A New Retina Camera for Premature and Early Infants

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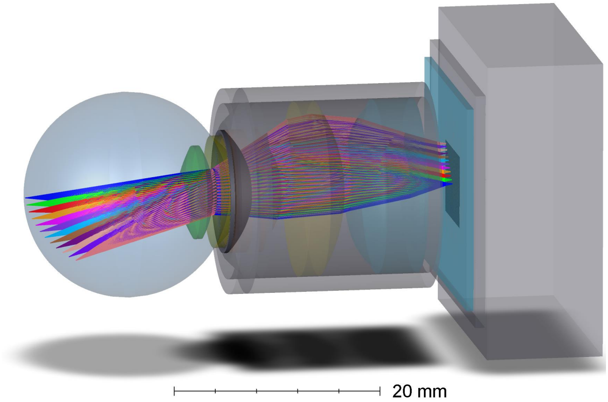
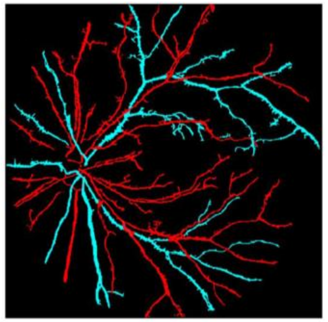
Reasons for Development - Retinopathy of Prematurity (ROP):

There is an urgent global need for an inexpensive, field-portable, hand-held pediatric retinal camera to:

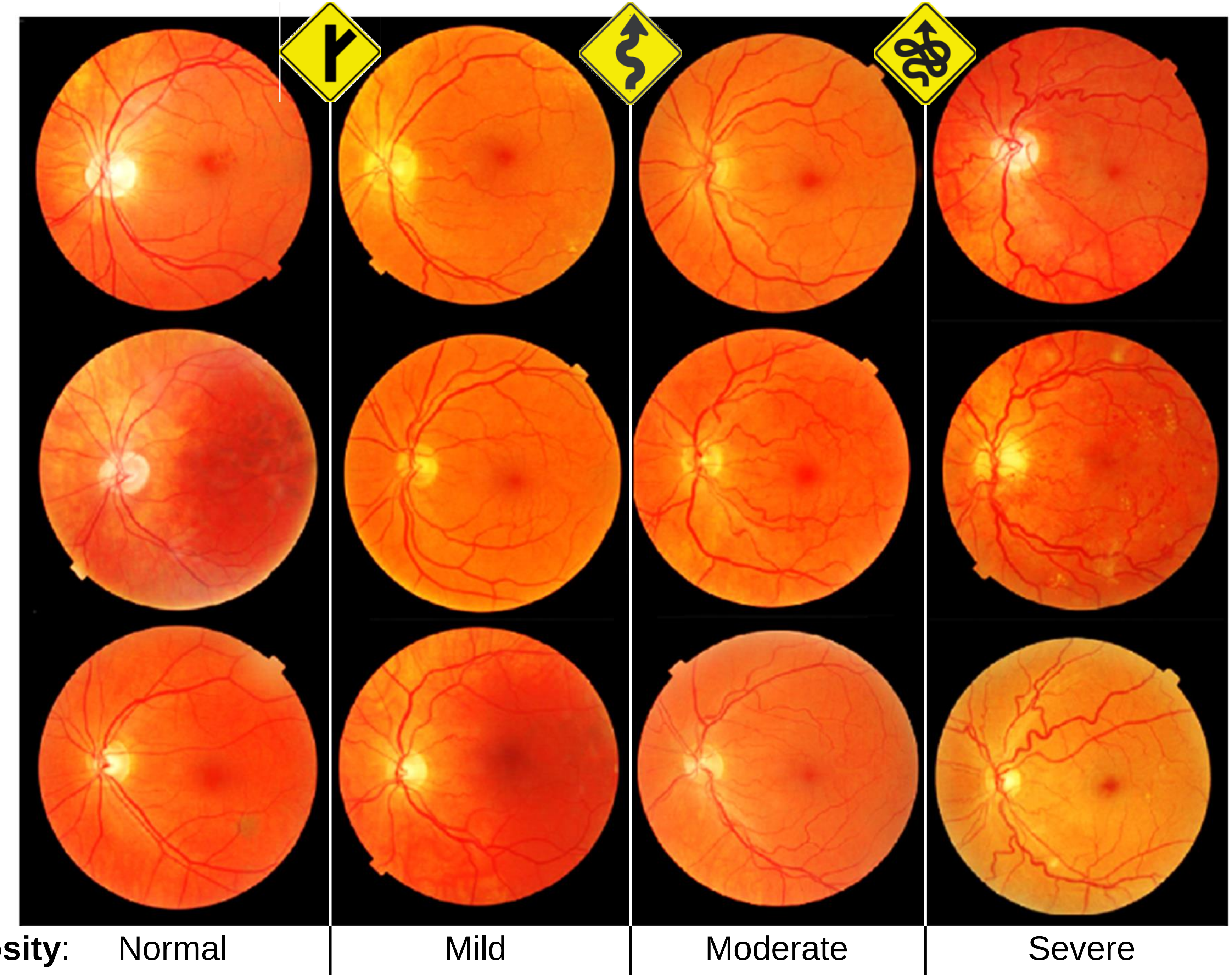
- Enable non-physicians to detect treatable ROP vascular abnormalities in infants that have survived ‘extreme’ prematurity, using validated diagnostic software
- Allow for ‘field-expedient’ medical treatment that can normalize blood flow to the retina and minimize the chances of permanent blindness





ROP: Retinopathy of Prematurity

Retinopathy of prematurity (ROP) is a leading cause of blindness in infants. ROP is a disease of the retina affecting prematurely-born, low birthweight infants who have received intensive neonatal care, and oxygen therapy. **Oxygen 'toxicity'** can cause the growth of abnormal retinal capillaries in the far periphery. These abnormal capillaries are heralded by Plus disease (defined as **dilation and tortuosity of the posterior central vessels**). They are fragile, leaky and can scar the retina, potentially leading to retinal detachment. The longer ROP goes untreated, the greater the risk of permanent vision loss in the affected eye. Retinopathy of prematurity is an <u>emergency</u> condition.



Pediatric Camera Requirements and Goals

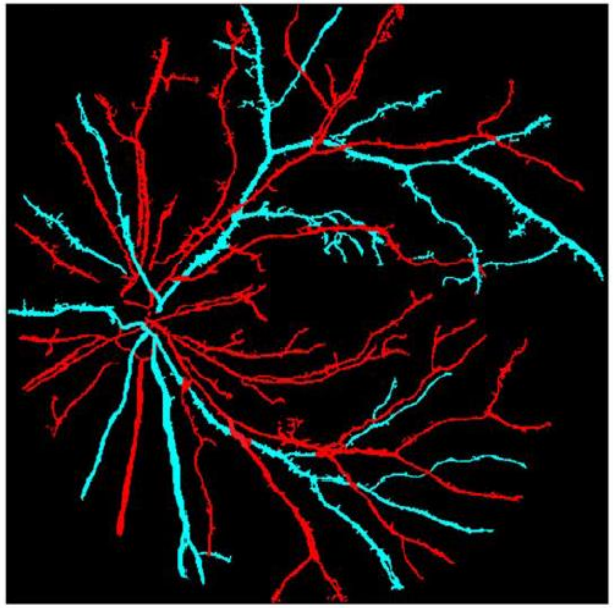
1. Develop a new retina camera designed specifically for detecting ROP in infants and premature babies
2. Design for infant eye globe diameters on the order of 16-20mm, much smaller than adult eyes
3. Have a field of view at the pediatric retina of a ±30º cone, centered on the fovea
4. Image over a spectral range of 565-600nm
5. Provide usable contrast, resolution of retinal vessels of < 50 µm/pixel, GOAL < 20 µm/pixel
6. Manual focusing for different eye globe diameters, near/far sightedness in infant eyes
7. Telecentric image - perpendicular, uniform imaging over entire sensor
8. Lens distortion - map and compensate in software to give rectilinear analysis imagery
9. Unit to be readily field-portable, hand-held, laptop-powered
10. Utilize resolution, color discrimination and AI-based image processing to detect vessel abnormalities
11. Achieve per-unit costs of 10-15% that of existing portable retina cameras
12. Design camera, computer and software system to facilitate rapid, reliable medical staff training

