Imperial College London

Interfacing EMCCD Camera used in Ion Trap experiments

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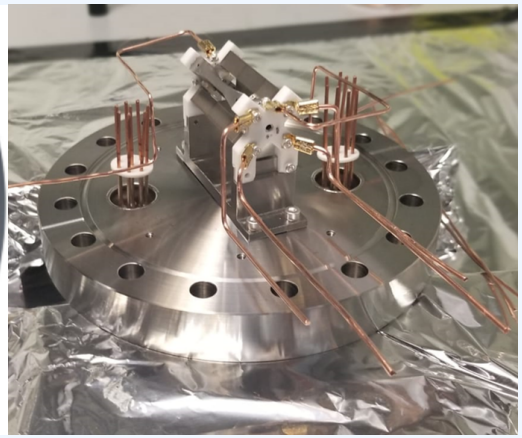
16/07/2019

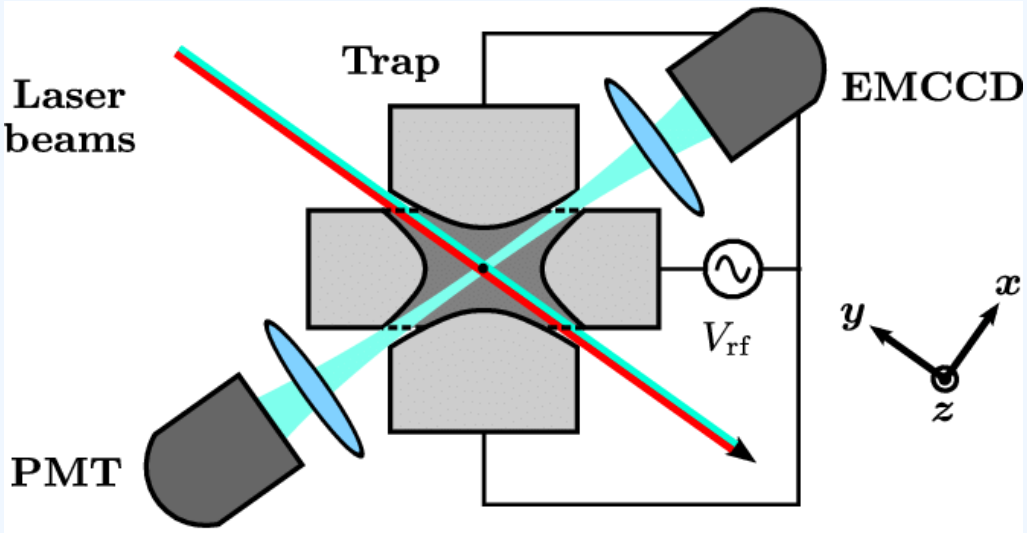


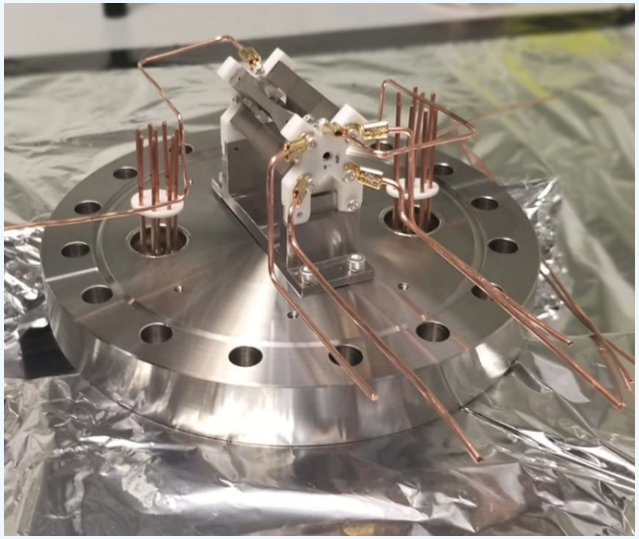
Overview

Ion traps

- Ion trap: e.g. Penning or Paul trap, used to levitate small clouds of ions, or a single atomic ion, in free space, inside a vacuum chamber.

