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Controlling experiments at Gemini (and EPAC)

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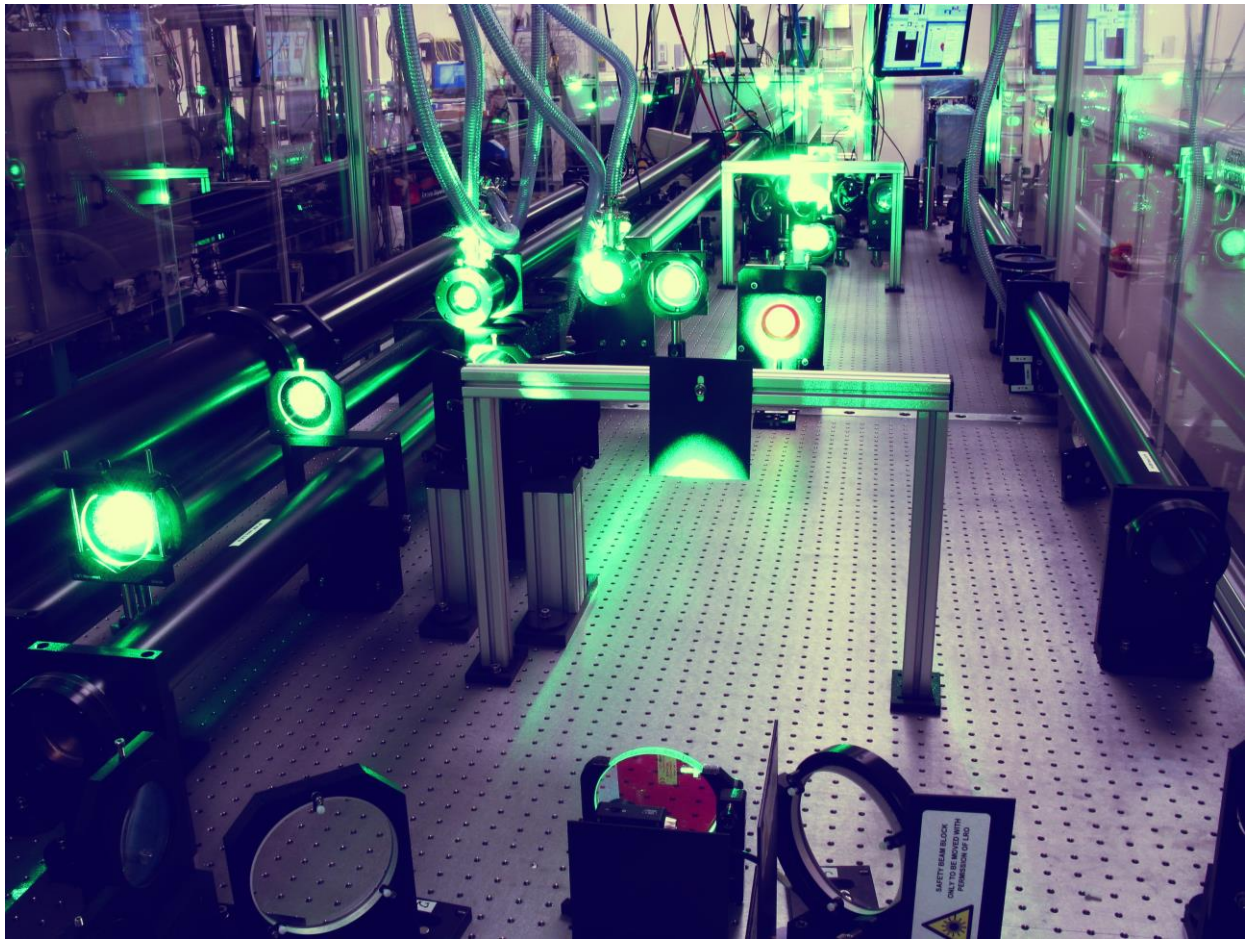
What is Gemini?