On-Retina Pediatric Camera Resolution Needed

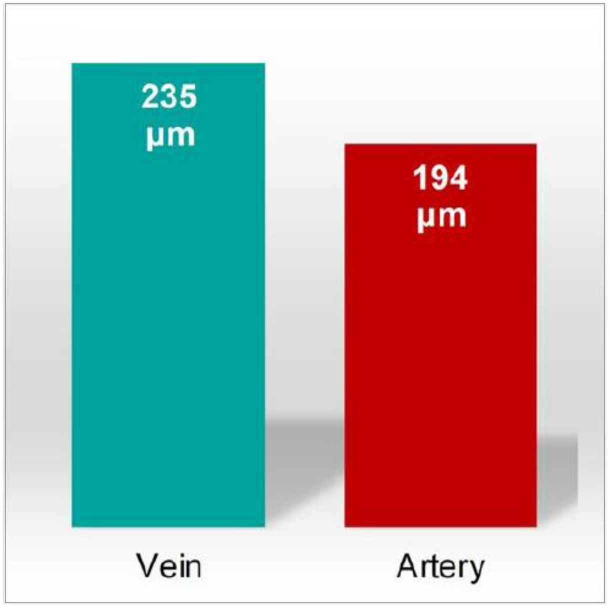
www.nature.com/scientificreports

Contact-free trans-pars-planar illumination enables snapshot fundus camera for nonmydriatic wide field photography

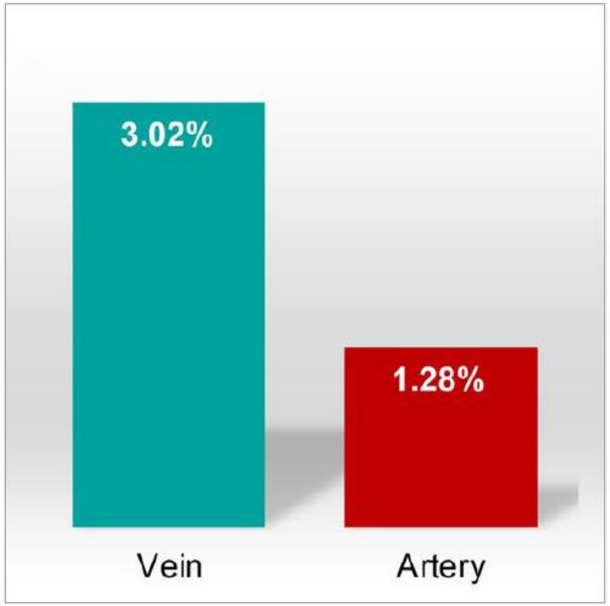
Benquan Wang, Devrim Toslak, Minhaj Nur Alam, R. V. Paul Chan & Xincheng Yao, June 8, 2018



Arteries (red)
Veins (cyan)



Average Diameters



Average Tortuosity

<u>Initial requirement:</u>

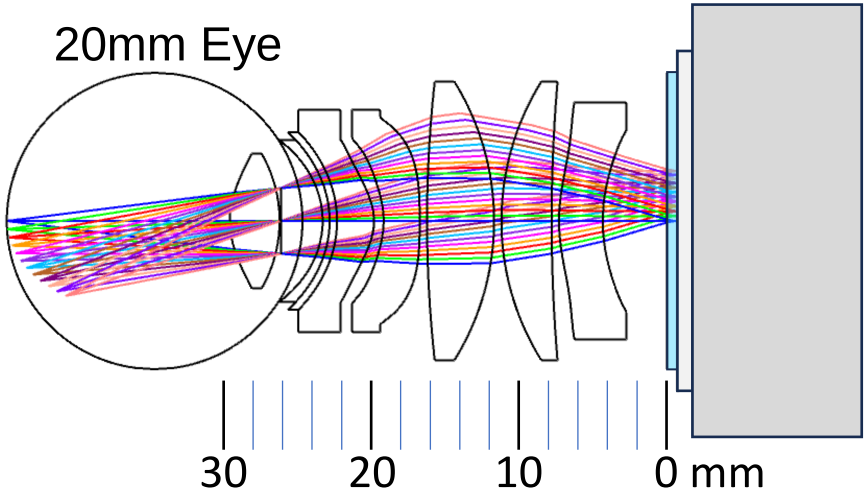
- 50µm/pixel is standard criterion
- Only puts 4-5 pixels on vessels
- Below Johnson recognition criteria

<u>Improved resolution goal:</u>

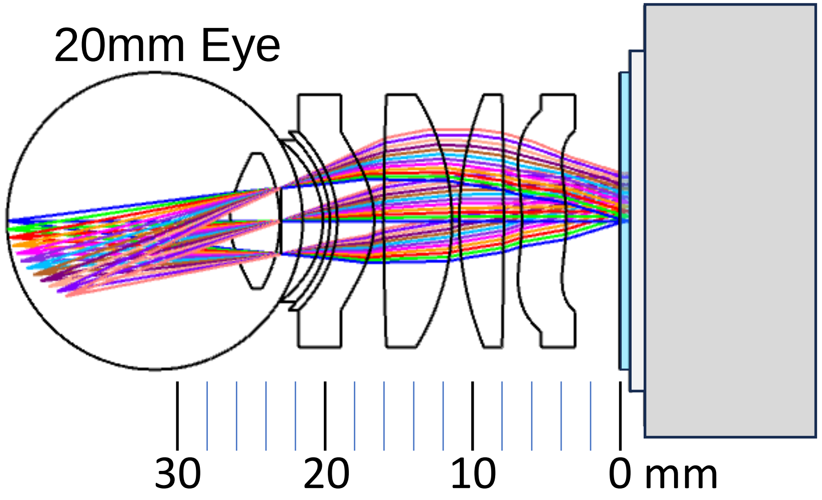
- 25µm/pixel = 8 pixels on vessels
- Meets Johnson recognition criteria
- 20µm/pixel = improved recognition on smaller vessels

