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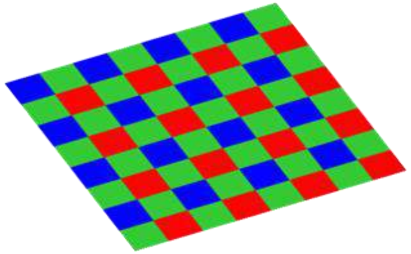
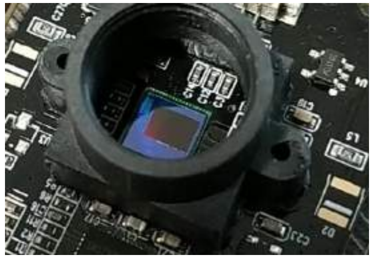
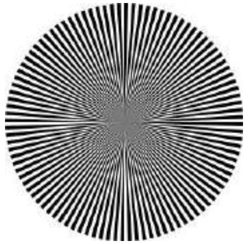




Computer Vision Optics



Engage Photonics LTD

14 October 2020

ASSOCIATION OF ENGINEERS, ARCHITECTS AND GRADUATES IN TECHNOLOGICAL SCIENCES IN ISRAEL

Photonics Israel

The Association of Photonics Industries in Israel

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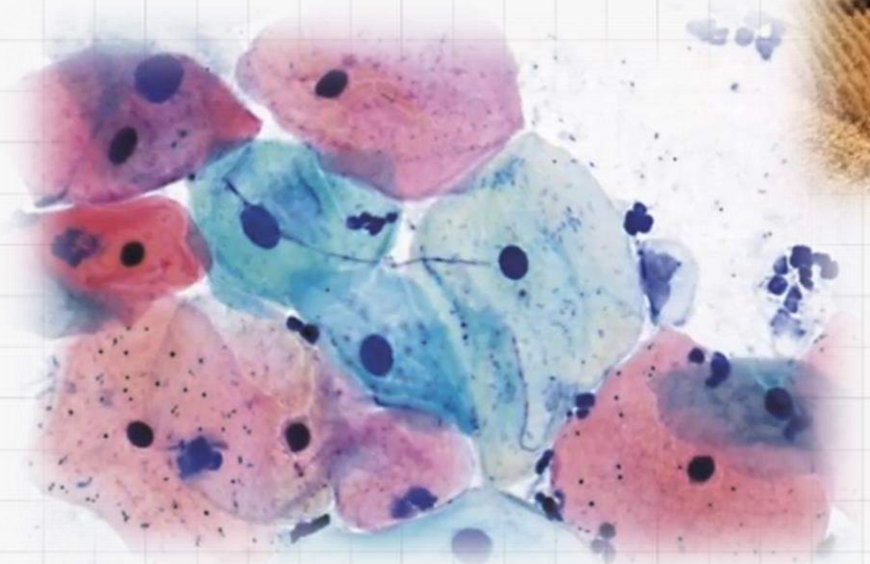
Computer Vision World

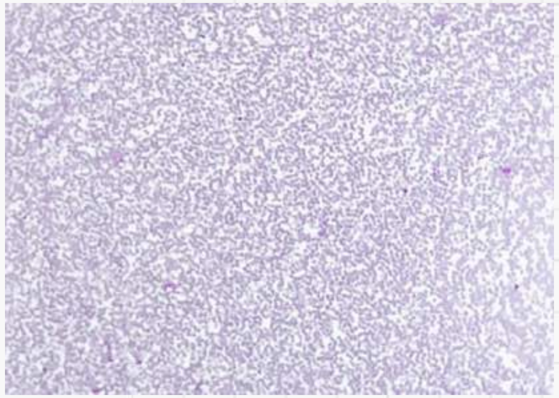


Computer Vision World

Computer Vision

Acquisition and Processing of Digital Images

Life Sciences
Cytometry



Count cells
Analyze cell morphology

Production
Inspection

Find Defects

Autonomous Vehicles

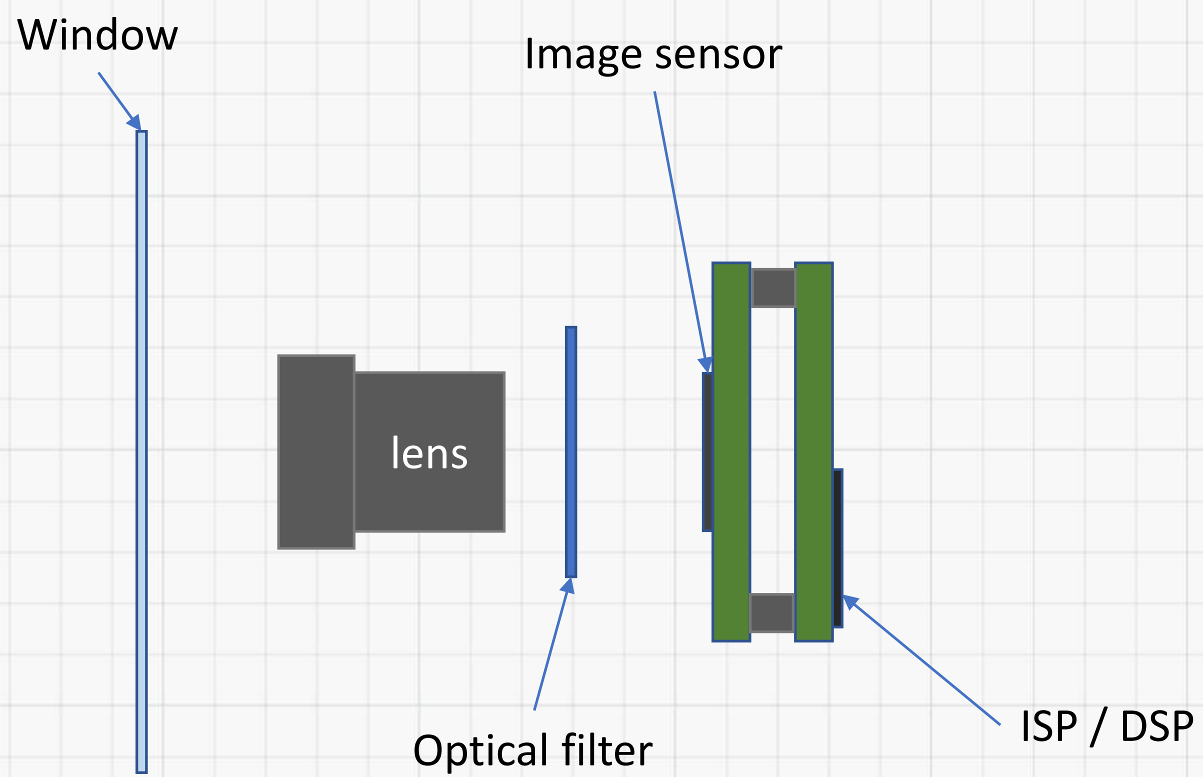
Localization
and mapping

Agriculture
Satellite Imaging

Growth condition

Basics

Anatomy of a digital camera



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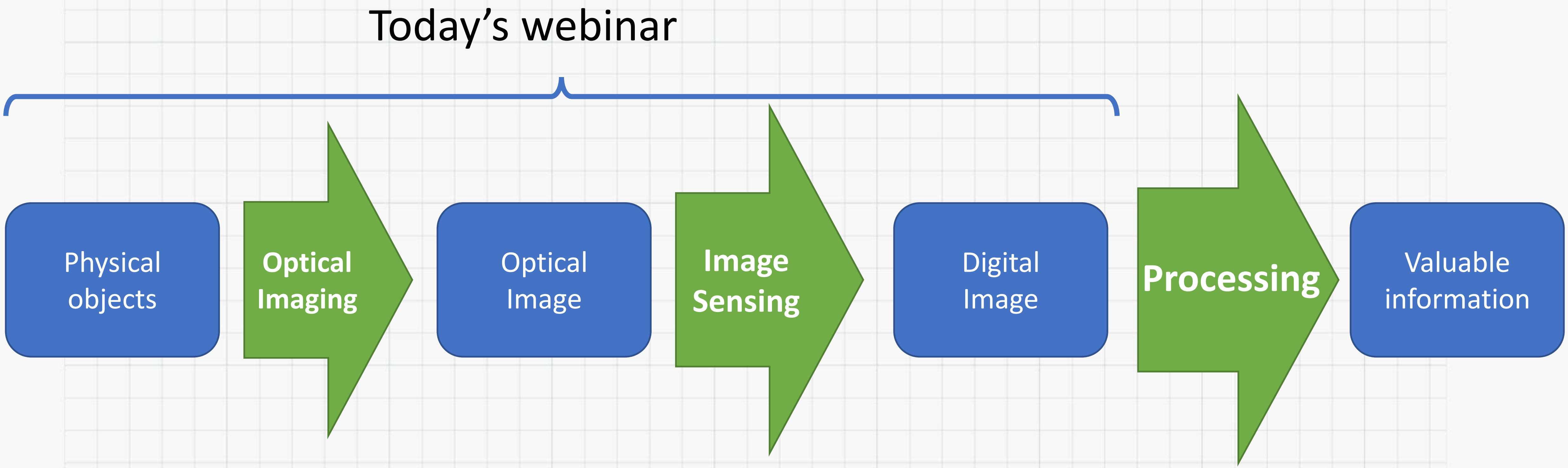
Importance of optimizing the digital camera

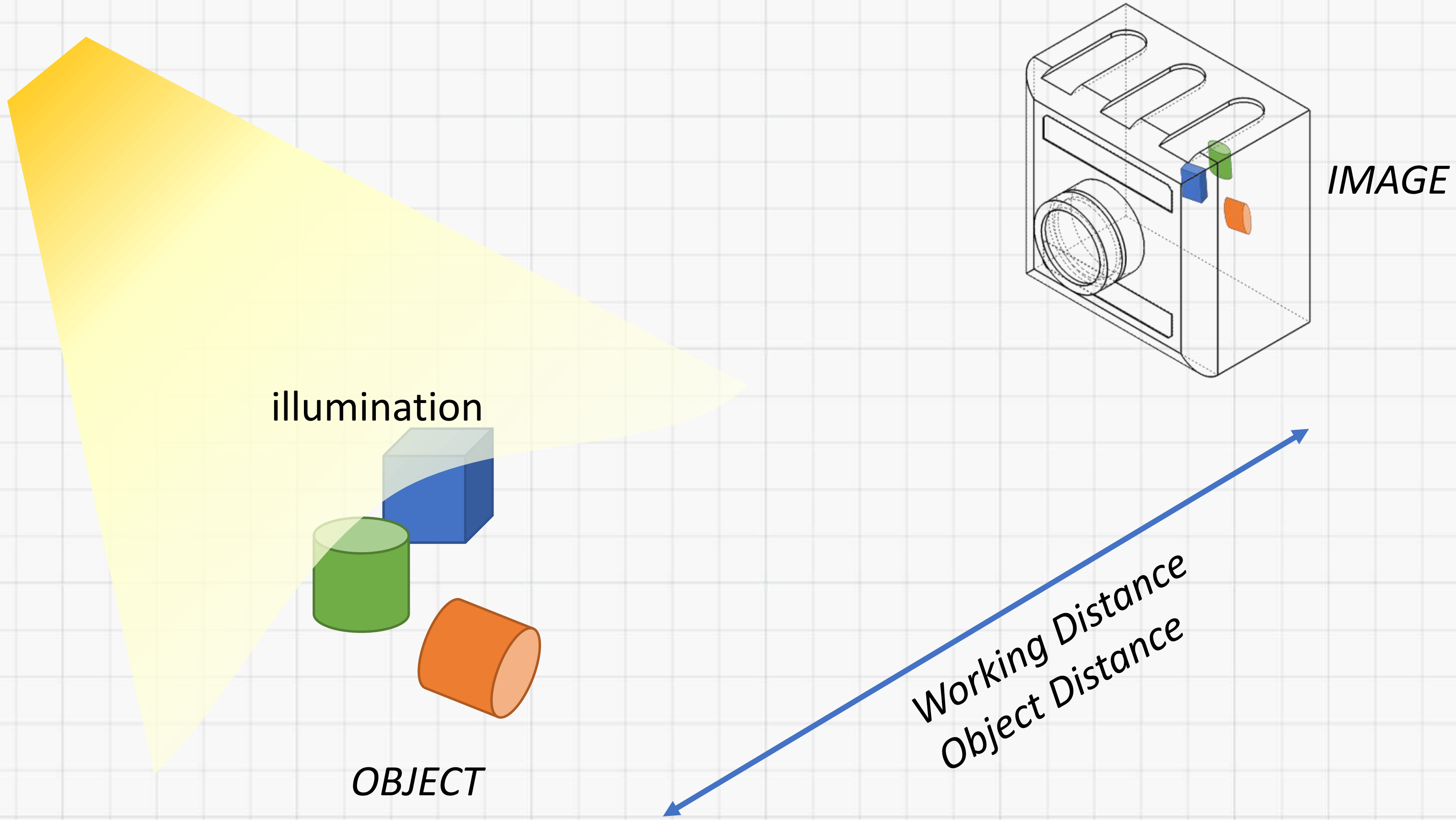
Making the right choices and intelligently balancing tradeoffs:

