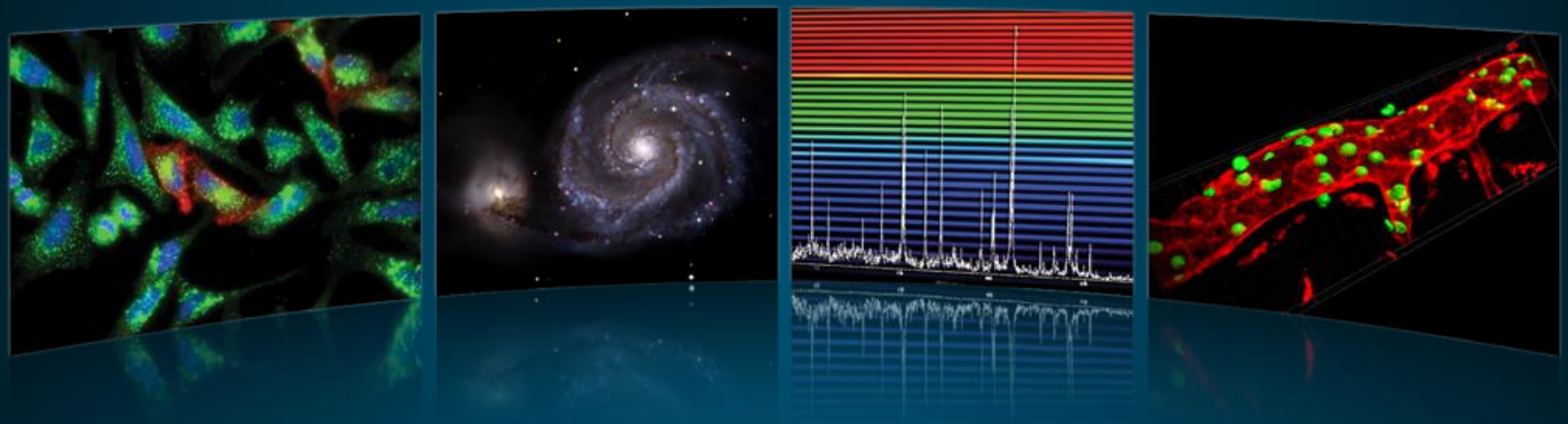
ANDOR™
TECHNOLOGY



# sCMOS

Orla Hanrahan, PhD

Application Specialist Life Science Imaging

discover new ways of seeing™

# Scientific imaging trade-offs…

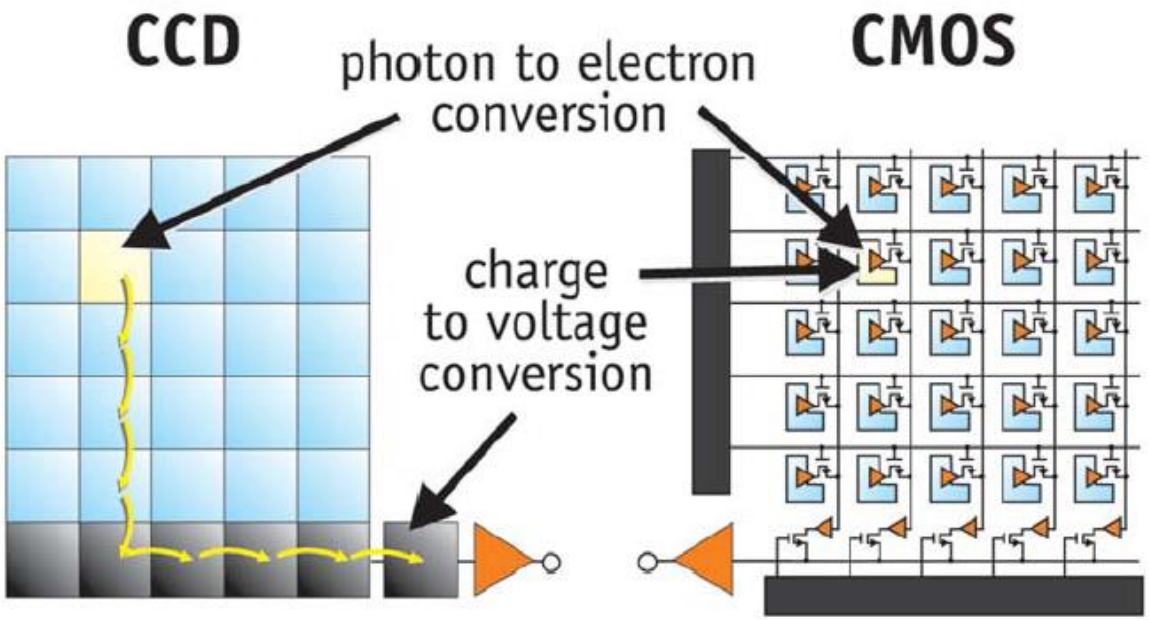
**Today's imaging detectors exhibit trade-offs between key performance parameters…**

- Low noise
- Rapid frame rates
- Wide dynamic range
- High resolution
- Large field of view

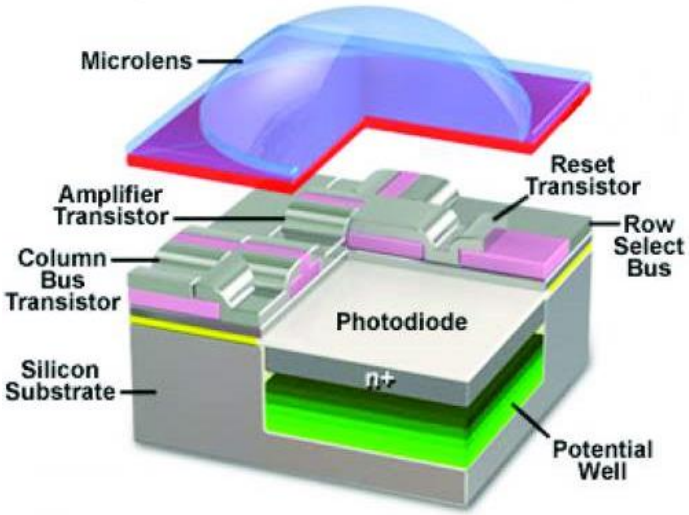
sCMOS technology overcomes trade-offs

**Scientific CMOS (sCMOS)**
**is *unique* in**
***simultaneously* offering:**

- Extremely low noise (without multiplication)
- Rapid frame rates
- Wide dynamic range
- High QE
- High resolution
- Large field of view



