

Class Notes October 9<sup>th</sup> 2009  
Computational Camera

## Traditional Photography

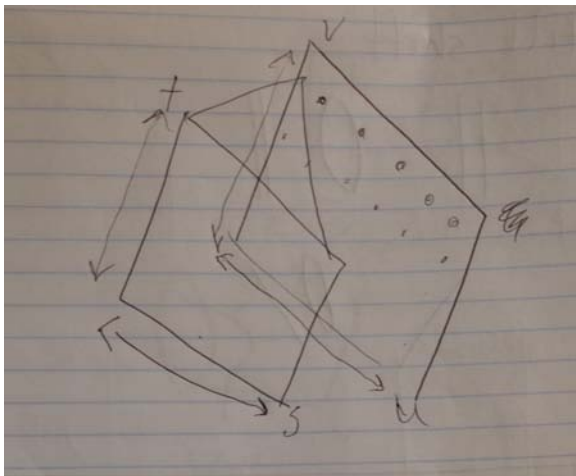
Photographers make their terms sound very exotic. F stop for example is complicated and it is wrong, so try to use simpler language to describe. Numerical aperture is used in microscopy, which is more exact.

## How to capture the entire world

Why is a ray is 5D and not 6D? Because there is no roll around the ray. It can be 4D if there are no occluding objects. Can be described as 2d position of two points on two plains, or 2d position and 2d rotation

If rays are parallel to a plane it is hard to represent it in 4D.

## Camera Arrays

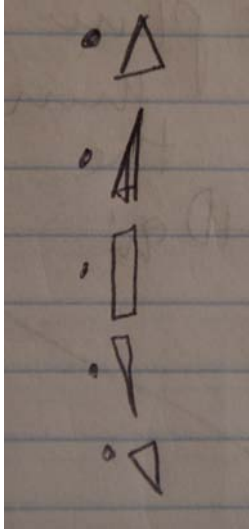


For a camera Area:

Every camera position is defined in UV coordinates, and each cameras image buffer captures in the ST plane.

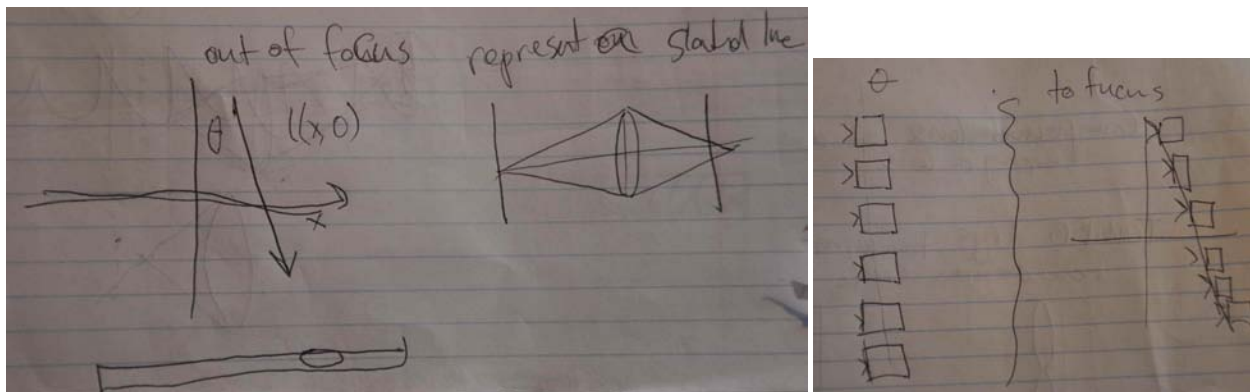
Rays are not captured if they pass in-between the cameras

Really the world is 4d not 3d, because it matters where the viewer is too



The difference between a giant lens and a camera area is that a lens is really sections of a prism, and in the camera area case it is more of a pin hole area