- Maximize SNR
- Contrast enhancement
- Seeing (resolving) critical object details
- Maximizing scanning system throughput
- Minimize distortion
- Obtain high color accuracy

Processes

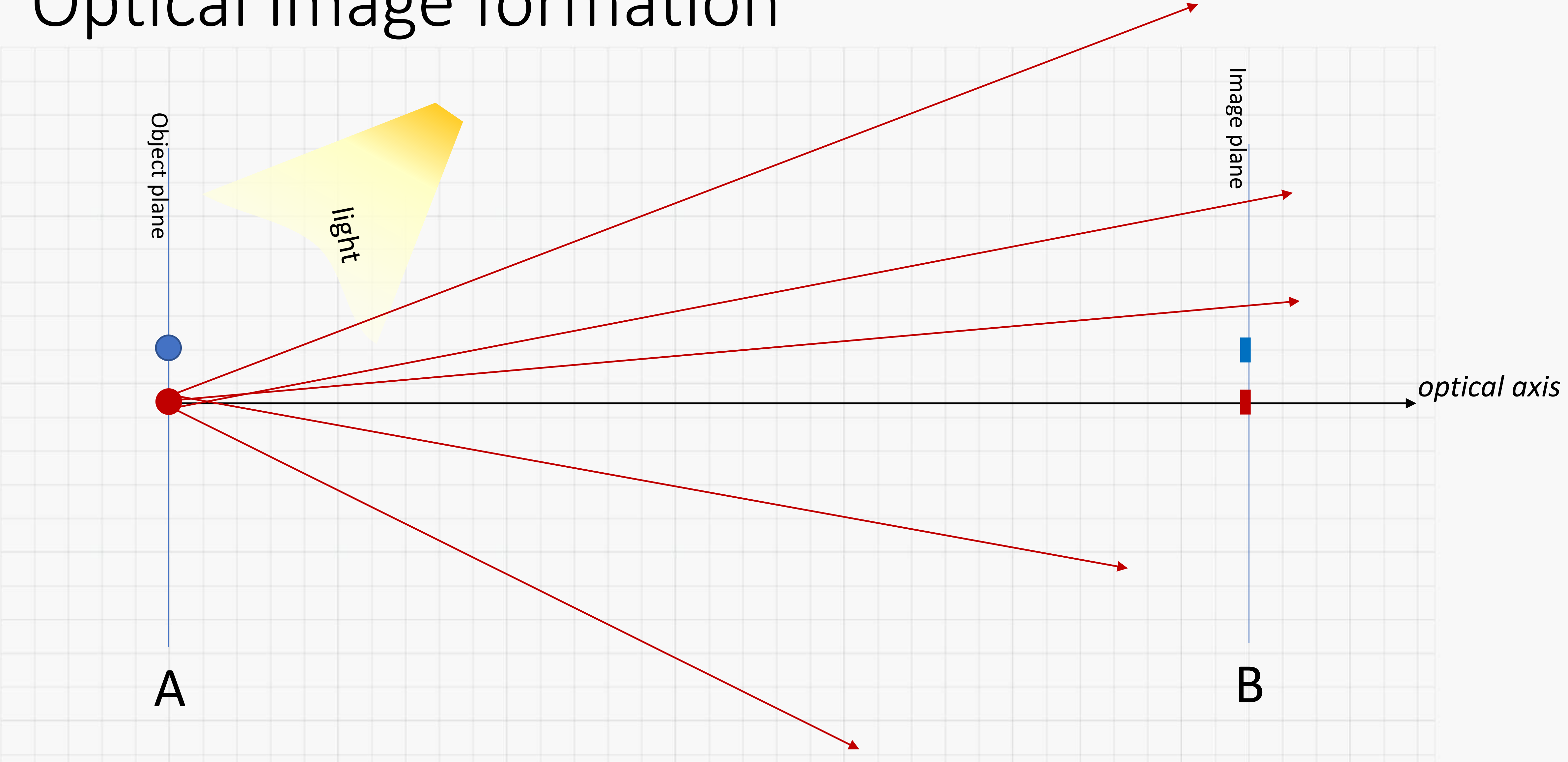

Today's webinar
Physical objects
Optical Imaging
Optical Image
Image Sensing
Digital Image
Processing
Valuable information