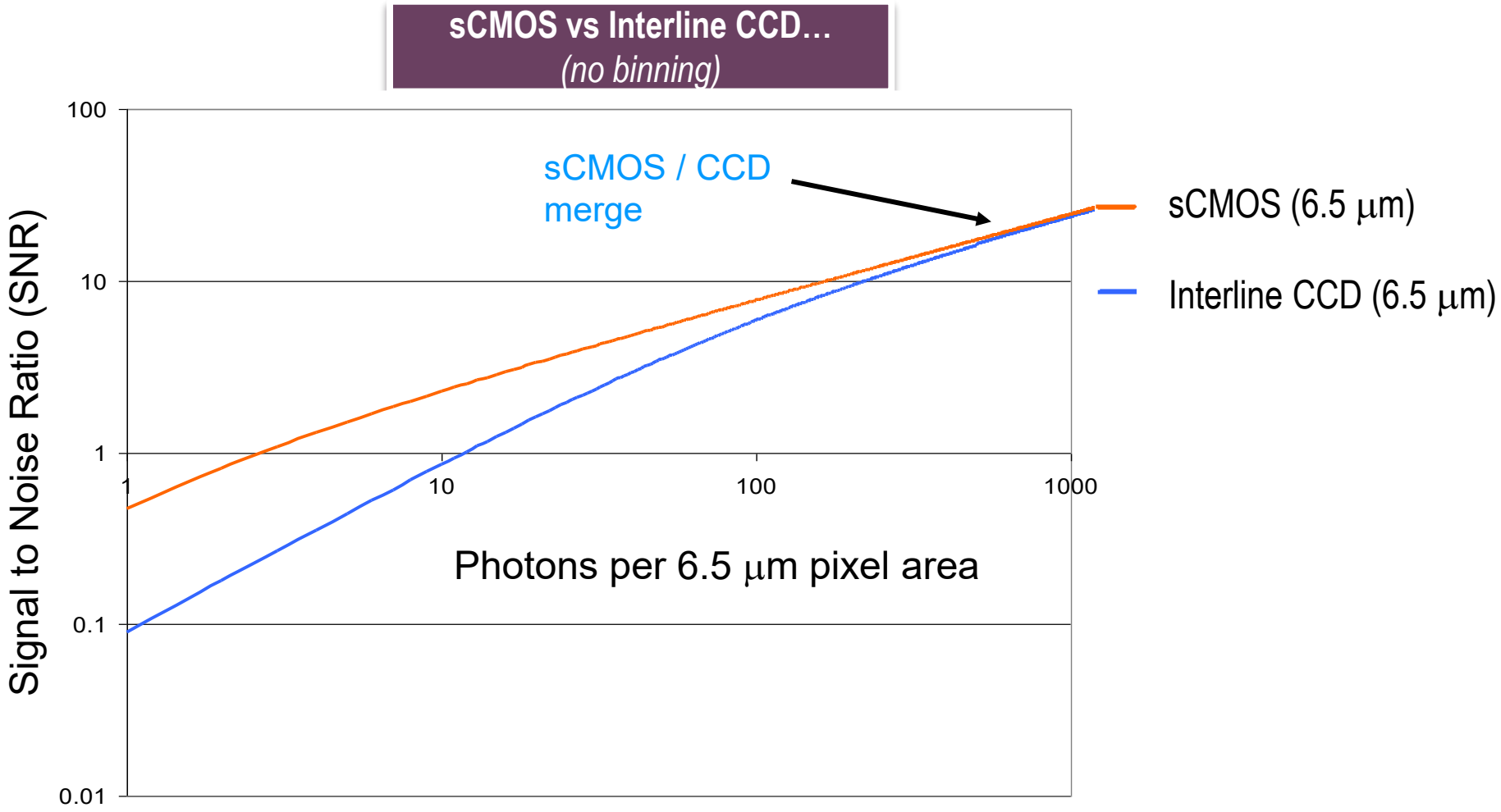

*CCDs move photogenerated charge from pixel to pixel and convert it to voltage at an output node. CMOS imagers convert charge to voltage inside each pixel.*



# sCMOS vs other imaging technologies…

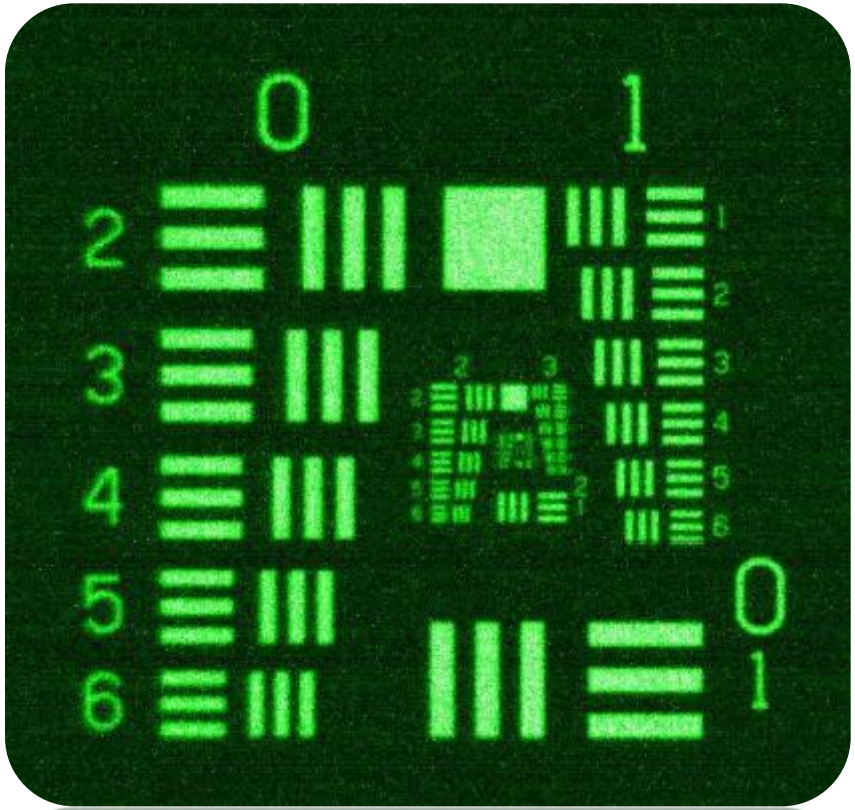
| | Sony interline | EMCCD | sCMOS |
|---|---|---|---|
| Sensor format | 1.4 MP | 1 MP (max.) | **5.5 MP** |
| Pixel size | 6.45 μm | 8 to 24μm | 6.5 μm |
| Max. frame rate | 12 fps @ 20MHz | > 30 fps | **100 fps** |
| Read noise | 4 – 8 $e^-$ | **Negligible (<1 $e^-$)** | **1 $e^-$ @ 30 fps**<br>**1.3 $e^-$ @ 100 fps** |
| QE | ~ 60% (FI) | 65% (FI) / >90% (BI) | ~ 57% (FI)<br>(excellent red response) |
| Dynamic range | ~ 3,000:1<br>(@ 11 frames/sec) | ~ 8,500:1<br>(@ 30 frames/sec) | **30,000:1**<br>**(@ 30 frames/sec)** |
| Darkcurrent (TE cooled) | **0.0003 e/pix/sec @ -55 $^0$C** | 0.001 e/pix/sec @ -85 $^0$C | 0.07 $e^-$/pix/sec @ -30 $^0$C |

# sCMOS vs interline CCD …

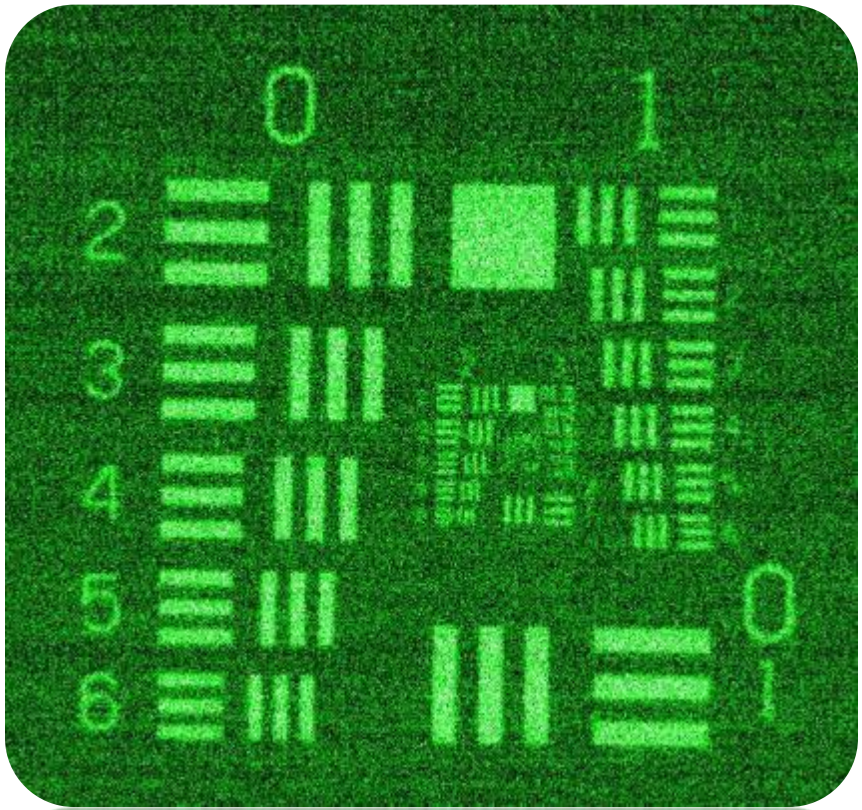


# sCMOS vs interline CCD image comparison...

**sCMOS –**
***1.2 $e^-$ noise***

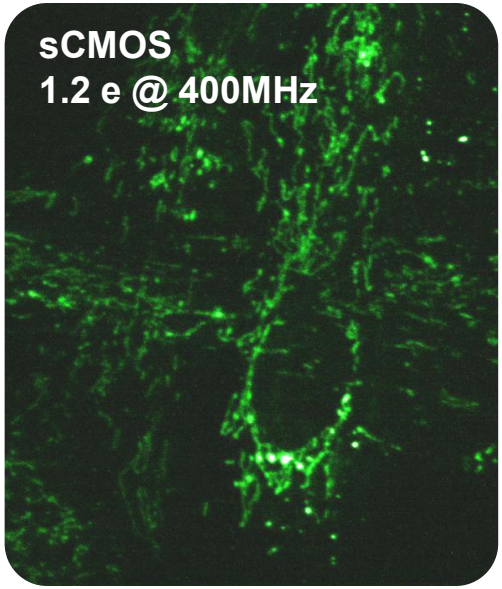


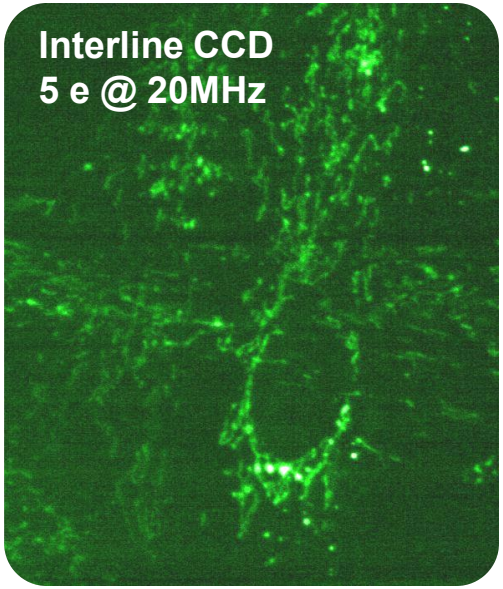
**Sony ICX285 Interline CCD –**
***5 $e^-$ noise***



