LEBANON CAMERA CLUB

Introduction to the Digital Camera

Part 4 – Lenses

Keith Kotay

Intro to the Digital Camera: Lenses

Introduction

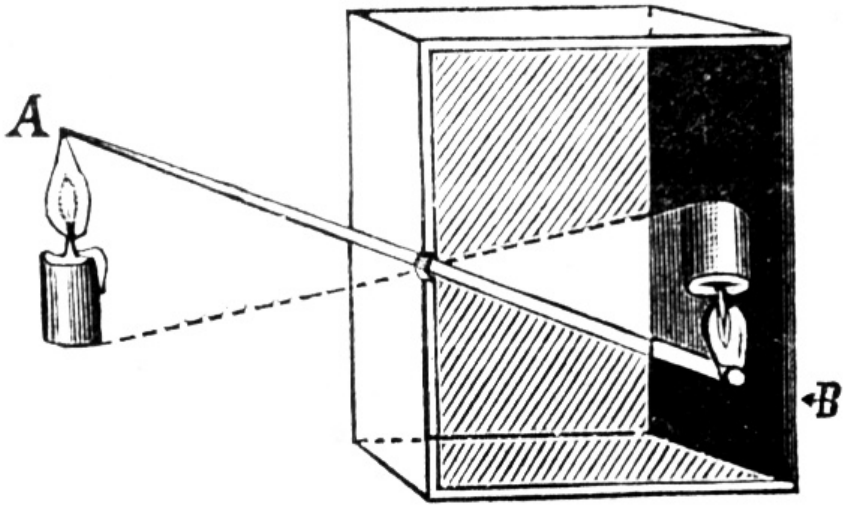
- Camera lens
  - Optical device used to project an image onto a light sensitive medium
- History
  - Pinhole effect

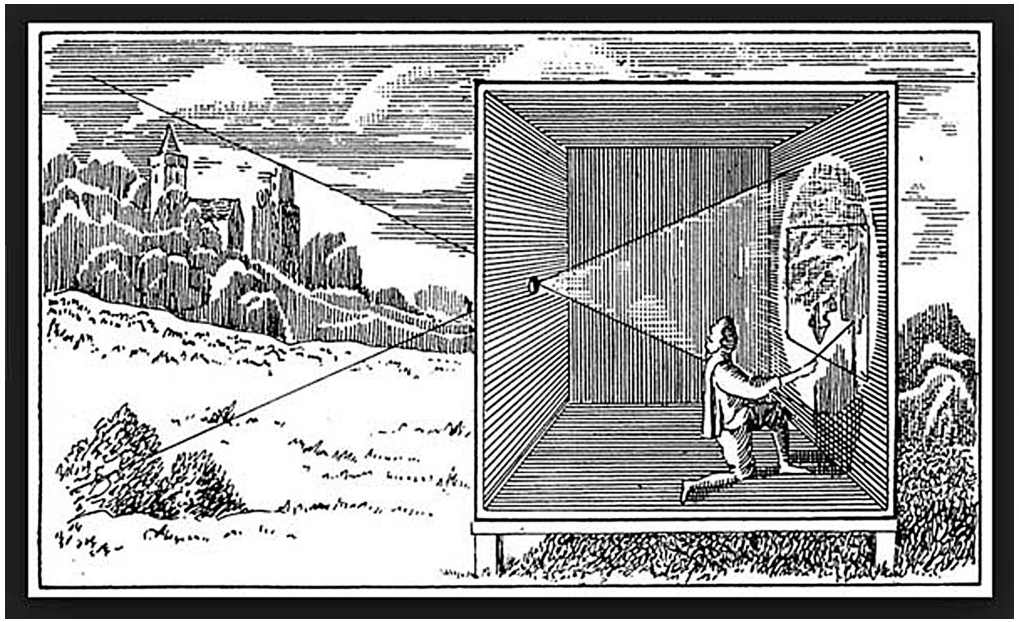
multiple solar eclipse images projected by small openings between leaves (“pinholes”)

Intro to the Digital Camera: Lenses

Introduction

- Camera lens
  - Optical device used to project an image onto a light sensitive medium
- History
  - Pinhole effect
  - Camera obscura





Intro to the Digital Camera: Lenses

Introduction

- Camera lens
  - Optical device used to project an image onto a light sensitive medium
- History
  - Pinhole effect
  - Camera obscura
- Camera types
  - Fixed lens: point & shoot, cell phone
    - May be able to add “supplemental lenses”

Intro to the Digital Camera: Lenses

Introduction

- Camera lens
  - Optical device used to project an image onto a light sensitive medium
- History
  - Pinhole effect
  - Camera obscura
- Camera types
  - Fixed lens: point & shoot, cell phone
    - May be able to add “supplemental lenses”
  - Interchangeable lens: DSLR, mirrorless

Intro to the Digital Camera: Lenses

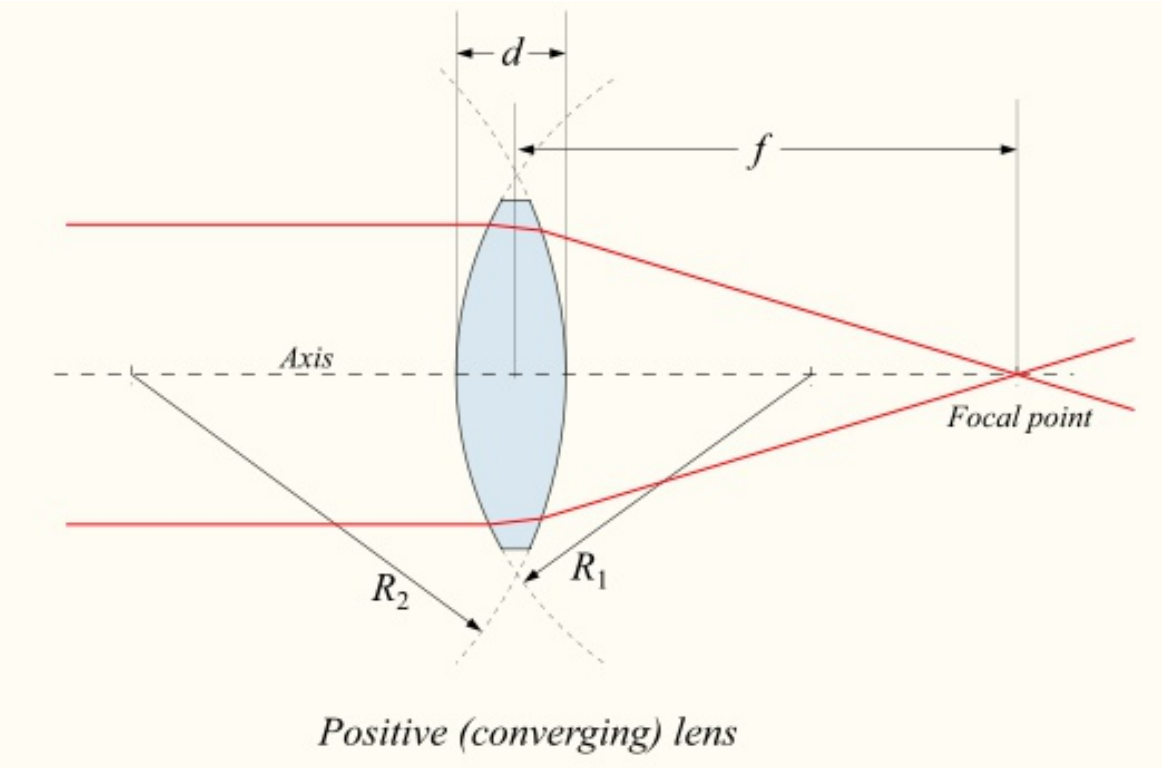
Introduction

- Lens construction
  - Pinhole lens
    - No glass
    - Cheap
    - Make your own!