Multiple Camera Lens Options Explored - MTF Comparisons

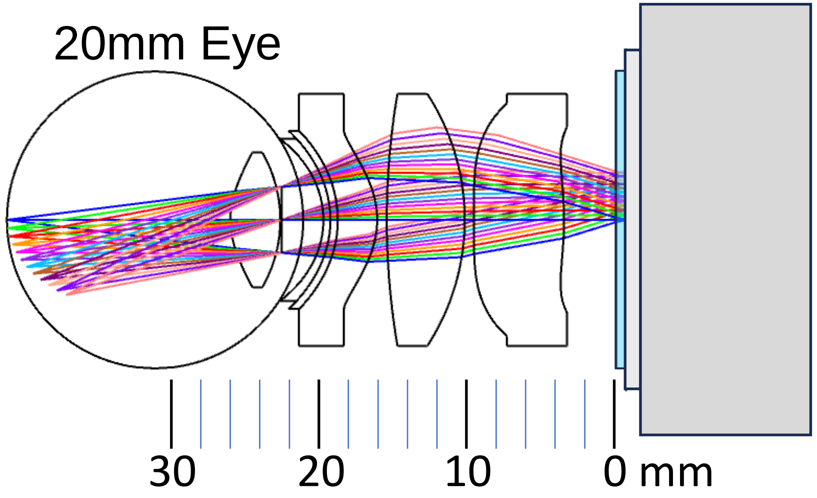
5-Element Design



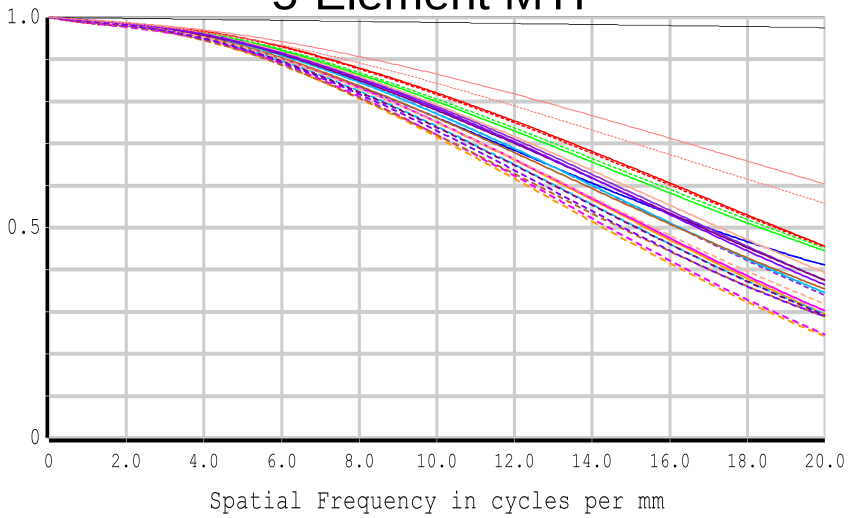
4-Element Design



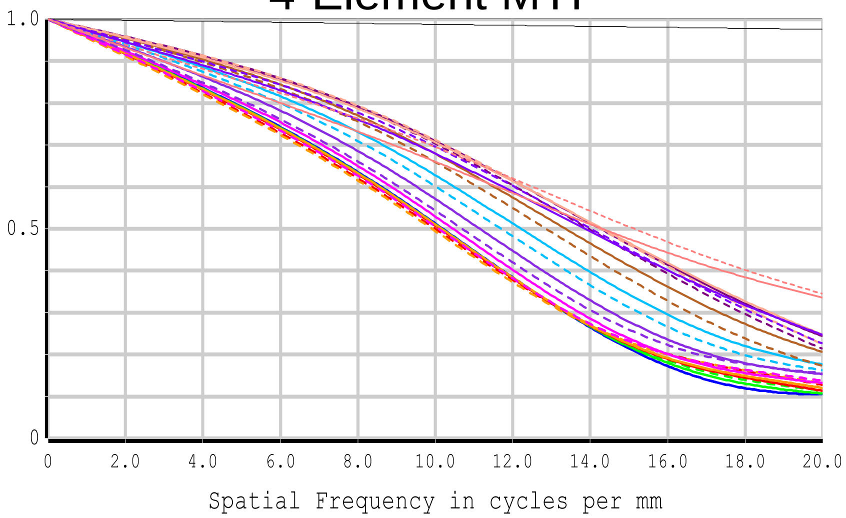
3-Element Design



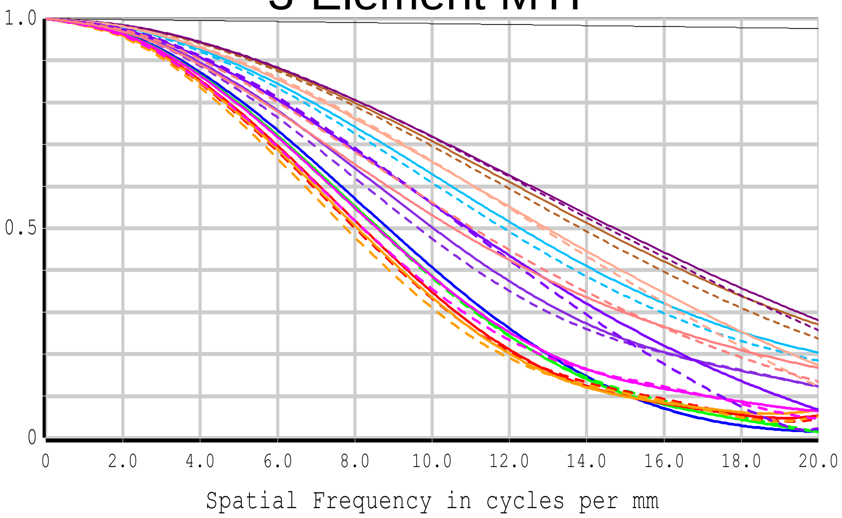
5-Element MTF



4-Element MTF

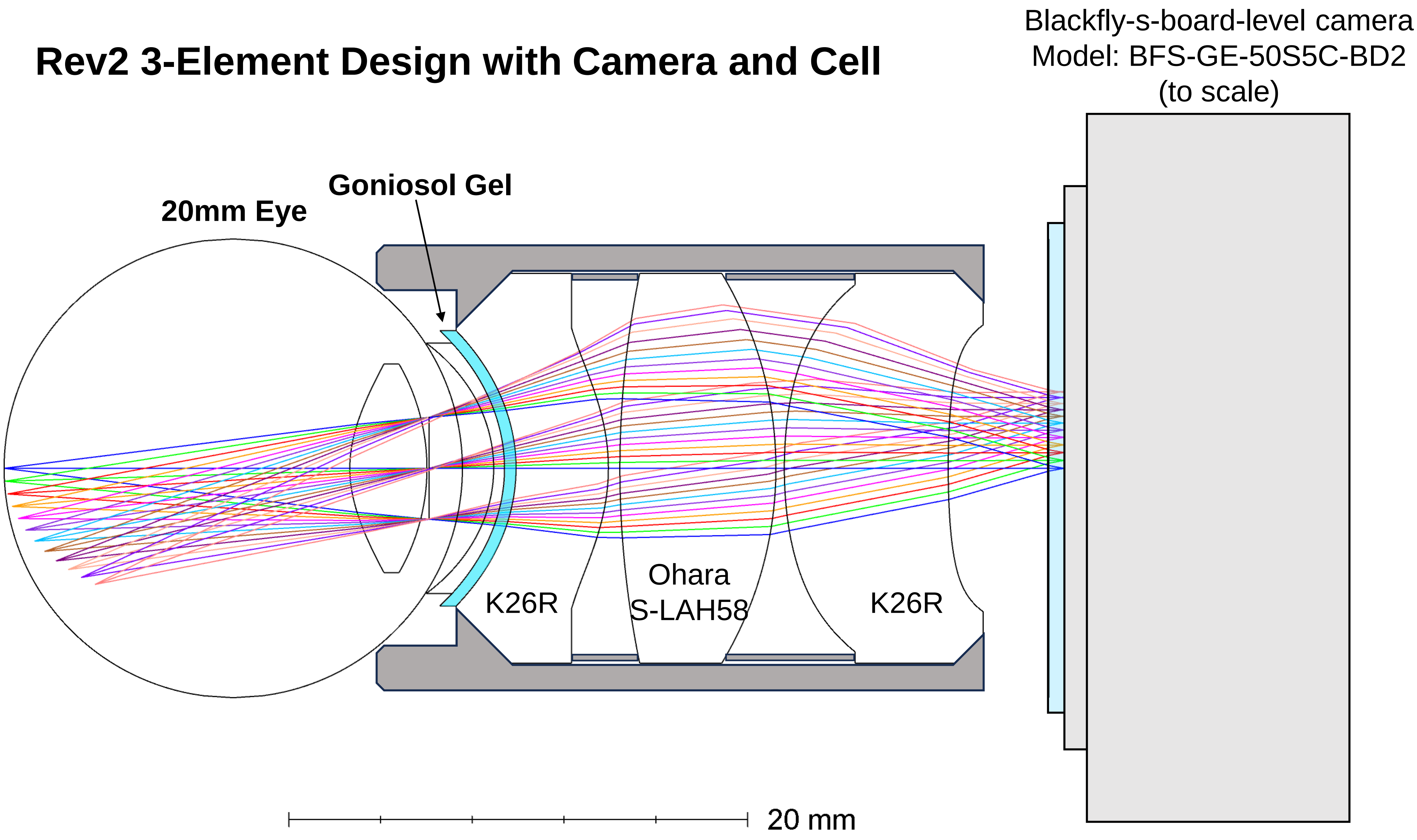


3-Element MTF

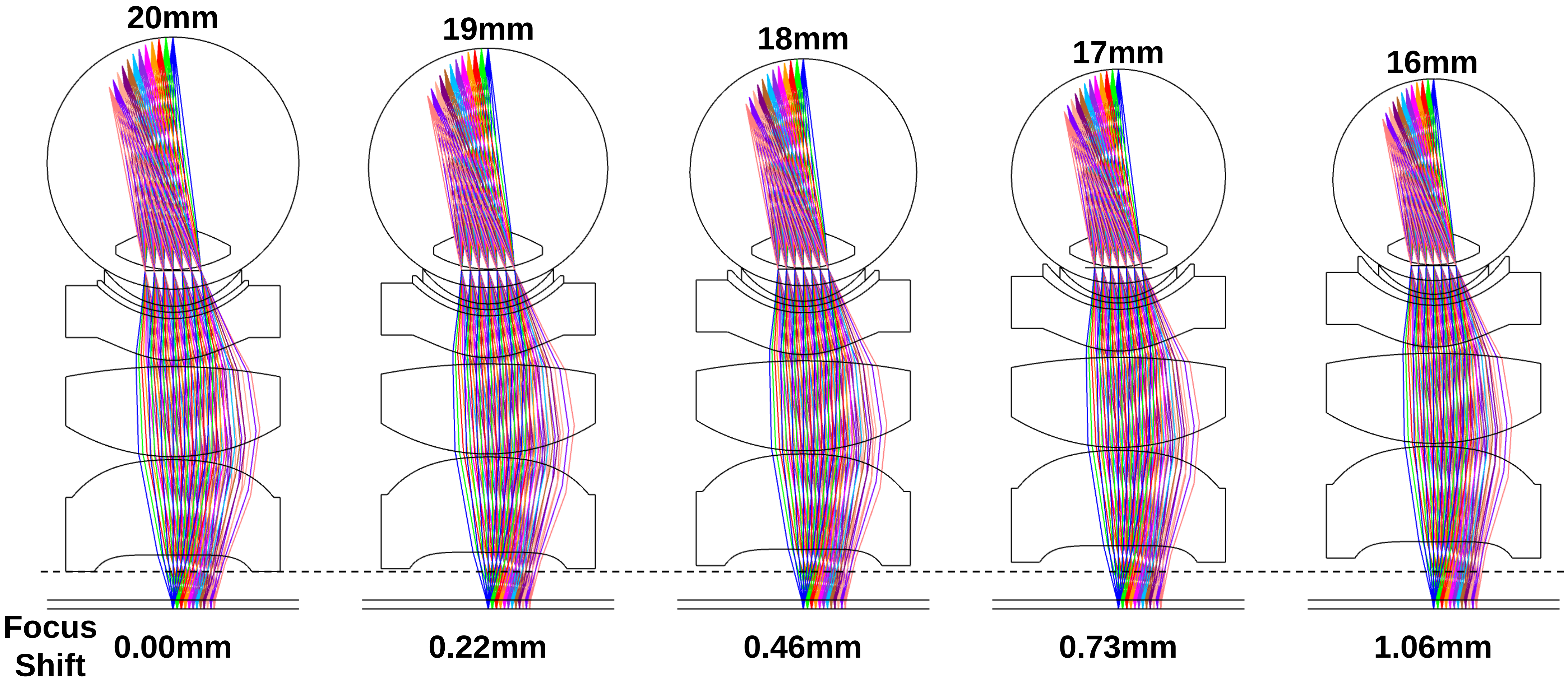


3-element lens is the most economical, but performance needs improving

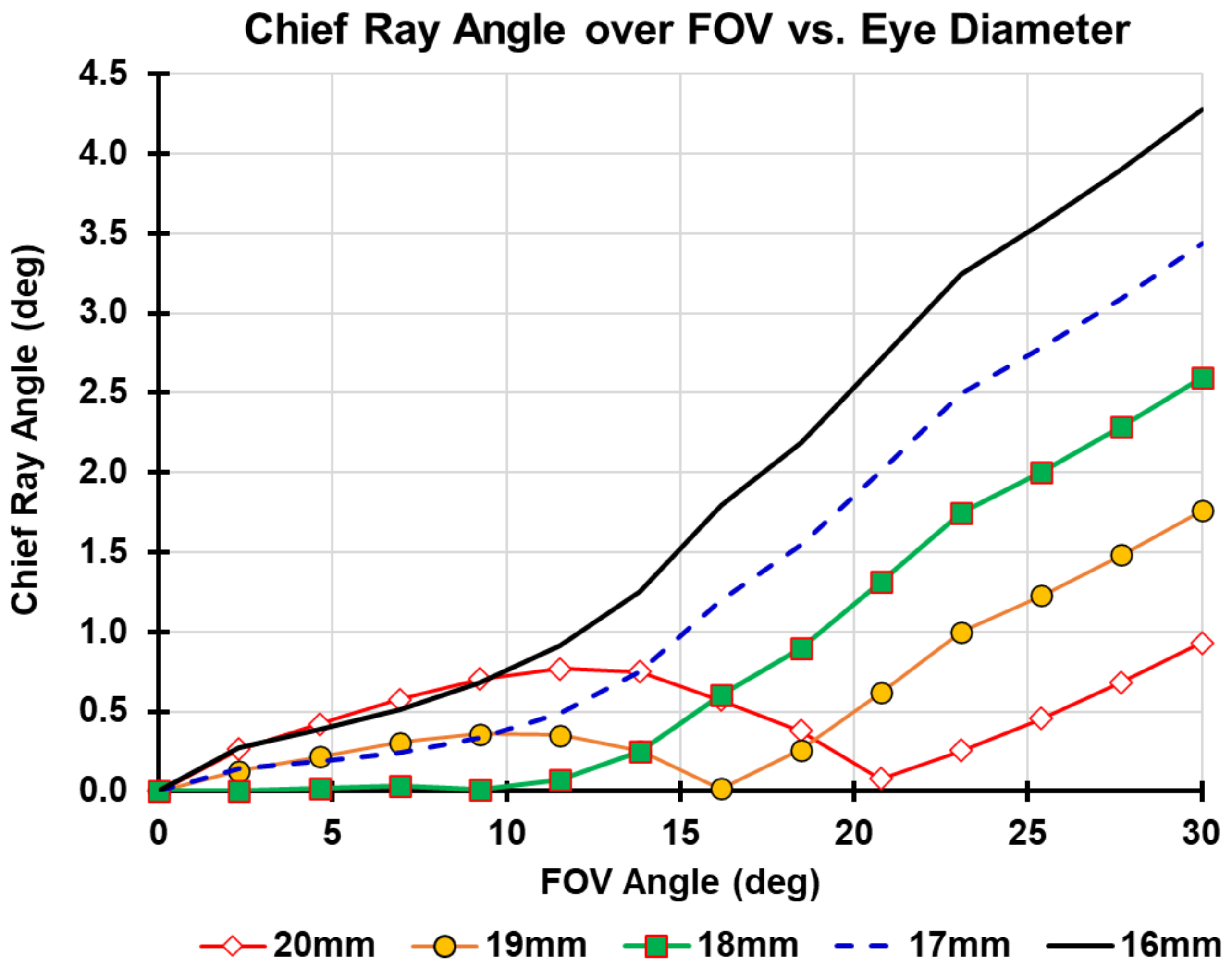
Rev2 3-Element Design with Camera and Cell