**~ 30 ph/pix**
**622nm**

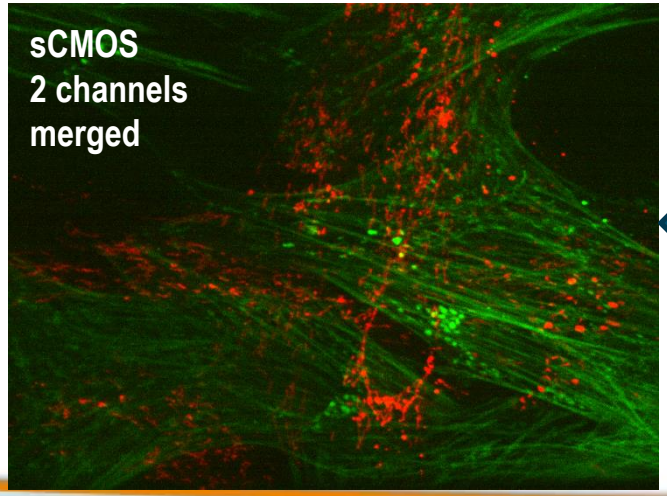
# sCMOS vs interline CCD image comparison…

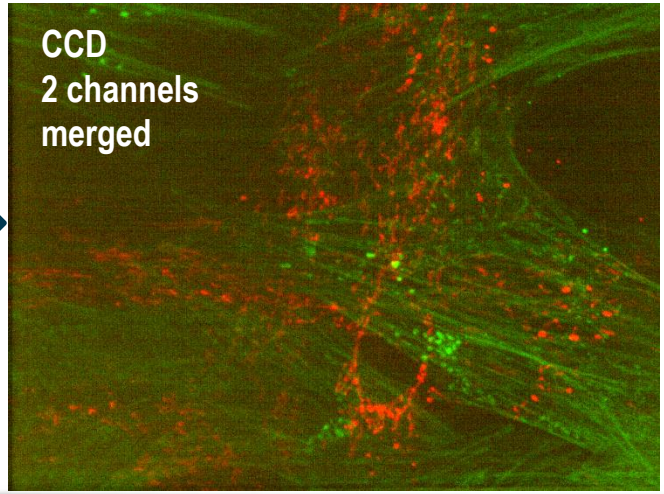


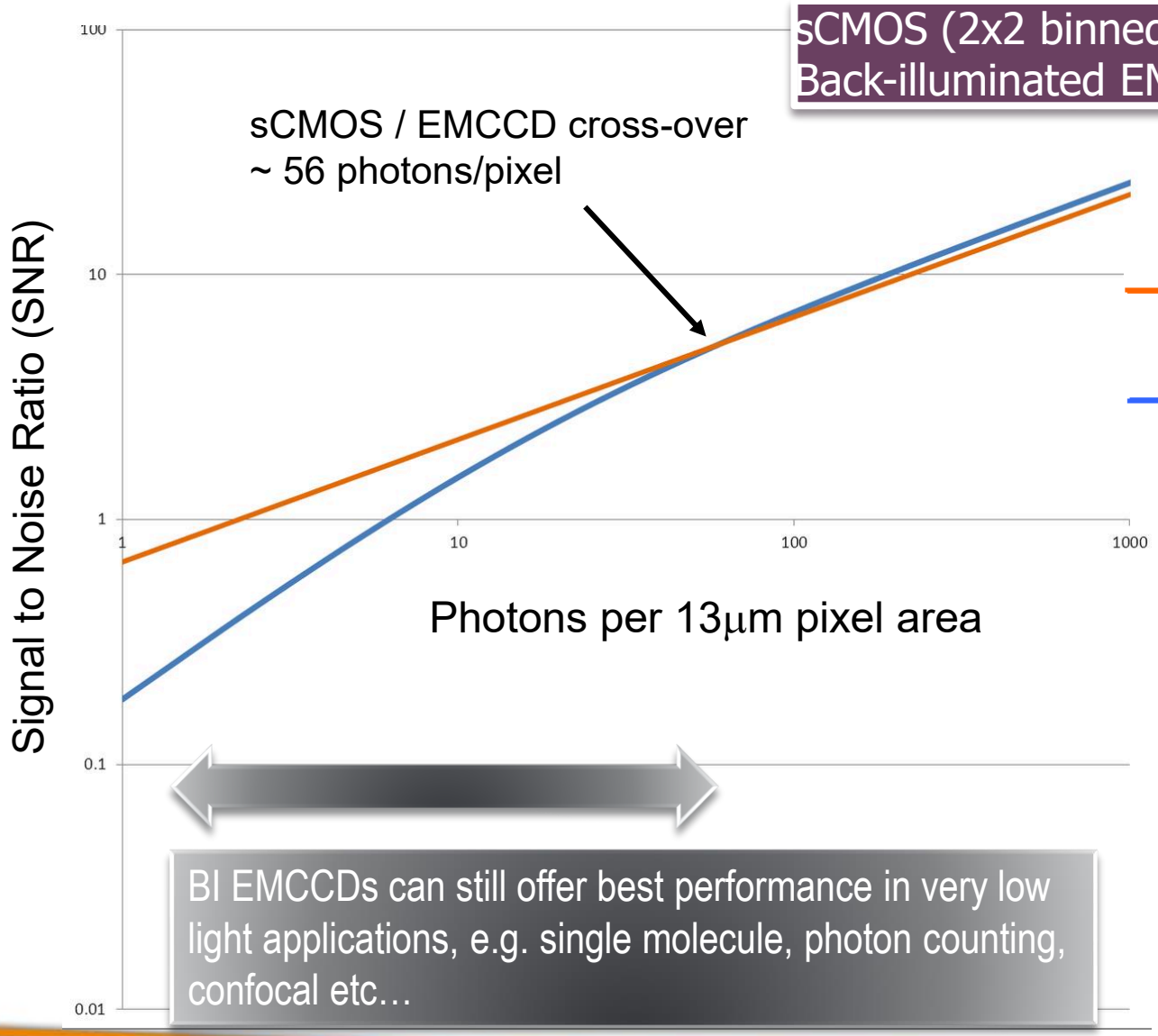

sCMOS (400MHz; 1.2 $e^-$ read noise) vs Interline ICX285 sensor (20MHz; 5 $e^-$ read noise)

- CSU-X spinning disk confocal microscope (x60 oil objective)
- each 100ms exposure
- same laser power
- displayed with same relative intensity scaling.