Optical imaging

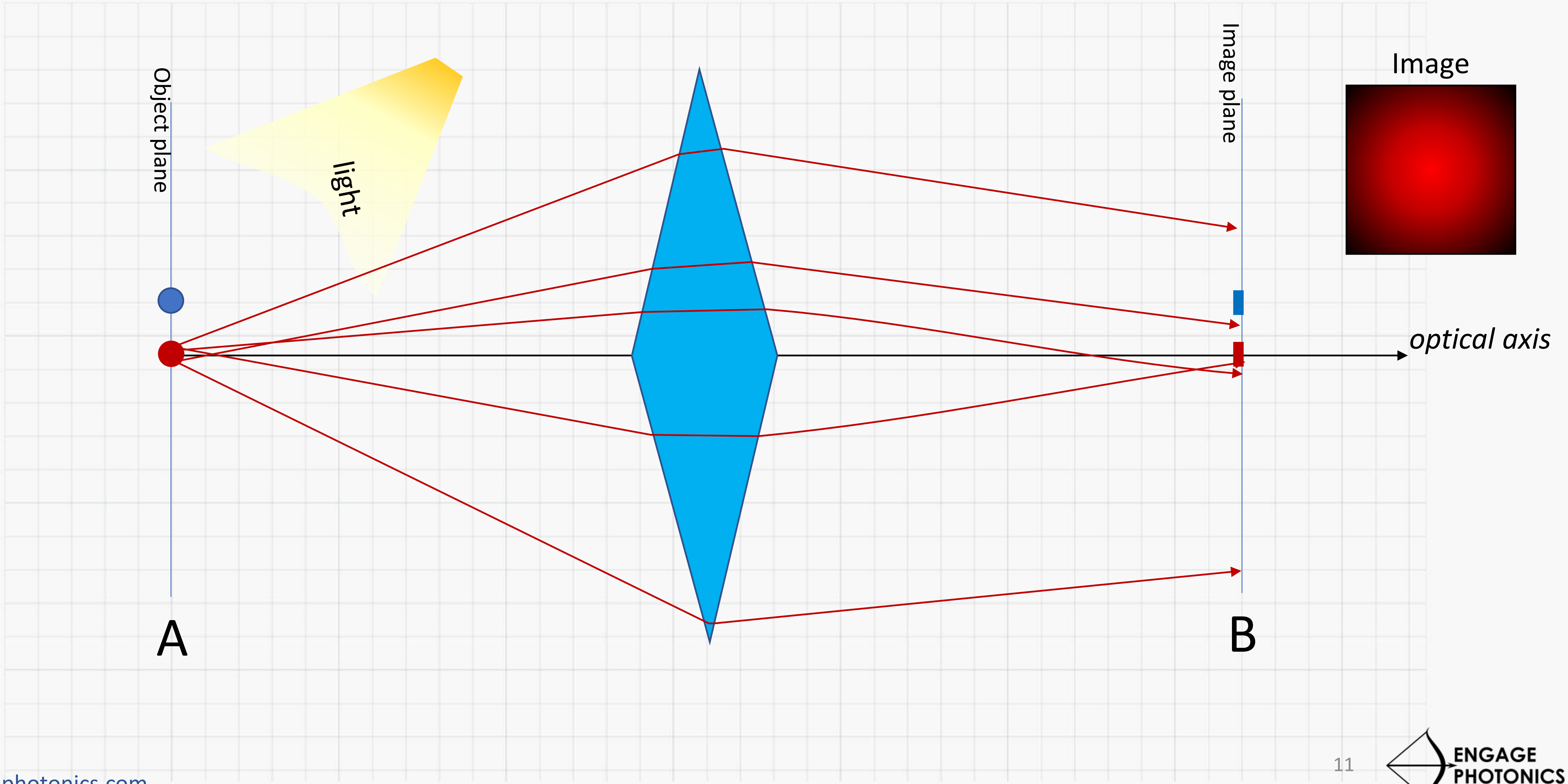


Optical image formation: 1st order optics and aberrations

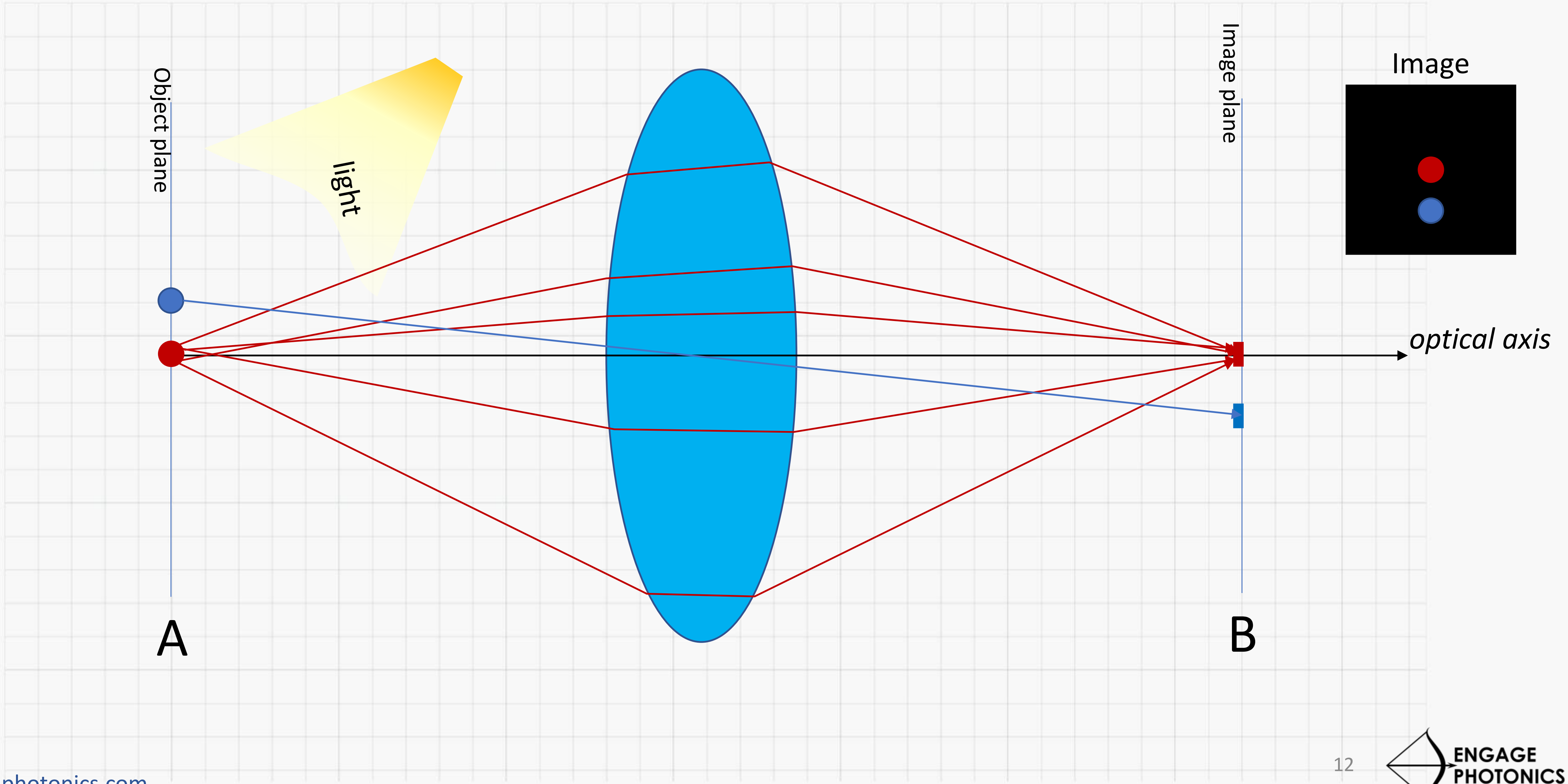
Optical image formation



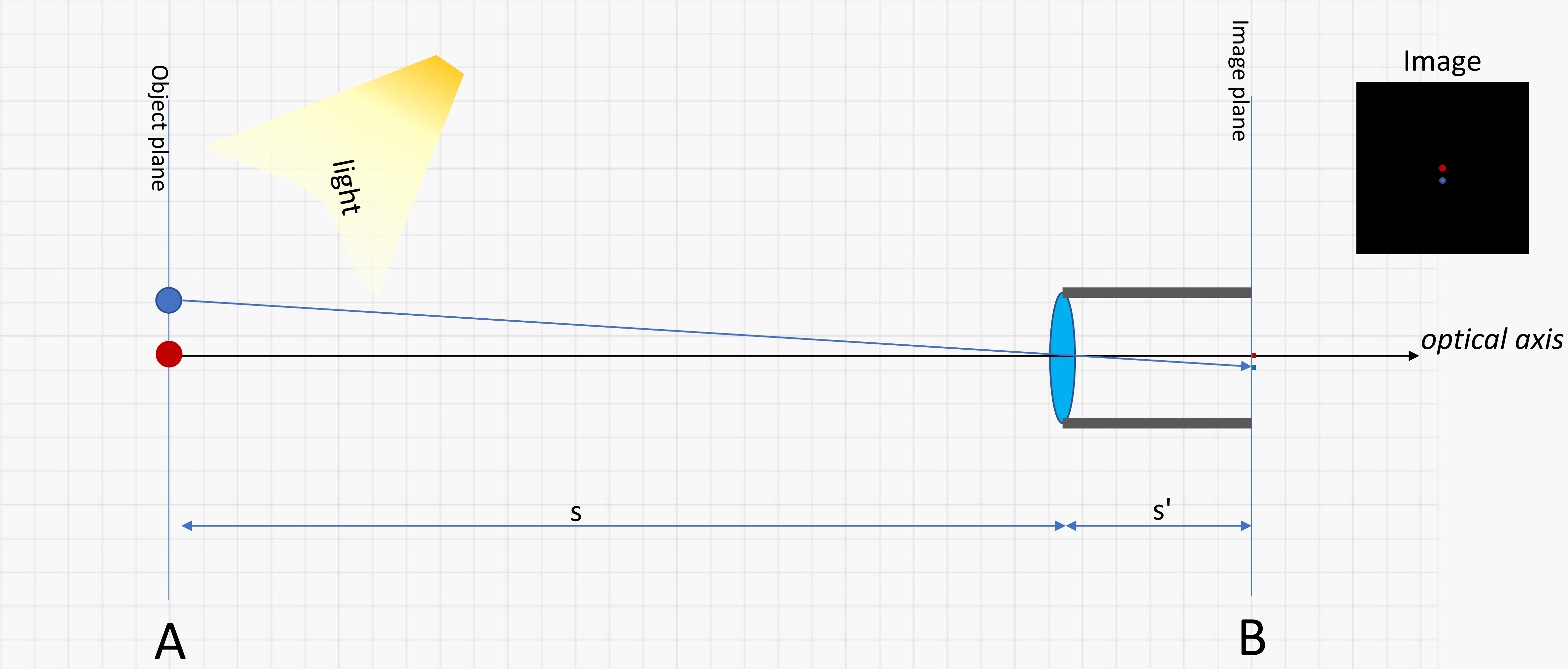
Optical image formation



Optical image formation

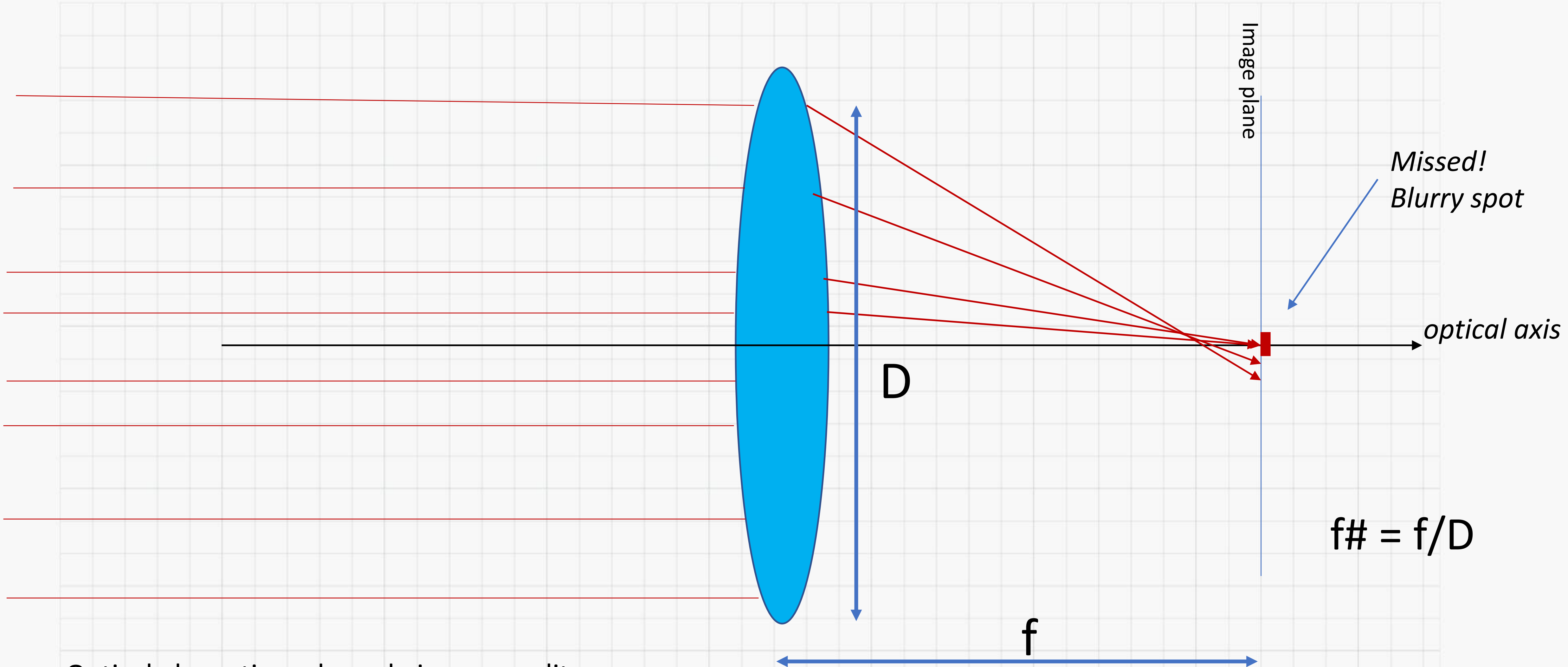


Optical image formation: Magnification



$1/s + 1/s' = 1/f$ $M=s'/s$ $y'=M*y$

Optical Aberrations

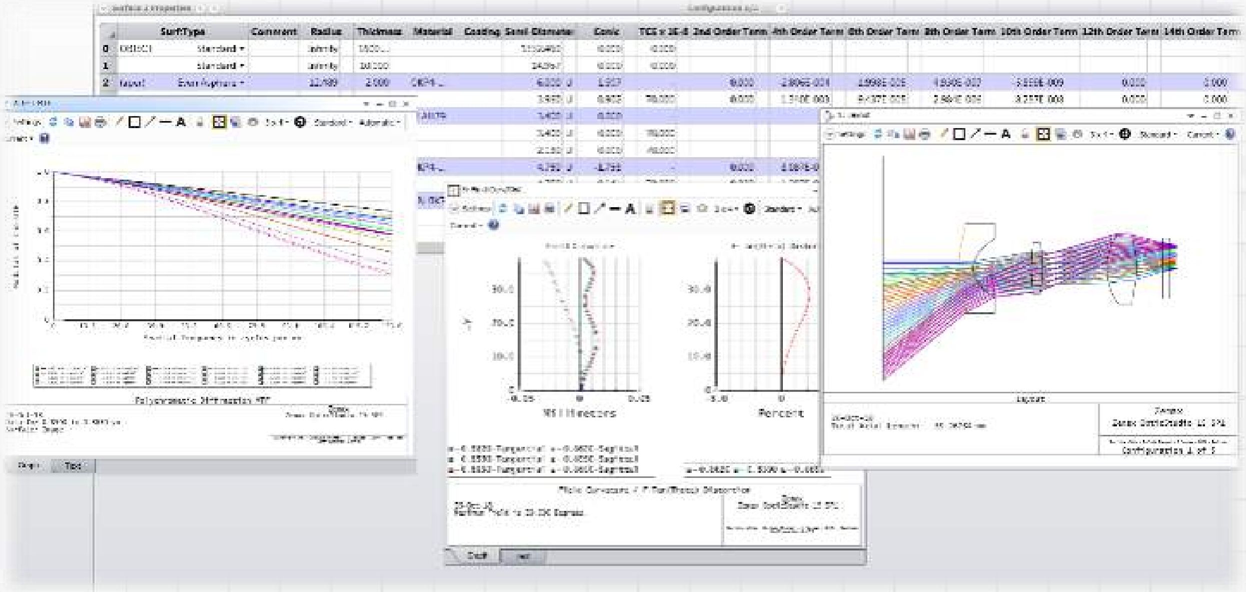


Optical aberrations degrade image quality
Sometimes can be controlled by f#

Real-world lenses

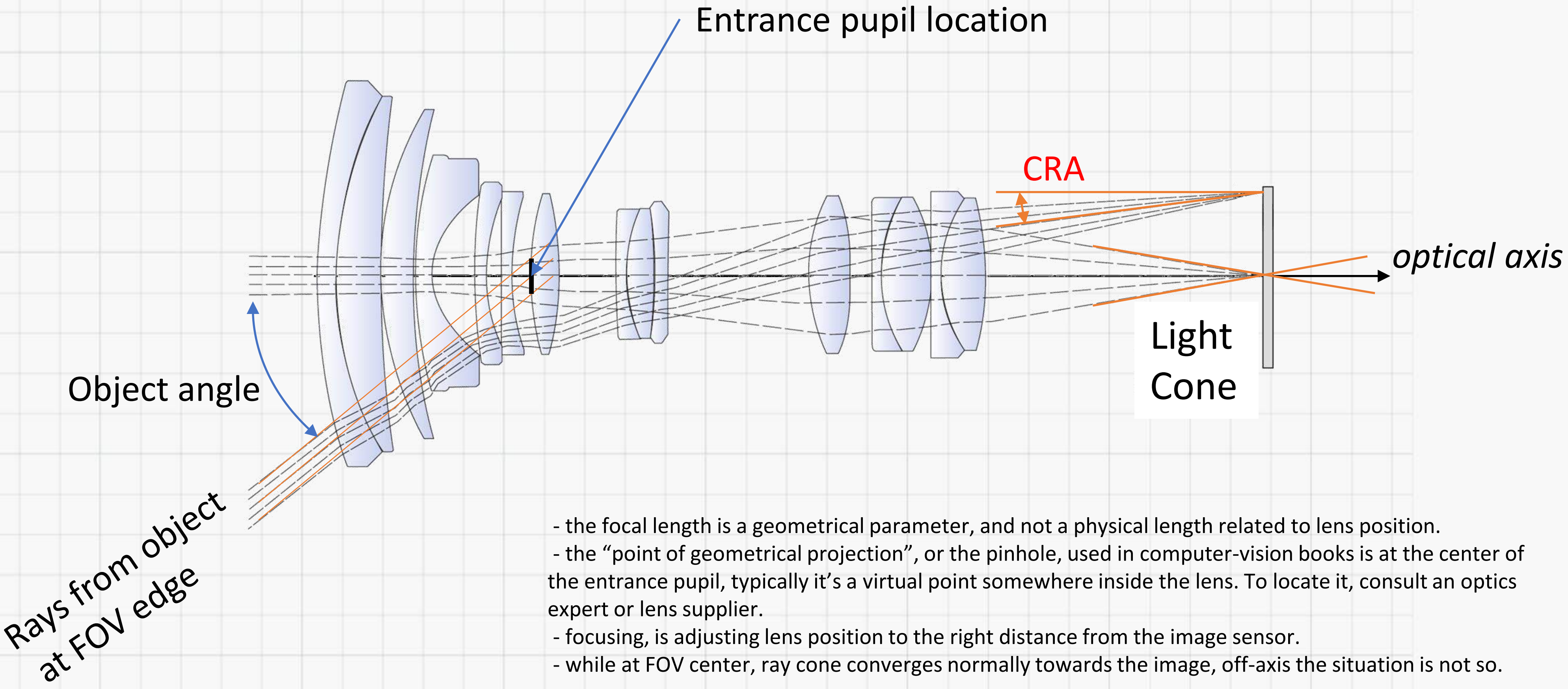
- AF/FF
- Zoom lens

Lens design in Zemax



Lens properties

- Focal length
- Focusing
- Entrance pupil
- CRA



- the focal length is a geometrical parameter, and not a physical length related to lens position.
- the "point of geometrical projection", or the pinhole, used in computer-vision books is at the center of the entrance pupil, typically it's a virtual point somewhere inside the lens. To locate it, consult an optics expert or lens supplier.
- focusing, is adjusting lens position to the right distance from the image sensor.
- while at FOV center, ray cone converges normally towards the image, off-axis the situation is not so.

