The Control of X-ray Deformable Mirrors

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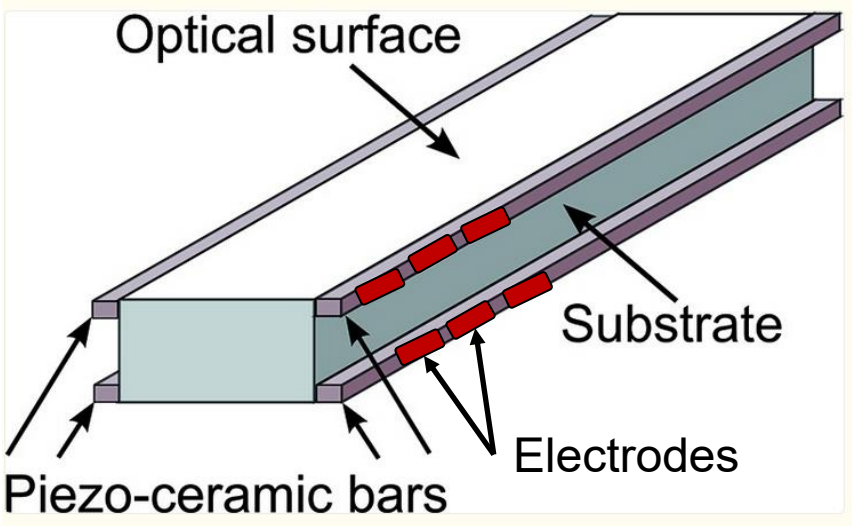
Introduction & Motivation

- Piezo-electric, deformable "bimorph" mirrors are used to focus X-rays at many synchrotrons and XFELS



- Original, older Bimorph Power Supplies, suffered from poor RS-232 communication, locks-ups and EPICS screens going white (disconnecting) while a command executes
- A particular problem was in the commissioning of a mirror when scripts, continually setting voltages and examining the response on the beam shape and size were left running overnight – only to find they'd failed 45 minutes after the scientist had gone home…

The beamline scientists weren't happy...

One night, over drinks, a plan was hatched...

I've found a new power supply!

What about EPICS support?

That's what the software guys are for…

WANTED
DEAD OR ALIVE

New Programmable HV Power Supply

- HV-ADAPTOS from CAEN (based on earlier Elettra model)
- Hardware is from CAEN, the software is from S.RI.Tech (excellent support from Matteo Fusco & Riccardo Signorato)
- Programmable voltages (speed & shape of voltage impulse)

HV Adaptos PSU Back

8-channels per amplifier card, possible 6 cards

HV-Adaptos Power Supply

- Channels can be configured into groups (mirrors) e.g. 16-channels, 8-channels etc
- Ubuntu Linux system underneath, but limited access for the facility
- Special Admin privileges to be able to set:
  - Maximum slew rate (typically more than 100V/s, cf. 10V/s previous PSU)
  - Maximum voltage between neighbouring bimorph electrodes (500V)
  - Maximum absolute voltage (+/-1500V)
- But these parameters depend on, at least:
  - The age of the mirror
  - The way the mirror is mounted
- Being too cavalier can end-up with a broken mirror!
- Set once by an Optics expert and left

