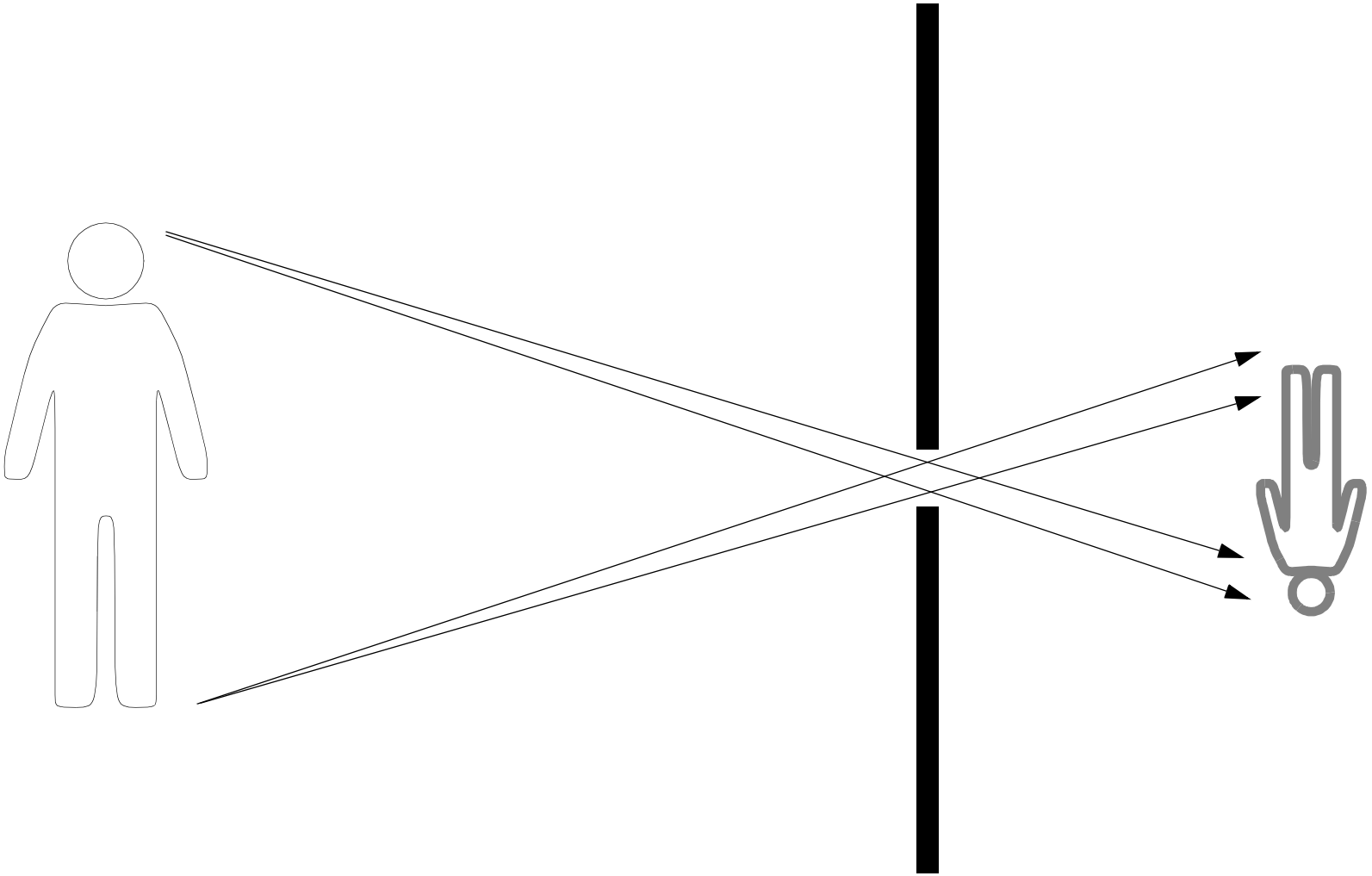
brief history of photography

foveon X3 imager technology description

imaging technology 30,000 BC

chauvet-pont-d’arc



pinhole camera principle first described by Aristotle fourth century B.C.

