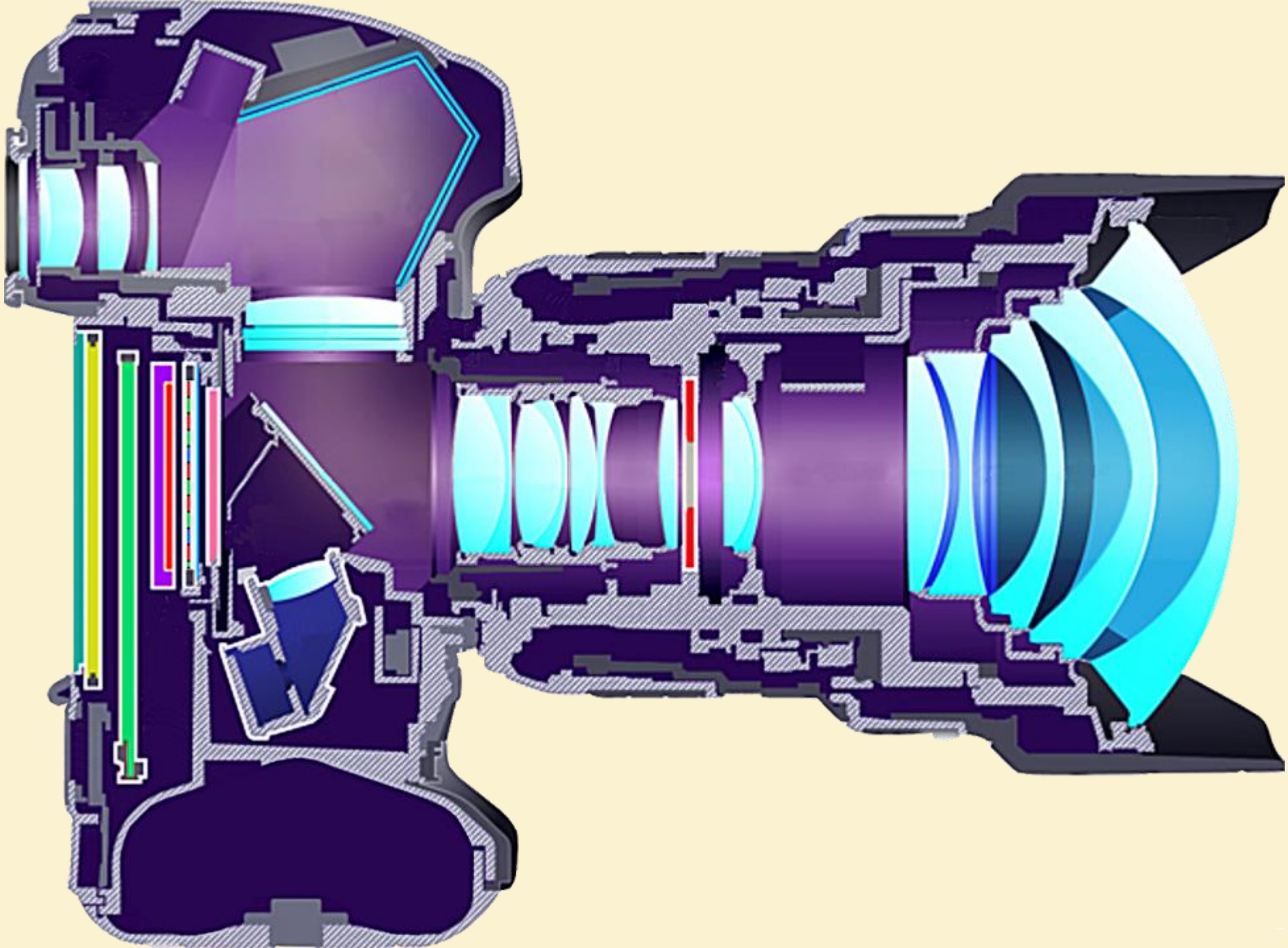
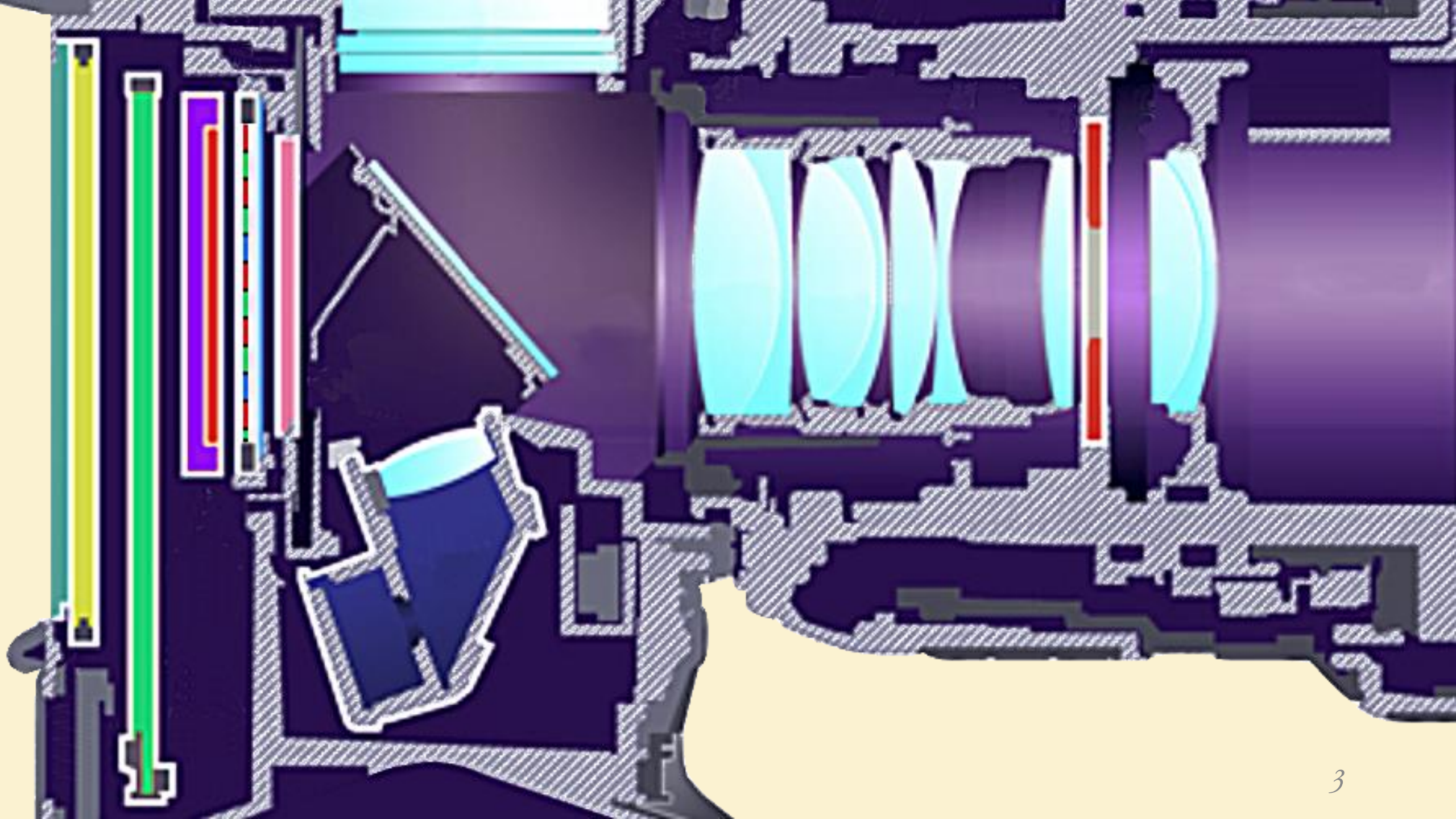
