Broadcast:

Imagers and FPGA based video processing.

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8-11-2018: D&E Event Eindhoven

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Agenda

- Who we are
- 3-imager camera
  - Signal levels
- From CCD to CMOS: why did it take so long
  - Feature size
- The big step: Inhouse imager design
  - HDR
- FPGA’s
- Imaging capture circle


Who is …
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History

For more than 55 years, Grass Valley, a Belden Brand, has worked closely with broadcast and media companies to produce, package and deliver compelling content.

Headquartered in Montreal, Grass Valley is part of St. Louis-based Belden Inc. As a proven, strategic leader in industrial, enterprise and broadcast market solutions, Belden gives Grass Valley the ability to scale rapidly and invest in innovations that are driving the industry forward.

Recognized expert with 21 Emmy® Awards and two Citations conferred by the National Academy of Television Arts and Sciences (NATAS) and the Academy of Television Arts and Sciences (ATAS).

Committed to Innovation

PATENTED

1,100

patents

21

Emmy
Awards

2016 BEST of SHOW TVTechnology

SMPTE

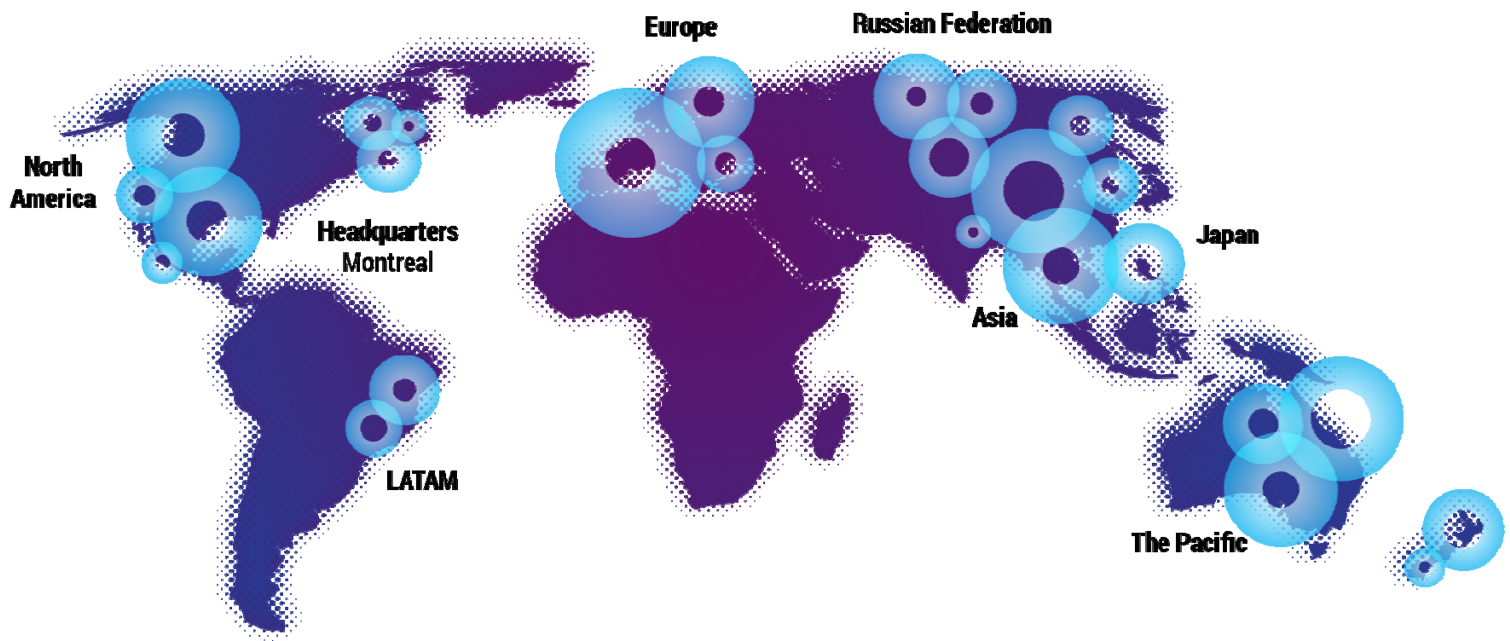
2016
Honors

IBC 2016 Innovation Awards

HPA AWARDS

A Global Footprint to Meet Global Demand

Broadcast is a global industry and we're able to serve every geography



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Capturing Emotion Around The World