Intro to the Digital Camera: Lenses

Introduction

- Lens construction
  - Normal lens → glass used to gather light

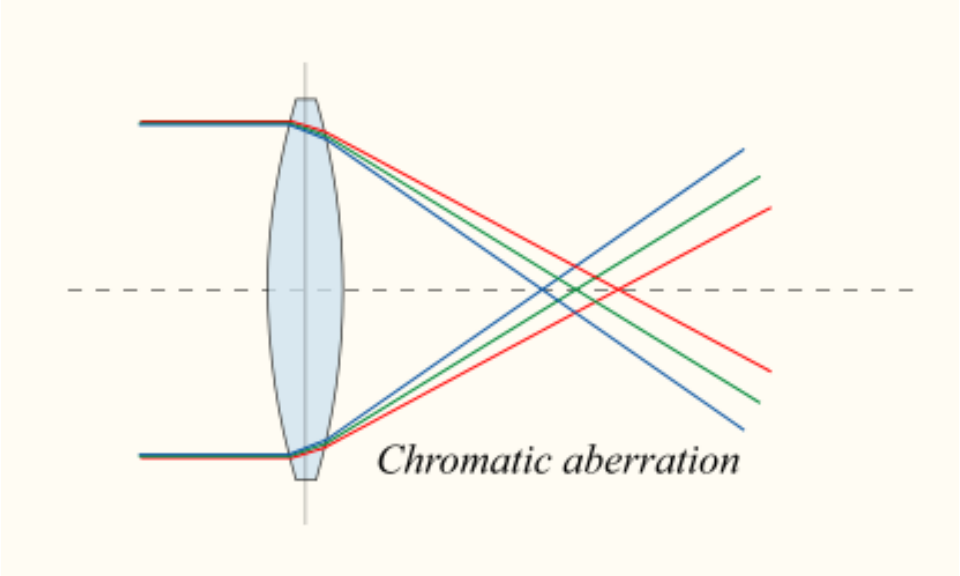


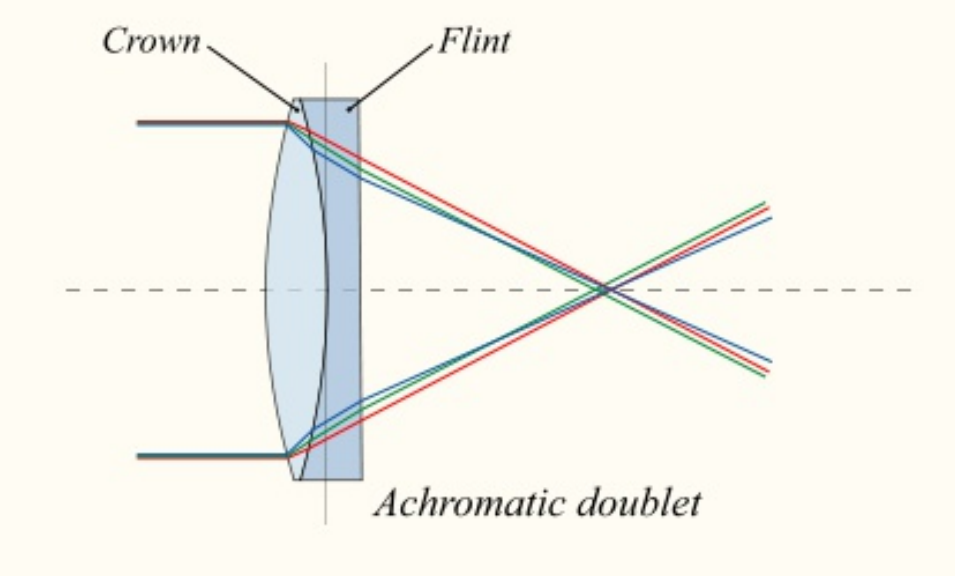
Positive (converging) lens

Intro to the Digital Camera: Lenses

Introduction

- Lens construction
  - Normal lens → glass used to gather light
    - Multiple glass 'elements' → single element cannot focus all colors





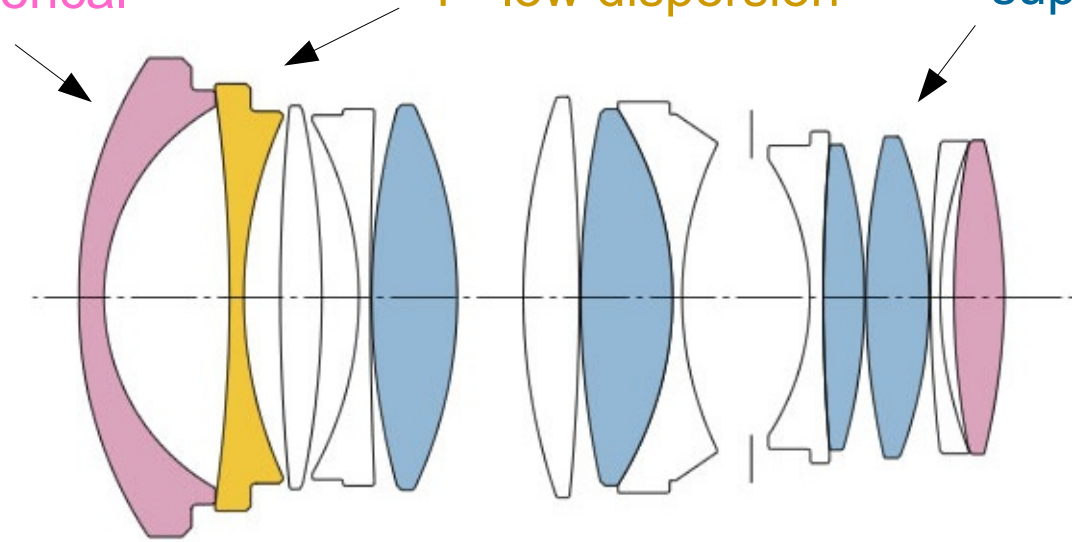
Intro to the Digital Camera: Lenses

Introduction

- Lens construction
  - Normal lens
    - Multiple glass 'elements' → single element cannot focus all colors
    - May have exotic glass types or shapes → exotic = expensive
    - Coatings reduce reflections, improve contrast → more elements

Air-Glass Surface Light Loss

No coating.....4.0%
Single coating...1935.....1.3%
Multi coating.....1970.....0.25%
Nano coating.....2005.....0.05%

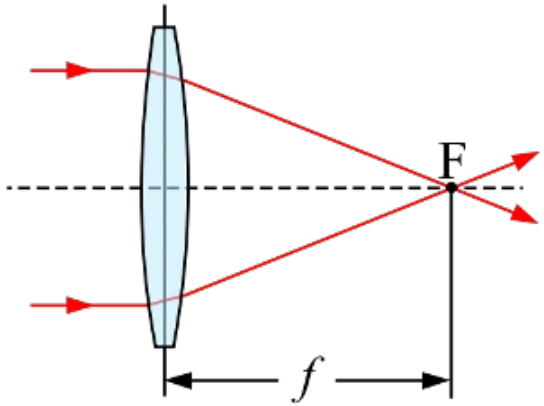


Sigma 35mm F1.4 DG HSM ART

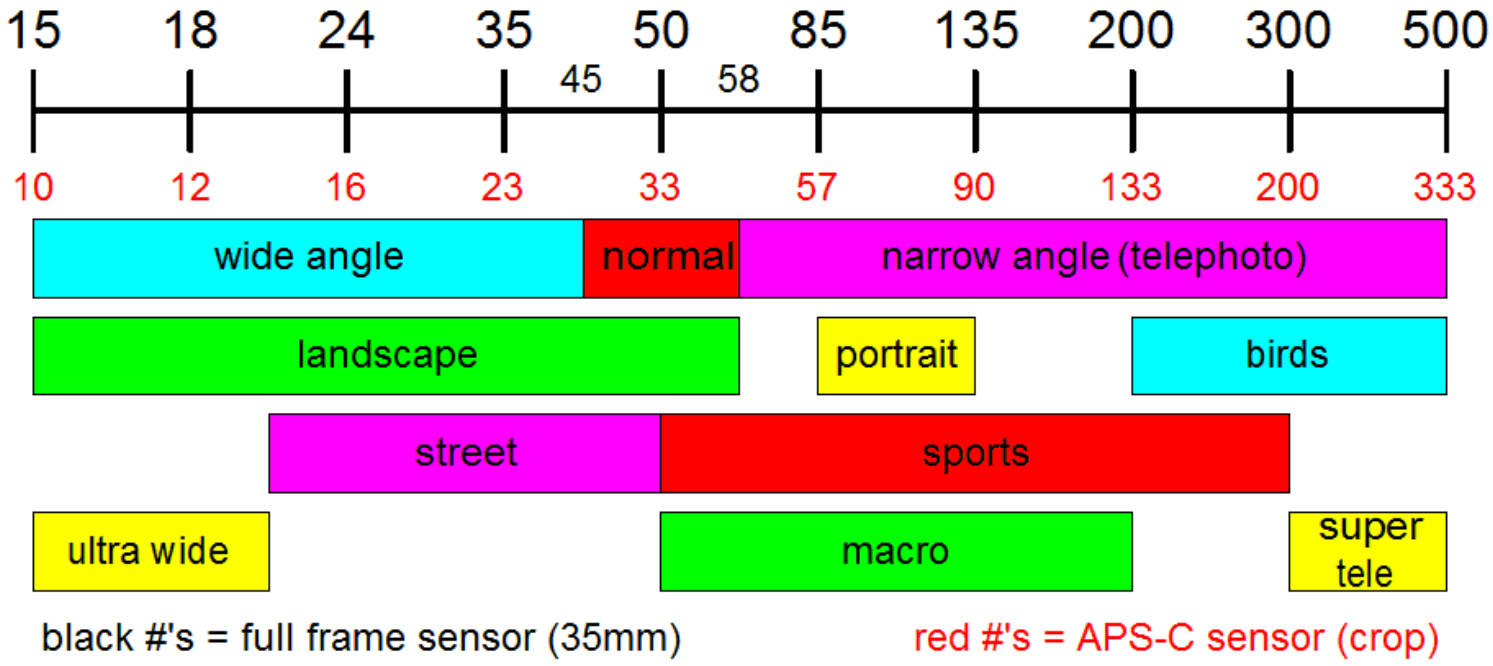
multi coated lens with green & magenta reflections

Intro to the Digital Camera: Lenses

Lens properties

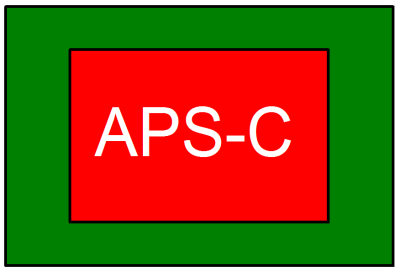


- Focal length
  - Measure of how strongly light converges
    - Short focal length → light converges faster
    - Determines magnification → longer focal length = more mag.
  - Ideal focal length depends on application

