Advances in Image Sensor Technology For Broadcast Cameras

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R&D Camera's

grass valley

Agenda

- The world of broadcast
- Performance parameters that matter
- CMOS

Where we came from…..

- Broadcast Camera
  - Philips -> Bosch -> Philips -> Thomson -> **Grass Valley**
- CCD
  - Philips -> Dalsa -> Teledyne Dalsa
- CMOS
  - Thomson -> Viimagic


•In cooperation with DALSA we added functionality to the CCD-imager, that was not found in imagers of the competition.
HD-DPM gave an competitive edge
•In cooperation with VIIMAGIC we developed the first CMOS imager with broadcast performance levels
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FUJINON

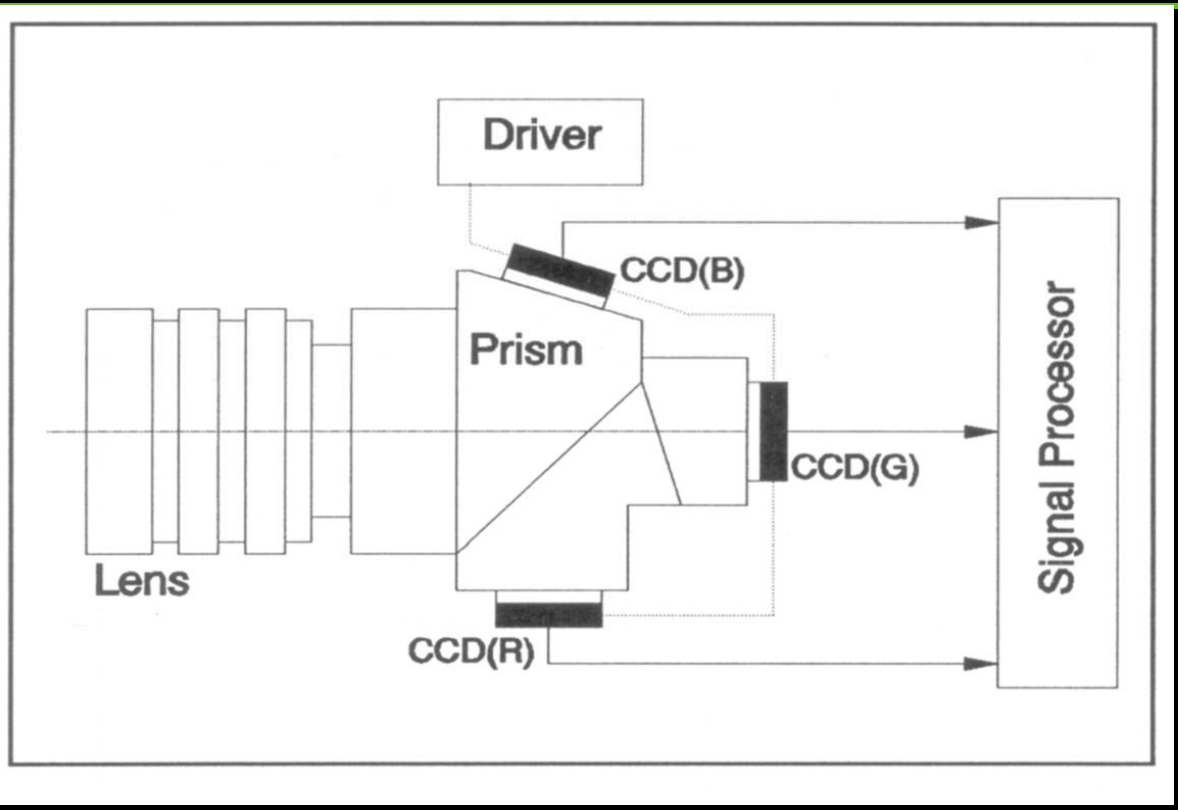
Broadcast

- Range
  - 0.1 lux, 2000 lux, highlights 10^5 lux
- Color temperature
  - 1800K, nominal 3200K, 20.000K
- Gain
  - -6dB, 0dB, …., 18dB, ……40dB
- VIDEO eg 60 fr/sec
- Modulated light sources
  - Fluorescent illumination
  - Periodically on/off interfere with the frame rate

