# DIGITAL CAMERAS FOR PHOTON DIAGNOSTICS AT THE ADVANCED PHOTON SOURCE

## TUPP040

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## ABSTRACT

- Cameras can be a very useful accelerator diagnostic, particularly because an image of the beam distribution can be quickly interpreted by human operators, and increasingly can serve as an input to machine learning algorithms.
- We present an implementation of digital cameras for triggered photon diagnostics at the Advanced Photon Source using the areaDetector framework in the Experimental Physics and Industrial Controls System.
- Beam size measurements from the synchrotron light monitors in the Particle Accumulator Ring using the new architecture are presented.
- The present cameras have been implemented in locations outside of radiation enclosures where a local soft IOC can be positioned within a few metres of the camera itself. This allows the use of USB3 protocol for communications, which provides for short cable lengths of only ~5 m between powered signal repeaters.
- In the present work, we highlight recent work integrating digital camera control and data acquisition in the APS control system. Graphical and programmatic interface tools are outlined. A demonstration of digital camera use for the collection of beam physics data is presented.

## MOTIVATION

- The APS has many cameras used to image the electron beam throughout the accelerator complex.
- Image output from most cameras is NTSC analogue video, from which individual frames are acquired using a DataCube Max Video MV200 system [1,2].
- In many other laboratories, digital cameras are used as part of the suite of accelerator diagnostics.
- In anticipation of future capabilities for data acquisition and control of image data, potential need of a digital camera architecture is foreseen.

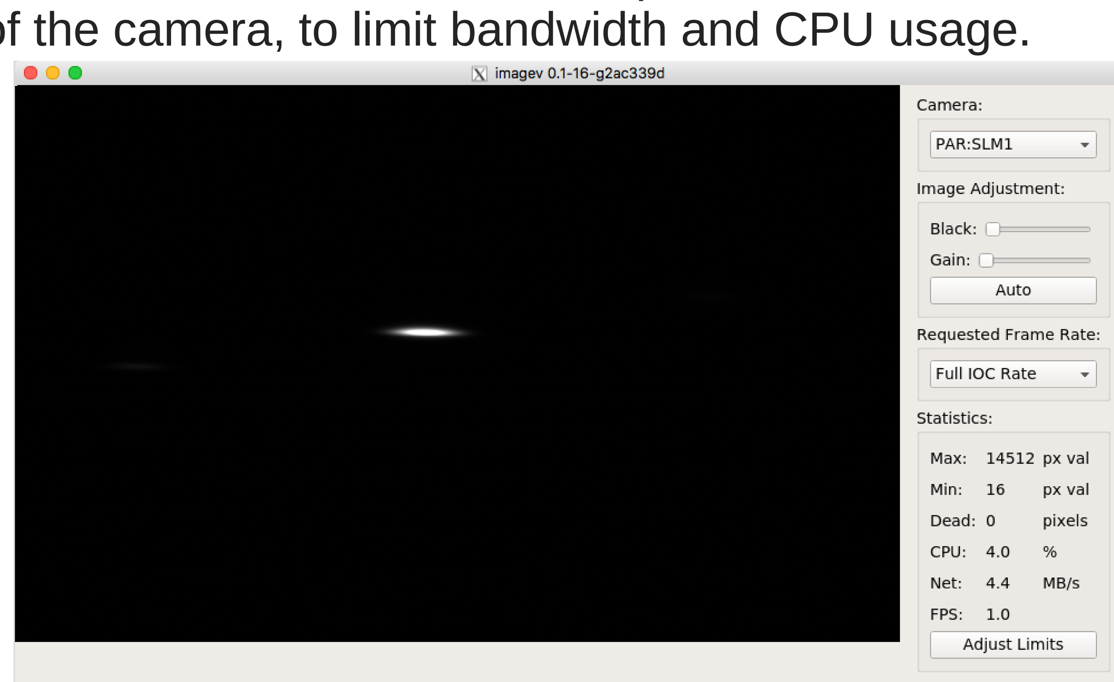
## METHODS

- At present the cameras used are FLIR Point Grey Research Grasshopper3 USB3 cameras.
- USB3 was selected for these locations because the communication protocol supports high frame rate output.
- The cameras are directly connected to soft IOCs running on local personal computers.
- We use `areaDetector` to interface with the cameras [3], primarily as an `EPICS` interface [4].
- In addition, `areaDetector` modules provide initial data processing and analysis before publication as process variables.
- For timing, we use an SRS DG645 digital delay generator