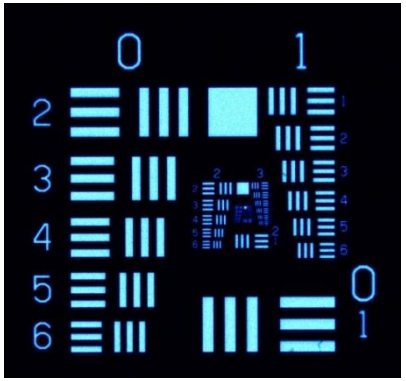
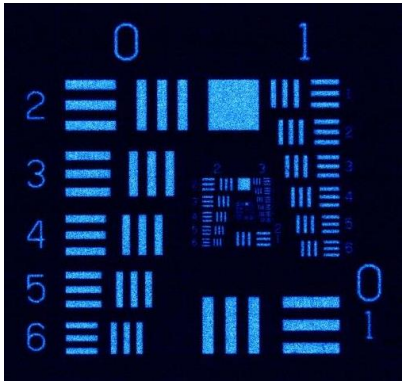
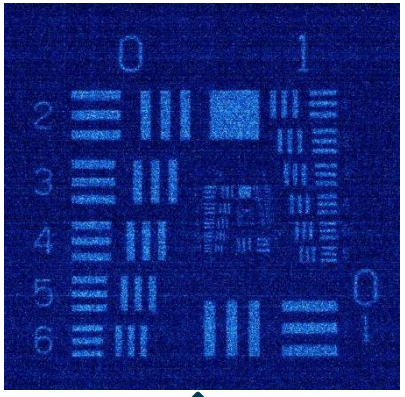
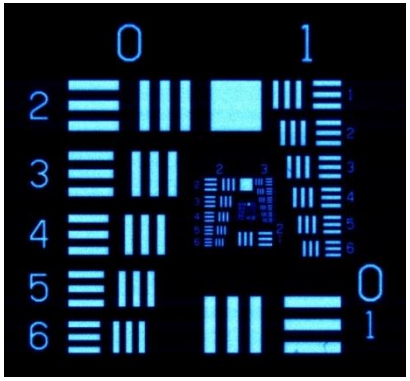
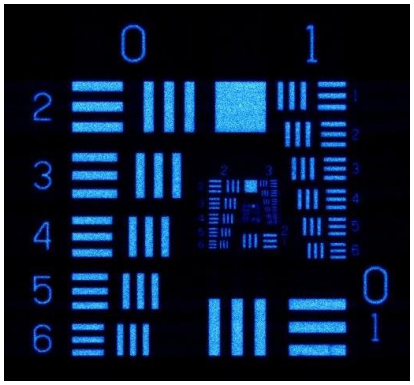
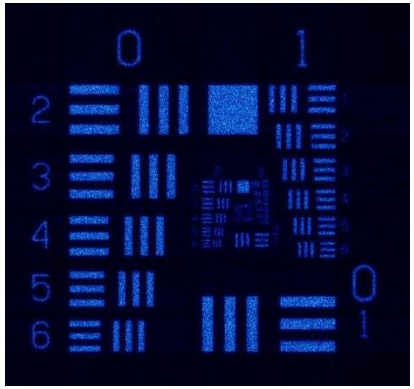


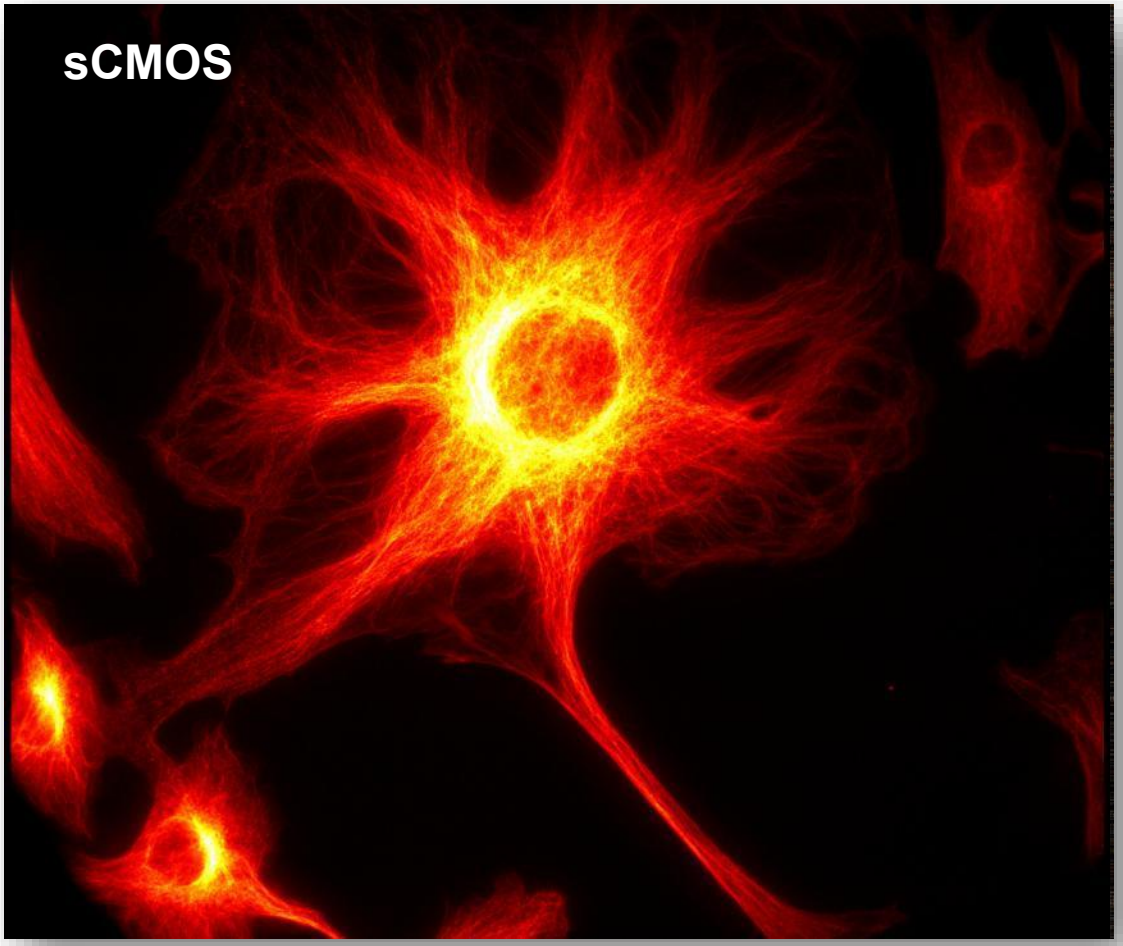
# sCMOS vs EMCCD …



# sCMOS vs EMCCD image comparison…

| | 490 photons per pixel | 68 photons per pixel | 8 photons per pixel |
|---|---|---|---|
| **sCMOS 2x2 binned (13 µm)** |  |  |  |
| **EMCCD (13 µm)** |  |  |  |