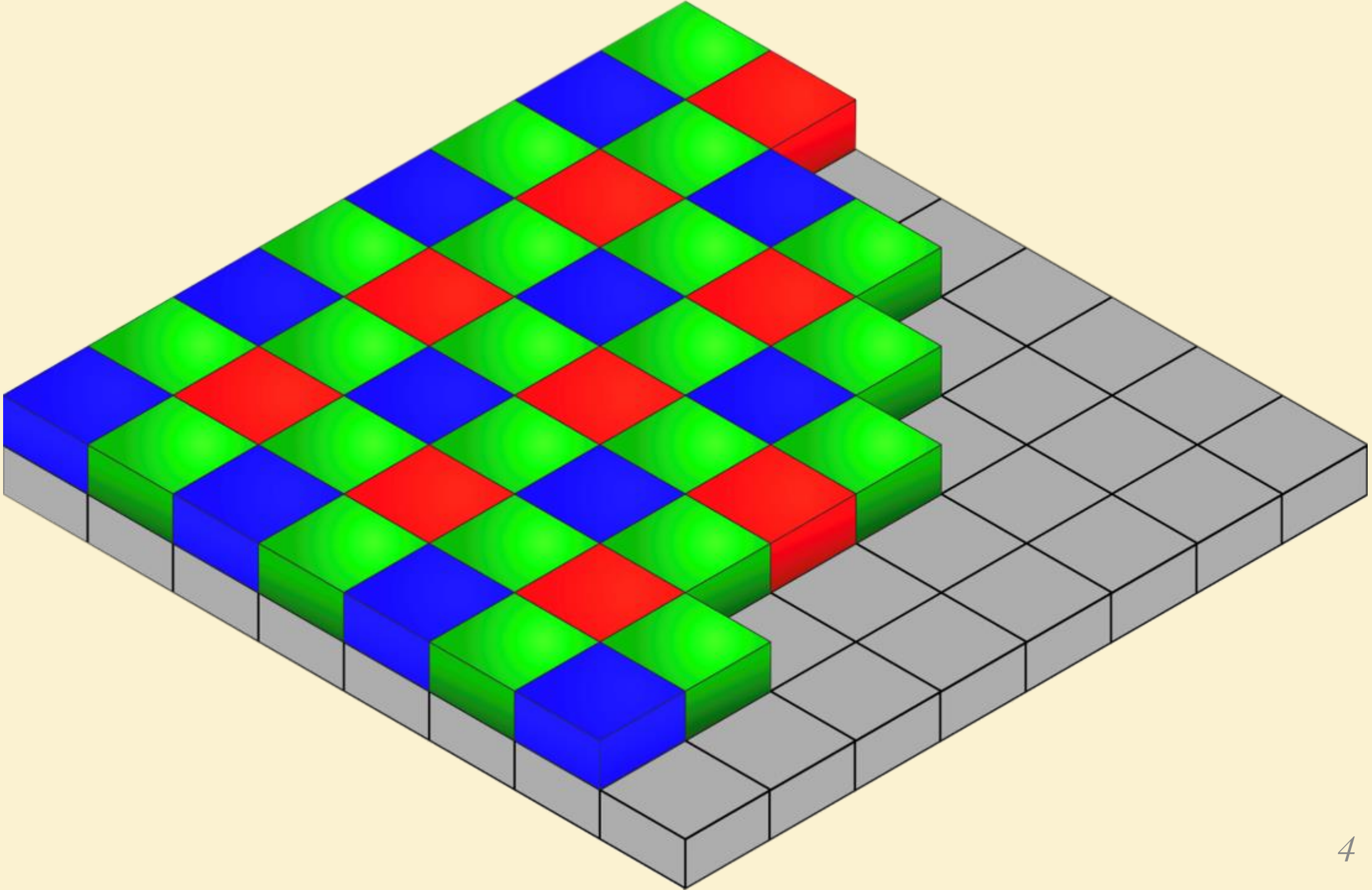
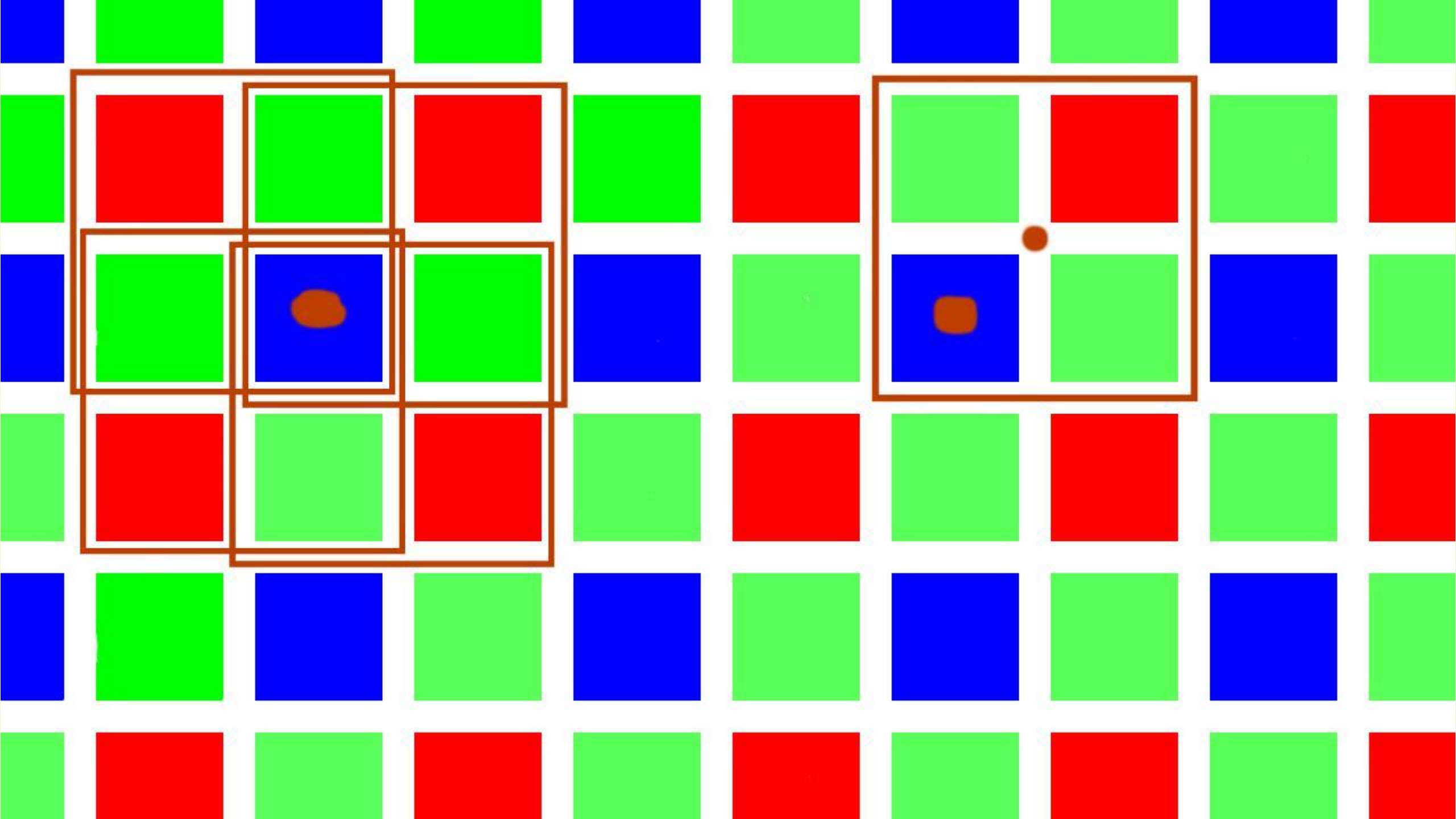
Sensor size and image impact