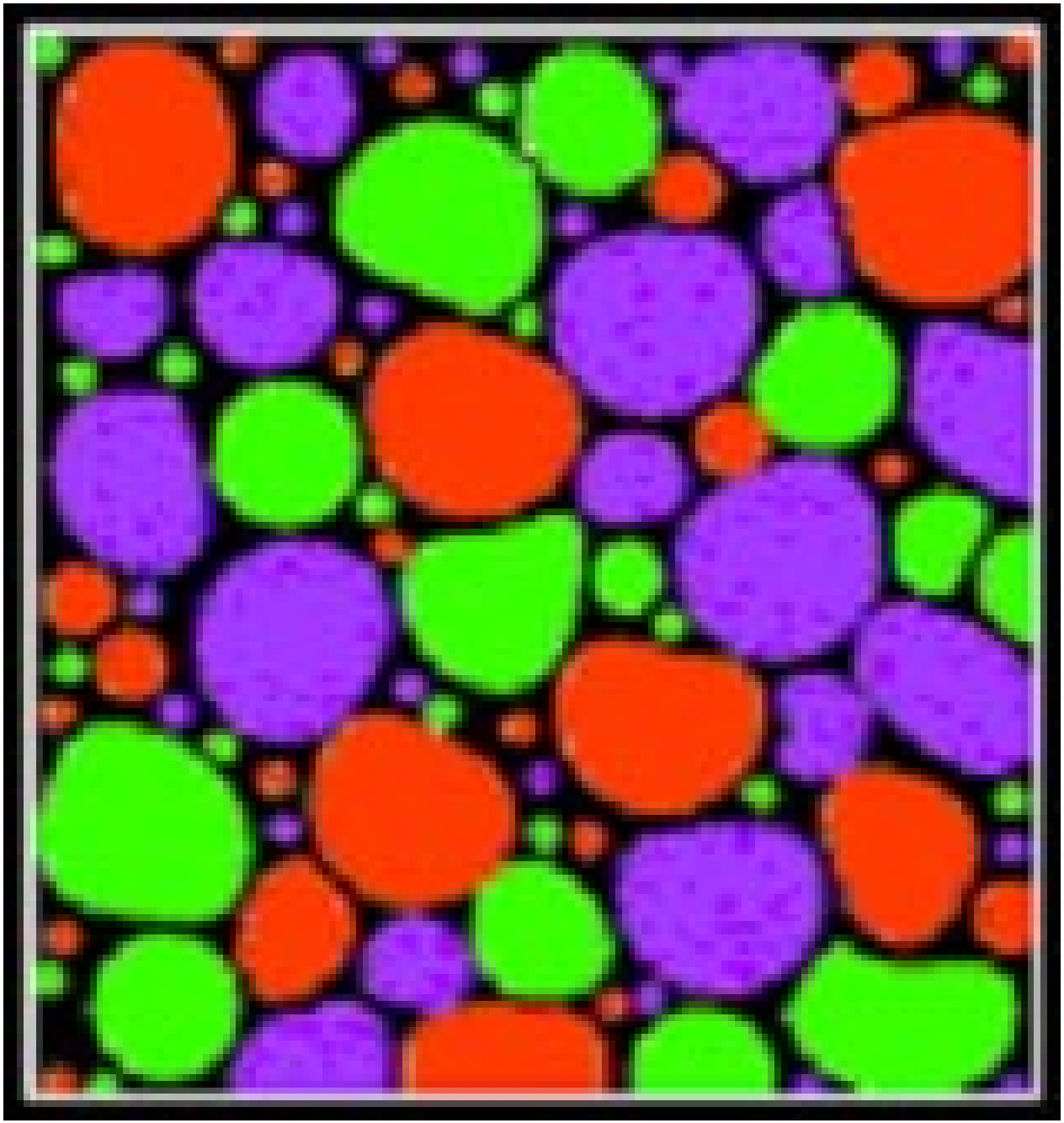
oldest known photograph

Nicéphore Niépce 1827

8 hour exposure using photosensitive asphalt

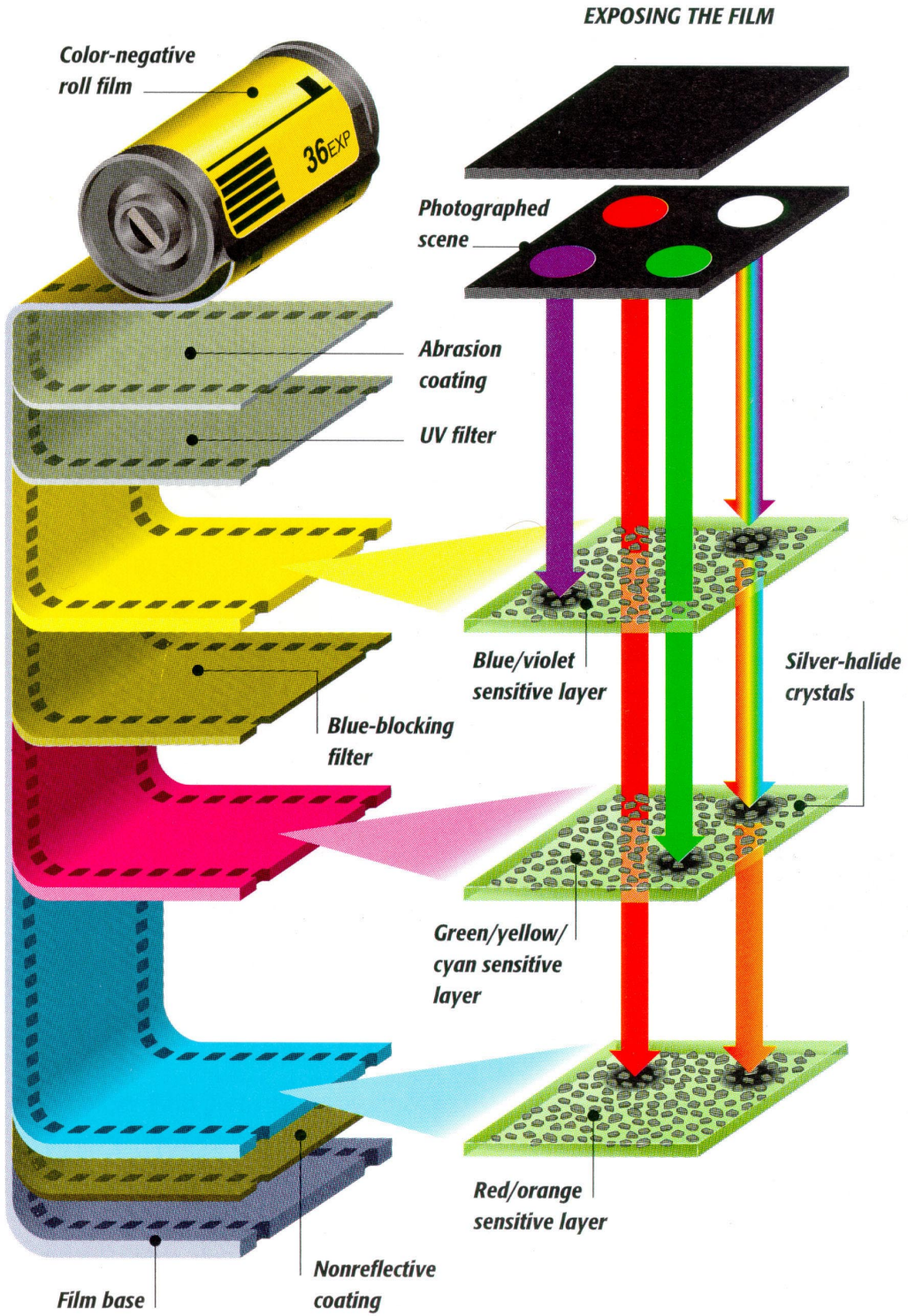
three shot color

James Clerk Maxwell 1861



autochrome using potato starch grains

Lumiere brothers 1907

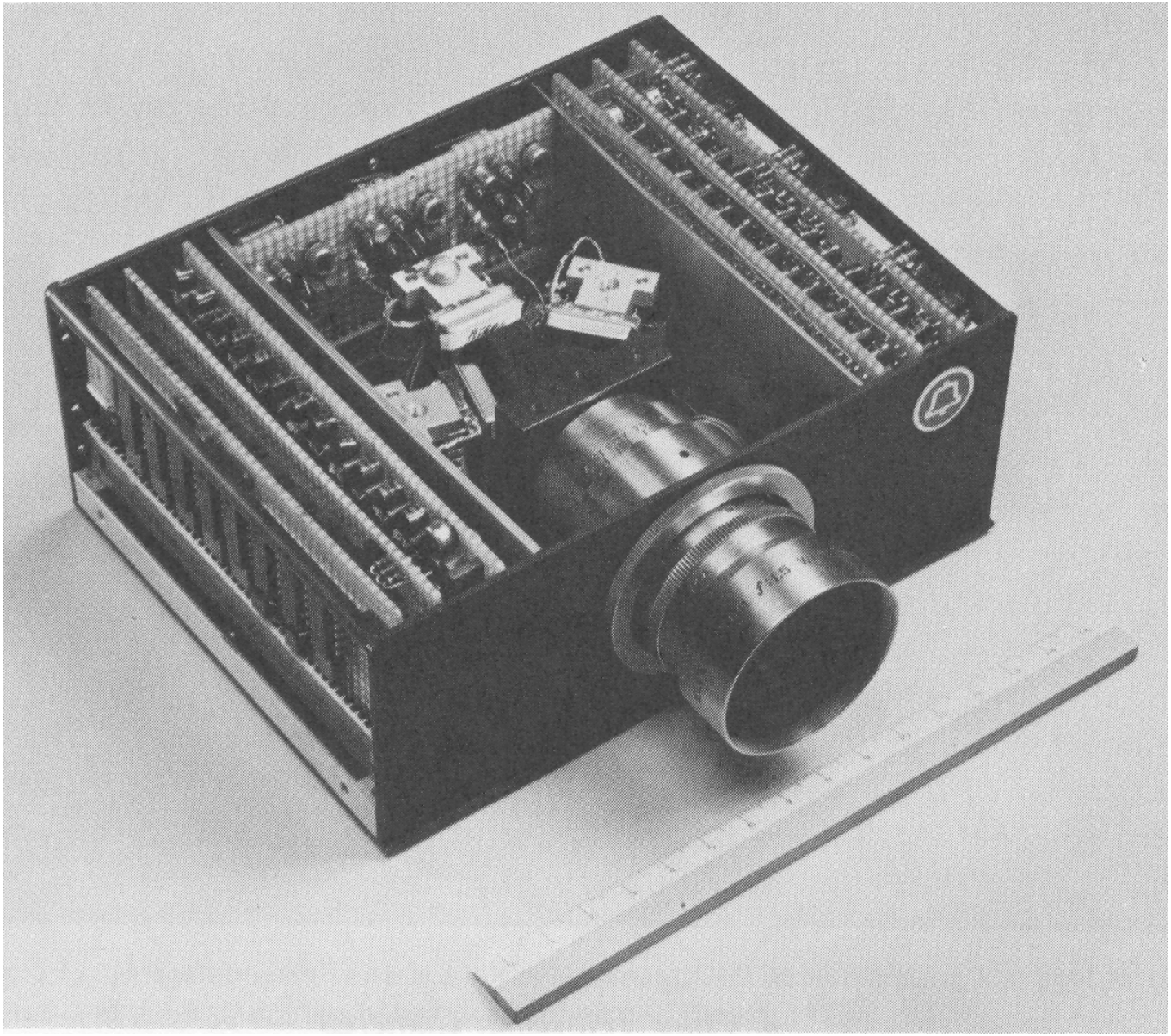


Kodachrome

1936

ISO = 10

1969 - Charged Coupled Device (CCD): G. Smith & W. Boyle



three CCD prism color camera

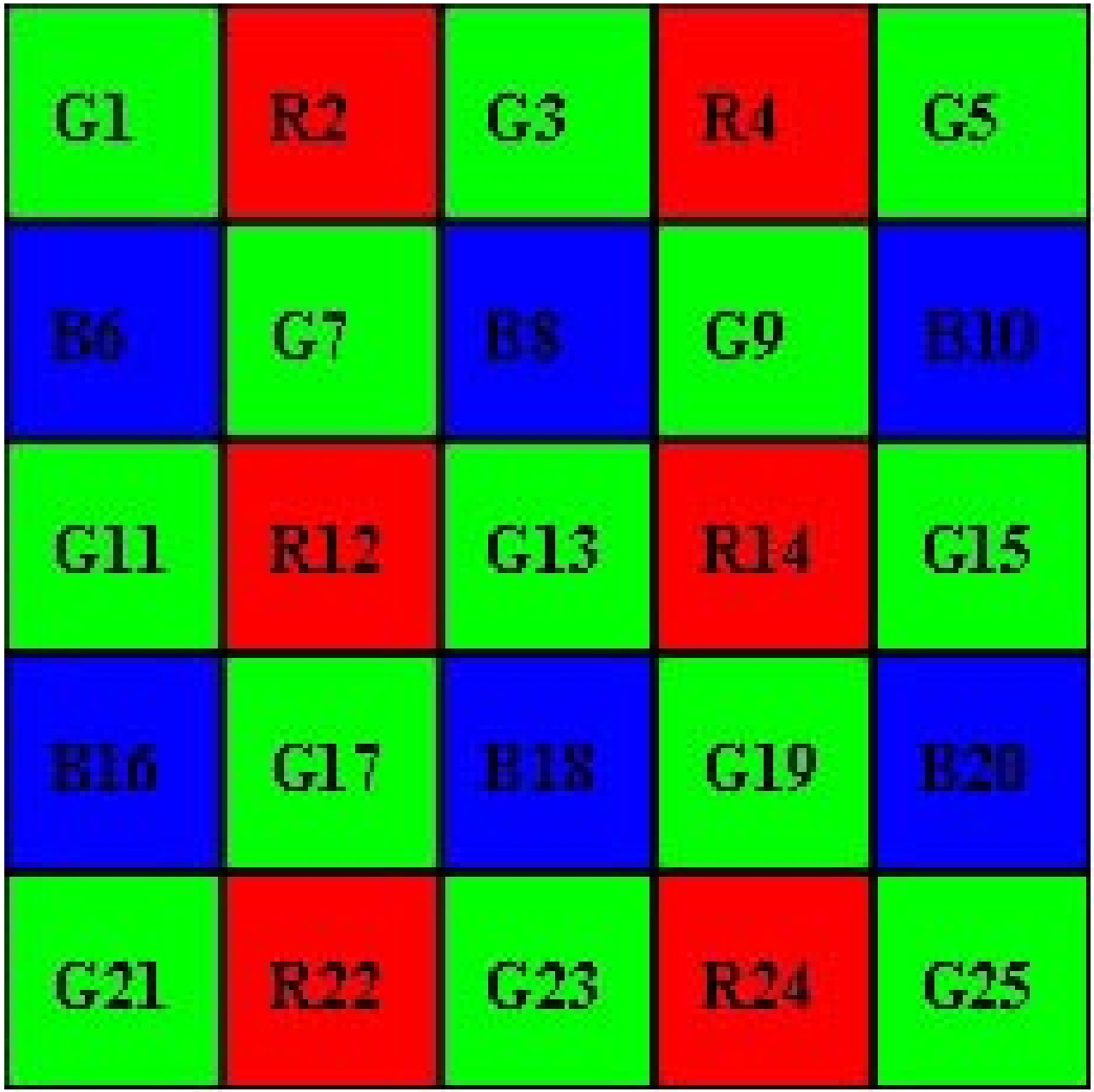
Séquin & Tompsett 1974

expensive

bulky

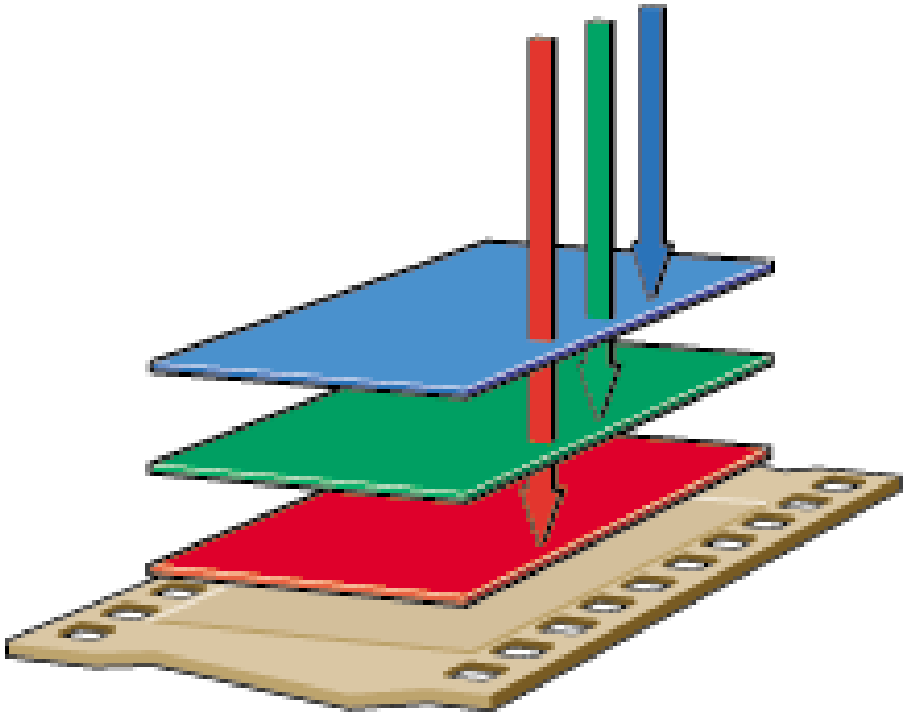
optical blurring

limited market



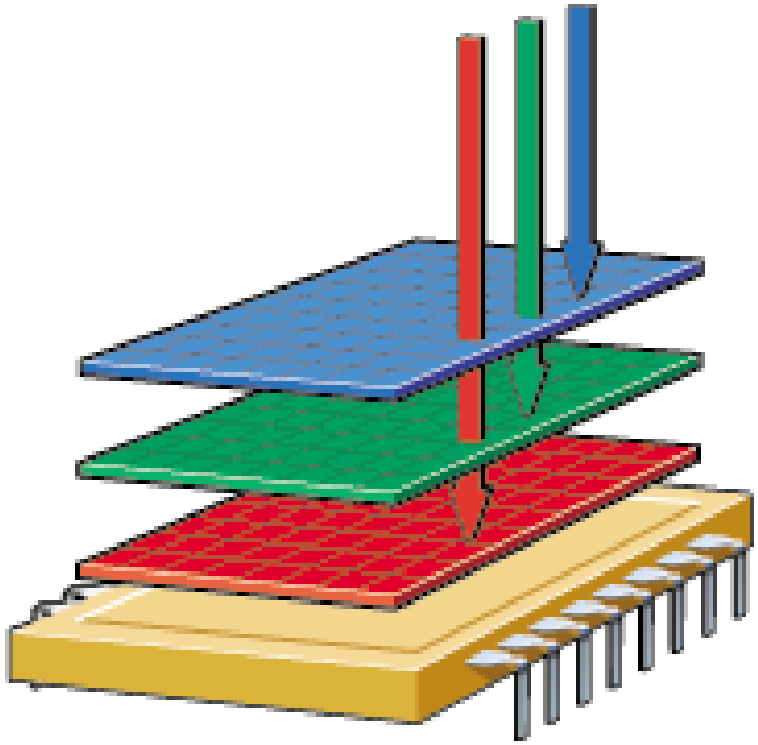
color filter array for solid state sensors

B. E. Bayer U.S. patent 3,971,065 1976



Kodachrome 1936

chemical
vertical
color
filter

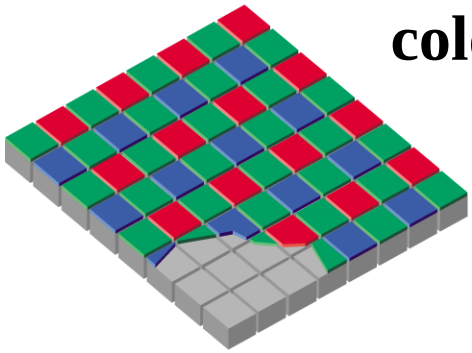


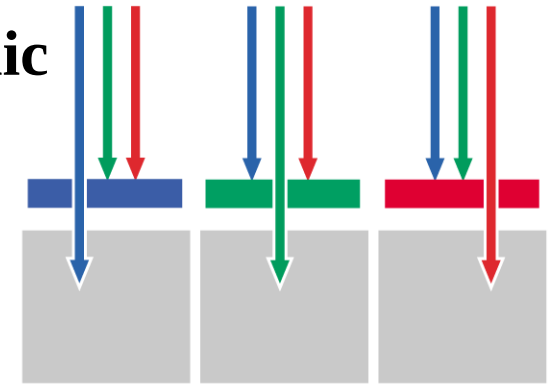
Foveon X3 2002

electrical
vertical
color
filter

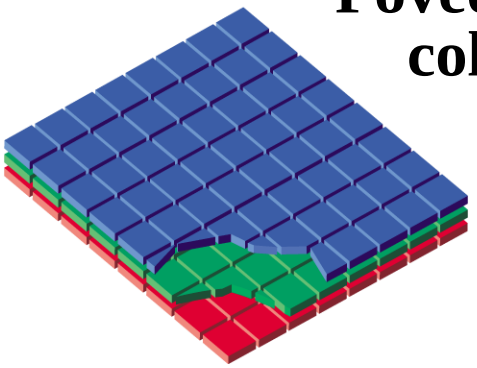
X3 imager technology has 3X more efficient use of photons