- Typically lasers used to manipulate the ions and an imaging system to detect the ion's fluorescence

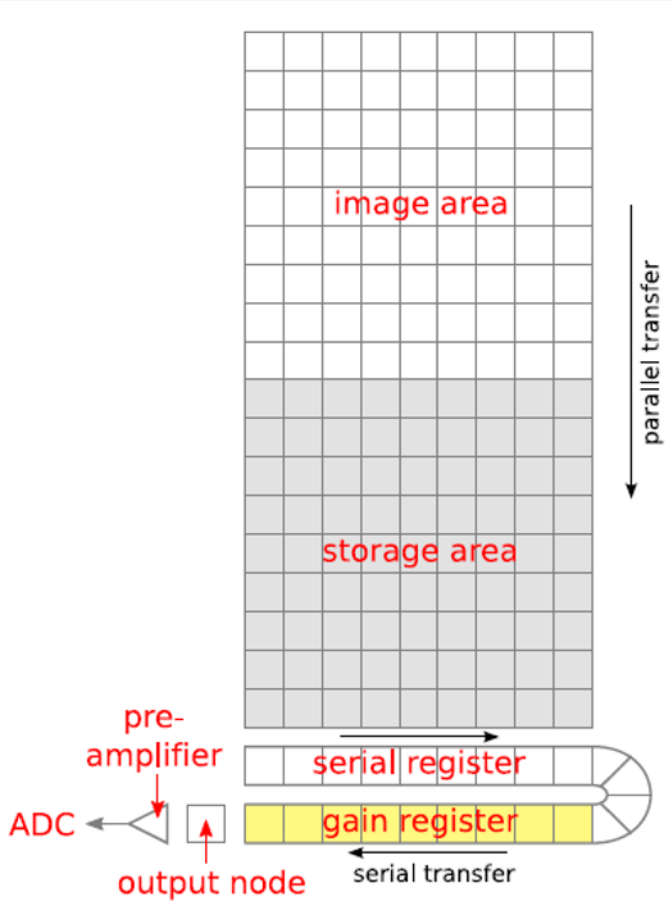




EMCCD Cameras

- Charged Coupled Device (CCD): silicon based semiconductor chip, captures light, converts the photons to digital data in the form of electrons
- Electron Multiplying CCD (EMCCD): identical structure to conventional CCDs BUT more sensitive and capable of single photo detection (e.g. fluorescence of single ions)
- EMCCDs widely used in ion trap experiments

EMCCD Cameras



- Shift register extended with Gain register => significantly improves low light detection
- Possible to read out only a part of the detector array

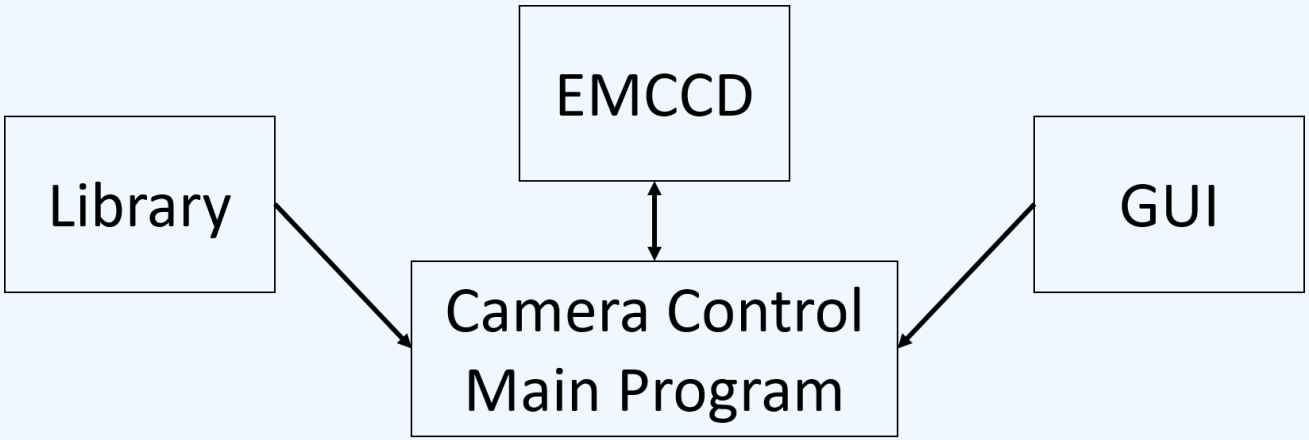
My Tasks

- Write a Python 3 program around existing library to interface our Andor iXon Ultra EMCCD camera
  - Commercial software fine for general imaging, but Python program can be tailored to experimental requirements
- Find a method of distinguishing between a bright and a dark ion
- Find optimal parameter settings to obtain best image in shortest exposure time

