



# Virtual and Augmented Reality

CS-GY 9223/CUSP-GX 6004

<https://nyu-icl.github.io/courses/2022fall-vr-ar>

Prof. Qi Sun  
[qisun@nyu.edu](mailto:qisun@nyu.edu) | [www.qisun.me](http://www.qisun.me)

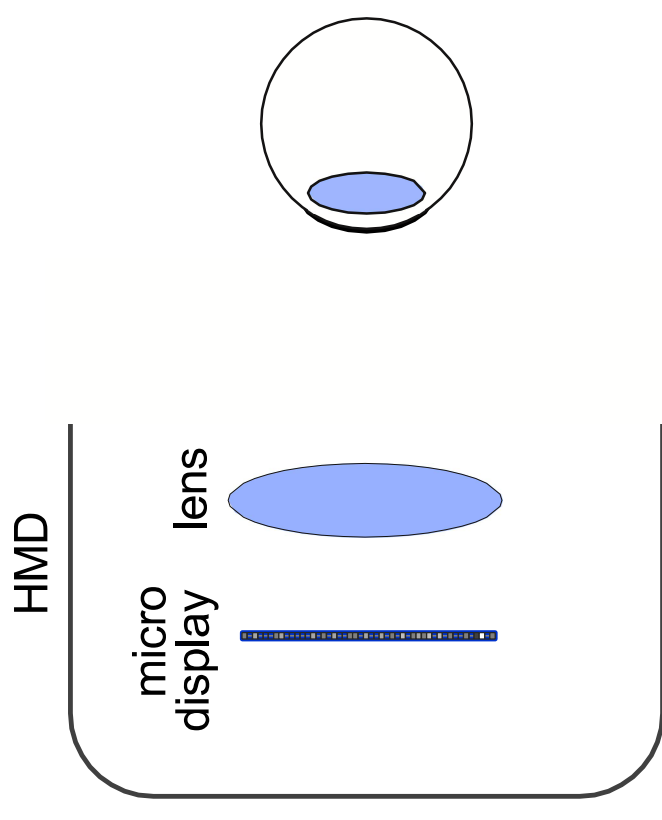
# Logistics

- No office hour this Fri.
- Assignment 2

# Stereo Rendering for HMDs

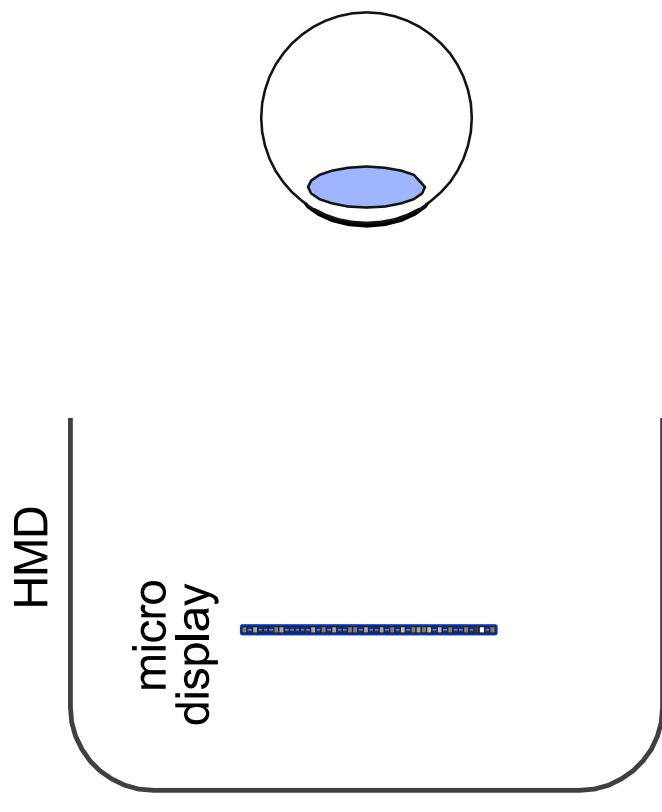
*All Current-generation VR HMDs are  
“Simple Magnifiers”*

# Image Formation



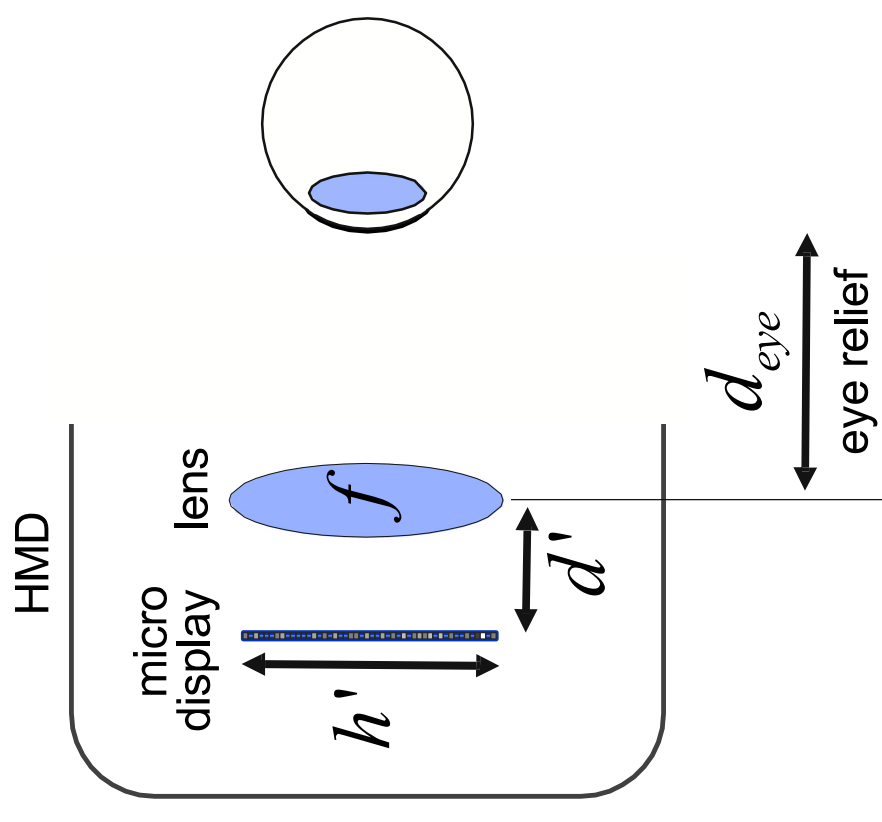
Side View

# What's the Problem?



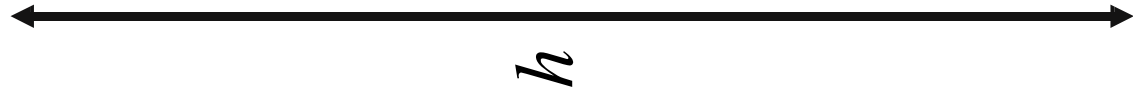
Side View

# Image Formation



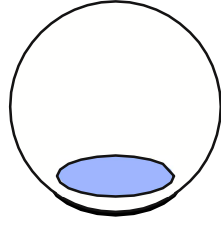
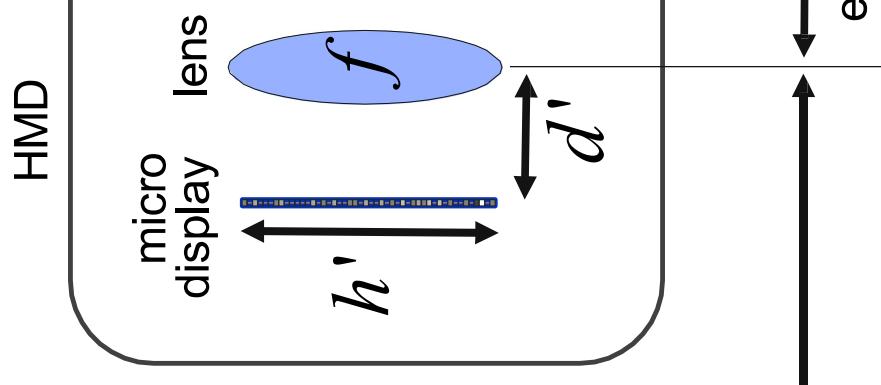
Side View

virtual image



world origin is in the center  
of the virtual image!

