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JAGIELLONIAN UNIVERSITY IN KRAKÓW

Automation of experiments on the SOLARIS beamlines with the Tango ecosystem

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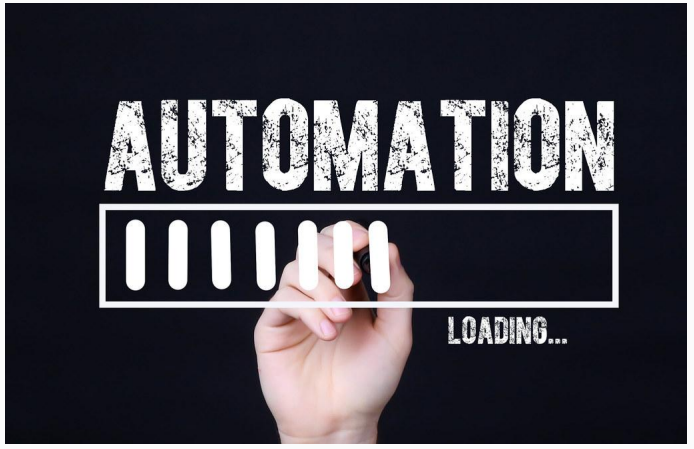
Automation

- *if an idea can be translated into a list of mechanical steps, it can be performed more efficiently by machines,*
- *human beings are bound to make mistakes while carrying out a long list of boring, iterative, mechanical steps over and over again,*
- repetitive actions for beamline commissioning, preparation for experiments or the experiment itself can be easily automated
- one of our key direction in software development is to **make user's life easier by automation**
- beamline managers report to us with ideas for the automation for their daily actions



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Agenda

- Automatic monochromator - insertion device movement
- Automatic mirrors position correction using PID controller
- Automatic beam quality assessment during scans

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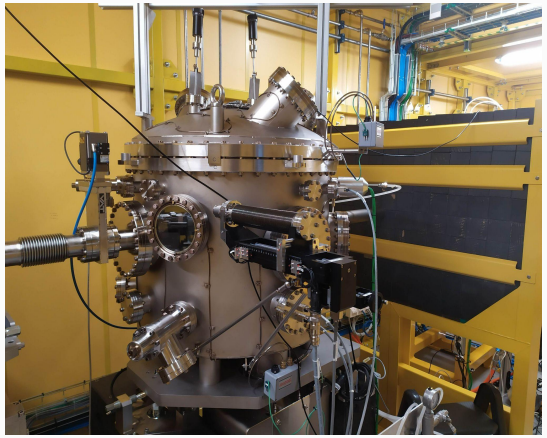
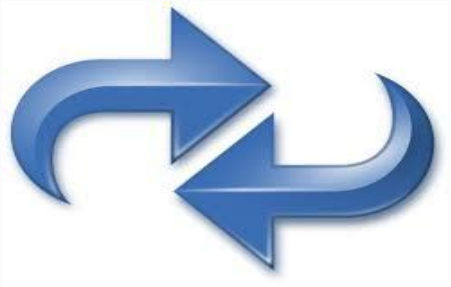
Automatic monochromator - insertion device movement

- experiments for ID beamlines (in SOLARIS only undulators for now) require combined insertion device movement to get best intensity for the consecutive harmonics
- when changing the energy, the undulator automatically should go to the GAP and PHASE values to be at the maximum of one of the selected spectrum peaks





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Features

- ID following monochromator movements (GAP and PHASE movement)
- support for different harmonics
- support for different polarisations
  - linear
    - horizontal
    - vertical
  - non-linear
    - circular
    - elliptical
- deadband - minimal difference between points for device to move
- possibility to disable combined movement
- offsets to the calculated positions - for source drifts

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Situation

monochromators' *Energy* already implemented in Sardana as pseudomotor (moving mirror and grating pitch motors); gap and phase controlled by attributes/commands in dedicated DeviceServer)

Idea

implement *gap* and *phase* as motors and keep the movement logic in Energy's *pseudomotorcontroller* class

Problem

undulator @ Solaris are not controlled by IcePAPs but by embedded software and PLC provided by producer - no reliable status flag, simultaneous gap and phase movement requires the use of a special command in the PLC