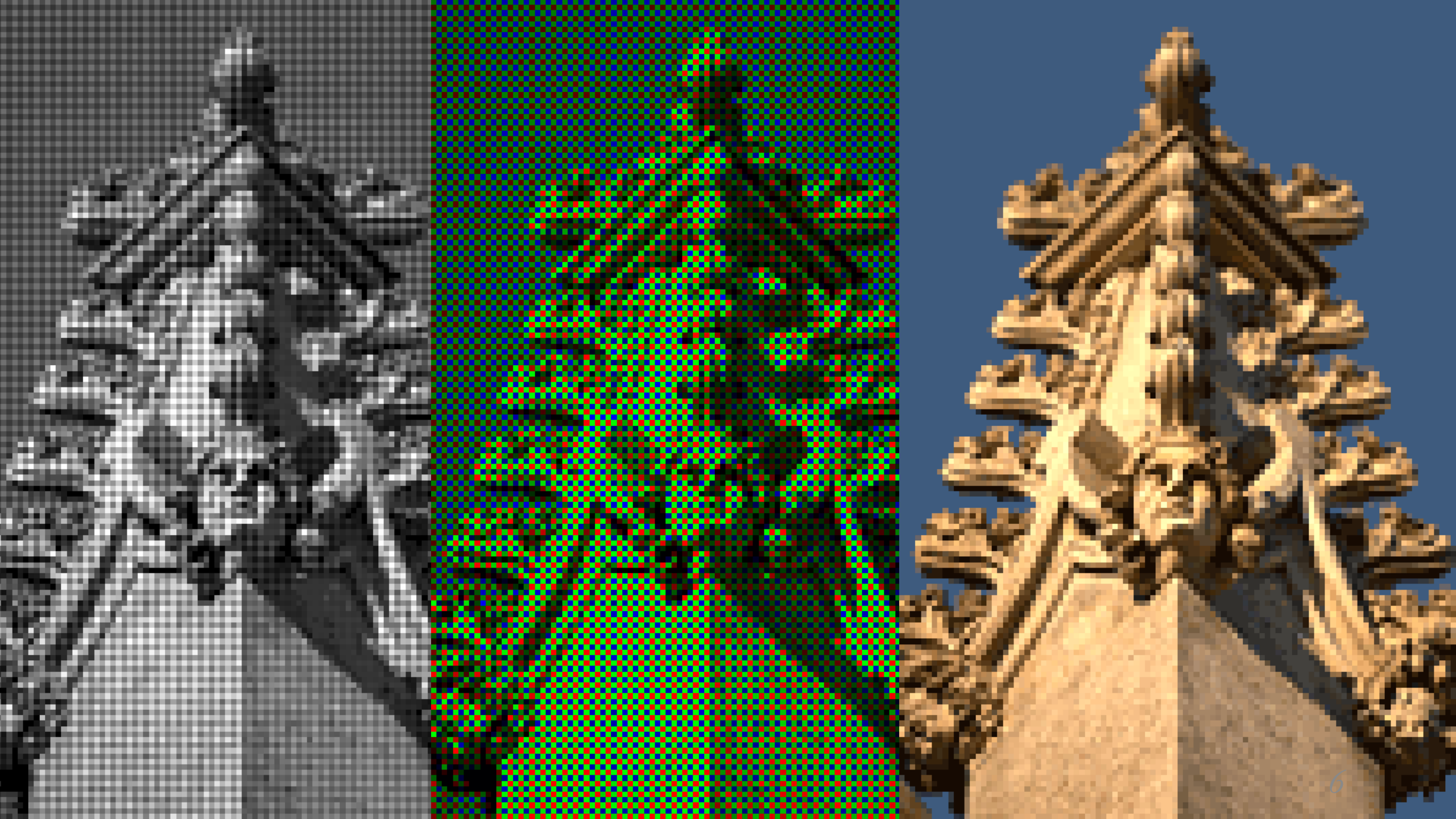
20th July 2018

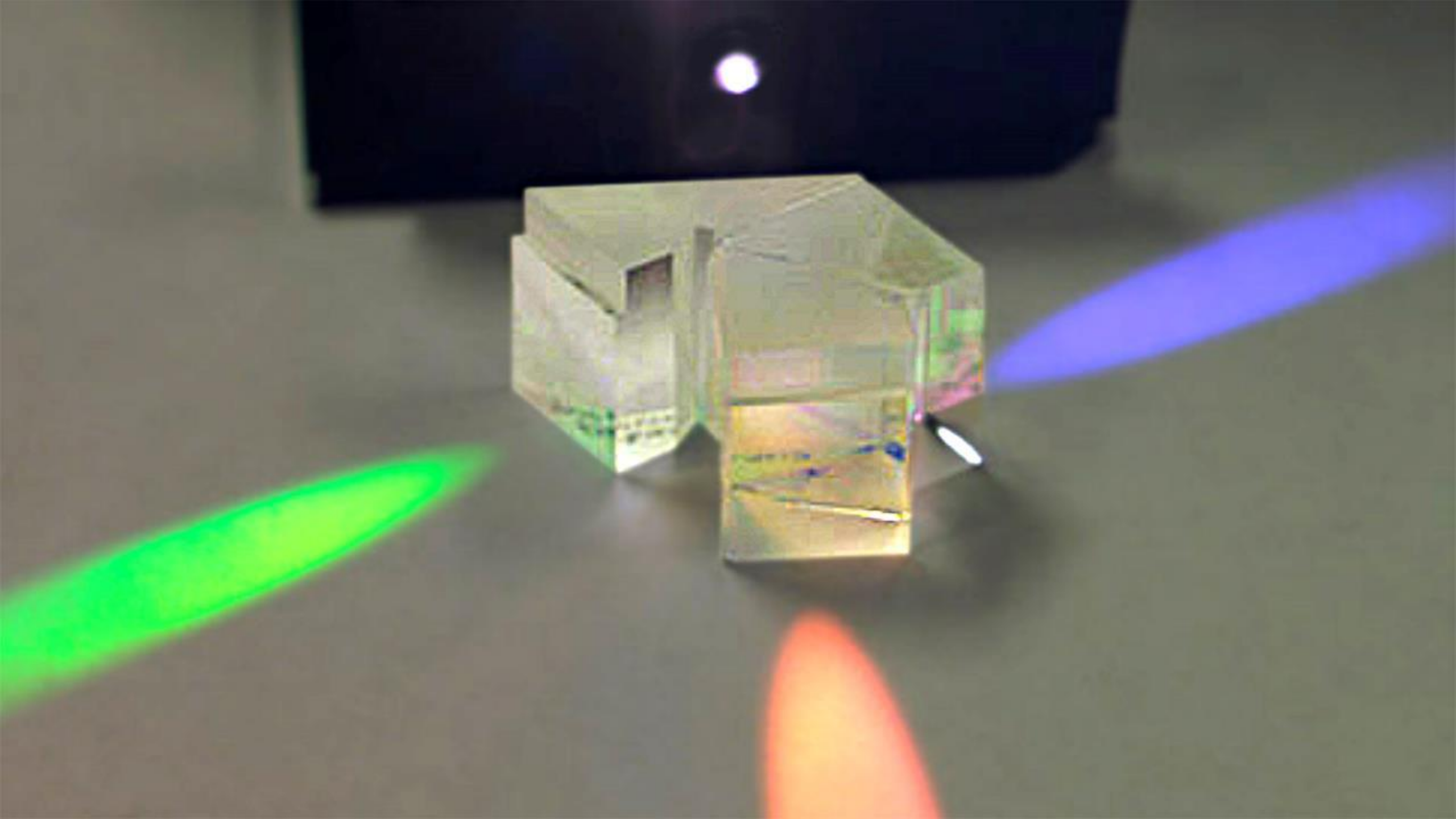












I have related the effects of sensor size to 35mm film equivalents as most of us are familiar with 35mm cameras.

Sensor size designation has a variety of historical precedents and is not standardized .

In terms of 35mm film area the range is from

0.14% (1/10" sensor) to

245% (Hasselblad H6D-100C sensor)

a huge range.

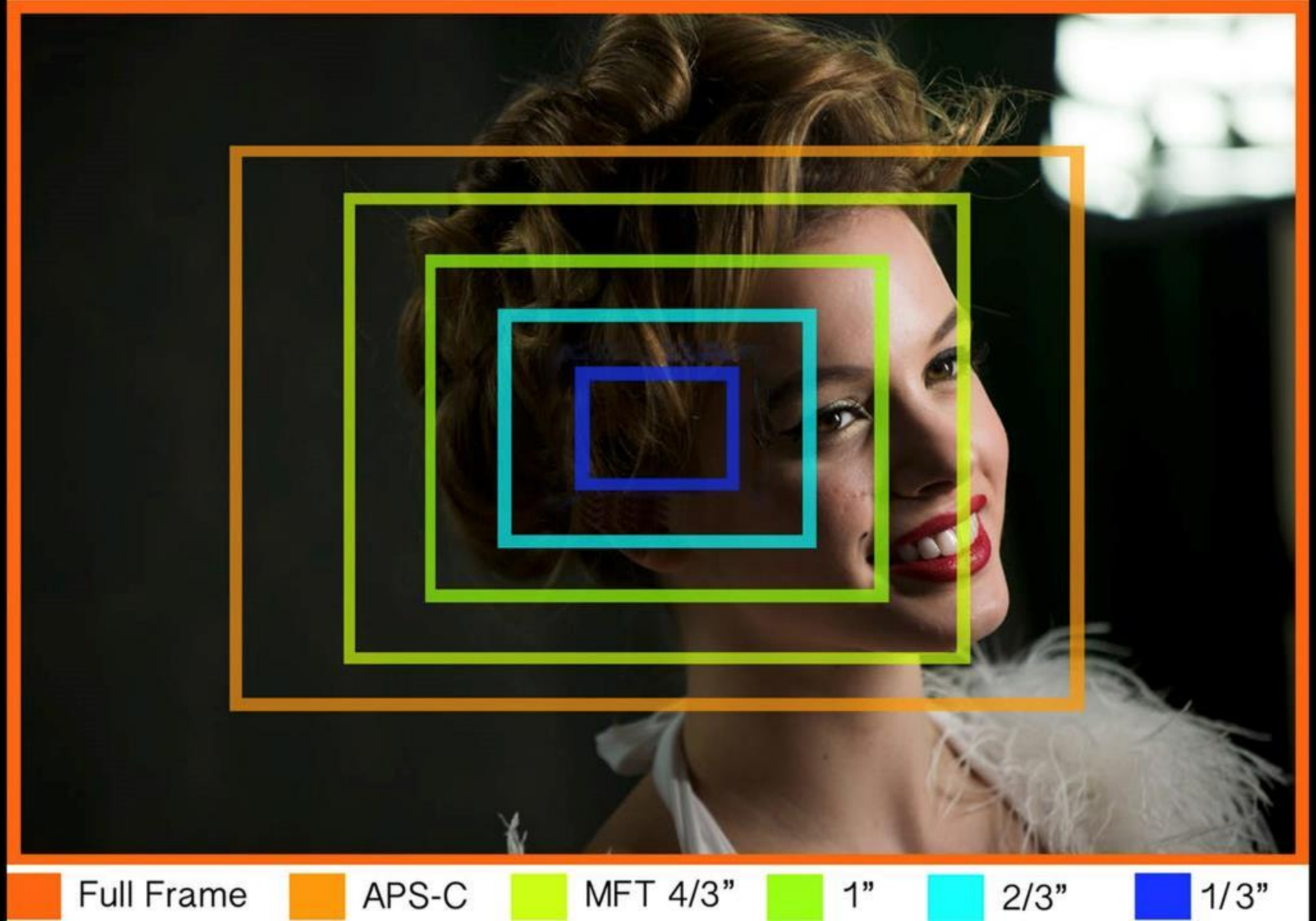
The most obvious effect of sensor size is the the light gathering capacity.

The smallest sensor loses nearly 10 stops of sensitivity
and the largest gains over one stop (all other things being equal).

This impacts not only the maximum usable ISO rating
but also the dynamic range.

Eye saccades give a range of 22 stops and the largest Hasselblad sensor achieves an impressive 15 stops.
35mm sensors manage 12 to 14 stops.

Sensor Designation	***Area*** *(% of full frame)*	***Typical cameras***
1/3”	*2%*	*iPhone 6*
2/3”	*7%*	*Olympus E10, E20*
1”	*13%*	*Sony RX10, RX100*
4/3 (MFT)	*26%*	*Olympus OM-D*
APS-C (DX)	*44%*	*Canon G1X*
Full frame (FX)	*100%*	*Nikon D5, Canon 1DX*


Full Frame
APS-C
MFT 4/3”
1”
2/3”
1/3”

The primary effect of sensor size is on the amount of light collected.