Target Area 2
500 mJ in 50 fs
5 Hz

Target Area 3
2×12 J in 40 fs
Every 20 s



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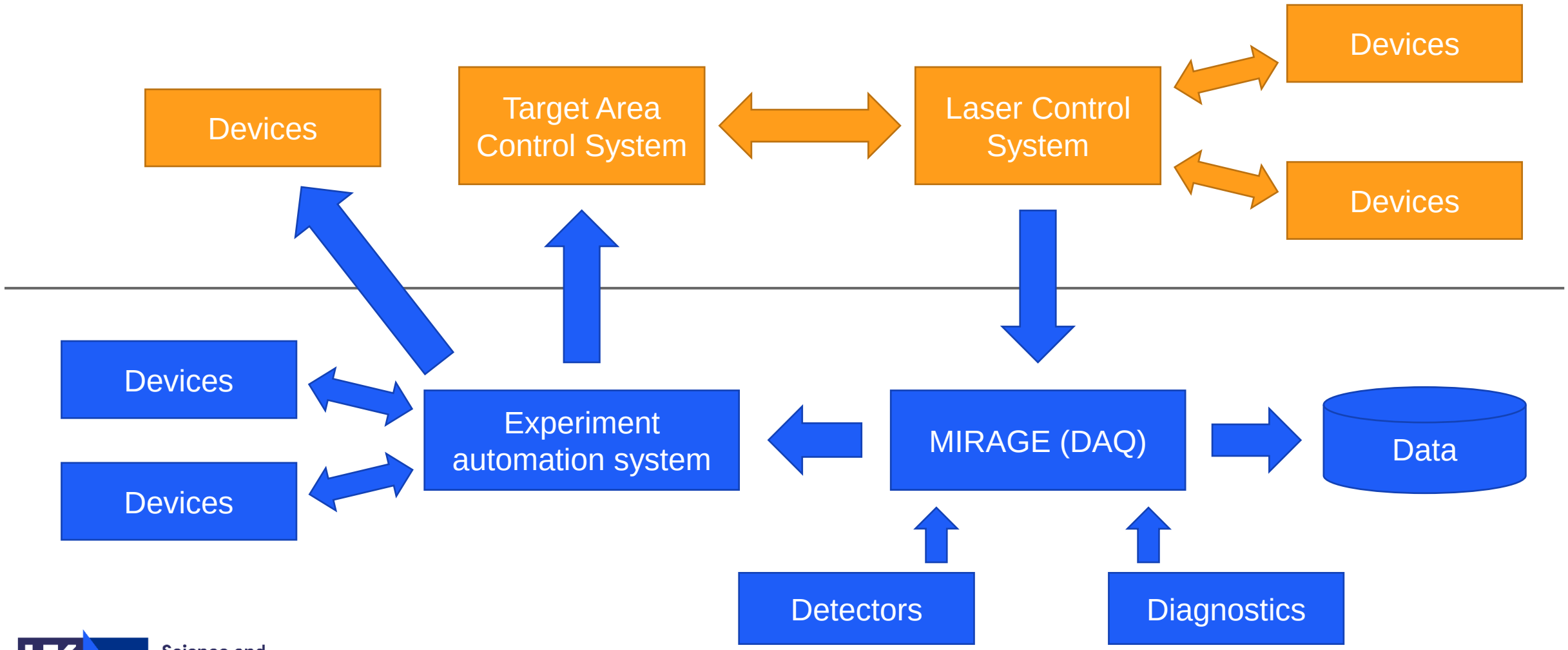
How everything fits together