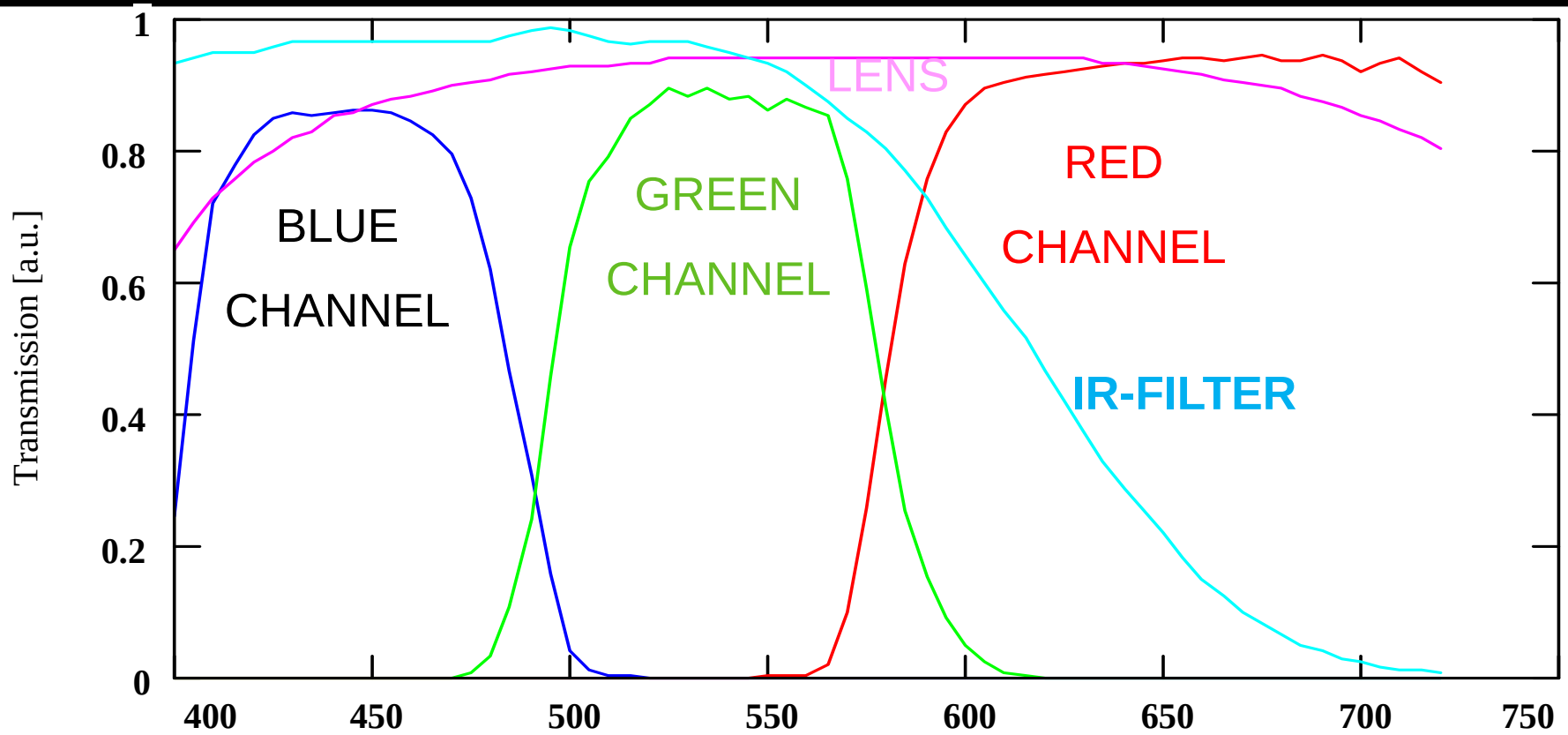
The Elements of a Broadcastcamera

- Lens, our customers have many expensive 2/3” lenses
  - f/1.4 maximum iris, often at f/4.0 for depth of field
- OLP, opticall low pass filter to reduce aliasing and jaggies
- IR-cutt filter for proper colorimetry
- Retardation plate (for specular reflection)
- Colorsplitter, R, G and B
- 3 (monochrome) Imagers
  - Signal pre-conditioning (CDS and Gain and black-levels) and Driving electronics
- Video Processing (SMPTE, ITU)
- Synchronized video at eg 60/1.001 frames/sec,
  - clock 74.25/1.001 MHz