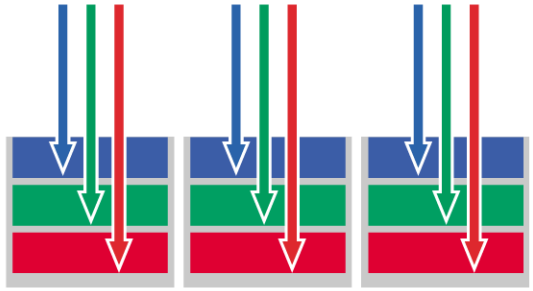
CCD mosaic color

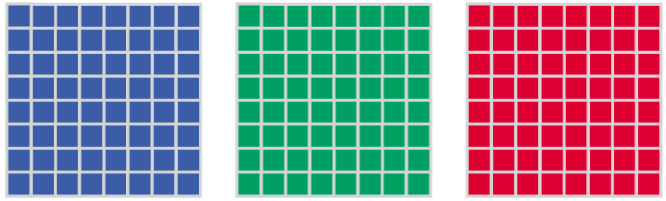




Foveon X3 color



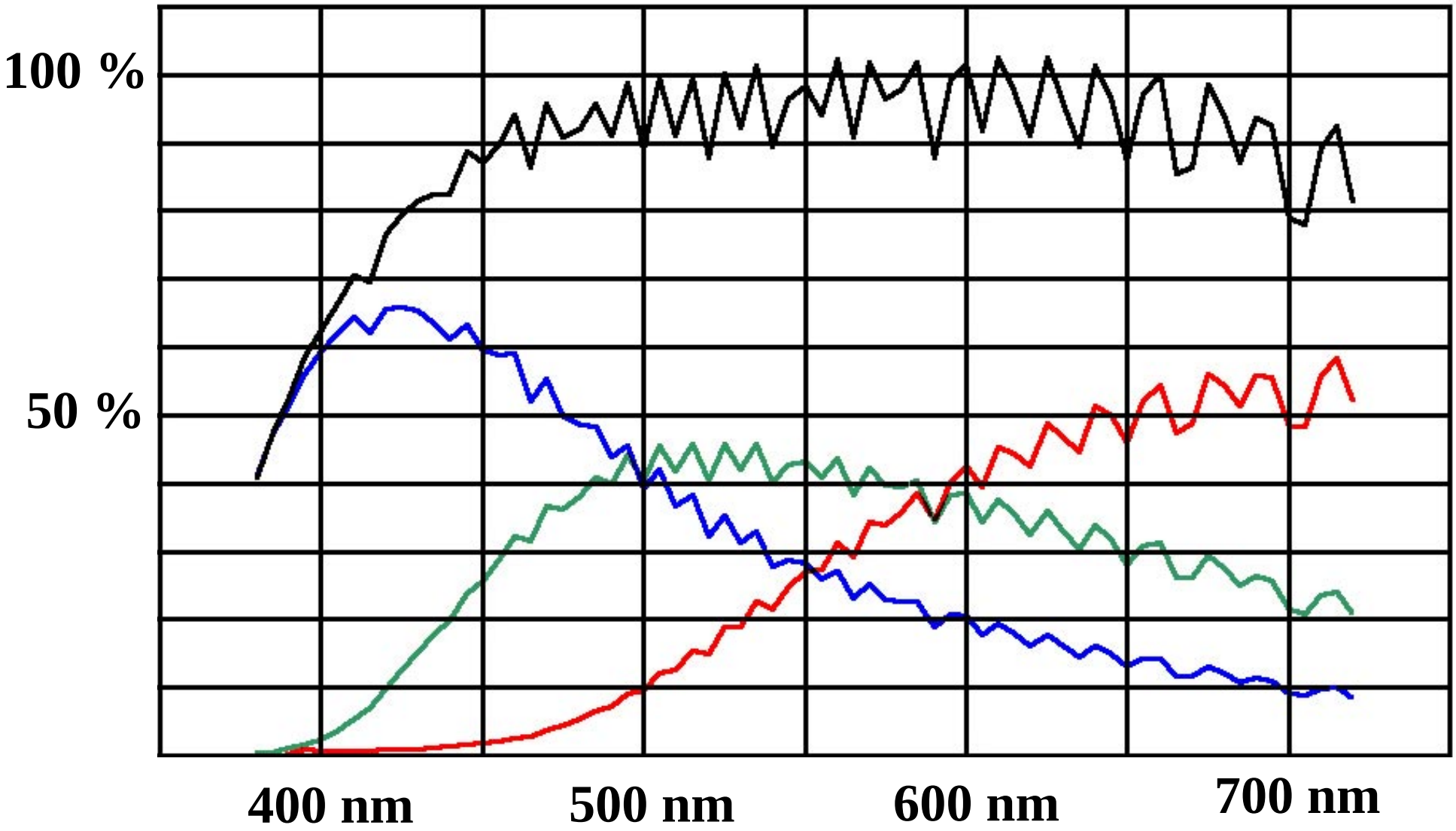




Mosaic filters absorb 2/3 of photons

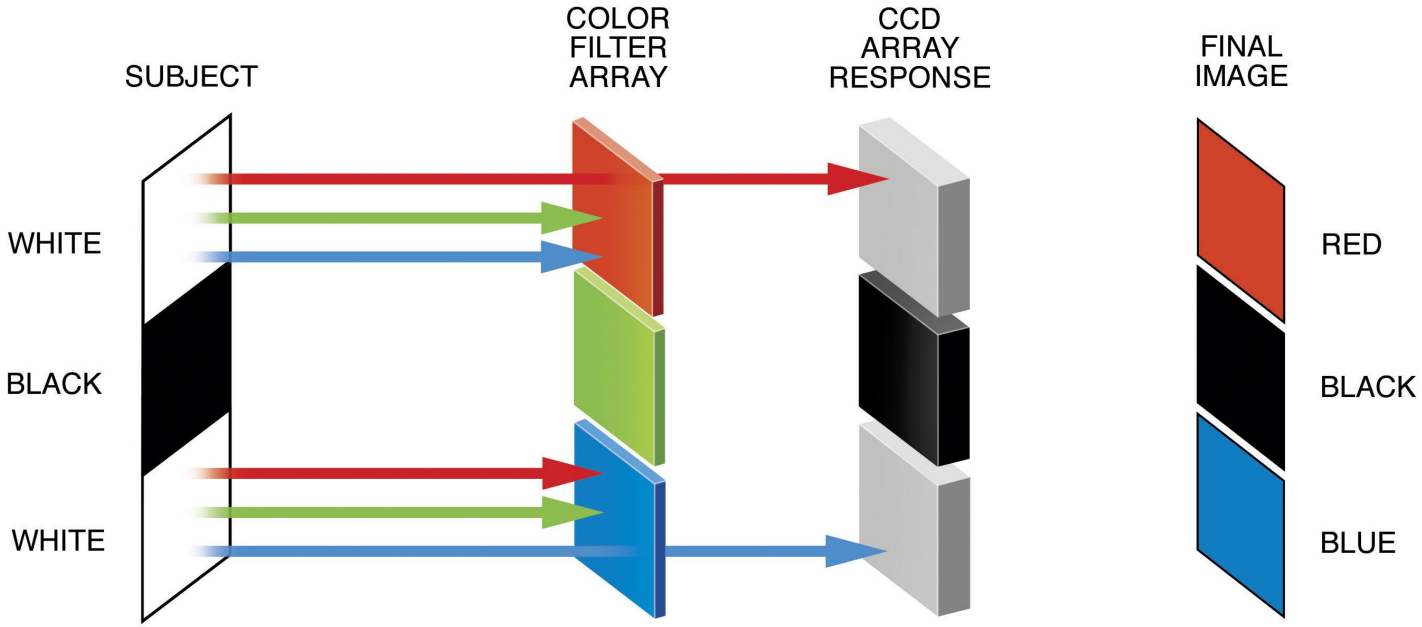
X3 has detectors at depths in the silicon appropriate to wavelength