Rev2 3-Element Lens with 16mm to 20mm Eyes



Rev2 3-Element Lens with 16mm to 20mm Eyes



- **Telecentricity gives better image uniformity, less scale change with focus**
- **Optimized for 20mm eye, may try to optimize for 18mm instead**

Rev2 3-Element Lens: Modulation Transfer Function for 16mm to 20mm Eyes

Object height = -0.05mm   Pixel Size = 0.00345mm

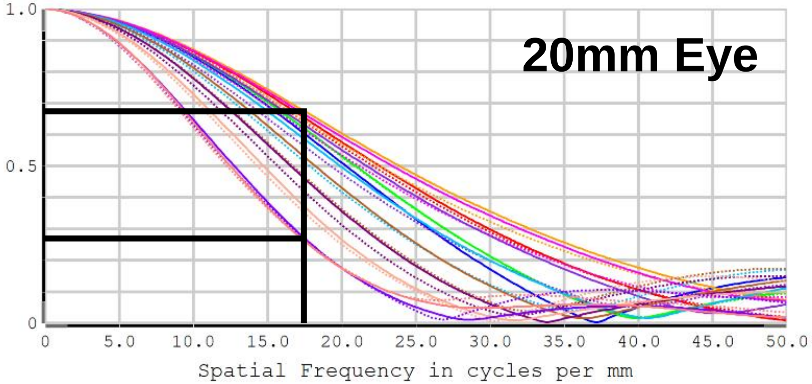


Image Height = 0.0290mm
Paraxial magnification = -0.580X
1 cycle = 2(0.0290) = 0.0579mm
50µm = 17.25 cy/mm on MTF
0.0290/0.00345 = 8.40 pixels
50µm / 8.40 = 5.95 µm/pixel