3-Imager Optical Block



Optical elements



Lighting conditions

Bright sun	50.000-100.000 lux
Cloud bright	10.000-25.000 lux
Studio	2000 lux
Good street lighting	10-20 lux
At +12 dB a camera produces an image with	16 lux
Sun set	1-100 lux
Full moon	0.01-0.1 lux

Table 2: *Illumination levels*

Only in studio environment in control

Broadcast

- **A full HDTV imager: 1920x1080**
  - In 2/3” one has 5um pixels and diffraction limit at around f/15 for Nyquist
  - In ½” one has 3.65um pixels and diff. lim. f/11 for Nyquist
- **The master clock is 74.25MHz or 74.25/1.001 MHz**
  - 74.25MHz for the p24, p25, p30, i50, i60
  - 74.25/1.001 for the p23.98, p29.97, i59.94
- **MTF**
  - SINE, SQUARE wave at input frequency of eg 27MHz
    - SQUARE wave about 1.2 times the sine value……it is a marketing thing

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Signal to noise in Broadcast

- SNR in HDTV……a lot of conditions
  - Camera settings
    - Linear (gamma off)
    - No contours
    - Matrix off
      - These are artificial setting to have a defined operating point for comparison
  - Noise in 0.2MHz - 30MHz bandwidth in black >-54dB in Y
    - Flat response
  - 0dB
    - Known as the nominal setting
    - This is defined by
      - 2000 lux; 89.9% reflectance; 3200K; **f/8-f/11**
    - The f number denotes the sensitivity

MTF, Aliasing and Resolution

- **MTF** is solemnly determined by the pixel aperture together with the transfer function of the optical parts
  - MTF=Modulation transfer Function
  - FFT(pixel)
- **ALIASING** is determined by the repetitiveness of the grid on which the pixels are put
  - Fsample
- RESOLUTION is determined though the interaction between MTF and ALIASING

Advances in the CCD technology

- In the last 20 years
  - Image diagonal 11mm (installed base, performance,)
  - 2000 lux, 3200K, 89.9%, f/8 - f/11 and 54dB-60dB
  - Video bandwidth from 4.2 MHz to 30MHz to 90MHz (SD ->HD->3x HD)
  - Pixel area from 112 um to 25 um (SD->HD)
    - SDTV 960(H)x480(V); 60dB in 4.2MHz; 10umx11um=110um; f/11
    - HDTV 1920(H)x1080(V); 60dB in 30MHz; 5umx5um=25um; f/8
  - ¼ sensitivity and 7 times more (noise)bandwidth
  - Overall 15dB gained in noise and sensitivity!!

Advances in the CCD technology

- Read Noise
  - 30 e in 5MHz down to 8 e in 30MHz
- Bandwidth of on-chip amplifier
  - 15 MHz to >200 MHz
- Transportspeed Hregister
  - 3.85 MHz to 111 MHz
- Verticalltransportspeed
  - 1 MHz to 10 MHz

How many bits are enough

- ***In a pixel electrons are generated. There are only 'whole' electrons. Hence the output signal is quantized in steps of 1-electron. So the maximum number of bits needed to represent a signal from an imager may always be limited to $^2log(Qmax)$.***
  - ***Qmax is the maximum number of electrons a pixel can contain.***

- **An example:**
  - **A 5x5µm^2 square pixel has a Qmax=15k electrons.**
  - **Hence the maximum number of levels is 15.000 and can be**
  - **represented with 14bit!**
    - **OR: why should one want to spend more bits if only to enhance the accuracy for expressing the noise.**

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Broadcast cameras

- Did you enjoy the slow-motion replays of the soccer game in South Africa or the Olympic games in China?

HD Super Motion Systems for acquisition, recording and Playback for Broadcast Entertainment and Sports Productions

NAC Image Technology, Inc.

EVS Broadcast Equipment, Inc.