# Image Formation



$d$

Side View

virtual image



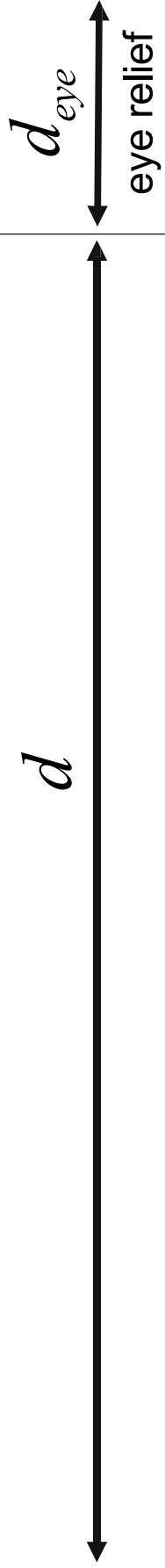
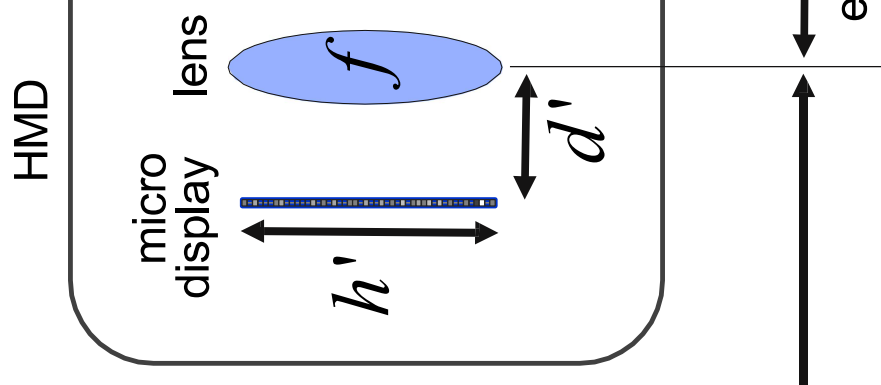
Gaussian thin lens formula:

$$\frac{1}{d} + \frac{1}{d'} = \frac{1}{f}$$

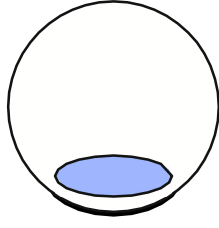
$\Leftrightarrow$

$$d = \left| \frac{1}{\frac{1}{f} - \frac{1}{d'}} \right|$$

# Image Formation

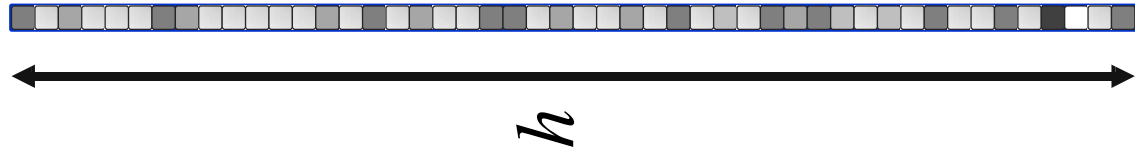


Side View





virtual image



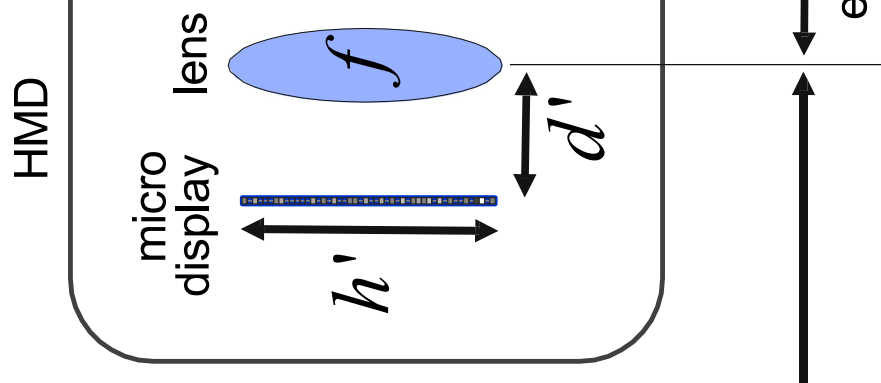
Gaussian thin lens formula:

$$\frac{1}{d} + \frac{1}{d'} = \frac{1}{f} \Leftrightarrow d = \left| \frac{1}{\frac{1}{f} - \frac{1}{d'}} \right|$$

Magnification:

$$M = \frac{f}{f - d'} \Rightarrow h = Mh'$$

# Image Formation

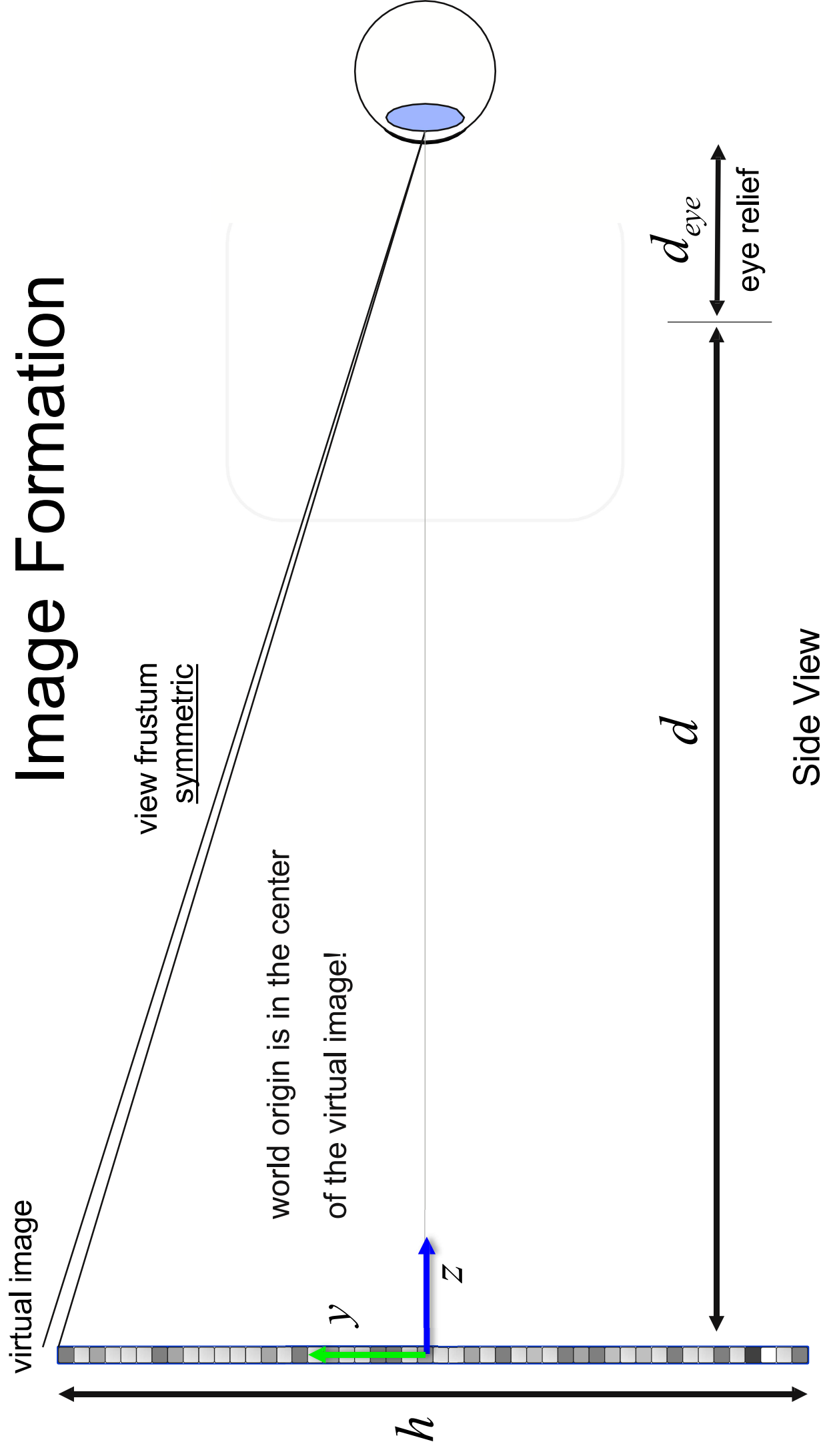


$d_{eye}$   
eye relief

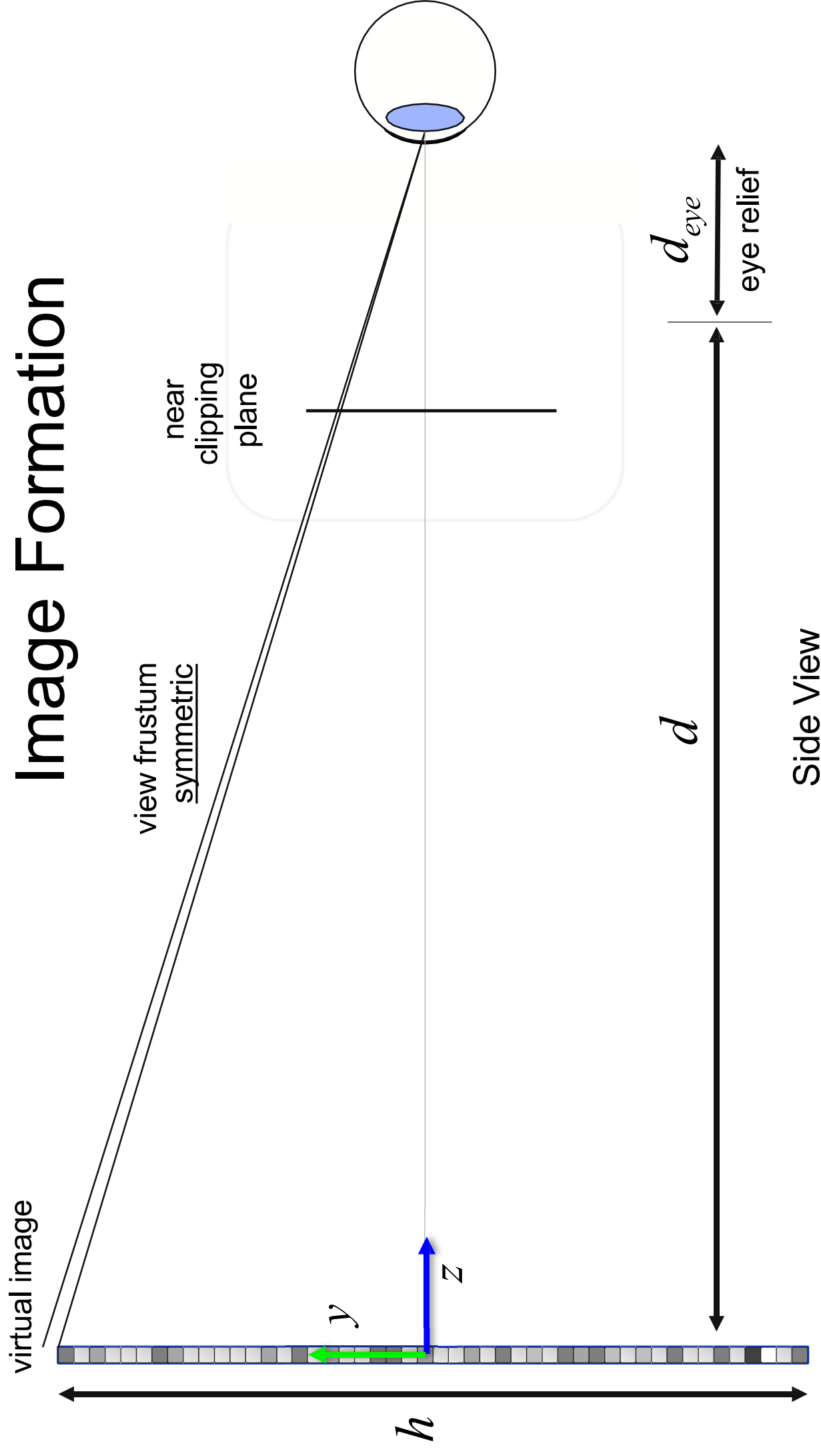
$d$

Side View

# Image Formation



# Image Formation



virtual image

# Image Formation

view frustum  
