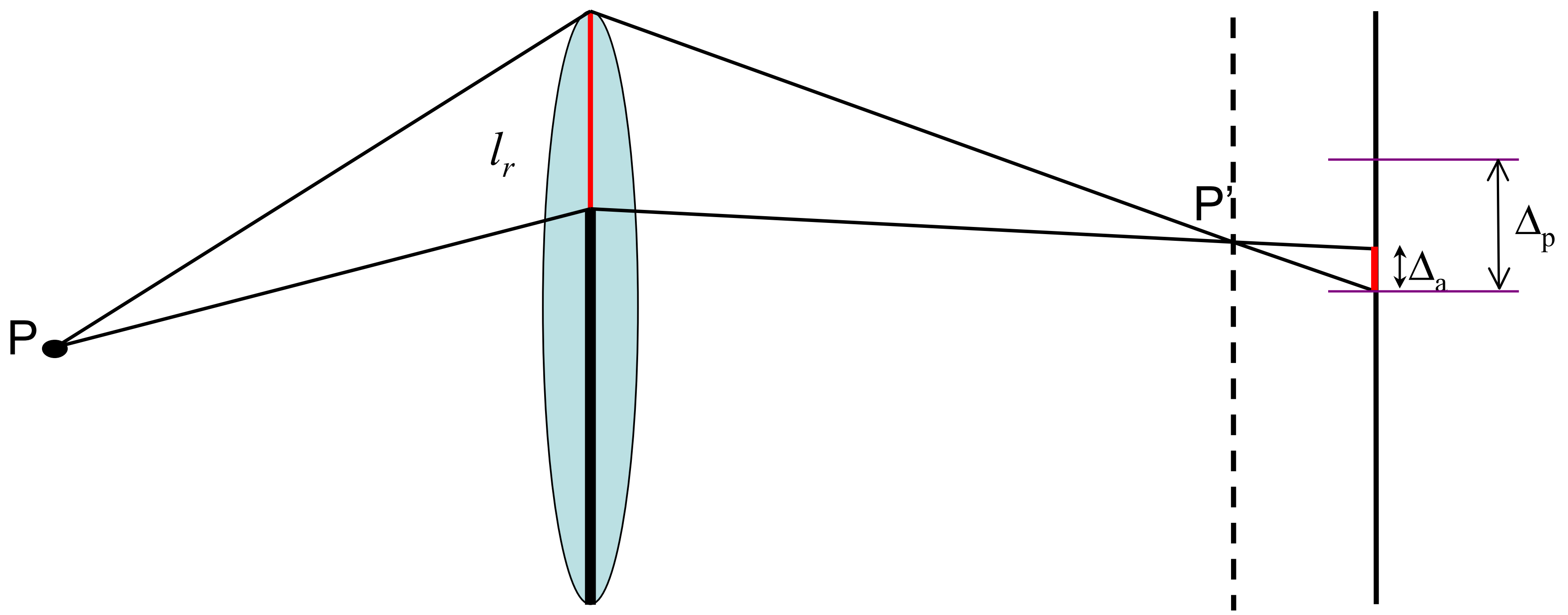
Use



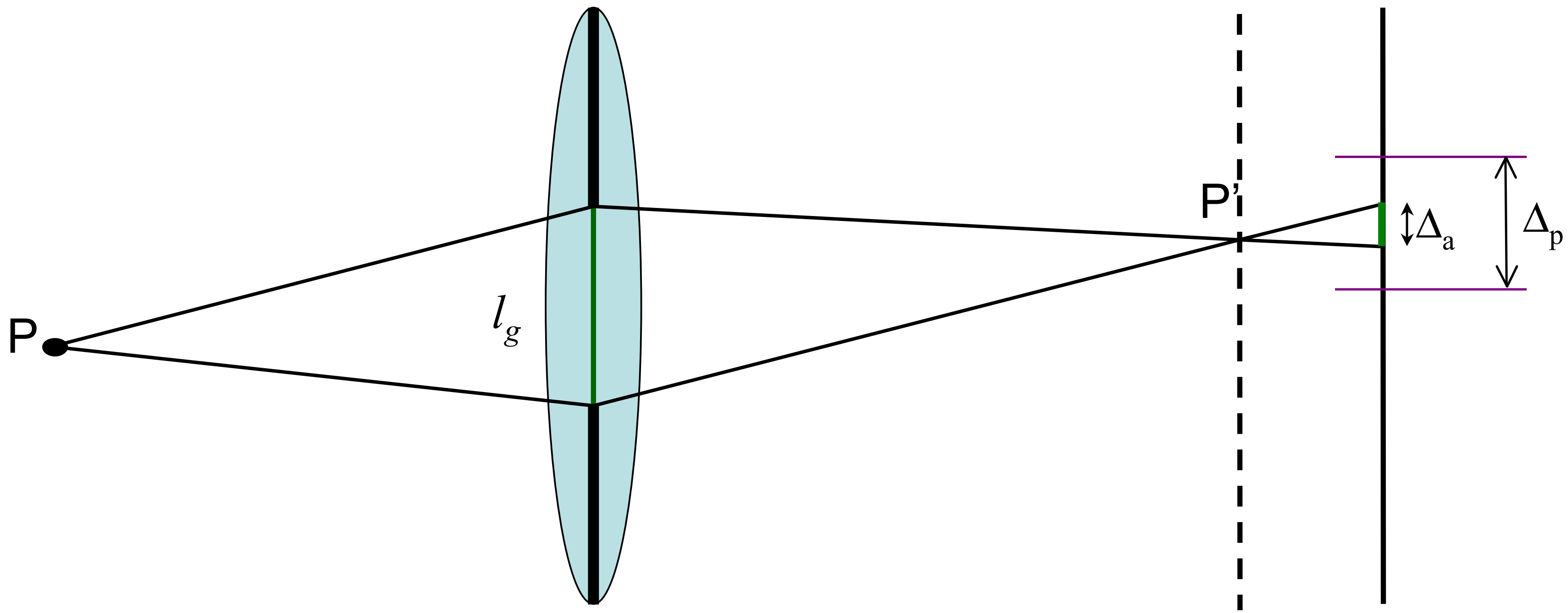
instead of



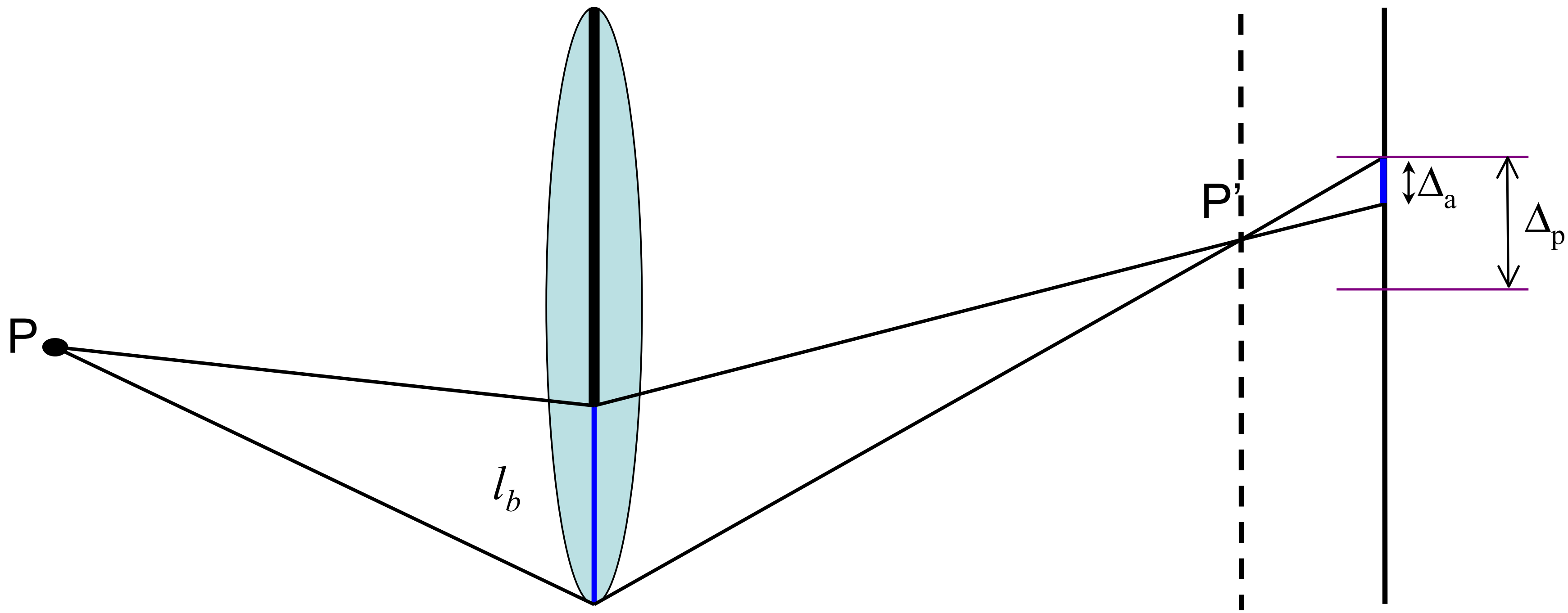
Unique finite sized aperture positions



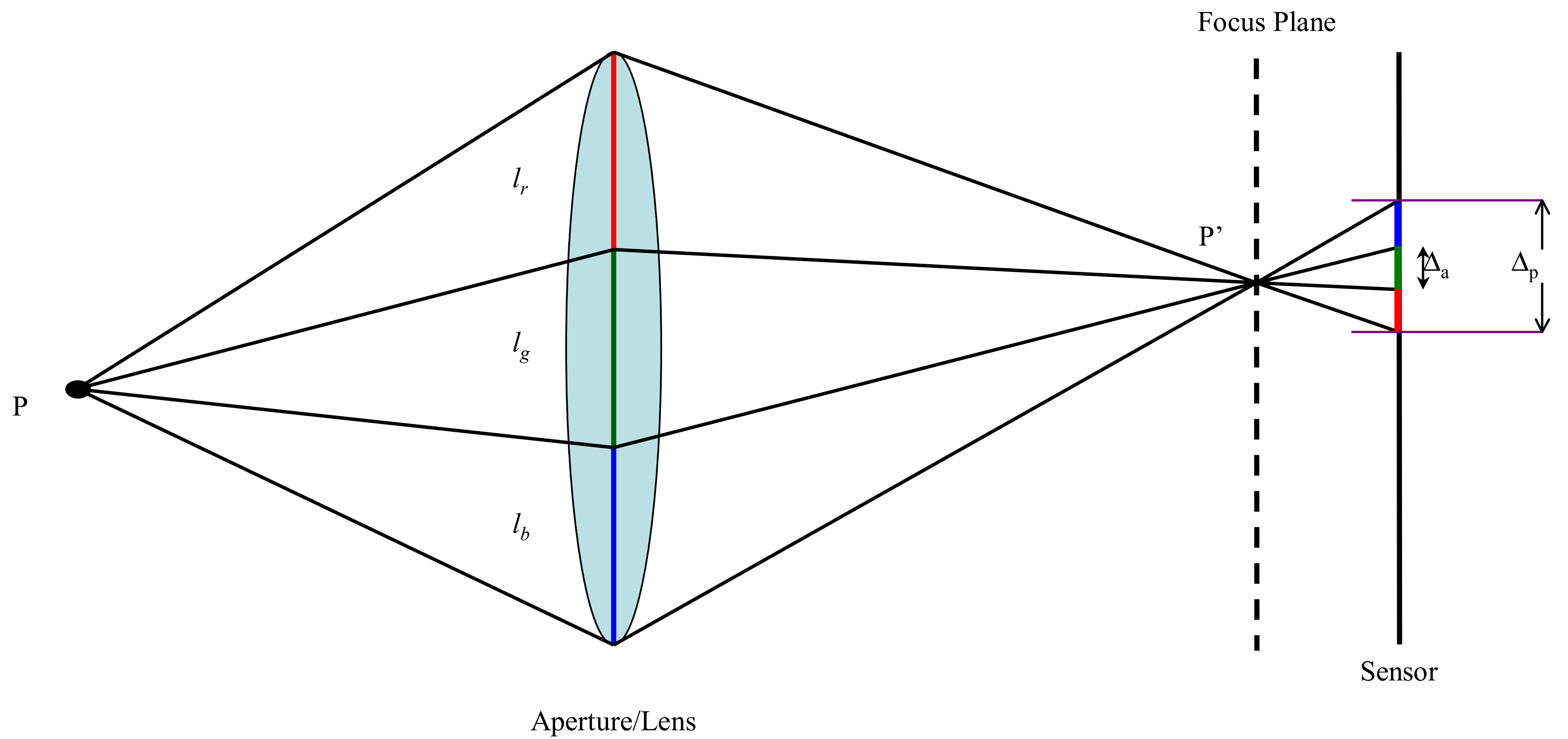