Vision Research (An AMETEKÅ® Company)

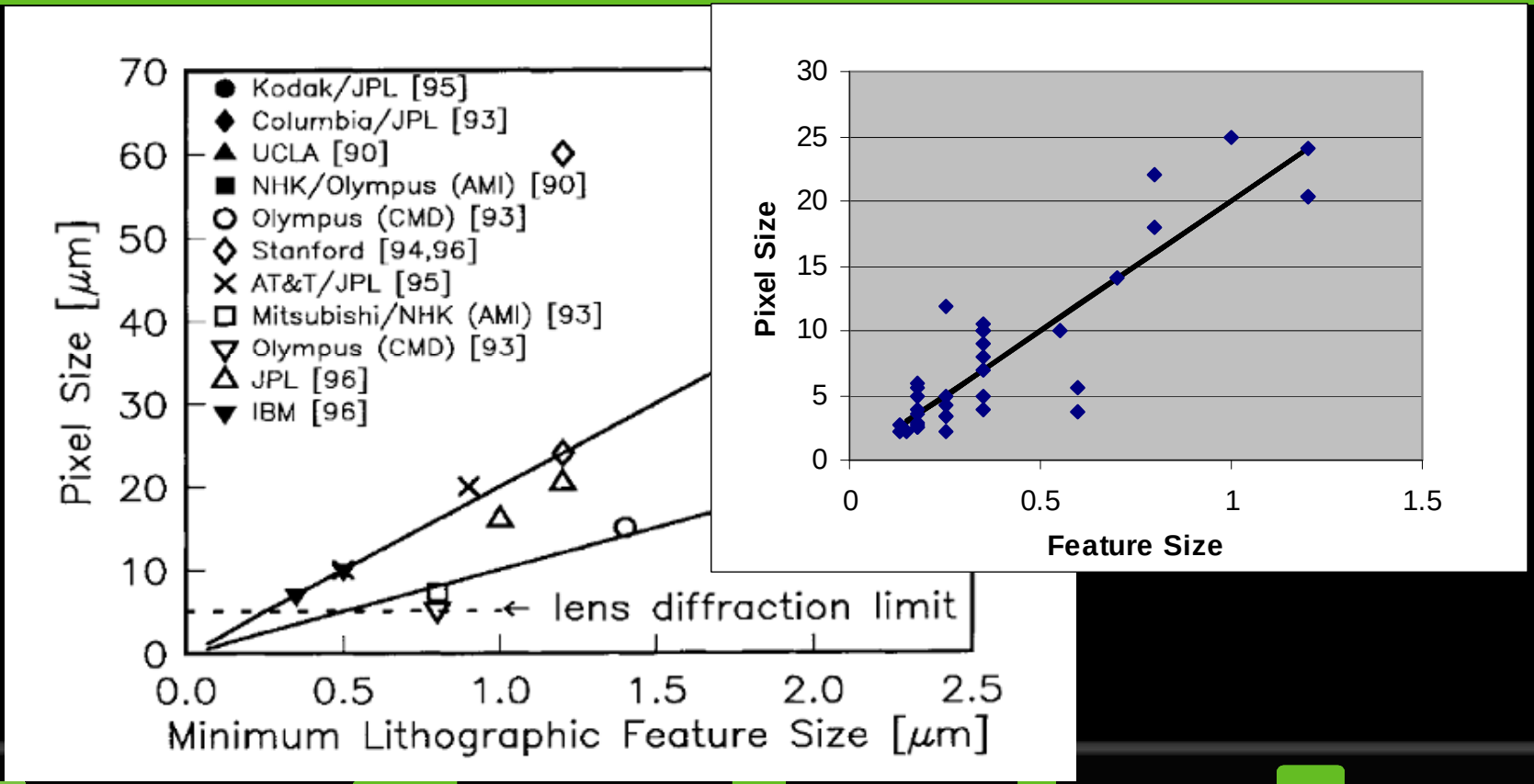
Grass Valley Group

Sony Coporation, Inc.