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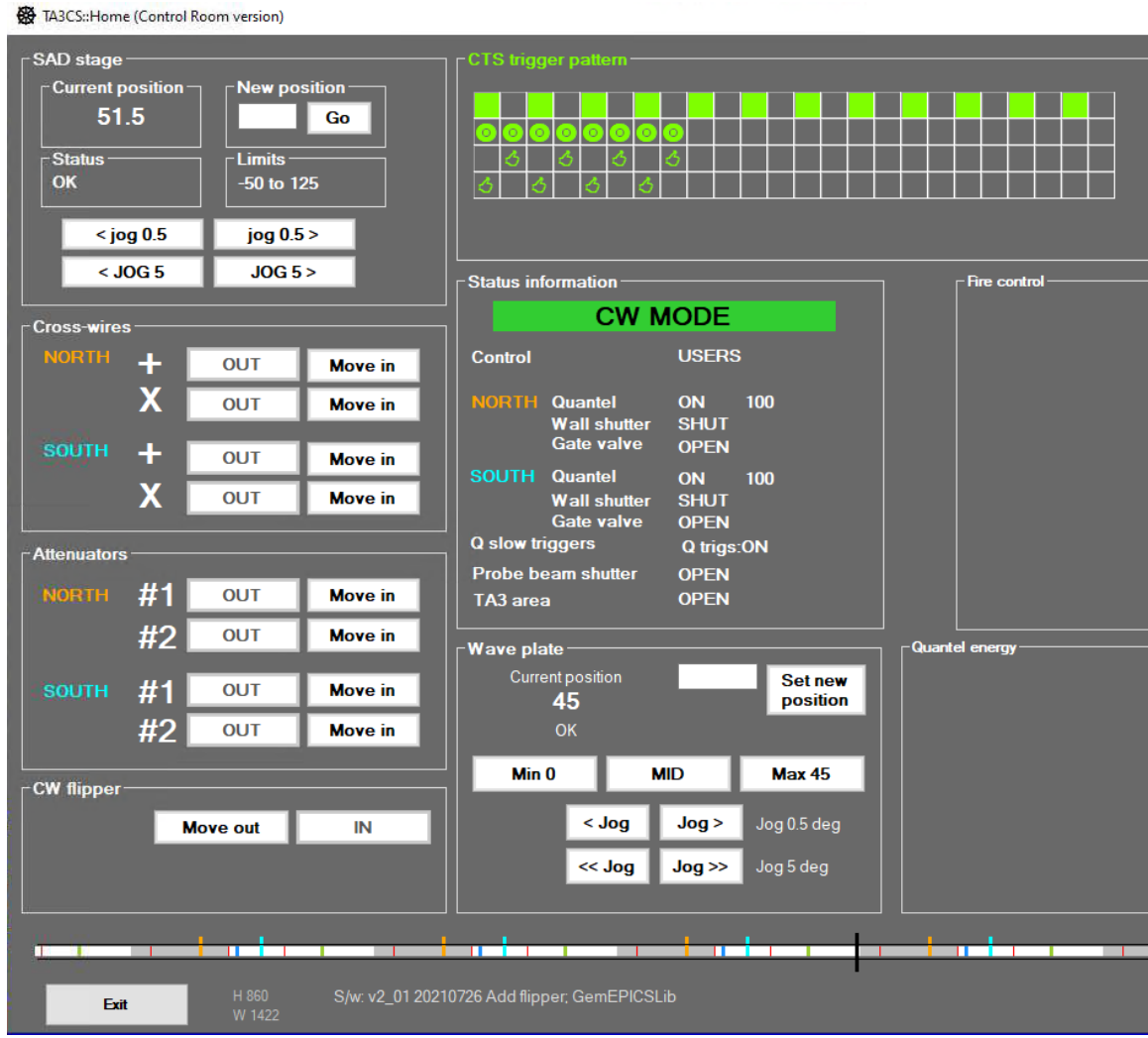
Timeline

2004 – Astra laser controlled “by hand”
2007 – Gemini upgrade: Laser Control System developed in VB6
2011 – Control System taken over by full-time software developer
2017 – Laser Control System rewritten in .NET
2018 – EPICS support added to Laser Control System
2018 – MIRAGE development begins
2019 – MIRAGE used in TA3
2019 – Experiment automation system developed
2020 – Parts of laser data acquisition now on EPICS

Laser Control System

- Originally developed by a laser operator; now one software engineer
- Multiple components with (mostly) EPICS communication
  - Main CS + 1 Laser Area
  - 2 Target Areas + 2 Control Rooms
- Users request shots from the Target Area Control System (see right)
- Laser diagnostics are recorded and saved automatically



