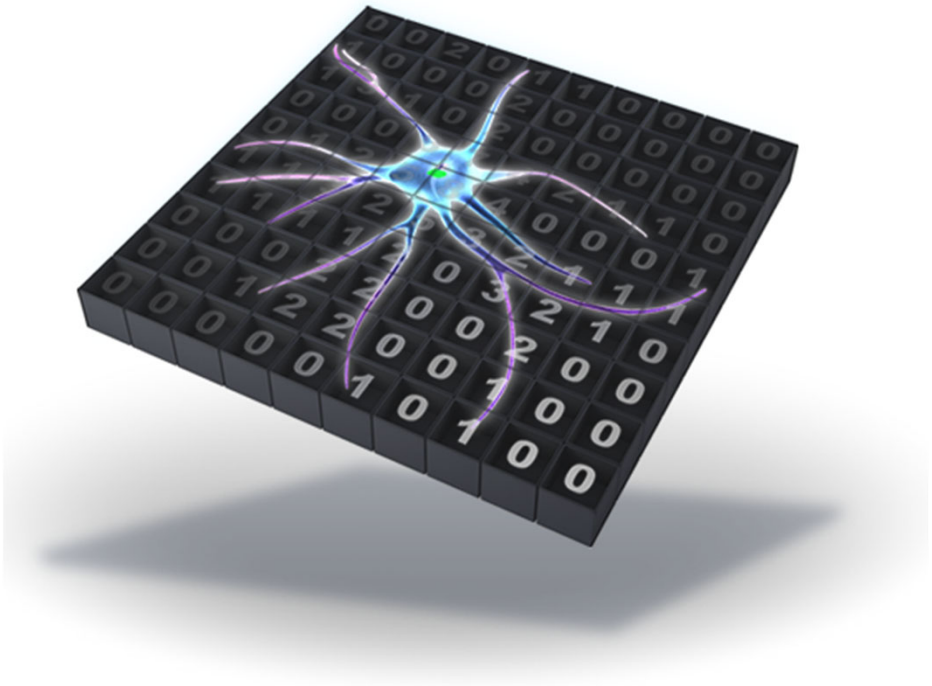
EMCCD Cameras



Rachit Mohindra
Photometrics

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EMCCDs – The Need for Low Light Imaging

- Low excitation energy to reduce photo-bleaching/toxicity
  - Live cell fluorescence
  - Fast bleaching dyes
- Samples in ultra-low concentrations
  - ~10^{-10} M in typical single molecule fluorescence applications
- Observe Processes with fast kinetics
  - Motility studies
  - Ion ratio imaging
- Essentially - Low Light and Speed

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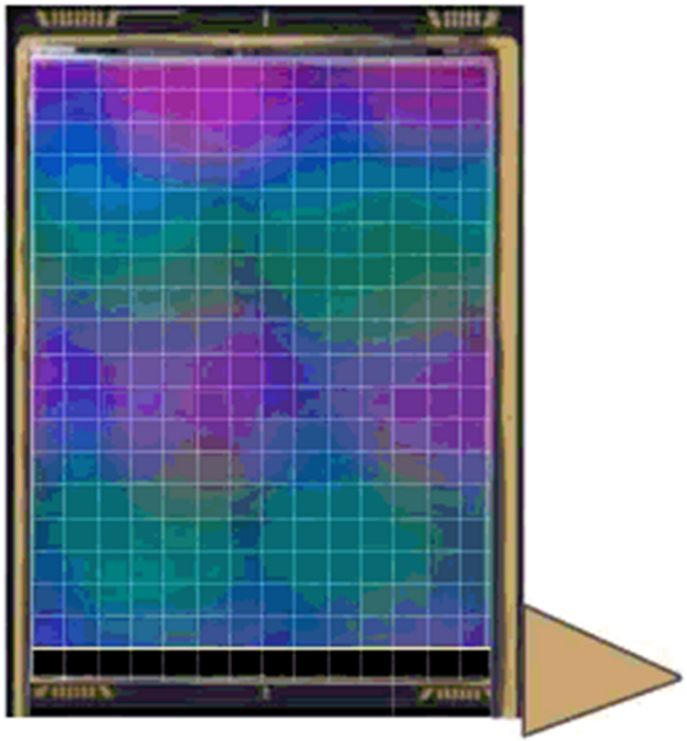
CCD Image Acquisition