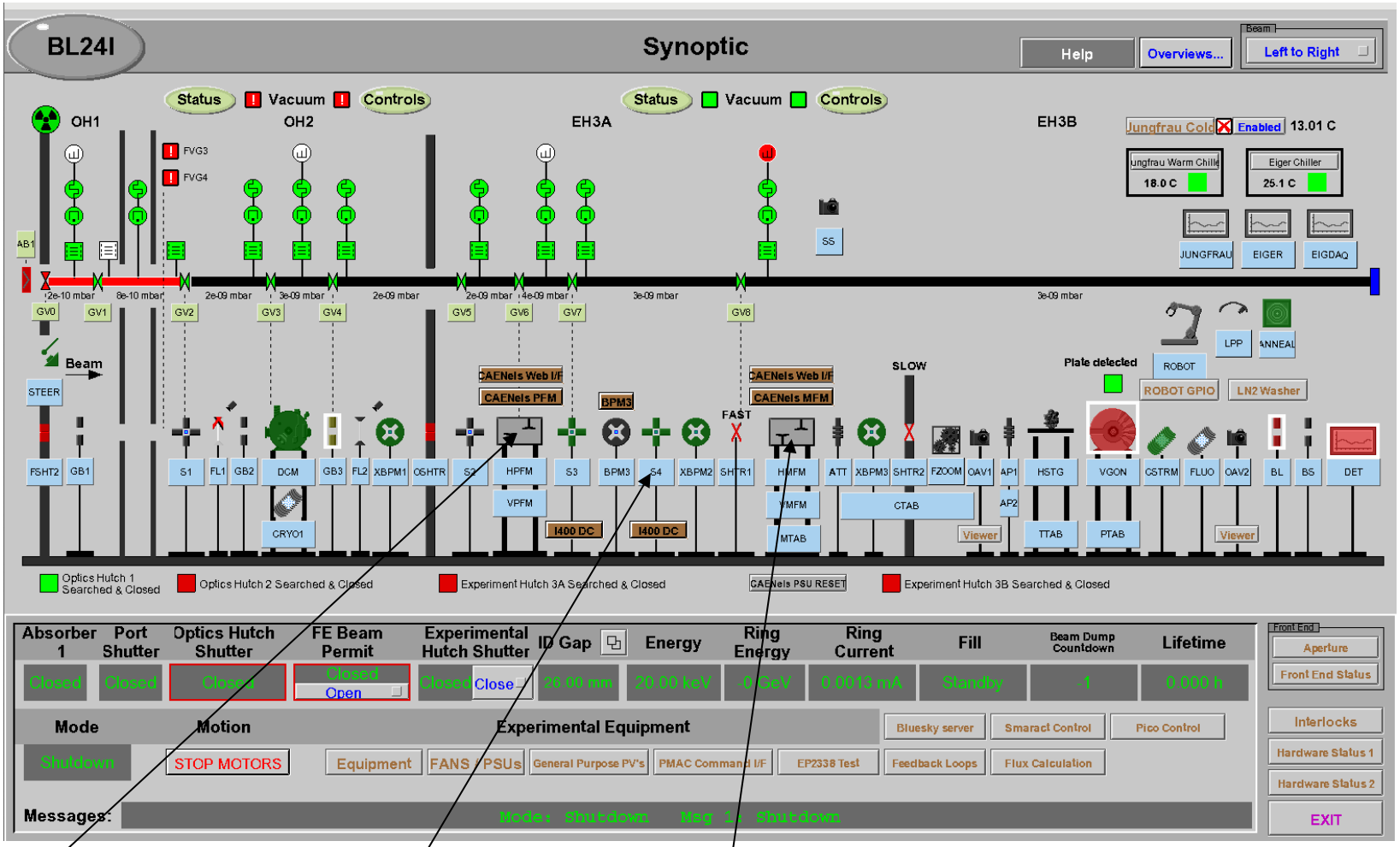
HV-Adaptos Power Supply
Originally, limited EPICS Support

- On-board EPICS IOC – abandoned: “black-box”, didn’t do what we wanted
- Instead, added a feature-rich TCP/IP interface which we can talk to from our own IOC’s
- We have worked closely with Riccardo & Matteo to improve the TCP/IP interface and the reliability of the communication
- Although the TCP/IP interface is simple ASCII commands like:

  “GROUP0:VOUT%d:%f”