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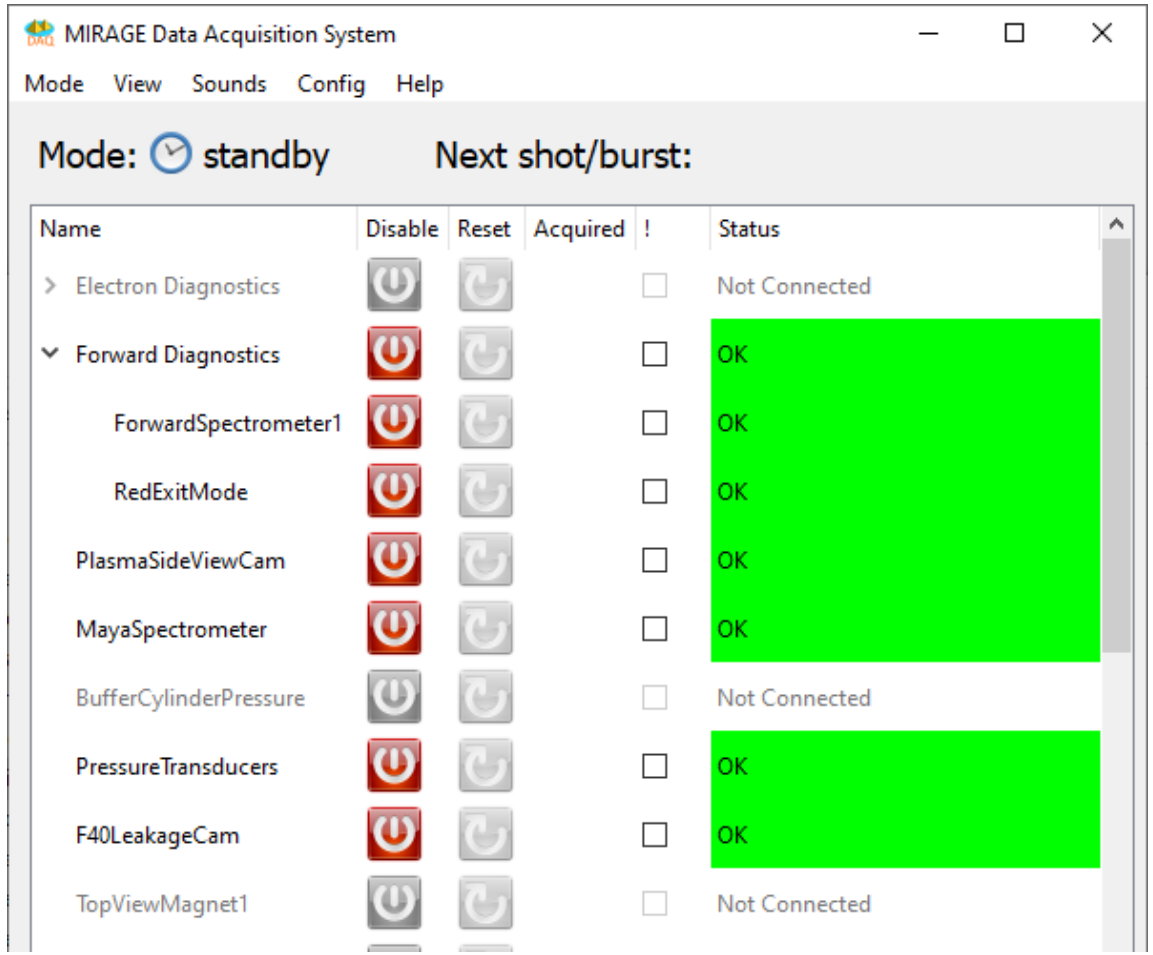
Data Acquisition System – MIRAGE

- Main features:
  - Copy data to central storage
  - Assign run/shot numbers
  - Display status
- Extra capabilities:
  - Test diagnostic operation
  - Real-time plots of data
- Works with autosave folders or EPICS PVs



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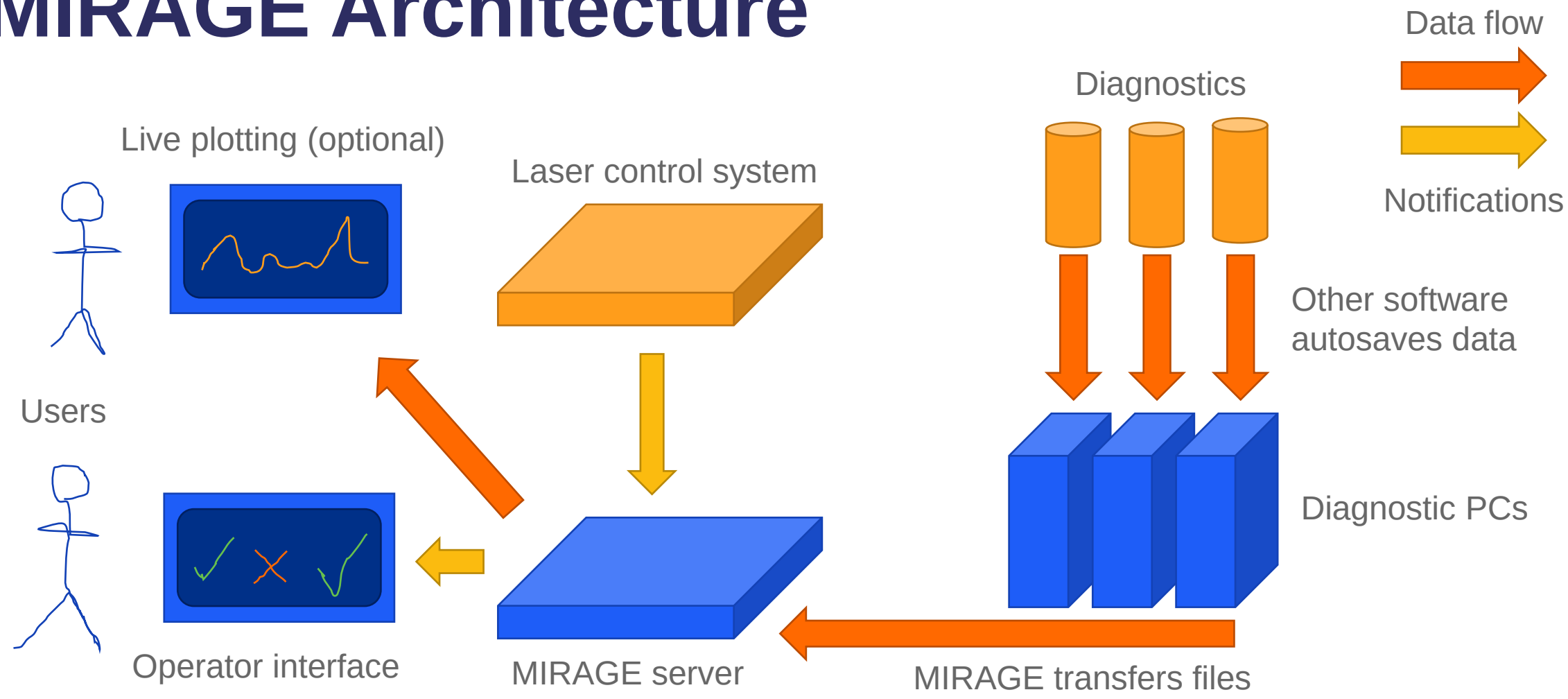
MIRAGE Architecture



