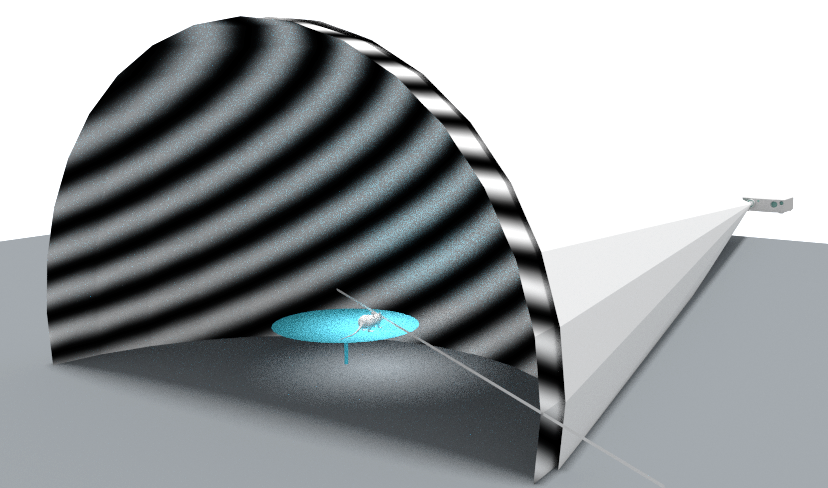
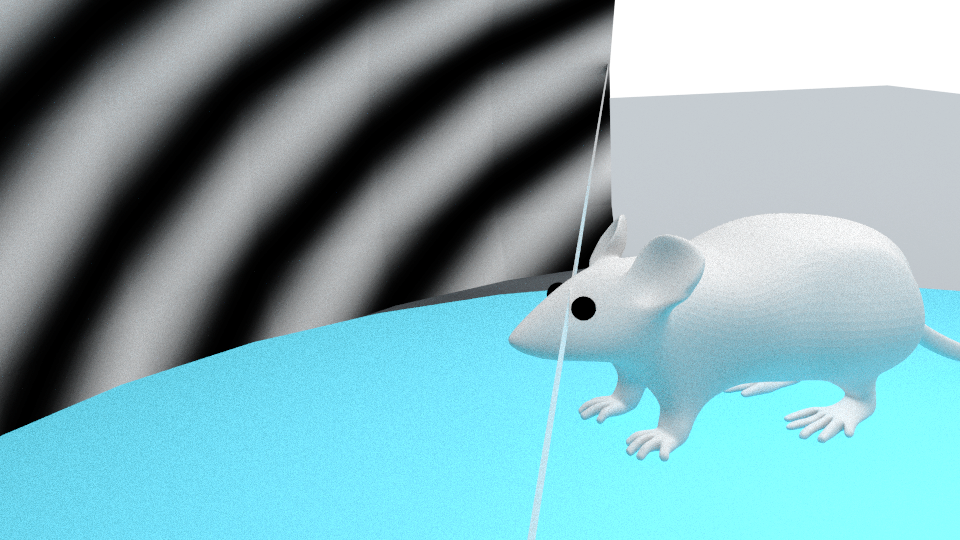
Immersive 180Hz UV Visual Stimulus Platform