Broadcast: 3-imager camera

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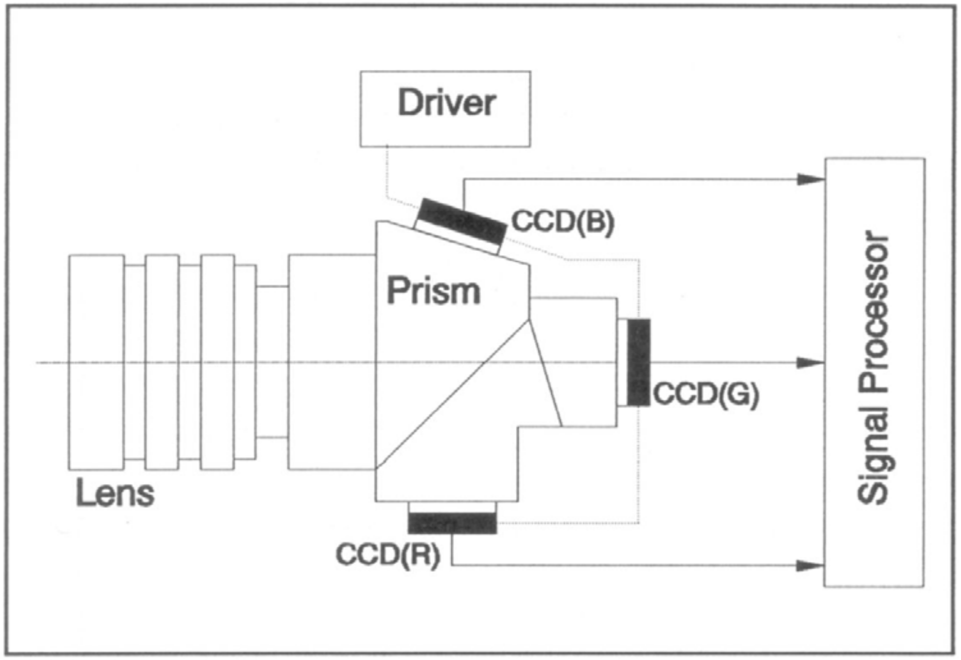
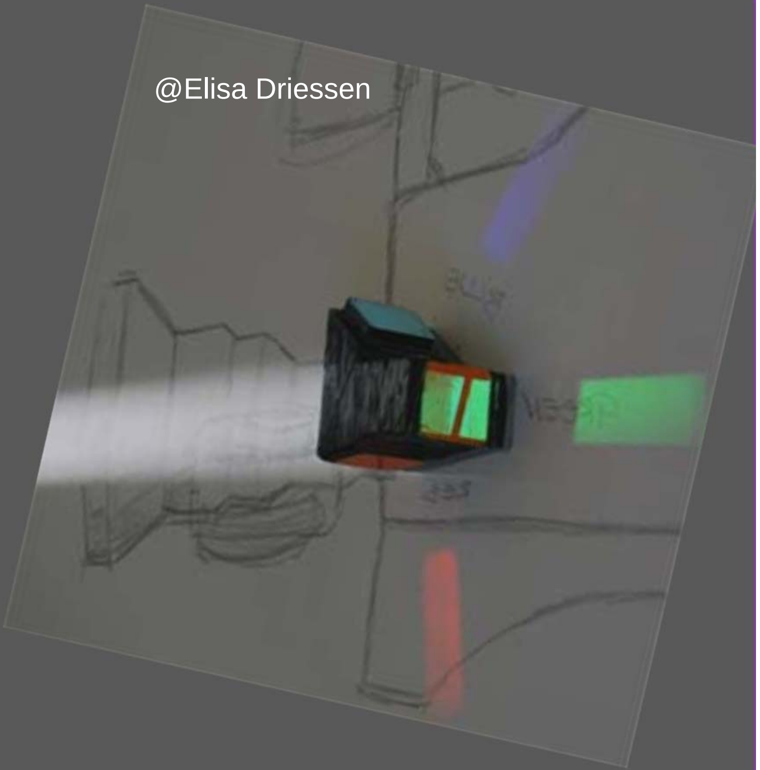
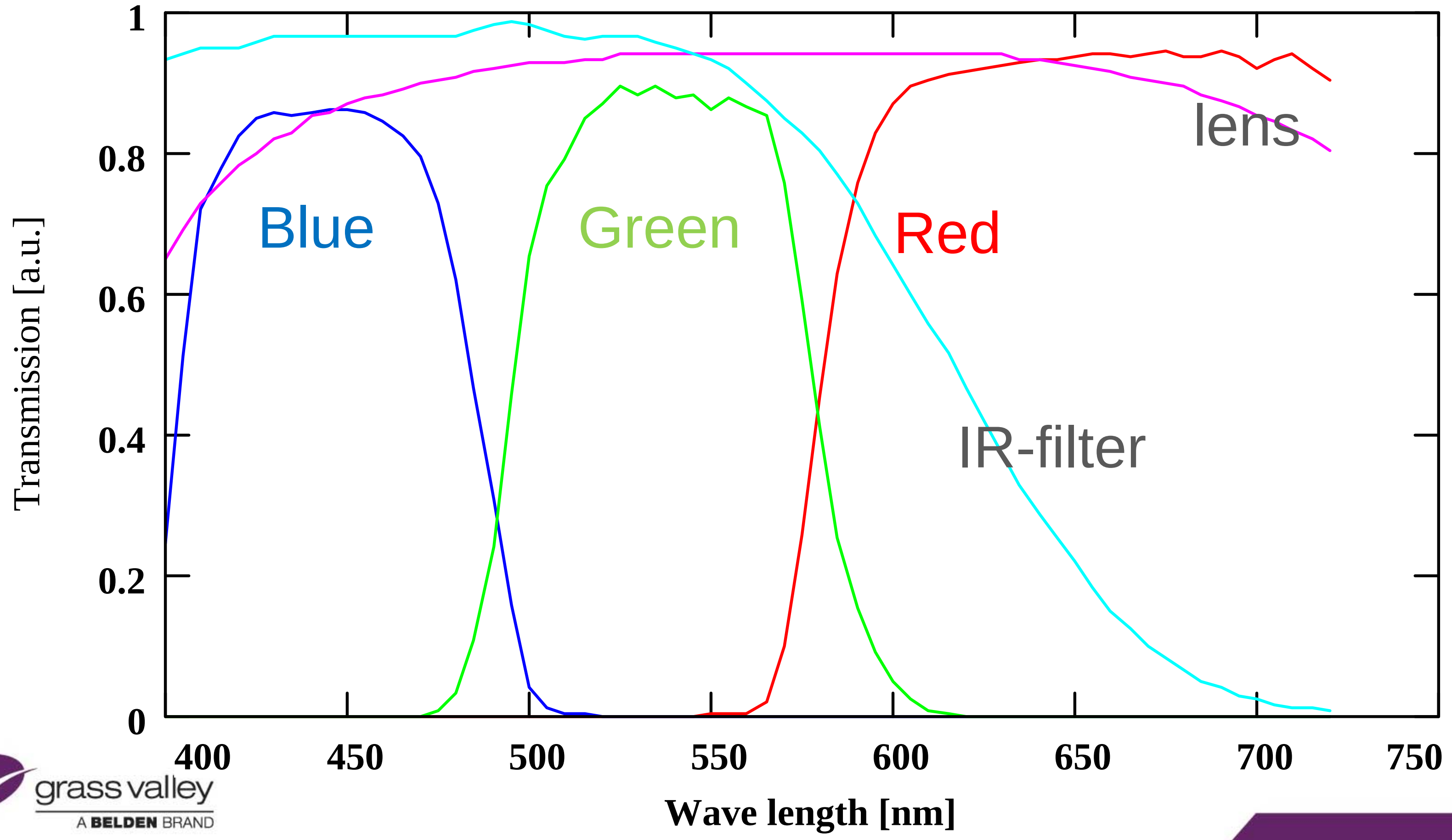
Colorsplitter with 3-imagers