Solution

- *gap* and *phase* as motors in Sardana from Tango Attributes using modified *TangoAttributeMotorController* class
  - some tricks with the status - combination of several conditions (flag from the PLC, last status, difference between current pos and setpoint …)
  - tune timeout conditions as ID's software is sometime rejecting commands
- Undulator's DeviceServer modified to force it to use dedicated asynchronous command for combined movement
- movement logic in Energy's *pseudomotorcontroller* class
  - gap and phase motors as physical

Data format

- ID position calculation accuracy: error less than 2-5 um.
  - for the first harmonics, the movement can be less strict (it can be even 10-20 um), for the higher harmonics - higher requirements.
- The data for LUT is 30-60 reference points (depending on the range of application of a given harmonic) stored in the CSV files.
- Calculation of the position based on the LUT using a 3rd degree polynomial from 5 neighboring points
- About 20 dependencies will be determined for one harmonic (for a solid phase giving a linear polarization rotation every 10 degrees, from 0 to 180) - plus two circular / elliptical polarizations.

Final architecture

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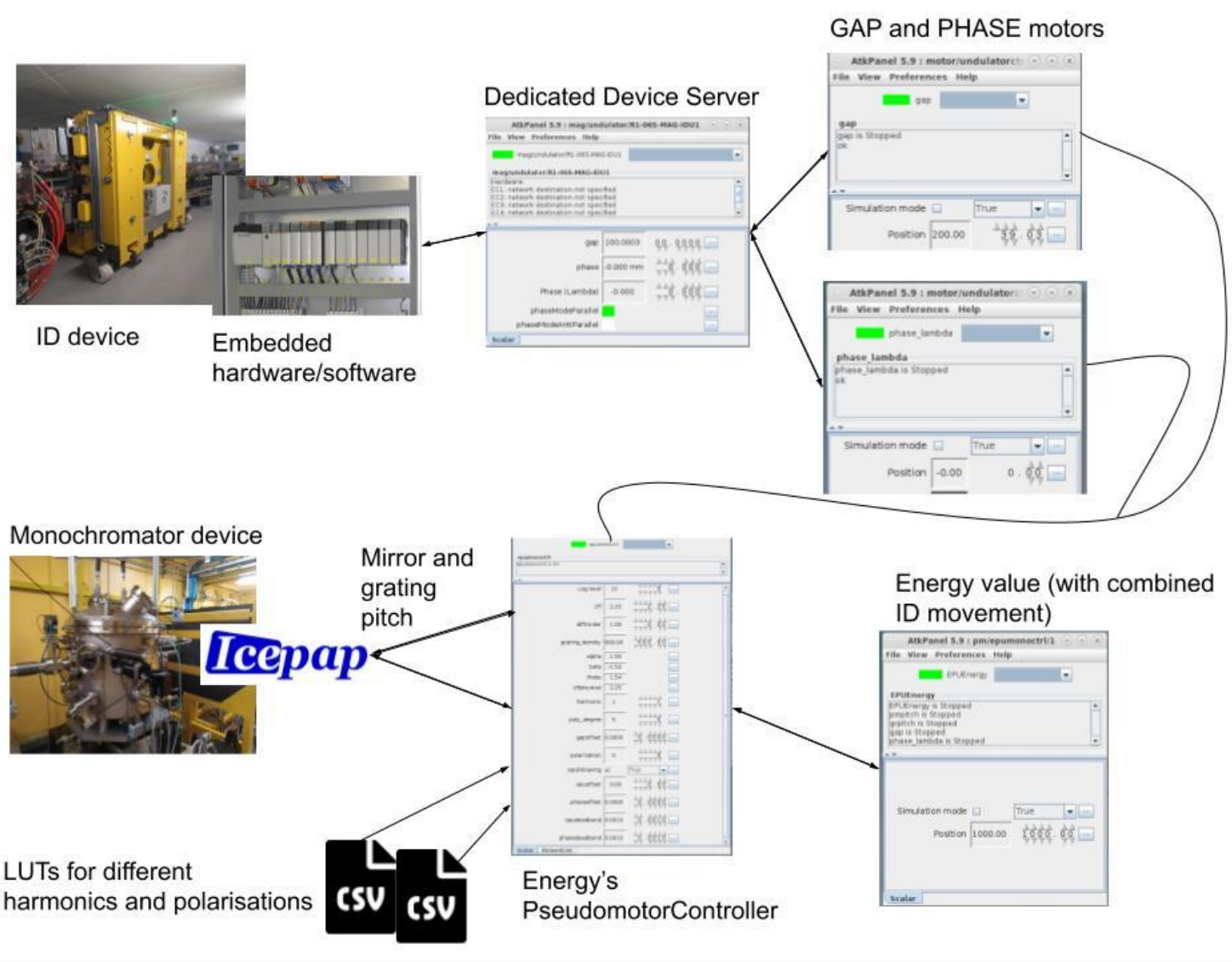