https://enphotonics.com/livefocus/

Lens Focusing (extra slide)

Lens focusing is a seemingly simple task,
however quantitative and repeatable focusing for production require SW tools

www.enphotonics.com/mtf-calculator/

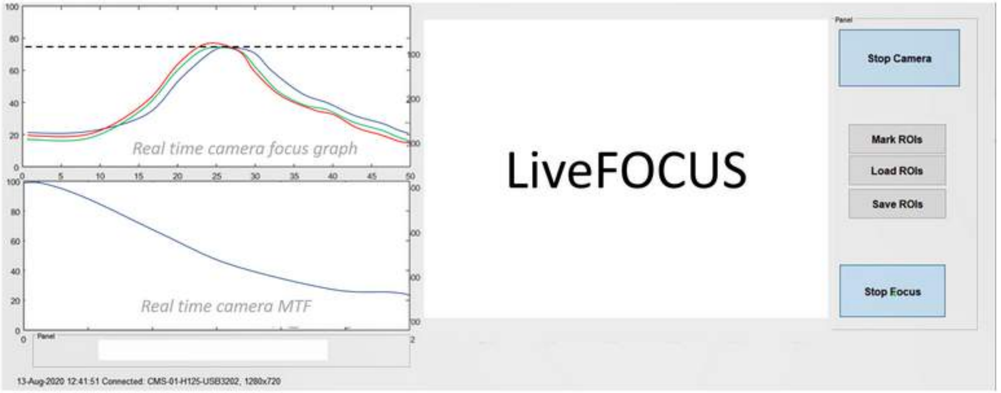
LiveFocus

Camera focusing SW for computer vision application development and for production line

Suitable for USB UVC, USB non-UVC, and GigE cameras.

Features:

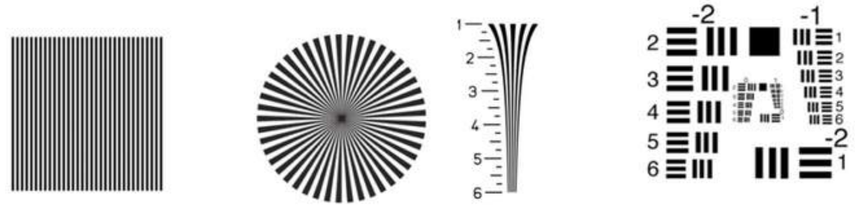
- Repeatable and quantitative camera focusing
- Does not require image sharpness evaluation by technician
- Fast
- Option: save MTF



Typical Camera focusing solutions

The commonly used setup for camera focusing is based on an illuminated target, which is positioned at the designated distance from the camera. The patterns in the target typically consist of fine features, such as Ronchi ruling, Spoke or other targets. Patterns in the industry vary by shapes and sizes, and they are never one-size-fits-all.

Ronchi   Spoke, PIMA   USAF 1951



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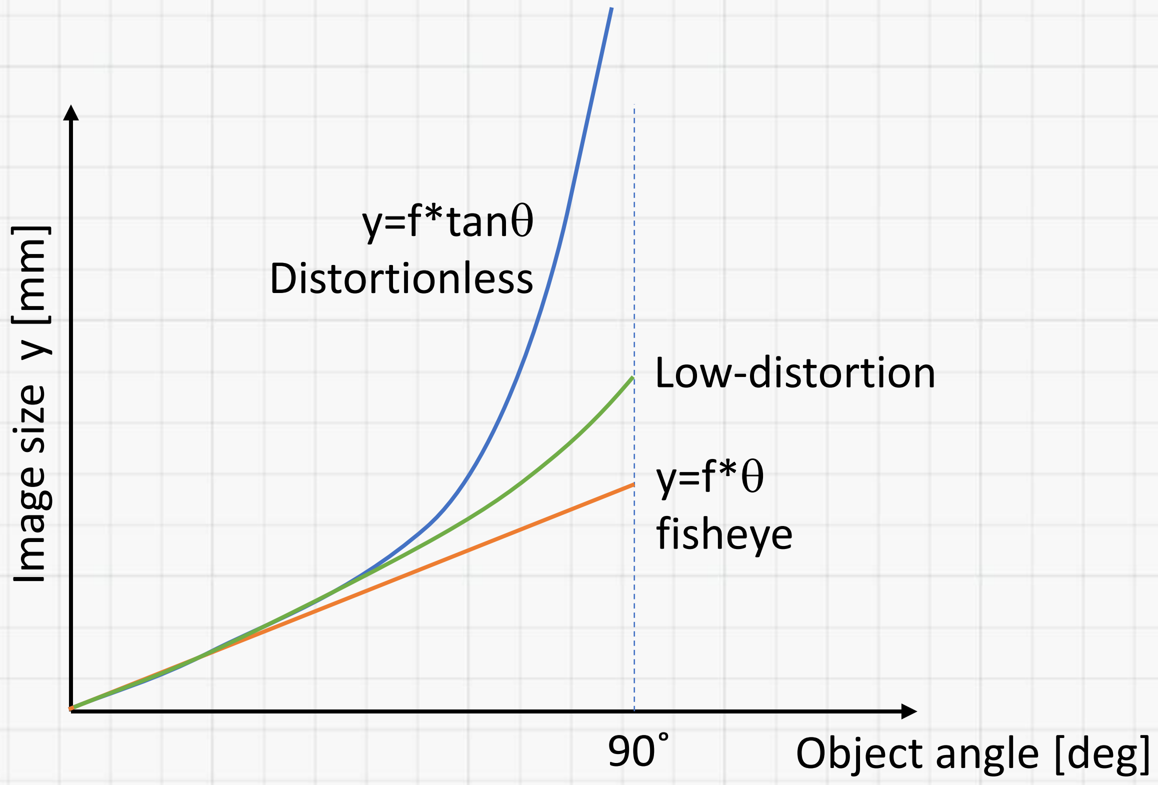
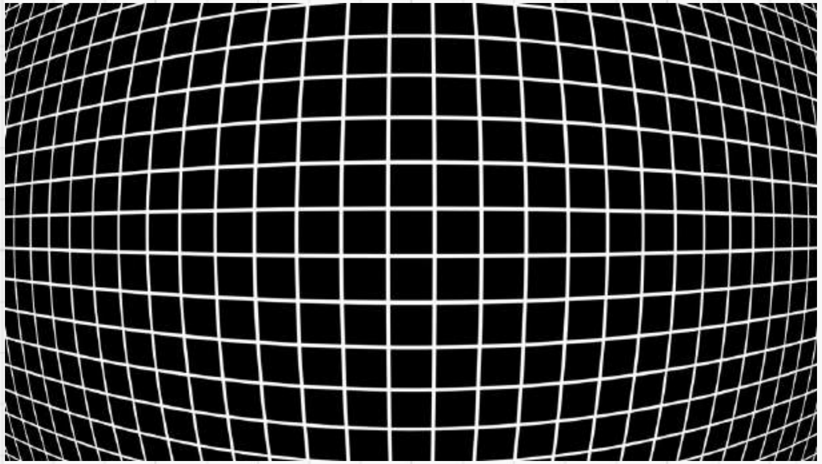
Distortion



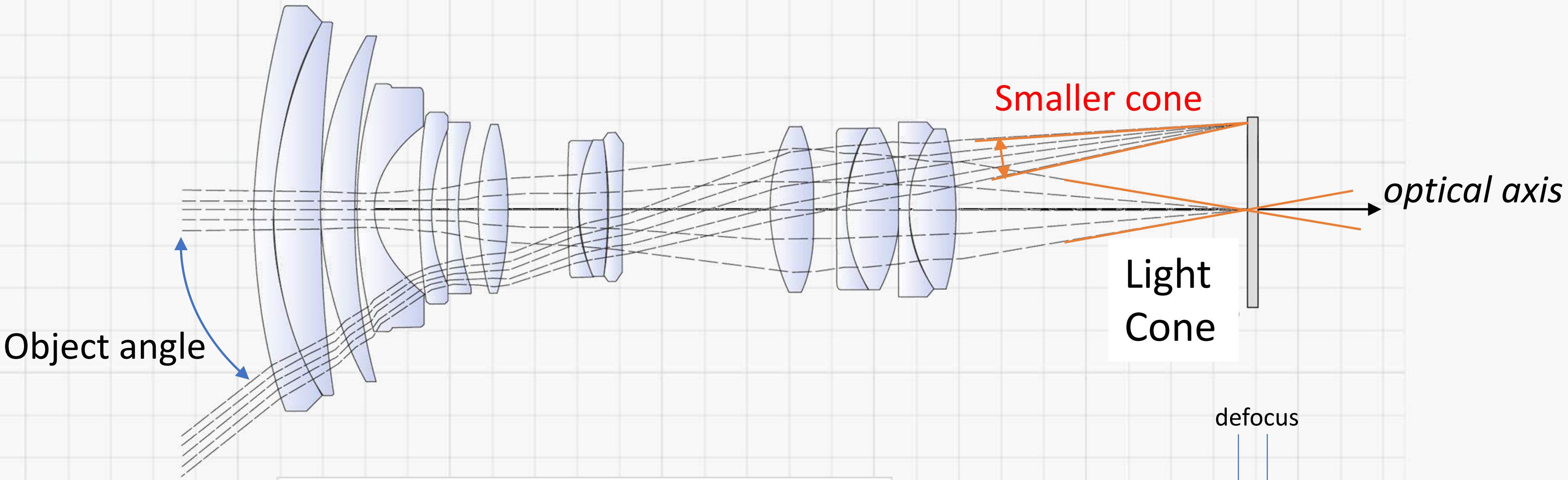
y=f*tanθ - distortionless
Low-distortion
y=f*θ - fisheye

Barrel distortion

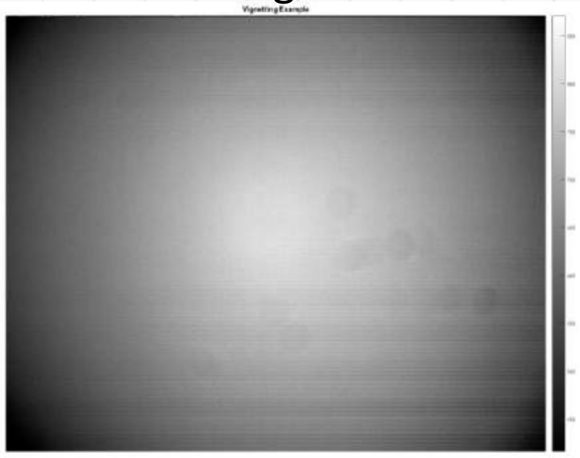


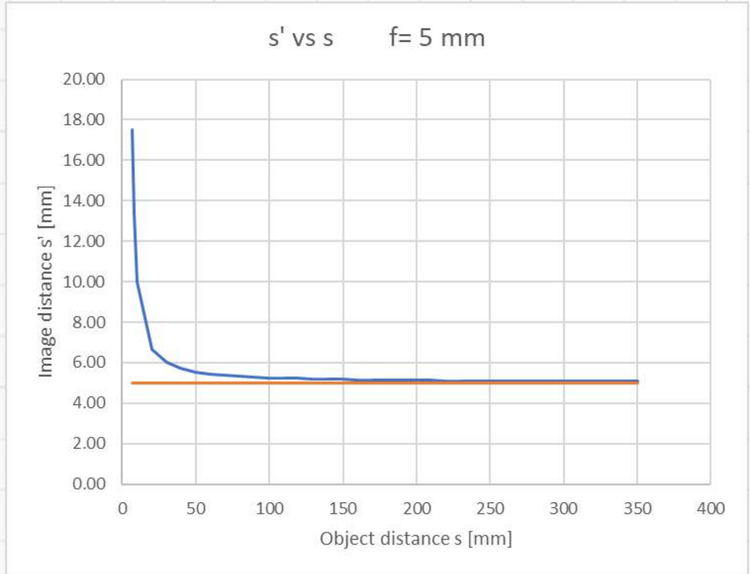
Physical lens limitations

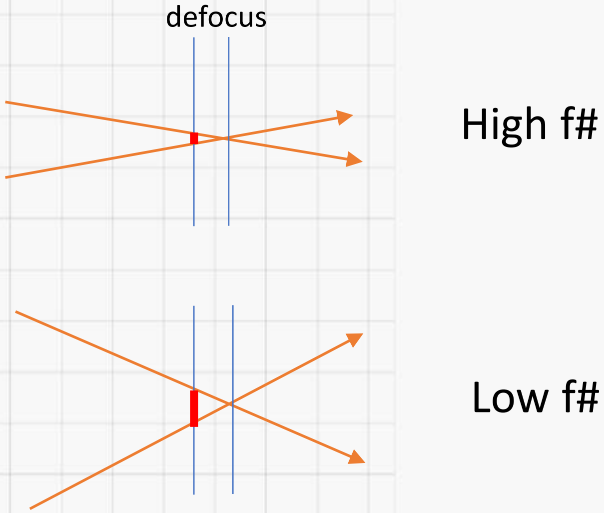
- Lens shading
- Vignetting
- Depth of focus
- Hyperfocal distance