=> quantum efficiency close to 100%

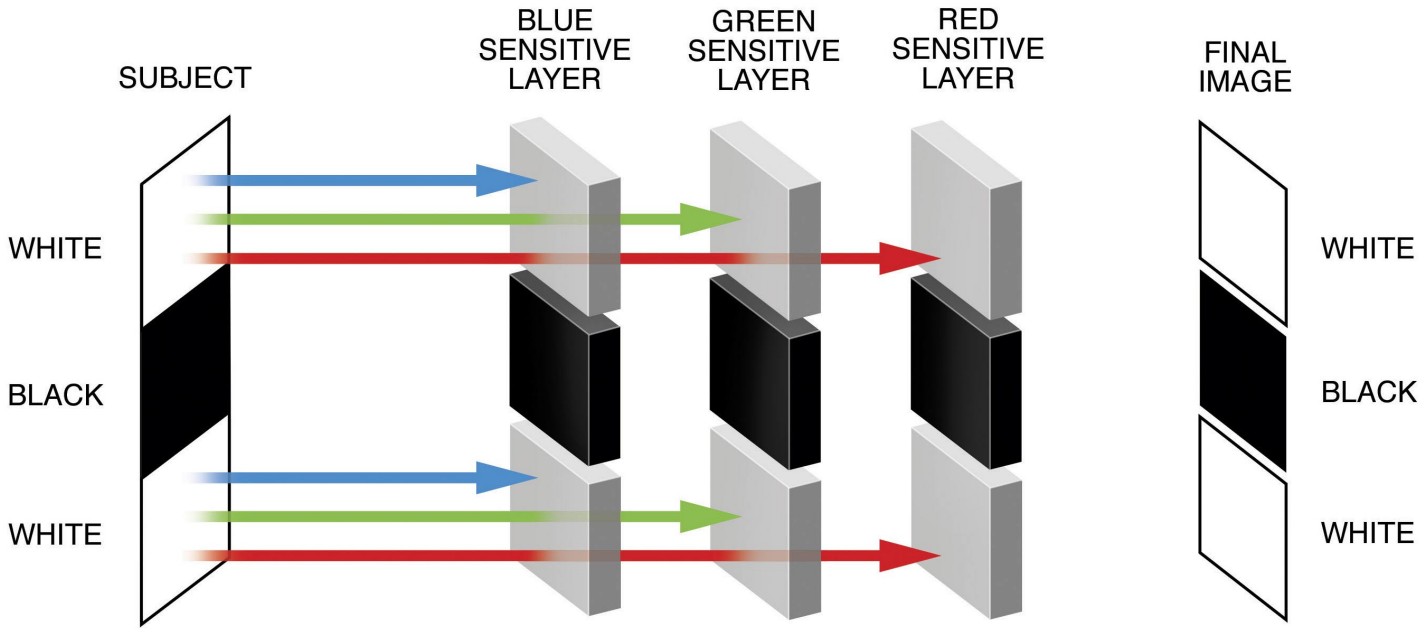


vertical color filter response: R, G, B and total

X3 imager technology has no color artifacts

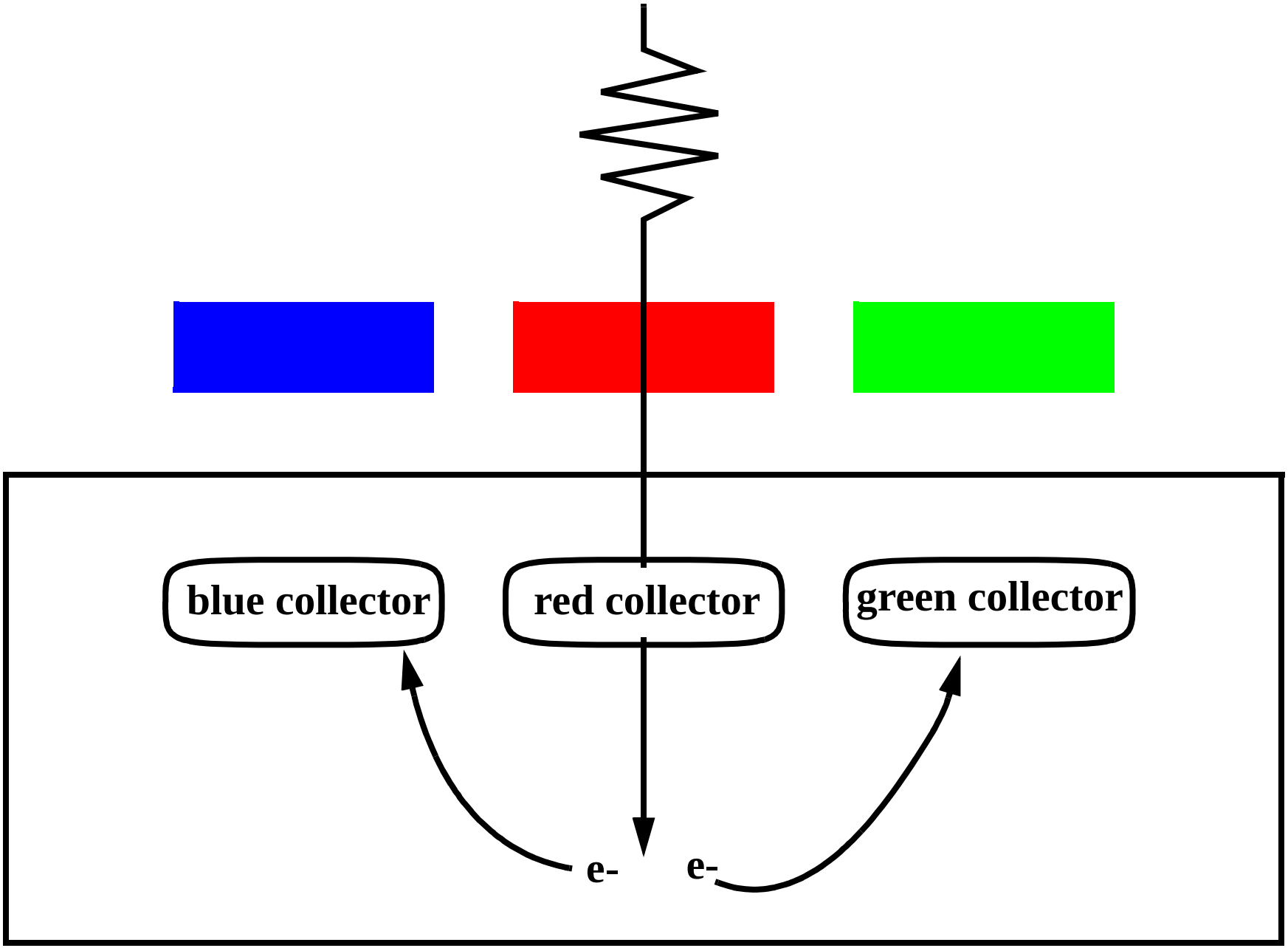


CCD / color mosaic sensor with color interpretation errors



x3 sensor with no color interpretation errors

optical color confusion with with CCD mosaic sensor

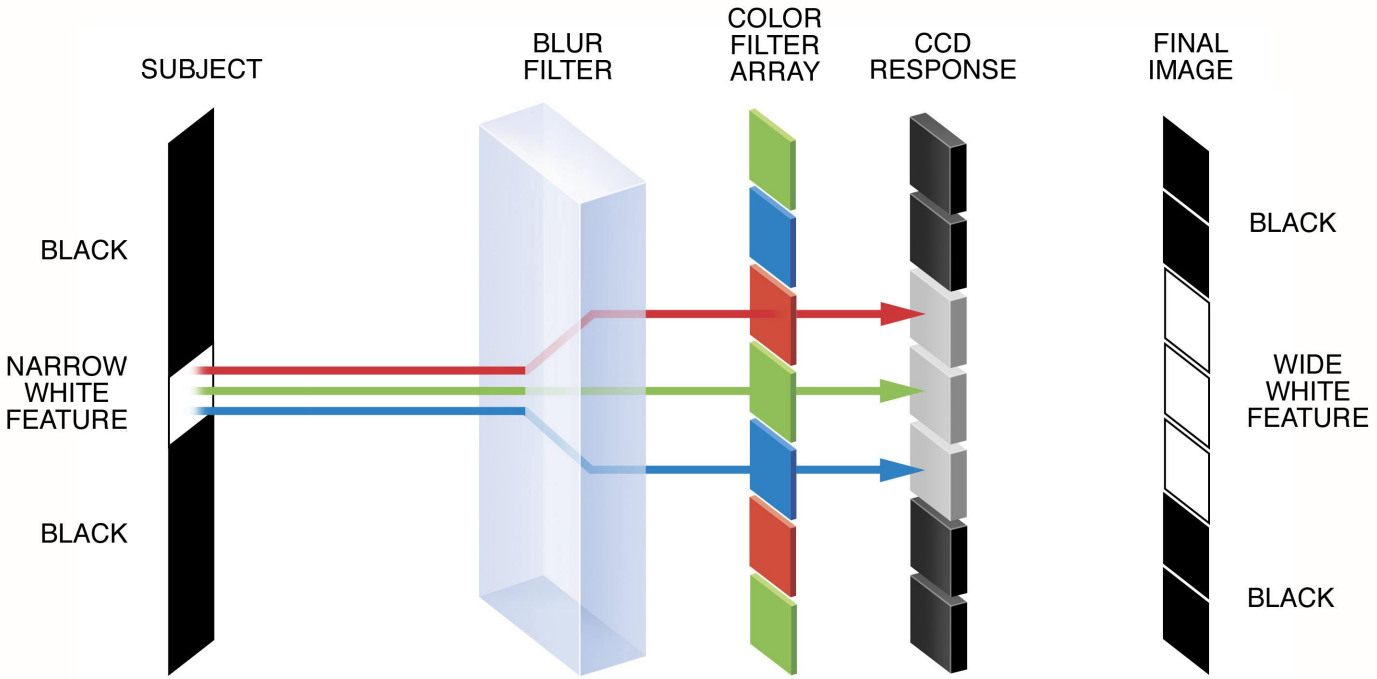


electrical color confusion with CCD mosaic sensor

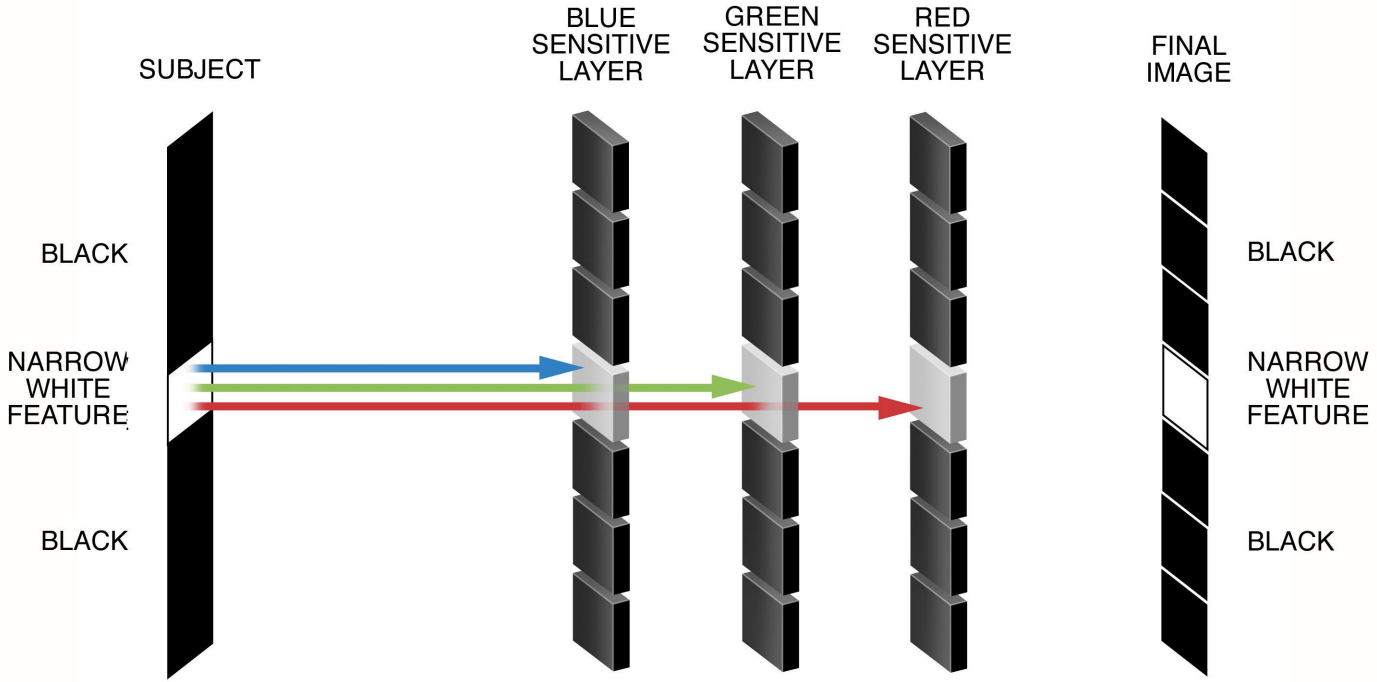
color filter mosaic artifacts

Foveon X3 image no artifacts

X3 imager technology has sharper images

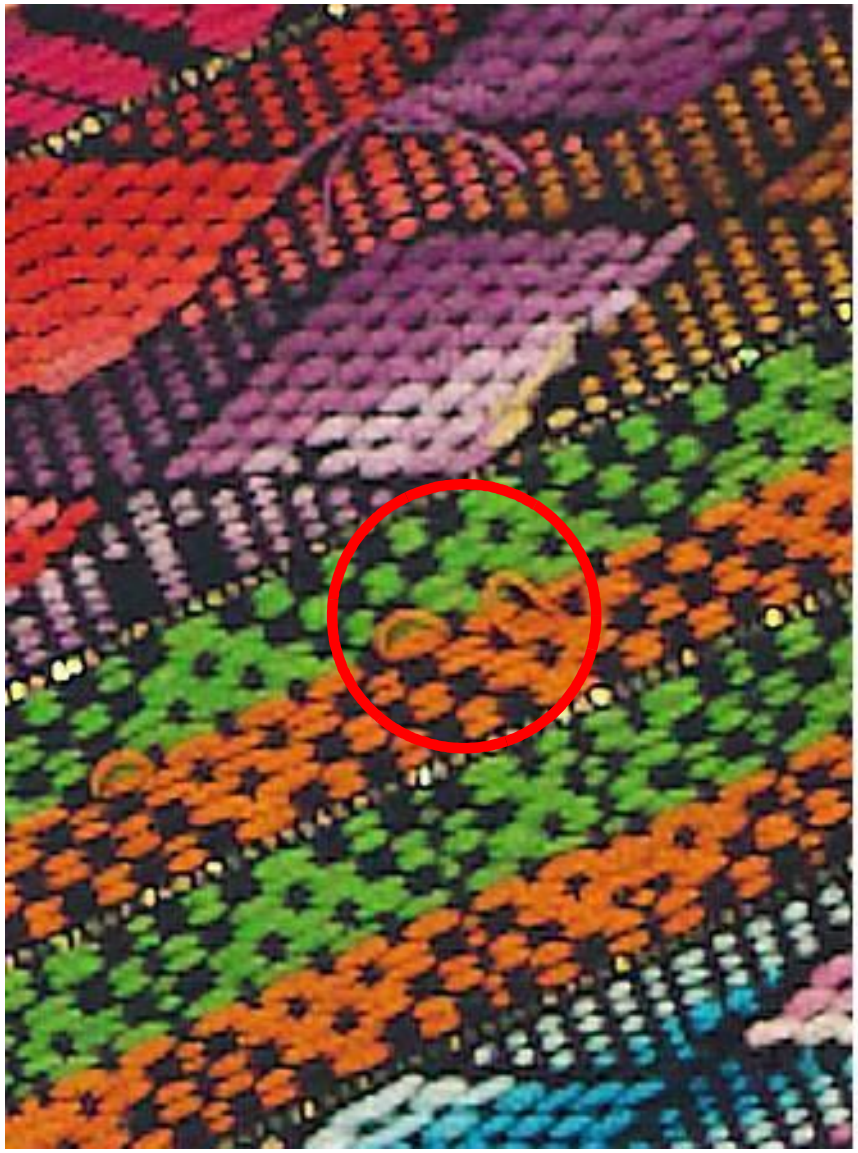


CCD sensor blurs color to suppress false color artifacts