Frame Transfer CCD



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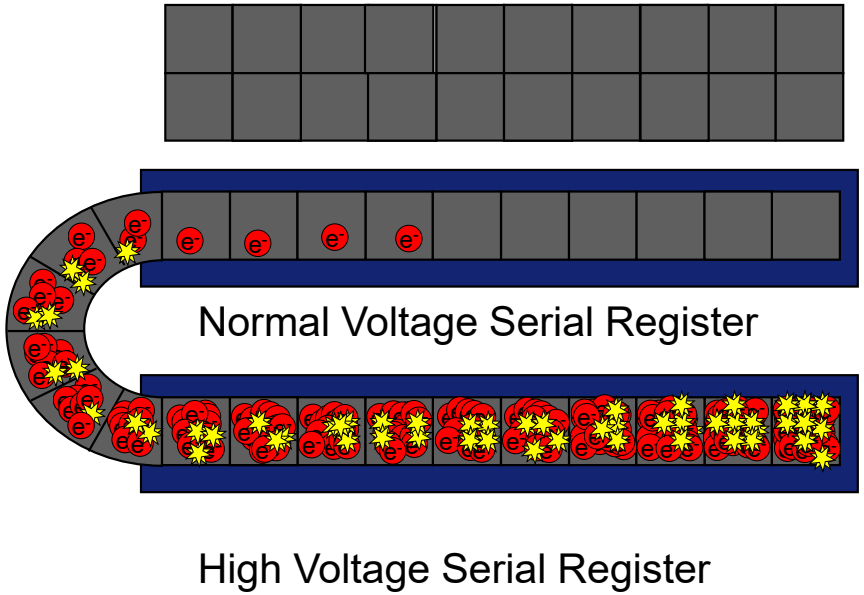
EMCCD Cameras



Back-illuminated, frame-transfer CCD (for >90% QE) or standard front-illuminated (65% QE)

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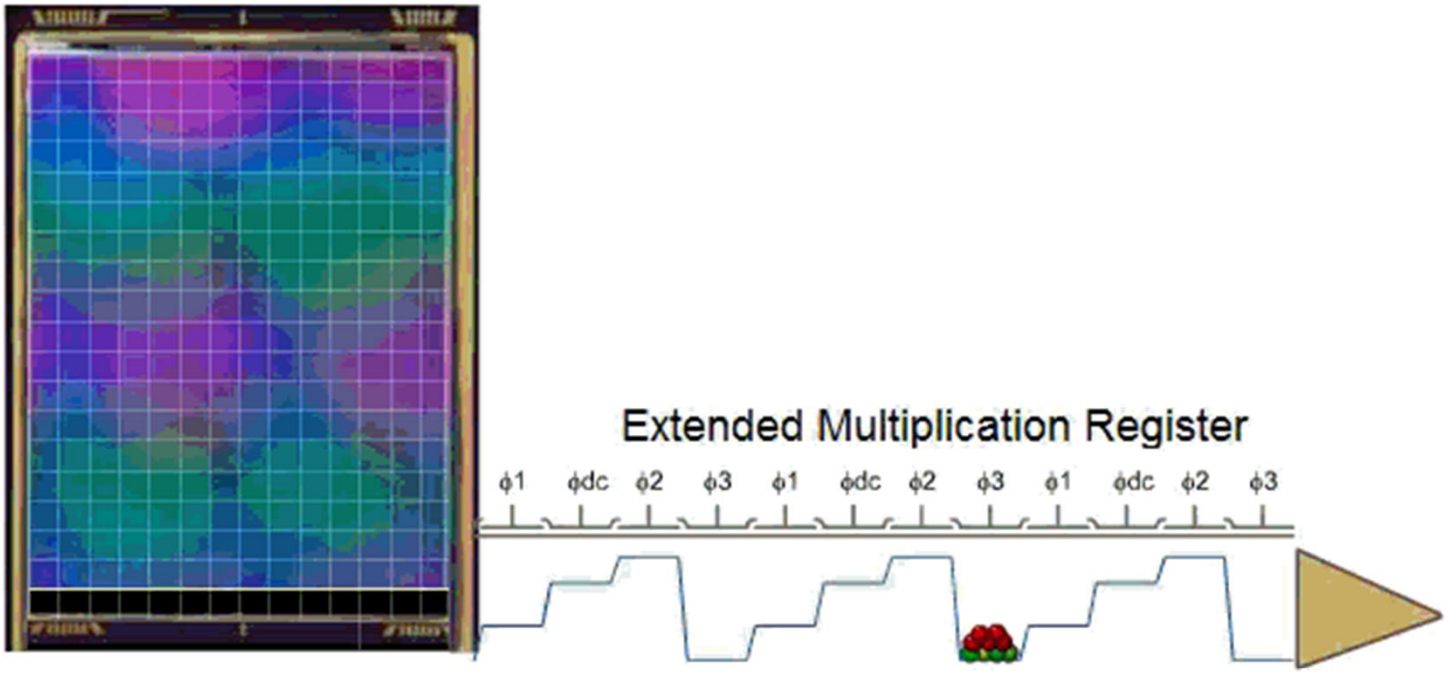
EMCCD Cameras