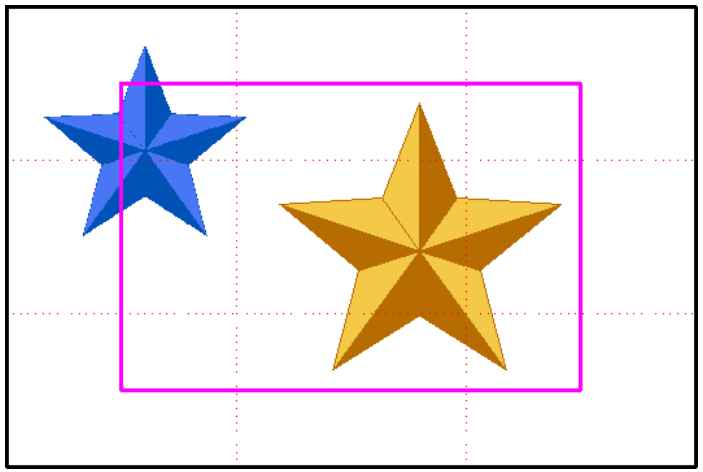


Intro to the Digital Camera: Lenses

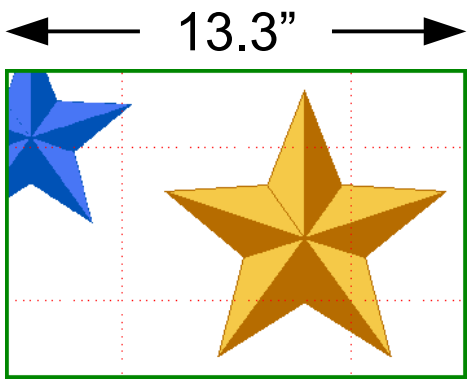
Lens properties



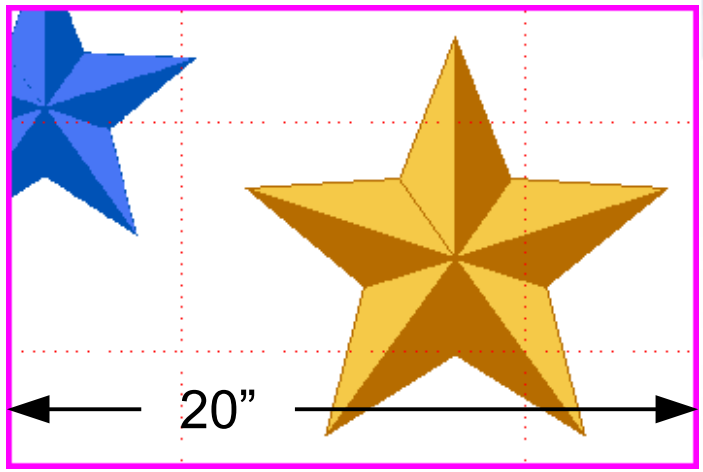
- Focal length
  - Crop factor (Nikon, Sony, Pentax = 1.5; Canon = 1.6; 4/3 = 2.0)
    - Focal length adjustment for equivalent angle of view (AOV)
    - AOV depends on focal length and sensor size
    - DOF: focal length, sensor size, # of pixels, subject dist., and aperture



FF camera + 100mm lens
APS-C camera + 100mm lens
FF camera + 150mm lens



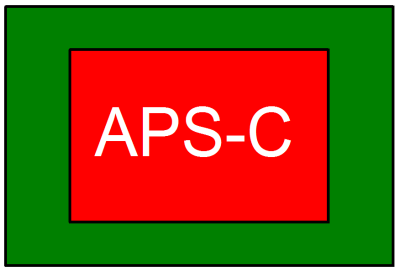
24MP FF crop =
10.7MP
@ 300 dpi
8.9” x 13.3”



24MP APS-C camera
@ 300 dpi
13.3” x 20”

Intro to the Digital Camera: Lenses

Lens properties



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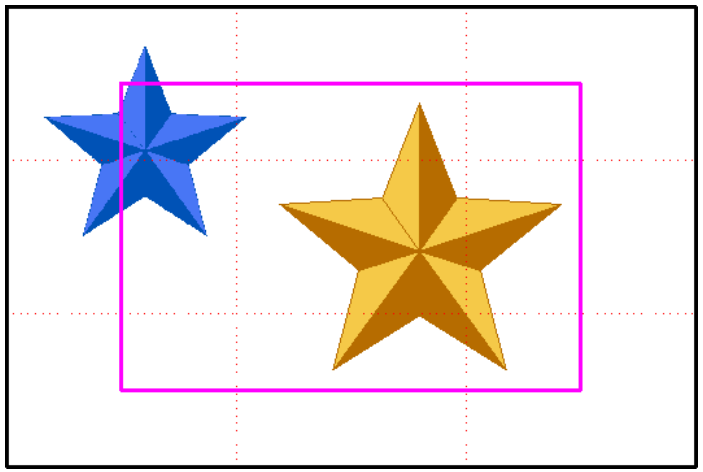


FF camera + 100mm lens
APS-C camera + 100mm lens
FF camera + 150mm lens

Equilavent Images (ISO & shutter speed equal)

Sensor Size	Pixels	Focal Length	*f*-num	Subject Dist.	DOF
Full Fr.	24 MP	150 mm	8.0	10 ft	0.66 ft
APS-C	24 MP	100 mm	5.6	10 ft	0.70 ft

8.0 / 1.5 = 5.33 → 5.6 is nearest to 5.33

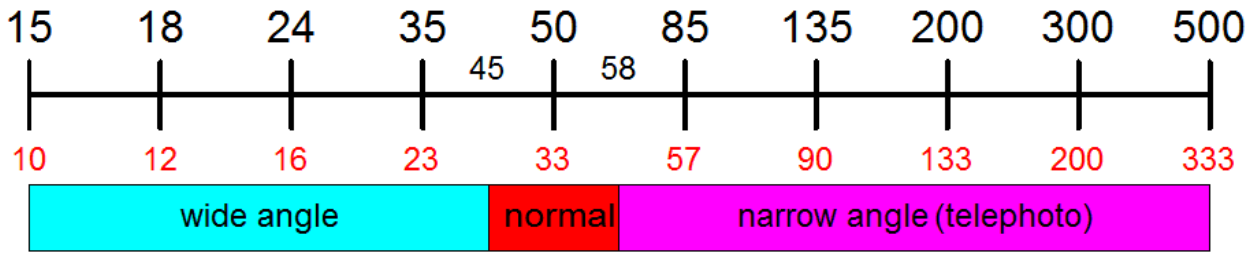
Intro to the Digital Camera: Lenses

Lens properties

- Focal length
  - "Prime" lens
    - Single focal length
    - Easiest to design → best optical quality
    - Not as convenient → have to change lenses
  - Zoom lens
    - Range of focal lengths → larger range has more compromises
    - More difficult to design → cannot compete with best primes
    - More convenient → larger & heaver, but lighter than several primes

Intro to the Digital Camera: Lenses

Lens properties



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  - Lens "kit"
    - Try to cover most used focal lengths
    - Primes → 21 *f*/2.8, 35 *f*/2, 50 *f*/1.4, 85 *f*/1.4, 100 macro, 135 *f*/2
    - Zooms → 16-35 *f*/4, 24-70 *f*/2.8, 70-200 *f*/2.8 –or– 28-300 *f*/3.5-5.6
    - Primes + zooms → 16-35 *f*/4, 50 macro, 85 *f*/1.8, 70-200 *f*/4

Intro to the Digital Camera: Lenses

Lens properties

- Aperture
  - Effective light gathering area
    - Controlled by lens design (focal length & element size) and diaphragm
    - Maximum aperture occurs when diaphragm is “wide open”
    - A “fast” lenses has a larger max. aperture than a “slow” lens

“slow” 50mm *f*/3.5
diameter ≈ 14mm

“fast” 50mm *f*/1.4
diameter ≈ 36mm
6.6x the area

Intro to the Digital Camera: Lenses

Lens properties

Full Fr.	24 MP	150 mm	8.0	10 ft	0.66 ft
APS-C	24 MP	100 mm	5.6	10 ft	0.70 ft

150mm / 8 = 18.75 → 100mm / 18.75 = 5.33

- Aperture
  - *f*-number = (focal length) / (optical diameter)
    - Examples: 50mm / 14.3mm = *f*/3.5; 50mm / 35.7mm = *f*/1.4
    - Expresses light gathering capability independently of focal length
    - As diaphragm is closed, *f*-number increases (optical diameter decreases)

"slow" 50mm *f*/3.5
diameter ≈ 14mm

"fast" 50mm *f*/1.4
diameter ≈ 36mm
6.6x the area

Intro to the Digital Camera: Lenses

Lens properties

- Aperture
  - "Fast" lenses are desirable
    - Small DOF if desired → portrait photography
    - Faster shutter speed or lower ISO in low light conditions
    - Better autofocus in low light → AF done wide open, so more light

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Intro to the Digital Camera: Lenses

Lens properties

- Aperture
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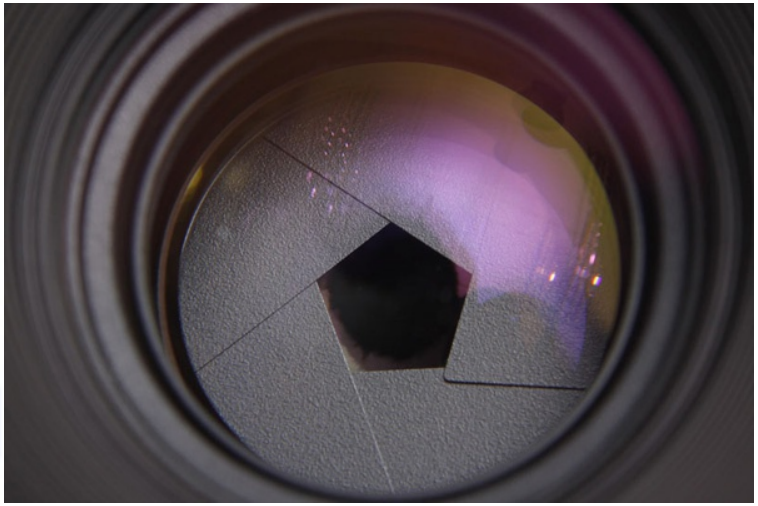
    - Small DOF if desired → portrait photography
    - Faster shutter speed or lower ISO in low light conditions
    - Better autofocus in low light → AF done wide open, so more light
  - Constant aperture zoom lenses are desirable
    - Do not change *f*-number when focal length is changed
    - Example: 24-70 *f*/2.8 vs. 24-85 *f*/3.5-4.5
    - Not considered a "pro" lens → exposure values can change

Intro to the Digital Camera: Lenses

Lens properties

- Aperture
  - Number of blades
    - Affects out-of-focus object shape when stopped down
    - 6 or 8 was common, but sometimes 15 or more were used
    - 10 or 12 can be found on some modern lenses (increases cost)



