

# Non-Telecentric DGP Reference Design


May 17<sup>th</sup>, 2022

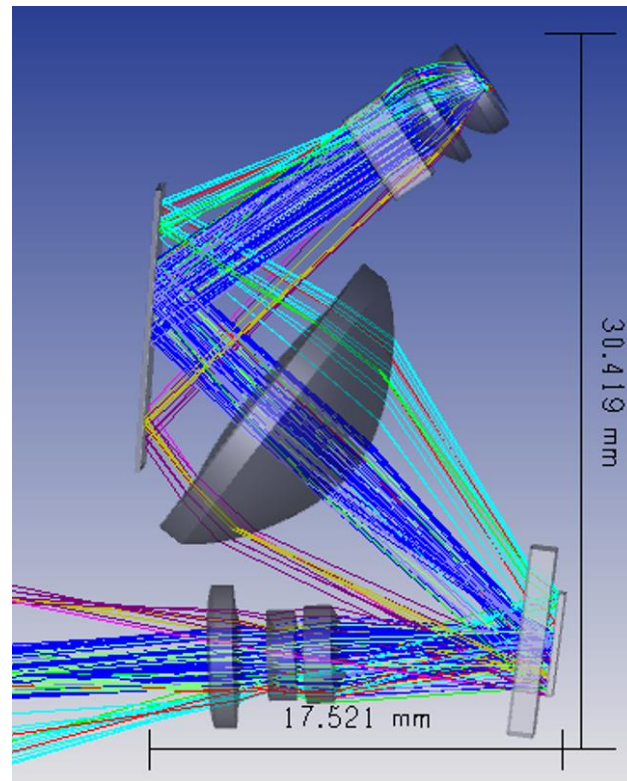
# Presentation Notes

- Please use this document as a reference only
- Designs shown in this document are preliminary
- No tolerance analysis or thermal analysis were performed
- Designs intended to be used as a starting point

# DLP2021-Q1 Non-telecentric Design

## Design Specification:

- DLP2021-Q1 (0.2" 588x330 )
- LED: WICOP UHL 1X1  SEOUL SEMICONDUCTOR
- F/2.4 Non-telecentric projection lens
- Image Diagonal: 54cm
- Projection distance: 1000mm
- Projection lens offset : 69%
- Illumination aoI on DMD: 32.7deg
- MTF>20% @2 pixel resolution (all fields)
- Optics only engine volume: 18mm x 30 mm x 9mm  
4.86cc
- Total Lumen Output: 87lm@1A
- Similar lux as .2" and .3" EVM



# Light Source



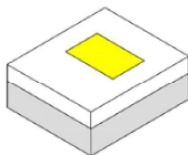
SEOUL SEMICONDUCTOR

WICOP UHL

High reliability and High quality of light

**High-Power LED for Automotive**

WICOP UHL 1x1



**LED Die Size: 0.6mm x 0.9mm**

**Max coupling efficiency ~96% @F/2.4 for .2"**

**Assuming 70 Deg LED collection angle, 10% overfill**

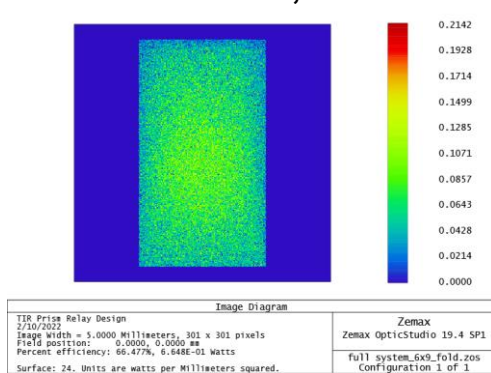
## Performance Characteristics

Table 1. Electro Optical Characteristics,  $I_F = 1.0A$ ,  $T_a = 25^\circ C$

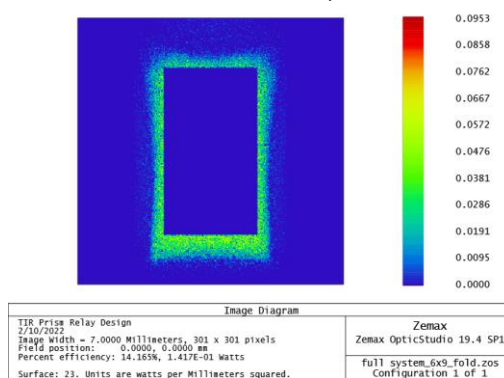
Parameter	Symbol	Min	Typ	Max	Unit
Forward Voltage	$V_F$	-	3.20	3.50	V
Luminous Flux	$\Phi_V$	275	-	-	lm
Color Coordinates	$CIE\ x$	0.33			
	$CIE\ y$	0.35			
Viewing Angle	$2\theta$	120		deg. [ ° ]	
Electrical Thermal resistance	$R_{th\ JS\ el}$	-	2.8	-	K / W
Real Thermal resistance	$R_{th\ JS\ real}$	-	3.8	-	K / W