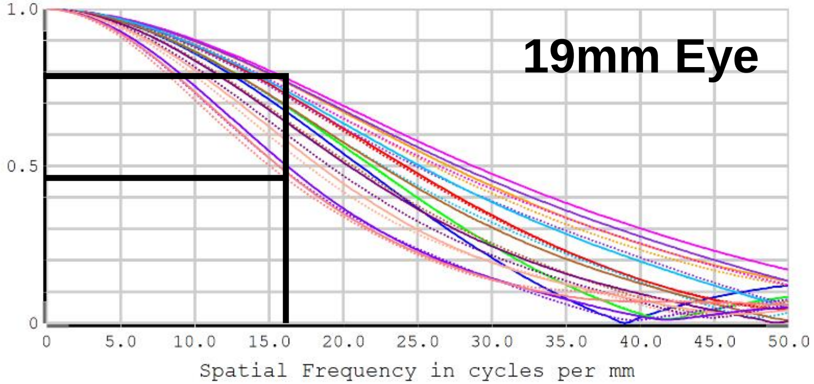


Image Height = 0.0306mm
Paraxial Magnification = -0.613X
1 cycle = 2(0.0306) = 0.0613mm
50µm = 16.30 cy/mm on MTF
0.0306/0.00345 = 8.89 pixels
50µm / 8.89 = 5.63 µm/pixel

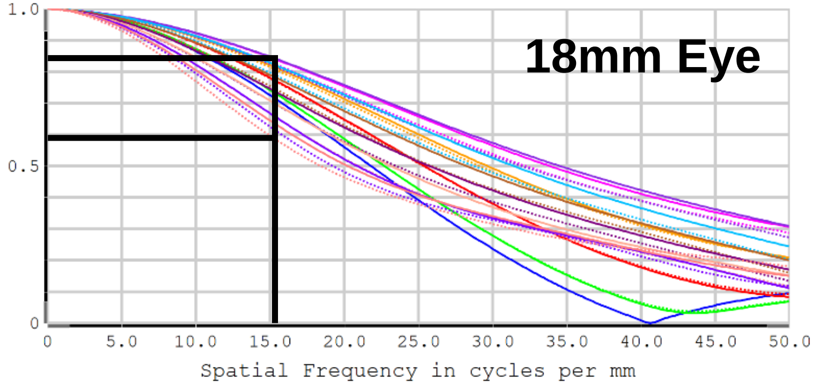


Image Height = 0.0326mm
Paraxial Magnification = -0.651X
1 cycle = 2(0.0326) = 0.0651mm
50µm = 15.36 cy/mm on MTF
0.0326/0.00345 = 9.44 pixels
50µm / 9.44 = 5.30 µm/pixel

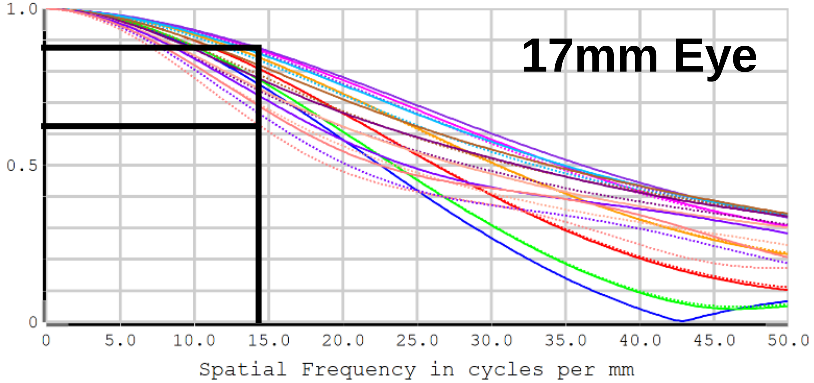


Image Height = 0.0347mm
Paraxial Magnification = -0.694X
1 cycle = 2(0.0347) = 0.0694mm
50µm = 14.41 cy/mm on MTF
0.0347/0.00345 = 10.06 pixels
50µm / 10.06 = 4.97 µm/pixel

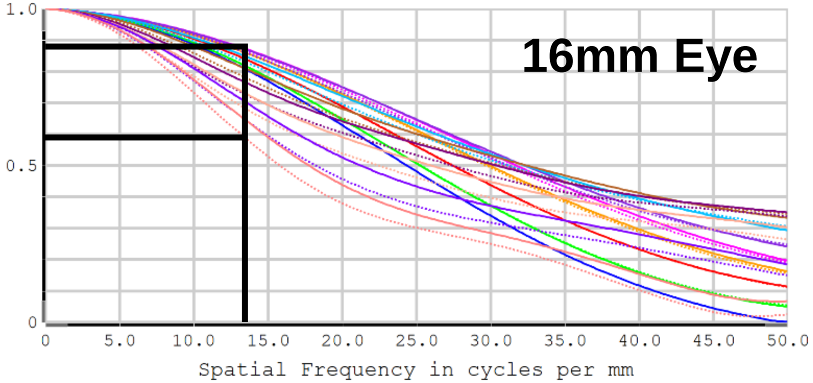
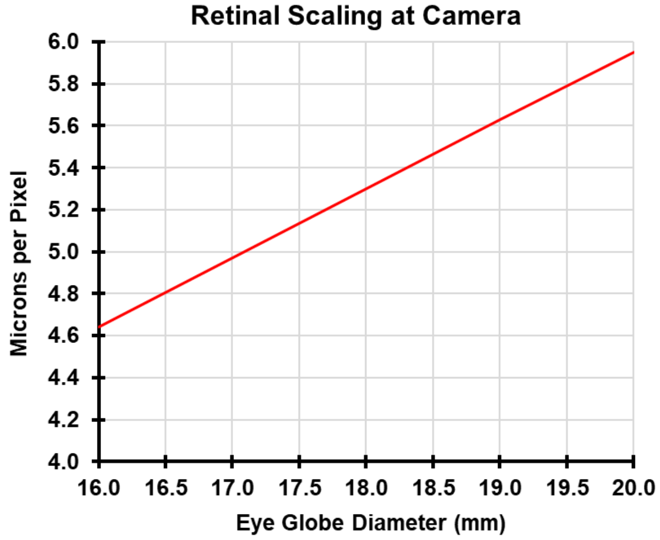
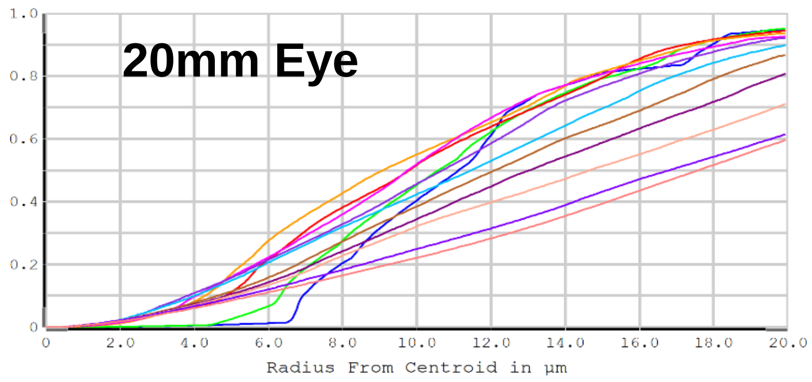
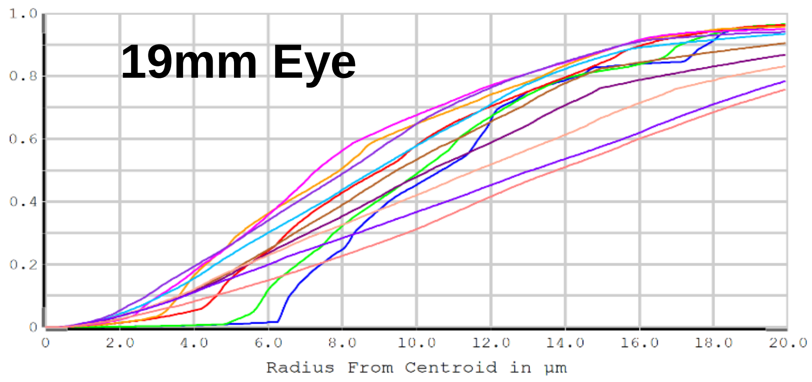