Jay Borseth 2013.12.04



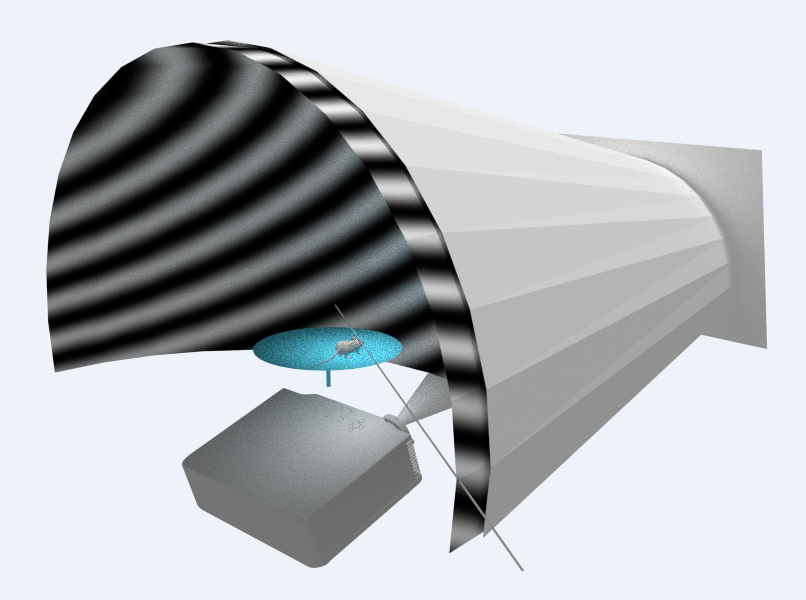


# Domes

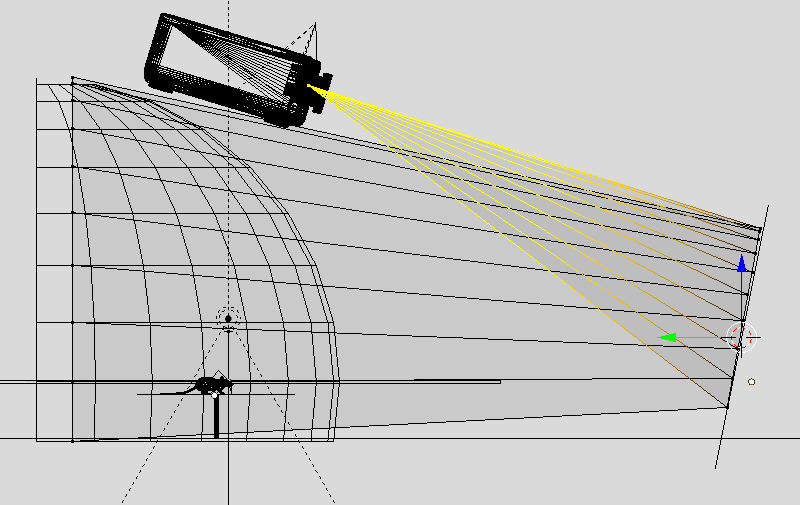
## 24” diameter, no mirrors

* Eye to dome: 11.2 cm
* 240 degree stimulation
* Dome to lens: 39.8” assuming LightCrafter 4500

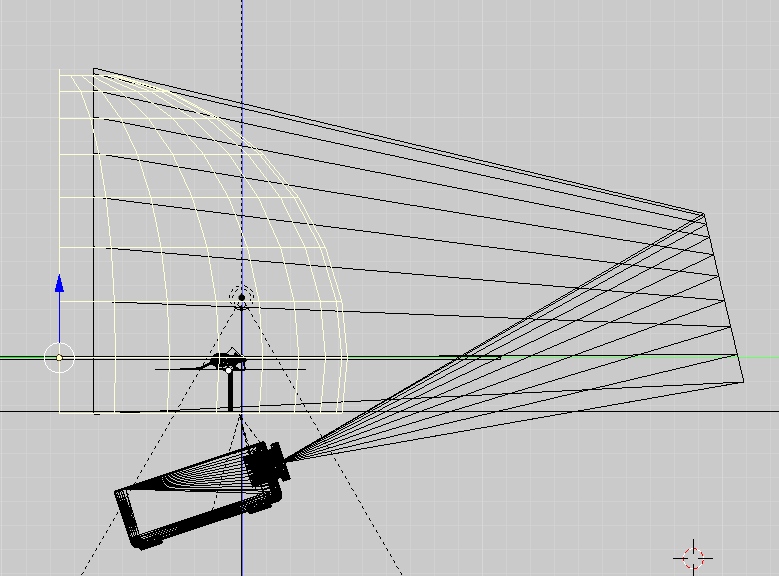
## 24” diameter, single mirror



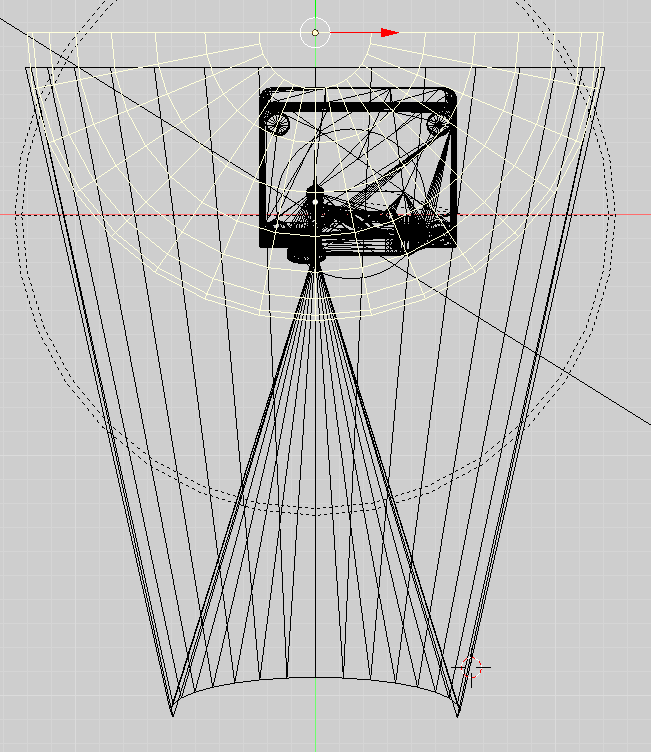
## 24” diameter, single mirror



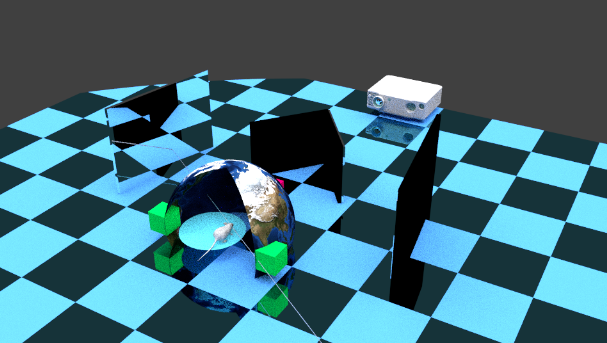
Folded light path, projector above: 29” deep (green) x ~18”high (blue) x 24” wide