symmetric

near  
clipping  
plane

$z_{near}$

top

bottom

$y$

$z$

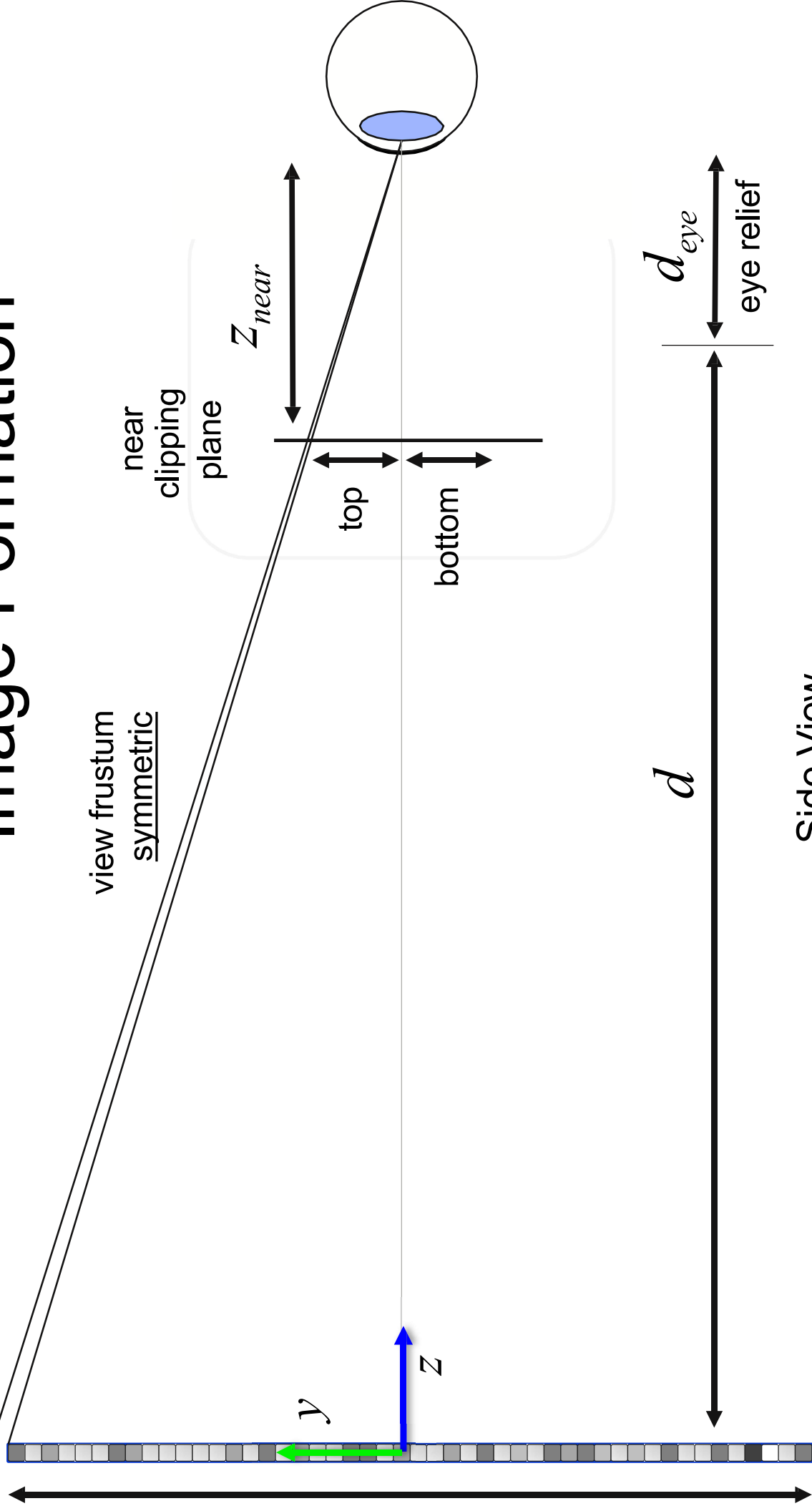
$h$

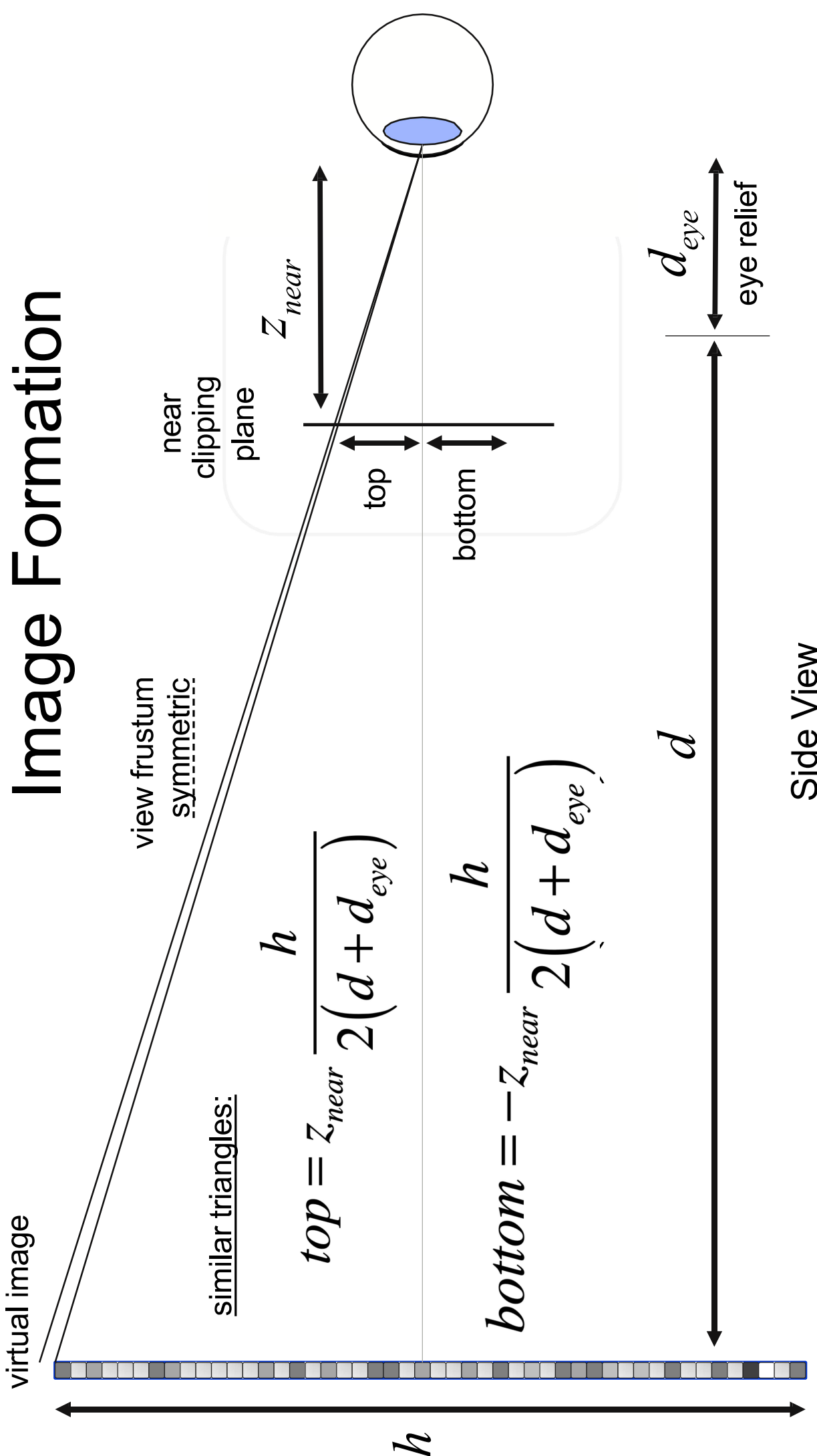
$d$

$d_{eye}$

eye relief

Side View





# Image Formation

view frustum  
symmetric

near  
clipping  
plane

similar triangles:

$$top = z_{near} \frac{h}{2(d + d_{eye})}$$

$$bottom = -z_{near} \frac{h}{2(d + d_{eye})}$$

$d_{eye}$   
eye relief

$d$

Side View

$h$

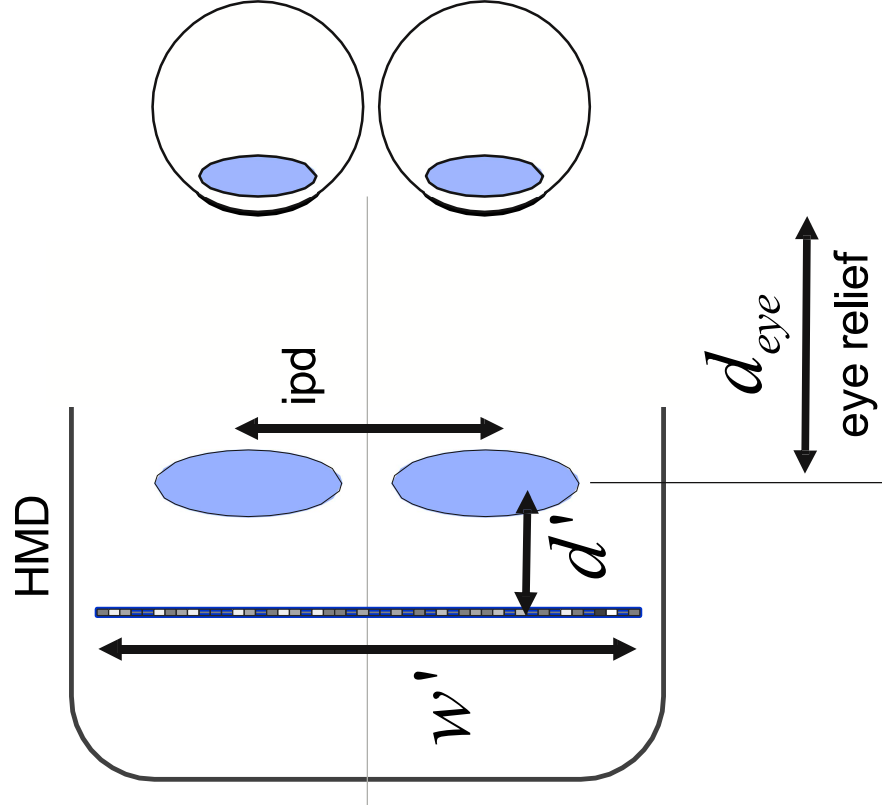
$z_{near}$

top

bottom

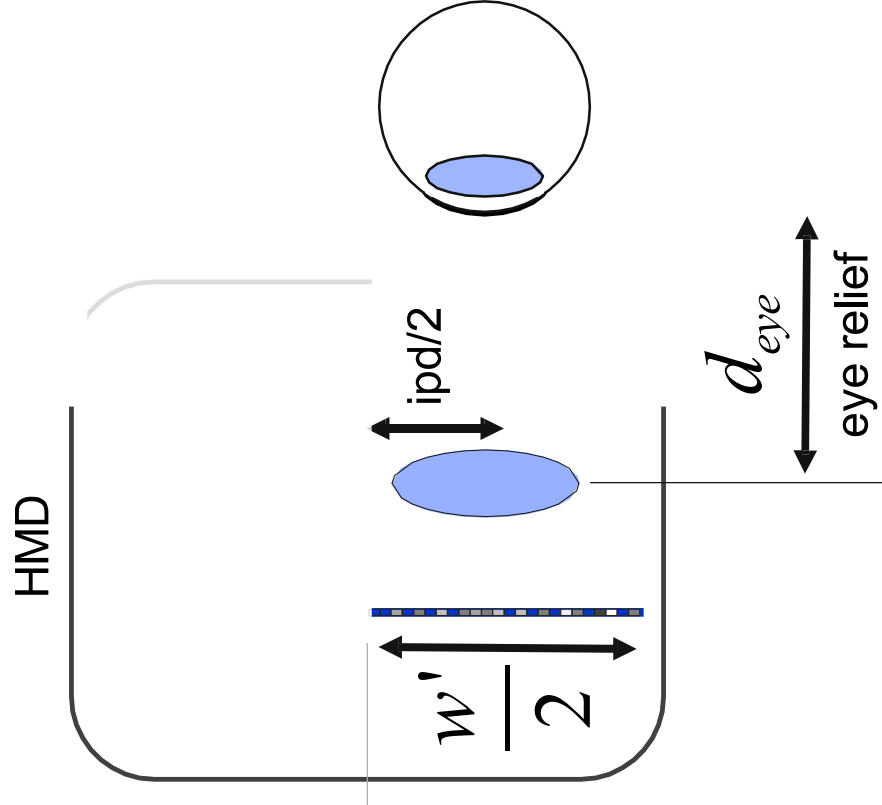
virtual image

# Image Formation



Top View

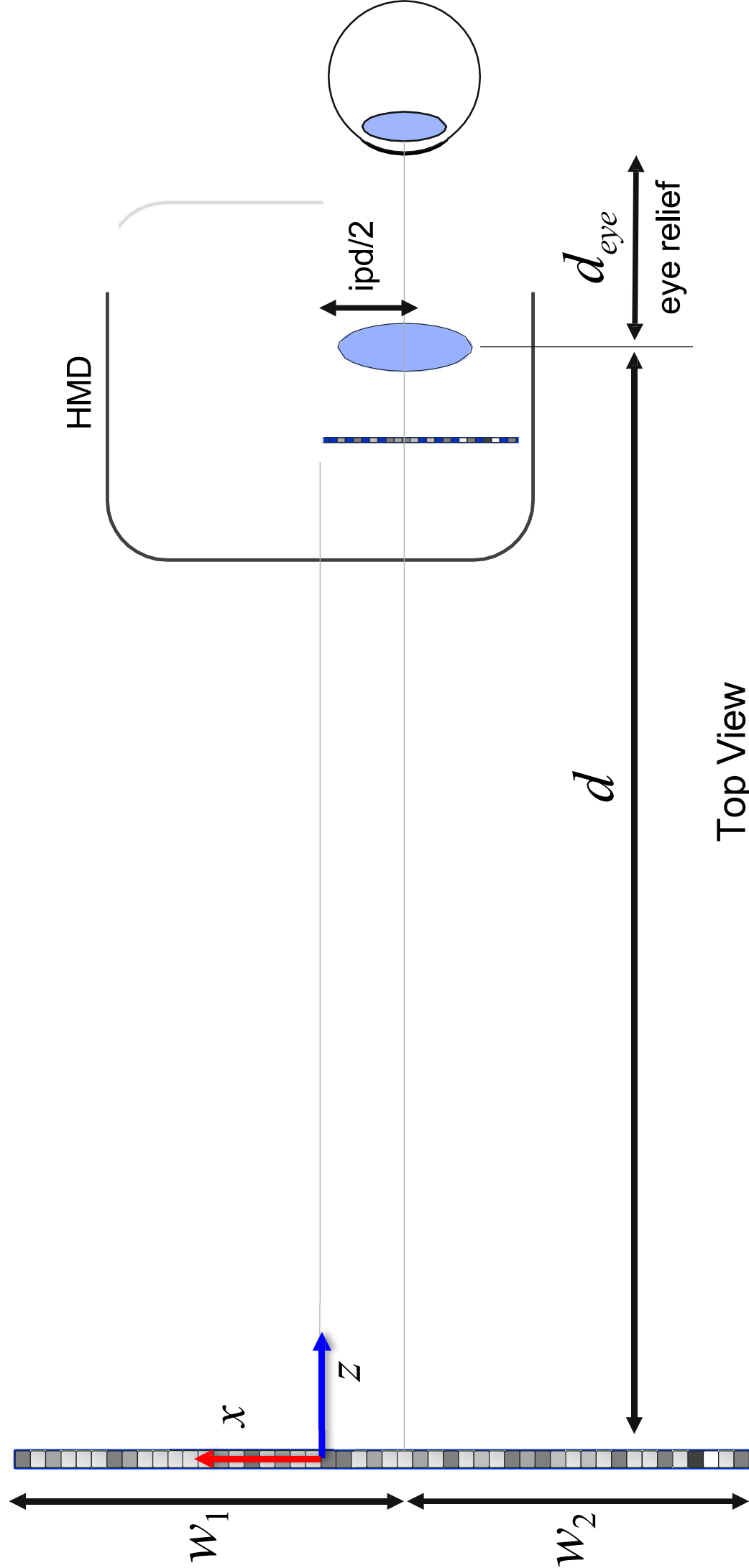
# Image Formation – Left Eye



Top View