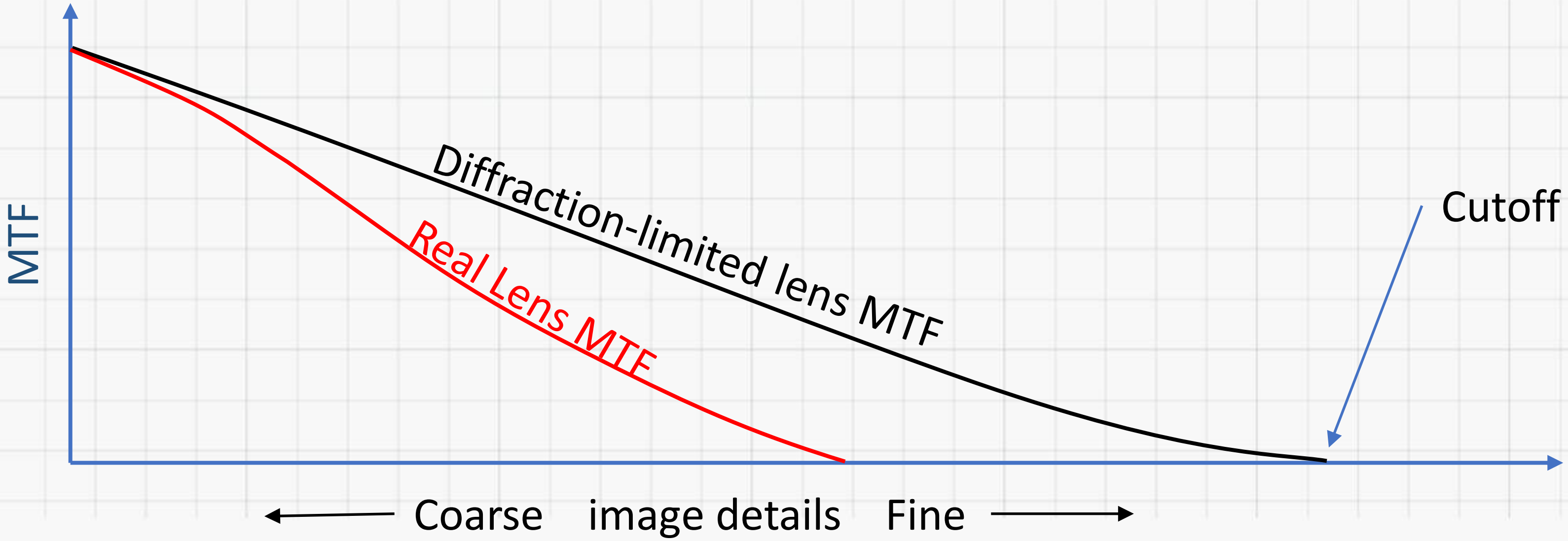
Lens shading





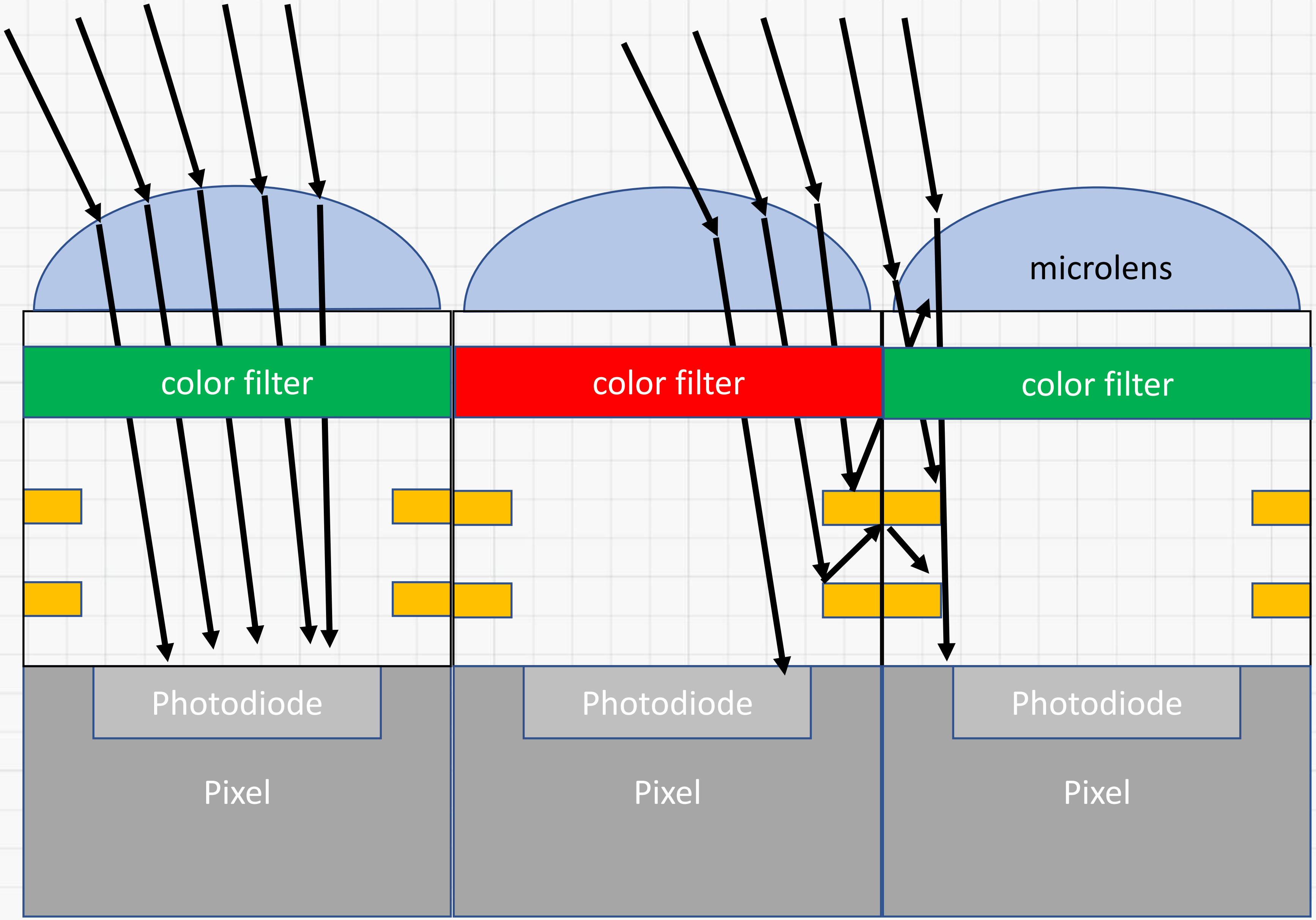


Physical lens limitations: diffraction and MTF

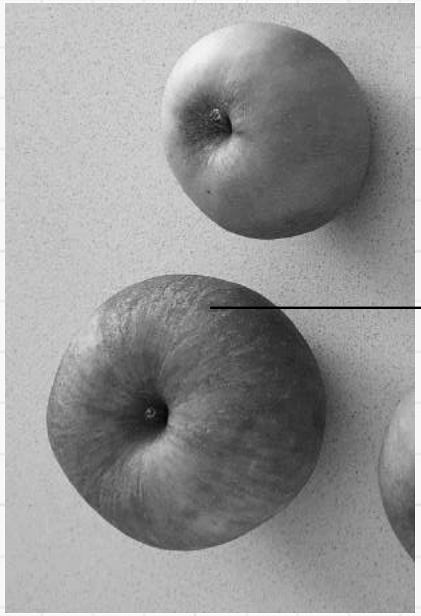


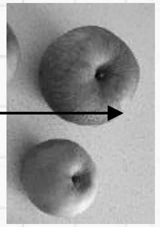
Optical to Digital image

Optical Image sensing

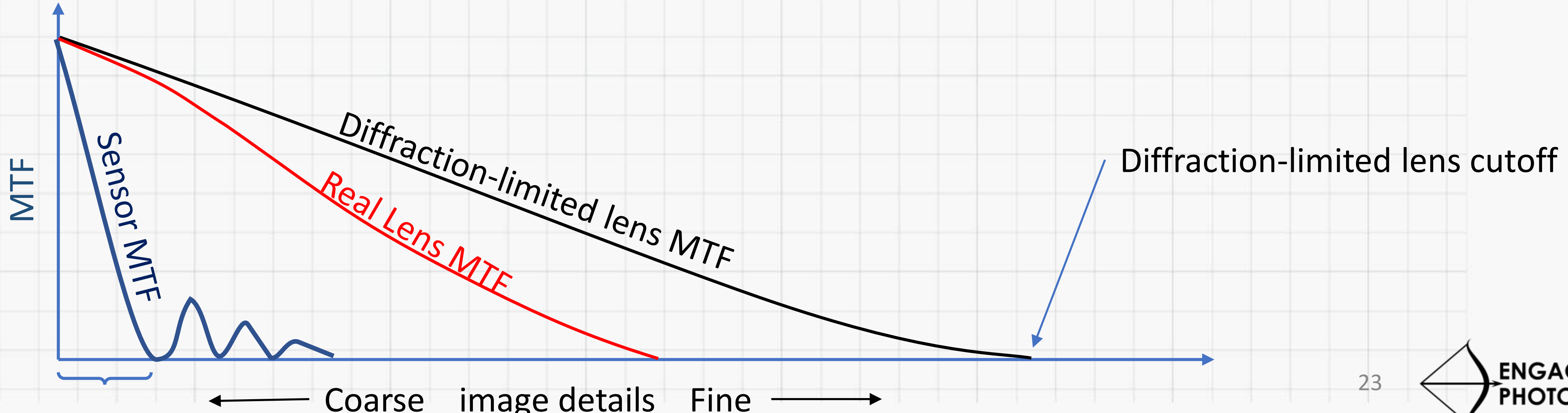


Physical lens limitations: diffraction and MTF



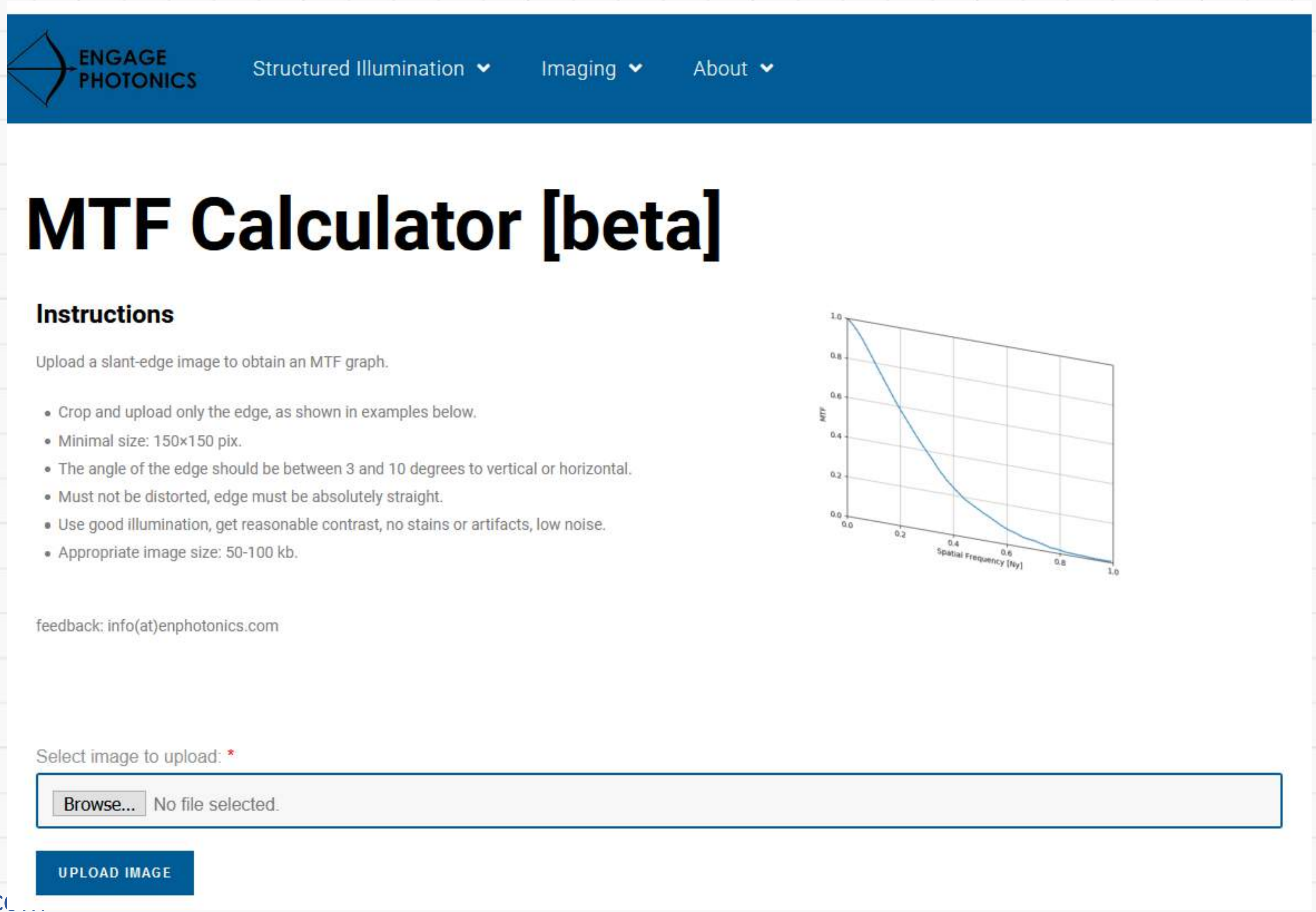


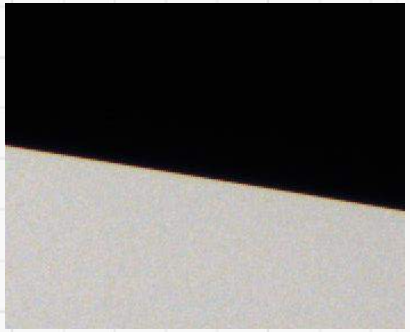
Often,
Sensor MTF is the limiting factor

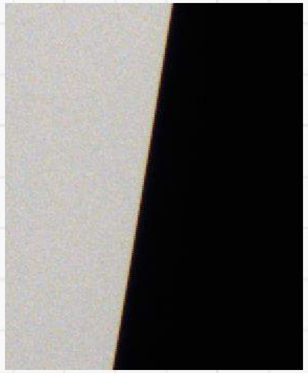


Camera MTF testing free tool

www.enphotonics.com/mtf-calculator/