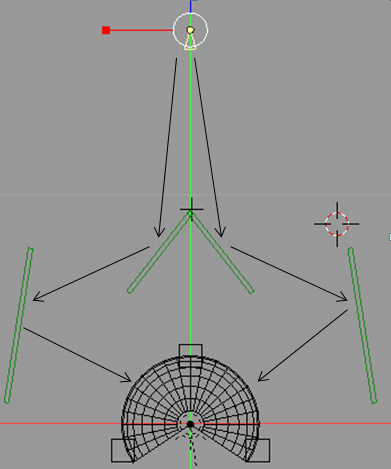


Folded light path, projector below: 29” deep (green) x 24”high (blue) x 24” wide

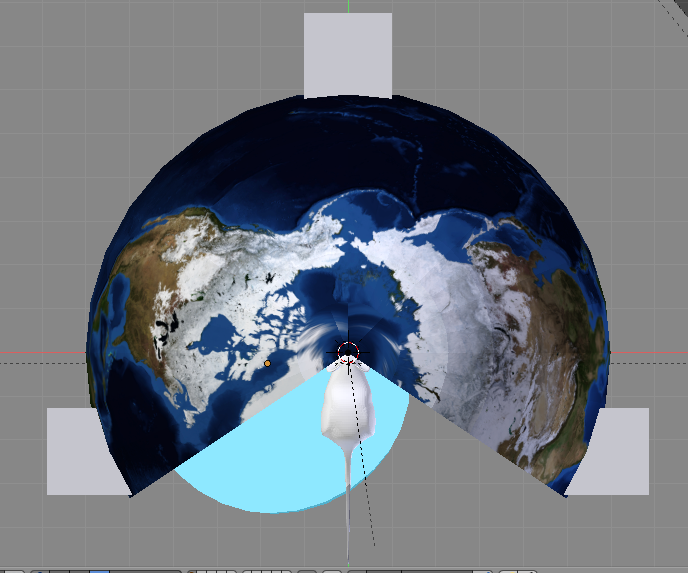


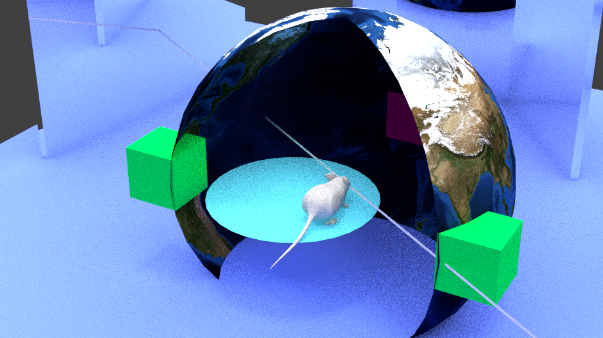
## 12” diameter, multiple mirrors



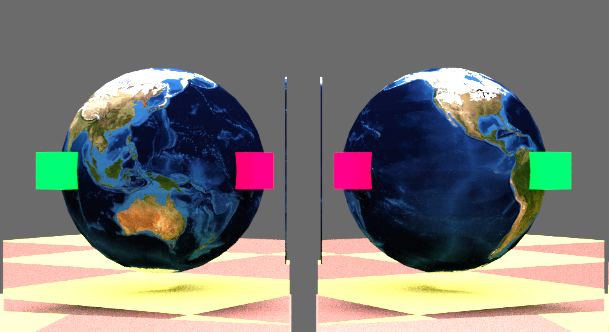


Projector at the top, mirrors are green  
32” wide, 32” deep, 10” high

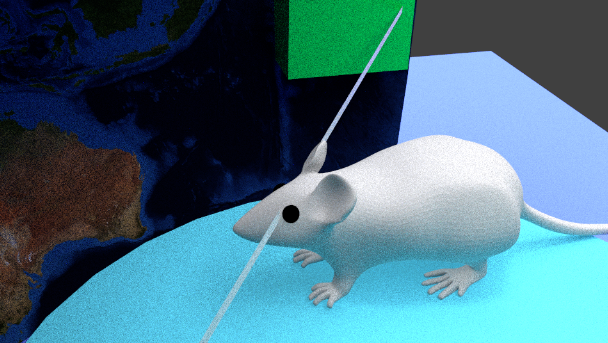




Eye to dome is 6” = 15.24 cm



View from projector



Floor is 4” below eye

### Projection Issues

Will the image be in focus over the entire surface since the light path lengths differ?

### Dome size, distance dome to projector for 1.66 throw angle (33.53 degrees beam angle)

|  |  |
| --- | --- |
| Dome Size | Projector to Dome |
| 12” | 19.96” |
| 18” | 29.88” |
| 24” | 39.84” |

# General Characteristics

## Two eye stimulus

* 240 degree visual stimulus
* 270 degree visual stimulus

## Spatial resolution

* 6 pixels per degree at equator of dome   
  0.95” DLP. 1080x1080 @180 degrees
* 5 pixels per degree at equator of dome   
  0.7”, 0.55”, 0.45” DLP. LCr4500 912x912 @180 degrees
* 3.3 pixels per degree at equator of dome   
  0.3” DLP. LCr3000 608x684 @180 degree