virtual image

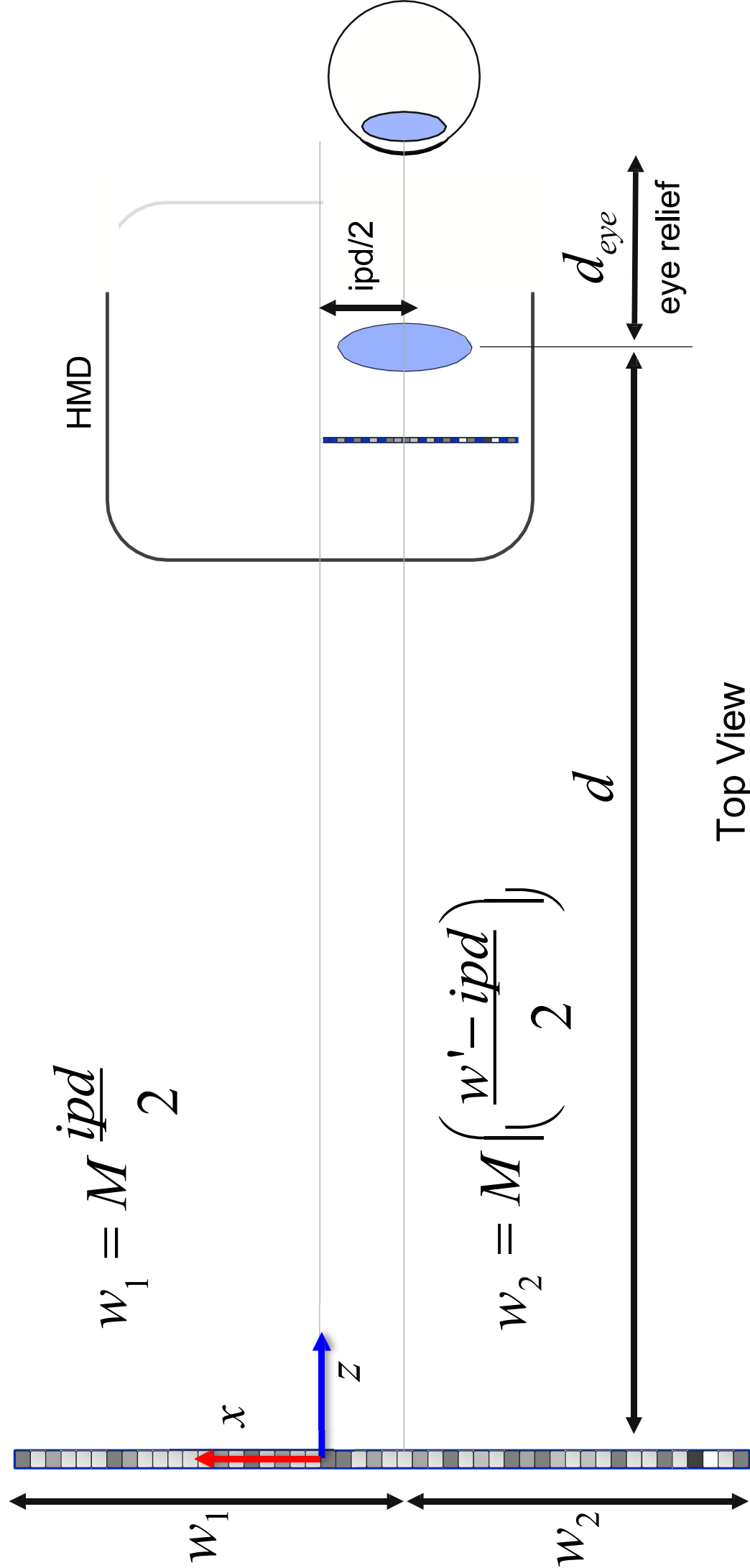
# Image Formation – Left Eye





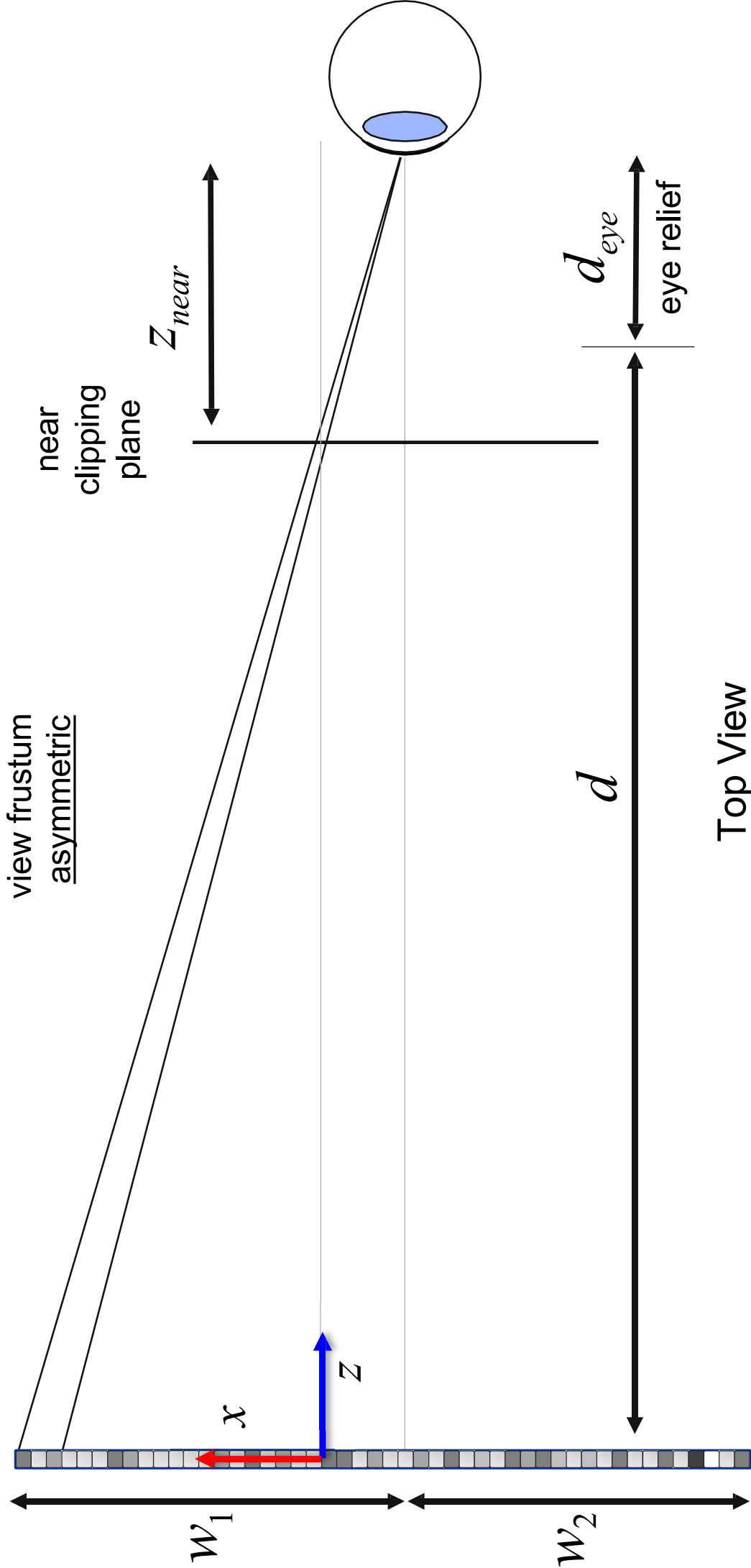
virtual image

# Image Formation – Left Eye



virtual image

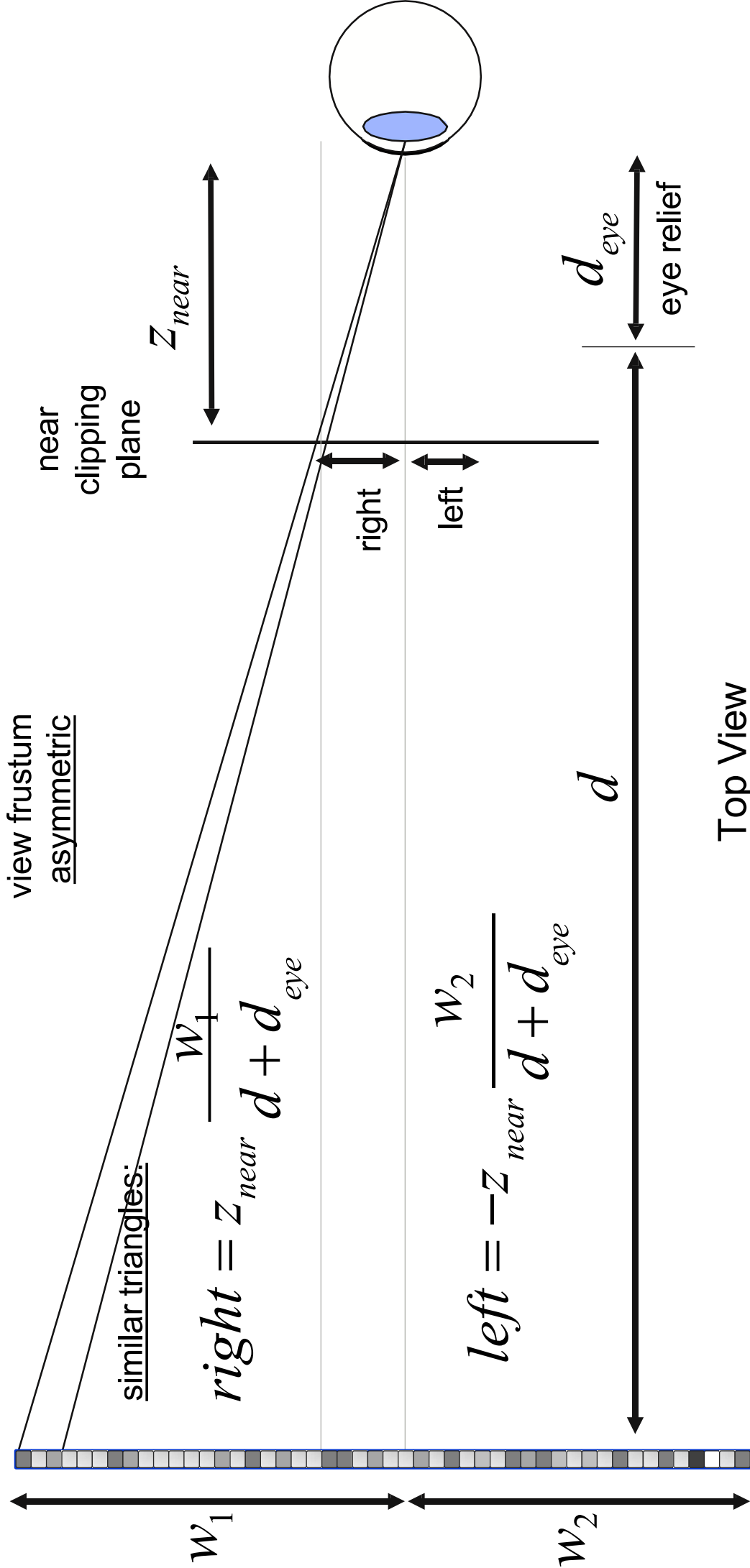
# Image Formation – Left Eye





virtual image

# Image Formation – Left Eye



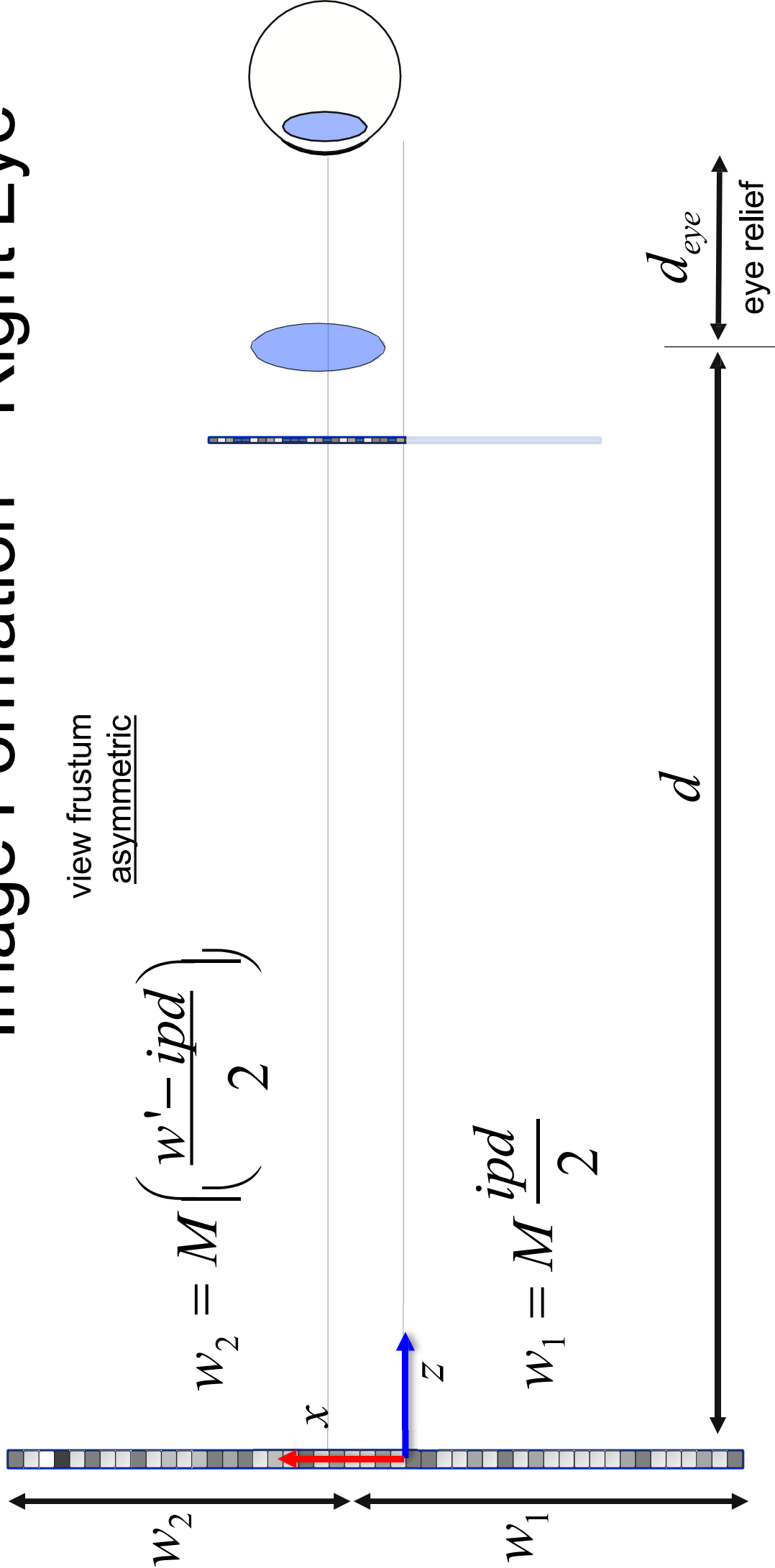