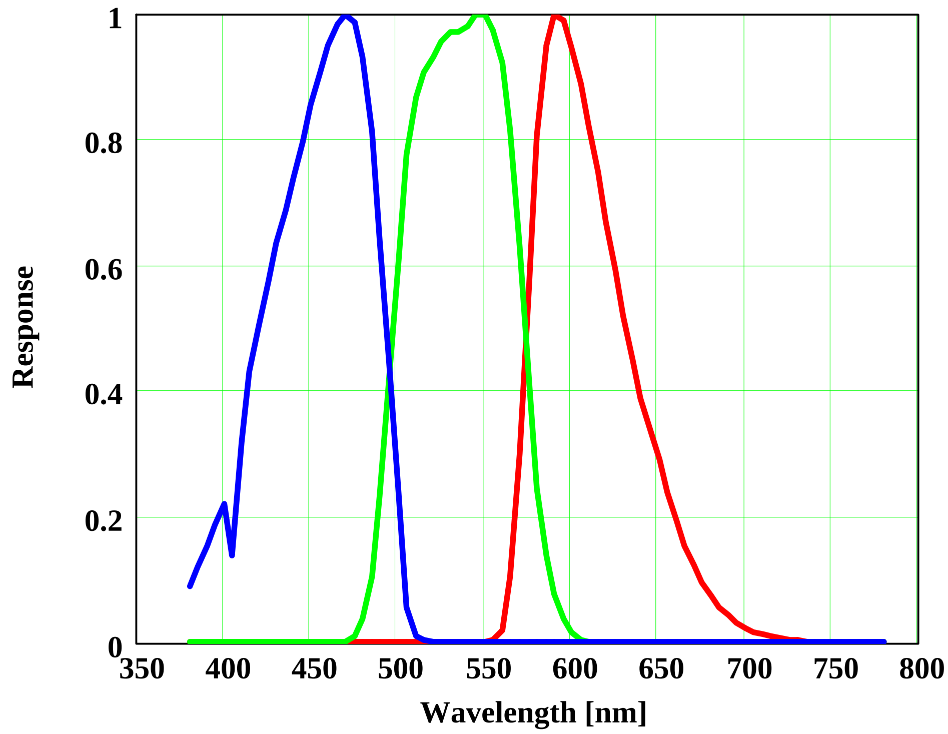




Spectral curves



Overall spectral responce in R,G,B



Signal levels

- **Broadcast camera at 2000lux; f/11; 3200K and 89.9% scene reflection**
- HDTV 1920x1080 pixel **5x5um^2** and **60 frames/sec** ;
- Photons per pixel
  - R 3.5kph
  - G 3.1kph
  - B 1.0kph
- Electrons per pixel
  - R 2100el
  - G 1860el
  - B 600el
- Noise 2el – 6el
- Qmax 10-20kel

From CCD to CMOS why did it take so long

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Feature Size and CMOS Imagers

MOS	1967	Wecker&Noble
CCD	1970	Boyle&Smith

- Why did it take so long for CMOS imagers to enter the market, even though they where conceived before the CCD imagers?
  - The word is **Lithographic Feature Size**
  - In general a CCD-pixel is simpler than a CMOS-pixel, the latter contains more active elements