Unique finite sized aperture positions



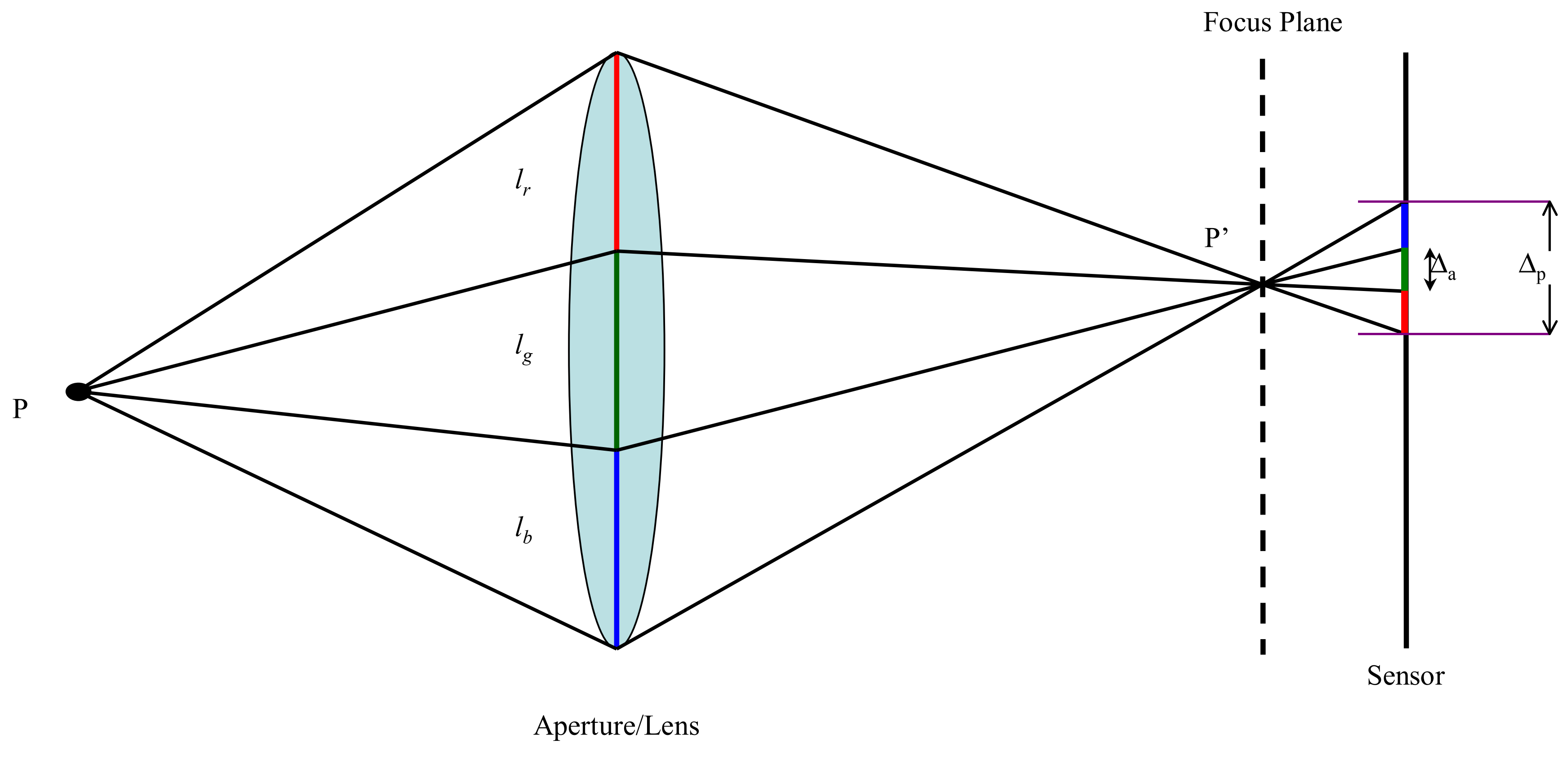
Unique finite sized aperture positions



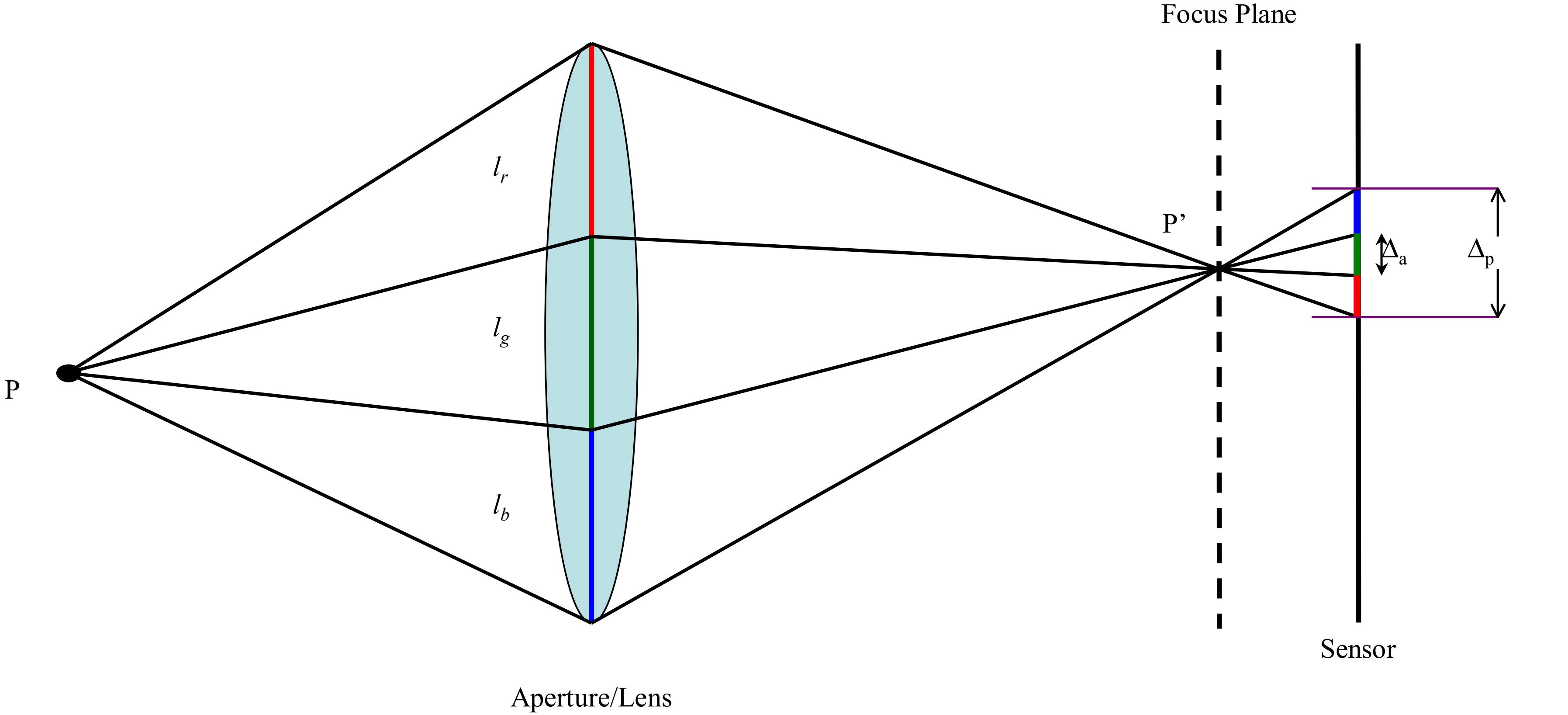
We capture multiple photos with out-of-focus sensor and unique finite sized aperture positions



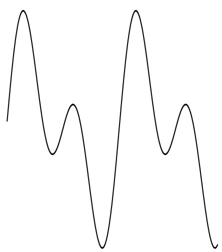
3x resolution enhancement: Capture 3 photos with aperture position l_r, l_g, and l_b



Total blur size = one pixel size (Δ_p)
Blur due to each partial aperture
$= \Delta_a = \Delta_p/3$