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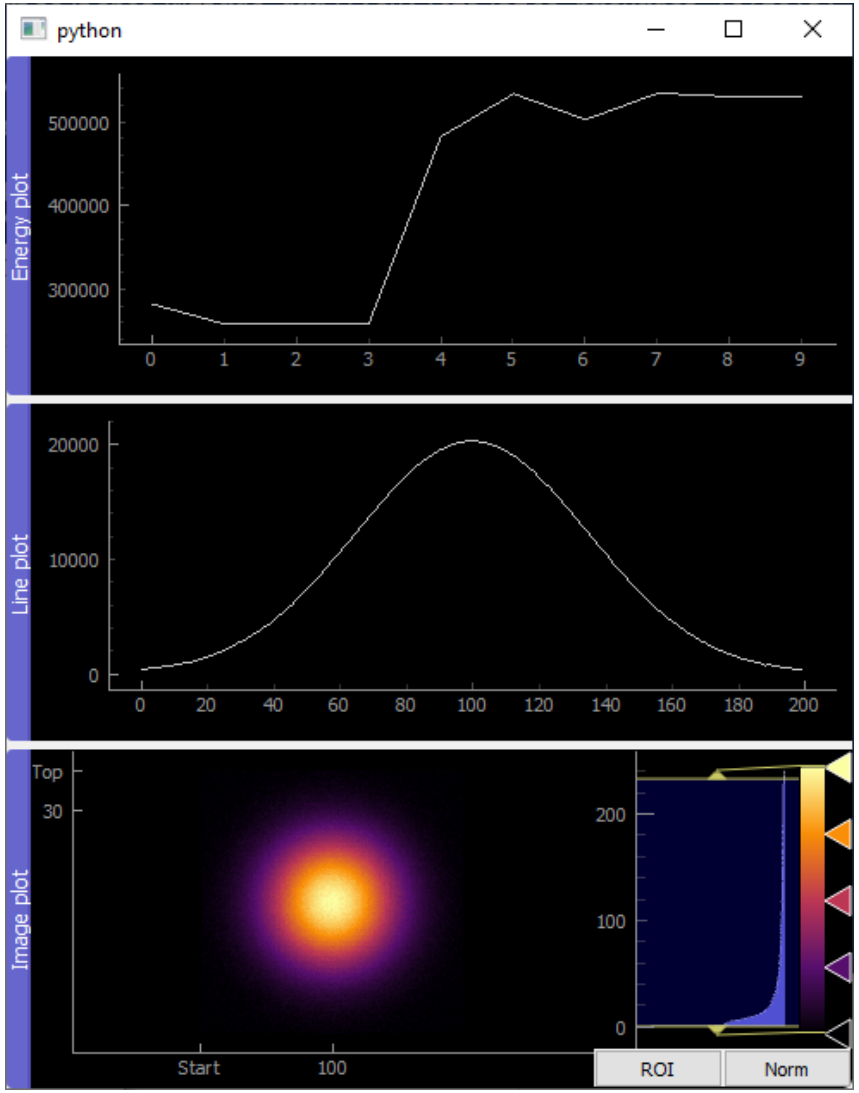
Live plotting with MIRAGE