4D captures all of the geometric properties of whatever is seen through the lens



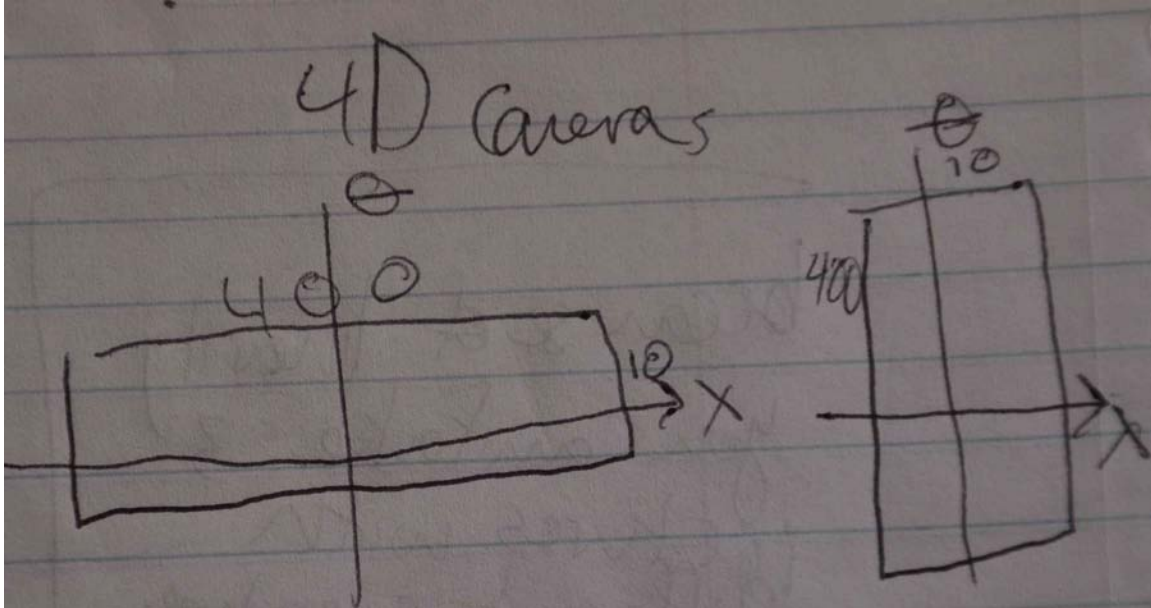
Here you can see that an out of focus object creates a diagonal line in the X Theta graph, so to refocus the image to that plane you have to essentially shift the cameras in a camera array to that diagonal line.

How you shift and add the pixels you captured with the lenslet array changes where the plane of focuses is. If you want to focus at infinity, just sum all cameras.

If you want to focus on a different plane you need to shift each image by a little.

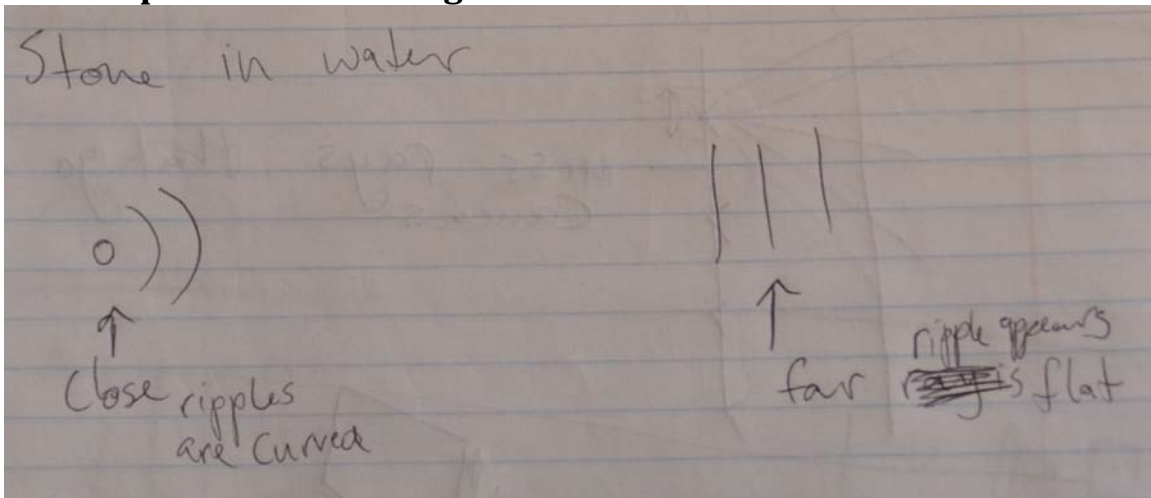
Why does traditional camera not capture a light field? Because it is only capturing the sum of the rays hitting a point, not the value of each ray.