# Optical Efficiency

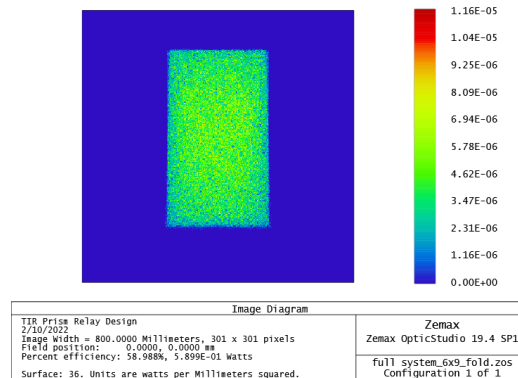
## DMD Plane, 66%



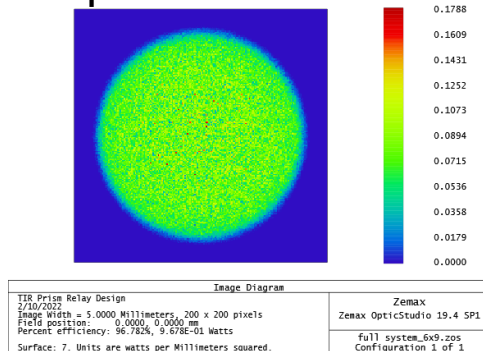
## DMD Overfill, 14%



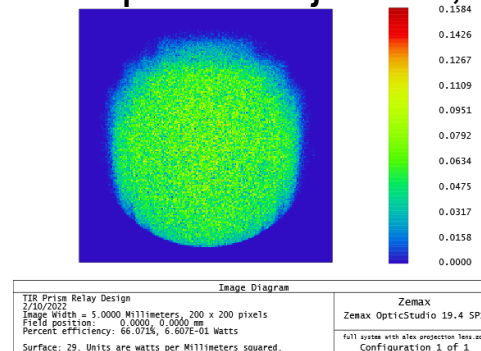
## Image Plane, 59%



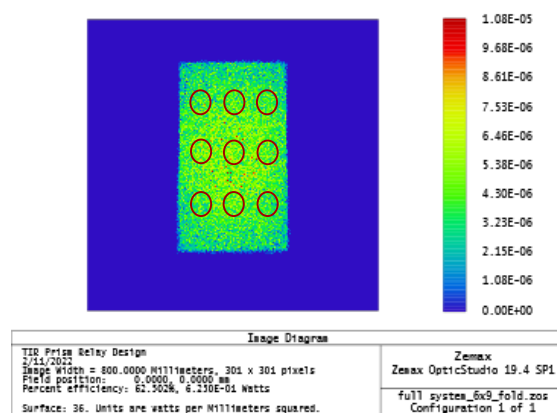
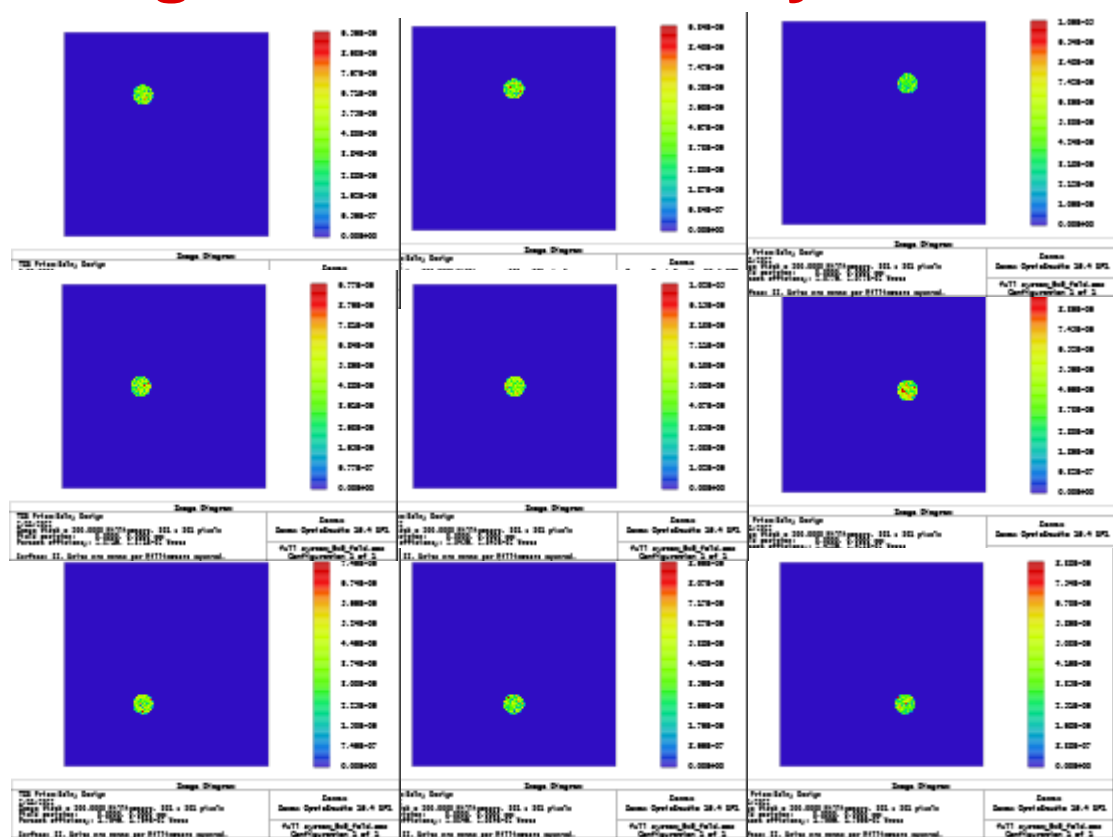
## Pupil @ illumination 97%



## Pupil at Projection, 66%



# Image Plane Uniformity



9 Points

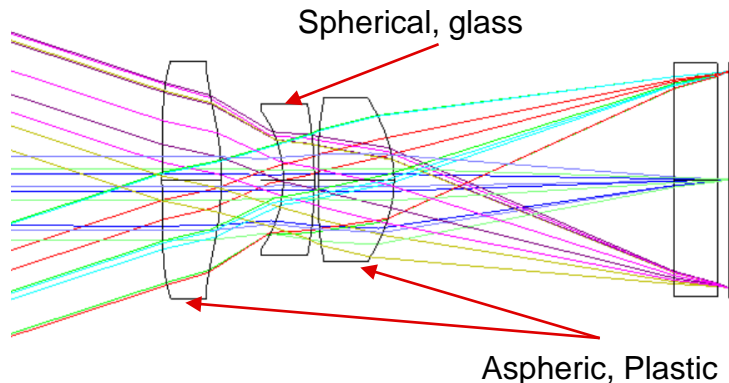
81%	90%	80%
88%	100%	86%
74%	83%	74%

Based on equal distance 40mm  
radius spot at 9 points

# Lumen Budget Estimation

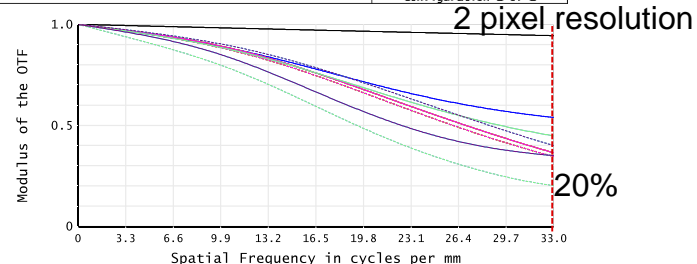
Illumination	WICOP UHL 1X1		
DMD	DLP2021-Q1 (0.2" 588x330 )		
	TI assumption		
	Efficiency factor	Lumens	Comments
Lumens out of color balanced LED		275	Estimated White lumens at 1A, 3.2V
Transmission			
Collimator lenses	0.96	264	Transmission – AR coating losses
Fly's Eye	0.93	246	Fly's eye estimated transmission
Illumination relay lens	0.98	240	AR coating loss
Illumination Fold	0.97	233	
Avg DMD efficiency	0.67	156	DMD efficiency (Mirror reflectivity + diffraction + fill + Transmission)
Projection lens (3 lenses)	0.94	147	Transmission of projection lens from coatings, field lens loss already calculated above
<b>transmission overall efficiency (avg)</b>	<b>0.53</b>	<b>147</b>	
<b>geometric overall efficiency</b>	<b>0.59</b>	<b>87</b>	
<b>overall efficiency (avg)</b>	<b>0.32</b>		
<b>Total Lumens</b>		<b>87</b>	Max brightness achievable (estimated)
System efficiency achieved (lm/Welec)		27 lm/W	Efficiency may be higher at lower lumen levels