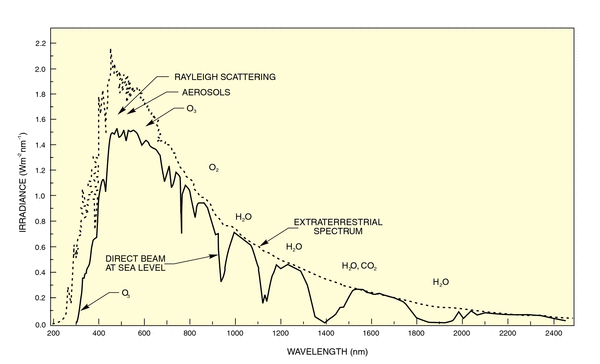
## Bits per pixel

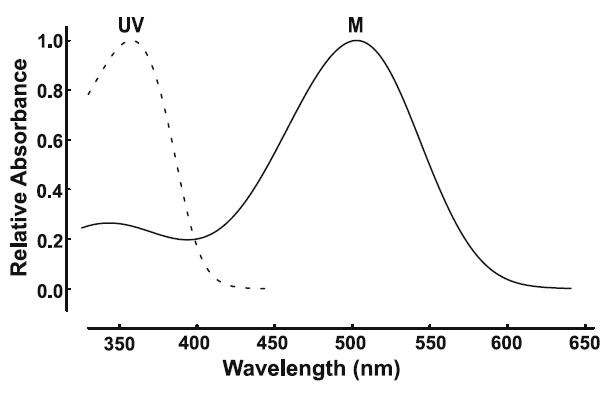
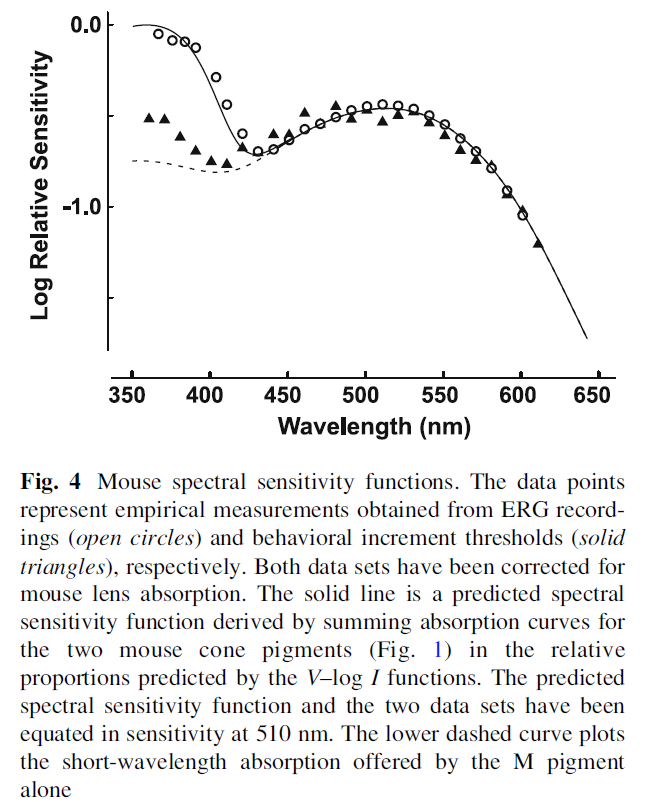
* 8 bits (implies higher end DLP chips, 0.7” and above)
* 7 bits (lower end DLP chips)

## Mouse platform

* Air bearing sphere
* Wheel

## Mouse eye sensitivity



## Visual Channels

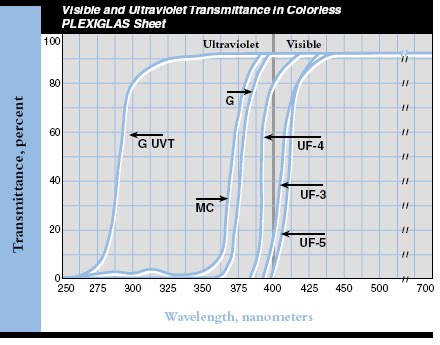


*C. palustris*  Panasonic GH-2, Coastal Optics 60 mm f/4 APO lens, daylight.

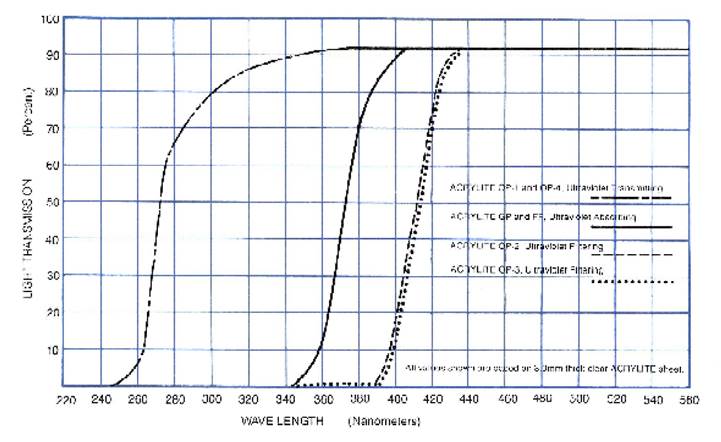
* One channel (UV & green together)
* Two channels (UV & green separate)
* Three channels (UV, blue, green)
* If only one channel, what is the relative proportion of UV/Green?
* If color source imagery is used, what is the mapping to monochrome?  
  Y = 0.2126 R + 0.7152 G + 0.0722 B (NTSC)
* Are other combinations possible, G/G/UV

## Typical Dome plastics

MC is the most common Plexiglas.