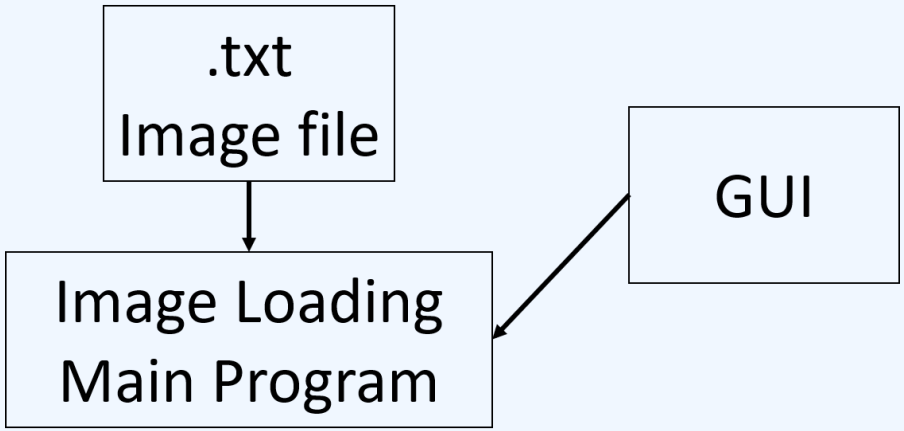
The Program

- Two separate programs: the EMCCD camera control program and the image loading program
- A Dynamic Link Library (DLL) containing various functions of the camera used by the program to control the camera
- Both programs are object oriented and have a graphical user interface (GUI) created using QT Creator software
- UI file from QT Creator converted to Python script with PyQt5 module => no need to write GUI in Python from scratch!

The Program (cont.)