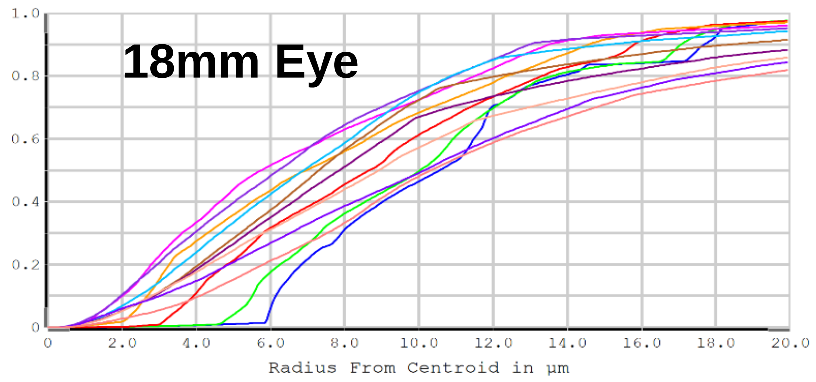
Image Height = 0.0372mm
Paraxial Magnification = -0.744X
1 cycle = 2(0.0372) = 0.0744mm
50µm = 13.45 cy/mm on MTF
0.0372/0.00345 = 10.78 pixels
50µm / 10.78 = 4.64 µm/pixel

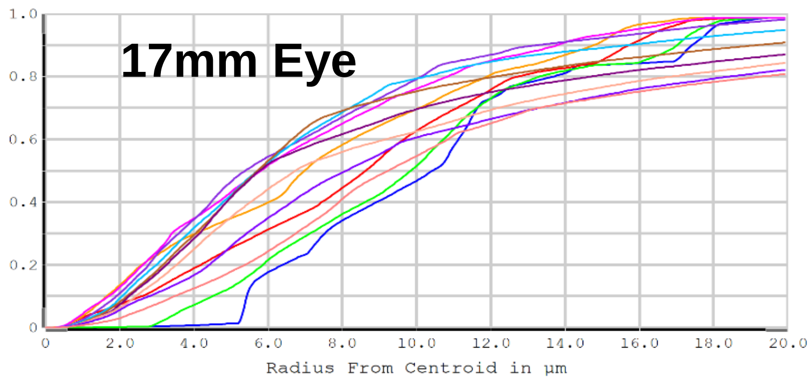


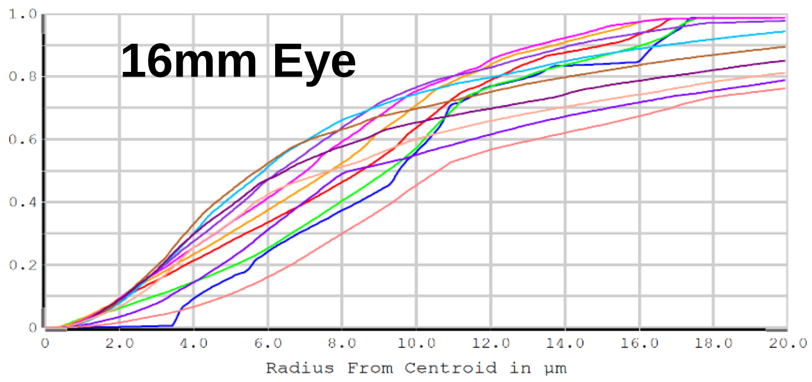
Rev2 3-Element Lens: Ensquared Energy for 16mm to 20mm Eyes







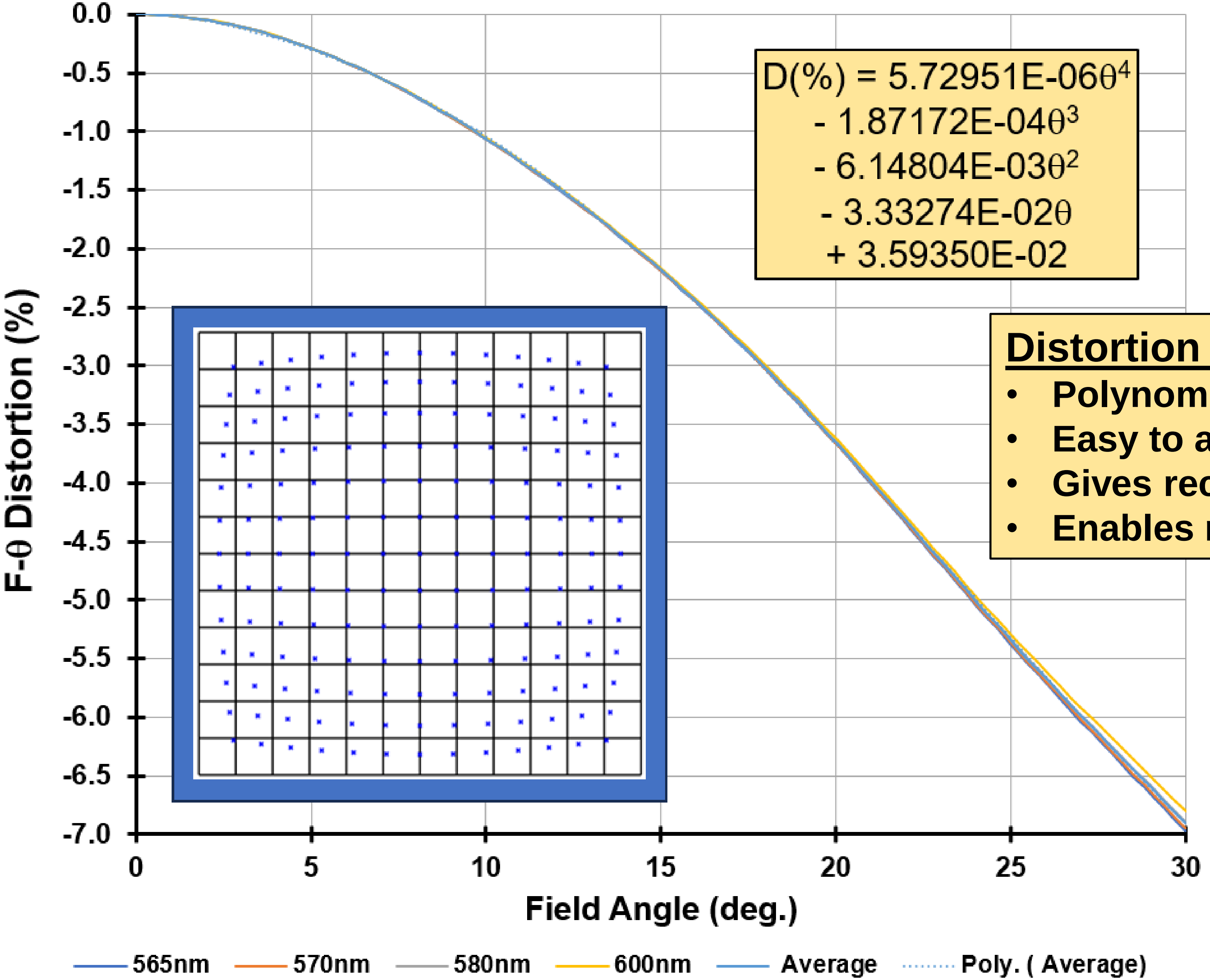




Design Goals:

- **Cluster ensquared energy curves together (uniform illumination over FOV)**
- **Get all curves at about the same range (uniform imagery vs. eye size)**

Rev2 3-Element F-Theta Lens Distortion Mapping



$D(\%) = 5.72951E{-}06\theta^4 - 1.87172E{-}04\theta^3 - 6.14804E{-}03\theta^2 - 3.33274E{-}02\theta + 3.59350E{-}02$

Distortion mapping:

- **Polynomial Fitted**
- **Easy to add to image processing**
- **Gives rectilinear display**
- **Enables measurement, tagging**