# Field of View comparisons….

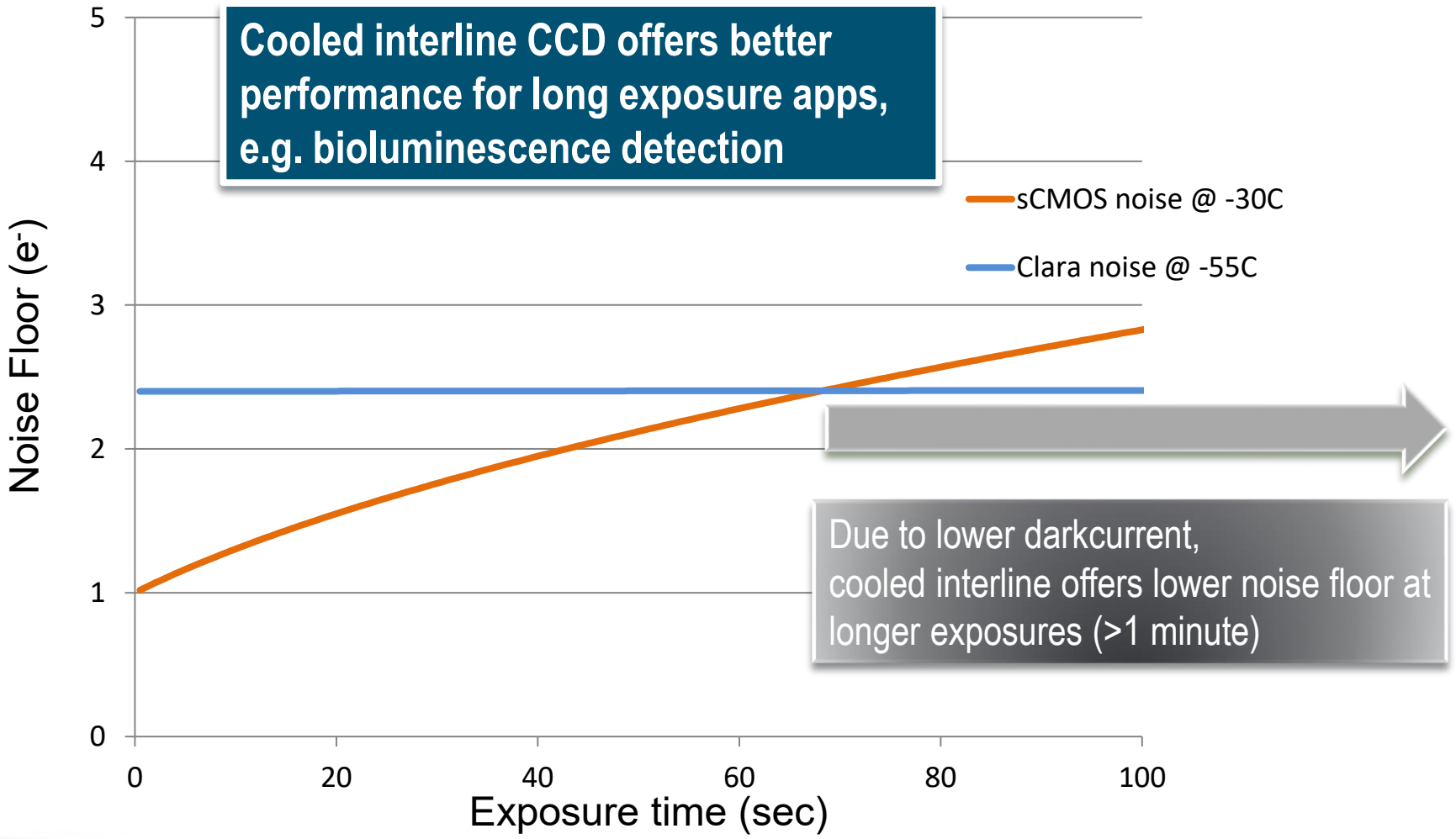



**Sony ICX285 interline**

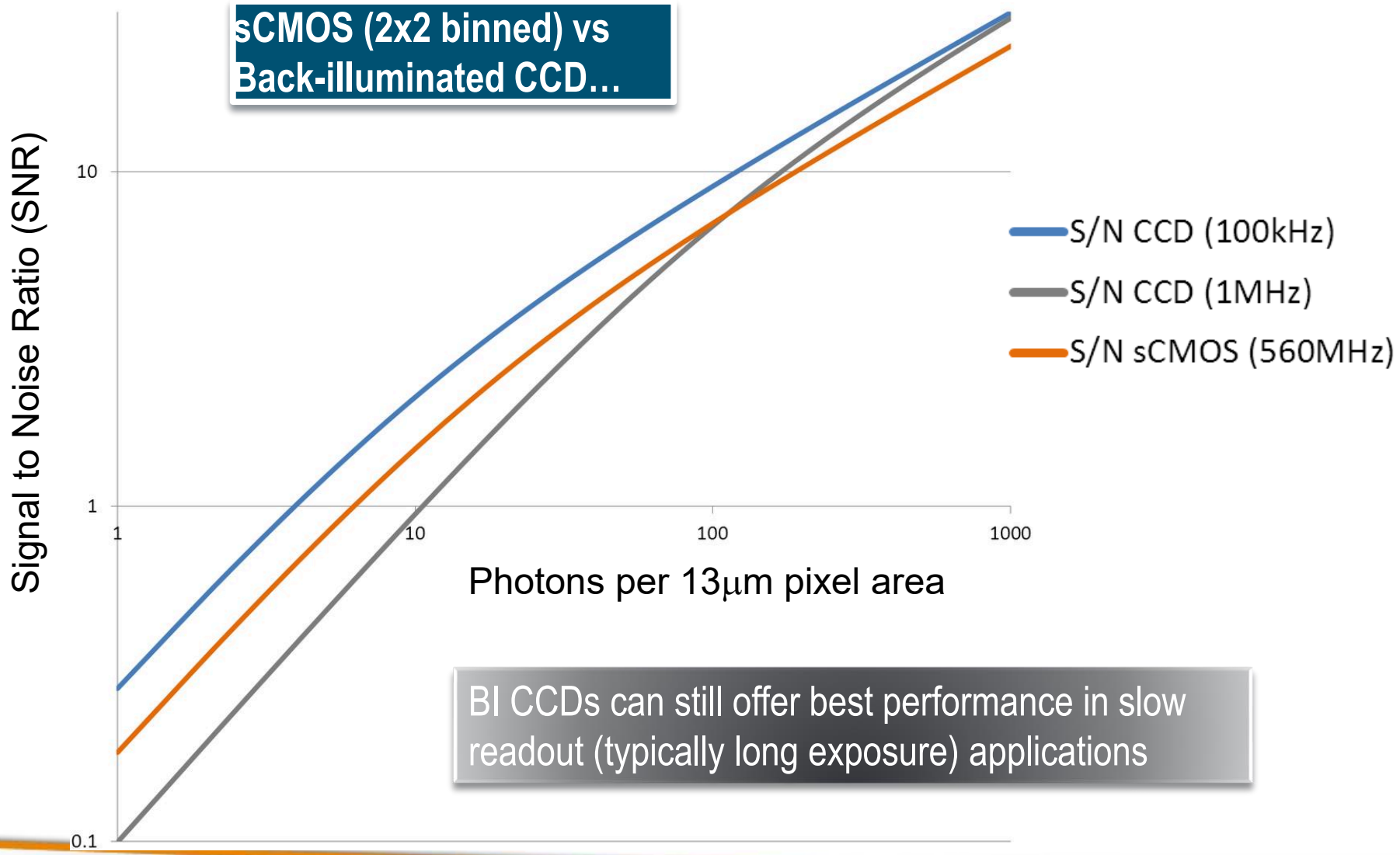
Field of view comparison of two technologies; x60 magnification; 1.25 NA; 5.5 megapixel sCMOS vs 1.4 megapixel interline CCD (each have ~ 6.5 μm pixel pitch).

# sCMOS vs interline CCD

## Noise Floor (read noise and dark noise) vs exposure



# sCMOS vs back-illuminated CCD…




BI CCDs can still offer best performance in slow readout (typically long exposure) applications

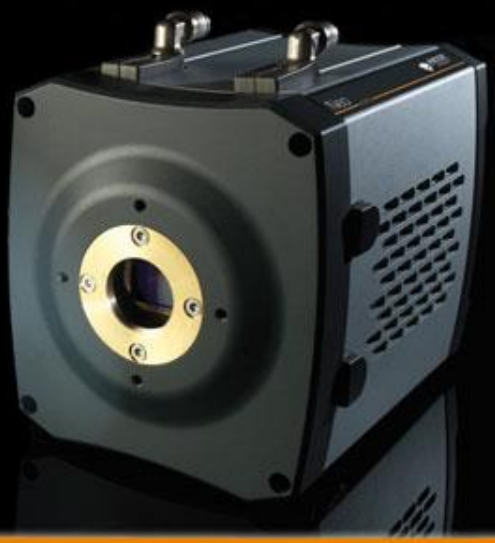
# sCMOS was conceptualised to become the ‘new interline’

## How to achieve this?

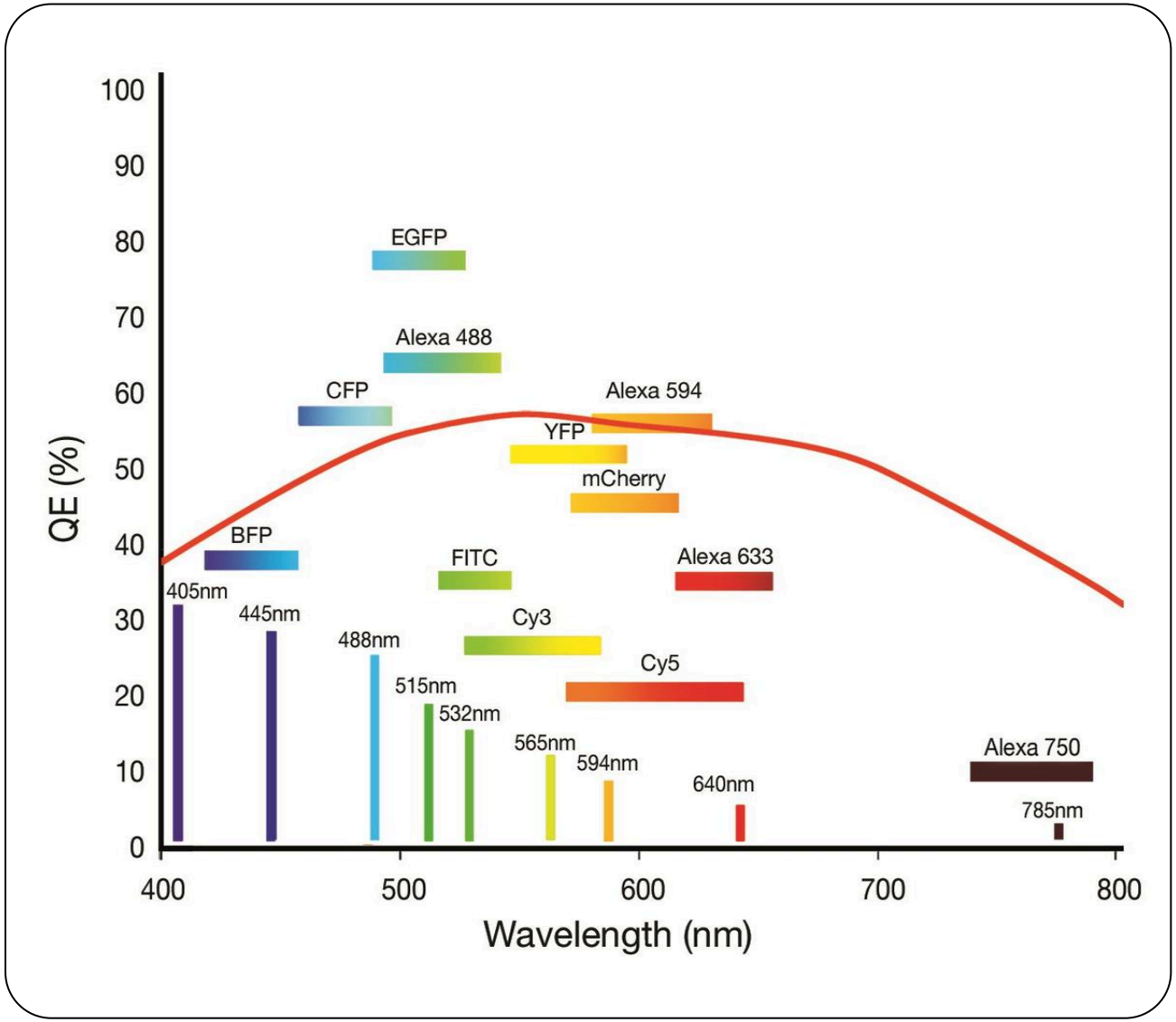
| Interline | sCMOS | |
|---|---|---|
| 4 to 8 $e^-$ | More Sensitive | 1$e^-$ |
| 11-16 fps | Faster | 30 fps sustained |
| < 12-bit | Wider Dynamic Range | > 14-bit |
| 1.4 MP | Larger FoV / Resolution | 5.5 MP |
| ‘Snapshot’ exposure | Rolling & Global exposure | ✓ |