# Projection Lens\_3pc



- F/2.4
- Image offset: 69%
- Throw ratio: 2.1
- Projected image size: 468mm x 276mm
- Projection distance: 1000mm
- MTF>20% @33lp/mm (all fields, 2 pixel resolution)
- Distortion<0.2%

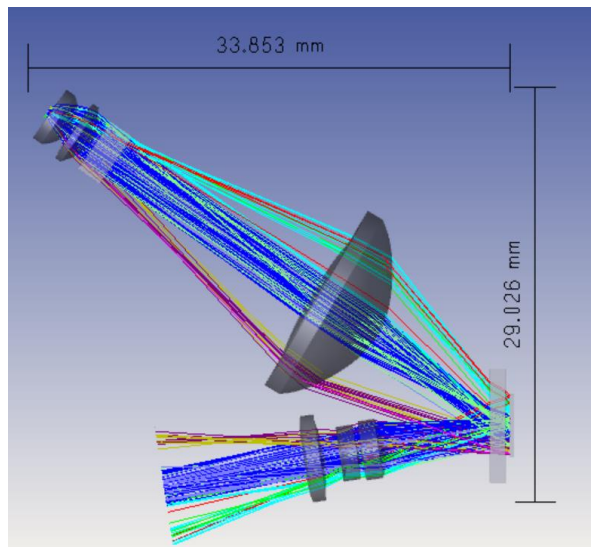
<b>PLASTIC PROJECTION LENS</b> 2/10/2022 Field: 4.55 w 2.56 h Millimeters Image: 4.24 w 2.38 h Millimeters Maximum distortion: 0.2047% SMTA TV distortion: 0.2407% Scale: 1.000X, Wavelength: 0.5870 $\mu$ m	<b>Zemax</b> Zemax OpticStudio 19.4 SP1 plens_3_pupil4.4.zos Configuration 1 of 1
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<b>Polychromatic Diffraction MTF</b> PLASTIC PROJECTION LENS 2/10/2022 Data for 0.4860 to 0.6560 $\mu$ m. Surface: Image Legend items refer to Field positions											
01-01, 1.041e-Sagittal -1.2400, -2.9700 mm-Sagittal -1.2400, -2.9700 mm-Sagittal -1.2400, -2.9700 mm-Sagittal						02-02, 1.041e-Sagittal -1.2400, -2.9700 mm-Sagittal -1.2400, -2.9700 mm-Sagittal -1.2400, -2.9700 mm-Sagittal					
03-03, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential						04-04, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential					
05-05, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential						06-06, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential -0.0000, 0.0000 mm-Tangential					

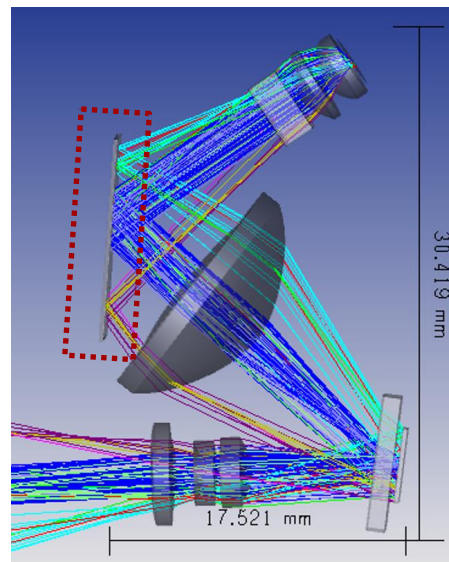



# Optical Engine Volume



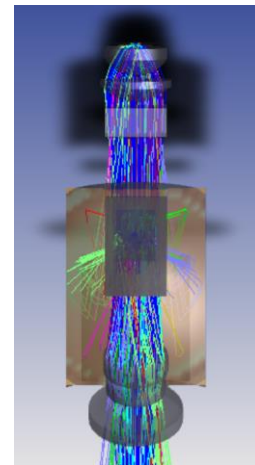
34mm x 29mm x 9mm  
8.87cc

Reduce volume  
by adding a fold  
mirror to the  
illumination

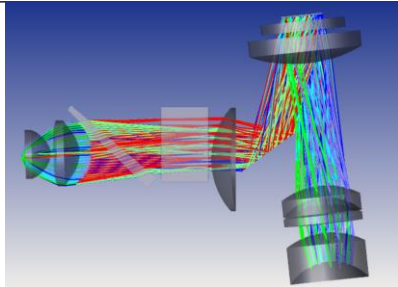
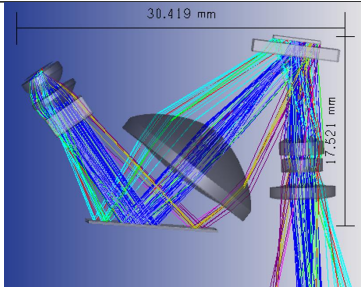


18mm x 30 mm x 9mm  
4.86cc

Side view



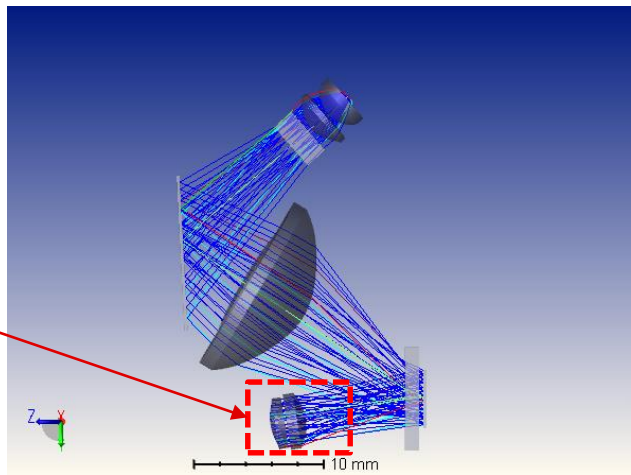
# Non-Telecentric V.S Field Lens Design

Designs	Field Lens	Non-telecentric
Layout		
Dimension	31mmx24.5mmx9mm	18mmx 30mmx 9mm
Total Volume	6.8cc	4.9cc
Element Count	9	8 or 7(2pc plens)
	2 collimating lenses, 1 flyeye, 1 relay lens, 1 folding mirror, 1 field lens, 3 projection lenses	2 collimating lenses, 1 flyeye, 1 relay lens, 1 folding mirror, 3 or 2 projection lenses
Geometric Efficiency	0.69	0.59 or 0.55(2pc plens)
Estimated Output	49lm @ 1.5W	87 or 83lm @ 3.2W
Pros and Cons	<p>Field Lens design is telecentric @DMD, better uniformity, slightly higher geometric efficiency, but will have a ghost image effect (not very noticeable when projected on ground);</p> <p>Non-telecentric design will have slightly lower geometric efficiency, worse uniformity at the bottom edge of the image, but is more compact with 1 or 2 less optical elements.</p>	