X3 sensor does not need to blur color so images are sharper

CCD color mosaic



Foveon X3

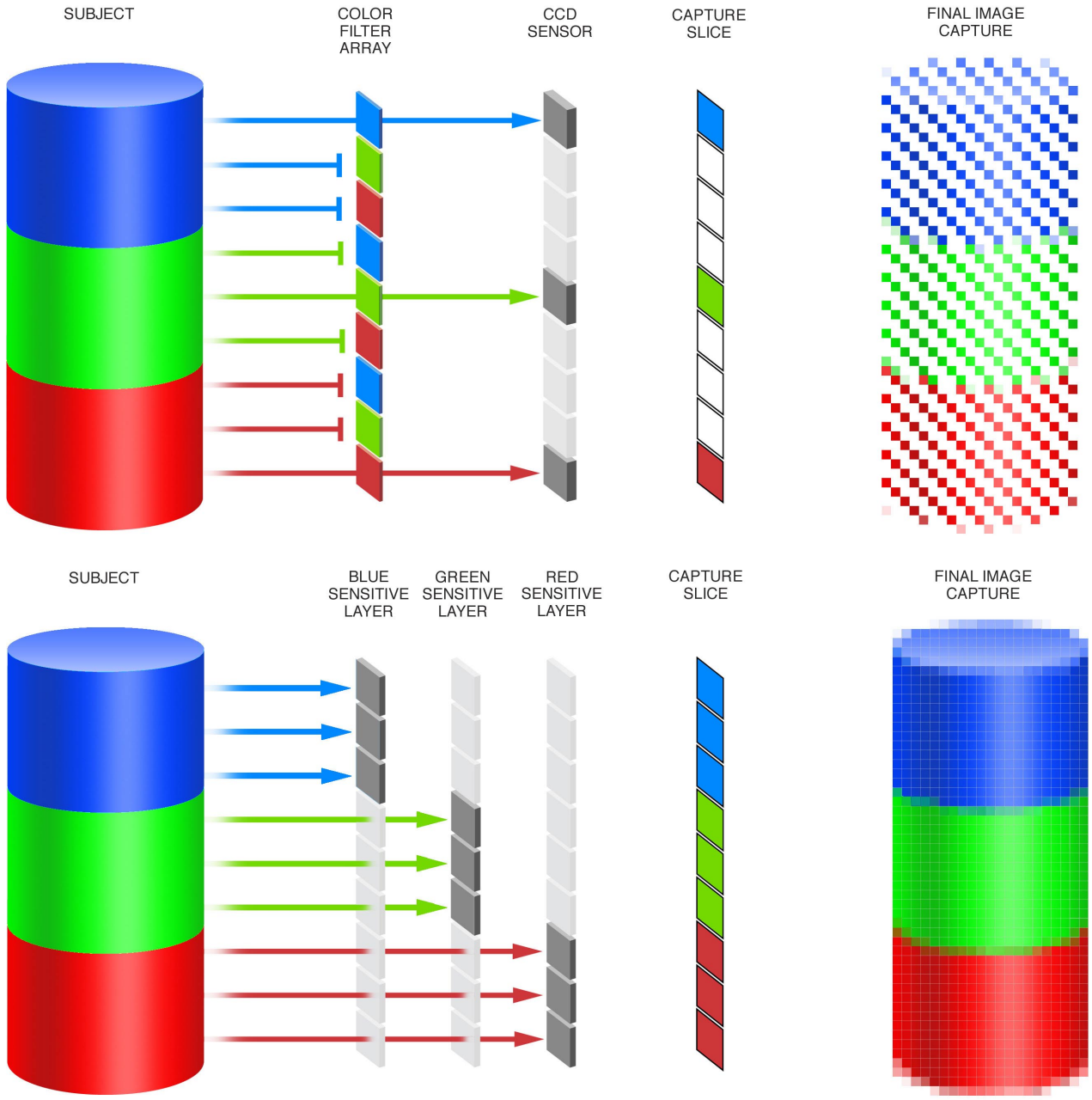
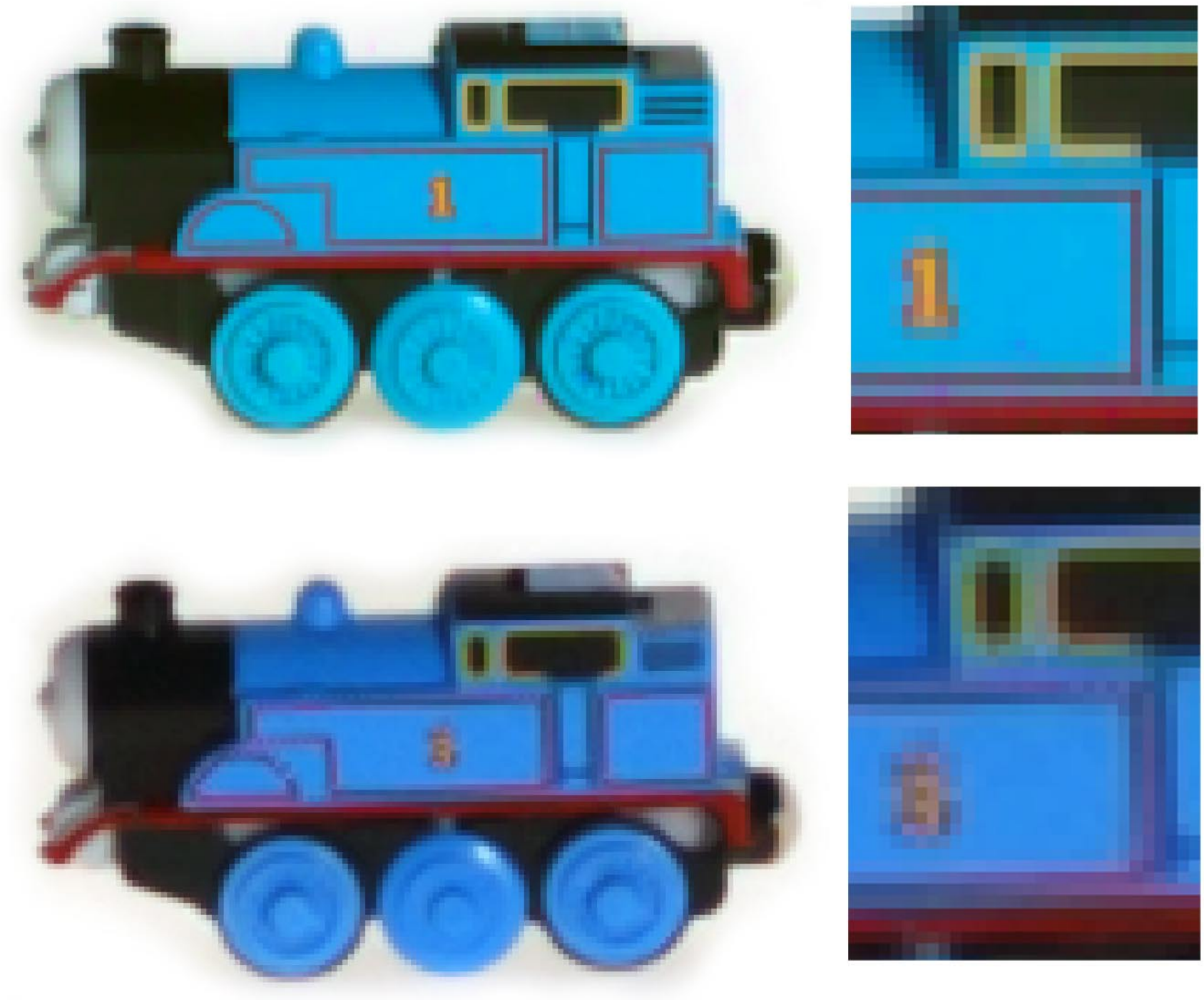


illustration of actual data measured for CCD and X3



pixel by pixel comparison of CCD mosaic image vs X3 image

applications for full measured color electronic imaging

better pictures for consumer cameras

forensics

medical

defense

scanners

digital cinema

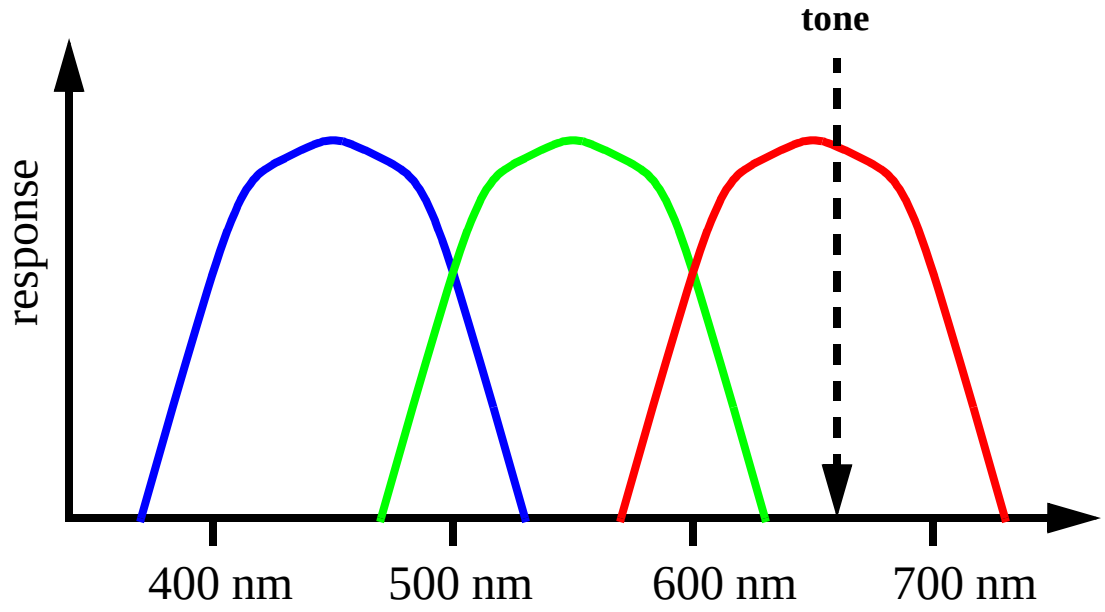
optical communications

whenever the color of every pixel is important !

SLR camera is a good proving ground for sensor technology

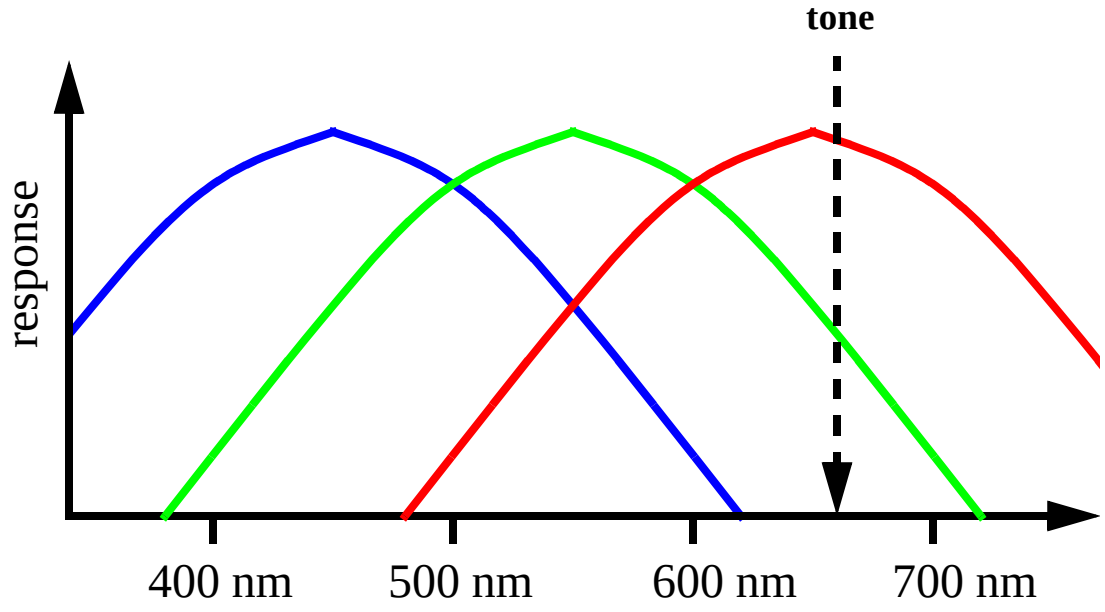
difficult photographic corner cases, high visibility product