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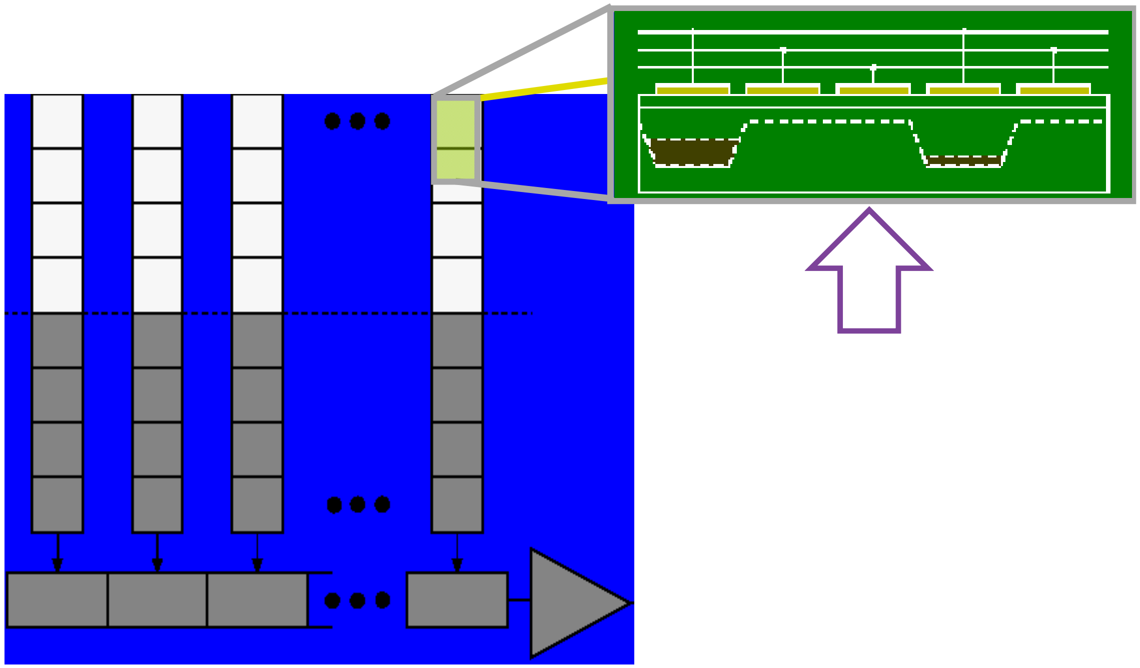
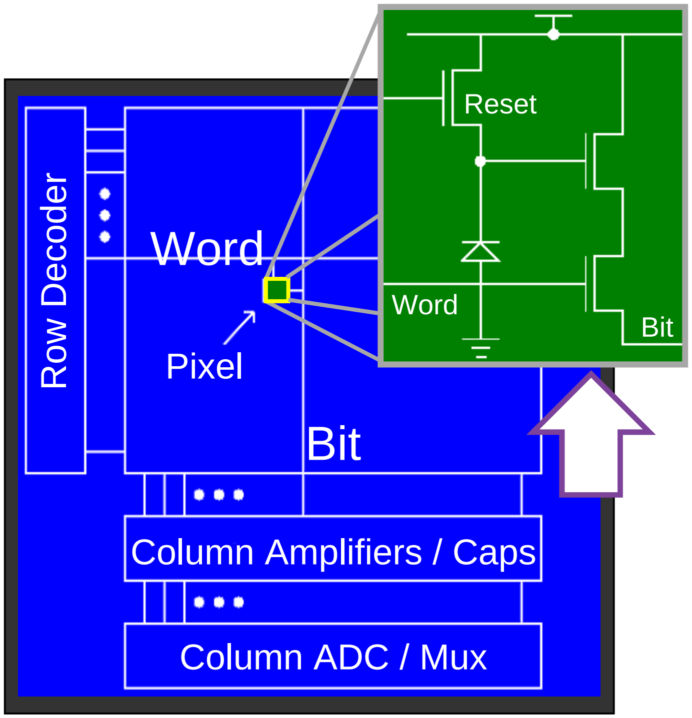
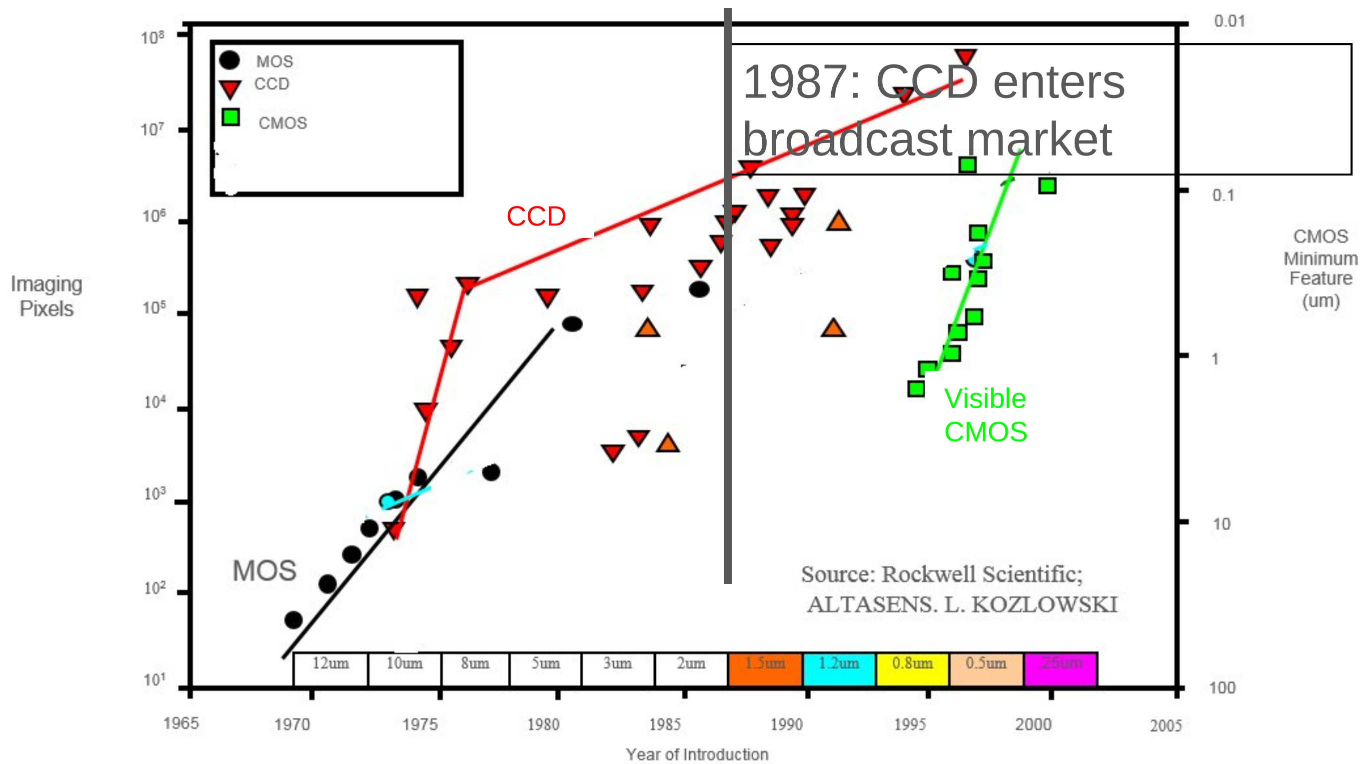
CCD-Imager CMOS-Imager





IEDM 2002 Gamal

Feature Size and CMOS Imagers



Notice the early ramp up of CCD imagers (1973) and the delayed ramp up of CMOS imagers (1970 /1995)

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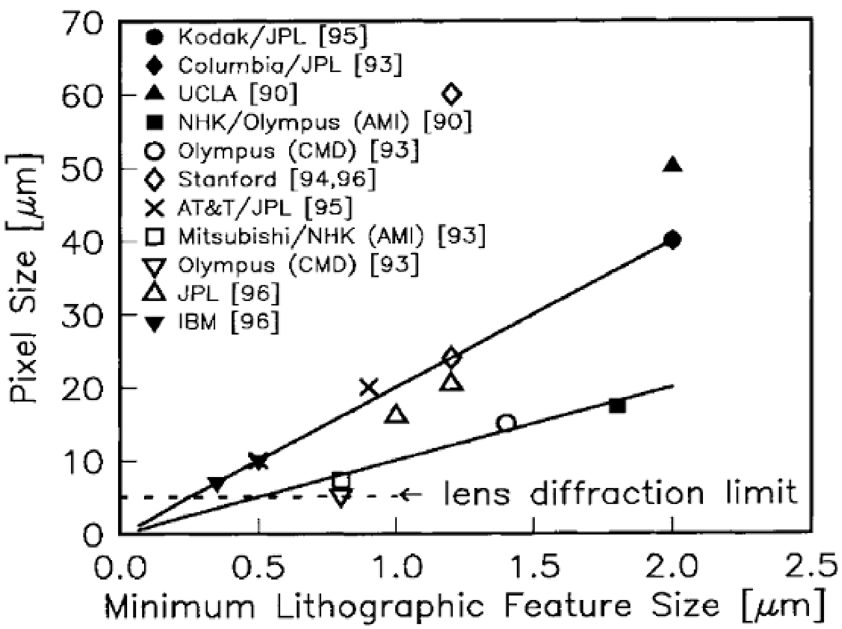
Feature Size and Pixel size