Decent image quality

Price

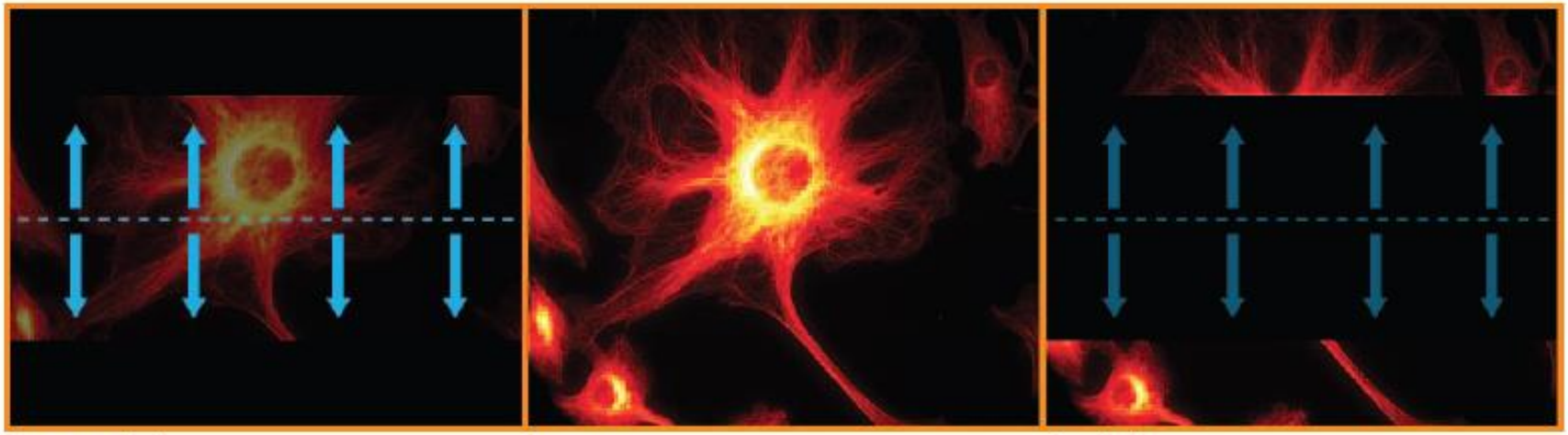


# sCMOS QE curve



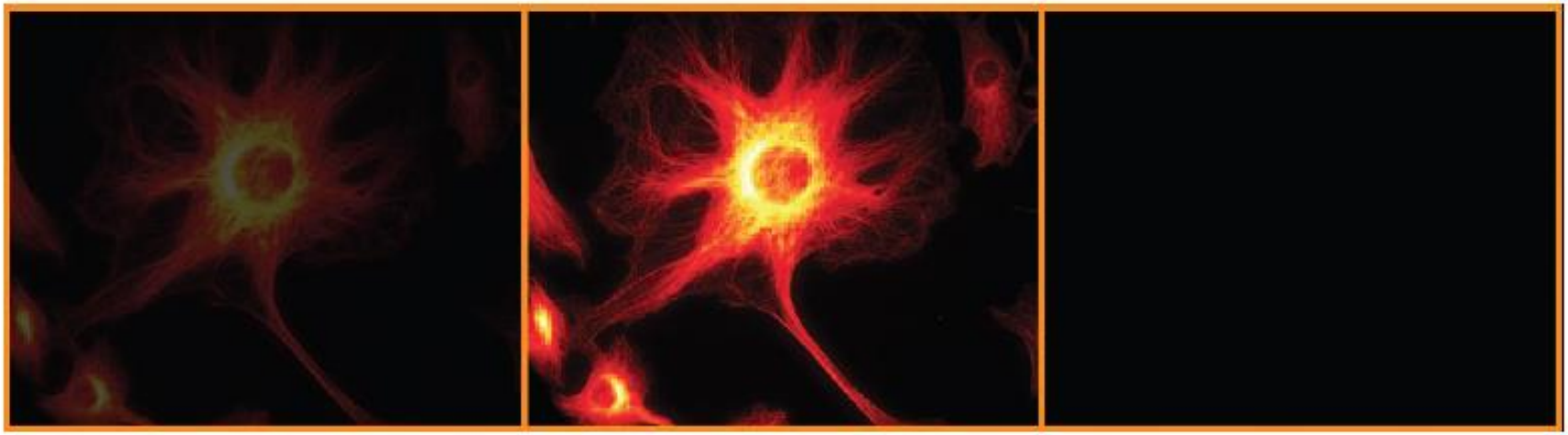
# Rolling and Global exposure modes

Rolling Shutter exposure and readout



Exposure start | Exposure | Readout

Global Shutter exposure and readout



Exposure start | Exposure | Exposure End

# Rolling or Global?

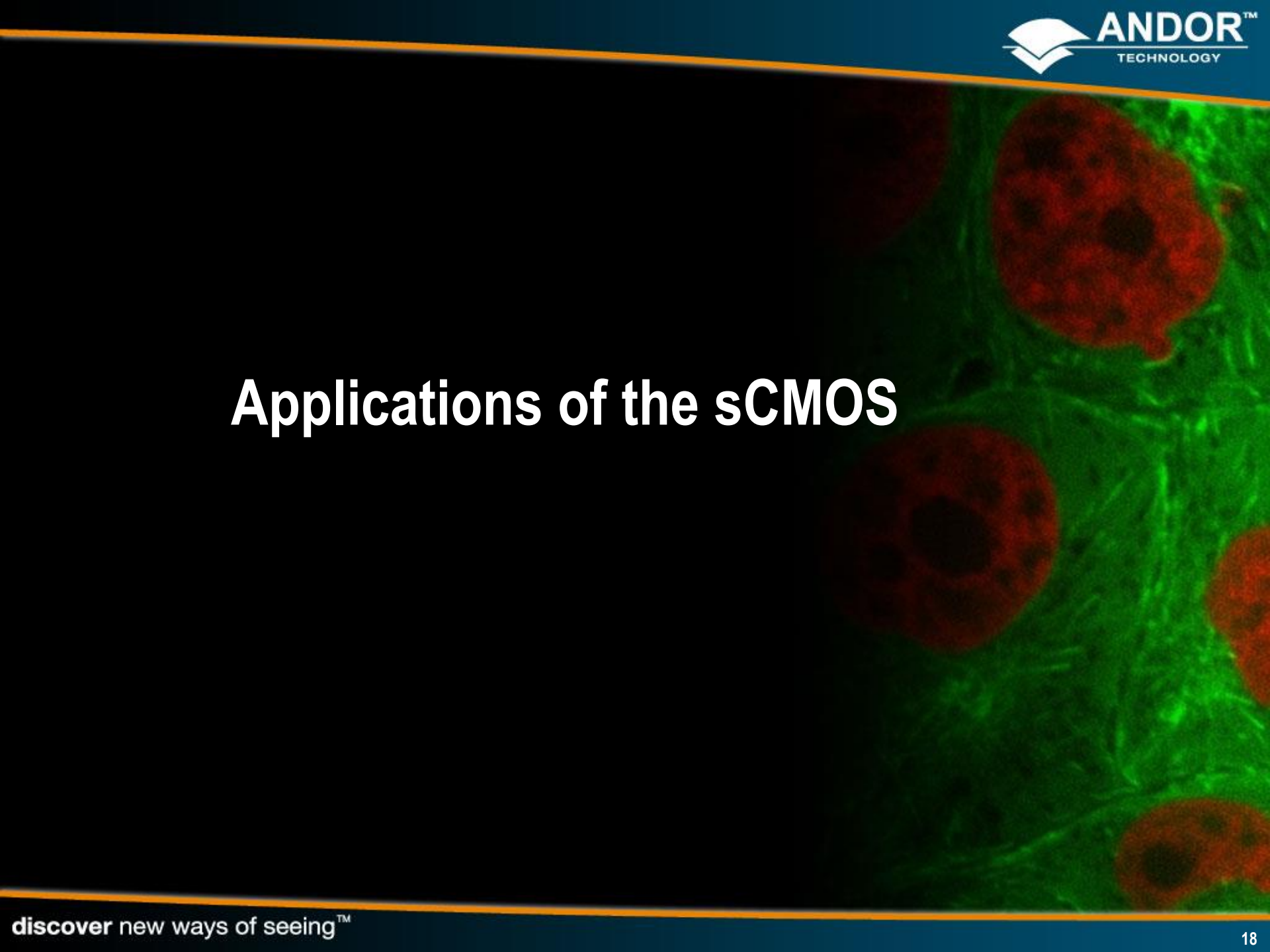
## *Rolling shutter*

- Use when do **not** require exact correlation in time between two separated regions of the image, e.g. vesicle tracking, calcium waves
- Use when no danger of spatial distortion in 'large' fast moving objects
- To achieve lowest possible read noise (1 to 1.3 $e^-$)
- To achieve fastest possible frame rates