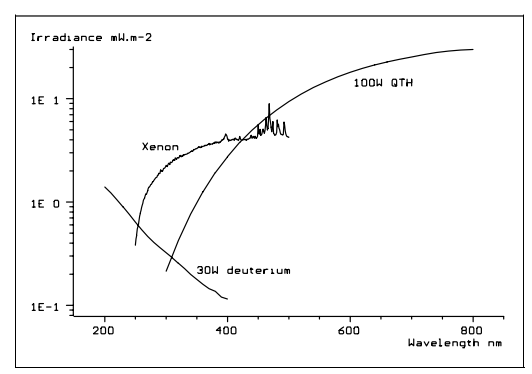
<http://www.cleardome.com/domes.htm> uses a comparable plastic called Acrylite FF which looks like:



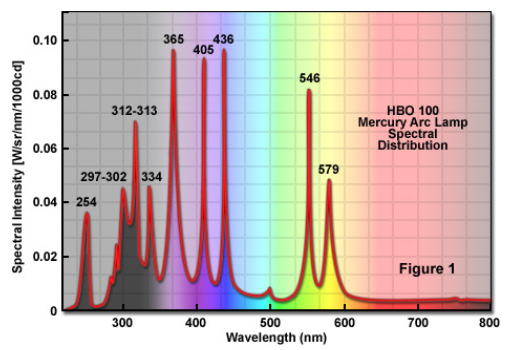
Solid line upwards at 340nm is Acrylite FF

## Light source

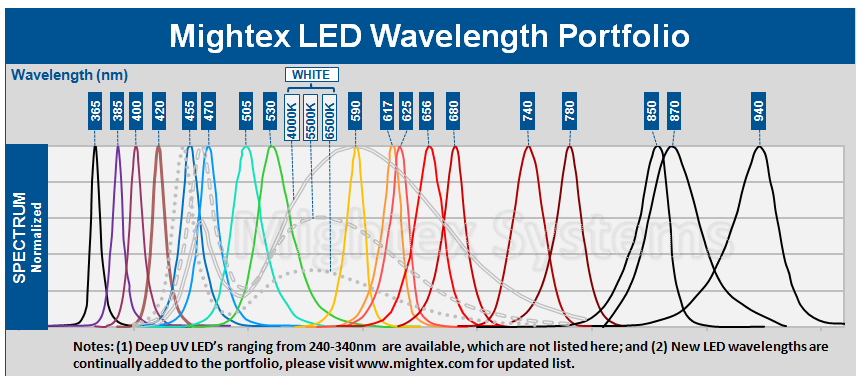
* Broad spectrum stimulus (Xenon lamp)



* HBO 100 Mercury Arc Lamp



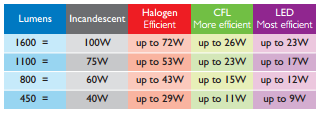
* Narrow spectrum (LEDs)



* Brightness range: maximum brightness of 20 mCd/m2

However, at ground level total sunlight power decreases to about 1000–1100 W/m2, and by energy fractions, is composed of 44% visible light, 3% ultraviolet (with the Sun at its zenith), and the remainder infrared.[[8]](http://en.wikipedia.org/wiki/Ultra_violet#cite_note-8)Thus, sunlight's composition at the zenith at ground level, per square meter, is about 527 W infrared radiation, 445 W [visible light](http://en.wikipedia.org/wiki/Visible_light), and 32 W UV.[[9]](http://en.wikipedia.org/wiki/Ultra_violet#cite_note-9)

Ordinary window glass passes about 90% of the light above 350 nm, but blocks over 90% of the light below 300 nm.[[12]](http://en.wikipedia.org/wiki/Ultra_violet#cite_note-12)[[13]](http://en.wikipedia.org/wiki/Ultra_violet#cite_note-13)[[14]](http://en.wikipedia.org/wiki/Ultra_violet#cite_note-14)



# Stimulus

## Framerate

* 60 Hz
* 120 Hz
* 180 Hz

## Movie Playback

* 60 Hz
* 120 Hz
* 180 Hz

## Patterns and Stimulus

* Grayscale Gradients
* Color Gradients / Objects
* Object scaling size to simulate depth
* Object occlusion
* Maximum number of objects displayed simultaneously
* 3D

# DLP

## Chipsets, resolutions, and Maximum Pattern Rates

Machine generated alternative text: Portfolio Overview
DLP Chipset Chipset Array Size Micromirror Micromirror Pitch Maximum Pattern
Components Orientation (pm) Rates
0.3 WVGA DLP3000 608x684 Diamond 7.6 4,000 Hz (binary)
DLPC300 120 Hz (8-bd)
0.45 WXGA DLP4500 912x1140 Diamond 7.6 4,225 Hz (binary)
DLPC35O 120 Hz (8-bd)
0.55 XGA DLP5500 1024x768 Orthogonal 10.8 5,000 Hz (binary)
DLPC200 120 Hz (8-bit)
DLPA200
0.7 XGA DLP7000 1 024x768 Orthogonal 13.6 32,552 Hz (binary)
DLPC41O 1,900Hz(8-bit)
DLPR41 O
DLPA200
0.95 1080p DLP9500 1920x1080 Orthogonal 10.8 23,148 Hz (binary)
DLPC41O 1,700 Hz (8-bd)
DLPR41 O
DLPA200 (x2)

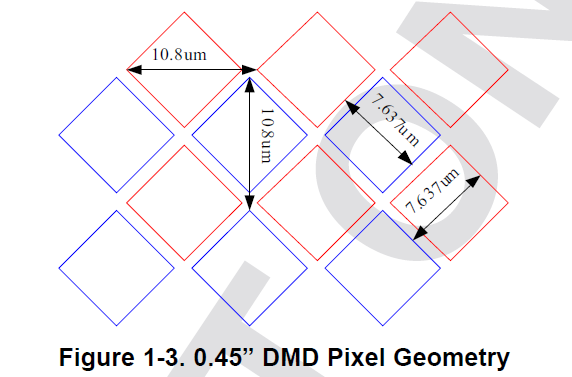
### DLP Prices

For just the micro-mirror chip itself

|  |  |
| --- | --- |
| DLP size | Qty. 1 price |
| 0.3” | $140 |
| 0.45” | $200 |
| 0.55” | $600 |
| 0.7” | $1100 |
| 0.95” | $4100 |

### DLP mirror geometry

Devices smaller 0.45” and smaller use a diamond geometry resulting in jagged vertical and horizontal lines. Larger devices use a rectangular mirror grid.