Note:
Near-zero chromatic variation of distortion

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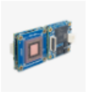
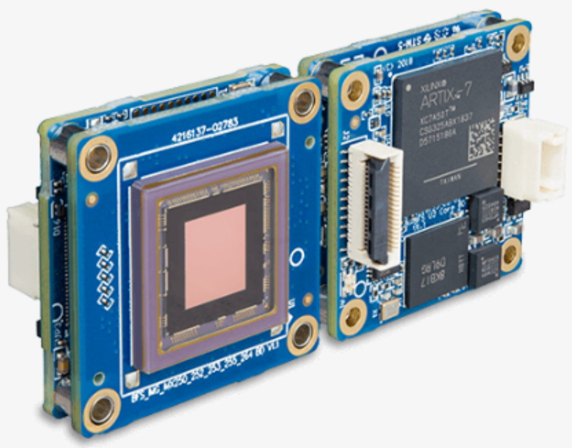


Blackfly S Board Level - Model: BFS-GE-50S5C-BD2: 5 MP, 24 FPS, Sony IMX264, Color

Change Selection »

$878.00



FAST SHIPPING

Tight-space embedding

Blackfly S Board Level

Model: BFS-GE-50S5C-BD2: 5 MP, 24 FPS, Sony IMX264, Color

Go to Product Support »

The FLIR Blackfly S Board Level variants are high performance, machine vision, area scan cameras designed for embedding into tight spaces. Unlike many board level cameras, it boasts a rich feature set applied to the latest CMOS sensors; the same feature set as the cased version. It is ready for integration with proven compatibility with popular SBCs and SOMs. The Blackfly S board level models enable OEMs to develop smaller, lighter, and lower cost solutions with embedded system connectivity and rich features.

The Blackfly S currently has a lead time of four weeks or less. Get the cameras you need – when you need them.

PRODUCT VARIATIONS:

BFS-GE-50S5C-BD2: 5 MP, 24 FPS, Sony IMX264, Color

$878.00

Available for purchase on credit terms. Learn More

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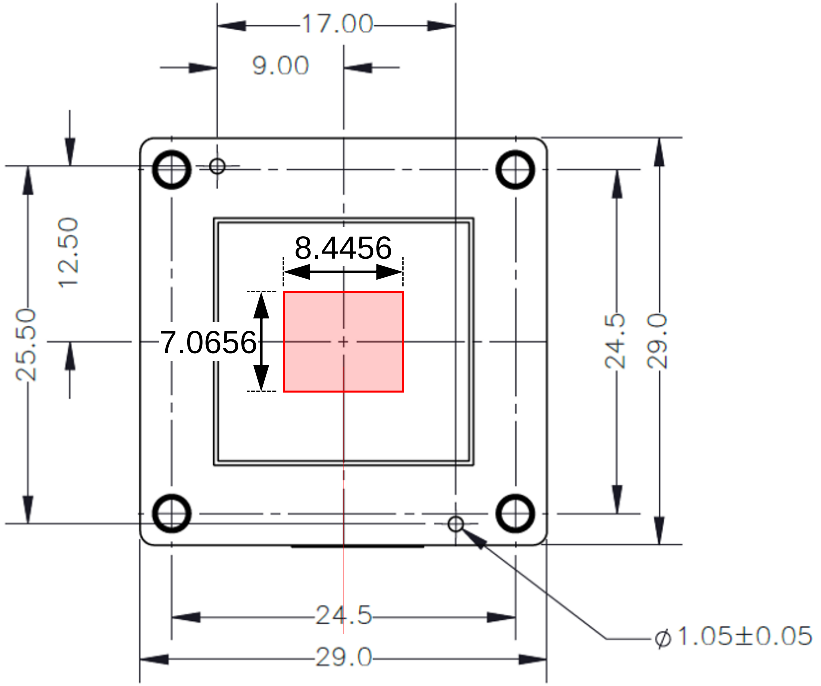
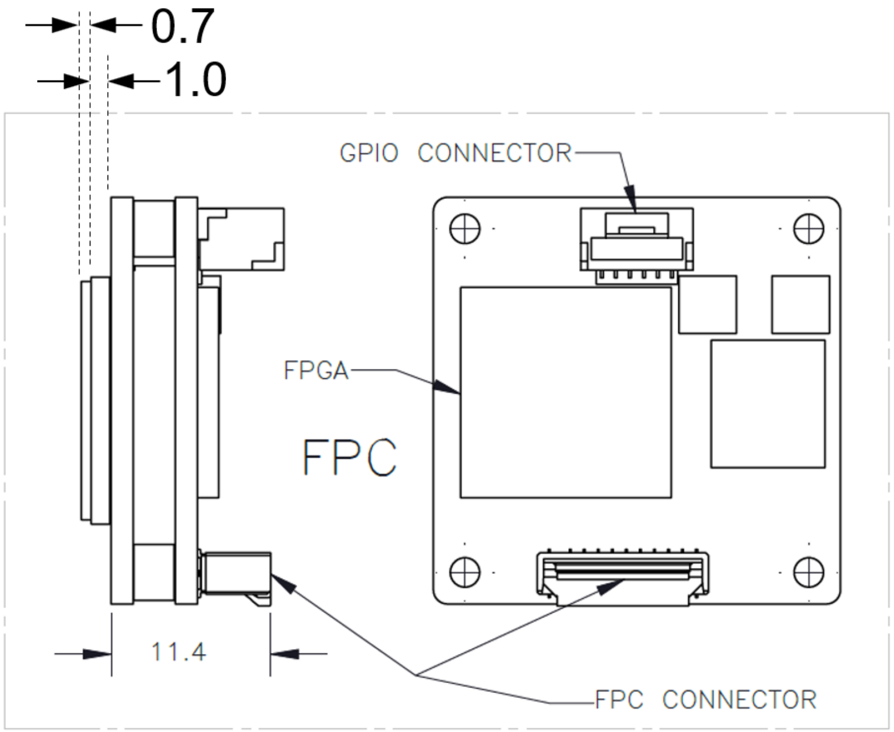
REVISIONS			
REV.	DESCRIPTION	DATE	DONE BY
0	INITIAL RELEASE	04.MAY.18	DANIEL
1	ADDED BFS-U3-32S4M/C-BD2, BFS-U3-31S4M/C-BD2 AND BFS-U3-88S6M/C-BD2 SPECIFICATIONS	27.APR.20	DAVID
2	ADDED SENSOR DIMS FOR MODELS 50S5, 88S6, 122S6, 63S4,16S2	14.DEC.20	DAVID