## *Global (Snapshot) shutter*

- This mode is analogous to 'interline CCD' snapshot mode of exposure and readout
- Use when time correlation between separate regions of image is required
- Read noise compromised slightly (2.3 to 2.5 $e^-$)

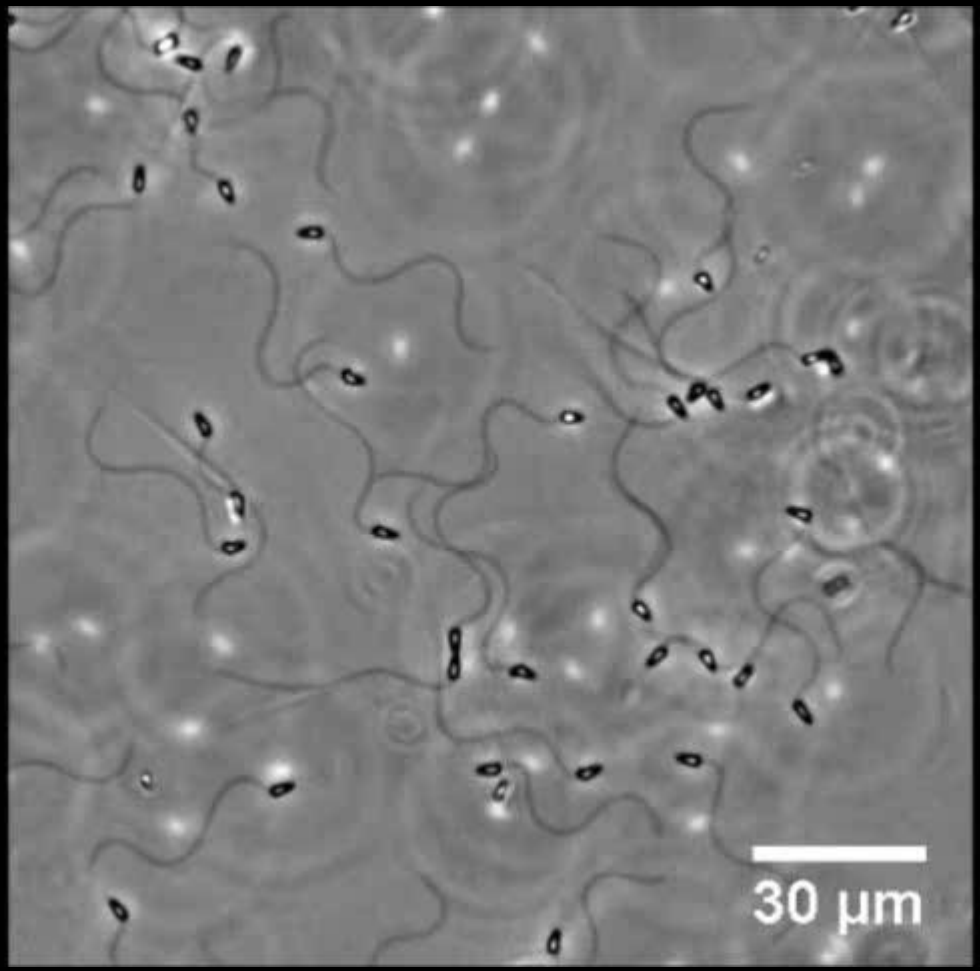
# Applications of the sCMOS



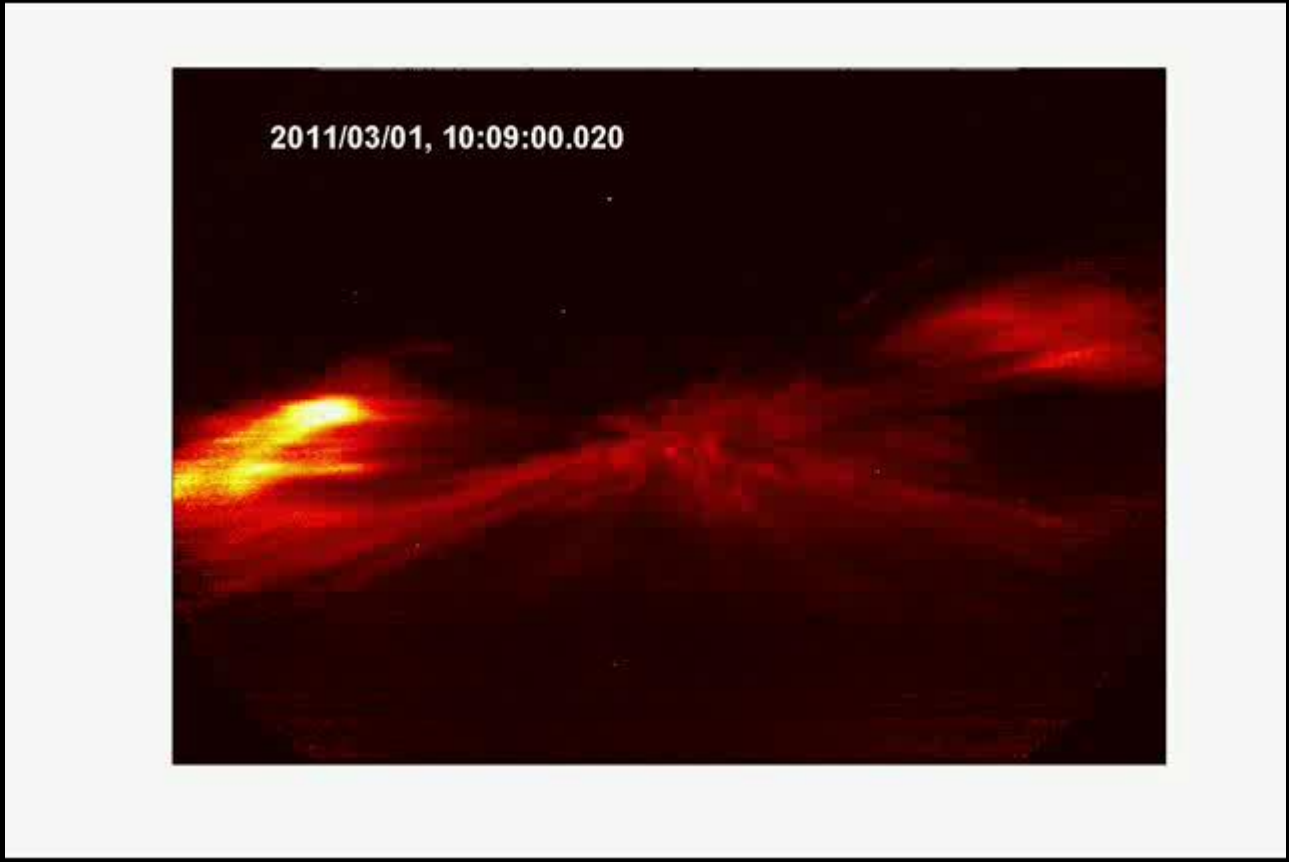
# Some uses of the sCMOS so far…

- SPIM
- Vesicle transport
- Cell motility
- Astronomy
- Motor proteins (myosin)
- Laser speckle imaging – blood flow
- Neural circuits
- Calcium signalling

Dr. Jeffrey Guasto, Dept. Of Civil & Environmental engineering, MIT-understanding the biomechanics of sperm cell movement-important for fertilization.