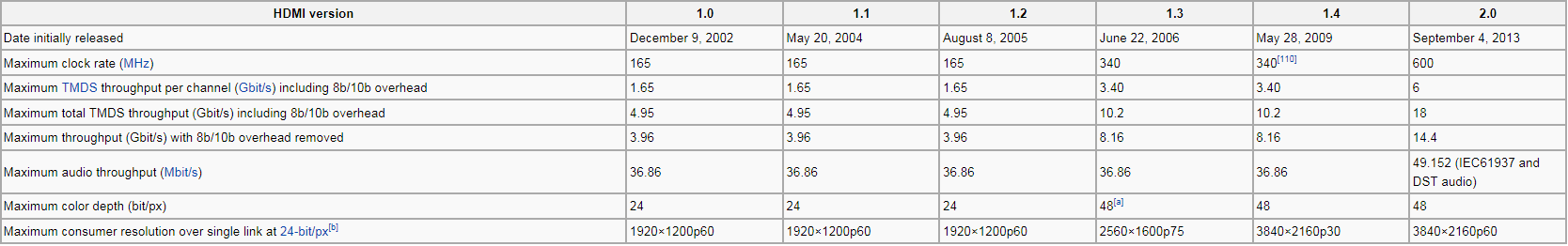


### DLP and UV

Problems with UV and DLP devices

* In many non-UV designed system there is a plastic lens called the “fly eye” in the light path which will yellow after just a day of high UV exposure.
* Optics typically have coatings which do not pass UV.
* Gas used between the cover and DLP mirrors acts as a lubricant for DLP mirrors and “thickens” with UV exposure. When it gets thick, the mirrors stop moving.

### HDMI / DVI connector bandwidths



Single link pixel clock: 340MHz - (1,920 × 1,080) @ 60 Hz with CVT-RB blanking (139 MHz)

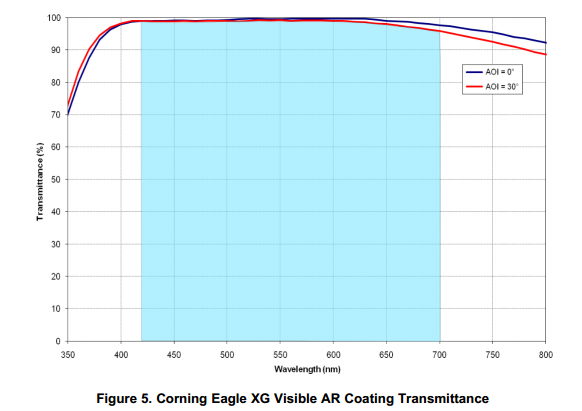
Dual link pixel clock: 680MHz - (1,920 × 1,200) @ 120 Hz with CVT-RB blanking (2 x 154 MHz)

## DLP window transmission

<http://www.ti.com/lit/an/dlpa031b/dlpa031b.pdf>

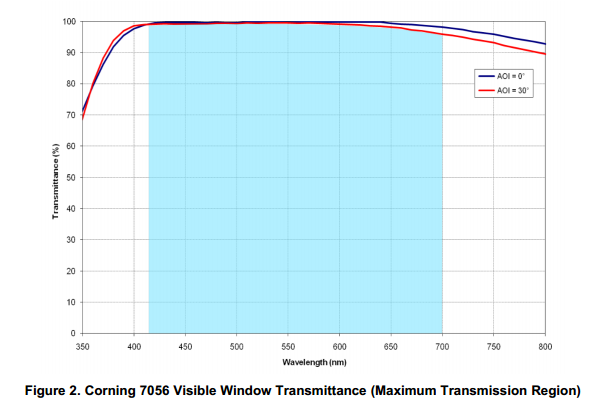
### DLP 0.17”, 0.33”, 0.55” (0.45 is unknown)

Corning Eagle XG <http://www.delta-technologies.com/downloads/Eagle%20XG.pdf>



### TYPE-A: 0.7”, 0.95”

Corning 7056



# DLP Hardware Options

## LC3000-PRO DLP Pico Projector with UV LED DLP Pico

<http://keynotephotonics.3dcartstores.com/LC3000-PRO-DLP-Pico-Projector-with-UV-LED-DLP-Pico-Projector_p_48.html>

$1450

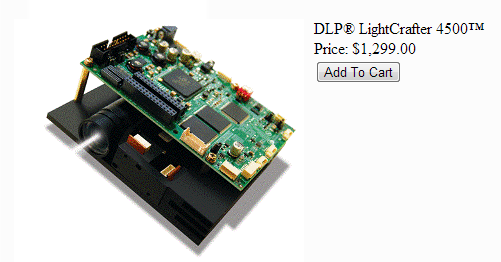


* 0.3” DLP
* 385, 400, 405 nm LED options. Replaces Blue LED with UV LED.
* 100 lumens (PRO with white LED), 50 lumens standard, UV not quoted
* ProjectorThrow ratio = 1.66
* Focus range 364mm to 2169mm (85.39 inches)
* width = distance / throw ratio
* 12” dome, dome to lens is 19”
* 18” dome, dome to lens is 29.88”
* 24” dome, dome to lens is 39.84”

### Issues

* 120 Hz @ 8-bits, 180 Hz @ 7-bits
* No spec given for UV output power
* No way to supply broadband light at 180Hz.