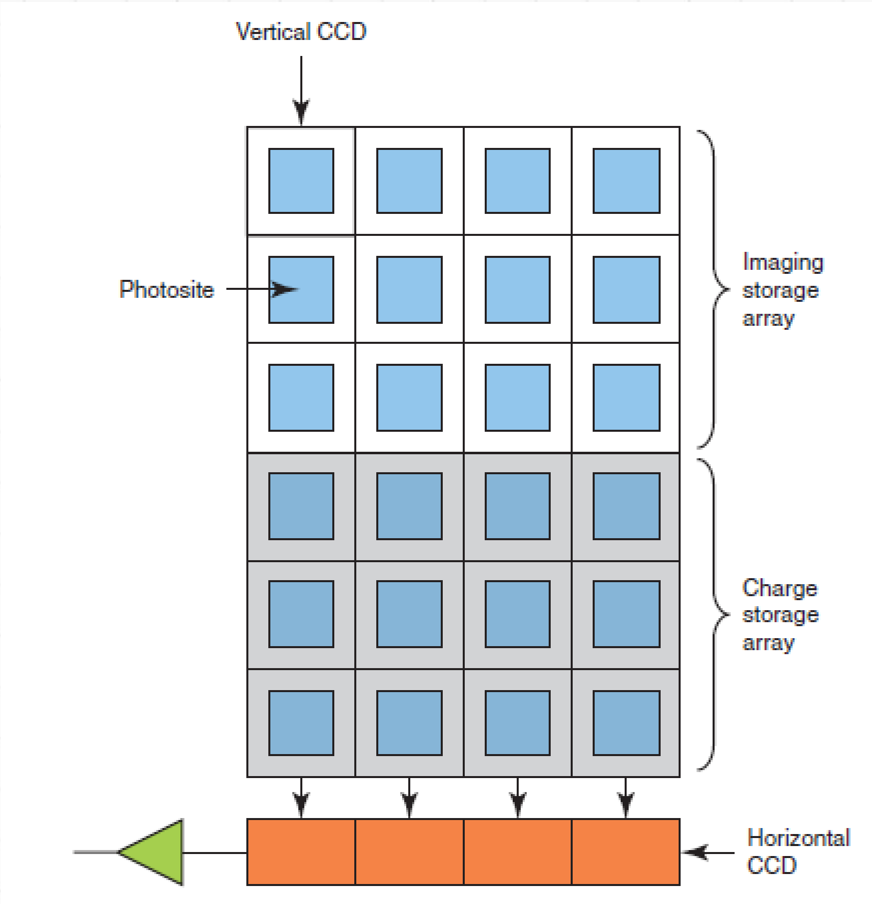




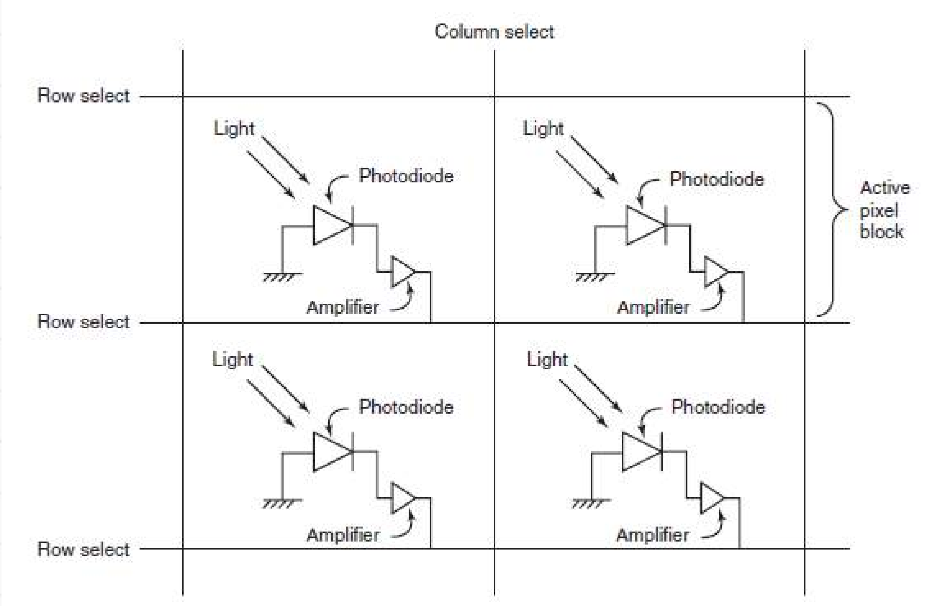


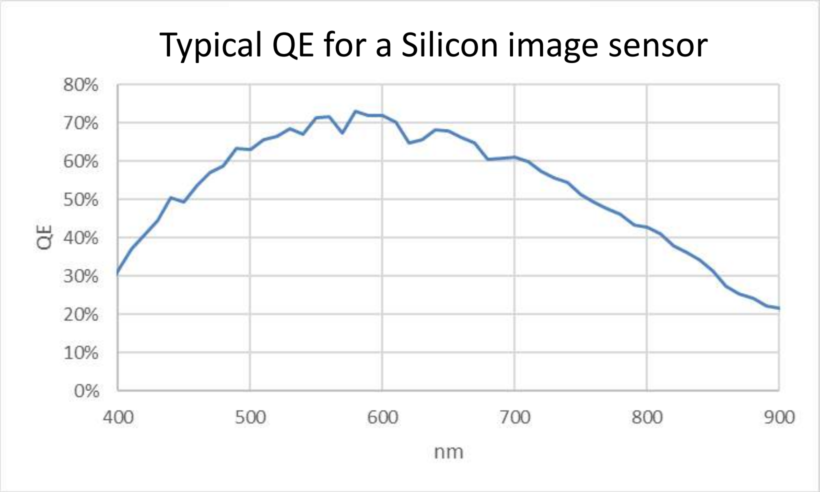
Electronic signal generation

CCD readout



CMOS image sensor





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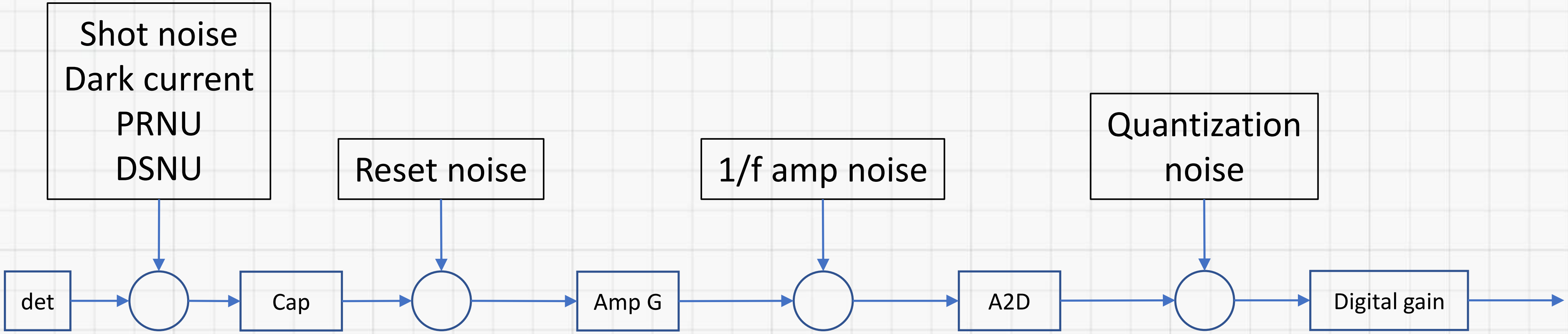
Gain factors and noise in signal generation

Gain Factor	From	Process	To	Limit
Exposure = Intensity × exposure time × QE	Photons	Absorption	Photoelectrons	Full well [ke-]
Sensitivity [V/lux*sec]	Photoelectrons	Sensing	Voltage	
Analog gain G	Voltage	Amp	Voltage	
Digital gain	Voltage	A2D, bits	Digital Level	2^bits