Multiple rays you can capture a 4d light field: time multiplexing, spatial multiplexing (give up spatial resolution for angular resolution)

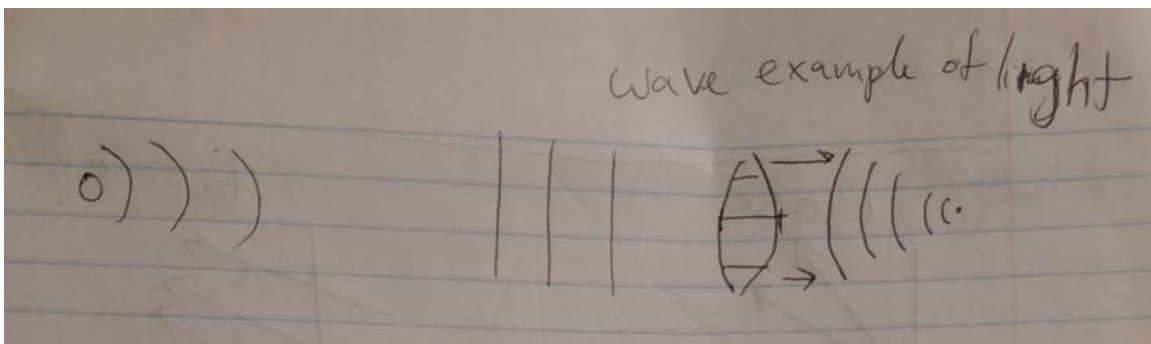


The graph on the left represents a camera with a lens and a lenslet array and on the right it represents a bare sensor and a lenslet array. There is a trade off between angular resolution and spatial resolution.