Pixel size is about Feature_Size*20.................still valid



IEEE ED Vol 43, DEC 1996, Hon-Sum Wong

Pixels in 0.18/0.11um technology

HDTV : 5x5um

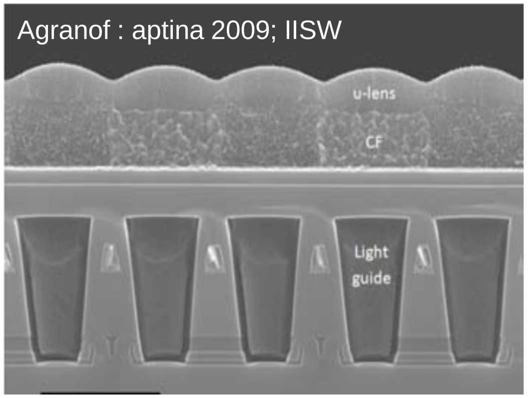
4k : 2.5x2.5um

Parameters that matter

- Temporal **Noise** or readnoise
- **Sensitivity** (QE and Fillfactor)
  - Together with readnoise it defines SNR
- **Overexposure** margin (Qmax, Vsat)
  - Together with the readnoise it defines dynamic range
- **Darkcurrent** or leakage current per pixel
- **Fixed Pattern Noise in dark** or offset differences per pixel
- **Fixed Pattern Noise in exposed images** or gain differences per pixel

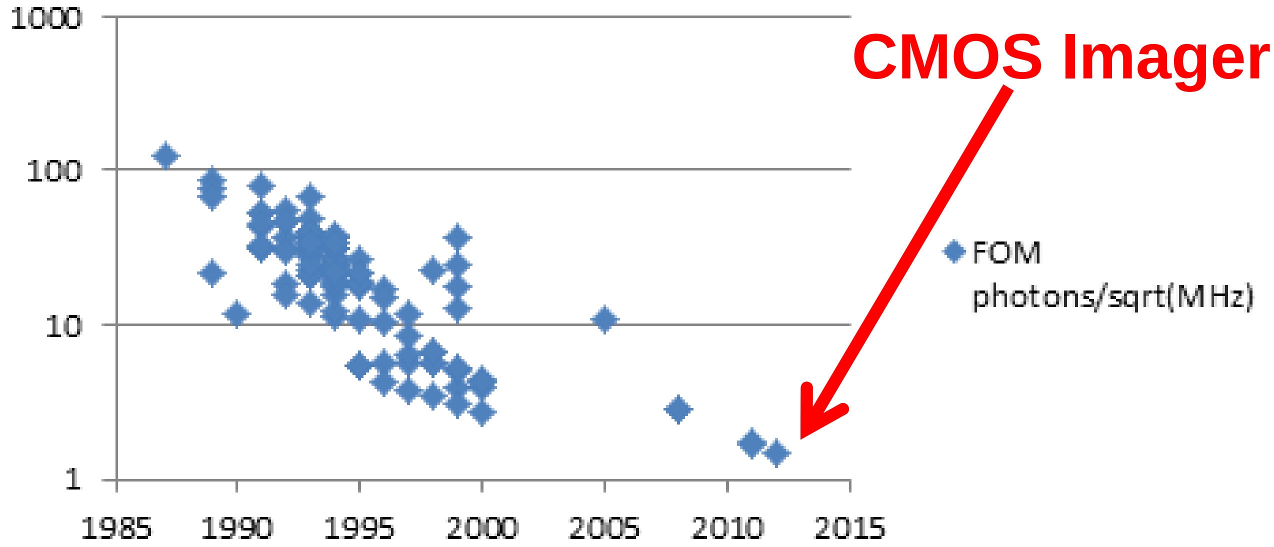
CCD’s paved the way

- CCDs have a long history and as such solved many of the performance related parameters
  - **Sensitivity**
    - – uLens, lightpiping
  - **Noise**
    - – real CDS or DDS
  - **Darkcurrent, FPN and LAG**
    - – P+toplayer
  - THESE solutions can be applied too in CMOS imagers but that needs additional masks and technology steps and hence is more **expensive**