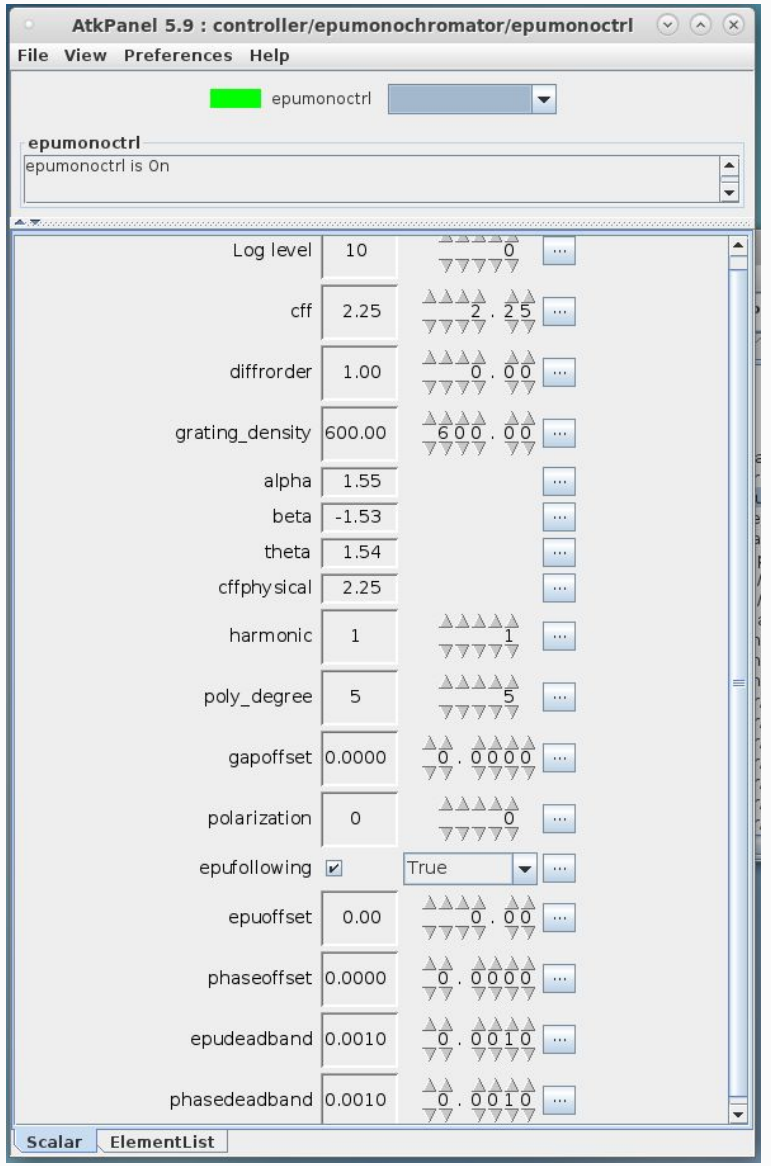

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TODOs

- nice GUI
- user-friendly way of modifying LUTs
- new ideas for beamlines
  - automatic harmonics selection
  - ….
- in the future use IcePAPs for ID devices