A 1" sensor catches 13% of the light caught by a full frame sensor.

If they both have the same number of pixels then each light receptor only catches 13% of the photons.

The result is lower sensitivity ***and*** *less dynamic range.*

This can be partly countered by reducing the pixel count of small sensors.

How many Megapixels (Mpx) do you really need ?

At 300 dots per inch for prints or displaying on HD or 4k screens.

Sensor Aspect Ratio	4k Screen	HD Screen	10" x 8" Print	6" x 4" Print	Sensor Type
4 x 3	12 Mpx	3 Mpx	8 Mpx	3 Mpx	$^{1}/_{3}$", $^{2}/_{3}$", MFT
3 x 2	10 Mpx	3 Mpx	9 Mpx	2 Mpx	1", APS-C, FX

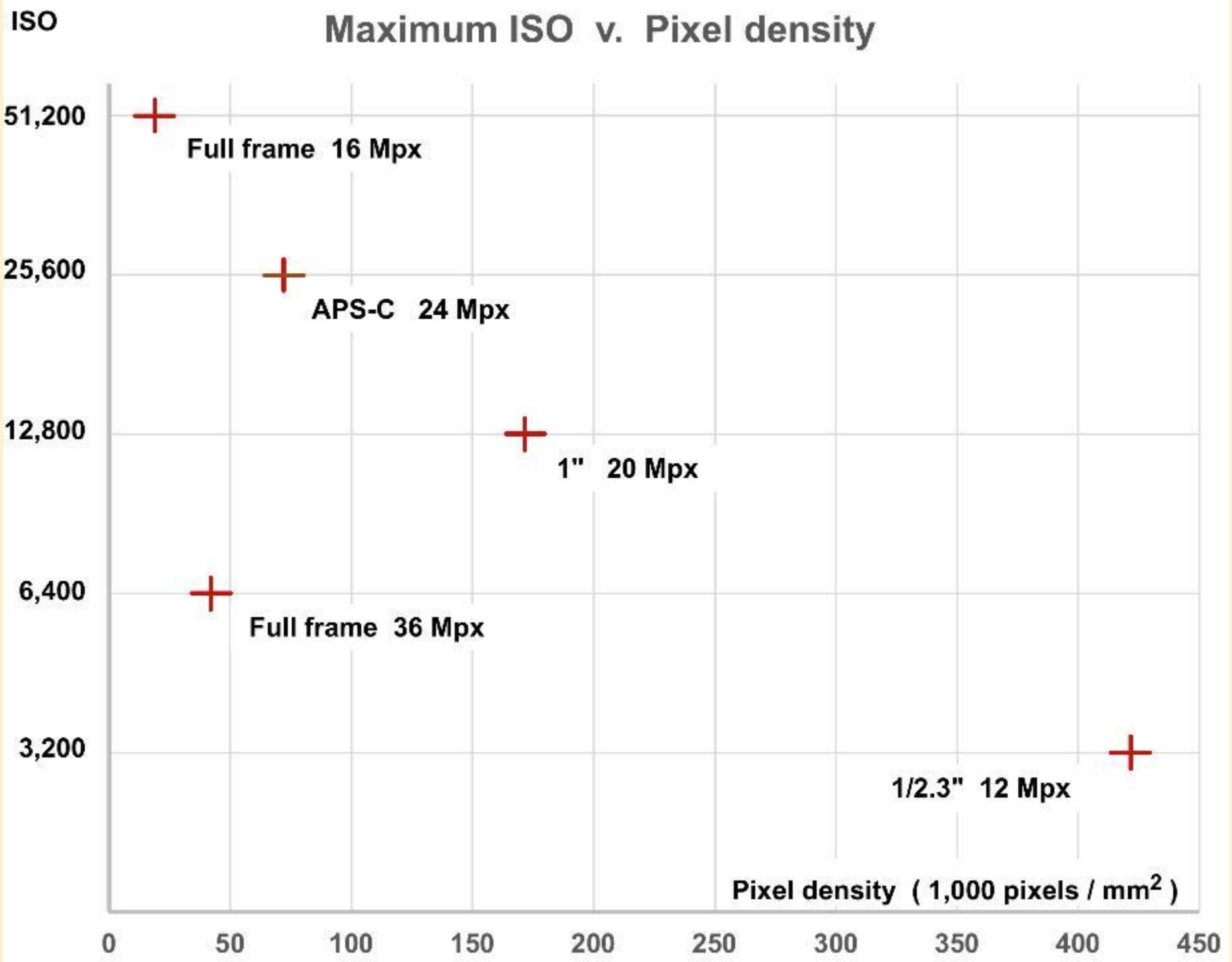
Assumes perfect framing and $^{1}/_{8}$" border on prints. *Megapixel figures rounded up.*

With small sensors you are likely to achieve better photographs with lower pixel counts as the sensor light receptors will be larger.

Low light sensitivity will be higher and there will be more opportunity to recover detail in shadows and highlights.

On the other hand, higher pixel counts allow more cropping and hence can be used to extend the telephoto range of the lens.

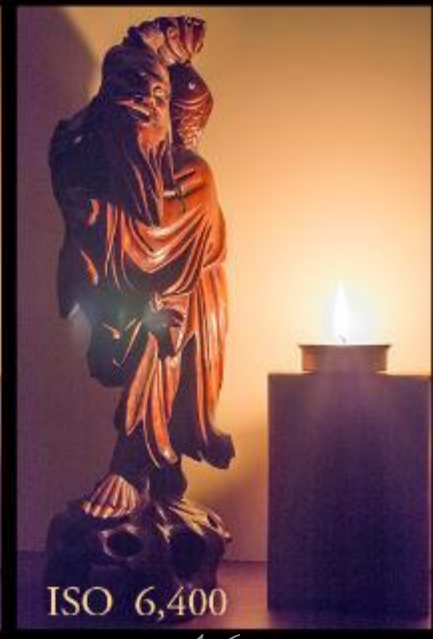
I have plotted light sensitivity for some of my cameras on the next chart.


Maximum ISO v. Pixel density
ISO
51,200
25,600
12,800
6,400
3,200
Full frame 16 Mpx
APS-C 24 Mpx
1" 20 Mpx
Full frame 36 Mpx
1/2.3" 12 Mpx
Pixel density (1,000 pixels / mm2)
0
50
100
150
200
250
300
350
400
450

16 Mpx full frame sensor

Effect of ISO setting on dynamic range

Low pixel density allows high ISO setttings



Full frame

ISO 100

Full frame

ISO 51,200


APS-C sensor
ISO 100


APS-C sensor
ISO 25,600


1” sensor
ISO 100


1” sensor
ISO 12,500

2/3” sensor

ISO 80

2/3” sensor

ISO 320

Sensor areas

iPhone 6

1/3” 17 mm²

1/2.3” 28 mm²

1” 116 mm²

APS-C 370 mm²

Full frame 860 mm²

Relative Weights

10% of full frame (1/3”)

20% of full frame (1/2.3”)

30% of full frame (1”)

40% of full frame (APS-C)

1 kg *(full frame)*

Relative Volumes

4% of full frame (1/3”)

10% of full frame (1/2.3”)

12% of full frame (1”)

30% of full frame (APS-C)

100% of full frame

Sensor size impacts camera size and lenses.