X3 technology has better color accuracy than CCD mosaic sensor



CCD mosaic color filters

no response from green or blue channel makes color ambiguous



X3 color filters

response from green *and* red channel enables more accurate determination of color

stable broad color filter response

X3 technology makes sharper images with cheaper lenses

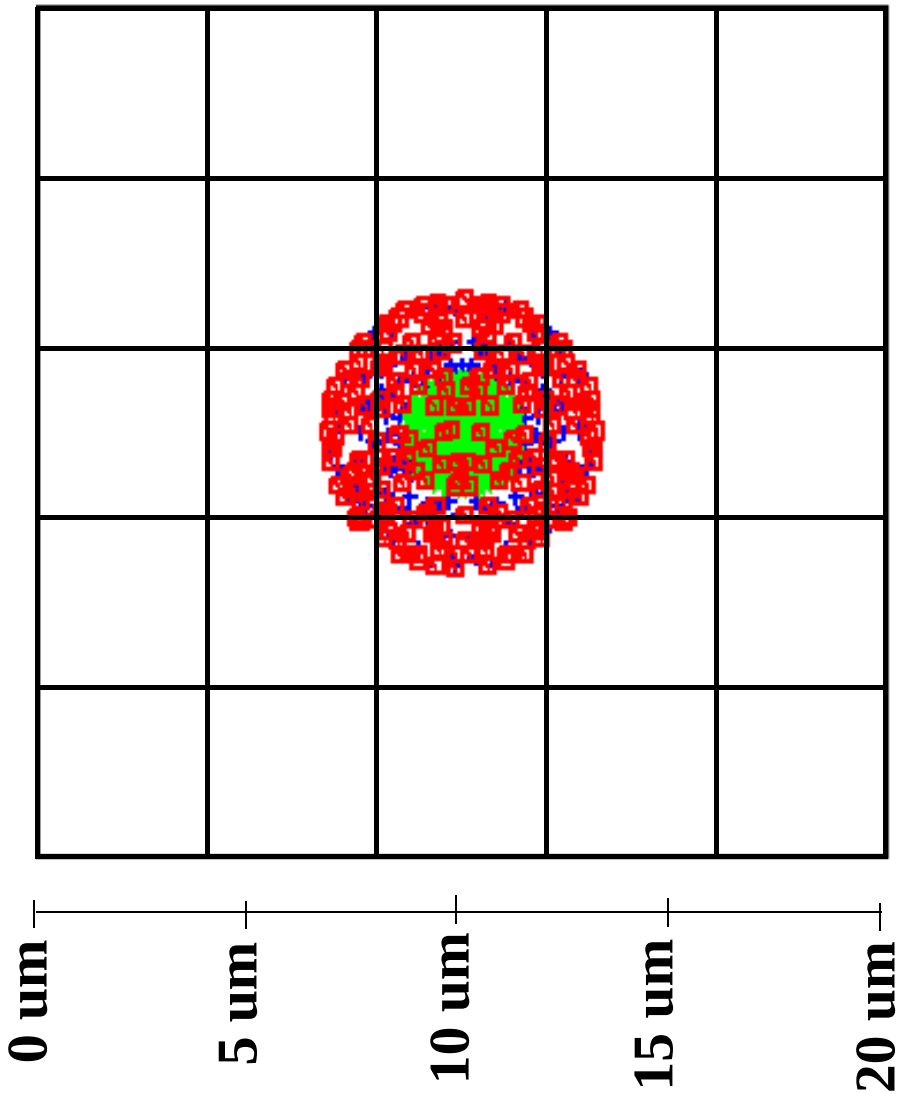
enables software correction of most difficult lens design problem (and most noticeable lens artifact): chromatic aberration

3X more information capture in a given lens spot size,

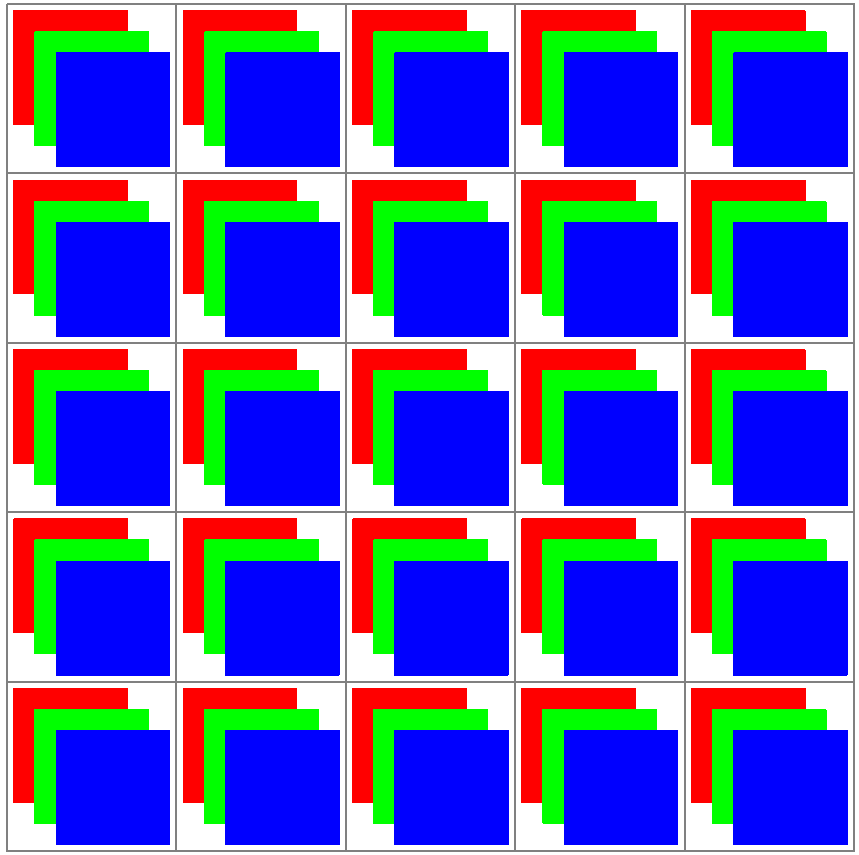
OR

cheaper lens with same information

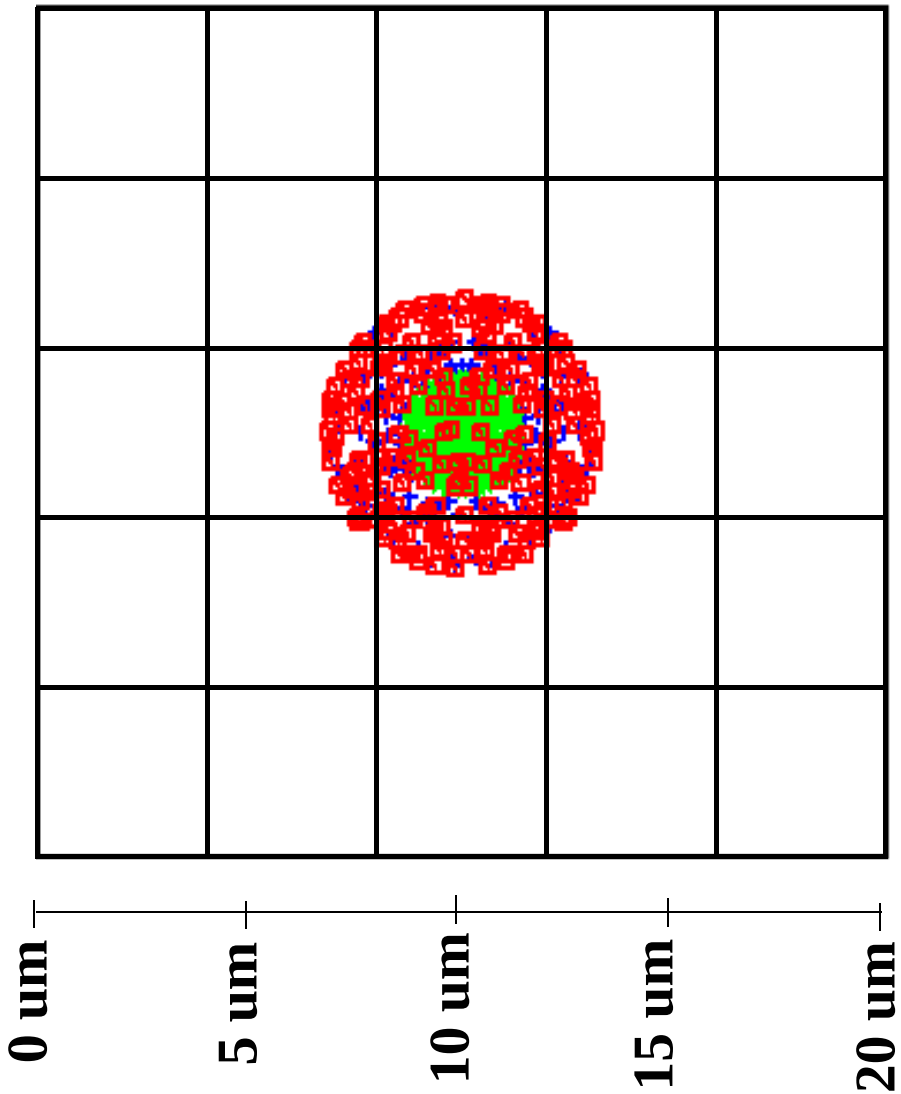
point source image
center field



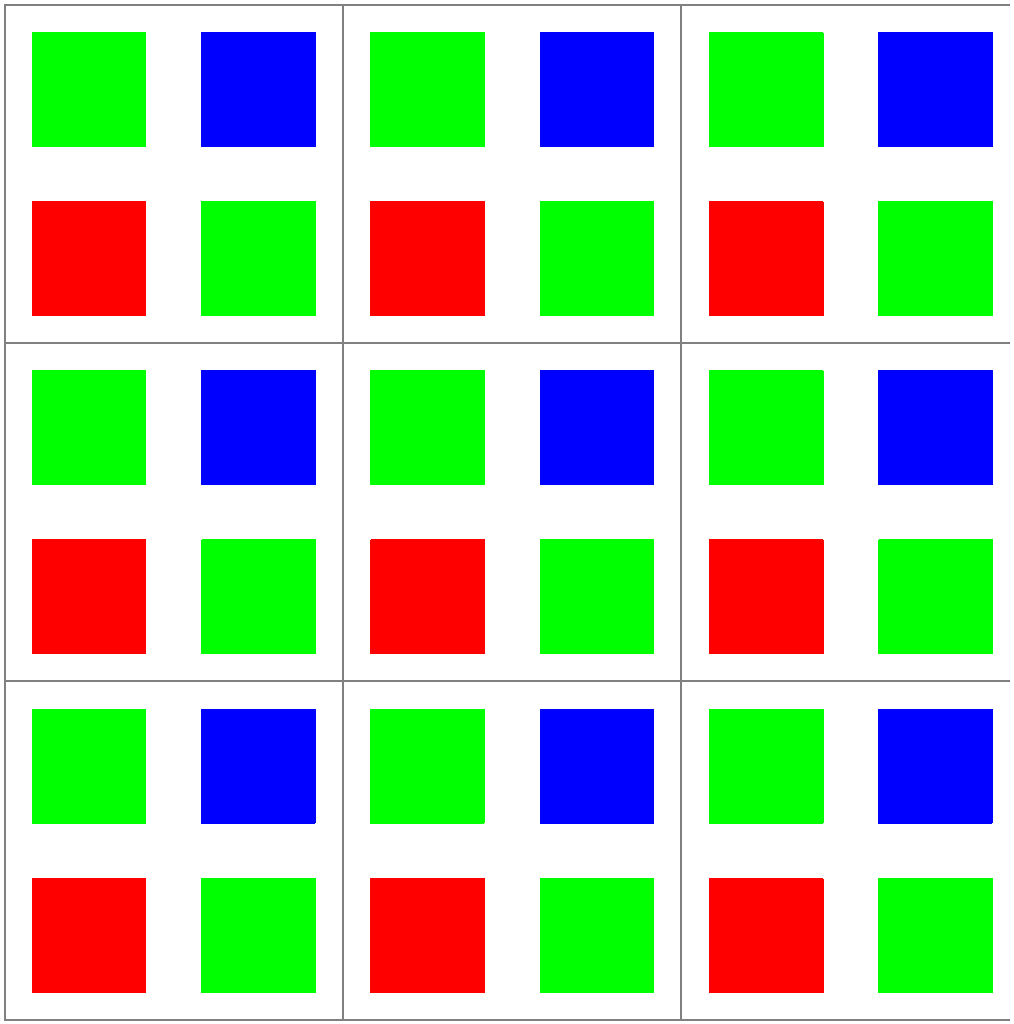
vertical color filter sampling
4 um pitch