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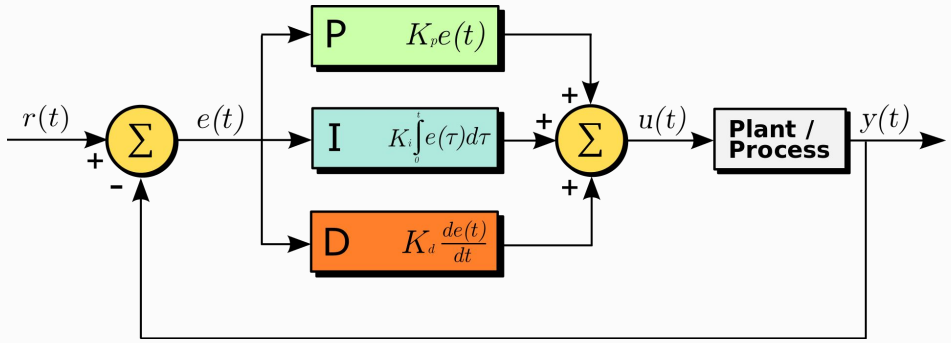
Automatic mirrors position correction using PID controller

- idea is to automatically correct the beam coming out of the mirror
- reason: imperfect optics



proportional–integral–derivative controller

Goal

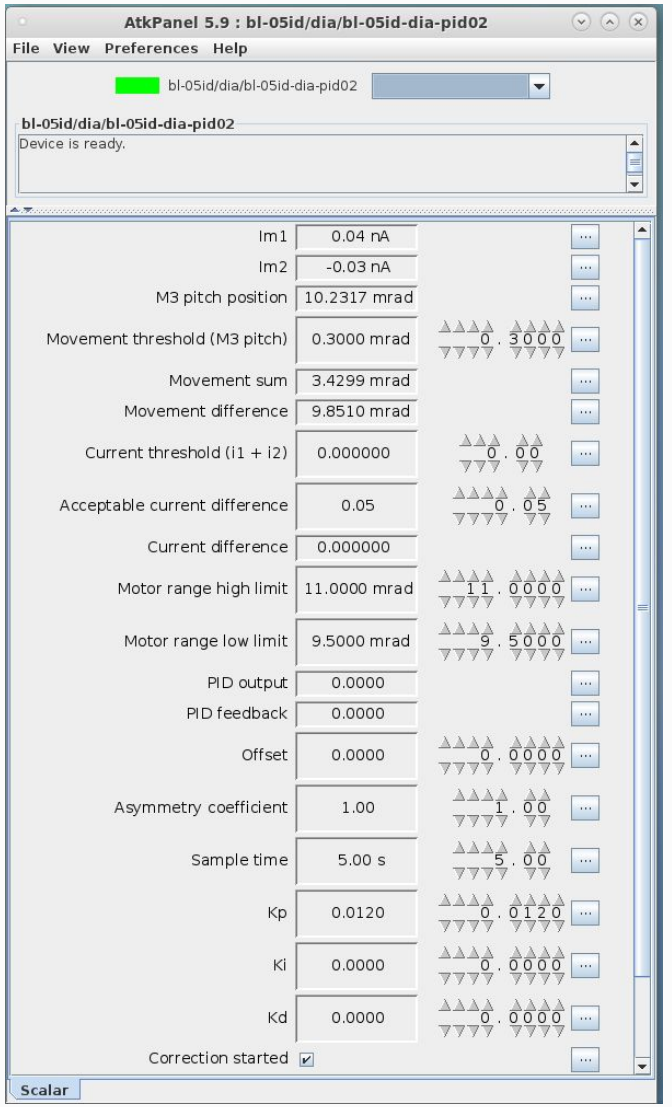
control mirror motors to keep the beam in the specified point on the mirror (usually in the center)

Details

- currently using only Proportional and Integral part
- PV used: Keithley Picoammeter readings from two blades
- goal: we want current on those blades to be even
- e(t) definition:

$$e(t) = \frac{I_1(t) - I_2(t)}{I_1(t) + I_2(t)}$$

- asyncio implementation (asynchronous reading from ammeters and motor)



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Automatic BeamQuality assessment