Smaller sensors have shorter sensor diagonals, and have shorter focal lengths for the same angle of view.

The weight of the lens is roughly the cube of the focal length making for lighter, cheaper cameras.

A full frame camera has a sensor diagonal of 43mm and an angle of view of 47° with a 50mm focal length lens.

Equivalent lens focal lengths with same diagonal angle of view as full frame

Full frame focal length	***24mm***	***50mm***	***100mm***	***200mm***	***400mm***
APS-C	*16mm*	*33mm*	*65mm*	*130mm*	*260mm*
MFT	*12mm*	*25mm*	*50mm*	*100mm*	*200mm*
1”	*8.8mm*	*18mm*	*37mm*	*73mm*	*150mm*
$^{2}/_{3}$”	*6.1mm*	*13mm*	*25mm*	*51mm*	*100mm*
$^{1}/_{3}$”	*3.3mm*	*6.9mm*	*14mm*	*28mm*	*55mm*

Sensor type	***Aspect Ratio***	***w x d*** *mm*	***Diagonal*** *mm*	***Crop factor****	***Area*** *mm^2*	***Stops loss***
1/3"	*4 x 3*	*4.8 x 3.6*	*6.0*	*n/a*	*17*	*5 1/2*
2/3"	*4 x 3*	*8.8 x 6.6*	*11.0*	*n/a*	*58*	*4*
1"	*3 x 2*	*13.2 x 8.8*	*15.9*	*2.7x*	*116*	*3*
4/3" (MFT)	*4 x 3*	*17.3 x 13*	*21.6*	*2.0x*	*225*	*2*
1.5"	*4 x 3*	*18.7 x 14*	*23.4*	*1.9x*	*262*	*1 3/4*
APS -C (DX)	*3 x 2*	*c. 23.7 x 15.6*	*28.3*	*c. 1.5x*	*369*	*1 1/4*
APS -H	*3 x 2*	*29.7 x 18.6*	*33.5*	*1.3x*	*519*	*3/4*
Full frame (FX)	***3 x 2***	***36 x 24***	***43.3***	***1.0x***	***864***	***none***

Multiply actual focal length by **Crop Factor to obtain 35mm (full frame) equivalent diagonal angle of view*

My mobile phone sensor is 1/3" and sports a single aperture of F/2.4 This has the same depth of field as F/16 on a full frame camera.

The table of equivalent F stops on the next slide has been rounded to the nearest main stop.

For the smallest sensors, limiting depth of field by opening up the aperture is not practicable.

Full frame equivalent depth of field F stops for smaller sensors

Full frame	***1.4***	***2***	***2.8***	***4***	***5.6***	***8***	***11***	***16***	***22***
APS -C		*1.4*	*2*	*2.8*	*4*	*5.6*	*8*	*11*	*16*
MFT			*1.4*	*2*	*2.8*	*4*	*5.6*	*8*	*11*
1"				*1.4*	*2*	*2.8*	*4*	*5.6*	*8*
$^{2}/_{3}$"					*1.4*	*2*	*2.8*	*4*	*5.6*
$^{1}/_{3}$"								***2.2***	

Nikon Df

Full frame

focal length 50mm

2.5 sec

F/22

ISO 100

Nikon Df

Full frame

focal length 50mm

1/80 sec

F/1.4

ISO 100

Canon G1X

APS-C

focal length 36mm

1/4 sec

F/16

ISO 400

Canon G1X

APS-C

focal length 36mm

1/30 sec

F/5.6

ISO 400

Sony RX100

1”

focal length 25mm

1/2 sec

F/11

ISO 100

Sony RX100

1”

focal length 26mm

1/15 sec

F/4

ISO 100

Nikon S8100

1/2.3”