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How Does this Help?

- If you are trying to measure signal that is lower than the read noise – You're not going to see anything
- If you multiply up the signal over the read-noise – Then you'll see something.
- But – the signal you're measuring isn't actually changing.
- You're effectively reducing the read noise

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Reduction of Read Noise

- Apply EM Gain factor of 200X
- Boost Signal 200X
- Equivalent to reducing the read noise by a factor of 200X
- If Read Noise is 50e-, after EM gain, it is equal to 0.25e-
- Allows extremely low-light detection

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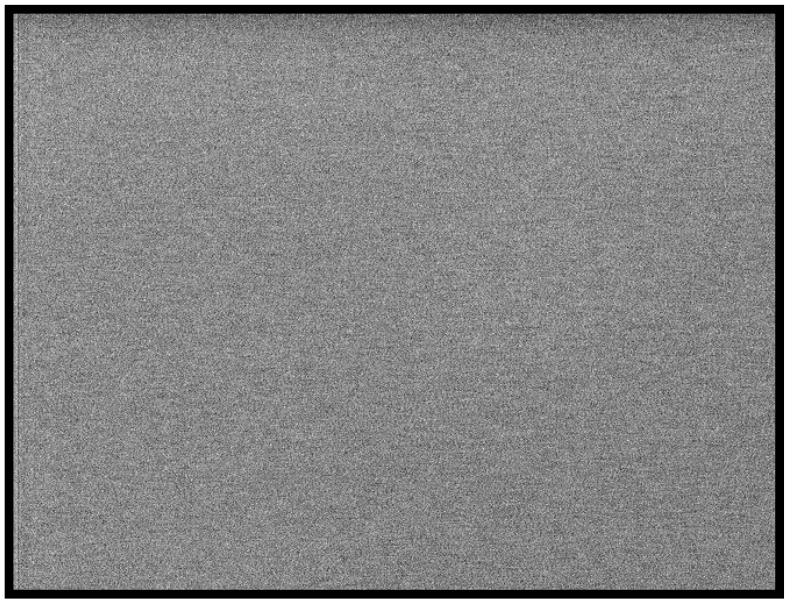
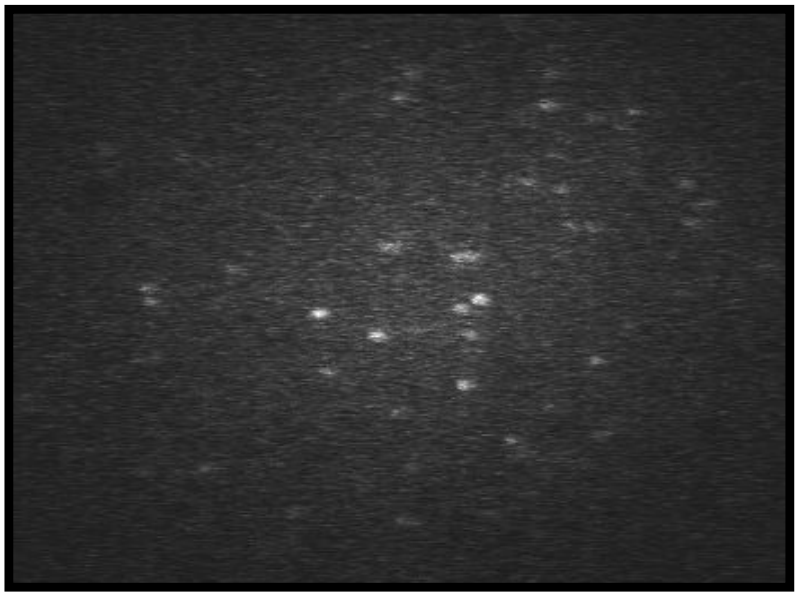
Detect Signals Below the Read-Noise