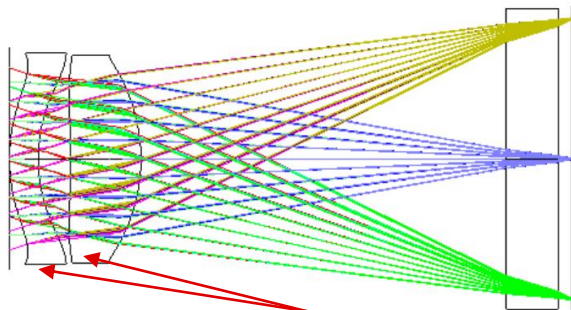
# Further Simplification on Projection Lens

- Projection lens count reduced from 3 to 2 elements
- Simulated projected images are compared between 3pc and 2pc design

2 element non-telecentric projection lens

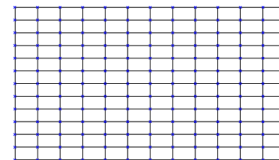


# Projection Lens\_2pc

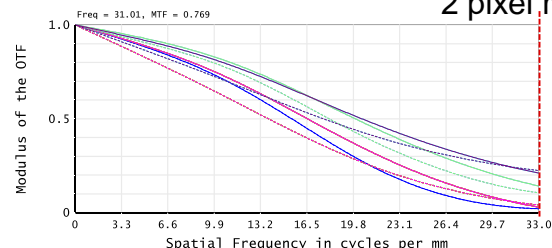


F/2.4  
 69% Offset  
 TR 2.1  
 Projected Image size: 484mm x 273mm  
 (557mm diagonal) @ 1000mm projection distance  
 MTF > 40% @ All field (4x4 pixel resolution)  
 Distortion < 0.3%

Aspheric, Plastic



5/16/2022 Field: 2.48 w 1.40 h Millimeters Image: 272.52 w 153.29 h Millimeters Maximum distortion: 0.2887% SMIA TV distortion: 0.2200% Scale: 1.000X, Wavelength: 0.5876 $\mu\text{m}$	Zemax Zemax OpticStudio 19.4 SP1 projection lens_simplified_2pc_real image_filed.ooo Configuration 1 of 1
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0.0000, 0.0000 mm-Tangential	0.0000, 0.0000 mm-Sagittal	-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal
-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal	-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal
-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal	-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal
-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal	-1.2400, 2.9700 mm-Tangential	-1.2400, 2.9700 mm-Sagittal

PLASTIC PROJECTION LENS 5/16/2022 Data for 0.4860 to 0.6560 $\mu\text{m}$ . Surface: Image Legend items refer to Field positions	Polychromatic Diffraction MTF Zemax Zemax OpticStudio 19.4 SP1 projection lens_simplified_2pc_real image.ooo Configuration 1 of 1
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# Image Simulation Comparison

Source

2pc

3pc

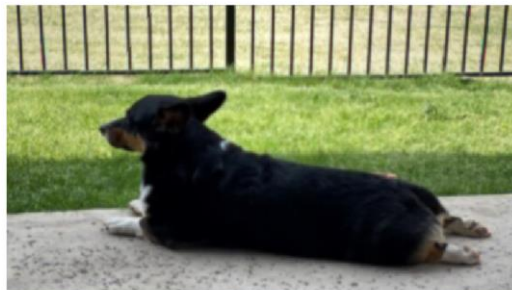


Image Simulation: Source Bitmap		Image Simulation: Geometric Aberrations		Image Simulation: Geometric Aberrations	
5/12/2022 Bitmap is 330 pixels high, 588 pixels wide. Bitmap file is dog_pic.jpg.	Zemax	5/16/2022 Object height is 2.4800 Millimeters. Field position: 0.0000, 0.0000 mm Center: chief ray Image size is 485.7544 W x 272.6173 H (Millimeters)	Zemax Zemax OpticStudio 19.4 SP1 projection_lens_flipped.zos Configuration 1 of 1	5/16/2022 Object height is 2.4800 Millimeters. Field position: 0.0000, 0.0000 mm Center: chief ray - relative illumination cannot be computed Image size is 516.5753 W x 289.9147 H (Millimeters)	Zemax Zemax OpticStudio 19.4 SP1 projection_lens_flipped.zos Configuration 1 of 1

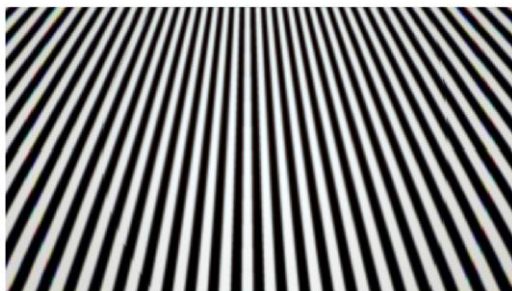
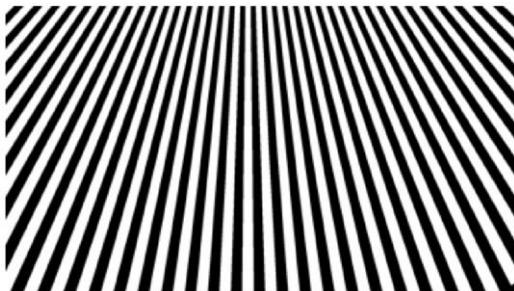
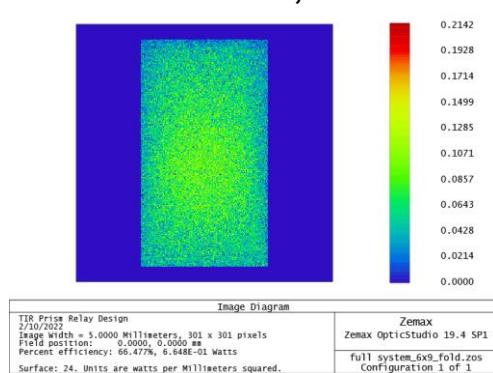