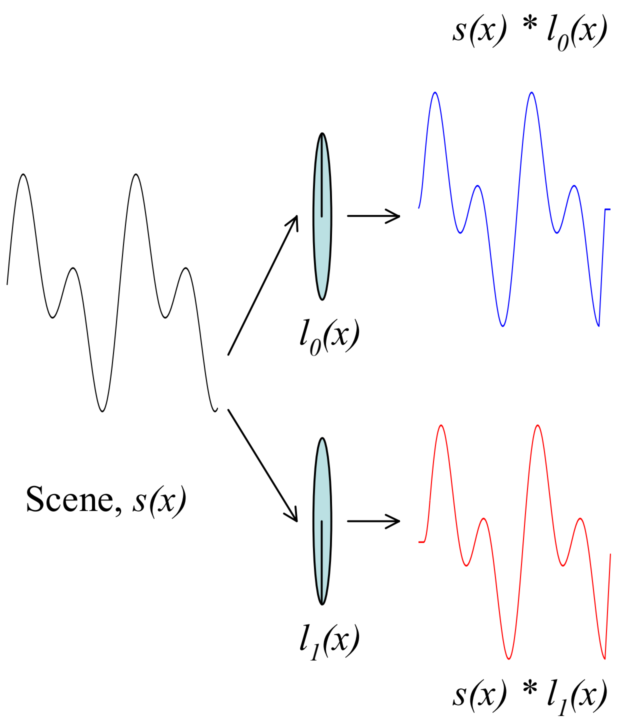


2x resolution enhancement for a 1D signal



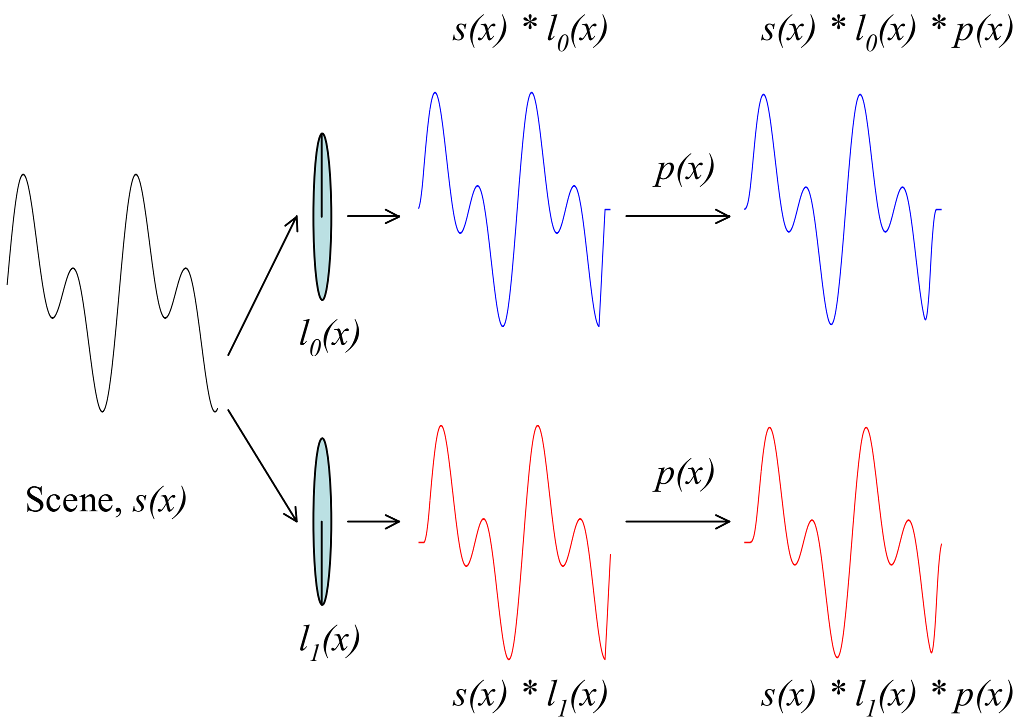
Scene, *s(x)*

Capture 2 photos with complimentary apertures

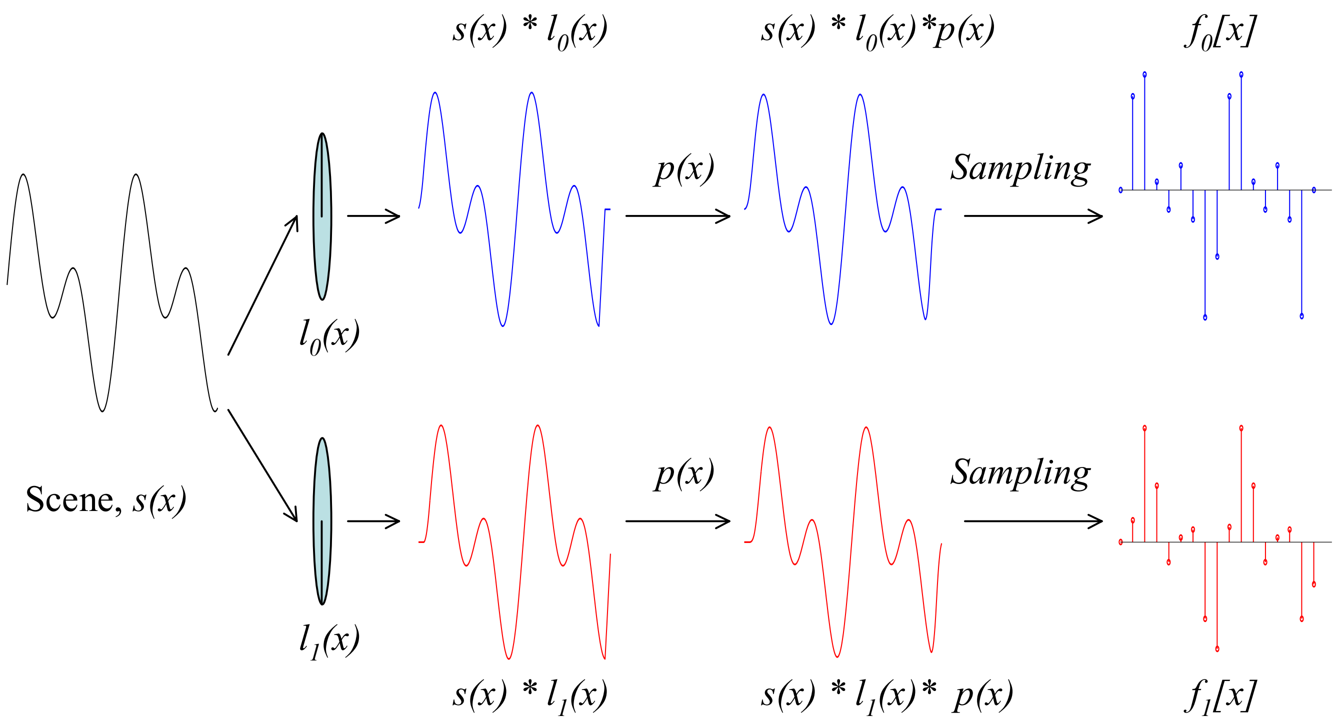


Notice the phase shift between the two signals. For a total blur of one pixel, this corresponds to half pixel shift.

Anti-aliasing due to finite pixel size

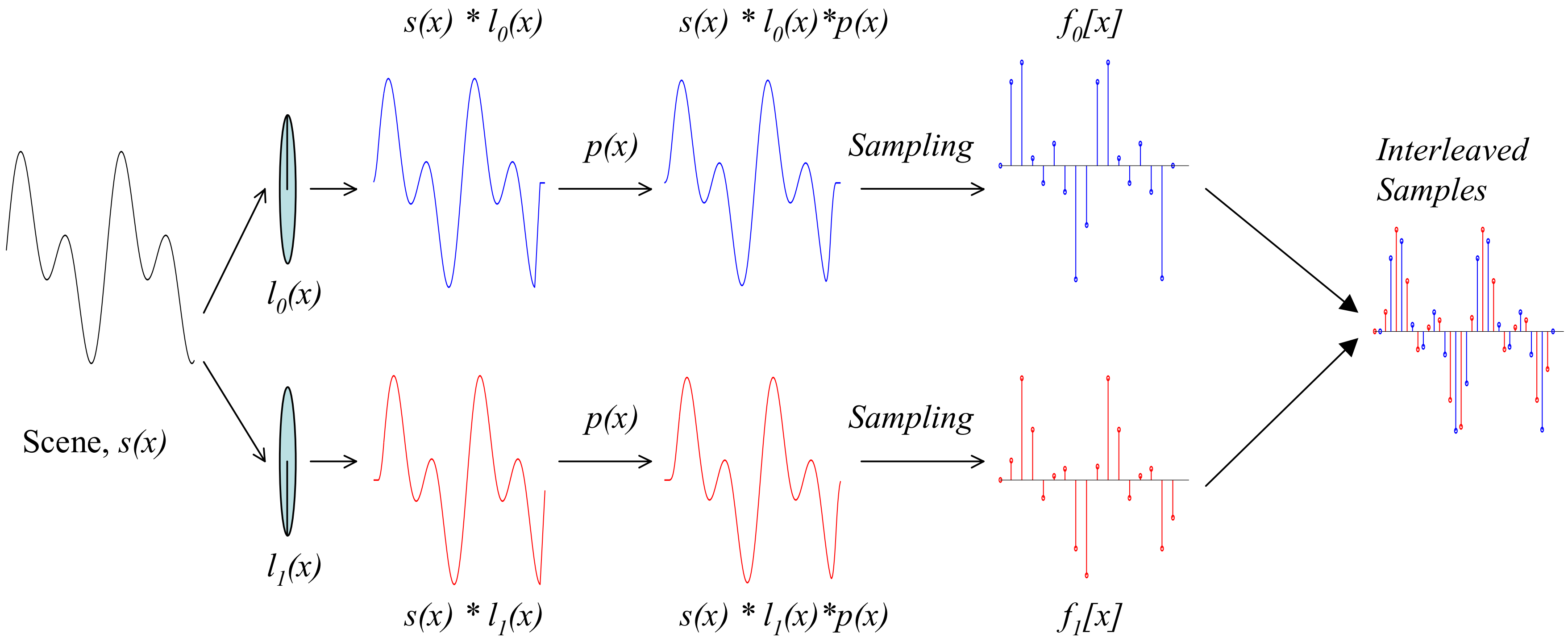


Discrete sampling due to pixels



Samples captured by the two photos are different.