- Connects to MIRAGE to grab data live
- New plots added by editing a script
- Data can be processed before being plotted

History plots

Line plots

Images



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Experiment automation system

Configurable “workspace” of devices to control

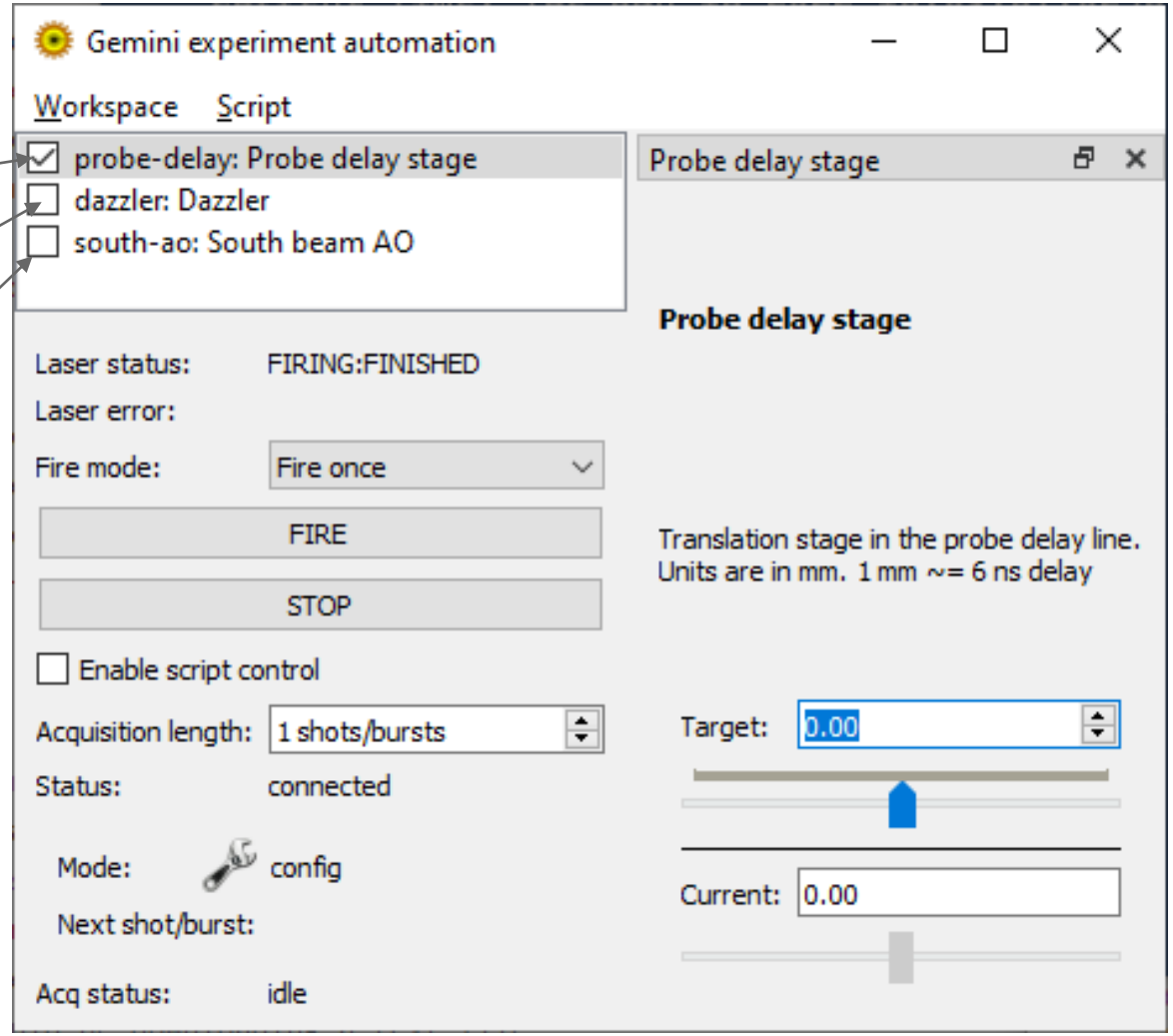
Drive system

Dazzler (pulse length)