(a) Camera control program architechture



(b) Image loading program architechture

Camera Control Program

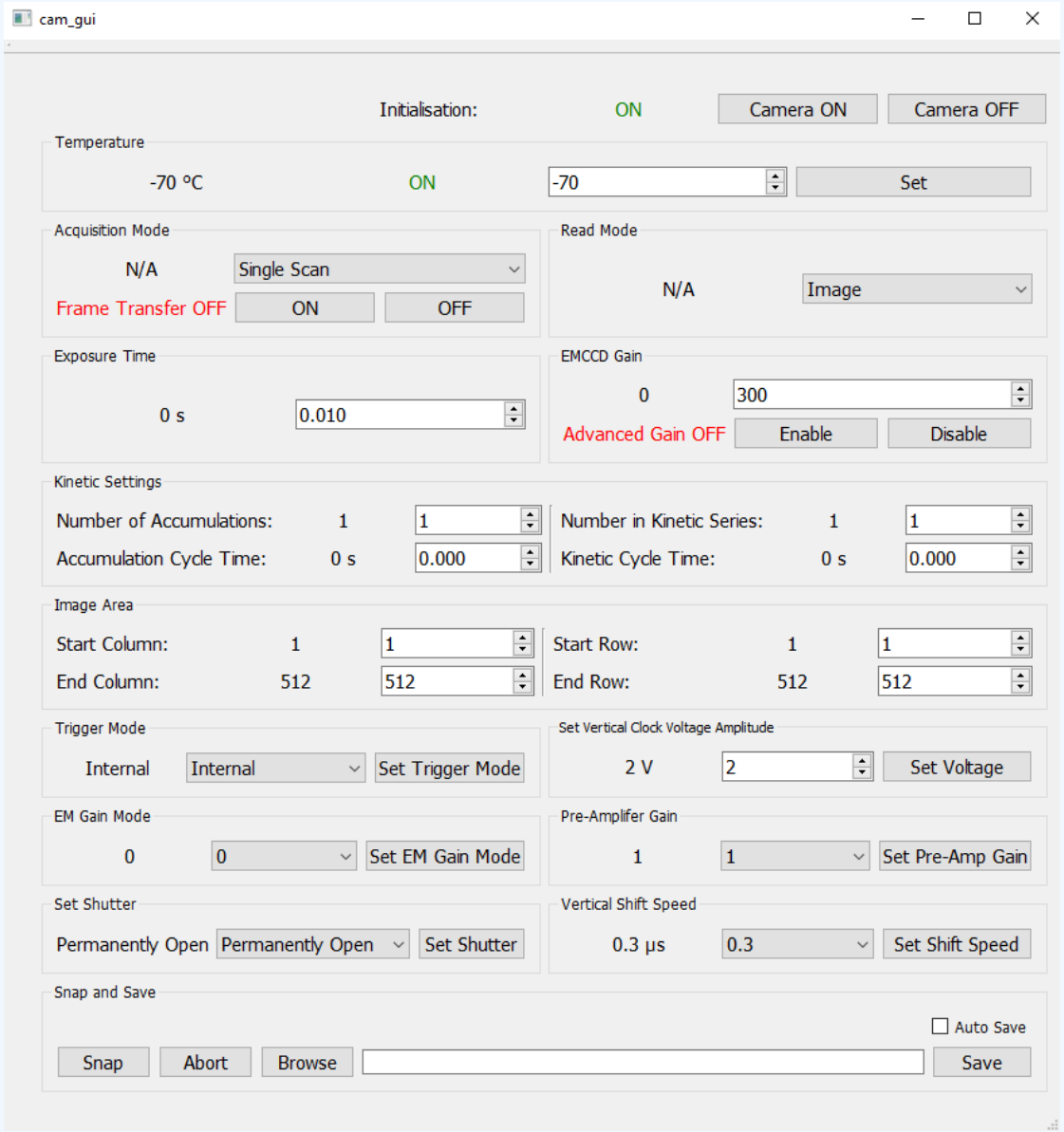
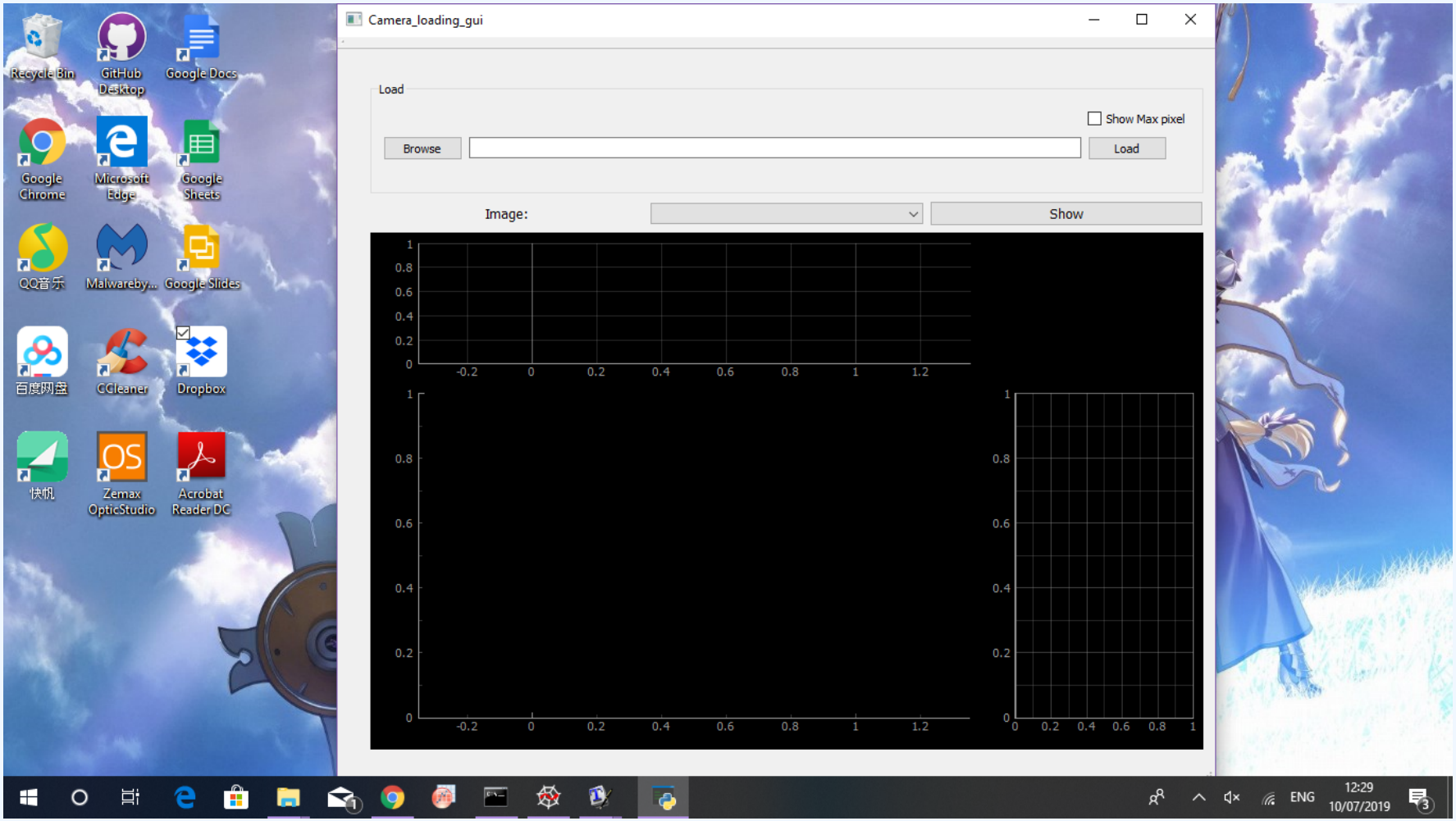