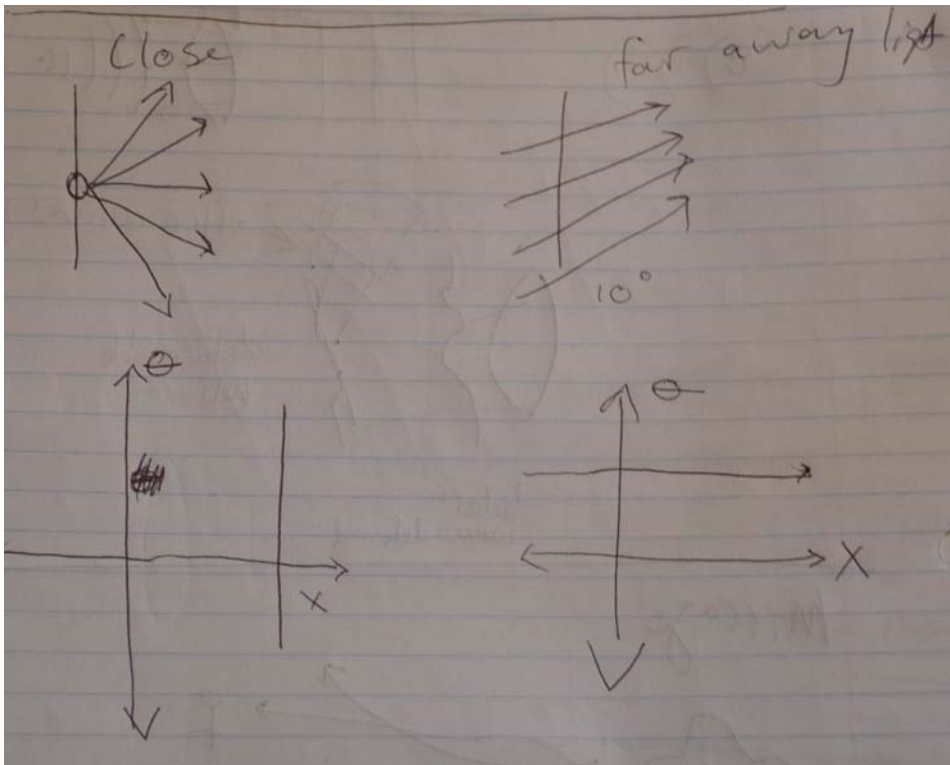
### Wave representation of Light



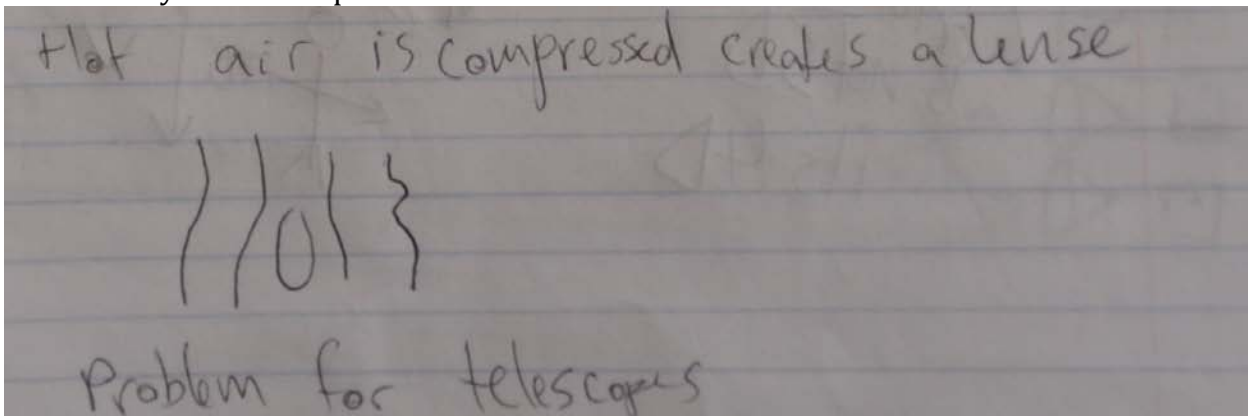
When ripples are close they are curved, but further out they appear flat.



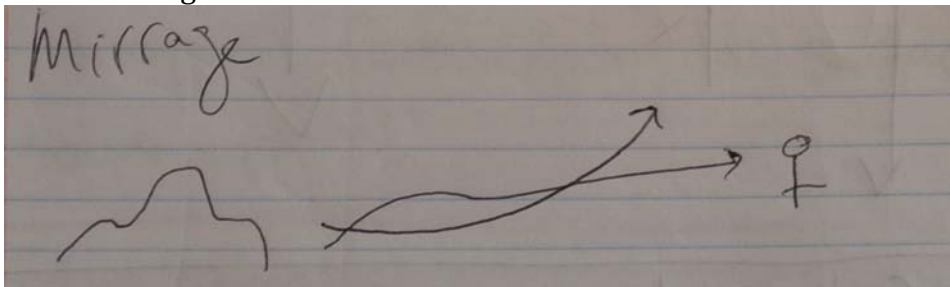
To refocus the parallel rays a lens is used