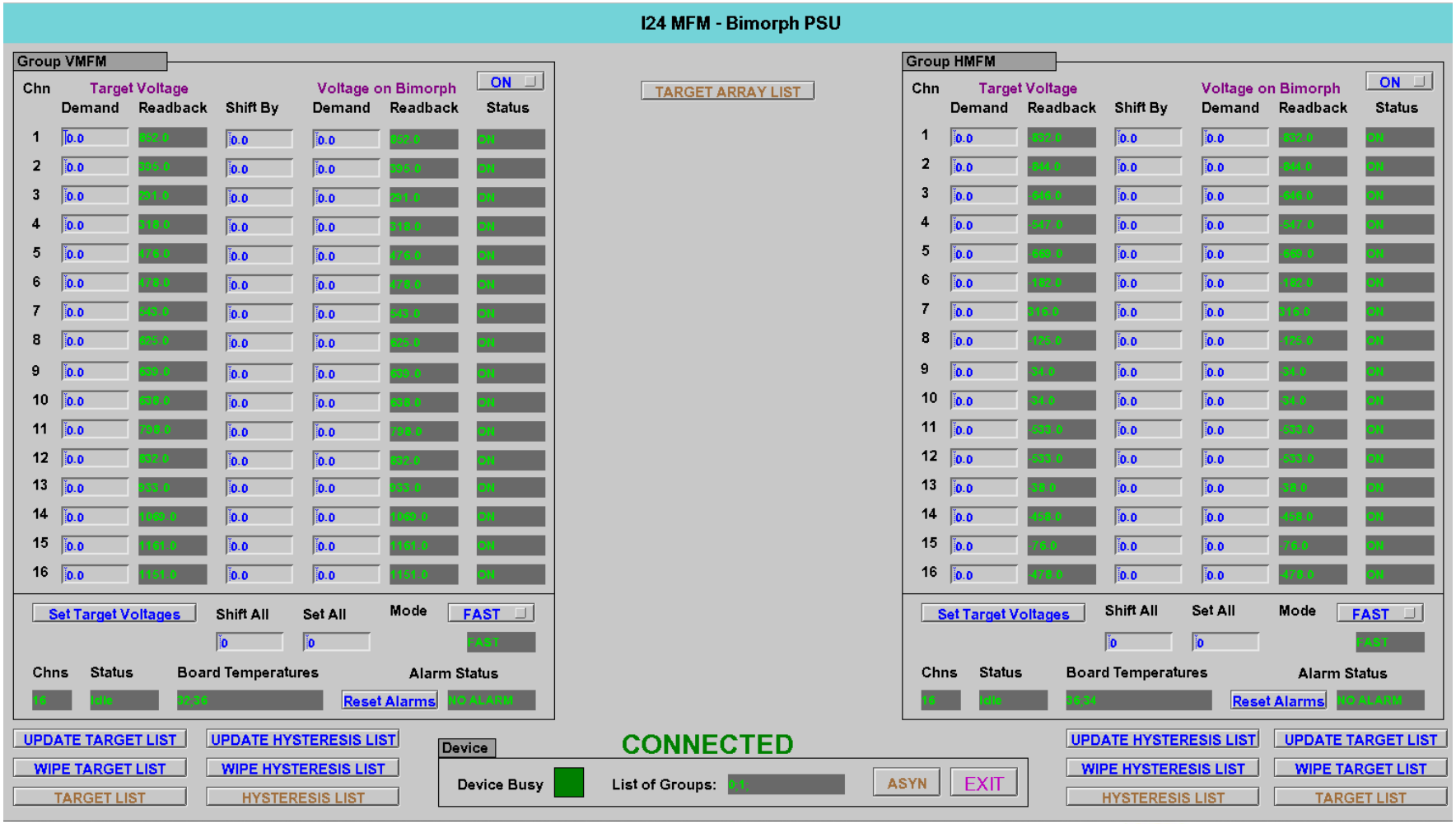
- We opted to write an asynPortDriver instead of using streamDevice for two reasons:
  - Initially there were some communication issues and we wanted to prove it was not at the EPICS level – easier to see what was going on in asynPortDriver code.
  - It was a good learning exercise!