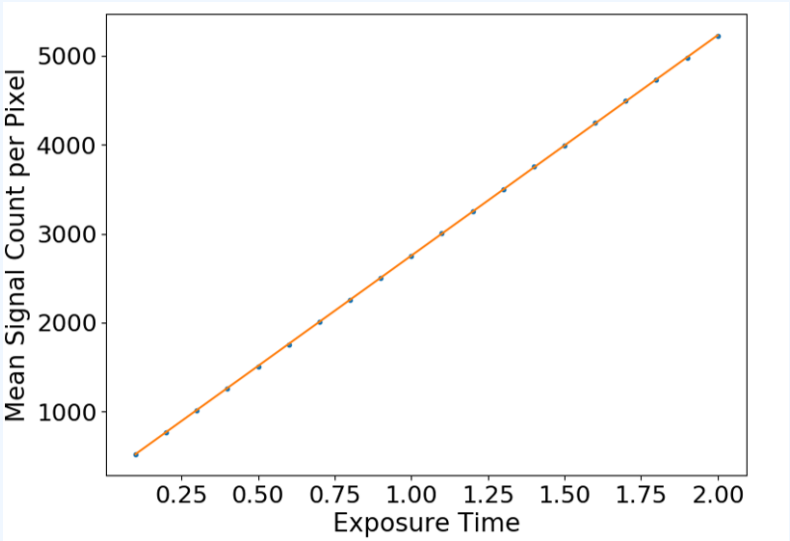
Image Loading Program

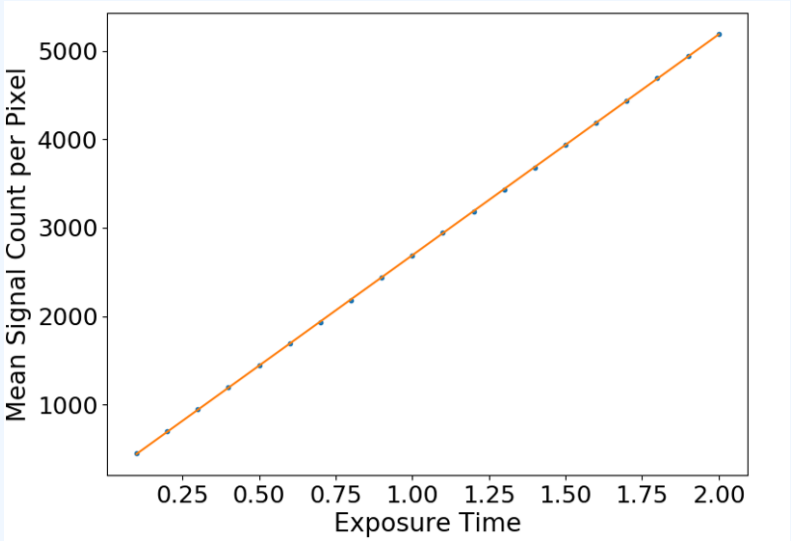


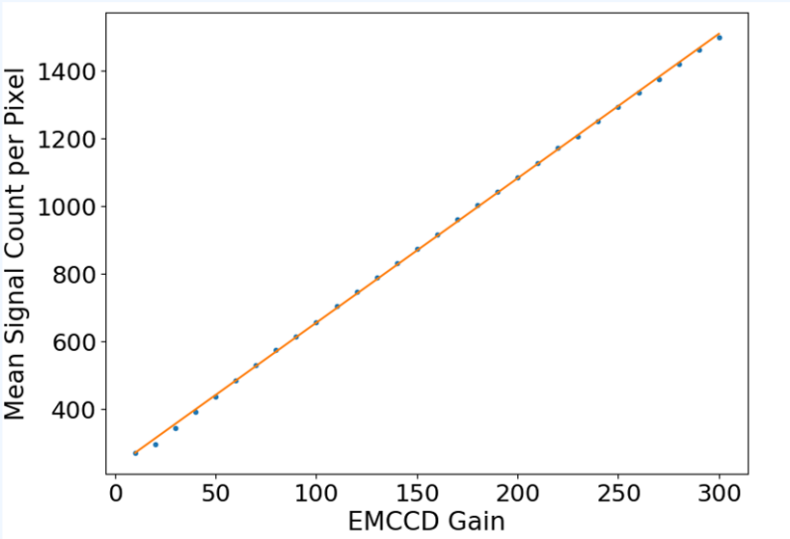
Investigating Camera Properties

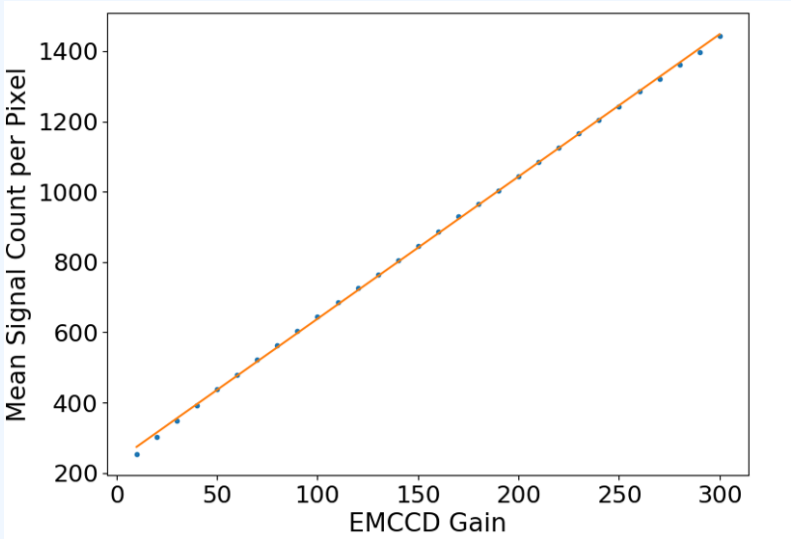
- The camera control program was first tested with noise readings and compared with commercial software to ensure the python program is working as expected
- The affect of the Exposure time and EMCCD gain on the mean noise reading per pixel were tested