virtual image

# Image Formation – Right Eye

view frustum  
asymmetric

$$w_2 = M \left( \frac{w' - ipd}{2} \right)$$

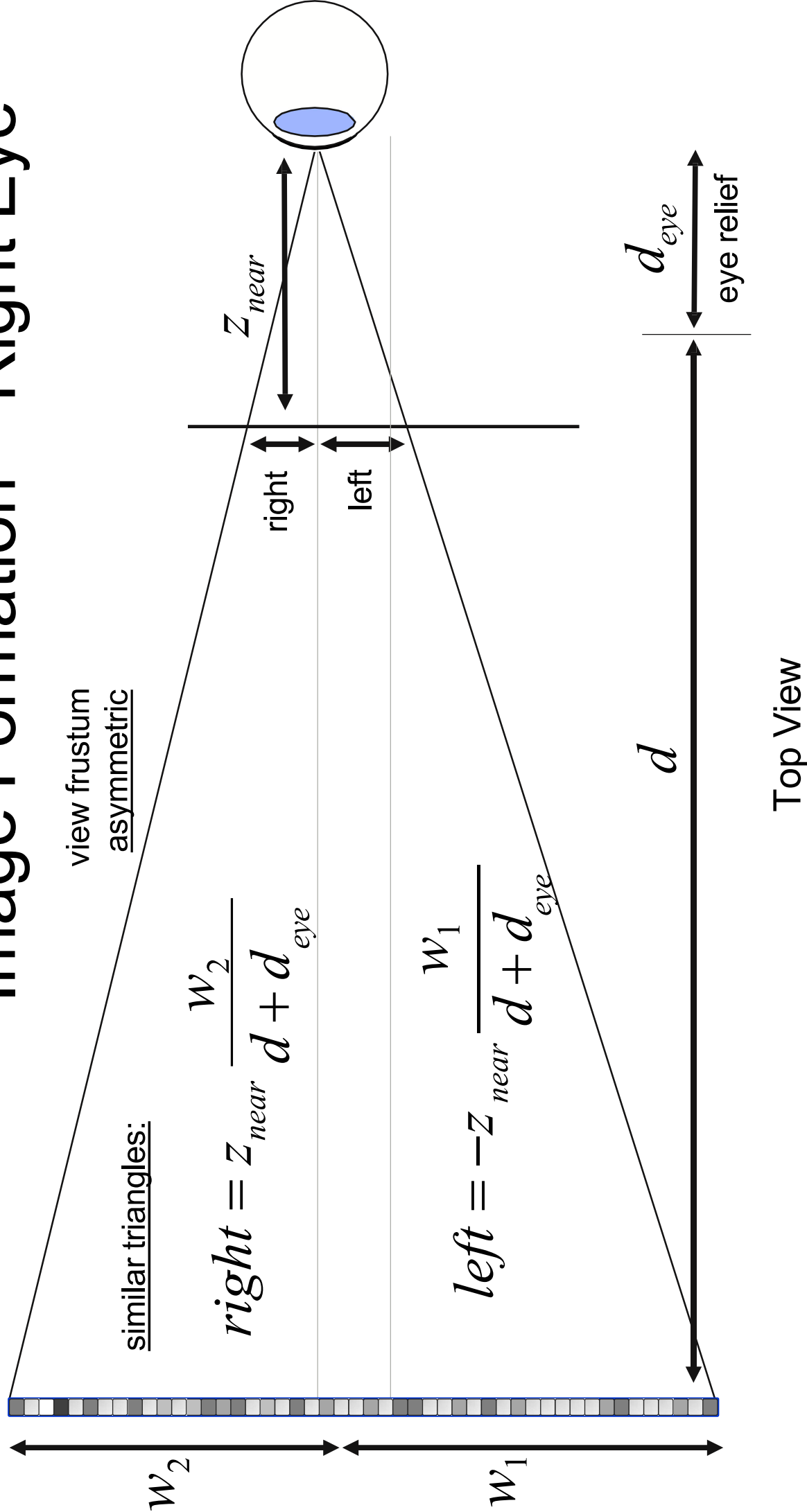
$$w_1 = M \frac{ipd}{2}$$



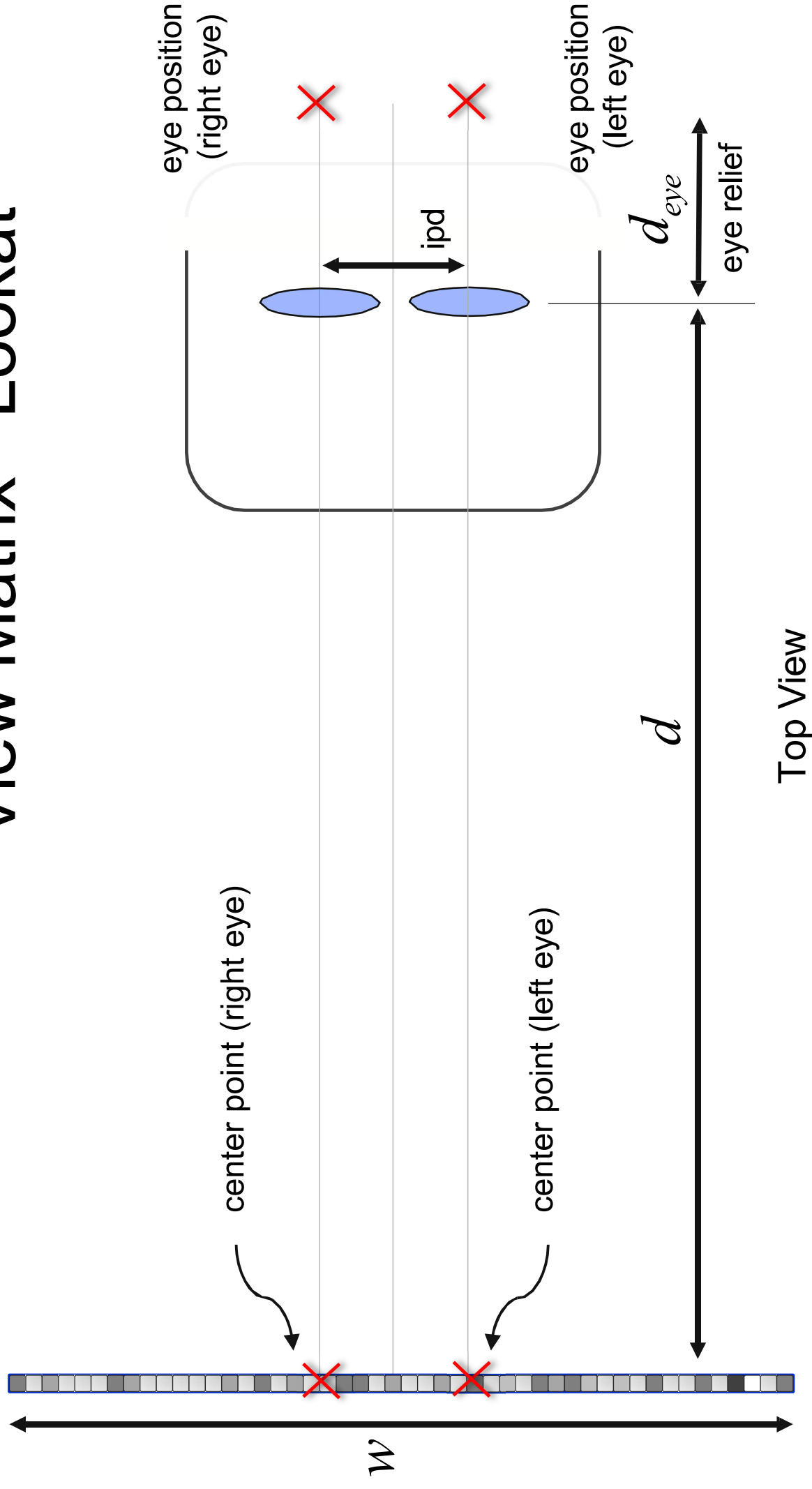
Top View

virtual image

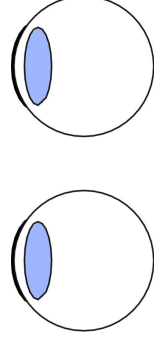
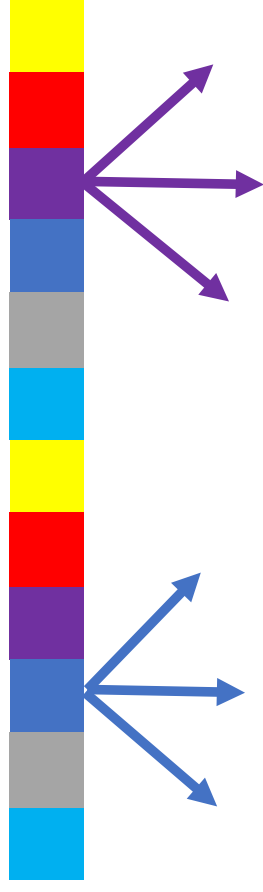
# Image Formation – Right Eye