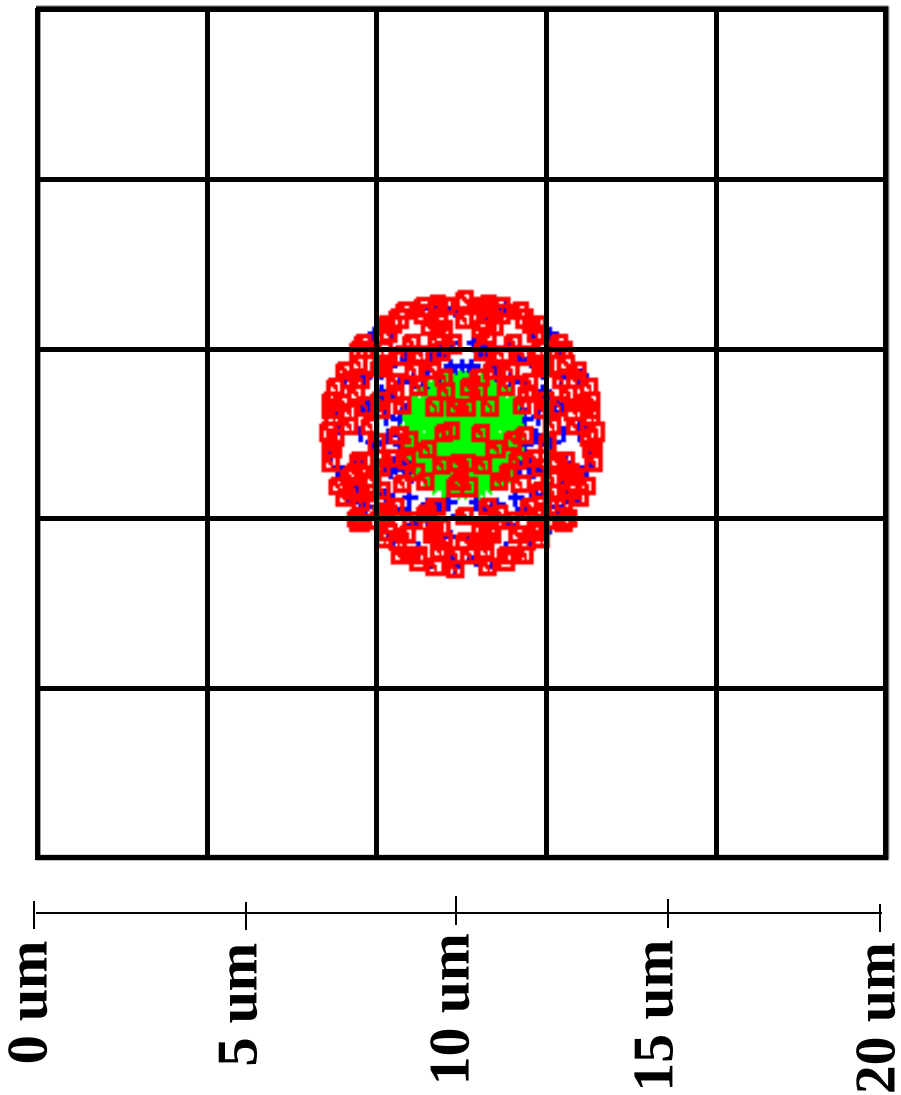
point source image
center field



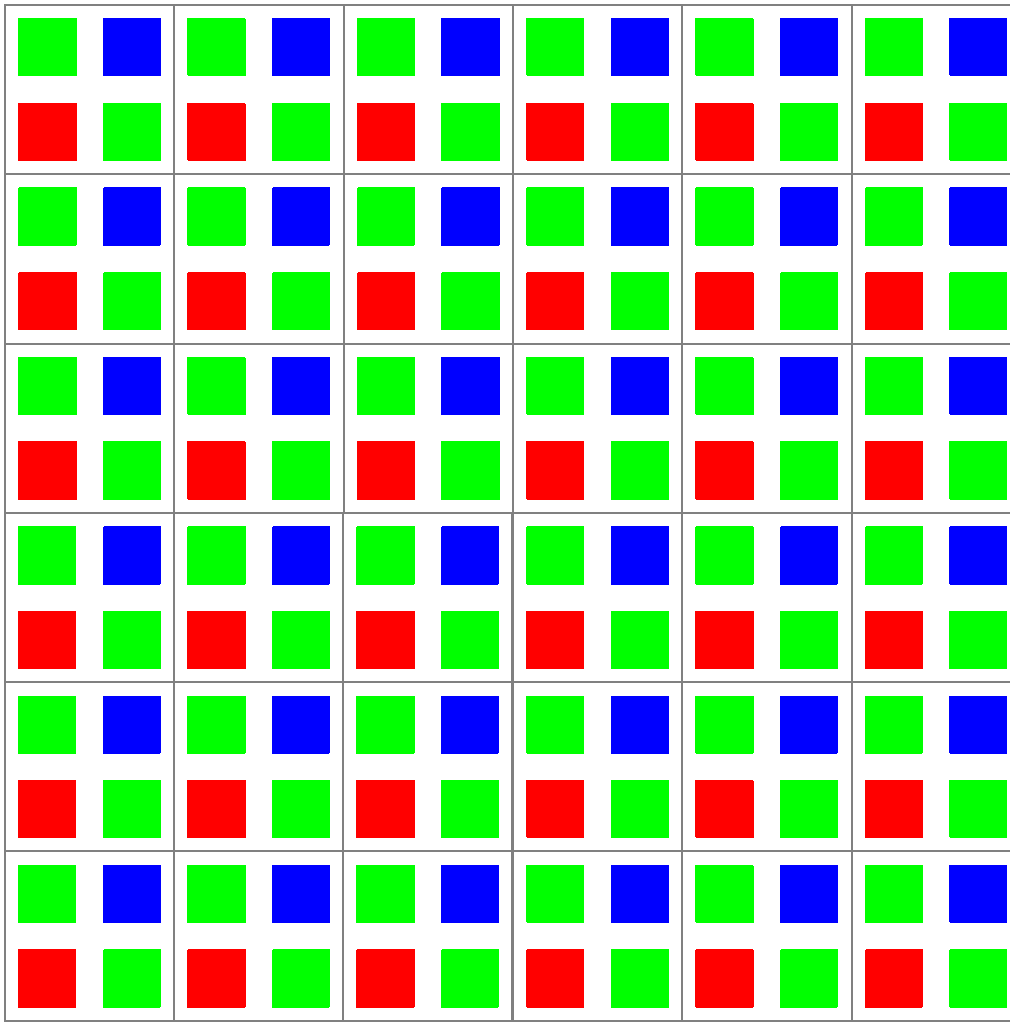
CCD mosaic sampling
4 um pitch



point source image
center field



CCD mosaic sampling
2 um pitch



lower limit on pixel size

1) photon capture

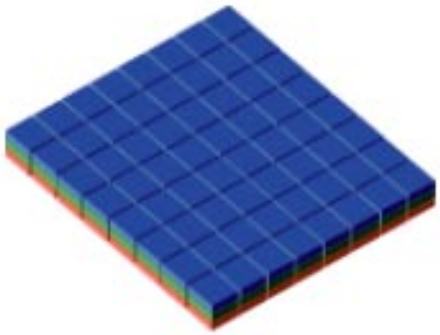
2) lens resolution

X3 is fundamentally better at both

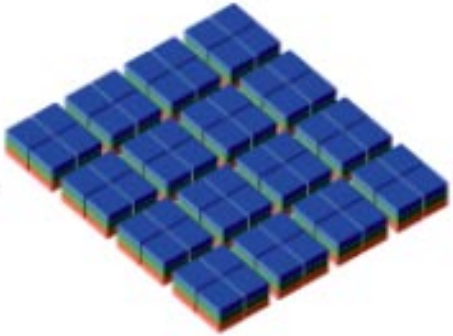
bottom line: X3 delivers more information per unit silicon area

=> better image quality per unit cost

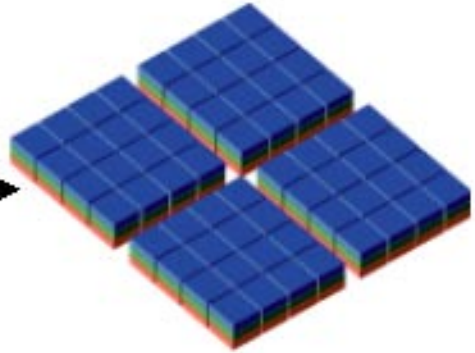
X3 technology makes variable pixel size arrays easy



1 x 1 Pixels



2 x 2 Pixels



4 x 4 Pixels

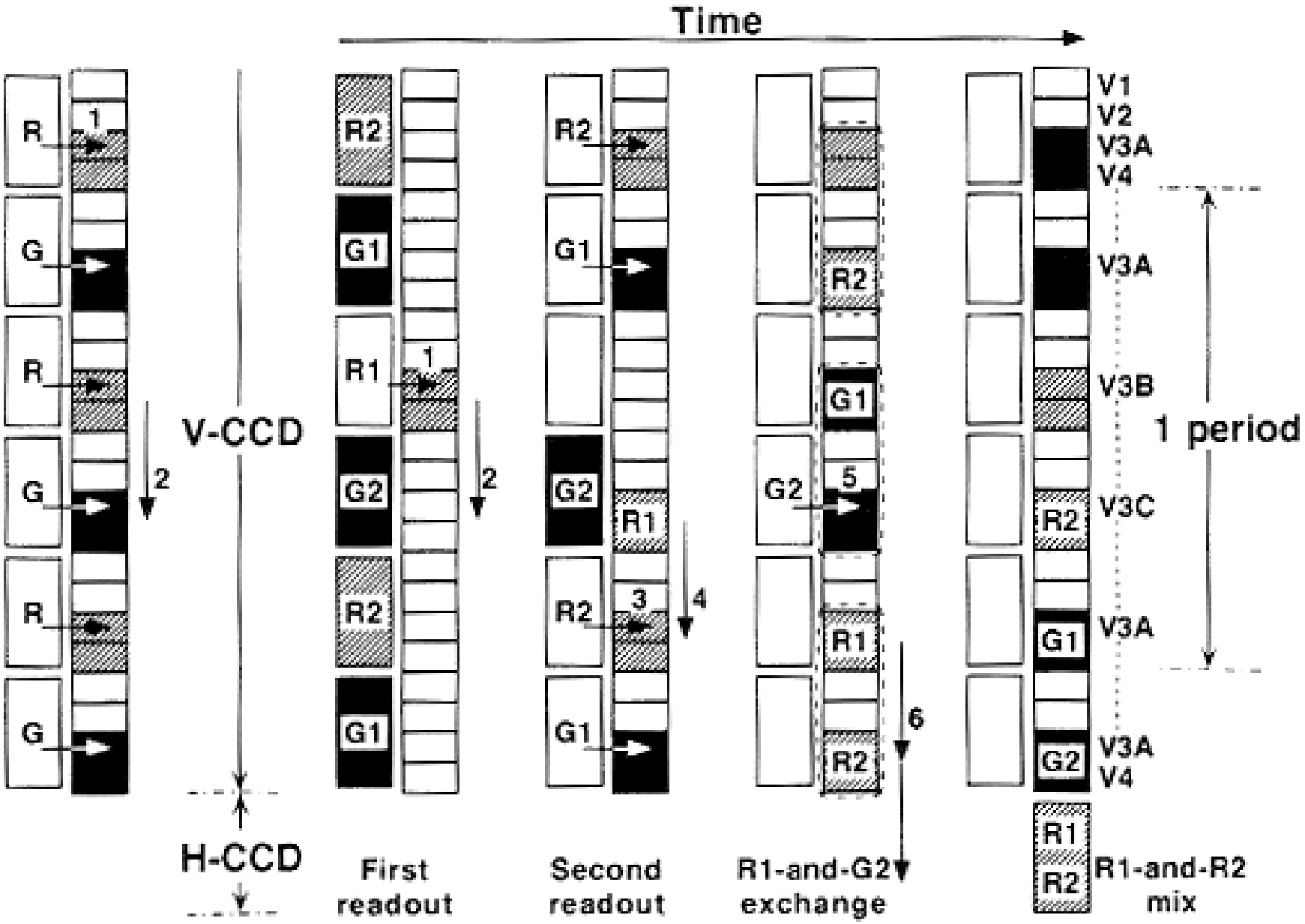
Still Photography
- High Resolution
- More Pixels