Without EM Gain



With EM Gain

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Downfalls of EMCCDs

- Clock Induced Charge increases
  - Time independent (unlike dark current)
  - Increases background events
- Excess Noise Factor
  - Increases noise by a factor of ~1.4
  - “Halves the Quantum Efficiency” – Not exactly
- Loss of Full Well Capacity
  - Inversely proportional to the amount of EM Gain applied
- Aging of EM Gain

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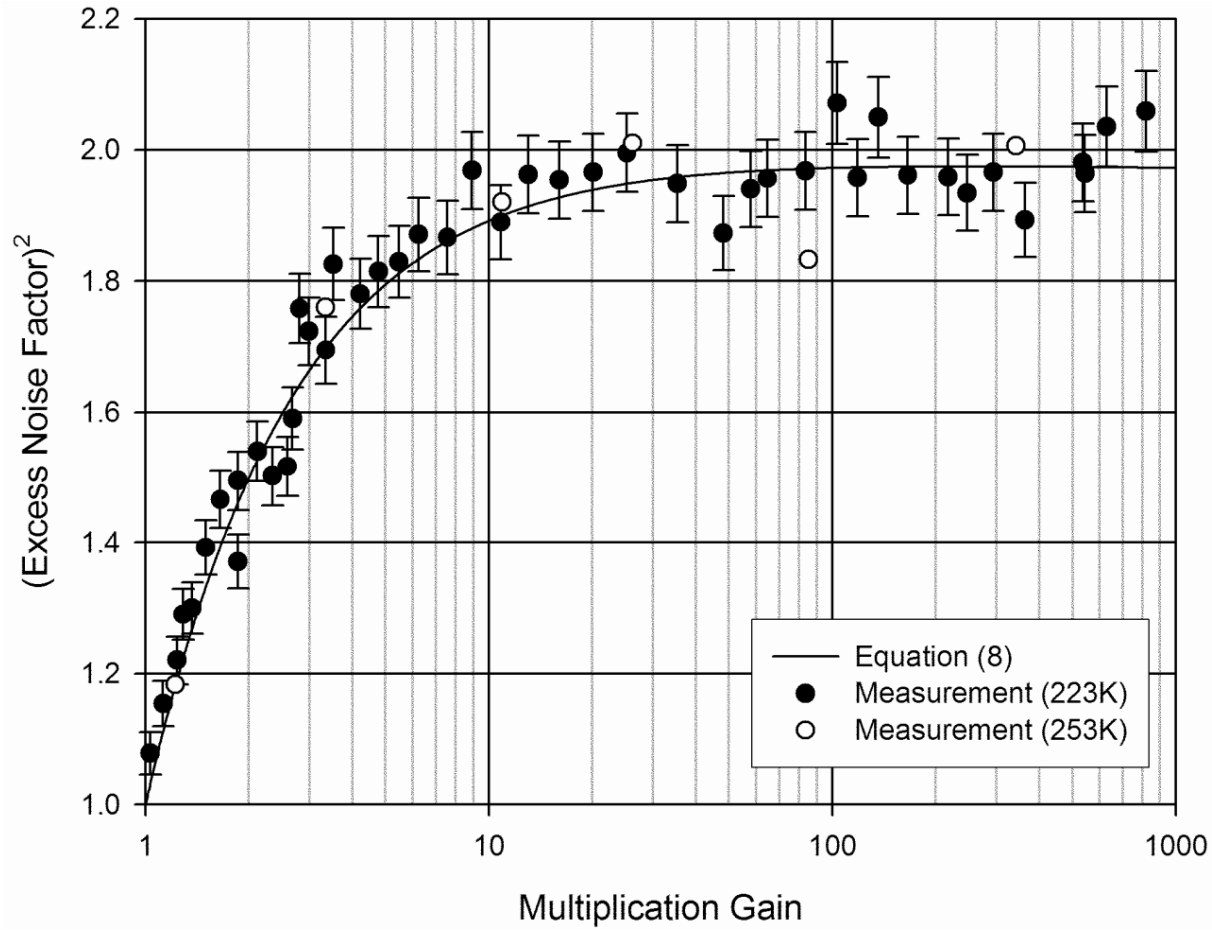
Excess Noise Factor



- Increases only Shot Noise and Dark Noise by a factor of ~√2 or ~1.4
- Important at higher light levels, where images are dominated by Shot Noise