Image Simulation: Source Bitmap		Image Simulation: Geometric Aberrations		Image Simulation: Geometric Aberrations	
5/12/2022 Bitmap is 330 pixels high, 588 pixels wide. Bitmap file is Spoke_588x330.jpg.	Zemax	5/16/2022 Object height is 2.4800 Millimeters. Field position: 0.0000, 0.0000 mm Center: chief ray Image size is 485.7544 W x 272.6173 H (Millimeters)	Zemax Zemax OpticStudio 19.4 SP1 projection_lens_flipped.zos Configuration 1 of 1	5/16/2022 Object height is 2.4800 Millimeters. Field position: 0.0000, 0.0000 mm Center: chief ray - relative illumination cannot be computed Image size is 516.5753 W x 289.9147 H (Millimeters)	Zemax Zemax OpticStudio 19.4 SP1 projection_lens_flipped.zos Configuration 1 of 1

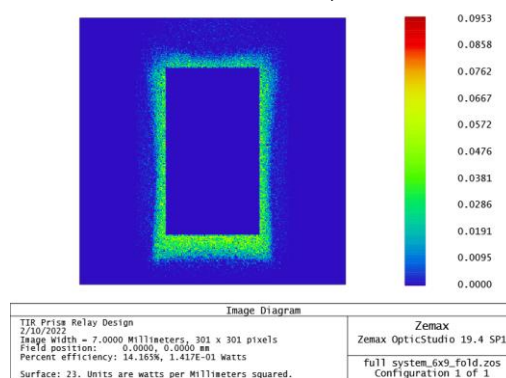


# Optical Efficiency

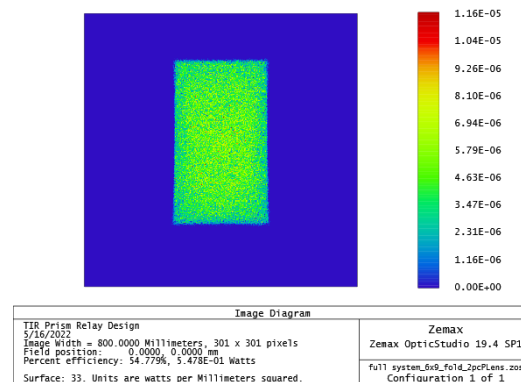
## DMD Plane, 66%



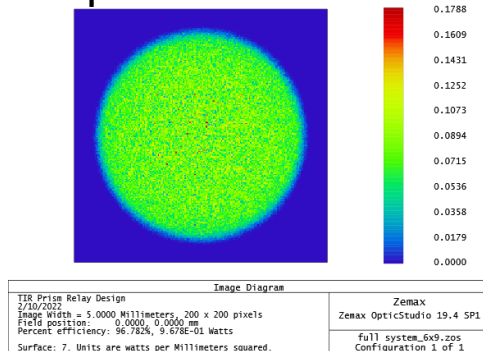
## DMD Overfill, 14%



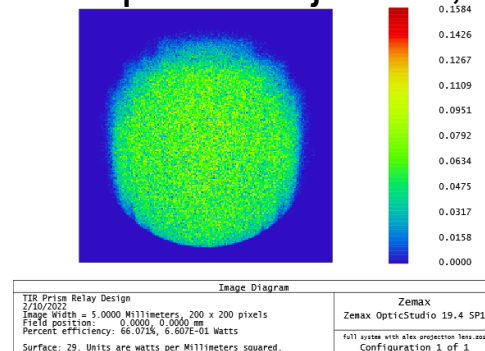
## Image Plane, 55%



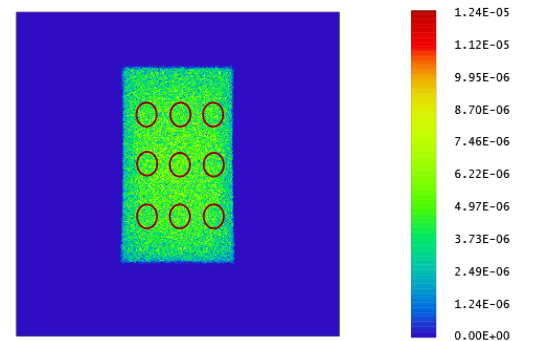
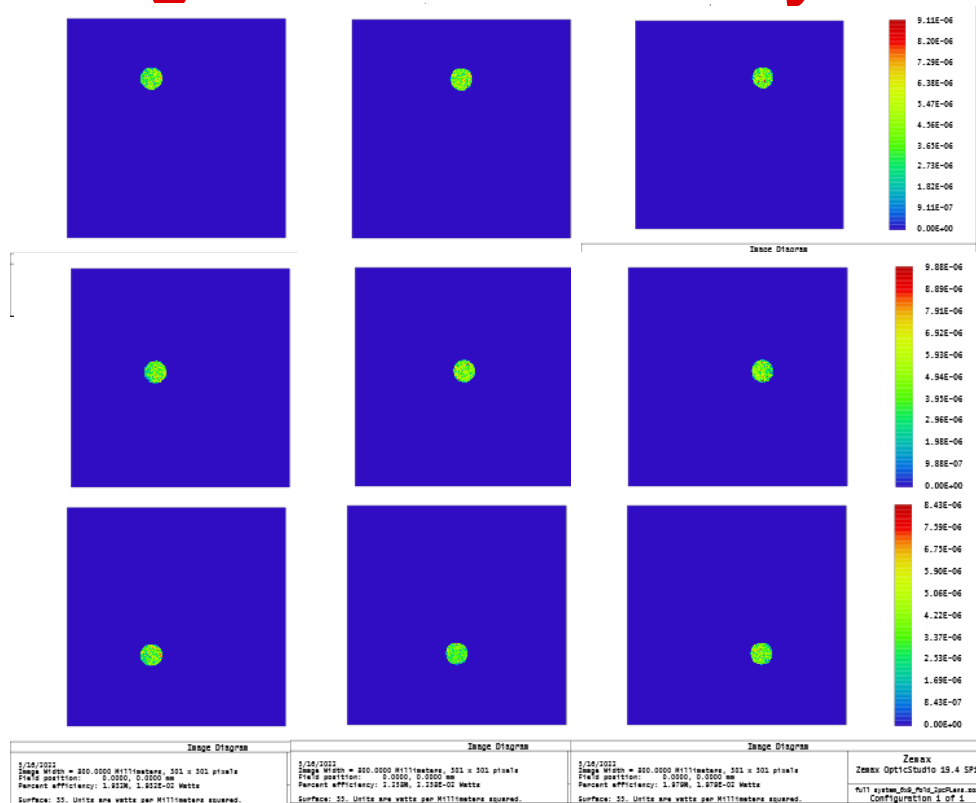
## Pupil @ illumination 97%