X3 Image Sensor
- Variable Resolution
- Variable ISO
- Variable Readout

Video Resolution
- Faster Readout
- Higher ISO

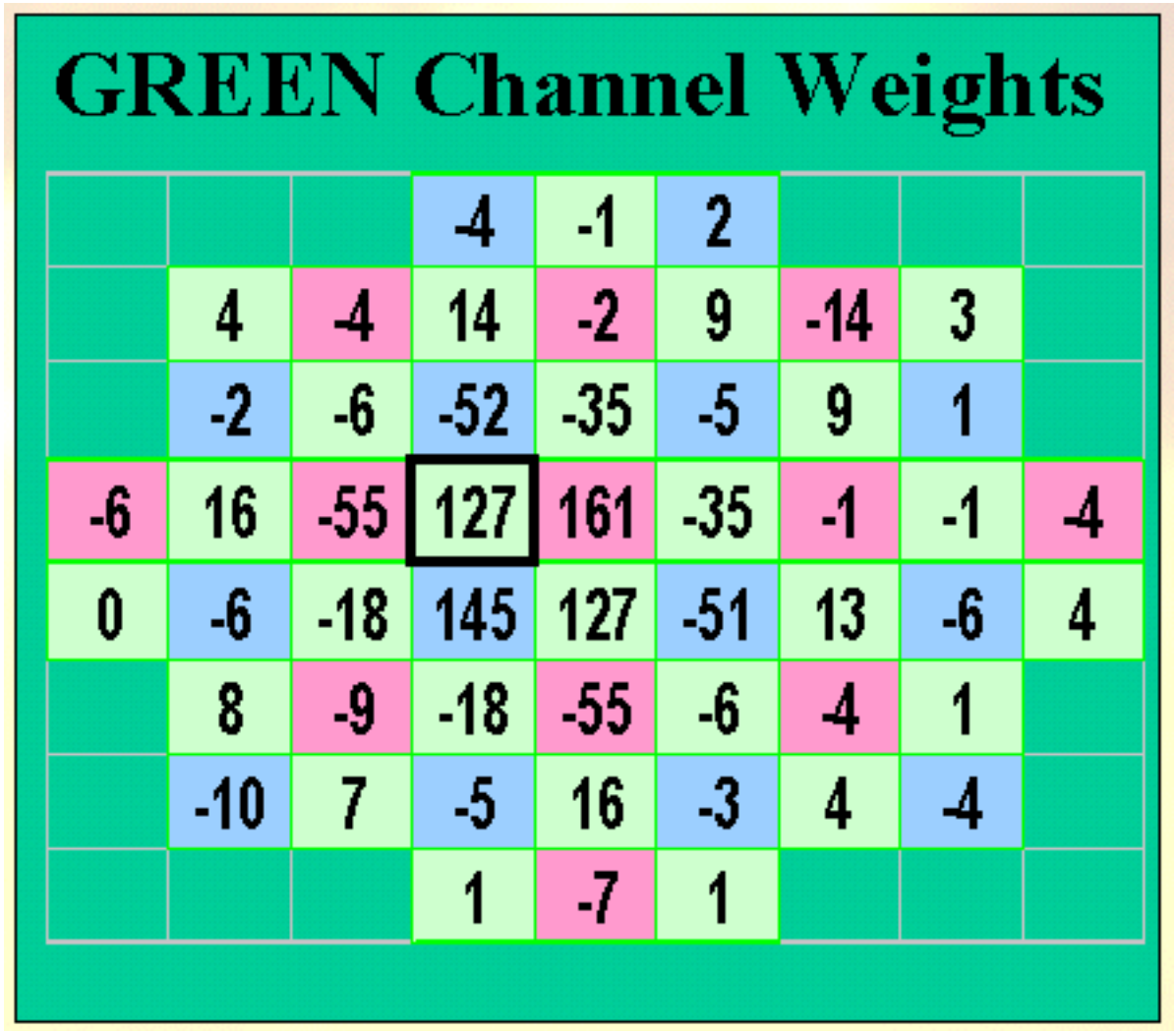
Foveon X3 enables new class of camera that captures high resolution still ***and*** digital quality full-motion video.

summing pixels together is easy when all the pixels are the same!



ISSCC 98 paper FA 11.6 *"A 1/2 inch 1.3M-pixel Progressive Scan IT CCD for Still and Motion Picture Applications"*

X3 technology simplifies digital signal processing for images



CCD color reconstruction takes a lot of math !

of course !

you mean they DON’T measure all the colors in every pixel ?

do they really clock 6000 wires 2000 times each to get the data out ?

hey actually do 109 multiplications to get a single color result for a pixel ?

.

.

.

manufacturing

1) enabled by National Semiconductor mixed signal expertise

2) added wafer cost for color filters lower for X3

3) added defects easier to correct in software

4) highly predictable color filter characteristics can reduce test & calibration cost

5) leverages worldwide investment in CMOS technology

reliability

silicon color filter will not fade over time and cannot be damaged by exposure to high temperatures or UV light (such as solar imaging) the electronic heirloom camera !

CMOS imagers are not as sensitive to bulk silicon defects generated by ionizing radiation - radiation hardness

X3 is CMOS based

low power compared to CCD

array random access applications

non destructive readout applications

signal plane image processing

SoC integration (specially enhanced by the nature of X3 technology)

bulk silicon defects cause bad columns with CCD, bad pixels for CMOS

CMOS technology trends relevant to optoelectronic ICs

1) SOI wafers becoming mainstream

2) integration of non-silicon semiconductors with CMOS

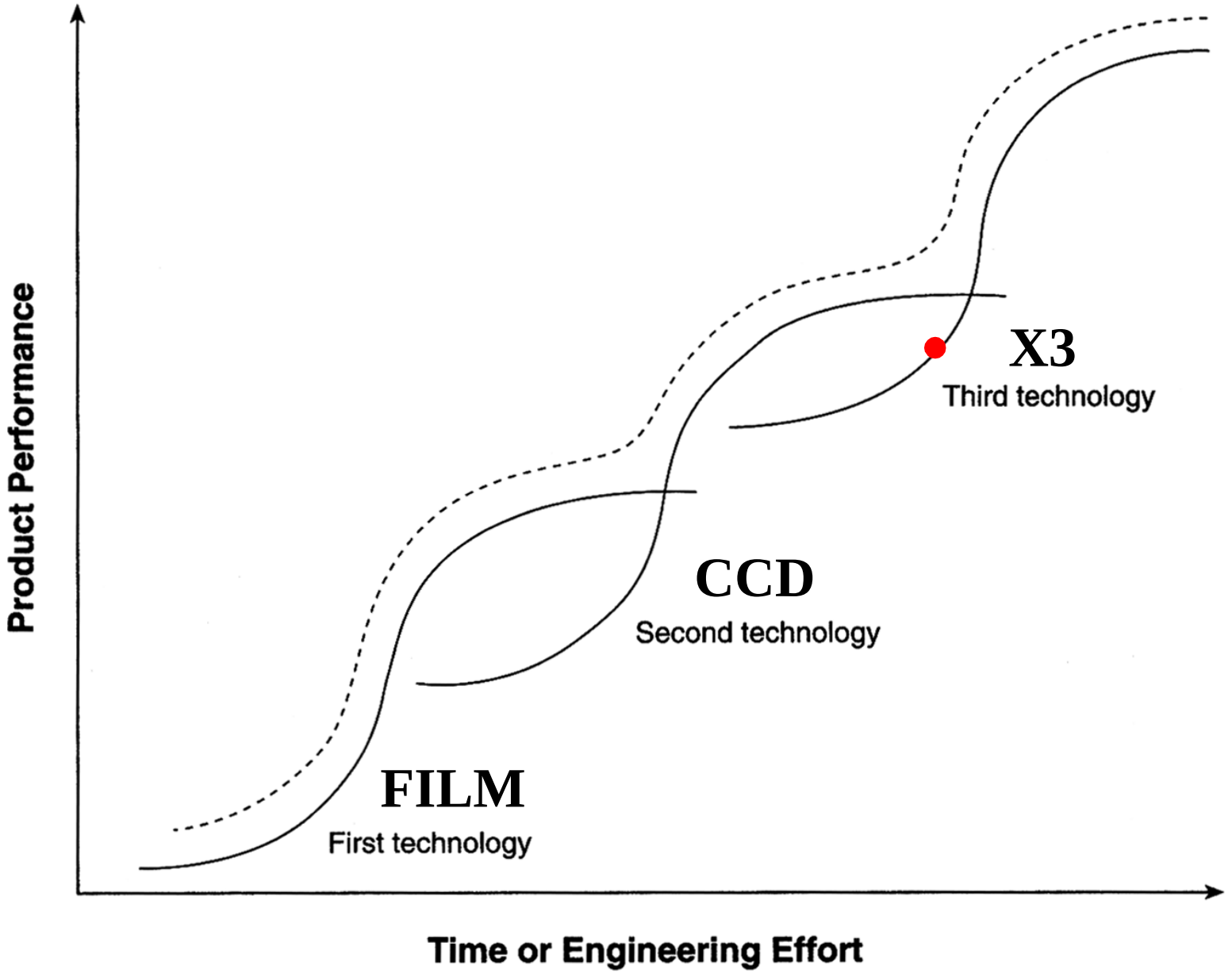
3) nano technology- feature size smaller than optical wavelength

4) CMOS feature size- Moore's law

5) MEMS becoming mainstream

6) vertical integration instead of lateral

Figure 2.5 The Conventional Technology S-Curve



Source: Clayton M. Christensen, "Exploring the Limits of the Technology S-Curve. Part I: Component Technologies," *Production and Operations Management* 1, no. 4 (Fall 1992): 340. Reprinted by permission.

marketing advantages

1) film like photographs appeals to the biggest customer base

2) novelty $\Rightarrow$ differentiation: ‘Foveon Inside’

3) better pixels instead of more pixels

4) entirely new applications not possible with CCD / CFA

X3 technology challenges

disruptive: required software and hardware support is different

CCD hegemony threatened

noise is higher

noise

the most fundamental imager noise is photon shot noise

3X more photons $\Rightarrow$ 1.7 times better SNR

all other noise is implementation dependent

. . . but X3 is better at more fundamental issues

1) efficient use of photons
2) lens limitations
3) artifacts & single pixel color accuracy
4) image sharpness
5) color accuracy
6) imager cost
7) system cost
8) consumer appeal & novel applications
9) learning curve
10) leverages technology trends
11) CMOS imager flexibility
12) reliability
13) small pixels
14) variable pixel size
15) ...

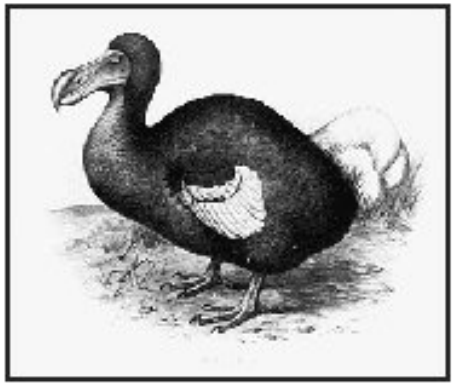
NAR WEB INTELLIGENCE

This Week's Special Report | Real Estate & Technology Now | Key Links
Archives | Upcoming Topics | Contact Web Wizards

NAR's Web Intelligence Summary - No. 28 (March 2002)

DIGITAL CAMERAS

Foveon's breakthrough X3 chip could add more detail to virtual house tours and make regular film go the way of the dodo



Orlando's Orange County Convention Center (a venue familiar to REALTORS® who attended NAR's annual convention in 1999) recently played host to one of the photography industry's premiere events, PMA 2002.

PMA 2002, the annual convention and trade show of the Photo Marketing Association International, offered education sessions and showcased new products for commercial photographers, and highlighted some of the latest developments in the world of digital photography. Nikon, Sony, Minolta, Kodak, Adobe, and other major players in digital imagery were there to promote their products and services to convention attendees.

X3 technology has direct appeal to the end customer (but is disruptive to the OEMs)