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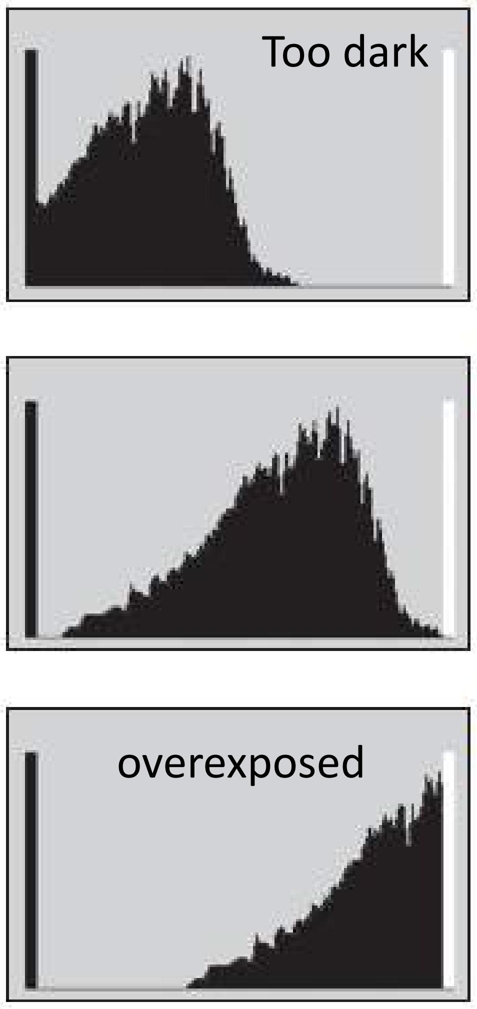
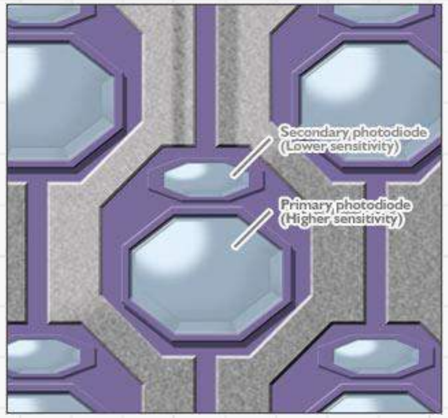
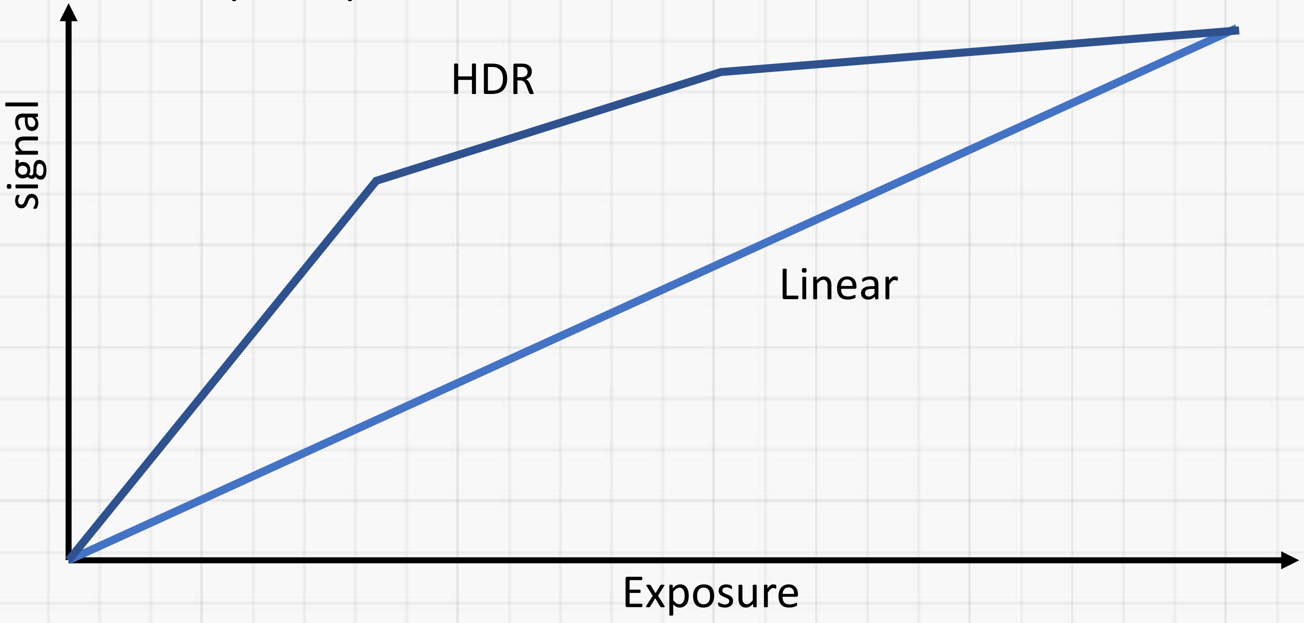
Signal histogram and HDR



FUJIFilm SuperCCD



Multiple exposure CMOS:



Main types of noise

Type	Noise	Dominance	
Fixed-pattern	DSNU (offset)	At low signal	Additive offset
Fixed-pattern	PRNU (gain)	At high signal	Gain proportional
Temporal	Dark noise	At low signal	Additive gaussian temporal
Temporal	Shotnoise	At high signal / anytime	Proportional to sqrt(signal)
	Quantization noise	At low signal	

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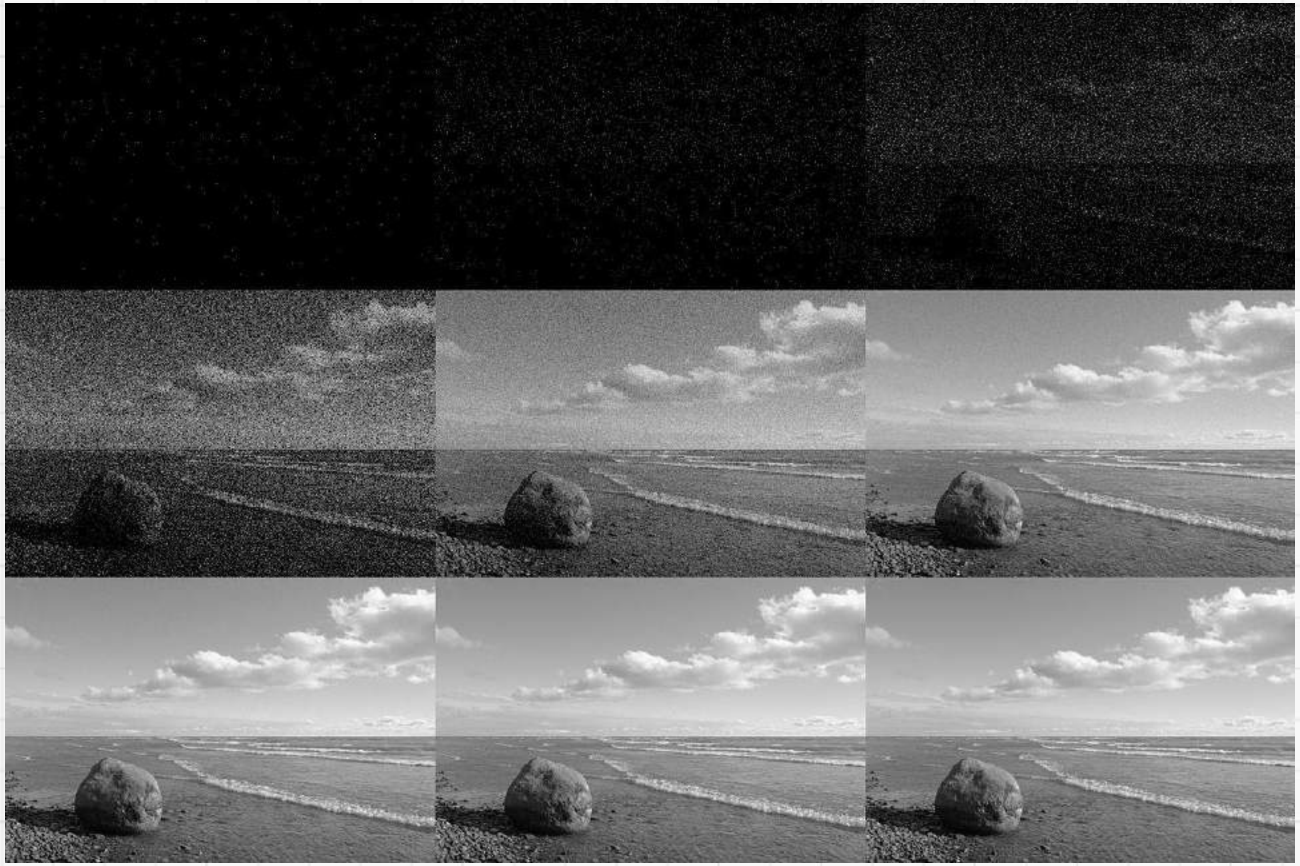
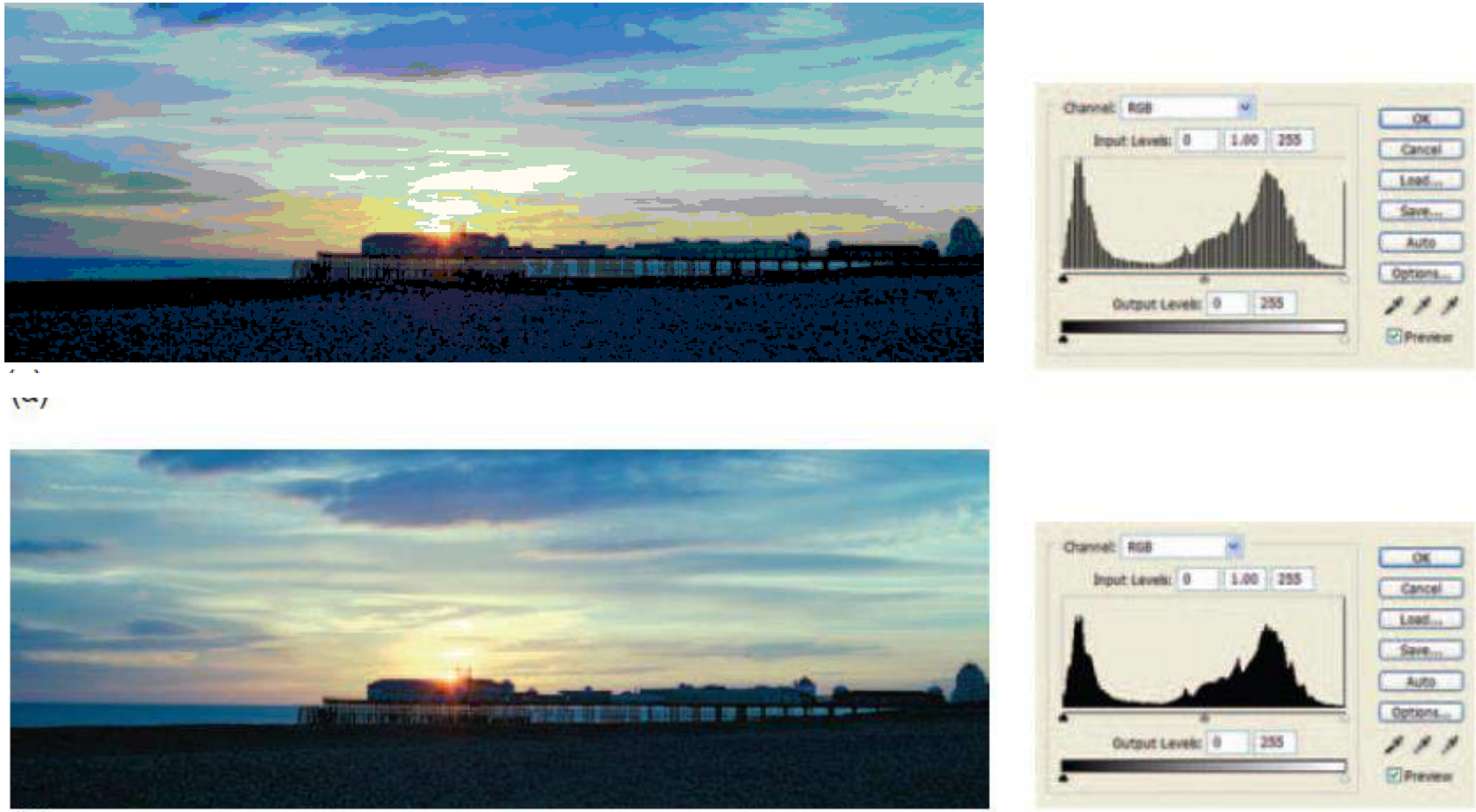
Shot noise

Shot-noise is proportional to square root of signal,
SNR is proportional to square root of signal as well.