Exposure Time and EMCCD Gain







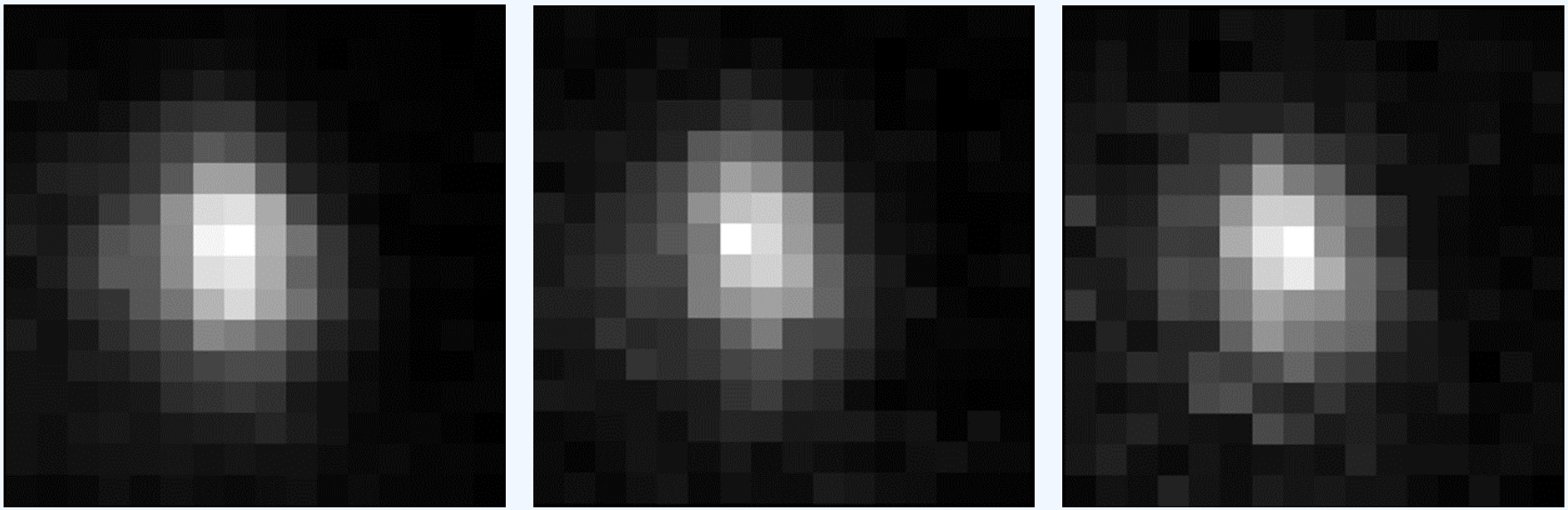


(a) Python Program

(b) Commercial Software

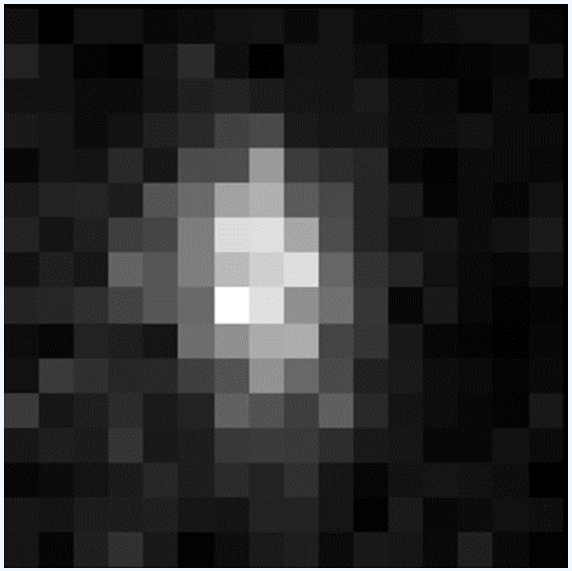
Images of Single Ion at Different Exposure Times

- Each Pixel of 16 µm x 16 µm, magnification of imaging system: x10
- diameter of ion image $\sim$ 6 pixels => diameter of ion fluorescence $\sim$ 9.6 µm