I24 Synoptic (Micro-Focus MX, 10um)



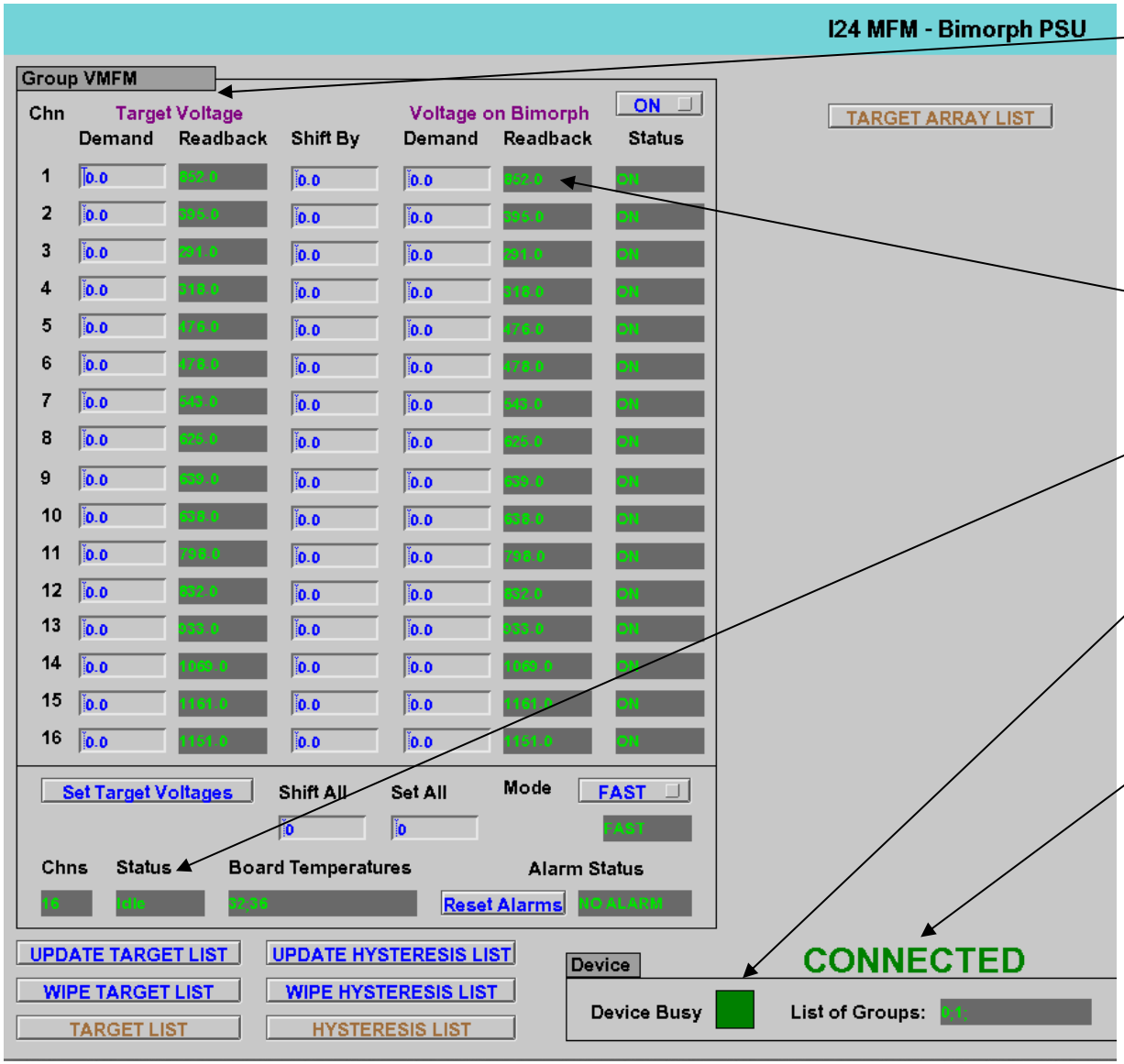
Pre-Focus Mirrors Secondary Source Micro-Focus Mirrors