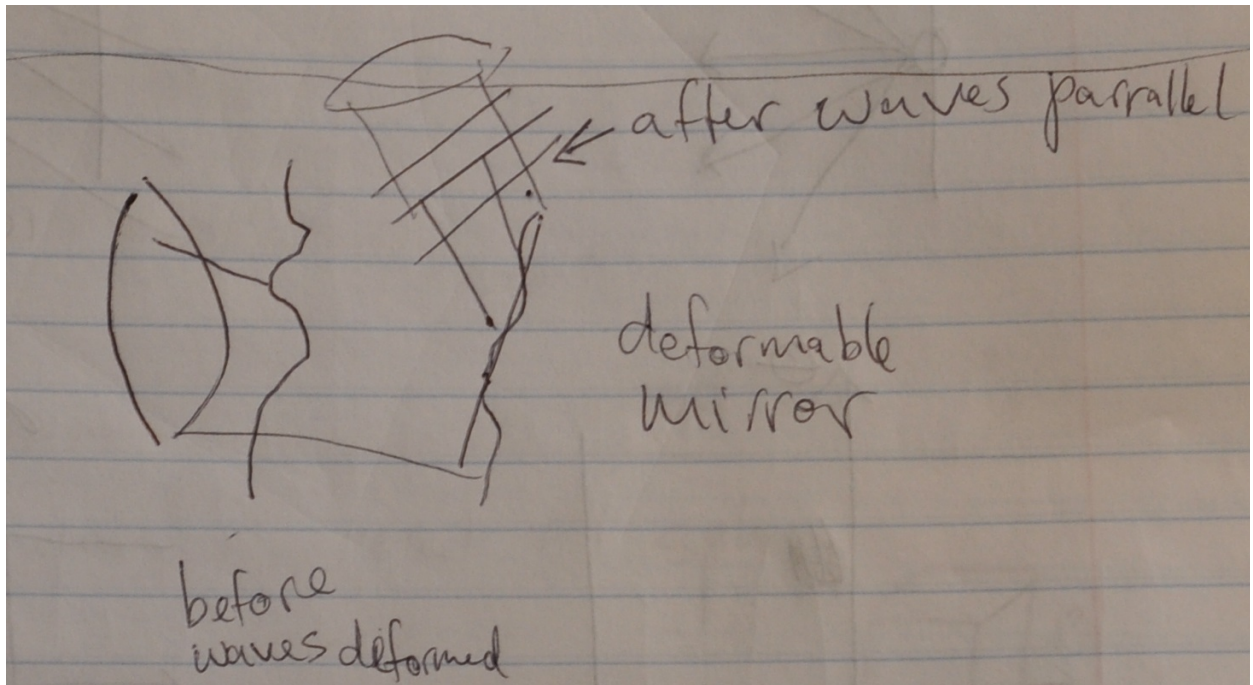
Here you can see that close to a light source there is a lot of angular information, but further away it is more spatial.



Heat in the air causes there to be regions of different densities of air. Pockets of hot air end up effectively creating lenses which distort light. This is similar to what happens when you see heat rising on the street and it looks like water.



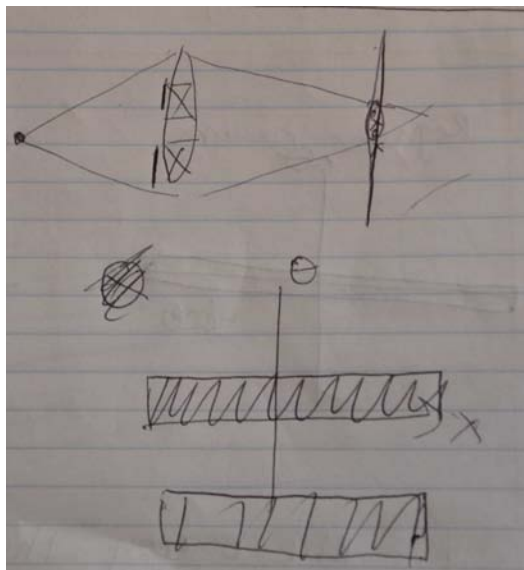
This same effect creates mirrages



These deformed waves due to atmosphere create problems for telescopes, so adaptive lenses were created. These lenses are deformable and change shape to make the deformed waves parallel again.

When correcting shape (phase) of a wavefront phase wrapping occurs, because you can only capture modular of  $2\pi$ .

---



You can use a mask over the aperture to effectively take multiple images, from slightly different views, using the same sensor and lens. This is what a pin hole array accomplishes.

MIT OpenCourseWare  
<http://ocw.mit.edu>

MAS.531 / MAS.131 Computational Camera and Photography  
Fall 2009

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.