## Pupil at Projection, 66%



# Image Plane Uniformity



## 9 Points

80%	87%	81%
87%	100%	86%
74%	87%	76%

Based on equal distance 40mm  
radius spot at 9 points

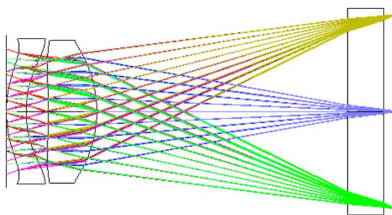
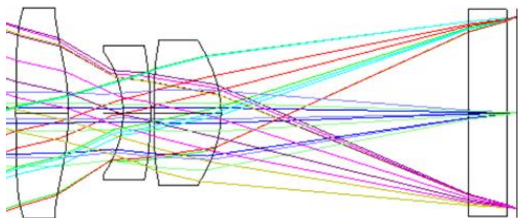
# Lumen Budget Estimation

Illumination	WICOP UHL 1X1		
DMD	DLP2021-Q1 (0.2" 588x330 )		
	TI assumption		
	Efficiency factor	Lumens	Comments
Lumens out of color balanced LED		275	Estimated White lumens at 1A, 3.2V
Transmission			
Collimator lenses	0.96	264	Transmission – AR coating losses
Fly's Eye	0.93	246	Fly's eye estimated transmission
Illumination relay lens	0.98	240	AR coating loss
Illumination Fold	0.97	233	
Avg DMD efficiency	0.67	156	DMD efficiency (Mirror reflectivity + diffraction + fill + Transmission)
Projection lens (3 lenses)	0.96	147	Transmission of projection lens from coatings, field lens loss already calculated above
<b>transmission overall efficiency (avg)</b>	<b>0.55</b>	<b>147</b>	
<b>geometric overall efficiency</b>	<b>0.55</b>	<b>87</b>	
<b>overall efficiency (avg)</b>	<b>0.30</b>		
<b>Total Lumens</b>		<b>83</b>	Max brightness achievable (estimated)
System efficiency achieved (lm/Welec)		26 lm/W	Efficiency may be higher at lower lumen levels



# Projection Lens Comparison

## Lens Layout



## Material

- 3pc,
- 2pc plastic/aspherical
- 1pc glass/spherical

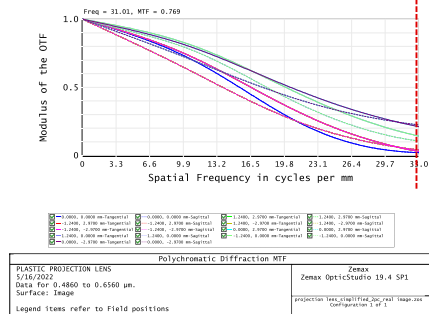
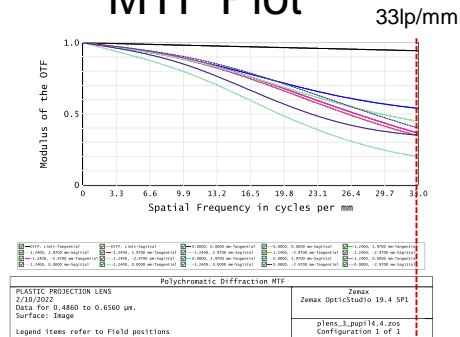
- 2pc,
- 2pc plastic/aspherical

## System Spec

- F/2.1
- Overall system efficiency: 32%
- 69% Offset
- TR 2.1
- Projected Image size: 468mm x 276mm
- Distortion<0.2%

- F/2.1
- Overall system efficiency: 30%
- 69% Offset
- TR 2.1
- Projected Image size: 484mm x 273mm
- Distortion<0.3%