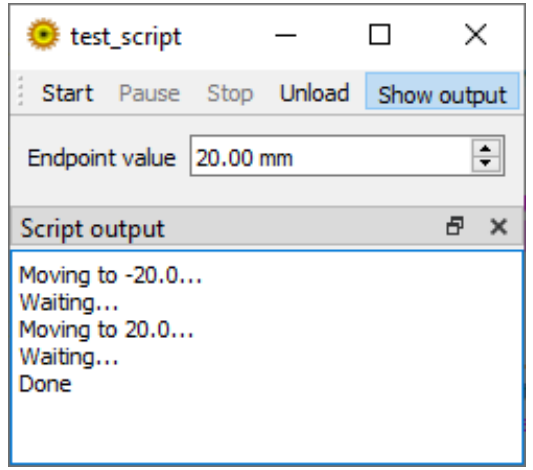
AO/deformable mirror

Integration with laser control system

Integration with MIRAGE



Devices can be controlled manually or used from Python scripts



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Scripting features

```
gui_widgets = [
        DecimalControl('focus_start', 'Starting focus', -2.5, 2.5,value=-2.5),
        DecimalControl('focus_stop', 'Stopping focus', -2.5, 2.5,value=2.5),
        IntegerControl('focus_steps', 'Number of steps', 2, 100,value=int(11)),
        ]

def main(focus_start, focus_stop, focus_steps):
    ao = AoHelper(get_component('ao').get_interface(DeformableMirror))
    laser = get_laser_interface()

    run_name = laser.next_run_name()
    logfile = resume_logging(f'focusScan_{run_name.replace("/","_")}.txt')
    logfile.add_header('run burst focus')

    n_bursts = focus_steps
    burst_counter = 0

    for focus in np.linspace(focus_start, focus_stop, focus_steps, endpoint=True):
        print('Set focus term to', focus)
        ao.set_focus(focus).wait()
        burst_counter += 1

        logfile.log(f'{laser.next_run_name()} {laser.next_shot_number()} {focus}')

        print('Waiting for shot.....')
        laser.acquire_data()

        print(run_name, '/', shot, f'complete ({burst_counter}/{n_bursts})')
```

Graphical widgets to set script parameters

Custom log files for important data
Source code and parameters are logged automatically

Simple control of experimental equipment

Integration with laser control system

Messages printed to screen are logged automatically

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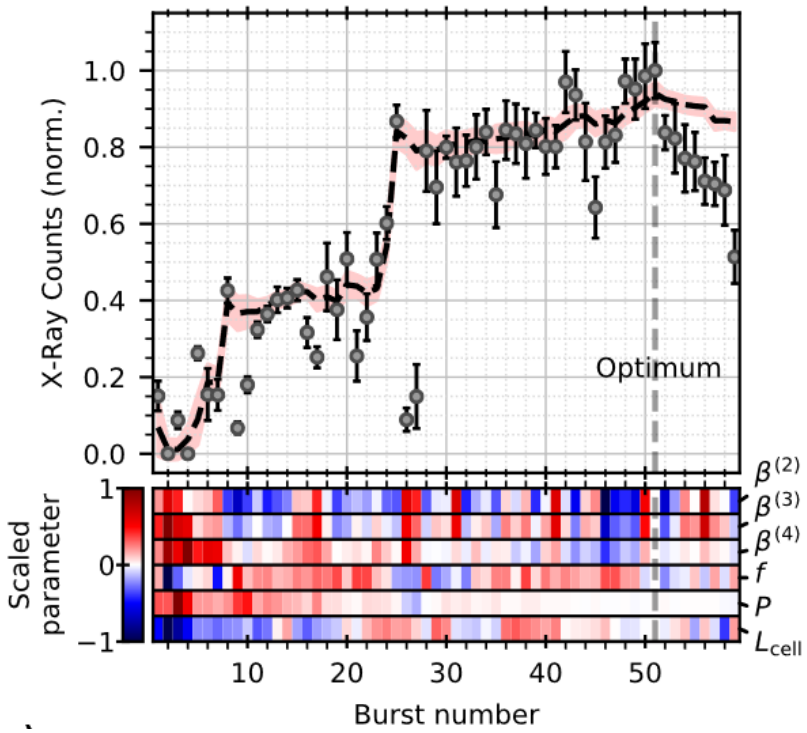
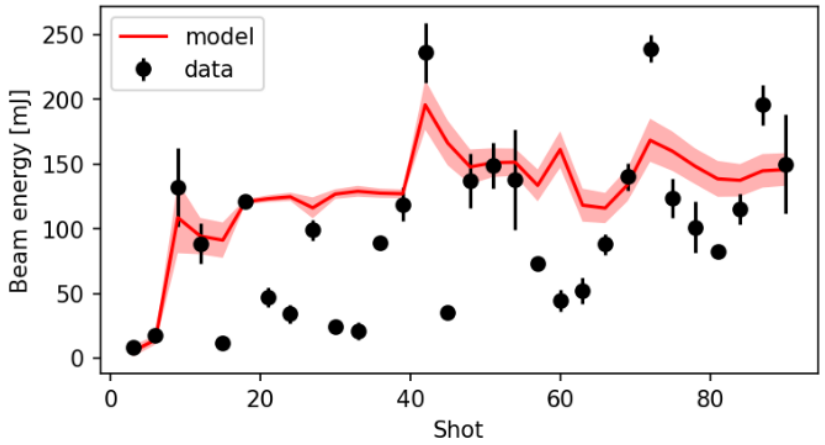
Achievements