Interleave samples from the two photos



Deblur the effect of *p(x)* and *l(x)*

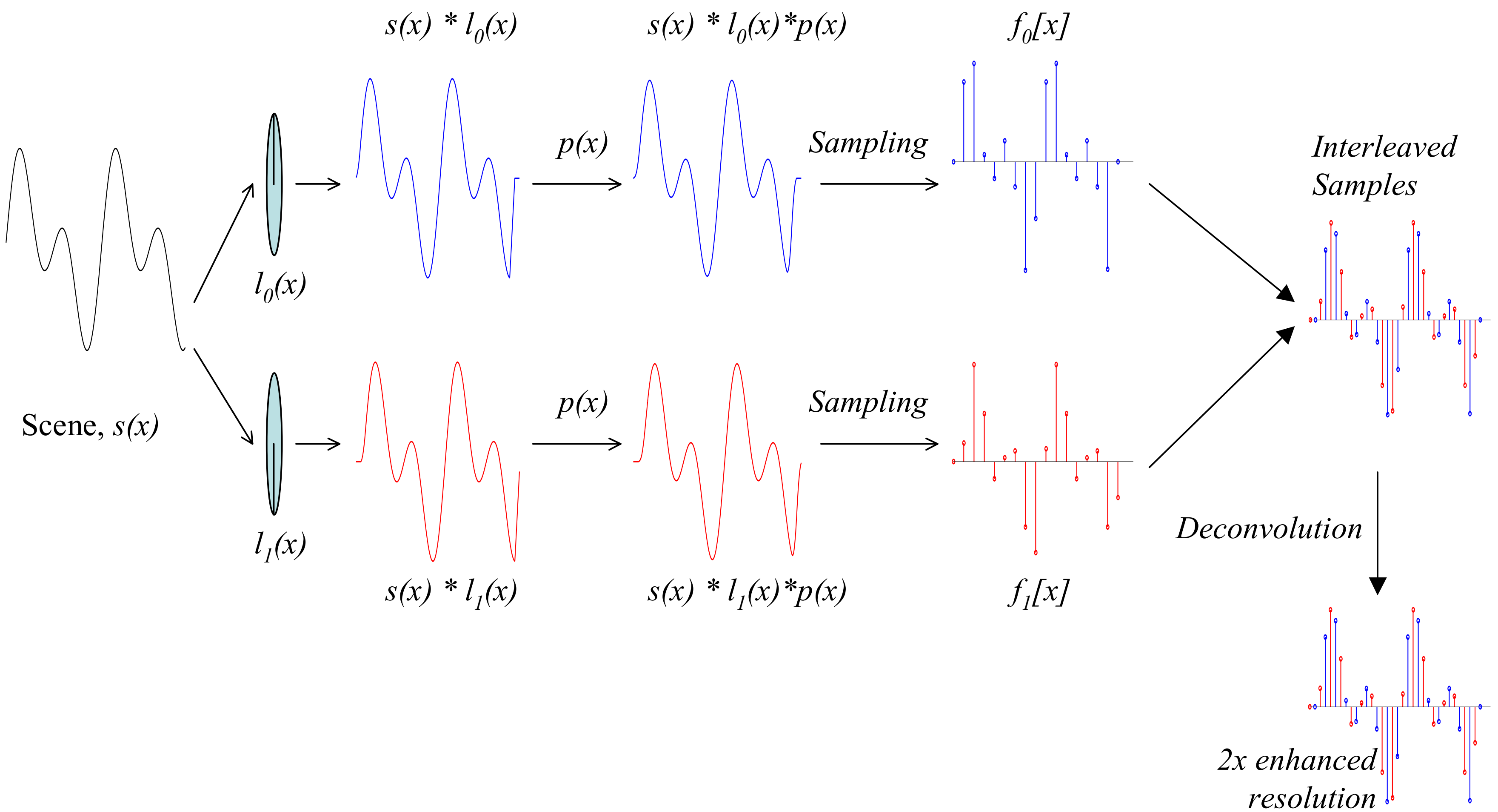
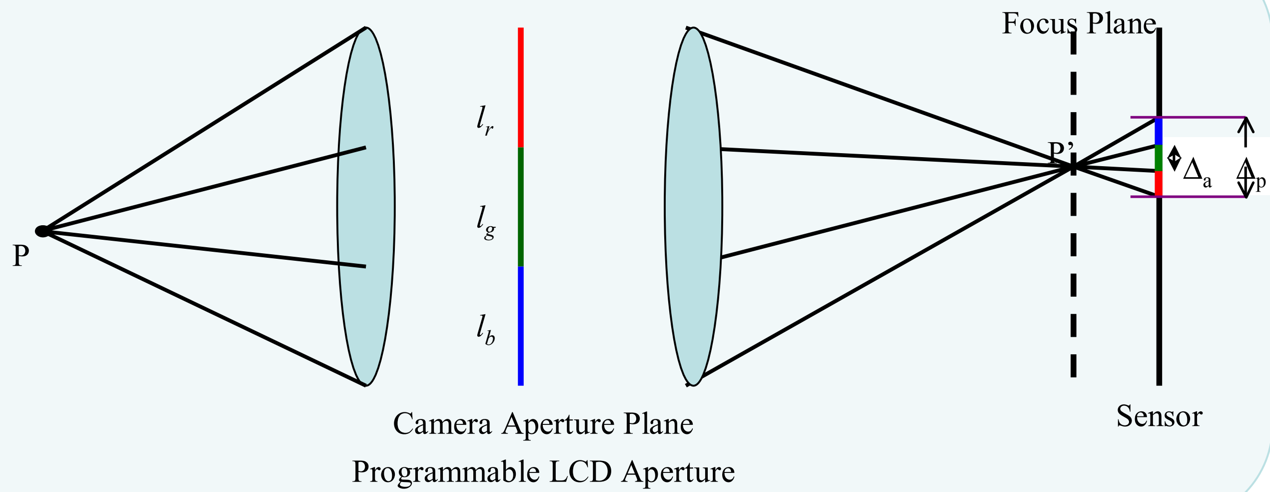
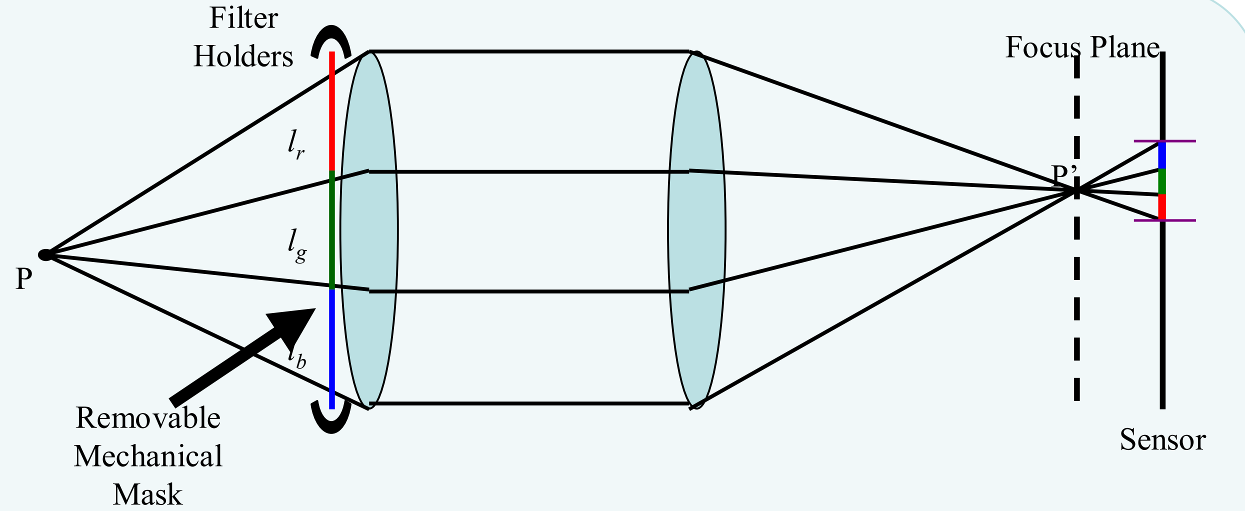


Image Shifting without Moving Parts

Suggested Design: Programmable Aperture with *NO* moving parts eliminating expensive precision or cumbersome registration