Intro to the Digital Camera: Lenses

Lens properties

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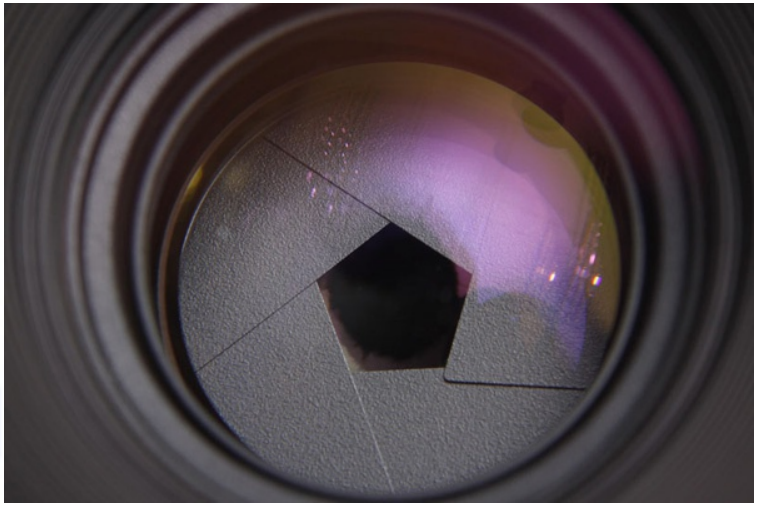
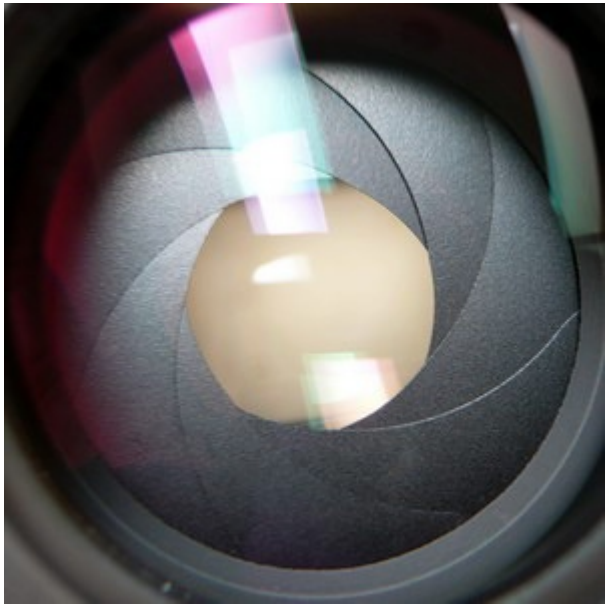
  - Rounded
    - Helps preserve circular aperture shape





Intro to the Digital Camera: Lenses

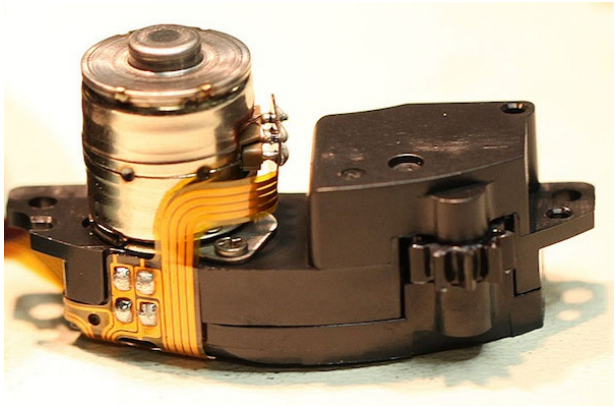
Lens properties

focusing helicoid

- Focus
  - Manual
    - Photographer turns ring, elements move
    - Moving whole lens away from sensor focuses closer
    - Slow, but can be very precise (modern DSLR focusing screens don't help)
    - Many photographers enjoy using manual focus lenses (not for sports)

Intro to the Digital Camera: Lenses

Lens properties



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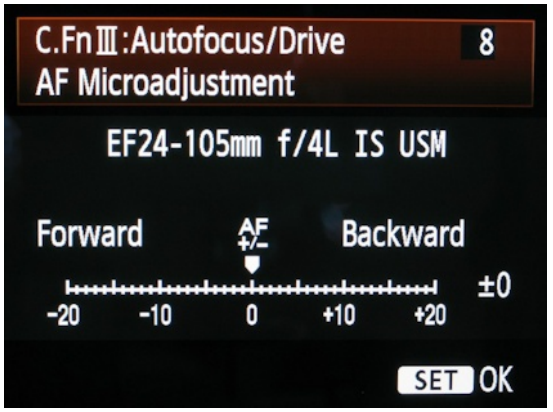
  - Autofocus
    - Motor in lens or camera body changes focus
    - Fast → essential for action photography
    - Errors: calibration, low light hunting, 3rd party lens, wrong AF spot

Intro to the Digital Camera: Lenses

Lens properties



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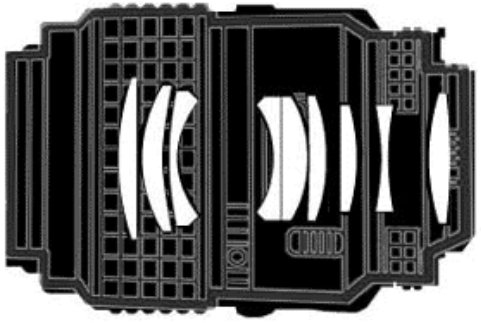
  - Autofocus
    - Motor in lens or camera body changes focus
    - Fast → essential for action photography
    - Errors: calibration, low light hunting, 3rd party lens, wrong AF spot
  - Autofocus calibration
    - More expensive DSLR's allow “micro-adjust” for lens focus
    - Can enter an offset for the lens at one subject distance
    - Sigma “Global Vision” lenses can be adjusted using USB dock

Intro to the Digital Camera: Lenses

Lens properties

some elements move for focusing



CRC: other elements move to help close focusing

- Focus
  - Near vs. far
    - Some lenses perform better at close range, others at infinity
    - Close range correction (CRC) → "floating" elements help near focus
    - Need to rely on reviews or user reports (fredmiranda.com forums)
  - Focus throw
    - How far the focusing ring is turned from min. focus dist. (MFD) to ∞
    - More throw allows for more precise manual focus → slower AF
    - AF lenses can have a throw of < 90° – macro lenses can have 720°
  - Focus-by-wire
    - MF ring tells body what user wants → body tells lens how to move
    - Often seen on non-interchangeable lens cameras
    - Now common on some mirrorless camera systems (Sony E-mount)
    - Can be "velocity controlled" → slower turn increases precision

Intro to the Digital Camera: Lenses

Lens qualities

- Resolution
  - Ability of lens to resolve fine detail
    - Often called "sharpness" → sharpness is "acutance" (edge contrast)
    - Acutance can be increased in postprocessing, resolution cannot

High acutance
Low resolution

Low acutance
High resolution

High acutance
High resolution

Intro to the Digital Camera: Lenses

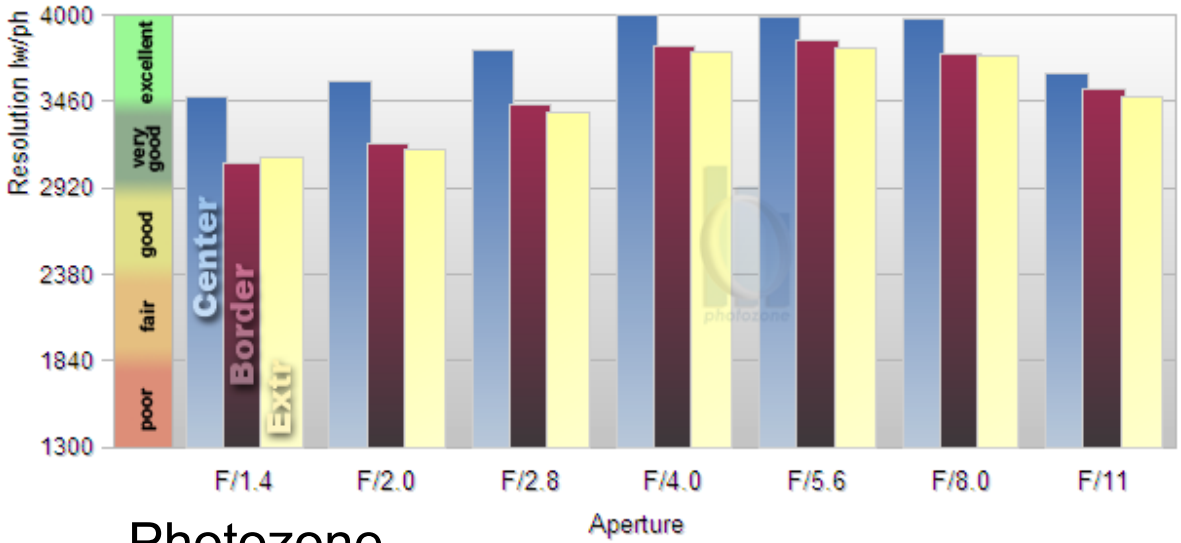
Lens qualities

- Resolution
  - Lens testing
    - Graph of resolution for different areas and different f-numbers