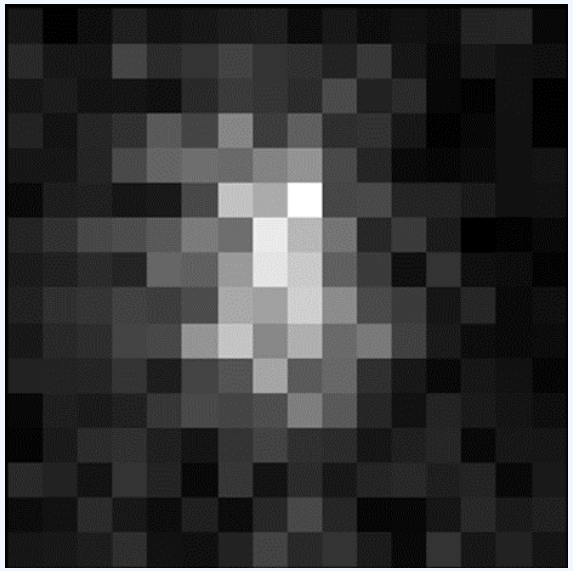


(a) 5 Second Exposure (b) 2 Second Exposure (c) 1 Second Exposure

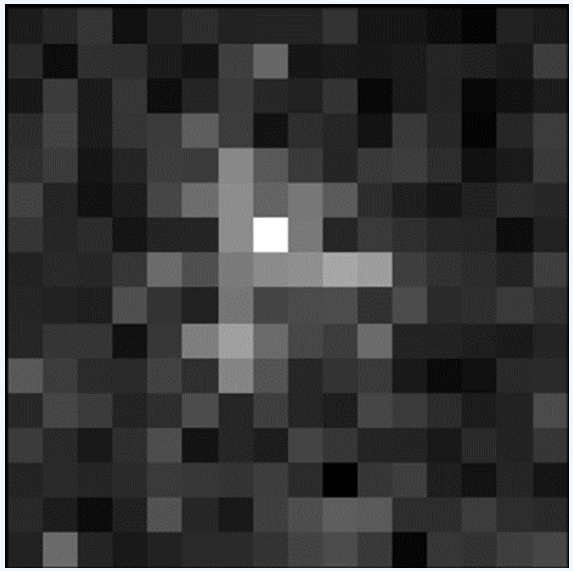
Images of Single Ion at Different Exposure Times (cont.)



(d) 0.7 Second Exposure



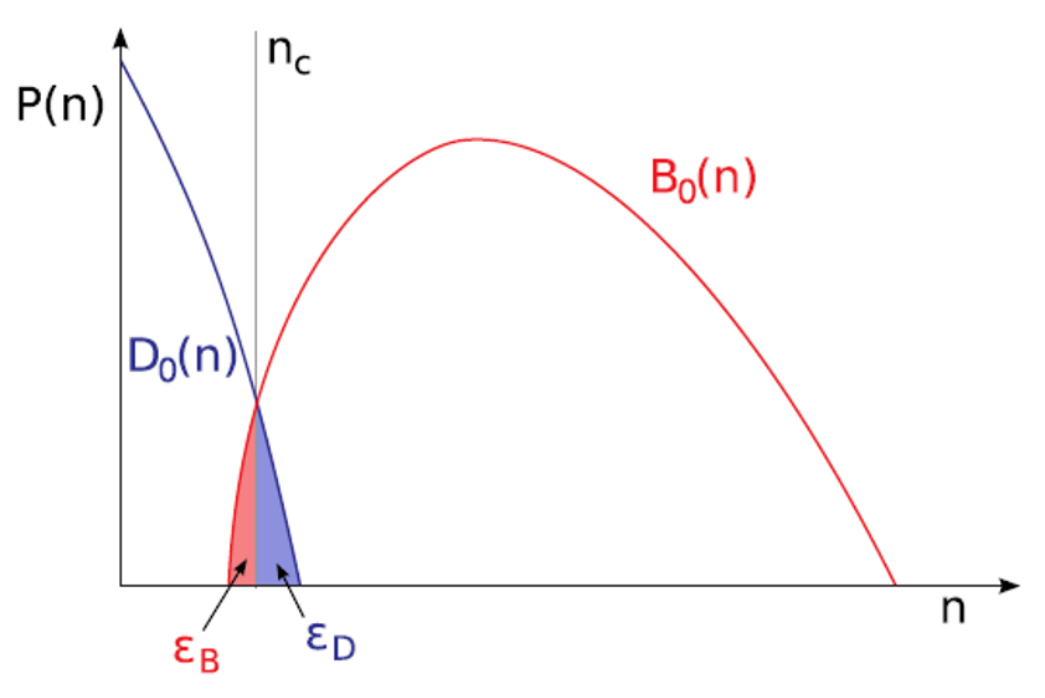
(e) 0.4 Second Exposure



f) 0.1 Second Exposure

Next Steps

- Investigate the minimum exposure required for a bright ion to be able to be distinguished from a dark ion
- A bright ion can no longer be distinguished from a dark ion if the distibution (P) of the brignt (B) and dark (D) ion signal counts have a large overlap



Future Plans (cont.)

- Comparing the differences in quality for image taken when the camera is externally triggered by the experiment and when the camera triggers the experiment and the start of exposure
- The EMCCD has a 'keep clean' cycle which clears the sensor to ensure it is charge free before the next exposure.
- Externally triggering the camera may interrupt the 'keep clean' cycle and produce a more noisy image
- The camera gives off a 'fire signal' during exposure => can be used to trigger the start of the experiment at the end of a 'keep clean' cycle

Conclusion

- A Python program with a GUI was created to acquire pictures of fluorescence of single ions and another program was created to view the images and show the vertical and horizontal projections
- A reliable method/algorithm is required to distinguish bright ions from dark ions at short exposure time
- Find the camera triggering mode which gives images of highest signal to noise ratio

Thank You for Listening!