Our Implementation: Masks in a Holder

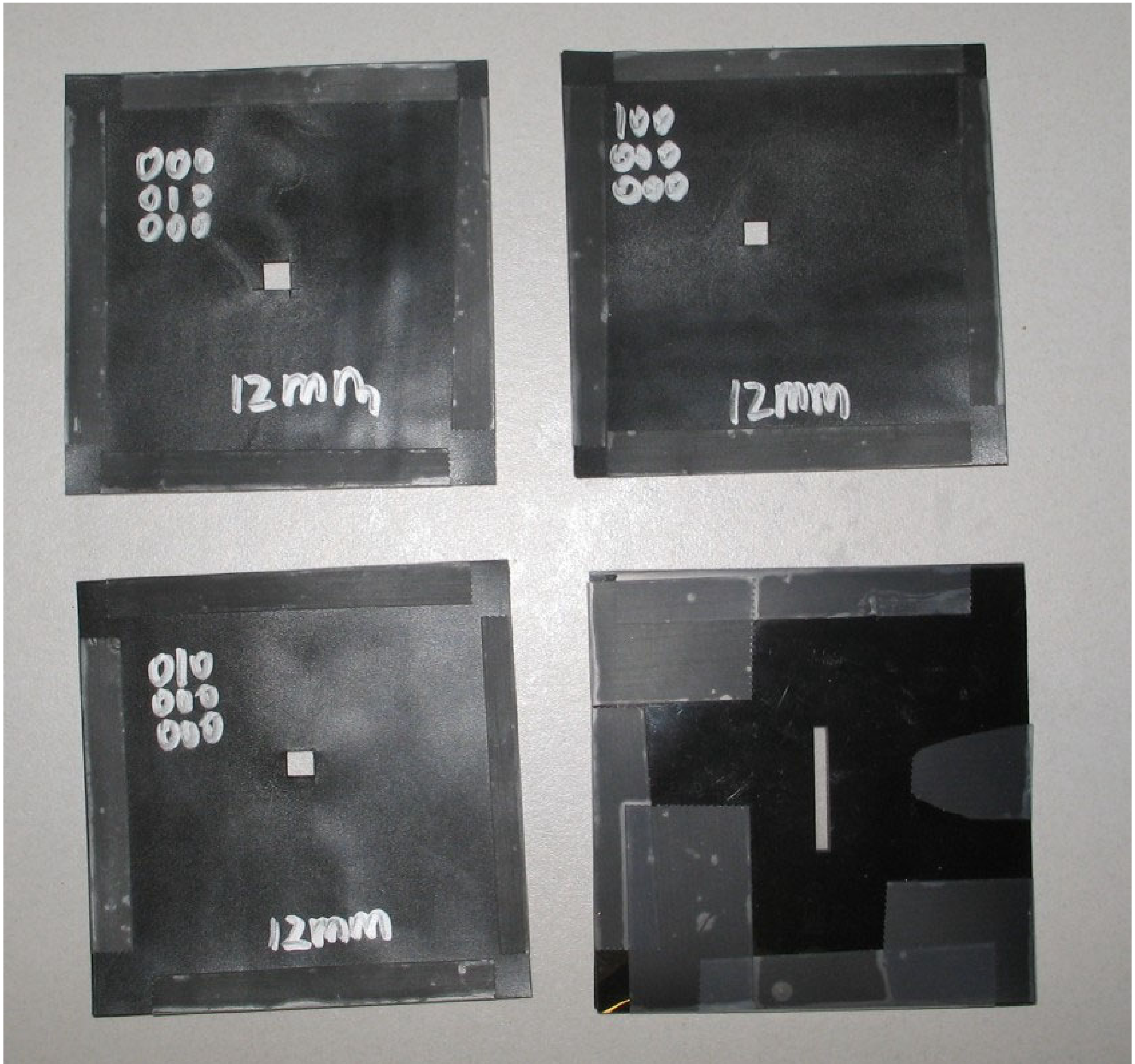


Prototype using a conventional SLR camera

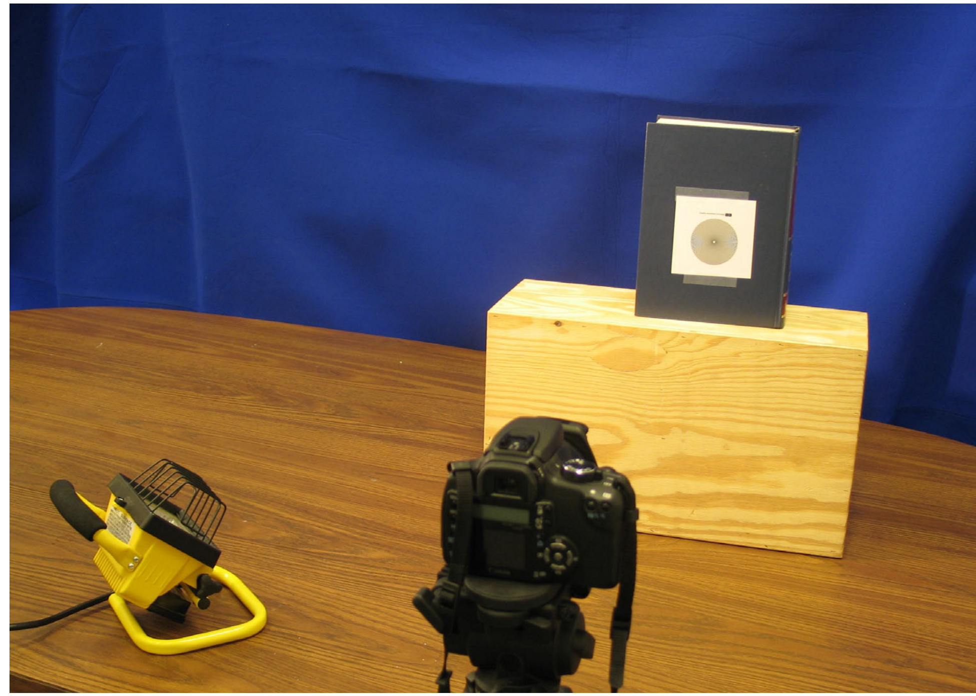
Cokin filter holder

Slide mask in front of the lens

Aperture Masks



Result: Radial spoke chart



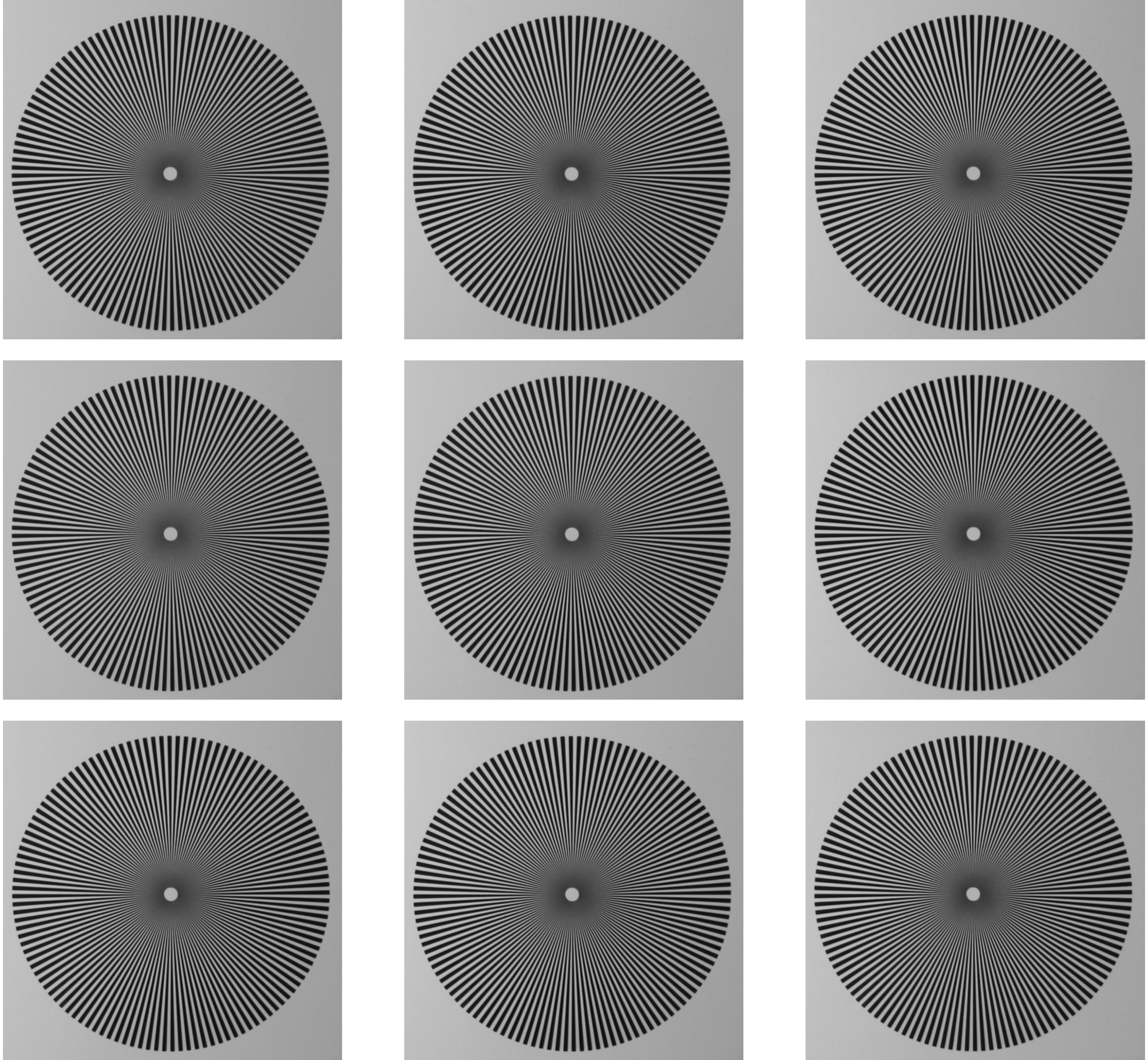
Mask size=12mm

Mask resolution=3x3

Image scale factor=1/1.7

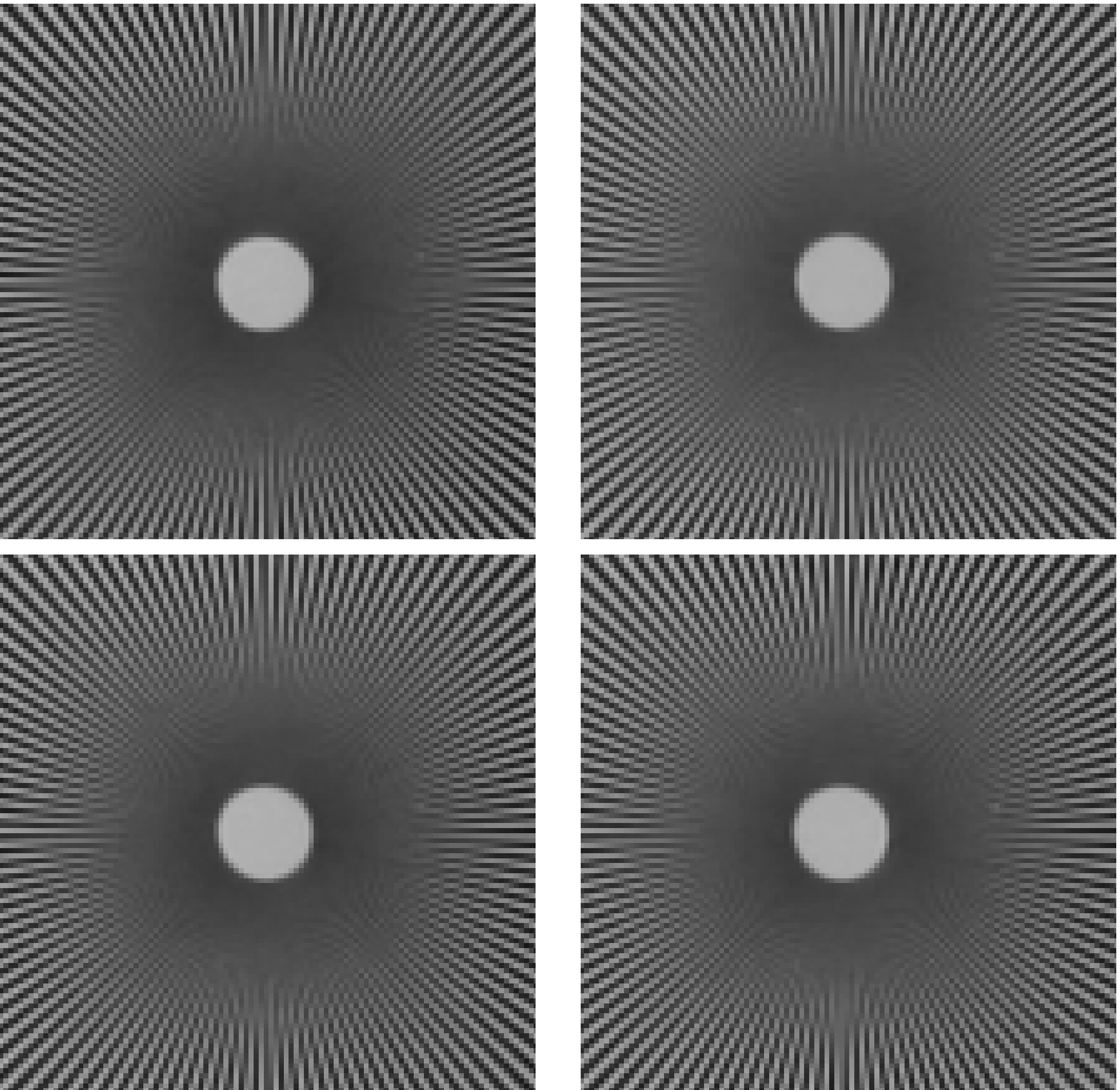