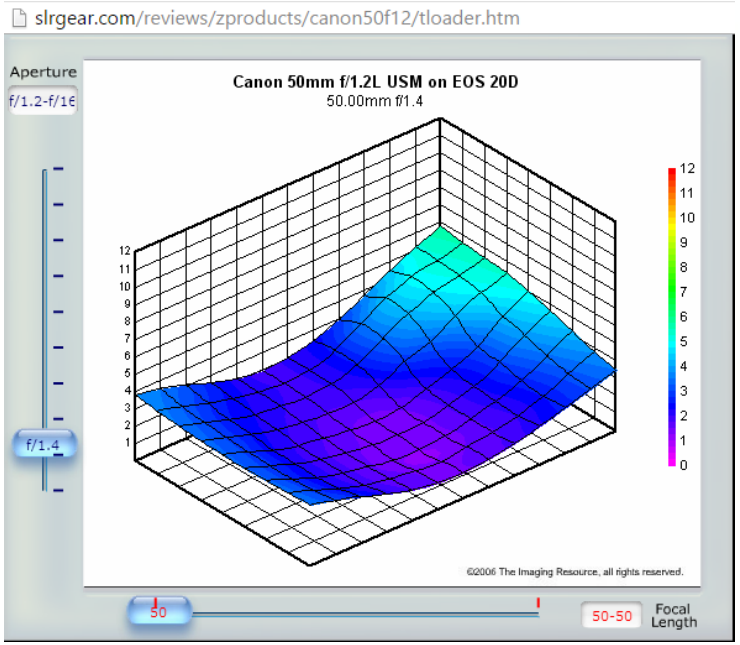
Note: lenses are normally tested at only one subject distance – test results are only a guide for what may occur at other distances

Nikon AF-S 85mm f/1.4 G full frame sensor

85 mm	F/1.4	F/2.0	F/2.8	F/4.0	F/5.6	F/8.0	F/11
Center	3485	3586	3787	4016	3989	3972	3632
Border	3074	3192	3445	3812	3839	3754	3544
Extreme	3112	3156	3388	3766	3797	3751	3489



Photozone



SLRGear

Intro to the Digital Camera: Lenses

Lens qualities

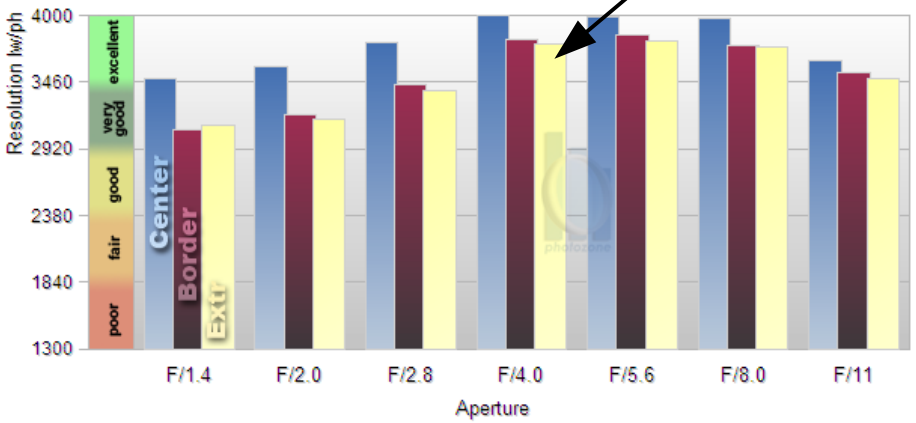
- Resolution
  - Lens testing
    - Graph of resolution for different areas and different *f*-numbers
    - Cannot compare resolution numbers between different sensors
    - Usually smaller sensors do better at the borders (but not in this case)

Note: at small apertures (large f-number) diffraction occurs, causing loss of resolution – noticeable beyond *f*/11 for full frame, *f*/8 for APS-C

full frame sensor

Nikon AF-S 85mm f/1.4 G

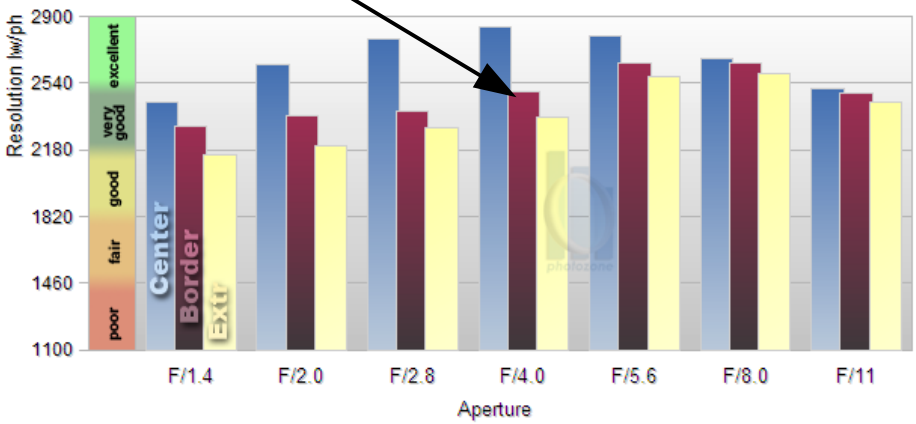
85 mm	F/1.4	F/2.0	F/2.8	F/4.0	F/5.6	F/8.0	F/11
Center	3485	3586	3787	4016	3989	3972	3632
Border	3074	3192	3445	3812	3839	3754	3544
Extreme	3112	3156	3388	3766	3797	3751	3489



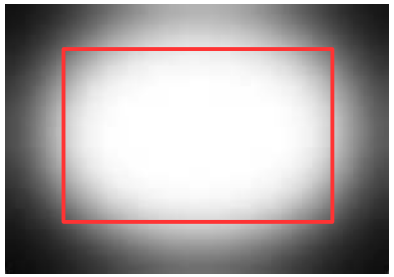
APS-C sensor

Nikon AF-S 85mm f/1.4 G

85 mm	F/1.4	F/2.0	F/2.8	F/4.0	F/5.6	F/8.0	F/11
Center	2434	2641	2775	2841	2796	2674	2514
Border	2309	2361	2391	2492	2647	2645	2488
Extreme	2157	2304	2301	2357	2573	2591	2434



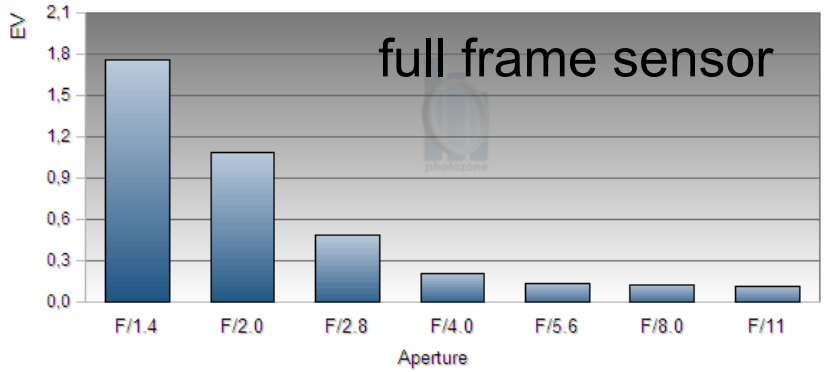
Intro to the Digital Camera: Lenses



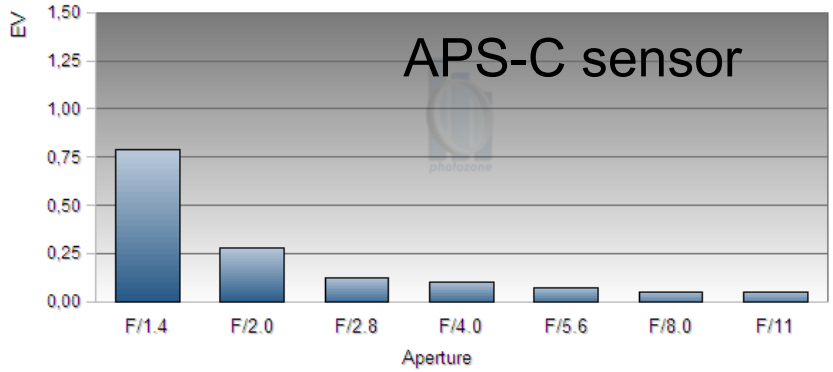
Lens qualities

- Vignetting
  - Reduction of image brightness away from image center
    - Common with older lenses or fast lenses used wide open
    - Can be corrected in an image editor → some quality loss in corners
  - Lens testing
    - Graph of brightness reduction at border for different *f*-numbers
    - Vignetting decreases as aperture size decreases (larger *f*-number)
    - Smaller sensor will always perform better

Vignetting	F/1.4	F/2.0	F/2.8	F/4.0	F/5.6	F/8.0	F/11
85 mm	1,76	1,08	0,48	0,20	0,13	0,12	0,11