$$\mathrm{SNR} = \frac{N}{\sqrt{N}} = \sqrt{N}.$$

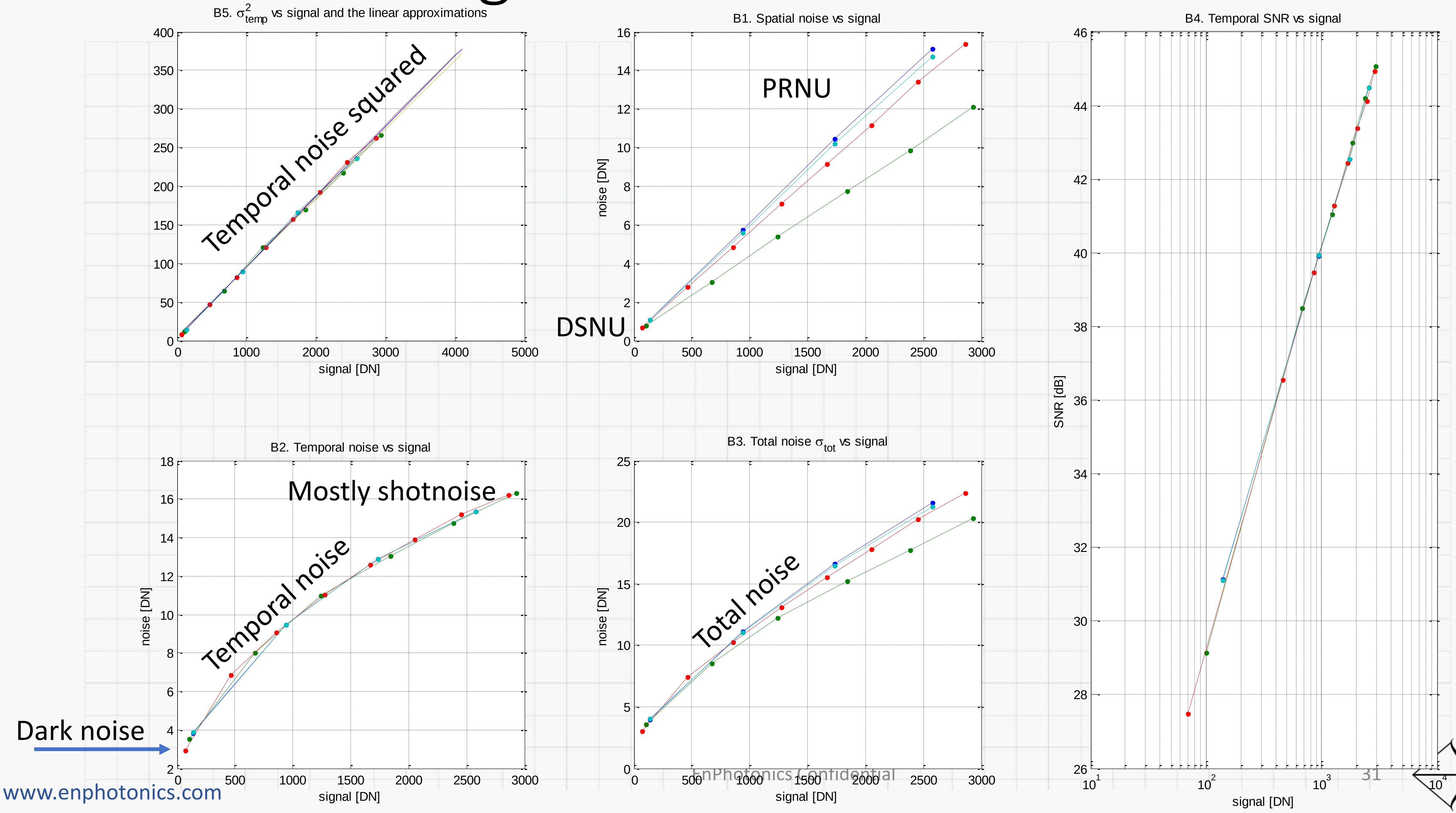


Quantization noise



(b)

Noise in image sensors



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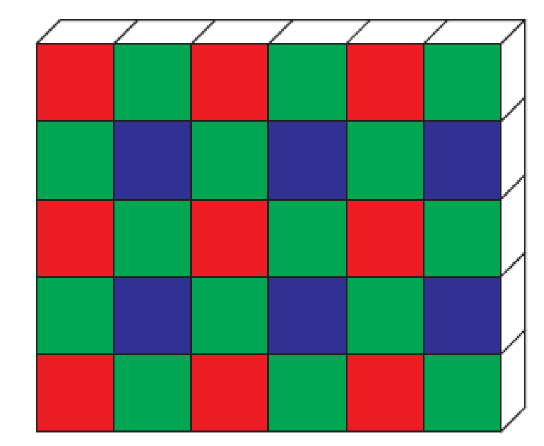
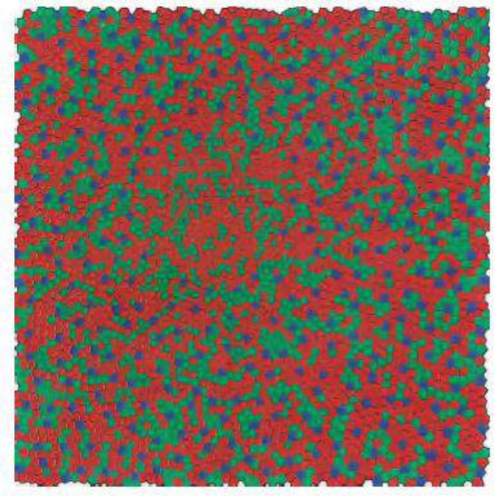
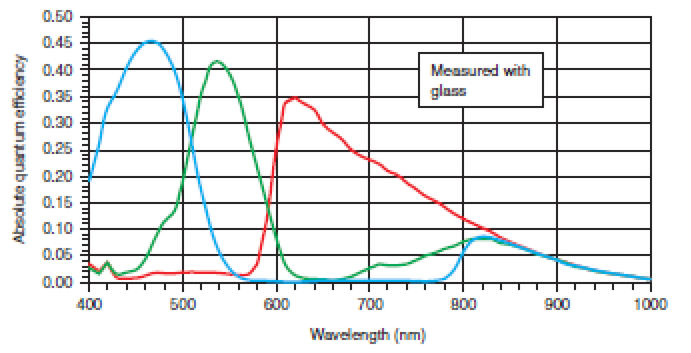
Color perception and color imaging

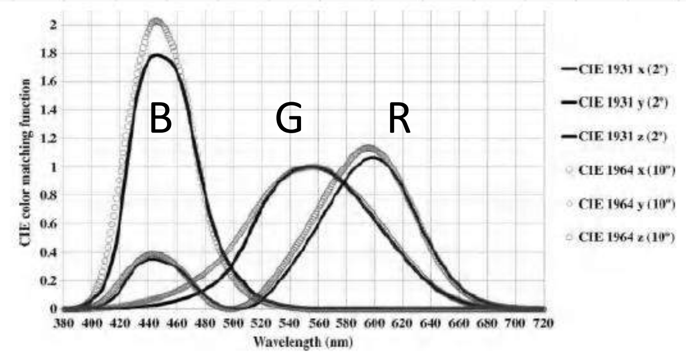
Bayer



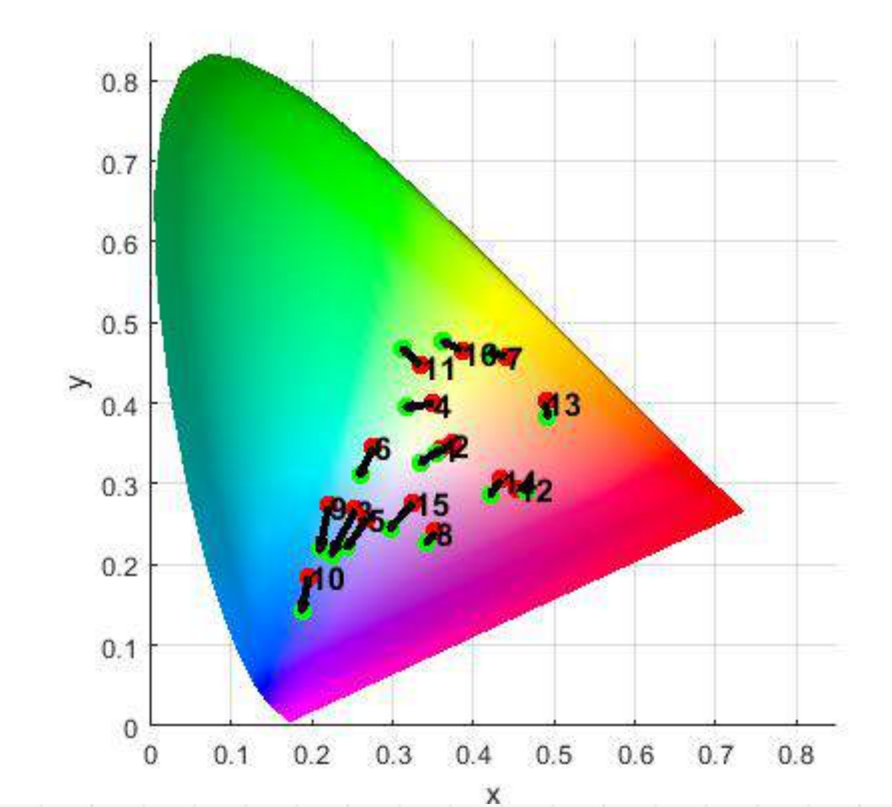
Retina





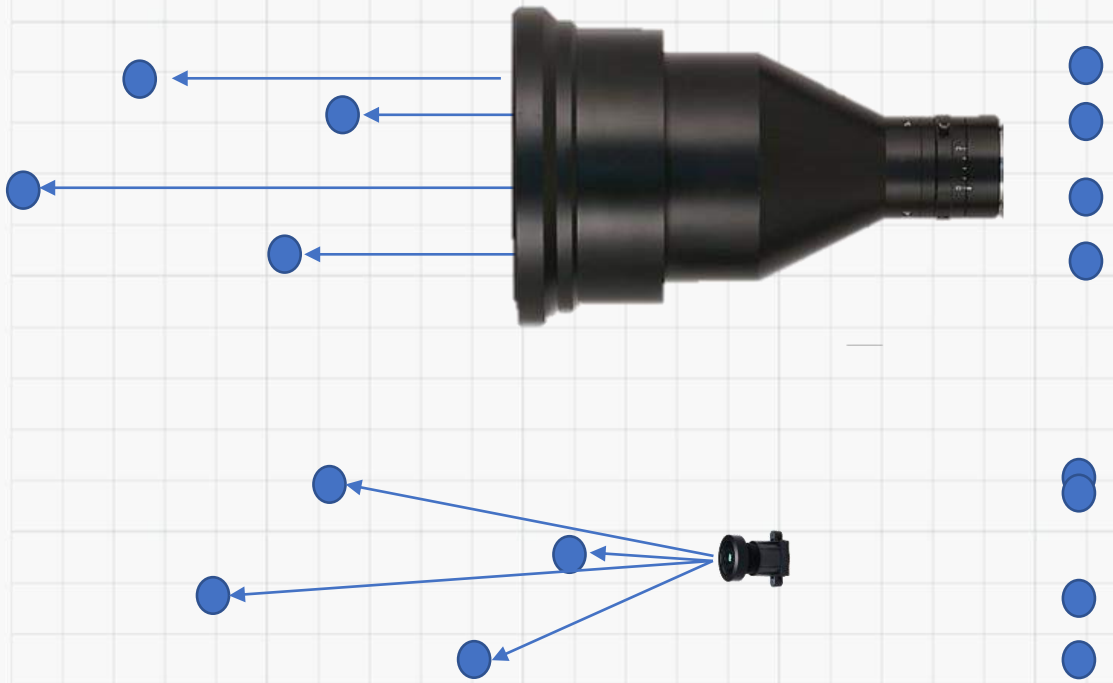


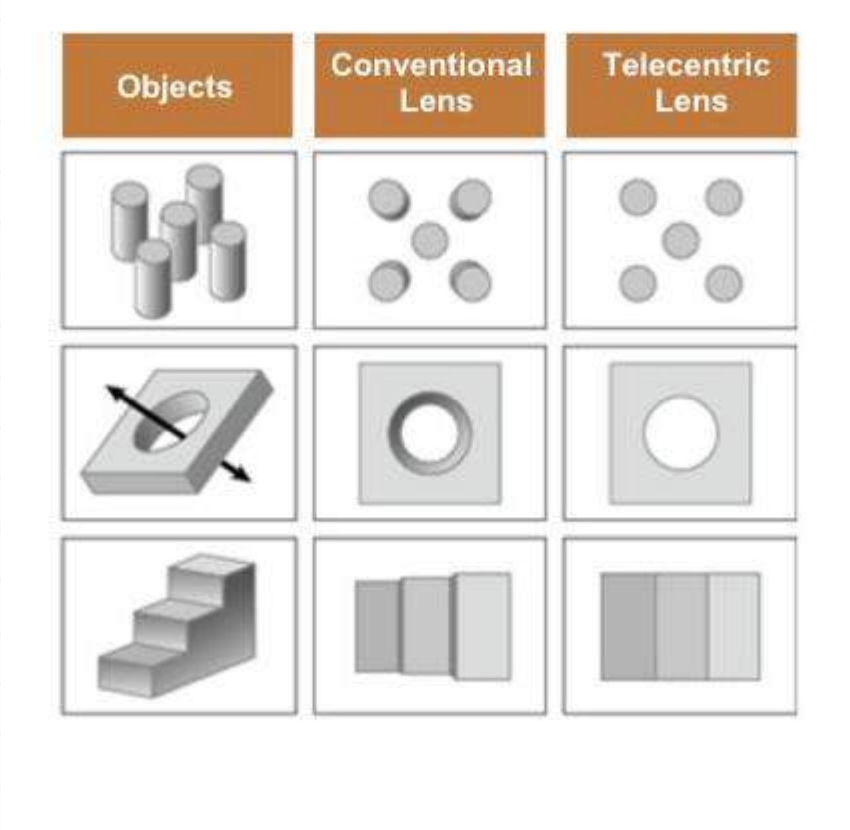
Color accuracy



Practical examples

Telecentric imager





Smartphone AF camera