## INTERFACES

### *Graphical*

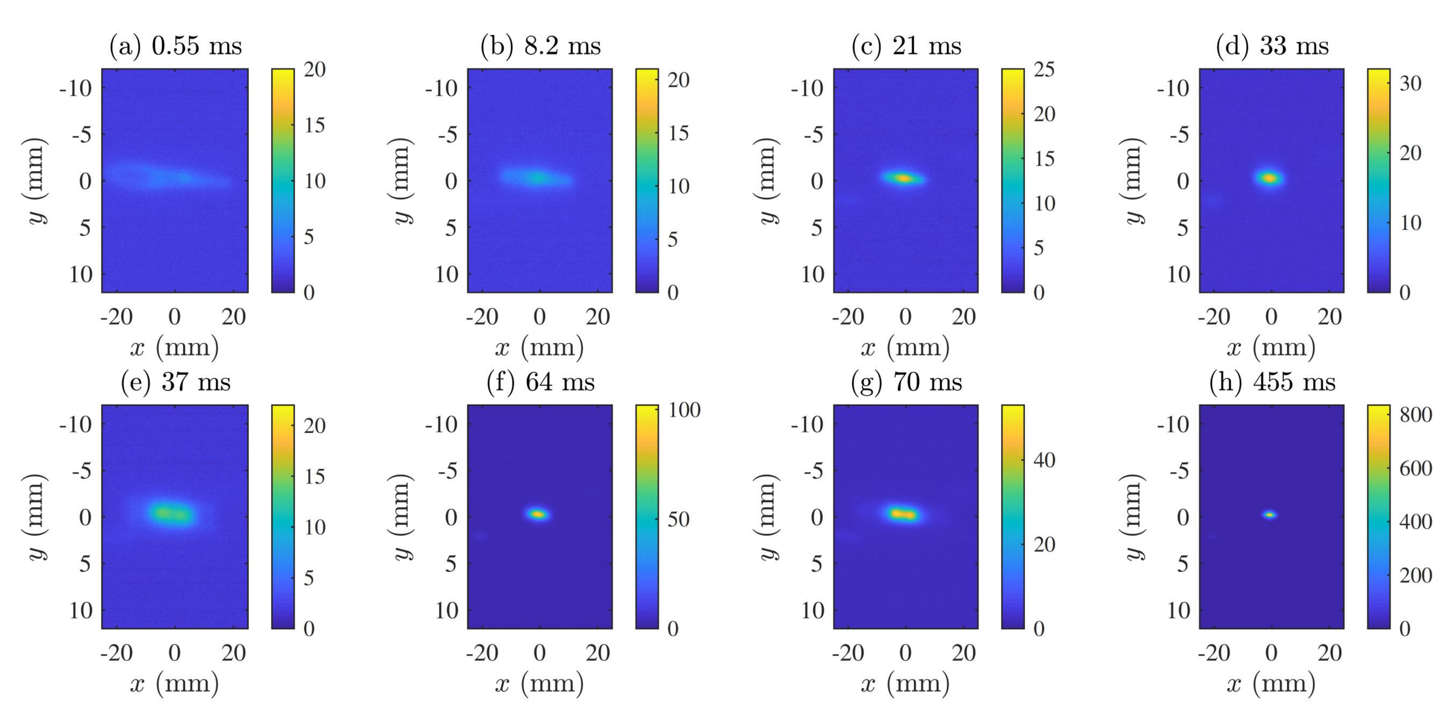
- A Python-based graphical user interface (GUI) has been developed. This makes use of PyEPICS and PVAccess. An example image of the GUI is shown in the figure at right.
- The frame rate of the GUI is separate from the frame rate of the camera, to limit bandwidth and CPU usage.