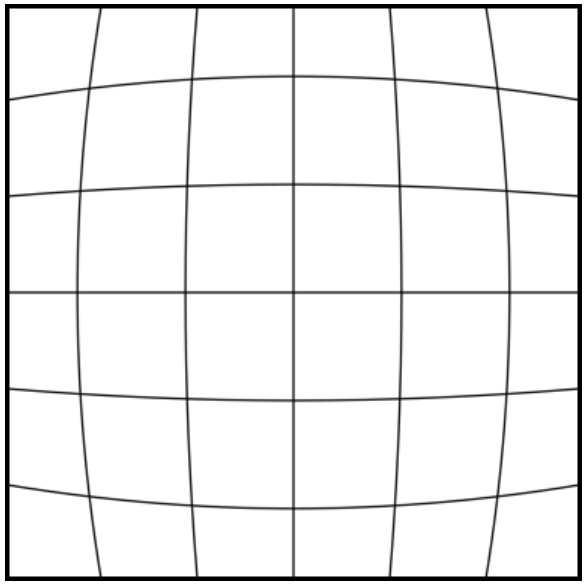
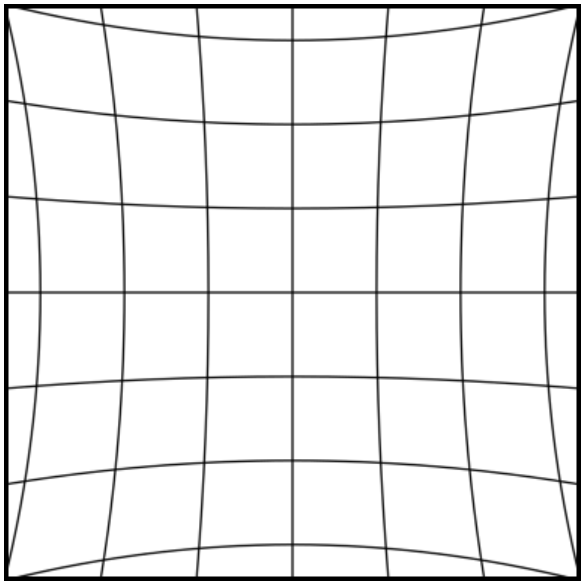
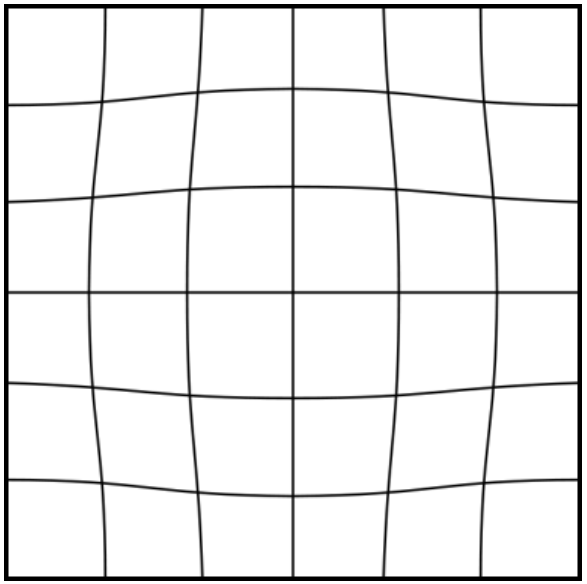
Vignetting	F/1.4	F/2.0	F/2.8	F/4.0	F/5.6	F/8.0	F/11
85 mm	0,79	0,28	0,12	0,10	0,07	0,05	0,05



Intro to the Digital Camera: Lenses

Lens qualities

- Distortion
  - Deviation from rectilinear projection (straight lines are straight)
    - Barrel → uniform barrel can be fixed in most image editors
    - Pincushion → uniform pincushion can be fixed in most image editors
    - Mustache → non-uniform barrel and/or pincushion distortion
    - Mustache distortion can only be fixed with a specific lens profile

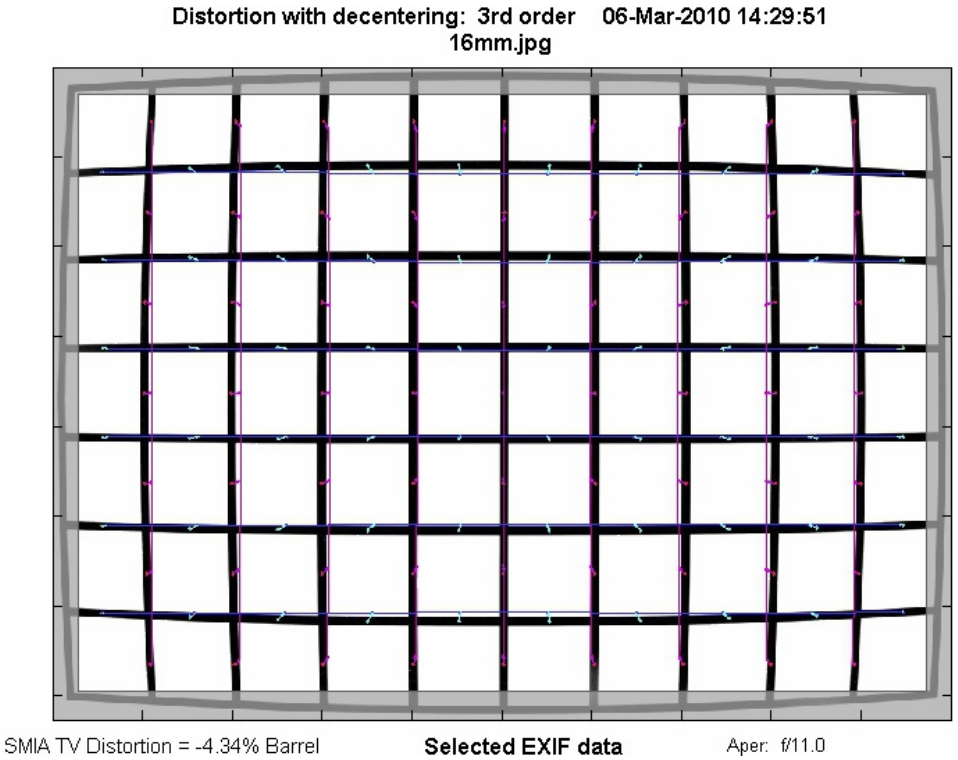




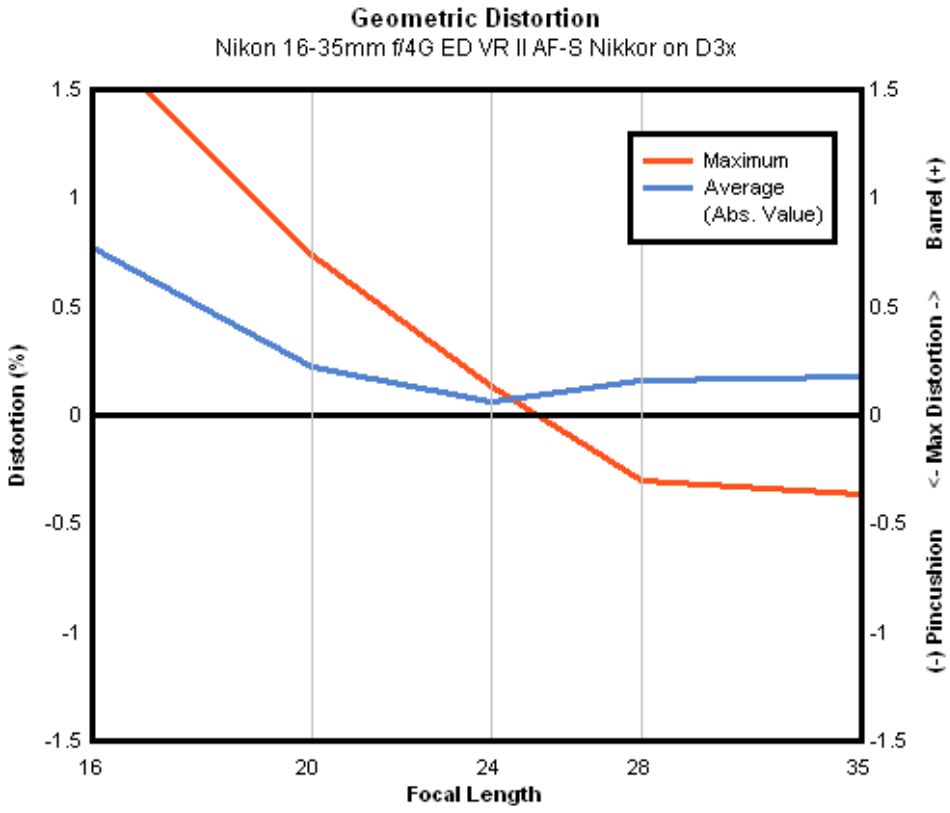
Intro to the Digital Camera: Lenses

Lens qualities

- Distortion
  - Lens testing
    - Pictures of distortion lines and percentage
    - Graph of distortion percentage

Note: wide angle zooms often have barrel distortion at the lower focal lengths, and pincushion distortion at the higher focal lengths

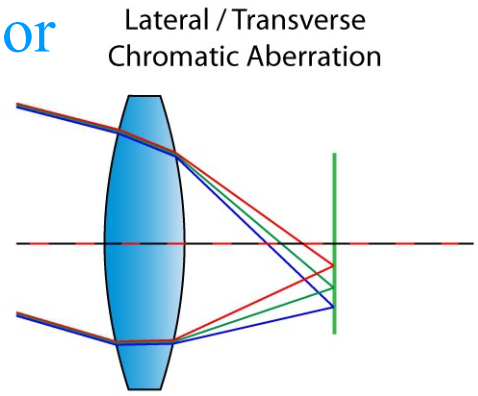




Intro to the Digital Camera: Lenses

Lens qualities

- Chromatic aberration (CA)
  - False color due to improper focusing of light wavelengths
    - Difficult to get all colors to focus over entire sensor
    - May improve with smaller aperture
  - Lateral (transverse)
    - False colors in the focal plane
    - Often more obvious near the image border
    - Red/cyan and blue/yellow color shifts
    - Can be corrected in most image editors



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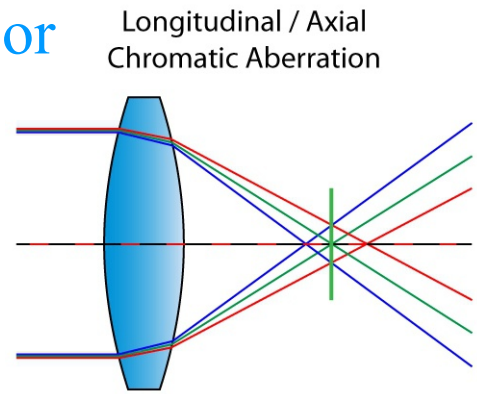
    - False colors in the focal plane
    - Often more obvious near the image border
    - Red/cyan and blue/yellow color shifts
    - Can be corrected in most image editors
  - Axial (longitudinal)
    - False colors in the optical axis: near/far
    - Often seen in out-of-focus areas
    - Magenta/green color shifts
    - Cannot be corrected