Noise and sensitivity improvements

$$FOM := \frac{ReadNoise}{QE \cdot \sqrt{BW}}$$



FOM: Figure of merrit
QE: quantum efficiency
BW: Bandwidth

2-3dB/year

The big step:
Inhouse imager design

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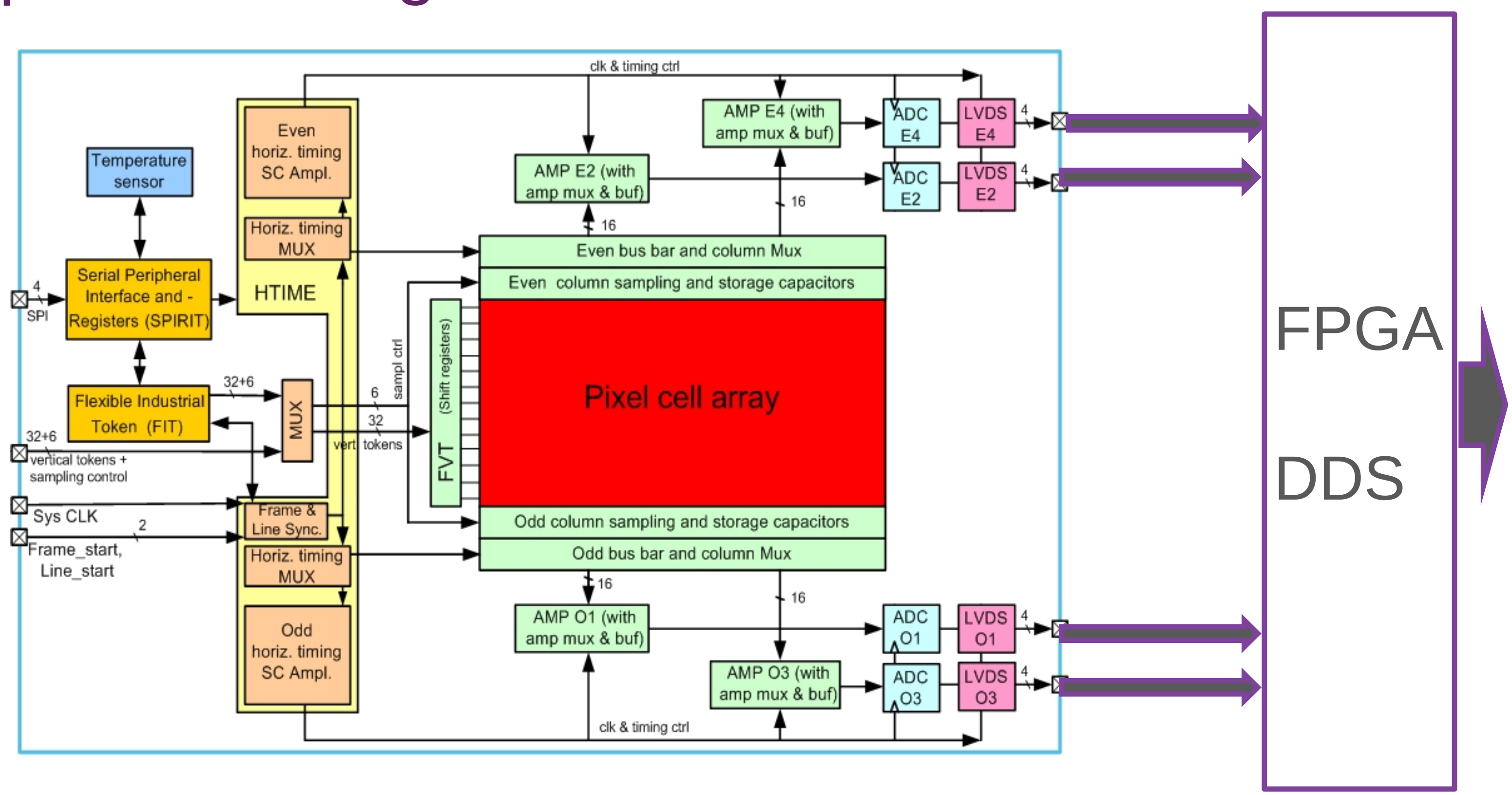
Inhouse imager design

- **With CMOS this is possible…..**
- Inhouse
  - Continuity
  - Best fit between application and technology
  - European and govermental support
- 3T-2/3” HDTV, 5um pixel
- 5T- Global shutter 2/3” HDTV, 5um pixel
- 5T- Global shutter 2/3” HDTV p180 and i360, 5um pixel
- 4k imager with 2.5um shared pixels
- Next gen imagers

Design Approach

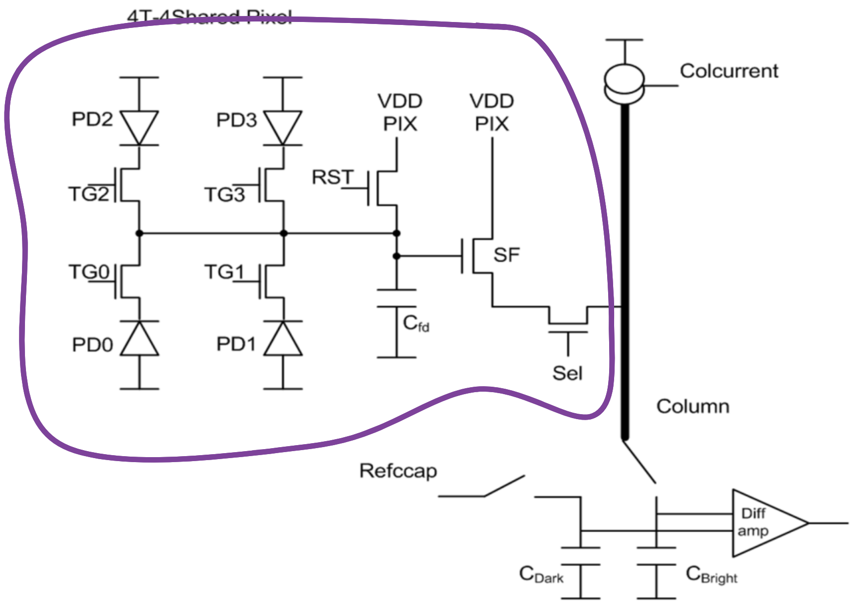
- **An imager is an ANALOG device**
  - Keep the imager as simple as possible and make use of of-the-shelf components like FPGA, memory, processing blocks
  - Allow for a simple state machine and ADC's on-chip
  - Flexibility in readout and in frame rate
  - Choose a camera architecture: video processing and imager, that eases CMOS image sensor design