Input image size=471x741

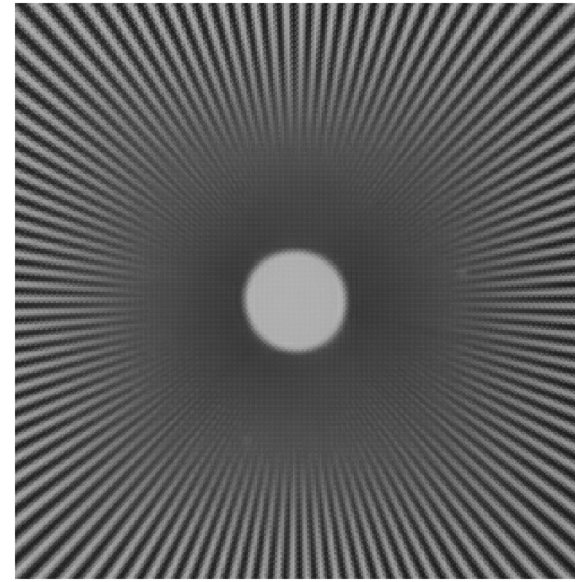
Output image size=1413x1413



Input images (3x3)

Cropped and bicubic interpolated **input** images (4 of 9 shown)





Cropped **result** with 3x samples

Observe the jaggies in the input images.
In the result, details in high spatial frequencies closer to center of the spoke are maintained upto a limit.

