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RADIATION CENTRE



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Automation of experiments on the SOLARIS beamlines with the Tango ecosystem

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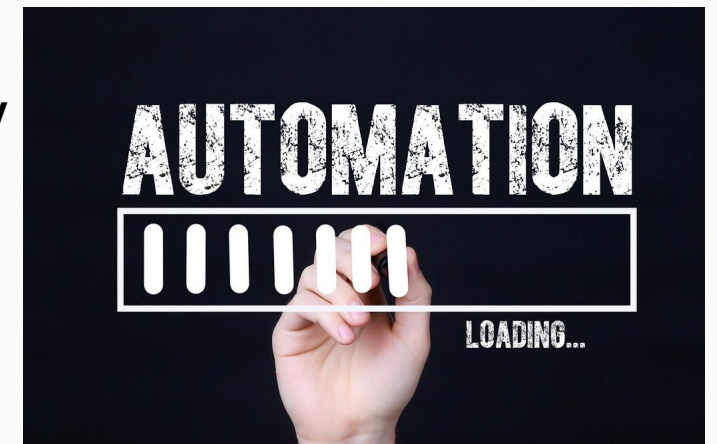
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Automation

- *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

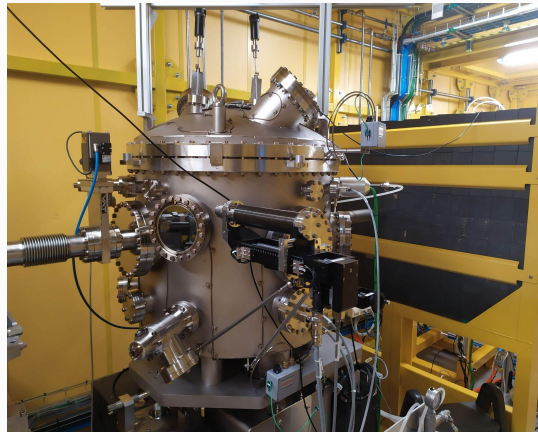




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Automatic monochromator - insertion device movement

- 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





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 μm .
 - for the first harmonics, the movement can be less strict (it can be even 10-20 μm), 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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ID device

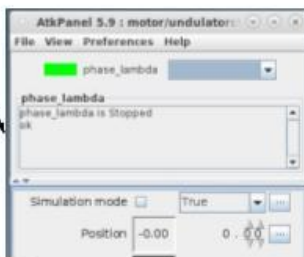
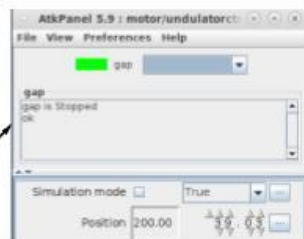


Embedded hardware/software

Dedicated Device Server



GAP and PHASE motors

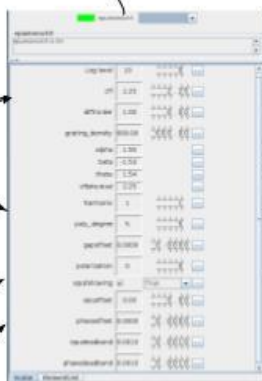


Monochromator device

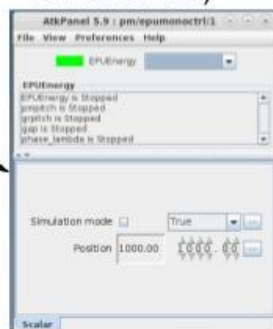


Icepap

Mirror and grating pitch



Energy value (with combined ID movement)



LUTs for different harmonics and polarisations



Energy's PseudomotorController

AtkPanel 5.9 : controller/epumonochromator/epumonoctrl

File View Preferences Help

epumonoctrl

epumonoctrl is On

Log level	10	0
cff	2.25	2.25
difforder	1.00	0.00
grating_density	600.00	600.00
alpha	1.55	
beta	-1.53	
theta	1.54	
cffphysical	2.25	
harmonic	1	1
poly_degree	5	5
gapoffset	0.0000	0.0000
polarization	0	0
epufollowing	<input checked="" type="checkbox"/>	True
epuoffset	0.00	0.00
phaseoffset	0.0000	0.0000
epudeadband	0.0010	0.0010
phasedeadband	0.0010	0.0010