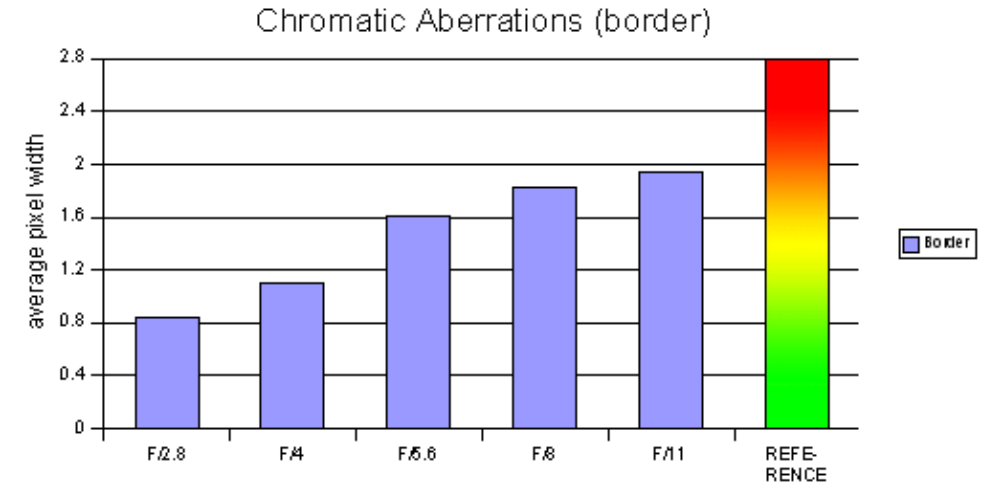
Intro to the Digital Camera: Lenses

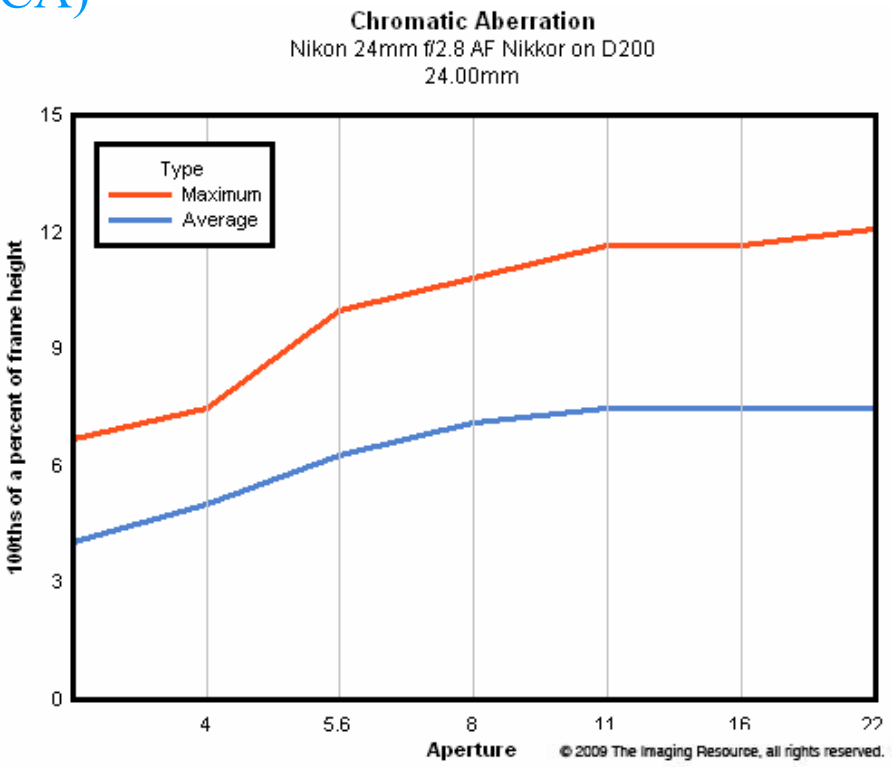
Lens qualities

- Chromatic aberration (CA)
  - Lens testing
    - Number of pixels of CA at different apertures (lateral CA)
    - Percentage of frame height (lateral CA)

Note: axial CA may be reported or shown in images, but the test results do not normally include axial CA

CAs	F/2.8	F/4	F/5.6	F/8	F/11
Border	0.84	1.1	1.61	1.82	1.95





Intro to the Digital Camera: Lenses

Lens qualities

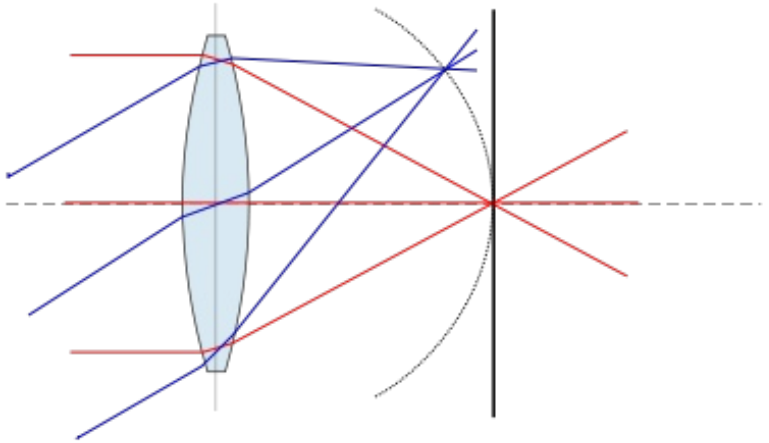
- Flare
  - Undesirable internal reflections inside a lens
    - Usually seen as spots of color from strong light sources (the sun)
    - Can happen even if the sun is not in the image (close to the edge)
    - Some people don't mind flare – others feel it degrades the image
  - Prevention
    - Try to shoot away from the sun
    - Lens shade can reduce or prevent it
  - Correction
    - Clone it out in an image editor?

"Late Afternoon Landscape"
by Deb Kreider (1st place AS)

Intro to the Digital Camera: Lenses

Lens qualities

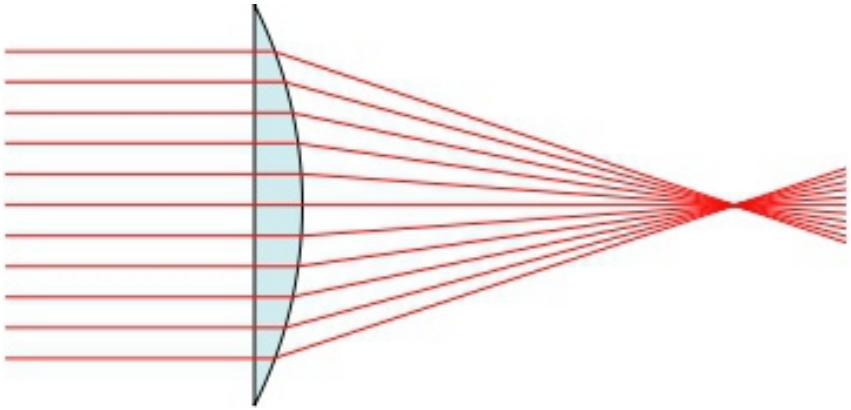
- Other aberrations
  - Field curvature
    - In-focus zone is not flat (sensor *is* flat)
    - Cannot be corrected
    - Most lenses have some field curvature → "flat wall test" may be confusing
    - Macro & "flat field" lenses have minimal field curvature

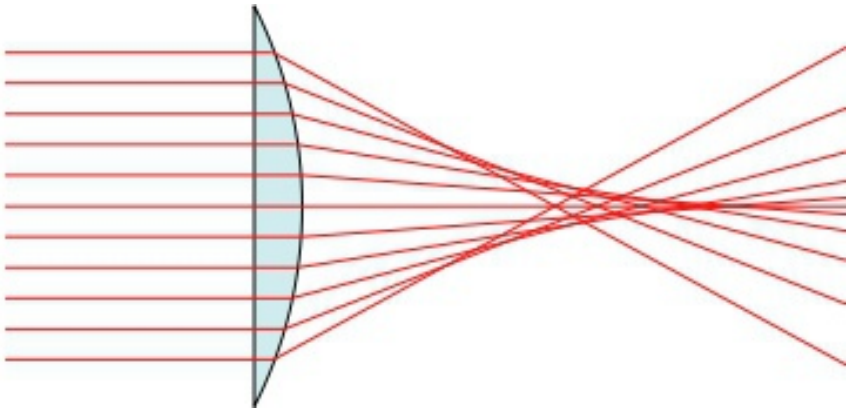


Intro to the Digital Camera: Lenses

Lens qualities

- Other aberrations
  - Field curvature
    - In-focus zone is not flat (sensor *is* flat)
    - Cannot be corrected
  - Spherical
    - Light rays at the edge of the lens focus differently from center rays
    - Often seen on older lenses
    - Improves with smaller aperture – cannot be corrected in an editor





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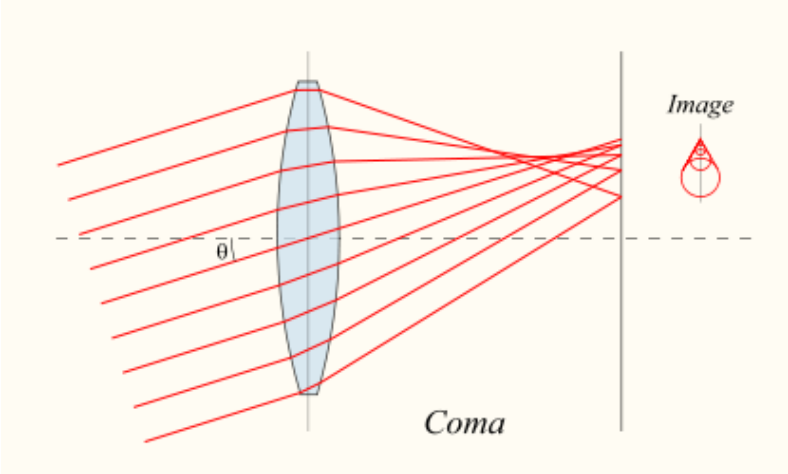
  - Astigmatism
    - Light in different planes focuses at different points
    - Cannot be corrected