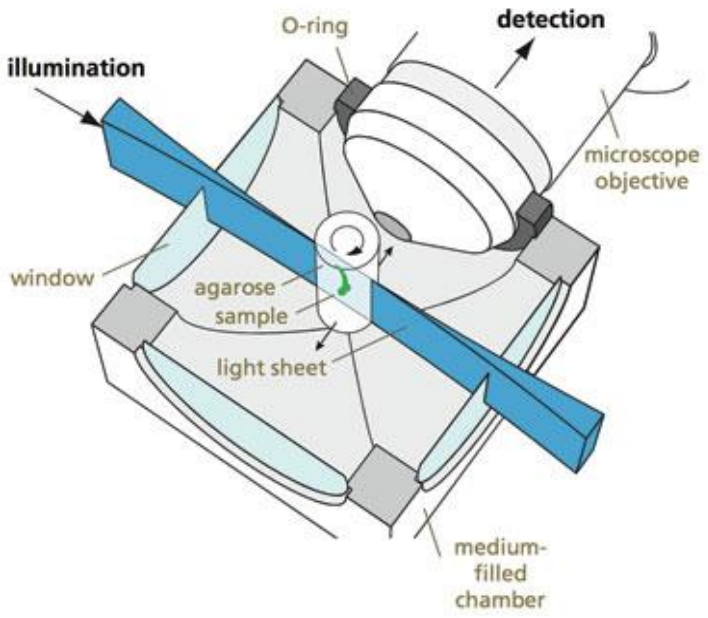


Dr. Robert Marshall, Centre for Space Physics, Boston University - Aurora Breakup event captured with the Neo at 50 fps, full frame




*"This data will allow us to make unprecedented measurements of morphology of small-scale auroral structures"*

# SPIM (Selective Plane Illumination Microscopy)




## Recommendation:

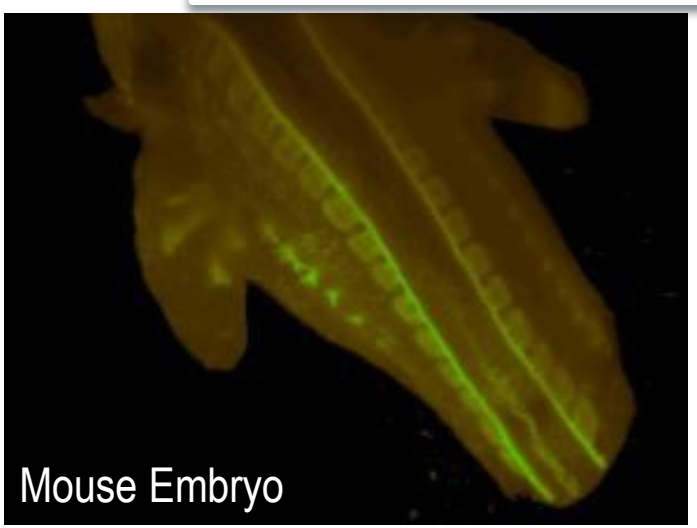
## Neo sCMOS

- ✓ **Resolution**
- ✓ **Field of View**
- ✓ **Speed**

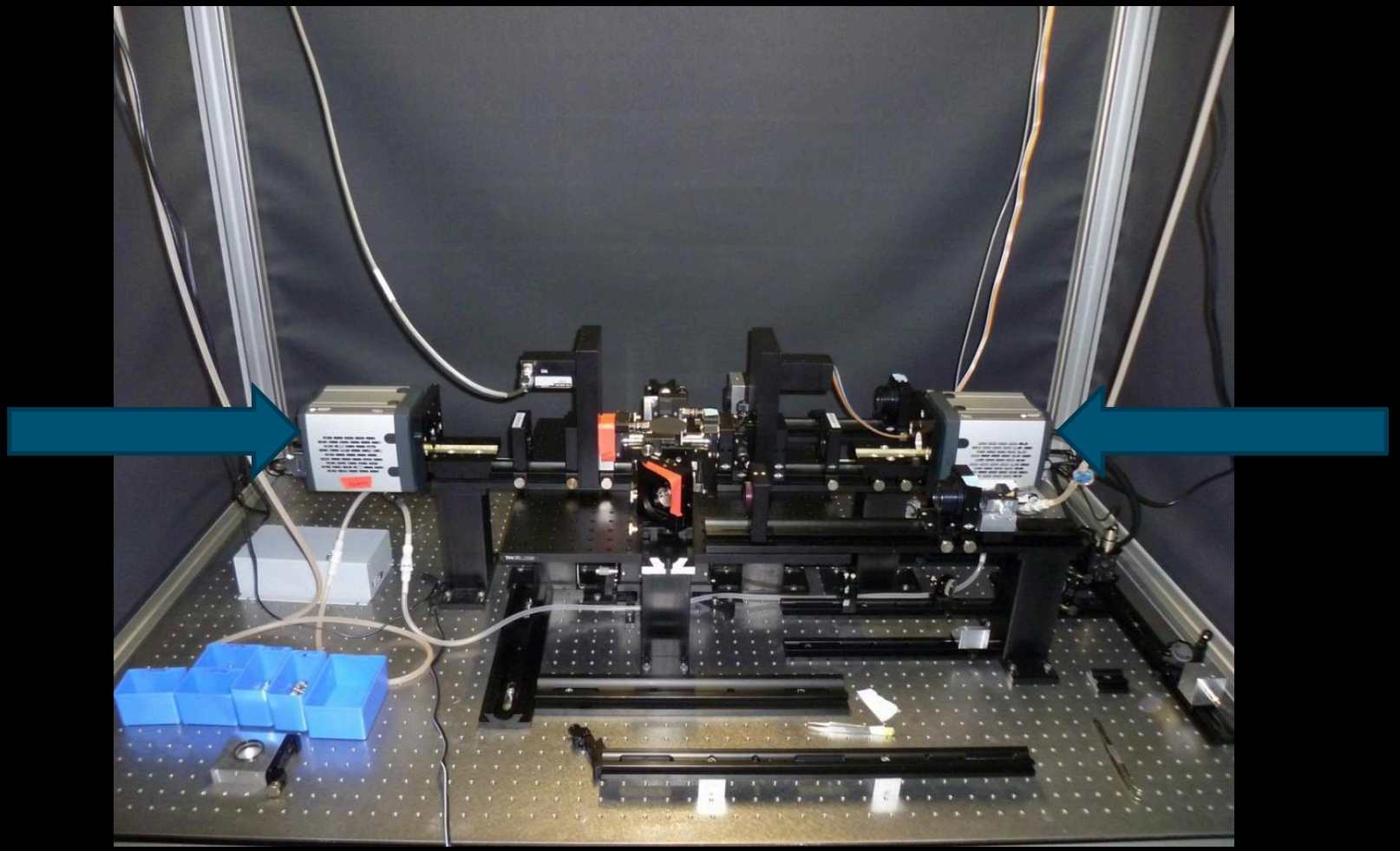
**Dr. Lars Hufnagel, Developmental Biology Unit, EMBL Heidelberg.**

'Without pushing it to the limit we managed to take 131 planes of the drosophila embryo in just 4 seconds (5.5 megapixels mode), which is practically instantaneous compared to the morphogenetic processes and out-performs by far everything we have tried before. **The camera is made for SPIM microscopy!**'

- Optical sectioning even with lenses that have a large working distance and a relatively low numerical aperture
- Especially well suited for the investigation of large samples (e.g. embryos) to study features such as growth, migration, morphological changes and gene expression patterns, that require high resolution, while being extended over a large volume.
- Single plane illumination significantly reduces photobleaching/phototoxicity



A photograph of a state-of-the-art 4-lens SPIM, courtesy of Uros Krizic of the Hufnagel Lab, EMBL, Heidelberg



Optical cross-sections through a developing Drosophila melanogaster embryo in stage 5/6. Two Neos are used to capture this 3-D structure and one of these can be captured every 20 seconds.

Movie of the motor protein myosin (fluorescently tagged with GFP) in the nematode C. Elegans immediately after Fertilization – movie courtesy of Sundar Naganathan (Grill research group, MPI, Dresden)