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Calibrate your EM Gain

- As EM Gain ages – setting 300X doesn't always provide 300X…
- Most Cameras provide you the ability to calibrate

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The Sweet Spot

- Maximum EM Gain is not the best setting
  - Maximizes Excess Noise
  - Maximizes Clock Induced Charge/Spurious noise
  - Drastically reduced Dynamic Range
  - Read Noise asymptotically reaches a minimum Read Noise

- Reduce the Read Noise to <1e-
  - No more EM Gain needed
  - Maximize the sensitivity, minimize the noise
  - Extend the life of the EM Gain

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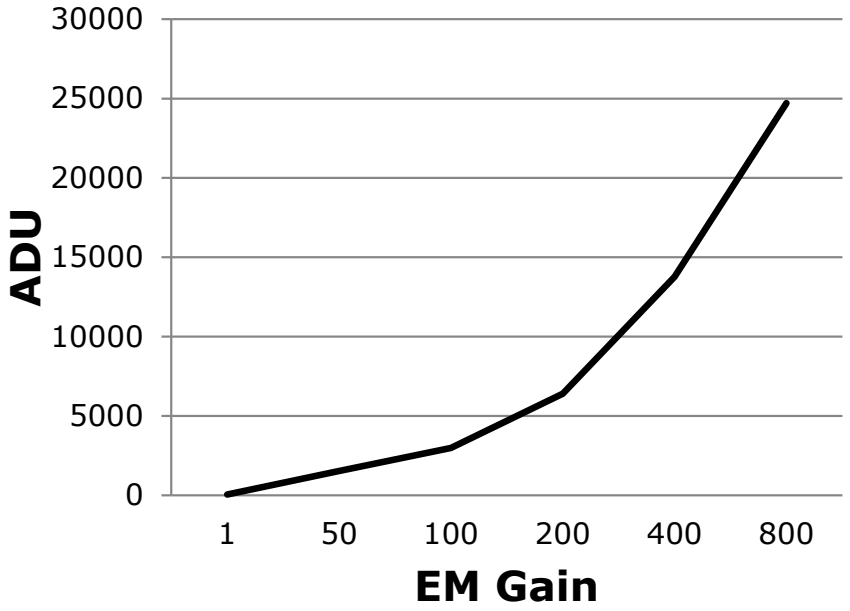

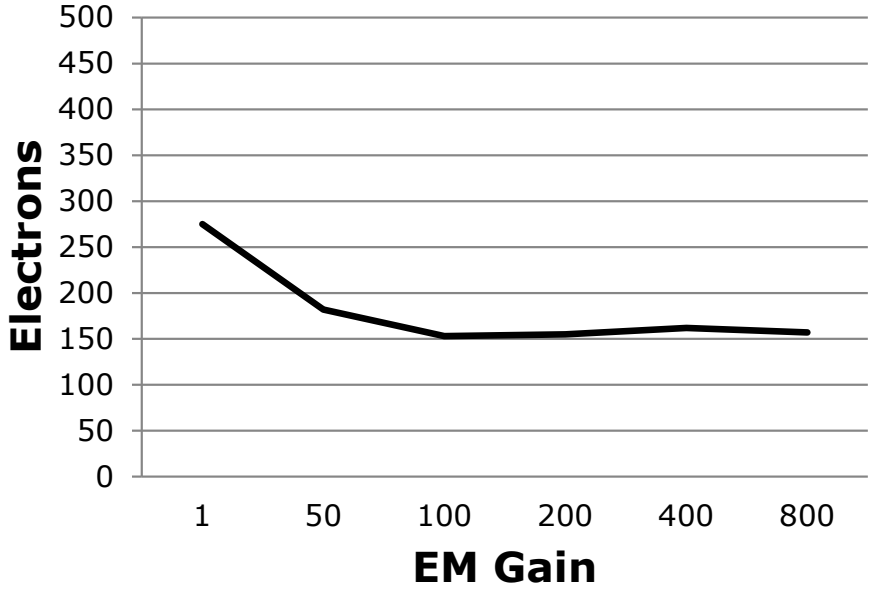

- With increasing EM Gain – ADU's increase, But Signal detected by the sensor remains constant
- After a certain point, the electron count will remain the same

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EMCCD's – A Summary

- Low Light Imaging that requires Speed
- Effectively reduces your EM Gain
- Not a perfect technology
- Find the Sweet Spot – Don't need more EM than this

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Thank You!

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