## LightCrafter 4500



* 0.45” DLP (912 x 1140)
* Brightness 150 lumen
* Throw ratio = 1.66
* Focus range 300mm to infinity
* width = distance / throw ratio
* 12” dome, dome to lens is 19”
* 18” dome, dome to lens is 29.88”
* 24” dome, dome to lens is 39.84”

### Issues

* Can’t substitute light modules.
* No way to supply broadband light at 180Hz.
* 120 Hz @ 8-bits, 180 Hz @ 7-bits
* Not rated for UV. “Fisheye” lens will yellow with UV exposure.

## LightCrafter Pro4500 for UV

<http://www.wintechdigital.com/product_s.asp?id=17>

$1975 (< $800 in high volumes)

* Same as regular LCr4500 with UV upgrades
* WinTechDigitial is manufacturer of LCr sold by TI
* New product, available end of Jan 2013 (30 units total manufactured)
* Pro model handles UV includes glass replacement for “flyeye” lens and different coating for the 20 other lenses in the light module.

### Issues

* No way to supply broadband light at 180Hz.
* 89.6 mm working distance lens! (designed for near field UV curing)
* Not yet available

### Contacts

* David Smith (Sales Mgr, Texas) 804 363-4266
* Charlie (David’s boss, Anaheim) 1-949-450-1014

## CEL5500-UV and CEL5500-Fiber

<https://www.dlinnovations.com/wp/?page_id=759>

~$6500



* .55” DLP (1024x768)
* UV specific model available.
* CEL model and Fiber model have identical output optics.
* 7mm Fiber Light-Guide available
* 37mm projection lens ring
* 1.8 throw ratio
* Red, green, blue, and white LEDs are available, with a typical output of 225 lm in the standard white package. The red LED has the brightest illumination of all the modules with a maximum of 245 lumens. The green has an LED output of 230 lumens and the blue LED provides up to 55 lumens. <https://www.dlinnovations.com/wp/?page_id=2048>

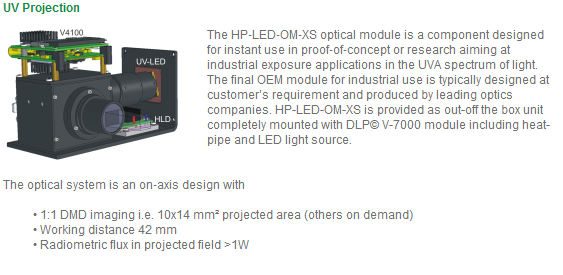
### Issues

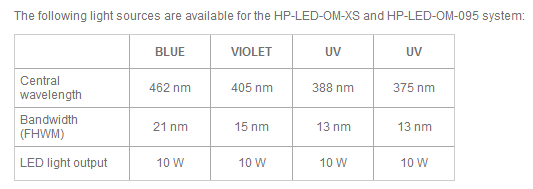
* UV LED version has only a single UV LED. No way to get green.
* Use Light Guide to supply broadband light source to all channels.

### Light Modules

Light Modules from Vialux for use with CEL5500

<http://www.vialux.de/HTML/optik_lichtq.htm#oben>





## X3 Machine Vision Solution with DLP 5500 (X3-PM55)

<http://keynotephotonics.3dcartstores.com/X3-Machine-Vision-Solution-with-DLP-5500-X3-PM55_p_14.html>

$3999



* .55” DLP (1024x769)
* No optics
* Can be converted to HDMI 8bit@180Hz monochrome for ~40K firmware development

### Issues

* Single link HDMI

### DepthQ 360 DLP Projector

<http://www.crsltd.com/tools-for-vision-science/displays/depthq-360-dlp-projector/nest/depthq-360-faq>  
Buy direct from: <http://www.depthq.com/specifications.html>  
Based on: <http://www.infocus.com/projectors/office-projectors/infocus-in2110-projector-series/infocus-in2116-projector>

$4995



* 0.55” DLP (1024x768)
* 360 Hz native projection using 120Hz from display controller. Will not run at 60Hz input.
* Developed in partnership with Howard Hughes Medical Center / LightSpeed / InFocus / TI
* Based on InFocus 2116, they just flash the FPGA and remove the color wheel.
* 2400/ 3600 Lumens
* Min image size 26”
* Min projection distance 3.94’

### HHMI

* Anthony Leonardo at HHMI Janelia Farm Research Campus ([leonardoa@janelia.hhmi.org](mailto:leonardoa@janelia.hhmi.org)) was the researcher responsible for getting LightSpeed, TI, and InFocus to jointly develop the DepthQ 360 DLP Projector in 2007 / 2008.
* HHMI paid $150K for customization of commercial InFocus IN2116 projector.
* HHMI purchased 40 of 50 units and probably 100 total were sold.
* InFocus IN2116 is out of production. Remaining stock is unknown.
* Cambridge Research Systems is just a reseller.
* Customization consists of removal of color wheel and reprogramming FPGA to not do 2x color wheel RGBW conversion but just present RGB as separate temporal grayscale images.
* TI performed FPGA programming. They retain the rights to this code, and apparently neither HHMI nor LightSpeed have the source.
* Each lab at HHMI further modifies the DepthQ 360 for optics customization, laser light guide in some cases, stereoscope micro-lens.
* Some labs are using Blender Game Engine for stim creation.
* They have custom rendering package called StimGL written in C++/OpenGL which performs grayscale to RGB24 packing. Uses unmodified graphics drivers. Sounds similar in capabilities to PsychoPy. Anthony said he would forward the source code.