Advances in the CMOS technology

- In 2005 we decided that the next step would be CMOS
  - **BUT**
- Broadcast is a low volume high performance market
  - In 2005 nobody in the CMOS field was interested in a dedicated imager development or had a design available!
  - We started an inhouse CMOS development (spin-off VIIMAGIC)

Pixelsize 20*feature size….a minimum condition



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

CMOS Imagers: A Self fulfilling Prophesy

- **PERCEPTION**
  - CMOS imagers are cheap and have low quality
  - Is the perception correct
    - –Yes……but not complete
- The sentence could also read
  - CMOS imagers are expensive and have high quality
- When you don’t apply all the skills and technology available then CMOS is kept cheap and at low quality
  - it is a mass market problem

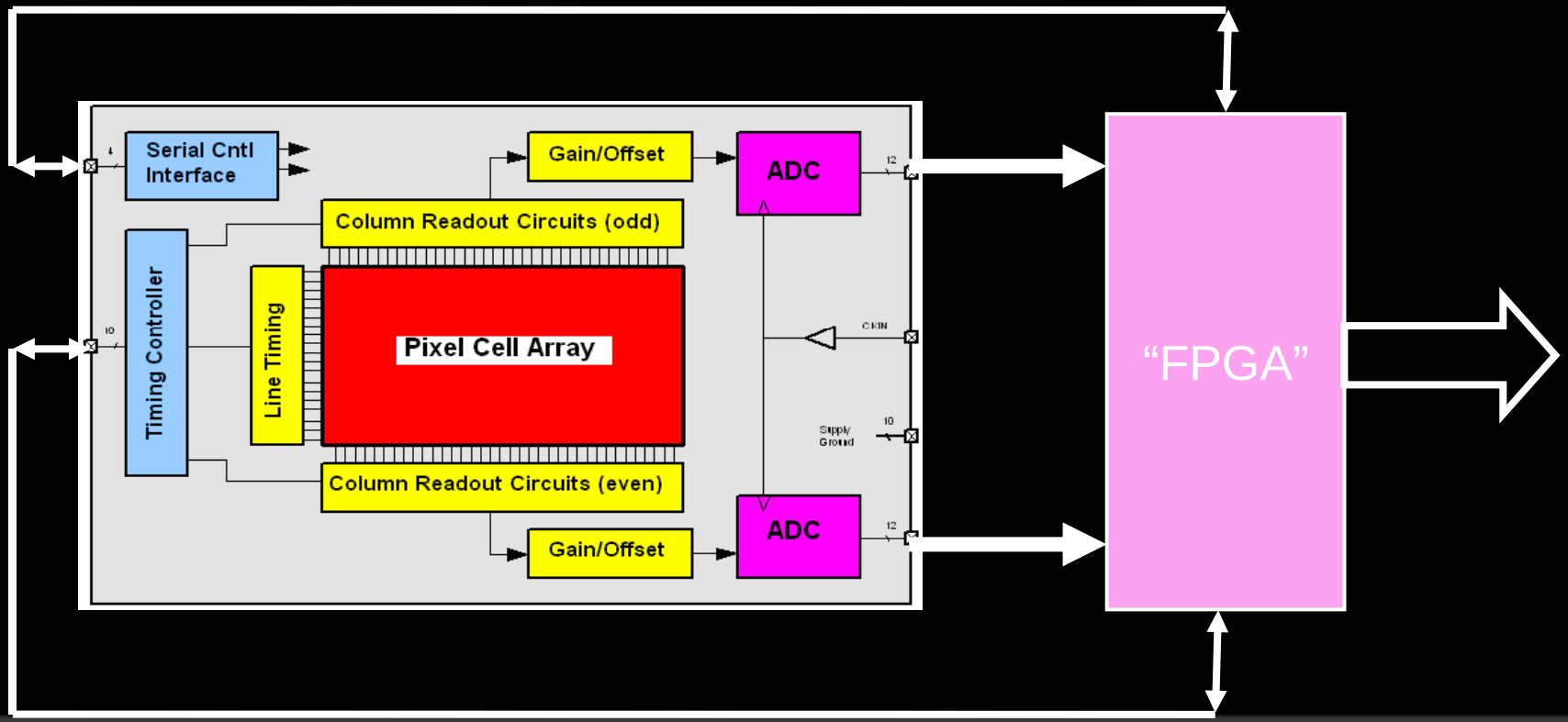
Challenges

- 1920(H)x1080(V) :5**µ**mx5**µ**m pixels and 11mm image diagonal
- Multimode :Interlaced (eg. 1080i60), progressive (eg. 1080p60)
- QE and Noise :2000 lux, 3200 K, 90%, f/8-f/11, SNR=54 dB in Y
- Dark current :FPN (16dB below RO, shotnoise)
- Qmax :over exposure margin >400%
- Lag :None
- 'Blooming' :must handle 16-fstop overexposure
- Pixel-to-pixel :PRNU<1%
- column-to-column :<0.06%
- 3-imagers synchronized for use in R,G and B simultaneously
- And many other imaging related topics both optical and electrical