# View Matrix - Lookat

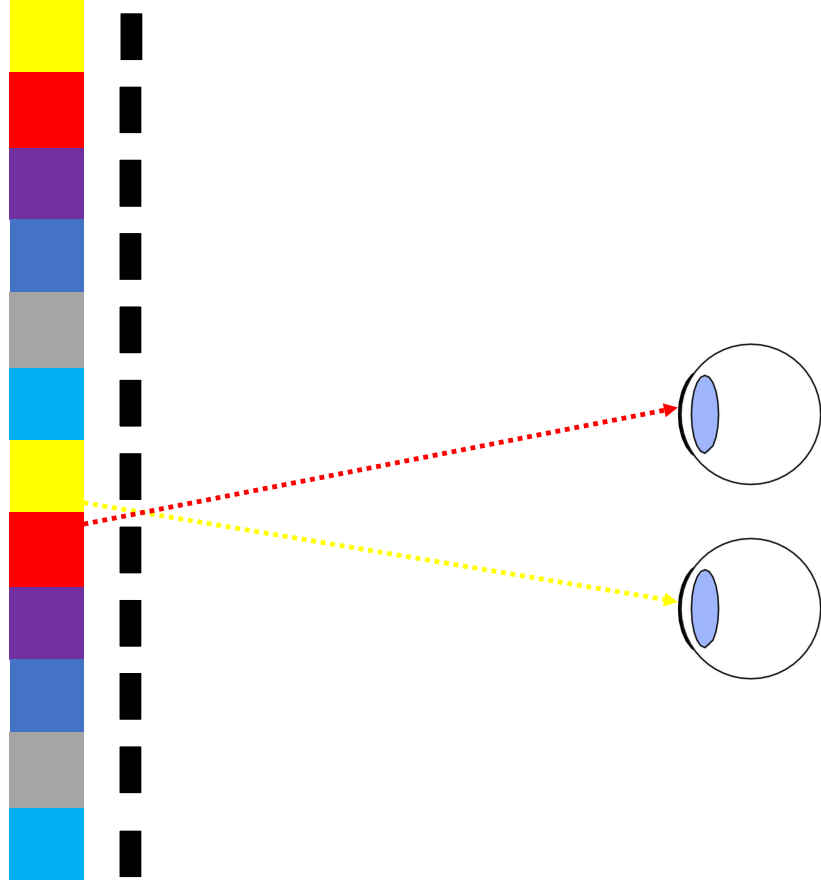


# Headset-Free Stereo

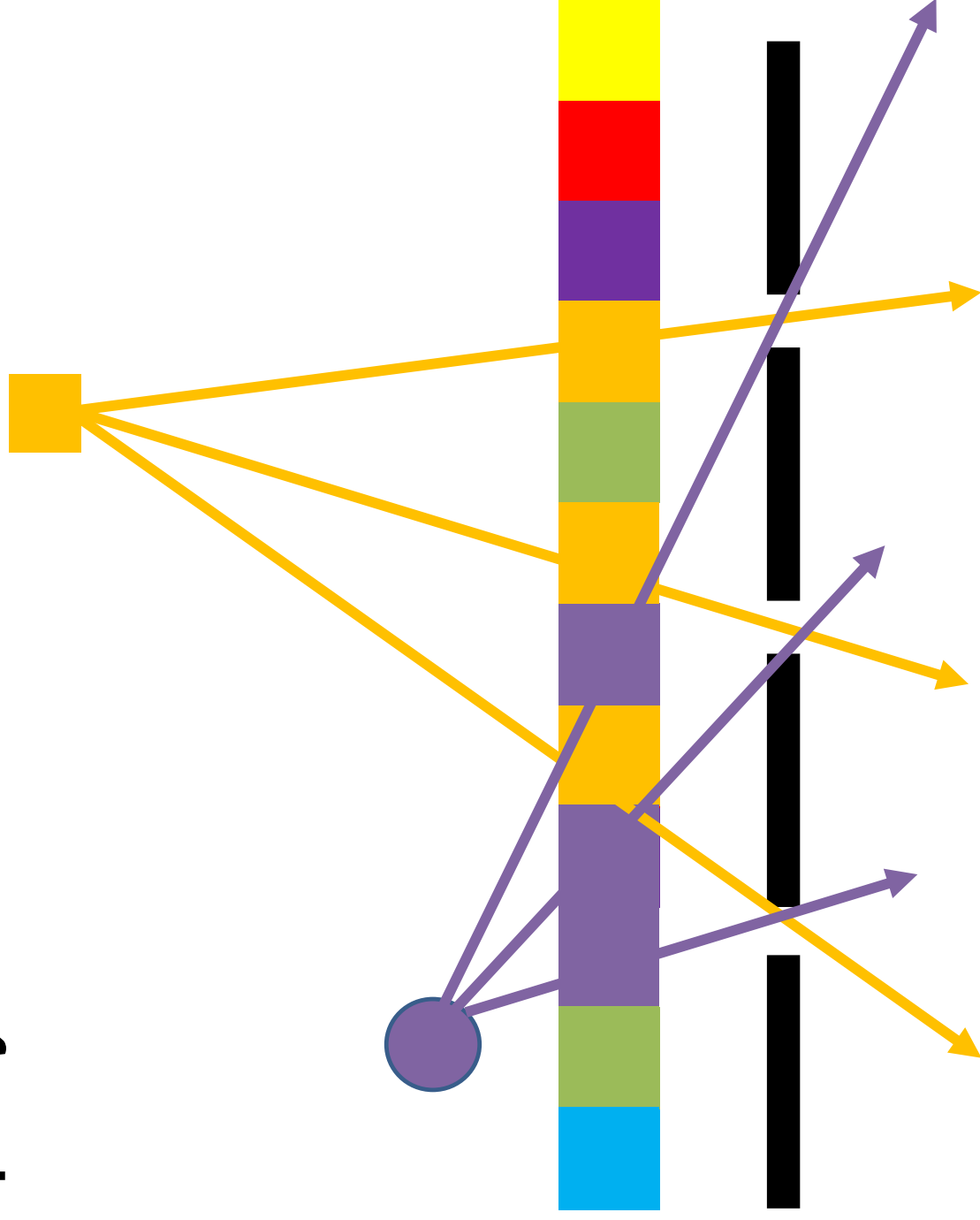




# Headset-Free Stereo



# Display with Accommodation





Perceptually-Guided Foveation for Light Field Displays  
*Qj Sun et al., SIGGRAPH Asia 2017*



Perceptually-Guided Foveation for Light Field Displays  
*Qi Sun et al., SIGGRAPH Asia 2017*





Perceptually-Guided Foveation for Light Field Displays  
*Qi Sun et al., SIGGRAPH Asia 2017*

# Light Field Displays



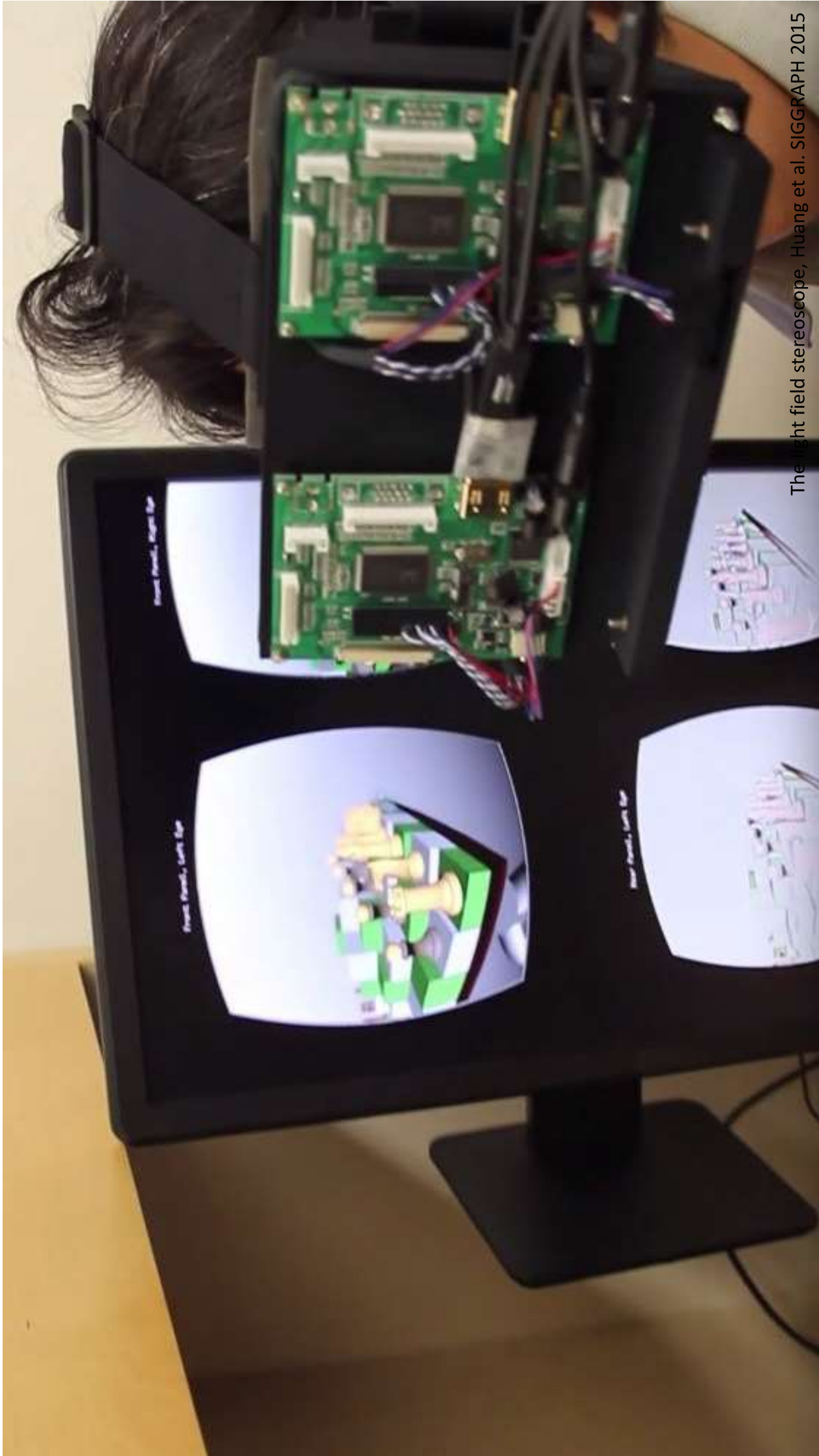
Perceptually-Guided Foveation for Light Field Displays  
*Qi Sun et al., SIGGRAPH Asia 2017*



# Light Field Displays



Perceptually-Guided Foveation for Light Field Displays  
*Qi Sun et al., SIGGRAPH Asia 2017*



The light field stereoscope, Huang et al. SIGGRAPH 2015