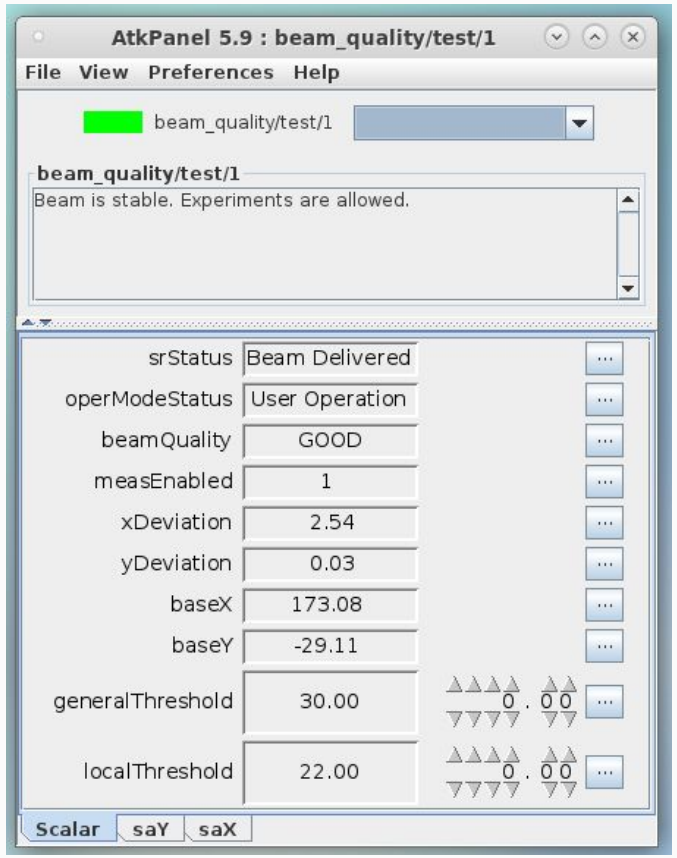
- originated from the need that scans/experiments should automatically stop/pause when the beam is noisy or lost
- as the vast majority of scans is done by Sardana suite, solution is based on it

Solution

- together with Operators find out what exactly does a noisy beam mean and how can it be mathematically determined
- prepare a *FacadeDevice* to assess conditions and return flag meaning the quality
- later use general hooks (invoke a macro) in Sardana (pre-acq hook) to check the flag before each acquisition
- the tool should not significantly affect the times of scans

Details

- X and Y planes of beam position from BPM are monitored
- each is gathered in 30s moving window
- two conditions
  - global (which is static - depending on the BPM)
  - local (dynamically calculated deviation from the mean in a time window)
- accelerator's state machine is taken into account
- hysteresis to change the flag



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```
Door_devel_1 [30]: %beam_check_set
Defining general hook
beam_quality
BeamQuality pre-acquisition hook set

Door_devel_1 [31]: lsgh
   Hook place        Hook(s)
 ------------ --------------
      pre-acq   beam_quality

Door_devel_1 [32]: ascan mot01 0 10 10 0.2
ScanDir is not defined. This operation will not be stored persistently. Use "expconf" or "newfile" to configure data storage
 eventually "senv ScanDir <abs directory>")
Scan #9 started at Mon Jun 27 18:33:42 2022. It will take at least 0:00:11.144272
 #Pt No    mot01      ct01      ct02      ct03      ct04       dt
   0         0        0.2       0.4       0.6       0.8     0.0927489
   1         1        0.2       0.4       0.6       0.8     1.32741
Beam is not stable. Oscillations are above the limit
Scan paused at Mon Jun 27 18:33:44 2022...
Scan resumed at Mon Jun 27 18:34:14 2022...
   2         2        0.2       0.4       0.6       0.8     2.52373
   3         3        0.2       0.4       0.6       0.8     33.8166
   4         4        0.2       0.4       0.6       0.8     35.0391
   5         5        0.2       0.4       0.6       0.8      36.232
   6         6        0.2       0.4       0.6       0.8     37.3919
   7         7        0.2       0.4       0.6       0.8      38.599
   8         8        0.2       0.4       0.6       0.8     39.8224
   9         9        0.2       0.4       0.6       0.8     41.0311
   10        10       0.2       0.4       0.6       0.8     42.2164
Scan #9 ended at Mon Jun 27 18:34:24 2022, taking 0:00:42.471229. Dead time 94.7% (setup time 0.1%, motion dead time 22.2%)

Door_devel_1 [33]: %beam_check_unset
Hook beam_quality is undefineed
BeamQuality pre-acquisition hook removed

Door_devel_1 [34]:
```

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TODOs

- use more BPM’s
- other metrics? mean square error (MSE)?
- use it in non-Sardana systems (i.e on end-stations)

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Thank you

for your attention

Questions?

https://synchrotron.uj.edu.pl/en_GB/start

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