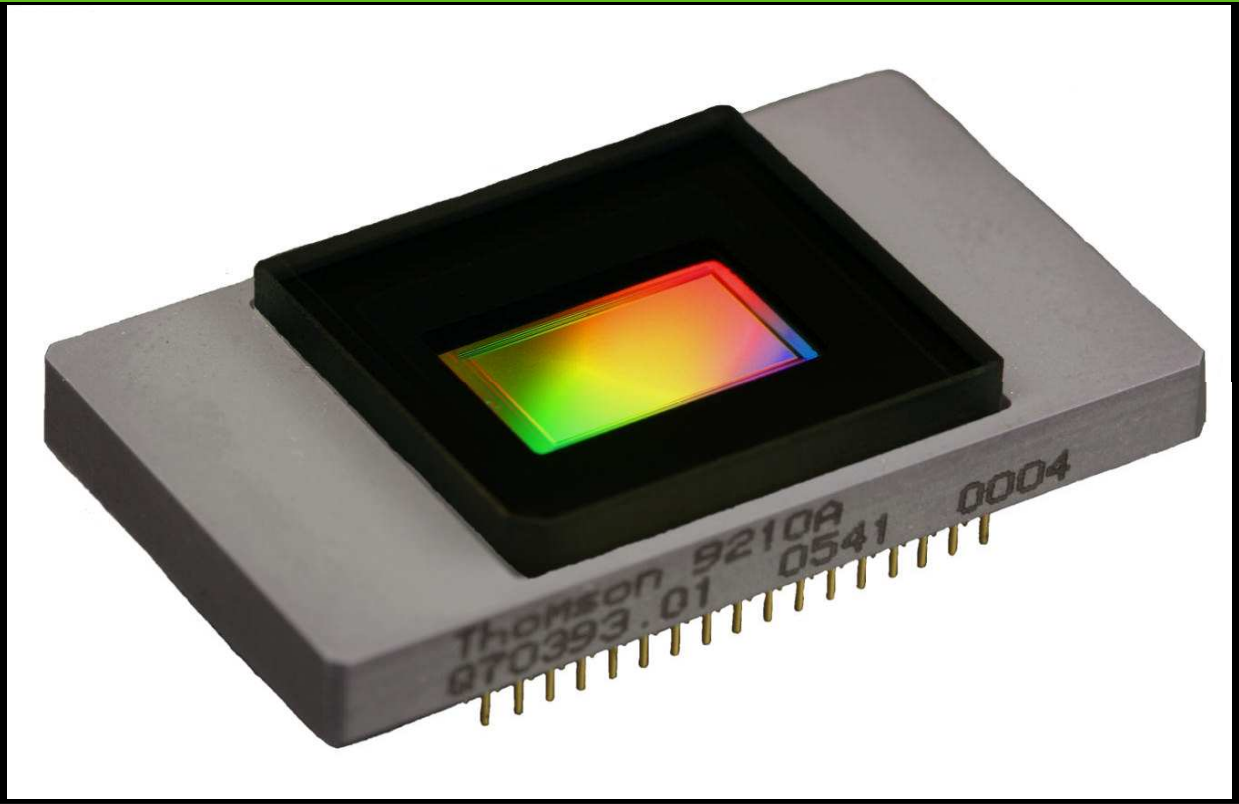
Challenges

- Overload, recovery and artefacts
- The electrical path
  - Streaking longterm and shortterm
- The optical path
  - Flare and reflections, opticall shielding
- The pixel
  - One pixel at 7000 photons and few pixels further 10^10 photons
  - Highlights giving a 10^6 overexposure
  - Global shuttered

A first step in the world of CMOS imaging



Xensium



Challenges

- PAST
  - CCD’s
- PRESENT
  - CCD’s and CMOS
- FUTURE
  - Imagers with additional features
  - Single imager 3D
  - HDR live video
  - Wide color gamut
  - HIghspeed

Questions?

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