Chip Block Diagram

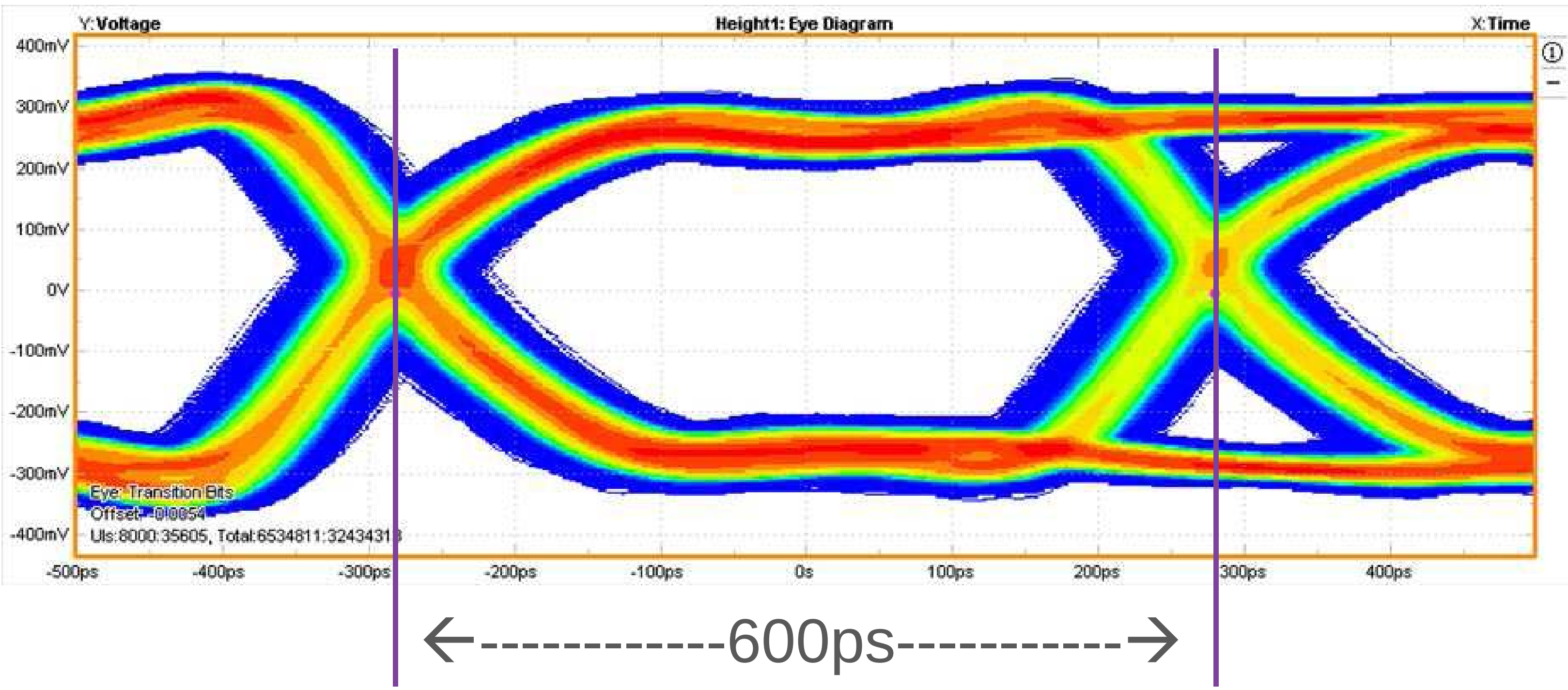


2.5um 4-T shared pixel in 4k-imager (8Mpixels)

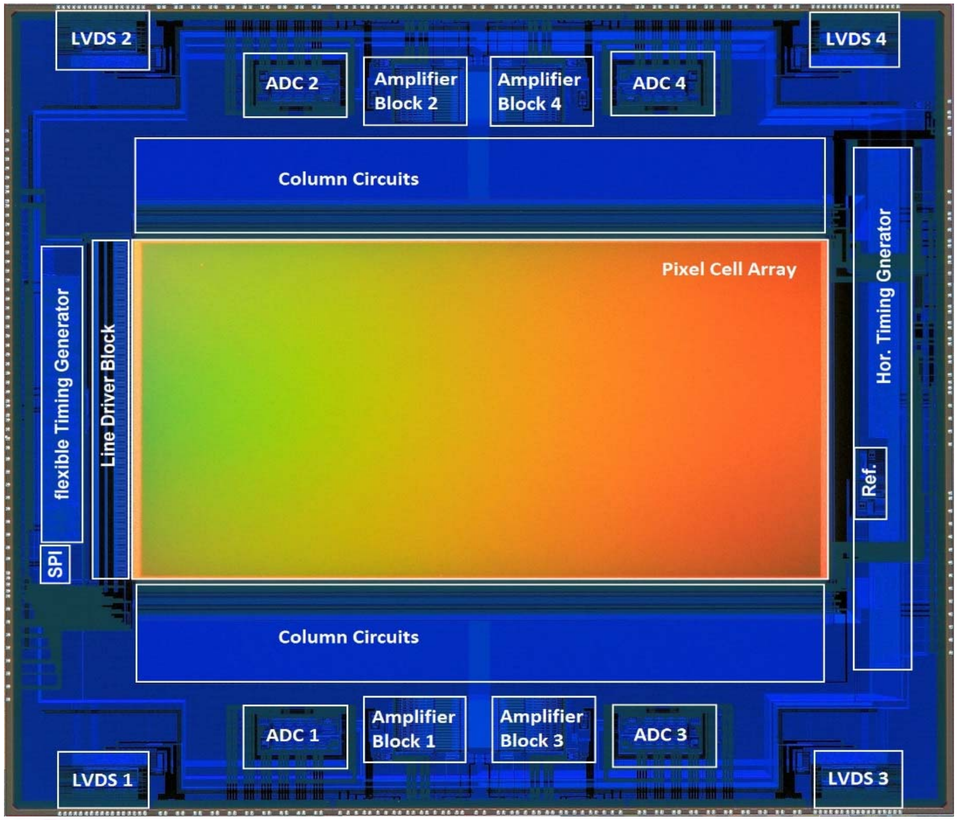
- 4 PhotoDiode + ReadOut packed in 5x5um

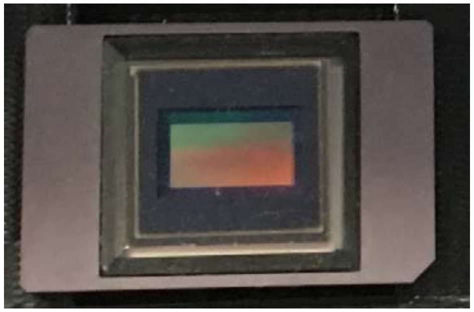


16 LVDS lanes



Used in the LDX series for HDTV and 4k





Die area:15x14mm

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Wide open lens

Advantage of CMOS

There is more in a pixel then Qmax

FPGA's

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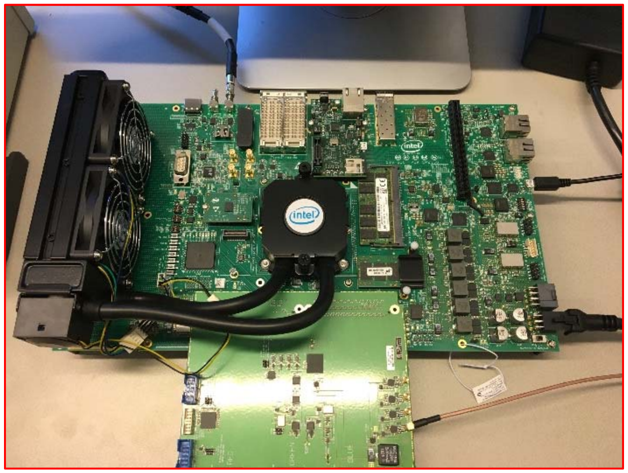
Why FPGA's