Intro to the Digital Camera: Lenses

Lens qualities



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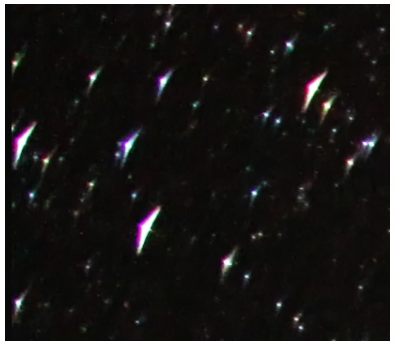
    - Improves with smaller aperture – cannot be corrected in an editor
  - Astigmatism
    - Light in different planes focuses at different points
    - Cannot be corrected
  - Coma
    - Off-axis point sources are distorted (comet or bird shape)
    - Cannot be corrected



Intro to the Digital Camera: Lenses

Lens qualities

- Contrast
  - Difference in brightness or color of objects in an image
    - Good lenses have high contrast → "pop" or "3-D effect"
    - Affected by the lens coatings which minimize light scattering
  - Modifying contrast in an image editor
    - Change overall image contrast
    - "Clarity" feature affects "local contrast" (large scale light/dark transitions)
    - Unsharp mask improves edge contrast (acutance)

contrast -50 contrast -25 original contrast +25 contrast +50

Intro to the Digital Camera: Lenses

Lens qualities

- Bokeh
  - Quality of the out-of-focus areas in an image
    - Bad bokeh is “nervous” or distracting – good bokeh is “creamy”

“busy” bokeh (Sony/Zeiss 24-70)

“nervous” bokeh

Intro to the Digital Camera: Lenses

Lens qualities

- Bokeh
  - Quality of the out-of-focus areas in an image
    - Bad bokeh is “nervous” or distracting – good bokeh is “creamy”

“swirly” bokeh (Helios 44)

“soap bubble” bokeh (Meyer Trioplan)

Intro to the Digital Camera: Lenses

Lens qualities

- Bokeh
  - Quality of the out-of-focus areas in an image
    - Bad bokeh is “nervous” or distracting – good bokeh is “creamy”
    - Fast lens wide open maximizes background blur
    - Affected by subject/camera and subject/background distances

“creamy” bokeh

good portrait bokeh

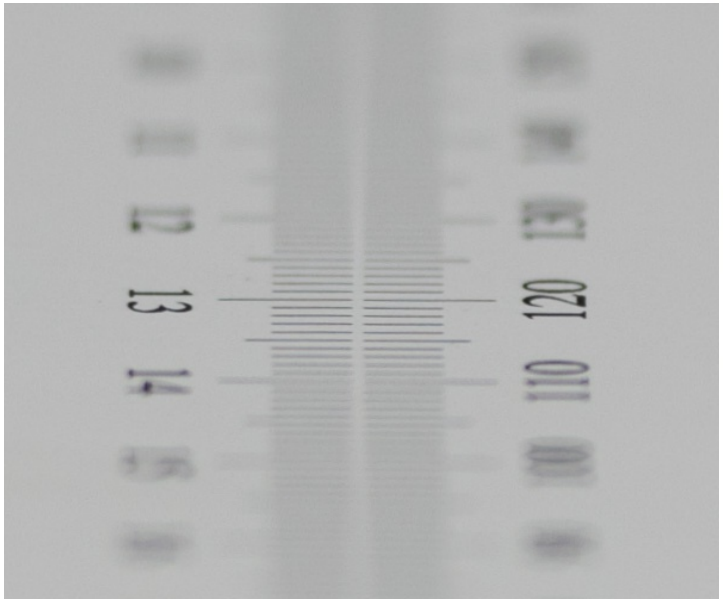
Intro to the Digital Camera: Lenses

Lens qualities

- Bokeh
  - Quality of the out-of-focus areas in an image
    - Bad bokeh is “nervous” or distracting – good bokeh is “creamy”
    - Fast lens wide open maximizes background blur
    - Affected by subject/camera and subject/background distances
    - False color from axial CA affects quality of bokeh

normal lens with axial CA (wide open)

APO lens with no axial CA (wide open)



Intro to the Digital Camera: Lenses

Lens qualities

- Bokeh
  - Lens testing
    - None → completely subjective, must rely on user reports
  - Special lenses for good bokeh
    - "Defocus Control" (DC) – Nikon 105mm & 135mm
    - "Smooth Transition Focus" (STF) – Sony 135mm, Laowa 105mm

135mm
DC

135mm
STF

Intro to the Digital Camera: Lenses

Lens defects

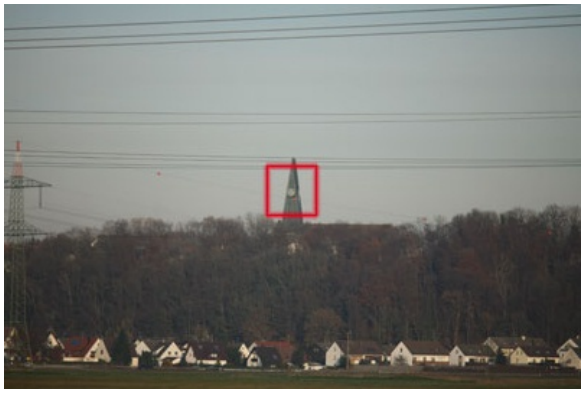
- Decentering
  - One or more elements tilted or offset from optical axis
    - Usually one side of image is good, and the other side is bad
    - May be more prominent at one end of focus range
  - Lens test (Gletscherbruch method) → test your new lens
    1. Select a near or far object (object > 25 yards away—more for wide angle)
    2. Select maximum aperture (lowest f-number), use manual exposure
    3. Shoot using cable release or timer—use mirror lockup if available
    4. With camera on tripod, manual focus with object in center of lens
    5. Without changing focus, move camera using tripod head
    6. Take photo with object in each corner of frame
    7. All corners should appear the same → if not, possible decentering
    8. If all corners are worse than the center → possible field curvature
    9. If #8, try again with smaller aperture (larger f-#) to increase DOF

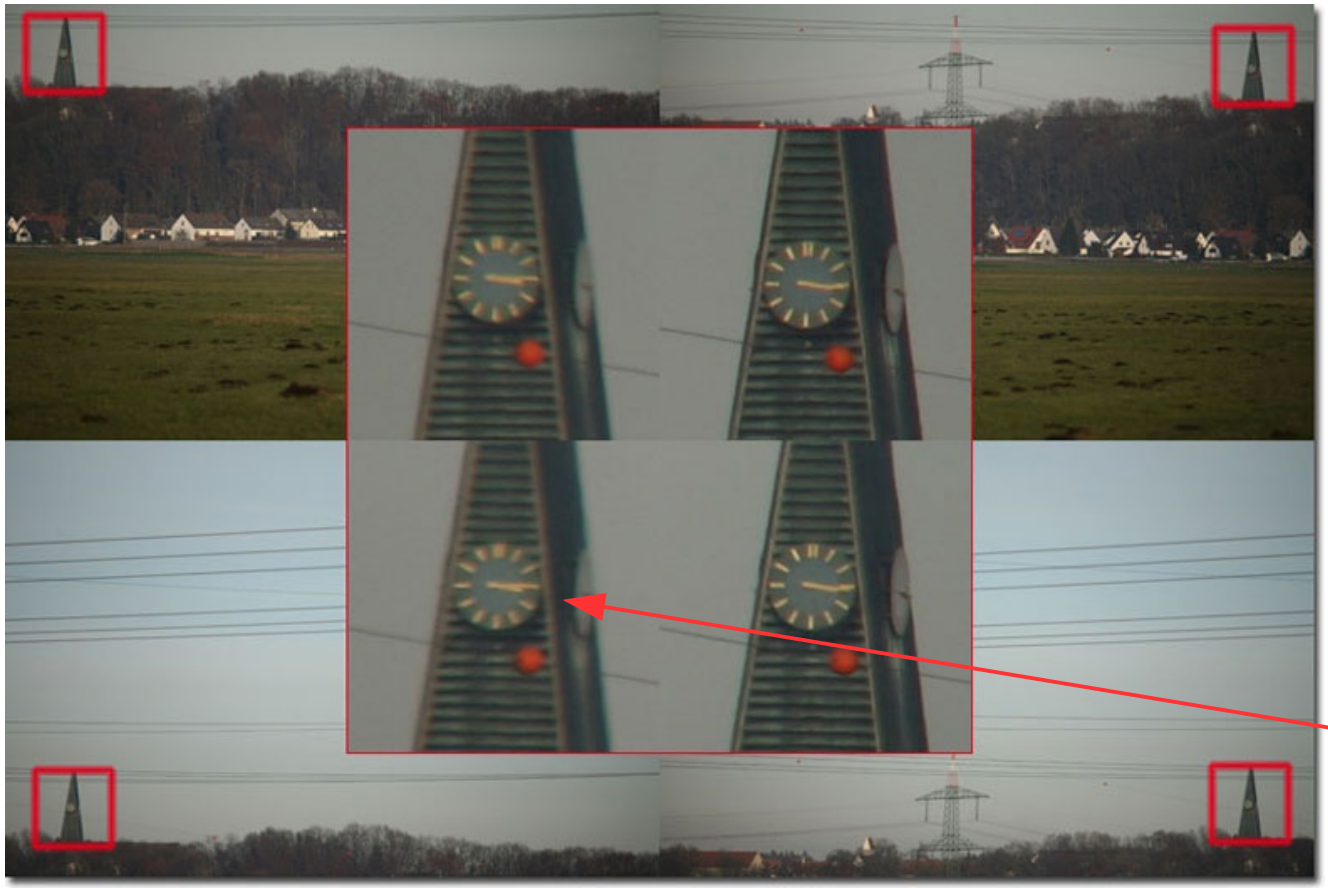
Intro to the Digital Camera: Lenses

Lens defects

- Decentering
  - Lens test example

Place object in center of frame and focus manually





Use tripod head to move object to each corner of frame without refocusing – all corners should have similar sharpness

sign of decentering