focal length
11mm

1/20 sec

F/4

ISO 160

iPhone 6

1/3” sensor

focal length 4.2mm

1/33 sec

F/2.2

ISO 40

Detail

iPad 3

1/3” sensor

focal length 4.3mm

1/30 sec

F/2.4

ISO 50

Detail

Nikon Df full frame

at F/8

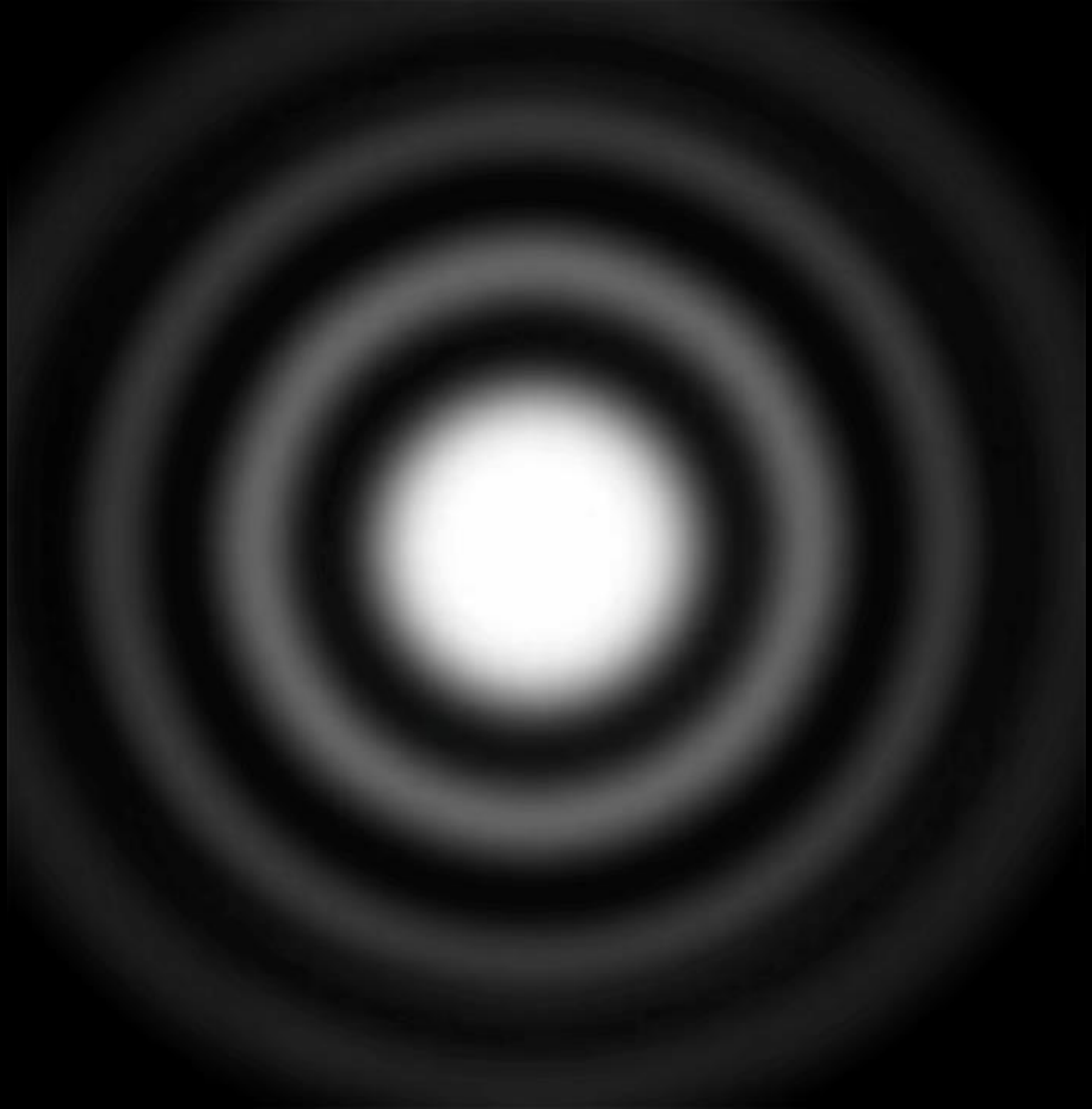
Detail

Diffraction and sensor size

Diffraction is a quantum mechanical effect where a single photon, whilst in transit, acts as a wave that has passes through the area of the camera aperture.

It has a probability of activating a position on the the sensor that is defined by the Airy function.

If the aperture is very small then the Airy function rings result in a fuzzing interference that becomes noticeable.



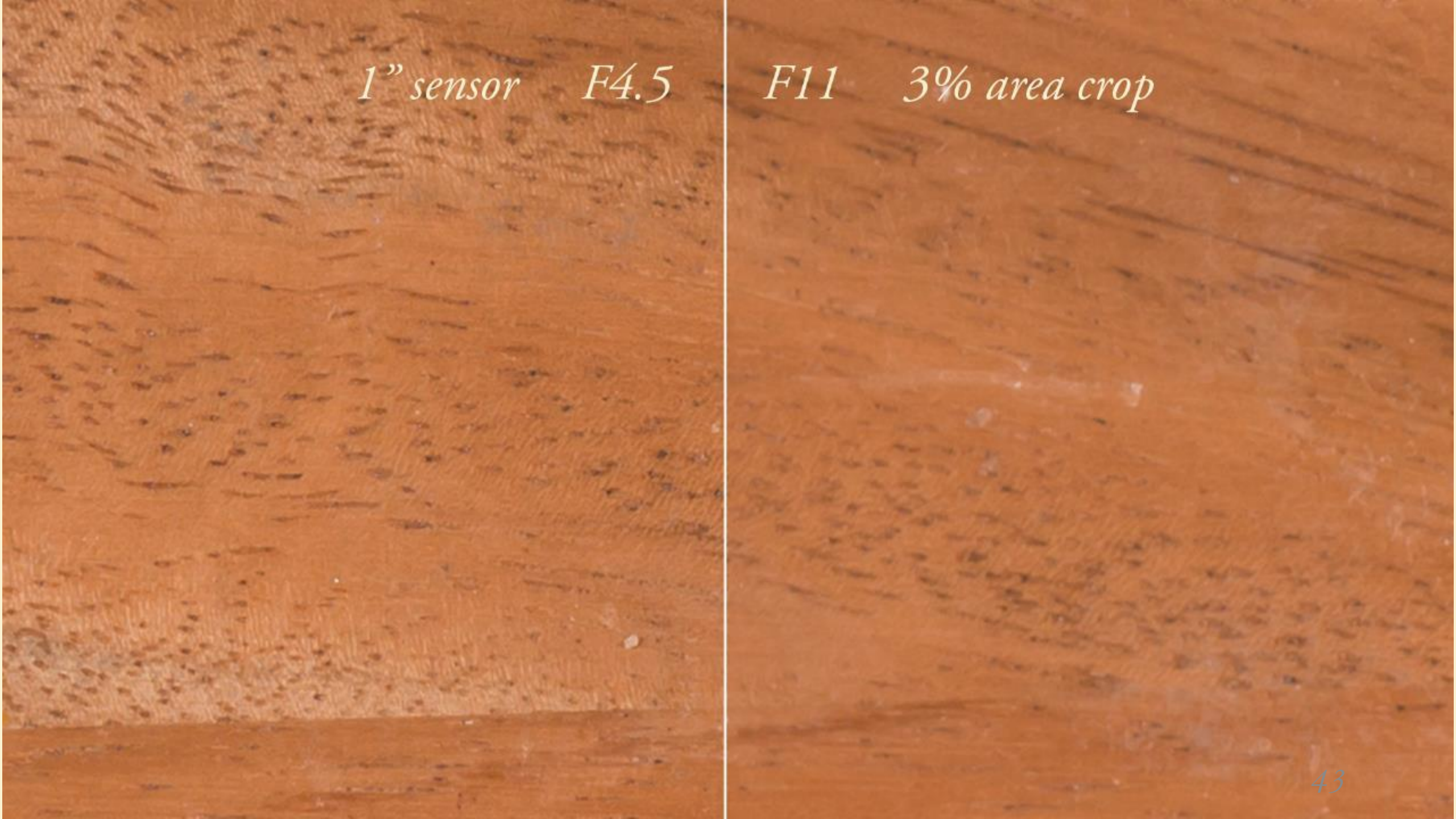
Unfortunately, it is the absolute size of the aperture determines the amount of diffraction.