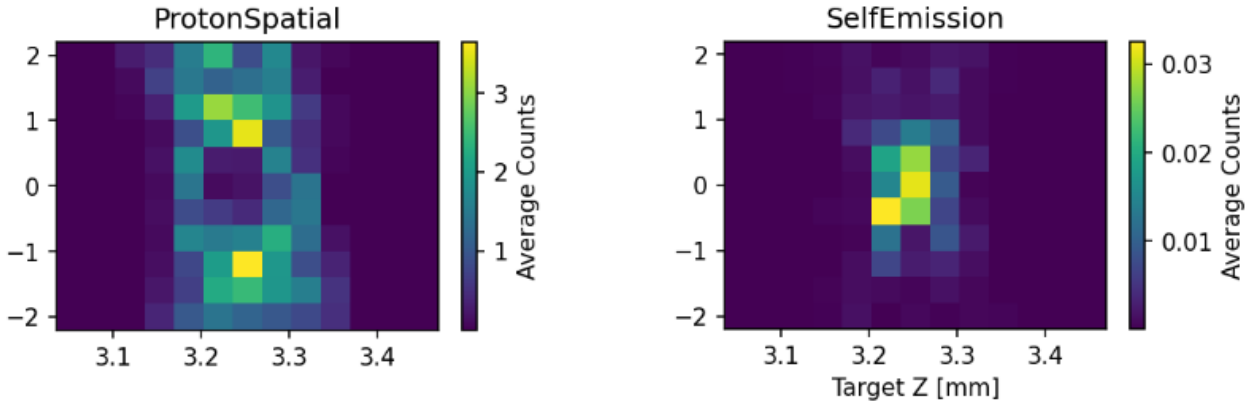
TA2: automatically optimising Betatron x-ray flux [1]





↑**TA3:** automatically optimising LWFA [2]

↓**TA2:** grid scans from a solid-target experiment [3]



[1] R. J. Shalloo et al, *Nature Comms.* **11** 6355 (2020)
[2] Unpublished, courtesy M. J. V. Streeter
[3] Unpublished, courtesy C. A. J. Palmer

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Data Analysis as a Service

DAaaS group

We developed DAaaS, a cloud-based data analysis platform, which enables scientists to access a virtual environment powered by STFC Cloud via a web browser.

DAaaS Platform is available to CLF scientists since October 2021.

- Anaconda
- Fiji (ImageJ)
- Jupyterlab from Anaconda
- Jupyter notebook from Anaconda
- Matlab 2020b

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DAaaS stories: https://www.scd.stfc.ac.uk/Pages/Dynamic-Infrastructure-Group.aspx

Extreme Photonics Application Centre (EPAC)

Funded by UK government strategic priorities fund

Facility exploiting CLF's proprietary DiPOLE technology *for academic, industry and security users*

D100 laser pumping a Ti:S amplifier, with an OPCPA front-end

30 J, 30 fs, 10 Hz

Online in 2024

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EPAC Control System

- Developed by the Controls Group at CLF
- Hardware controlled through EPICS
- Local and remote control for laser operators
- Higher levels are not on EPICS
- Automation system provides logic for the laser as a whole
- Machine protection system prevents equipment damage
  - Separate from personnel safety system

Data Acquisition and Management

- Most data acquired through **EPICS**, including **AreaDetector**
- Acquired data is sent to an **Apache Kafka** message queue
- Data read out of message queue and written to **HDF5** files
- Files stored on common platform for all STFC facilities

Decouple data producers, transformers, and consumers

Common data format makes it easier to add new tools

Experiment Orchestrator

- Allow users to run **simple** and **complex** experiments
- Interact with **control** system and **data management** system
- Currently planning to base it on **Bluesky**

Plans written in Python

Support for **adaptive** experiments

Integration with data storage, analysis, plotting

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Thanks for watching