## MTF Plot

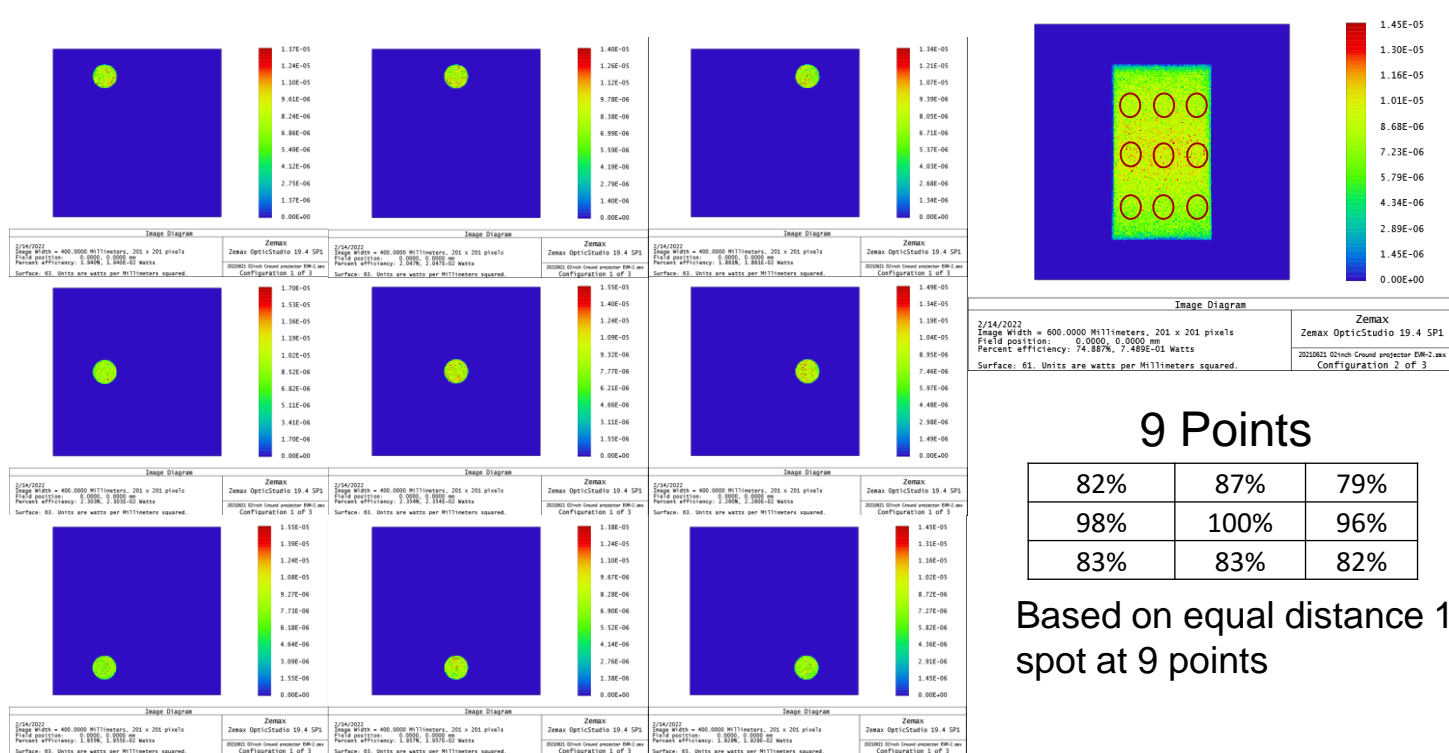


# Summary

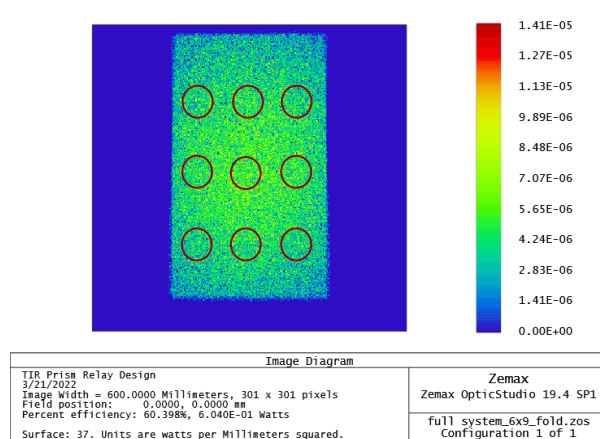
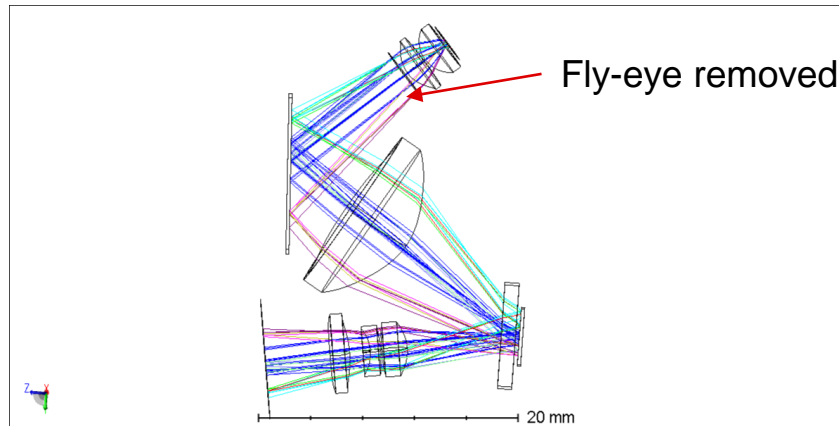
- Created a non-telecentric optical design for DGP
- Compared performance to previous field lens DGP design
  - Field lens design has higher efficiency, better uniformity, but ghost reflection in image
  - Non-telecentric design is more compact with lower element count
- Simplified non-telecentric projection lens by removing one optical element
  - MTF is reduced, but image simulation shows acceptable performance
  - 2 element design is smaller and expected to be lower cost

# Backup

# Field Lens Uniformity



# Further Simplified Design Concept (Removing FEA)



Geometric efficiency:  
60%  
(Same as with fly-eye)

Uniformity with fly-eye (9points)

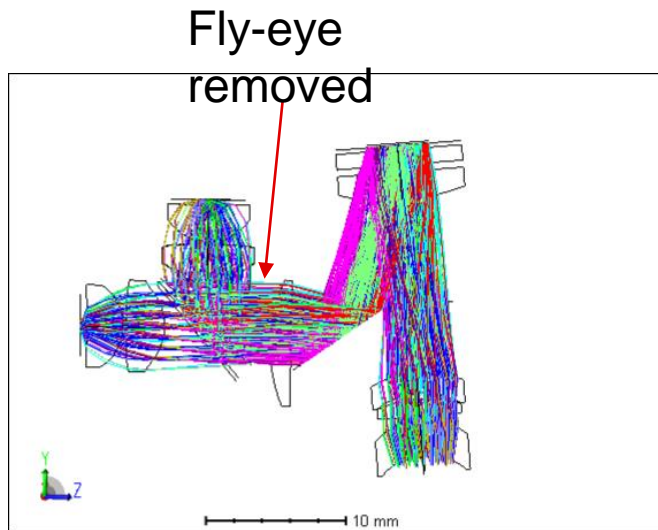
81%	90%	80%
88%	100%	86%
74%	83%	74%

Uniformity without fly-eye (9points)

74%	86%	73%
82%	100%	86%
69%	77%	73%

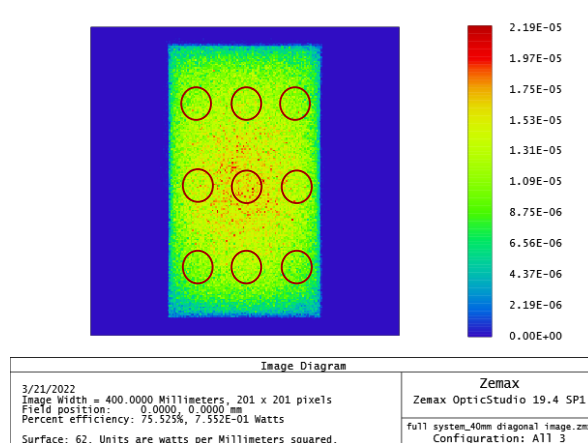
Based on equal distance 40mm  
radius spot at 9 points

# Further Simplified Design Concept (Removing FEA)



Uniformity with fly-eye(9points)

82%	87%	79%
98%	100%	96%
83%	83%	82%



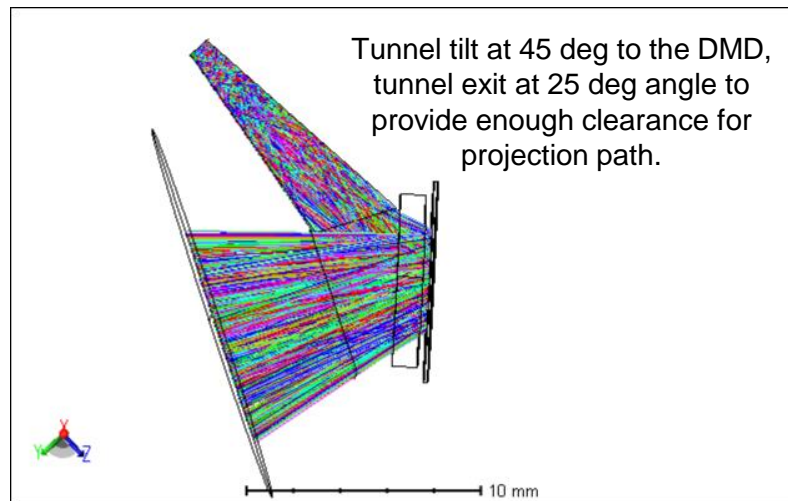
Geometric efficiency:  
75%  
(67% with fly-eye)