I24 Micro-Focus Control



Blue – writeable demand
Green – readback value

Zooming in…



Target Voltages are a staging post

These are the voltages on the outputs

Tells us if a mirror is busy

Tells us when the device is busy

Are we still talking to the power supply? Uses ASYN record .CNCT field

Device Busy PV

- The asynPortDriver has a polling task (1 second)
- One of its jobs is to read back the status of each mirror (group) and update the PV's for the state of each mirror
- A CALC record combines the two individual states to give us "Device Busy"
- Using this PV is **crucial** in the way we drive the power supply
  - We don't want to flood the power supply with commands, while it is still busy
  - If we do, commands are lost, voltage settings don't happen
- So, our client code must always look for: IDLE->BUSY->IDLE, after sending each command, and before sending the next command
- Following this paradigm, the communication is rock solid and there are no disconnections

Back to commissioning…

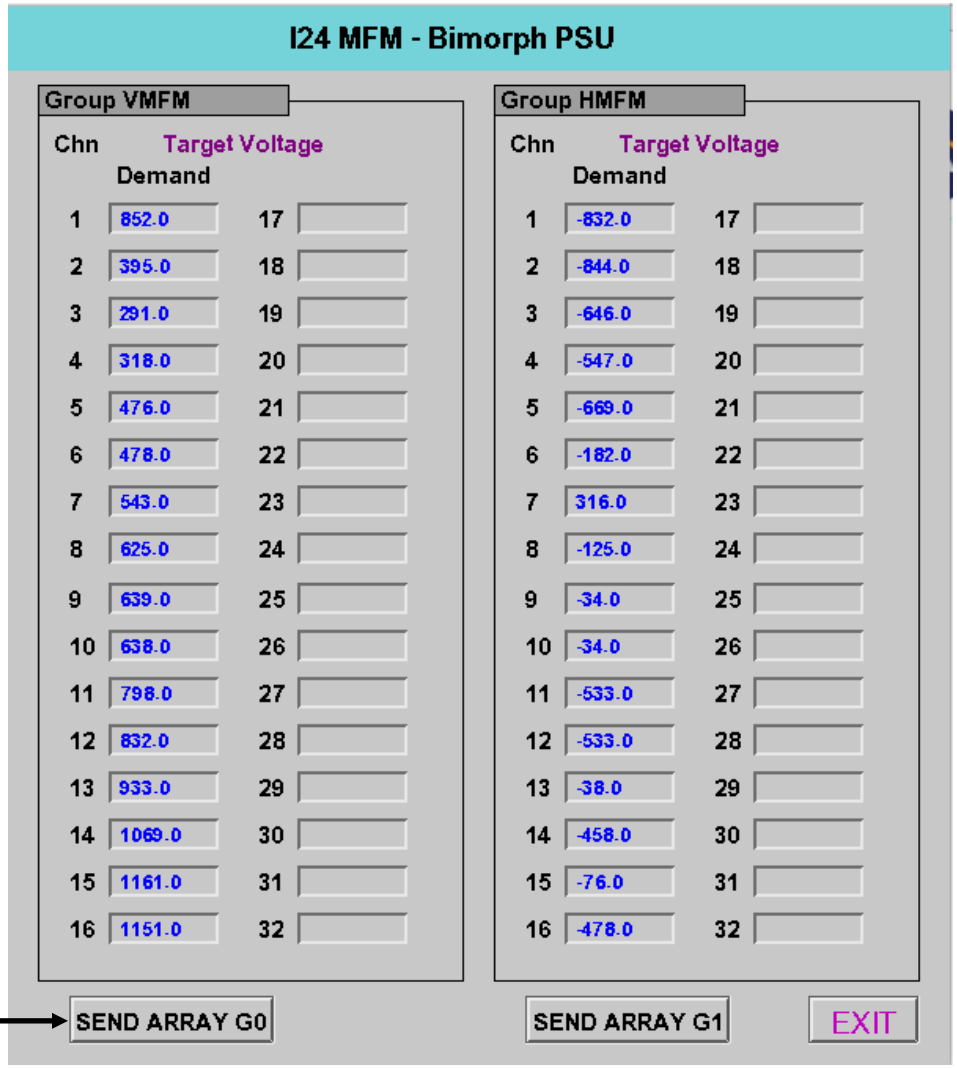
- What happens during commissioning?
  - We set each voltage to a value and make a measurement of the beam off the mirror. This is done multiple times, to generate a response matrix.
  - But that means for every set of voltages, we have to send 16 commands, per mirror, and wait IDLE->BUSY->IDLE for each one - still quite slow…
- Wouldn't it be better if we could send all 16 as an array?
  - That's where the Target Voltages come in!
  - We can send the whole set of Target Voltages to the outputs with a single command ("Set Target Voltages" button on the interface)
  - But, hold on, we still have to set each individual target voltage first, that's 16-commands!!
- At this point…

This thing is still too slow...