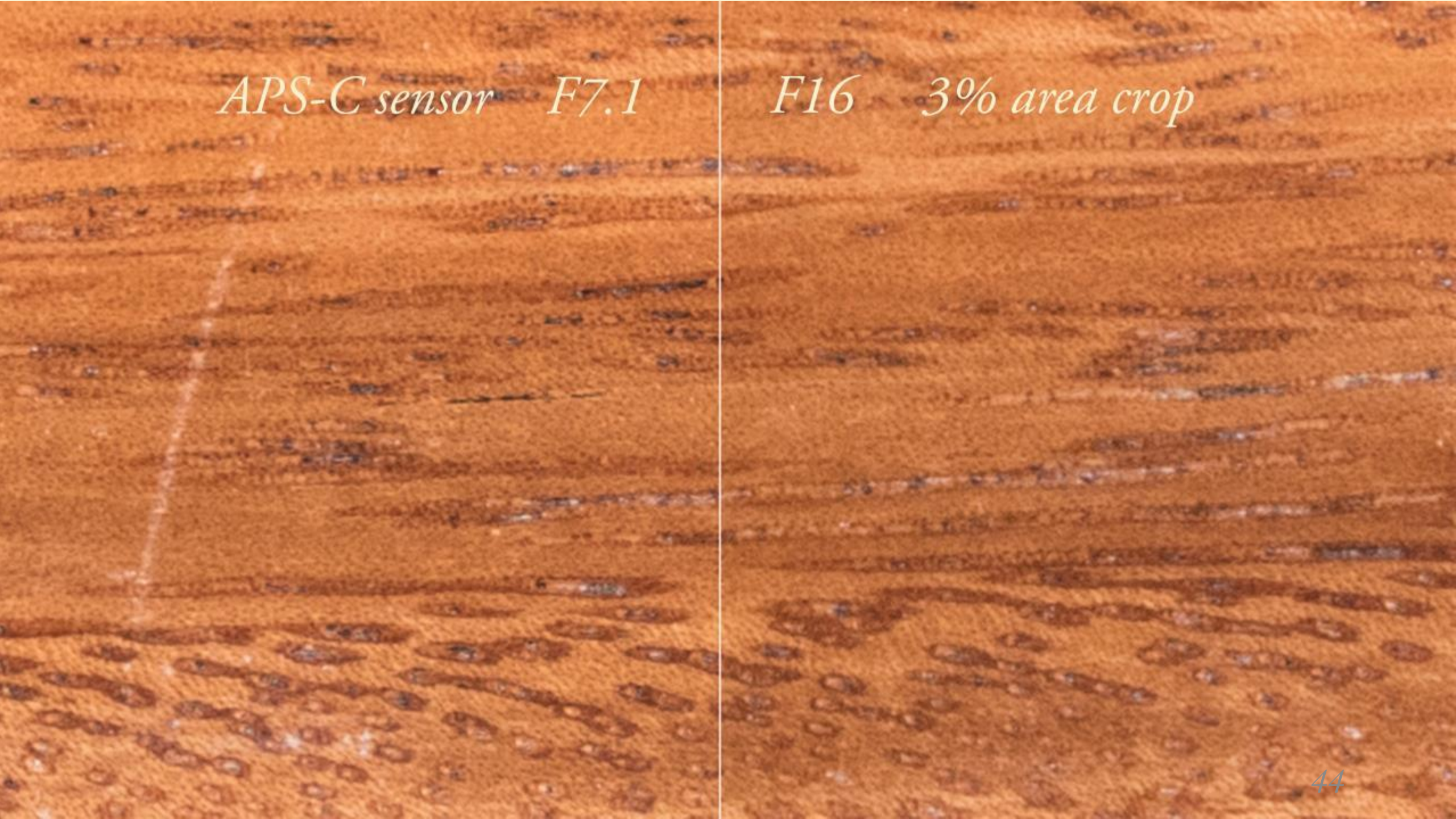
Small sensors use small apertures and are more affected by diffraction.

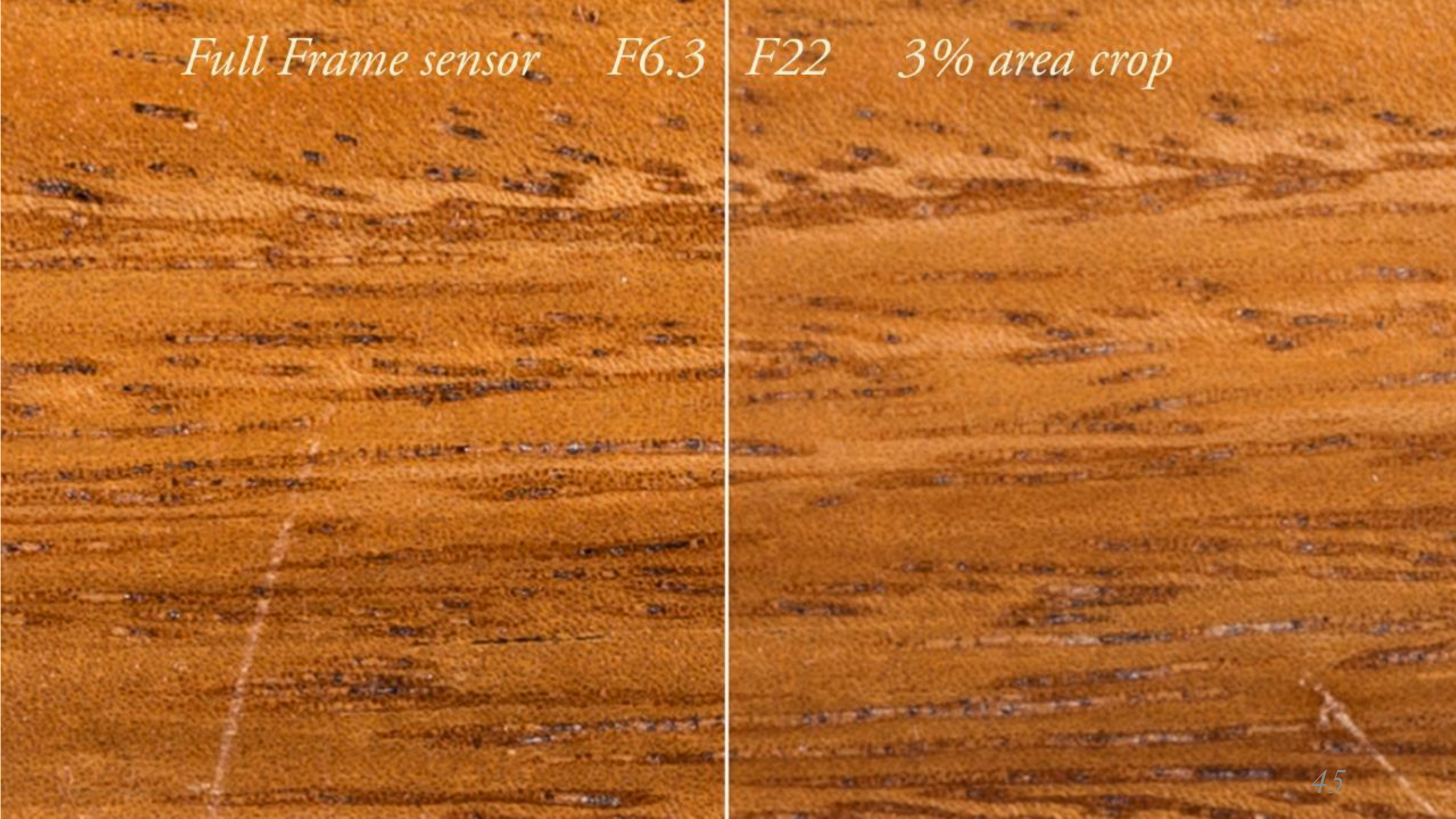
Cameras with small sensors do not offer small apertures for this reason.

On my cameras the smallest apertures are:

Full frame	***APS-C***	***1”***	***1/3”***
F/22	F/16	F/11	F/2.4


1” sensor F4.5
F11 3% area crop


APS-C sensor F7.1
F16 3% area crop


Full Frame sensor F6.3
F22 3% area crop


1% area
crop
1/3” sensor


1% area
crop
2/3” sensor


1% area
crop
1” sensor


1% area
crop
APS-C sensor


1% area
crop
Full frame sensor


1”
sensor
Full frame
sensor


1/3”
sensor
(iPhone)
Full frame
sensor

Conclusion

The most versatile cameras use full frame sensors.

Camera control reduces as sensor size shrinks.

Full frame cameras offer huge range of lenses and accessories.

But, weight and cost penalty.

Advice:
Buy camera with largest sensor that is within your comfortable weight range, Full frame > APS-C > MFT > 1".