Rear View

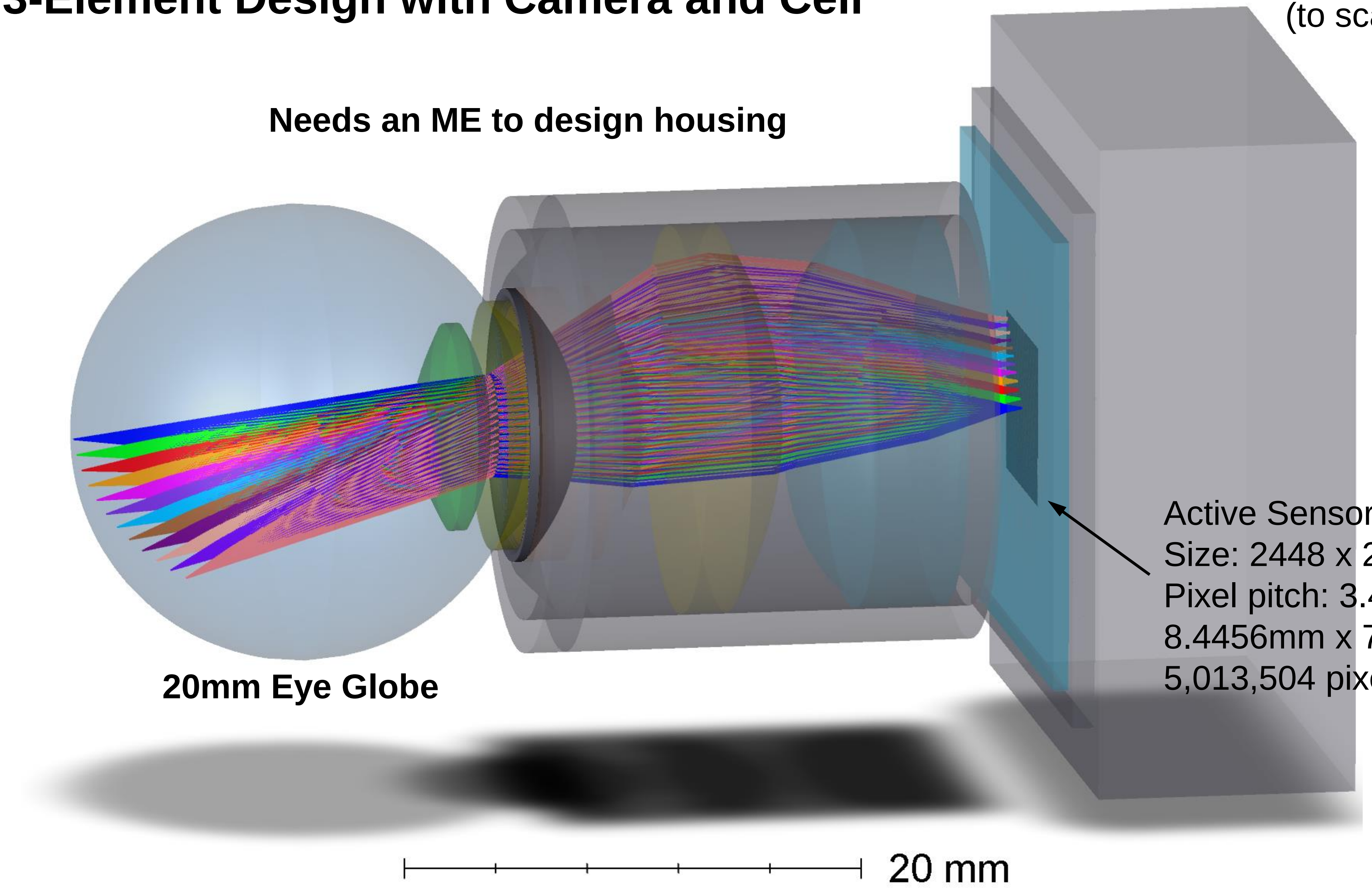




BFS-GE-50S5C-BD2

FLIR	3RD ANGLE PROJ	TOLERANCES	UNLESS OTHERWISE STATED:	SCALE	DWG NO	SHEET	REV
		X.X ±0.3 X.XX ±0.10 X.XXX ±0.020 ANGLES ±0.5°	ALL DIMENSIONS IN MM MACHINE FINISH 1.6µM	2:1	BFS_BD-051-R0	1 OF 5	2
				SIZE A	TITLE BFS-BD FPC/MICRO_B CONN		

3-Element Design with Camera and Cell



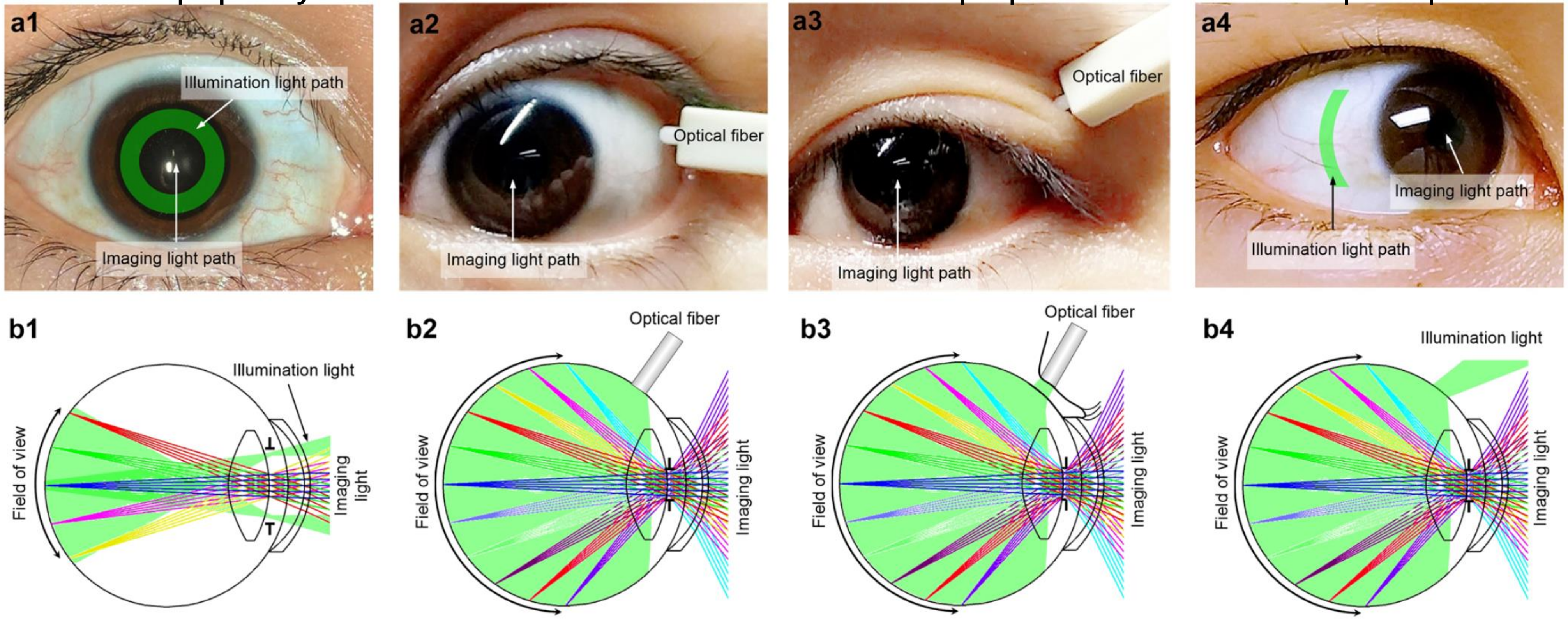
Retinal Illumination Techniques

www.nature.com/scientificreports

Contact-free trans-pars-planar illumination enables snapshot fundus camera for nonmydriatic wide field photography

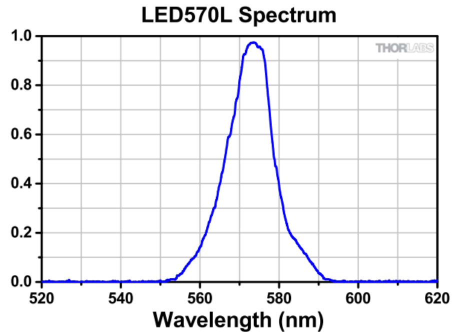
Benquan Wang, Devrim Toslak, Minhaj Nur Alam, R. V. Paul Chan & Xincheng Yao, June 8, 2018

Trans-pupillary | Trans-scleral | Trans-palpebral | Trans-pars-planar

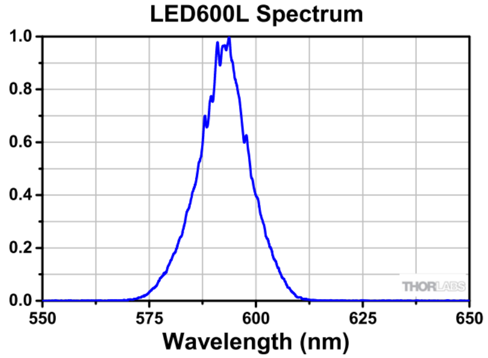


- Trans-pars-planar “may” be the way we go
- Must be careful about LED thermal hazards
- Sclera is ~0.5mm thick, visible transmission 10-30%
- Keep irradiance power density below 200mw/cm²

Thorlabs narrowband LEDs identified



Note λ scale changes



Progress as of Nov. 15, 2023

- **Multiple optical design candidates developed that give needed resolution, contrast**
- **All employ bi-aspheric optical plastic elements as well as spherical optical glass elements**
- **Fresnel Technologies (Fort Worth TX) will manufacture the plastic bi-aspherics**
- **Plentiful suppliers for optical glass elements, Ohara**
- **Optical tolerancing underway**
- **Thorlabs narrowband LED-based illumination concepts in work**
- **Camera and programming/AI software person identified**
  - ***Software is the antichrist of any development program!***
  - ***Work to begin soon on camera / laptop interface and operability***
- **Lens/barrel will be a separate unit to be installed in the housing**
- **Mechanical designer needed to design housing for lens barrel, illumination, camera**

Issues:

- **Need a dedicated mechanical engineer!**

QUESTIONS?

POC:
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508.654.1207