...can we make it go quicker?!?

Target Array Command

- The answer is, of course, YES!
- We add another command, which allows us to **set** the target voltages as an array
- We need another set of EPICS records to hold the values. Writing to these does not send a command to the device. They are just “soft” records
- Use ca_put_callback() in the client code, to know when they are all written
- Now send the new command!

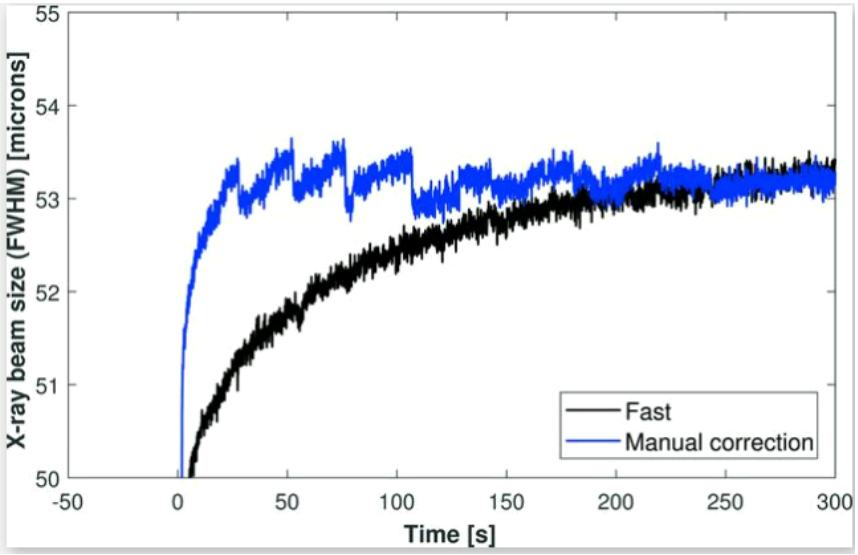


Database logic formats the command and sends it the device

Timings…

- Using the Target Array Command:
  - 500 sets of 32 random voltages on a single mirror: 250 minutes
- Compared to setting output voltages individually:
  - Running the same 500 sets of 32 voltages: 534 minutes
- In continuous running, we have achieved more than 72 hours and never had a problem with lock-ups or communication. We stopped the script at that point.
- Remember where we started from with the old power supplies…
  - Failure after 45 minutes!

More Features



"Dynamic adaptive X-ray optics. Part II. High-speed piezoelectric bimorph deformable Kirkpatrick-Baez mirrors for rapid variation of the 2D size and shape of X-ray beams", S.G. Alcock, I-T. Nistea, R. Signorato, R.L. Owen, D. Axford, J.P. Sutter, A.J. Foster, K. Sawhney. J. Synchrotron Radiat. 26, 45-51 (2019) https://doi.org/10.1107/S1600577518015965

- Piezo creep can be reliably predicted and automatically compensated
- Hysteresis command
- Apply larger target voltage
- Then, automatically apply small voltage offsets as a time series afterwards
- 2-D X-ray beam size changed and stabilised in < 10 seconds!!

- Once we have our sets of commissioned voltages for various foci and beam shape
- Up to 16 sets can be read from a JSON file and made available to EPICS through the "Update Target List" command.
- These can be applied, at will, to change focus etc.

Acknowledgements

- Dr Kawal Sawhney – Diamond, Head of Optics & Metrology
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- Matteo Fusco – CAEN, Software Engineer
- Many Diamond Beamline Scientists… for their patience!

The End

Thanks for your attention!

Time to ride off into the sunset...