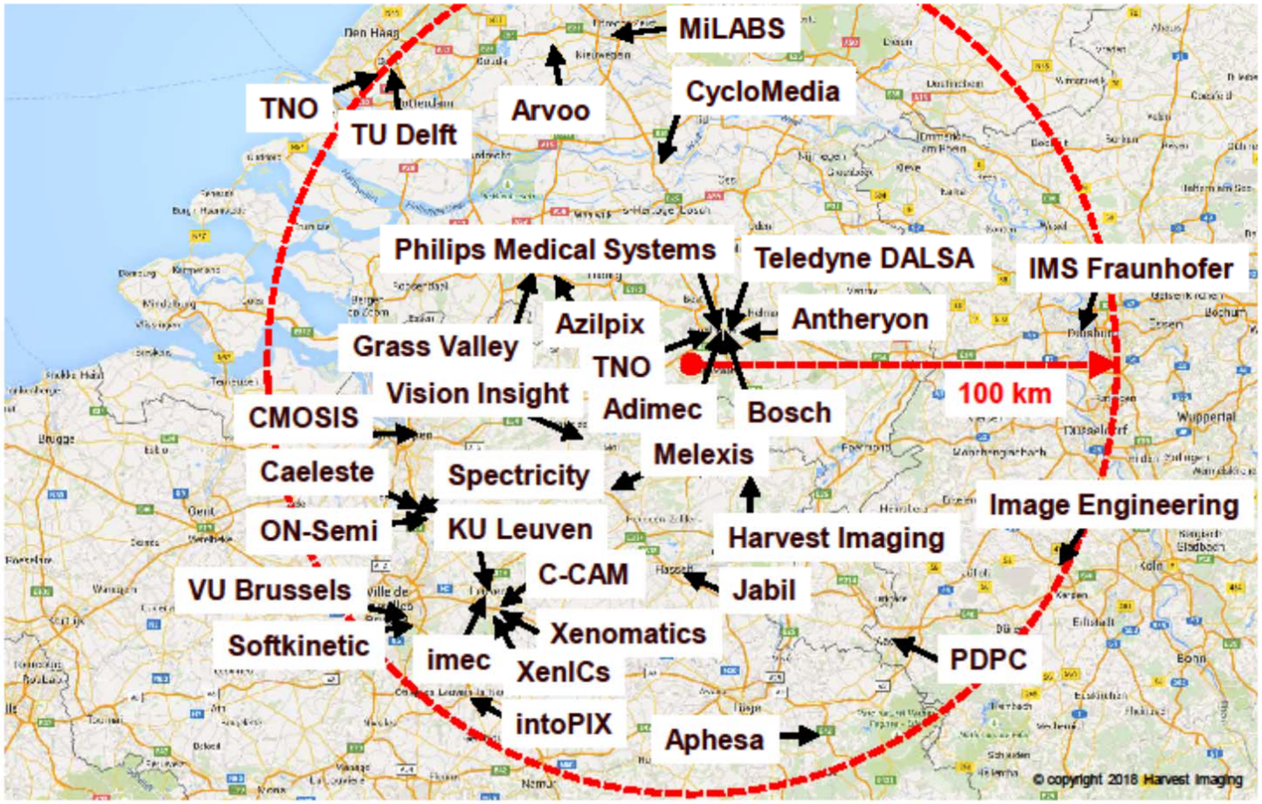
- Low volume market
  - Investments in ASIC's run's into the M$$$
- Flexibility
  - Throughput time
  - Has some trial and error type of development to reduce t2t
  - Gives developers the possiblity to work at bleeding edge☺
  - Adding functionality over time…they always tend to 90%-ish
- Full video processing chain in FPGA
  - 720p, 1080p, 1080i, 4k
  - Matrix, White balance, Gain, colorimetry, contour, skin contour, gamma, PQ, HLG, pixelcorrector, chromatic aberation corrections
  - Frame rates: p30 - p180/360
  - IP, PTP, Jpeg2000

FPGA's used

- Intel /Altera
  - Stratix 10 MX — Video processing
  - Arria V — Triax Transmission
  - Cyclone 10 — Sensor Board
  - Max10 — Configuration Interface
- Xilinx
  - Ultrascale+ — IP Transmission
  - Kintex 7 — Video processing



"Image Capturing" Circle



Albert Theuwissen, Harvest Imaging

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Intermezzo: Cellphone camera

- Ever wondered why your small cellphone camera makes such amazing good pictures?
  - **When ratio between pixel-size (H) and f-number (F) is constant then the number of photons on the pixel is constant and MTF at Nyquist is the same**

$$\text{Sensitivity} \propto \left(\frac{H}{F}\right)^2 \qquad \text{Sharpness\_MTF} \propto \left(\frac{H}{F}\right)$$

- It is because in a small region of illumination and f/numbers you get the same sensitivity (read SNR) and sharpness as in broadcast cameras

International achievements for imaging

- **7-Emmy's**
  - 1967 Plumbicon
  - 1992 Triax
  - 1993 Colorsplitter, prism
  - 1994 Skin contour
  - 2003 HD-Dynamic Pixel Management, DPM
  - 2010 Highspeed HD Slow Motion Camera Systems & Flicker Reduction LDK 8300
  - 2014 Application of HD-DPM and HDTV TRIAX, LDK6000
- **Oscar technical achievement award**
  - 2017 VIPER Filmstream camera
- **Jean-Pierre Noblanc Award**
  - 2006 3T-CMOS imager development
- **David Sarnoff Award**
  - 2016 Transition from CCD to CMOS Imagers in broadcast cameras