Uniformity without fly-eye (9points)

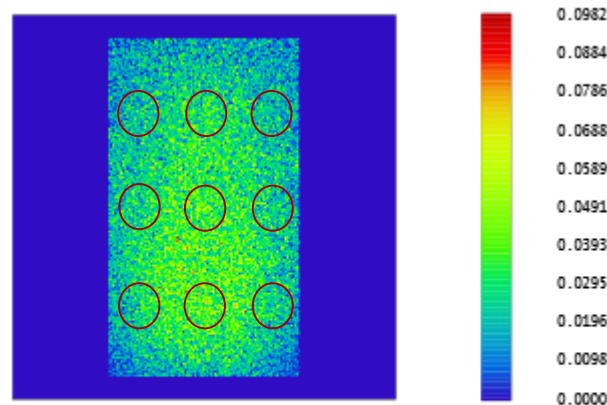
71%	78%	70%
87%	100%	85%
65%	79%	64%

Based on equal distance 14mm  
radius spot at 9 points

# Other Concept-Direct Tunnel



No projection lens design, yet. Might be  
challenging, more time needed to evaluate.



Geometric  
efficiency at DMD:  
29%

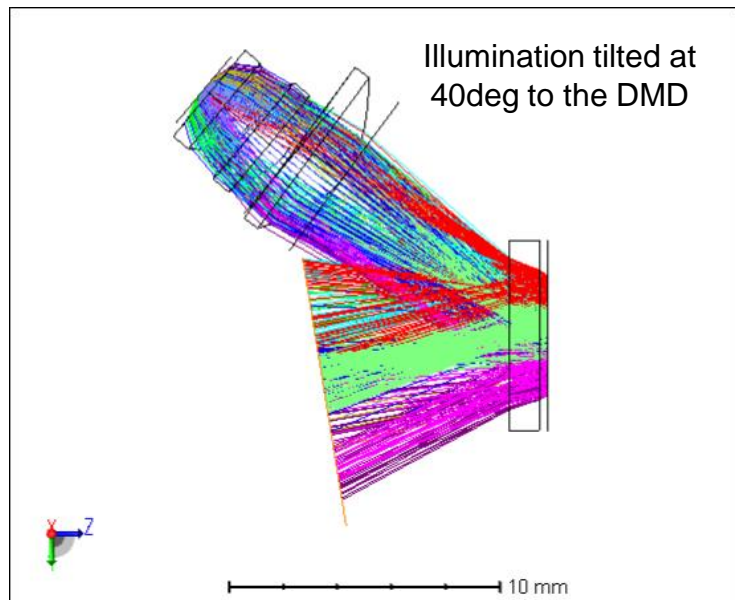
Image Diagram	
3/21/2022	Zemax
Image Width = 3.0000 Millimeters, 301 x 301 pixels	Zemax OpticStudio 19.4 SP1
Field position: 0.0000, 0.0000 mm	Source: TheZemaxSource, SourceType: TheZemaxSource
Percent efficiency: 29.162%, 2.916E-01 Watts	Configuration 1 of 1
Surface: 12. Units are watts per Millimeters squared.	

Uniformity (9points)

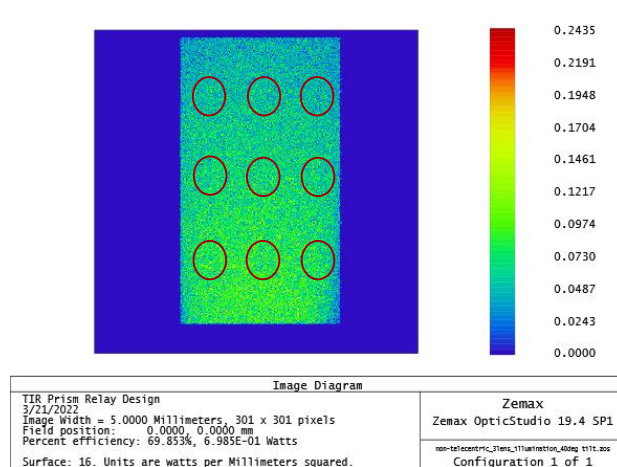
63%	80%	63%
76%	100%	70%
88%	113%	84%

Based on equal distance 0.2mm radius spot  
at 9 points at DMD plane

## Alternate Concept-Collimating lens with a focusing lens



No projection lens design, yet. Might be challenging, more time needed to evaluate.



Geometric efficiency  
at DMD: 70%

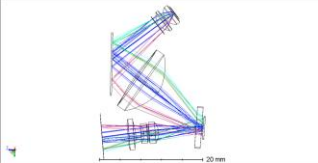
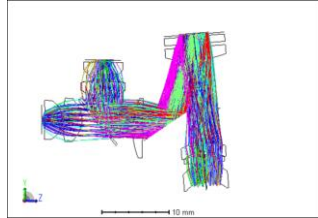
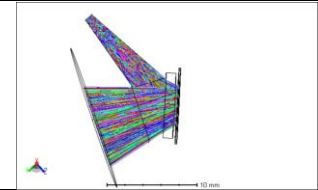
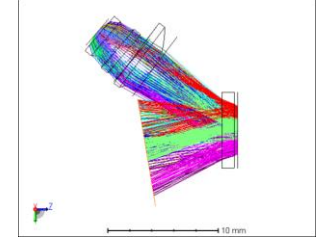
## Uniformity (9points)

74%	78%	71%
98%	100%	95%
117%	126%	113%

Based on equal distance 0.2mm  
radius spot at 9 points at DMD plane



# Comparison Table

Design	Layout	Element Count	Geometric efficiency	Pros/Cons
Non-telecentric design		7 (2 collimating lens, 1 folding mirror, 1 relay lens, 3 projection lens) Folding mirror can be removed if larger size is	60%@Image plane	Low element count for high efficiency, non-telecentric
Field Lens Design		8 (2 collimating lens, 1 relay lens, 1 folding mirror, 1 field lens, 3 projection lens)	75%@Image plane	Telecentric design, will be ghost image from field lens double reflection
Direct Tunnel		1 tunnel+ projection lens	29%@DMD	Lowest Element count, trade-off efficiency and uniformity
Kohler Illumination		2 collimating lens + 1 focusing lens+ projection lens	70%@DMD	More compact illumination compares to design 1, projection lens will probably be larger. Still exploring.