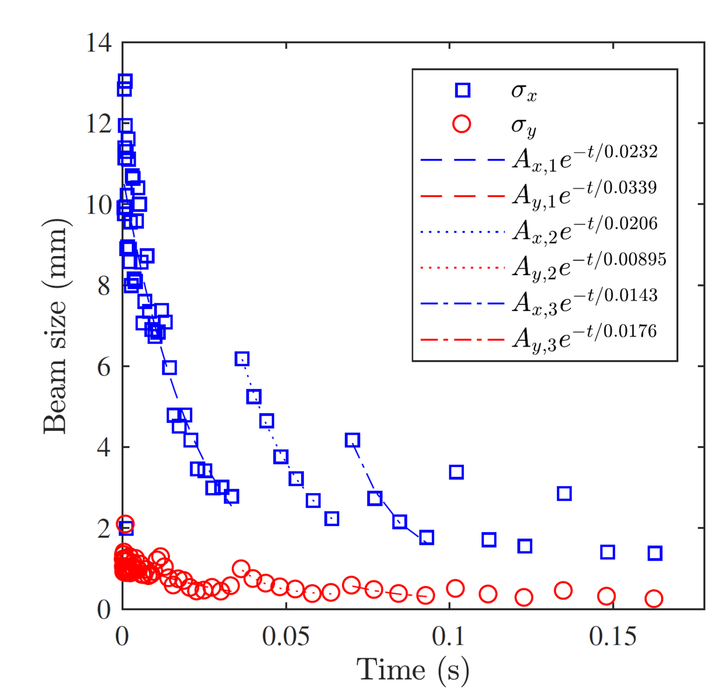
### *Programmatic*

- For programmatic access to digital camera data, a Self-Describing Data Sets (SDDS) function was written called `sddsimagemonitor` [5,6].
- The function provides similar functionality to `sddswmonitor`, optimised for cameras controlled through `areaDetector`.
- Using `sddsimagemonitor` we were able to acquire images using channel access protocol at a high throughput of about 100 FPS with 128 x 128 pixels ROI. This may be useful for specific time-resolved studies.

## MEASURING THE BEAM SIZE IN PAR




Transverse profiles of electron beam distribution acquired with digital camera at the PAR. (a) t = 0:55 ms. Immediately after the first injection of charge from the linac. (b) t = 8:2 ms. Damping of first injection of charge from the linac. (c) t = 21 ms. Damping of first injection of charge from the linac. (d) t = 33 ms. Just before the second injection, the beam distribution is damping. (e) t = 37 ms. Immediately after the second injection into the damping ring. (f) t = 64 ms. Immediately before the third injection into the damping ring. (g) t = 70 ms. Immediately after the third injection into the damping ring. (h) t = 455 ms. After several injections into the damping ring and the transverse emittance has damped to equilibrium.




Measured electron beam RMS horizontal and vertical dimensions in the PAR damping ring. Successive injections into the PAR damping ring occur at 30 Hz (33.3 ms). The damping times in both the horizontal and vertical directions were fitted by fitting successive exponential distributions to the beam size with time after each injection.

- We have used this system successfully to image the electron beam in the Particle Accumulator Ring (PAR) and in the Booster Synchrotron of the APS accelerator complex. An example of the electron beam size measured using the PAR synchrotron light monitor is illustrated above.
- One nice feature of the digital cameras is the 12-bit analogue to digital converter. This allowed the acquisition of all eight images in the above figure on the same intensity scale, without changing neutral density filters sensor exposure time, or gain.
- The acquisition time of the camera was varied using the externally-delayed trigger.
- By varying this, we acquired a sequence of images at different times in the PAR injection cycle, to fit the damping time of the beam size. This is plotted above.

## CONCLUSIONS

- We have demonstrated an implementation of digital cameras for control and data acquisition of the APS accelerators.
- Camera data acquisition and controlled are handled using `areaDetector` and `EPICS`.
- A demonstration of functionality provided by digital cameras in contrast to analogue cameras is given for the electron beam size transverse damping in the PAR damping ring.

## NEXT STEPS

- Using USB3 cameras interfaced to local soft IOCs, we have demonstrated functionality of digital cameras for beam physics measurements that is not presently available with the existing suite of analogue video cameras.
- Prioritise particular imaging locations where the replacement of an analogue camera with a digital camera would provide immediate benefits to operations and physics analysis.
- Cameras may need to be positioned inside the accelerator enclosure. GigE power over ethernet connections to cameras may be more appropriate.

## REFERENCES

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