Scalar ElementList



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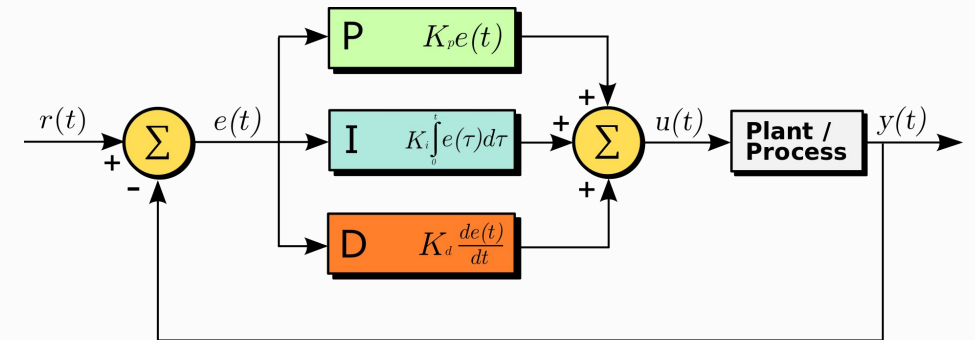
TODOs

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



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)



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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)

The screenshot shows the 'AtkPanel 5.9' interface for a device named 'bl-05id/dia/bl-05id-dia-pid02'. The status bar indicates 'Device is ready.' The main panel displays various control parameters and their current values:

Parameter	Value	Control Element
Im1	0.04 nA	Text field
Im2	-0.03 nA	Text field
M3 pitch position	10.2317 mrad	Text field
Movement threshold (M3 pitch)	0.3000 mrad	Slider (0.3000)
Movement sum	3.4299 mrad	Text field
Movement difference	9.8510 mrad	Text field
Current threshold (i1 + i2)	0.000000	Slider (0.00)
Acceptable current difference	0.05	Slider (0.05)
Current difference	0.000000	Text field
Motor range high limit	11.0000 mrad	Slider (11.0000)
Motor range low limit	9.5000 mrad	Slider (9.5000)
PID output	0.0000	Text field
PID feedback	0.0000	Text field
Offset	0.0000	Slider (0.0000)
Asymmetry coefficient	1.00	Slider (1.00)
Sample time	5.00 s	Slider (5.00)
Kp	0.0120	Slider (0.0120)
Ki	0.0000	Slider (0.0000)
Kd	0.0000	Slider (0.0000)
Correction started	<input checked="" type="checkbox"/>	Checkbox

At the bottom of the window, there is a 'Scalar' button.



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

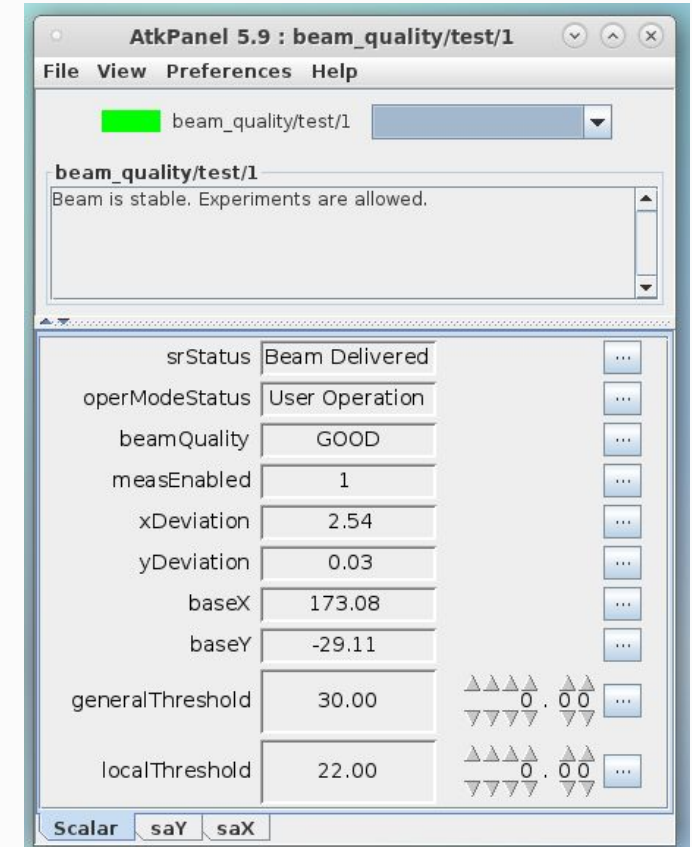
Solution

- 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 undefined
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?

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