Result: Barcode

Mask size=12mm

Mask resolution=4x1

Image scale factor=1/3

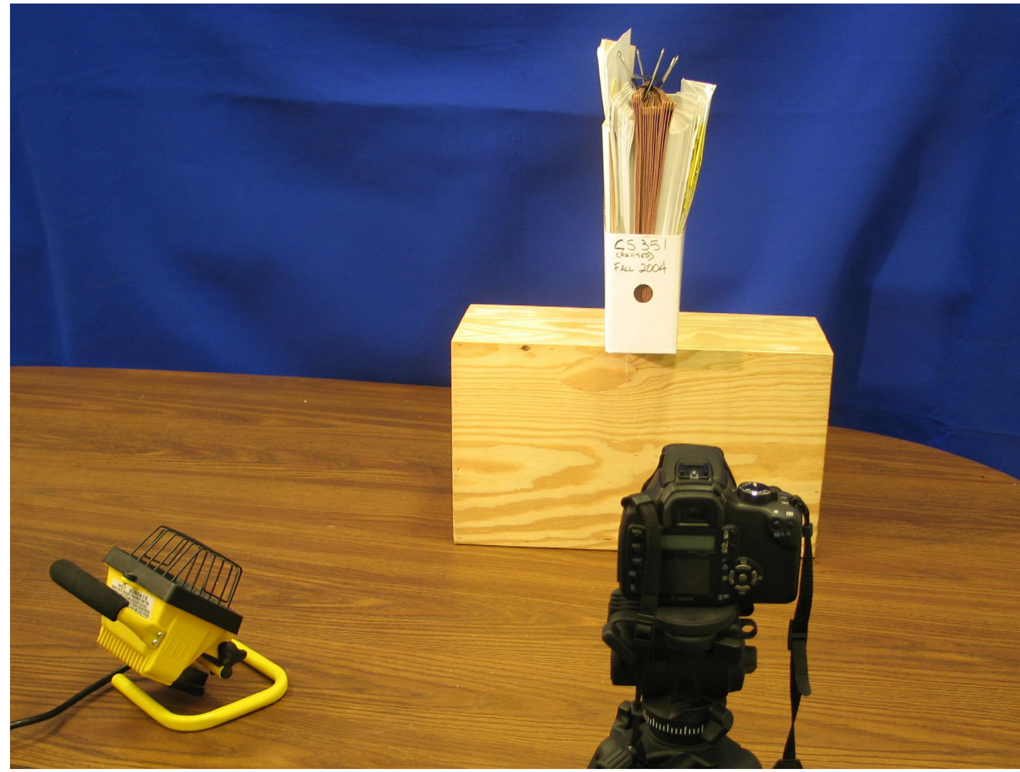
Input image size=171x416

Output image size=684x416

Input Images (4x1)

Result: 4x increase in horizontal resolution

Result: Sheets of paper



Mask size=12mm

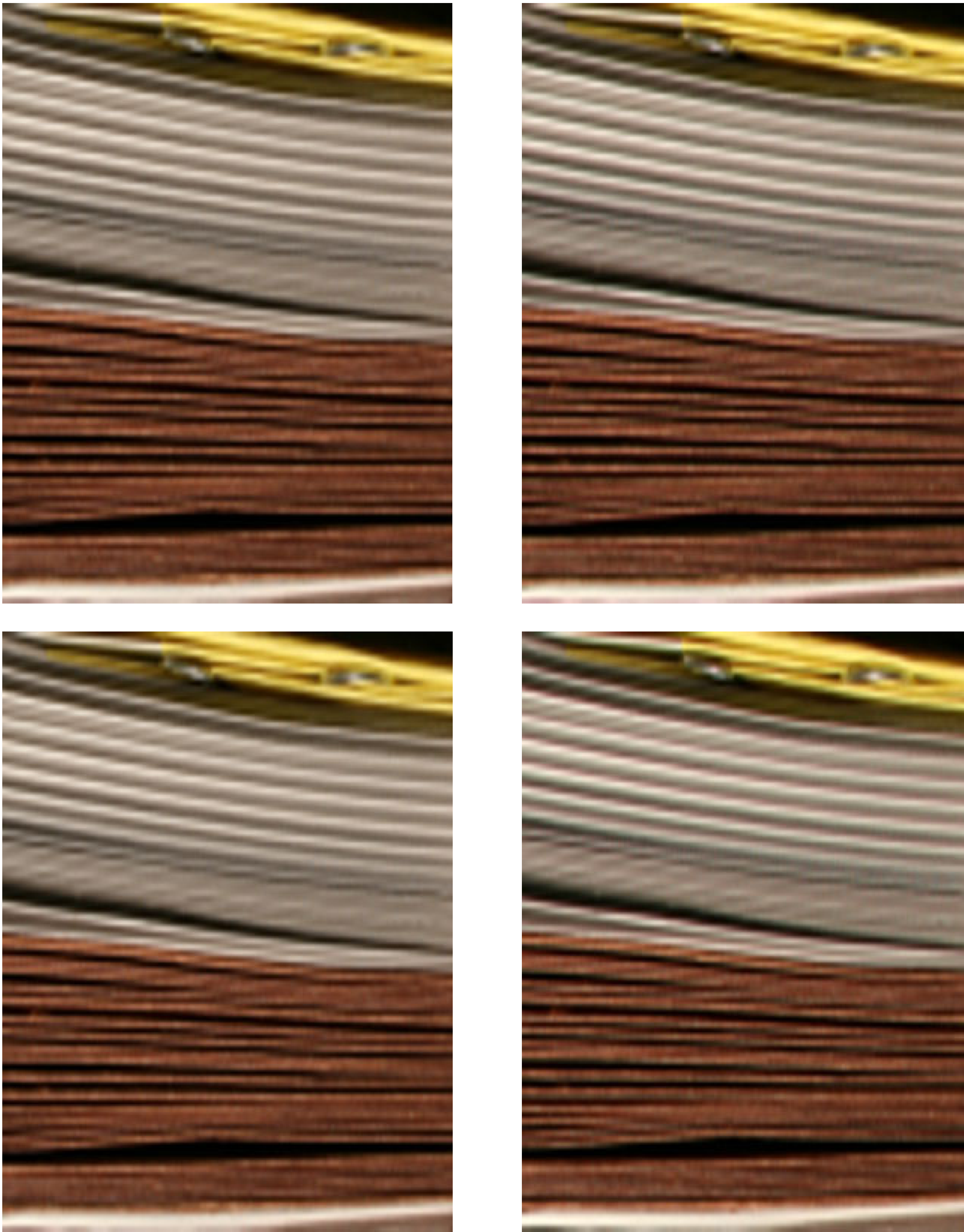
Mask resolution=4x1

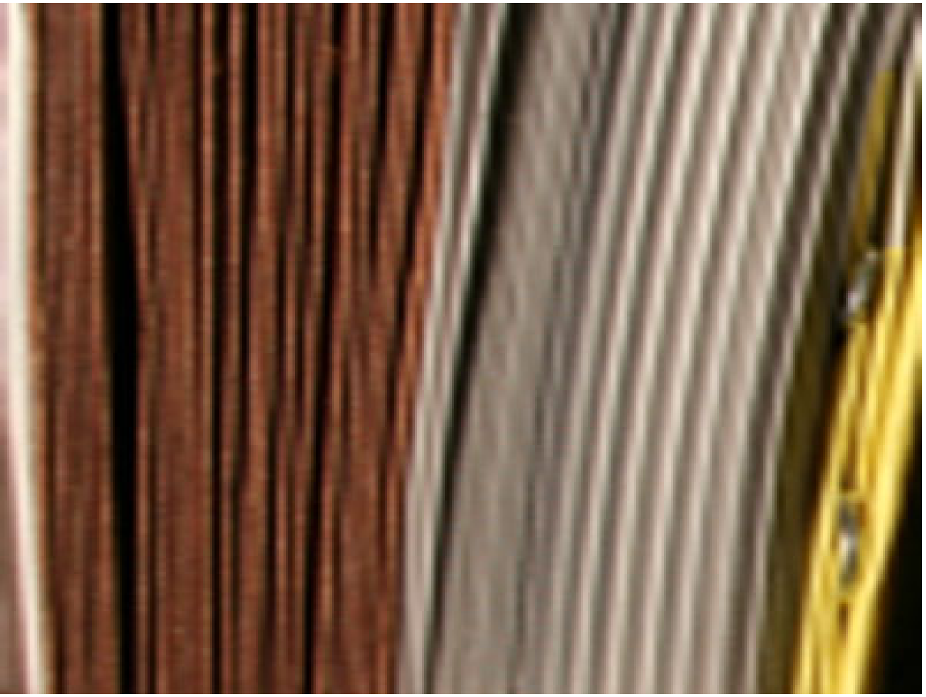
Image scale factor=1/8

Input image size=100x300

Output image size=400x300

Input images (4x1)





2 of the 4 **input** images

Result: 4x increase in horizontal resolution

Result: Carpet tile

Mask size=12mm

Mask resolution=2x2

Image scale factor=1/2

Input image size=256x256

Output image size=512x512

Input images (2x2)

Result

Please blink-compare with next page

One of the **Inputs**

Please blink-compare with previous page