.

### References

DragonFly <http://zoology.ou.edu/pdf_documents/Neuromunch/Gonzalez-Bellido_et_al_2013.pdf>

### Contacts

Dan Lawrence 206 290-0251 [dan@lightspeed.com](mailto:dan@lightspeed.com)

[dan.lawrence@lightspeeddesign.com](mailto:dan.lawrence@lightspeeddesign.com)>

Leonardo, Anthony [leonardoa@janelia.hhmi.org](mailto:leonardoa@janelia.hhmi.org) led design project at HMMI

## DLi3000 Digital Light Innovations

<https://www.dlinnovations.com/wp/?page_id=750>

$

* 0.7” (1024x768) or 0.95” (1920X1080) DLP
* No optics included, but light fiber and LED options available
* Integrated DVI connector

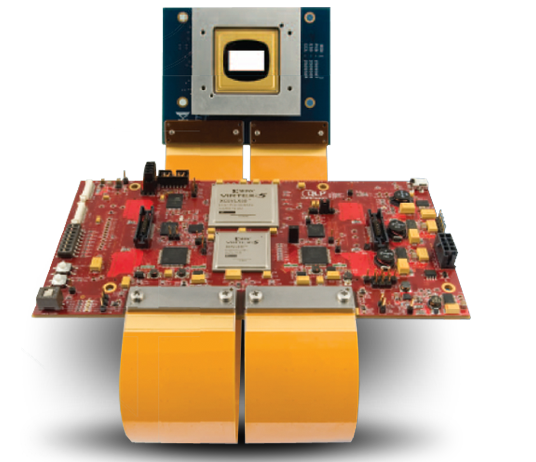
### Issues

* Single link HDMI via D2D DVI Interface Expansion card (Silicon Image Sil1161 DVI receiver max is 165 Mhz)

## DLi4110 Digital Light Innovations

<https://www.dlinnovations.com/wp/?page_id=932>

$

* 0.7” (1024x768) or 0.95” (1920X1080) DLP
* No optics included, but light fiber and LED options available

### Issues

* Single link HDMI via D2D DVI Interface Expansion card (Silicon Image Sil1161 DVI receiver max is 165 Mhz)

## VPixx ProPixx

<http://www.vpixx.com/products/visual-stimulus-displays/propixx-lite.html>

$31K



* 0.95” DMD, (1920 x 1080)
* 180 Hz native projection (3 channels!)
* Brightness: 600 lumens
* Run any software application without modification at 180Hz

### Issues

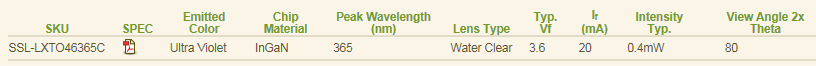
* $31K

# UV LED Sources

## Lumex 355, 365, 377, 385, 405 nm

<http://www.lumex.com/en/products>





## LED Engin, 365 nm

<http://www.mouser.com/ds/2/228/LZ1-00UV00-257812.pdf>



365nm UV LED with industry highest flux performance

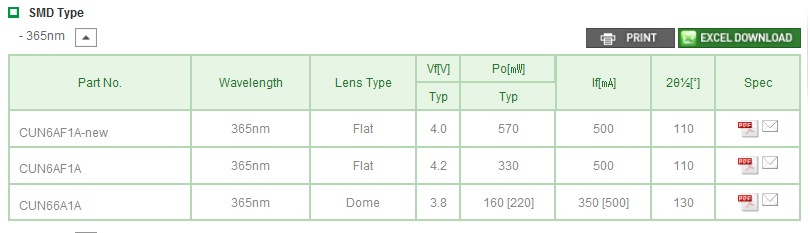
Up to 1000mW flux output at 2.8W power dissipation

Ultra-small foot print – 4.4mm x 4.4mm

## Seoul VioSys, 365, 375, 385, 395 nm



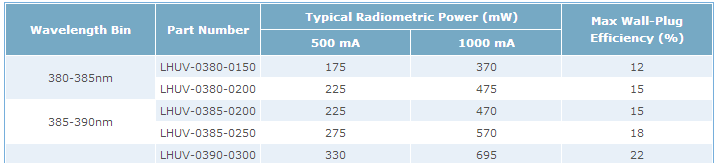
<http://www.socled.com/en/product/categorys.asp?catecode=1002003>



## Philips Luxeon

<http://www.philipslumileds.com/products/luxeon-uv>

* 2.2mm2 micro footprint
* 1A max drive current



# Software

## Operating System

* Windows
* Mac
* Linux

## Applications

* PsychoPy
* matlab
* visionegg
* other