

DCM - User Guide

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June 23, 2023

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This document is intended to be a guide dedicated to the beamline staff using the DCM.

First the Hardware associated to the DCM is listed in Section 1. Then, the procedure to start and stop the DCM (during long shutdown for instance) is described in Section 2. The DCM calibration procedure is explained in Section 3. And finally, a small Bliss guide related to the DCM is given in Section 4.

1 Hardware

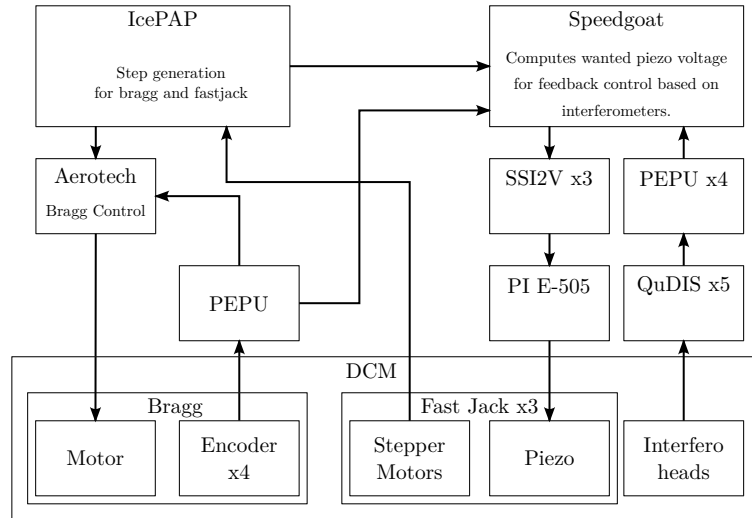


Figure 1.1: Overview of DCM control hardware

1.1 Crystals

There are two pairs of crystals in each DCM. One pair is to the “Hall” side while the other pair is to the “Ring” side.

Table 1.1: List of Crystal used for the different DCM

	ID21	ID24
Ring	111	311
Hall	311	111

1.2 Interferometers

Each interferometer “box” (either Attocube or QuDIS) has 3 measurement channels. As 15 distances have to be measured, 5 interferometer “boxes” are used:

1. Interf Xtal 1 Ring
2. Interf Xtal 1 Hall

3. Interf Xtal 2 Ring
4. Interf Xtal 2 Hall
5. Interf Metrology Frame

The 15 interferometer measurements are summarized in Table 1.2.

Table 1.2: List of Interferometer measurements

Notation	Variable	Interferometer	Channel
$z_{1r,u}$	z_{1r_u}	First “Ring” Crystal, “upstream”	1
$z_{1r,c}$	z_{1r_c}	First “Ring” Crystal, “center”	2
$z_{1r,d}$	z_{1r_d}	First “Ring” Crystal, “downstream”	3
$z_{1h,u}$	z_{1h_u}	First “Hall” Crystal, “upstream”	4
$z_{1h,c}$	z_{1h_c}	First “Hall” Crystal, “center”	5
$z_{1h,d}$	z_{1h_d}	First “Hall” Crystal, “downstream”	6
$z_{2r,u}$	z_{2r_u}	Second “Ring” Crystal, “upstream”	7
$z_{2r,c}$	z_{2r_c}	Second “Ring” Crystal, “center”	8
$z_{2r,d}$	z_{2r_d}	Second “Ring” Crystal, “downstream”	9
$z_{2h,u}$	z_{2h_u}	Second “Hall” Crystal, “upstream”	10
$z_{2h,c}$	z_{2h_c}	Second “Hall” Crystal, “center”	11
$z_{2h,d}$	z_{2h_d}	Second “Hall” Crystal, “downstream”	12
$z_{mf,u}$	z_{mf_u}	Metrology Frame, “upstream”	13
$z_{mf,dh}$	z_{mf_dh}	Metrology Frame, “downstream-hall”	14
$z_{mf,dr}$	z_{mf_dr}	Metrology Frame, “downstream-ring”	15

1.3 PEPU

Several PEPU are used:

- 4 are used to convert HSSL output of interferometers (QuDIS or Attocube) to SSI
- 1 is used to average the 4 encoders of for the Bragg angle and to dispatch the average to the Speedgoat as well as to the Aerotech controller

1.4 IcePAP

The IcePAP is used to:

- Control the motion of the fastjack stepper motors
- Control the motion of the “msafe” and “mcoil” motors
- Generate the steps to give the wanted bragg position to the aerotech controller
- Synchronize the Bragg and Fast Jack motions to have fix exit scans

- Integrate the calibration of the fast jack errors (calibration table)

1.5 Aerotech controller for Bragg angle

An aerotech controller is used to control the Bragg axis. The aerotech controller just receive the steps generated by the IcePAP and controls the bragg motor to follow the received trajectory.

The position of the Bragg angle is regulated from the average of 4 encoders. There is an offset between the read average angle from the encoders and the 0 deg angle as measured in the PAMU. This offset is manually set in two locations:

- in the Aerotech controller
- in the Speedgoat (variable `bragg_offset` in the `ym1` configuration file)

The available stroke for the bragg angle is different for each DCM (see Table 1.3).

Table 1.3: List of Bragg strokes for different DCM

	ID21	ID24
Bragg [deg]	5 to 85	2 to 35

1.6 SSI2V

Three SSI2V are configured in **unipolar mode** (output voltage from 0V to 10.24V). These SSI2V are directly connected to the Speedgoat (SSI slave ports 1, 2 and 3) and are used to generate the voltages at the input of the PI voltage amplifier.

1.7 Piezoelectric Amplifier

PI E-505 voltage amplifiers are used to drive the piezoelectric actuators. Several analog filters are included in the PI E-505 that should be manually disable upon installation as all the filtering is performed in the Speedgoat machine.

1.8 Speedgoat

The Speedgoat machine is responsible for:

- the real time control of the piezoelectric actuators in such a way that the primary and secondary crystals are parallel (as measured by the online metrology) and at a specific distance in such a way that there is a fix exit beam

- the calibration of the online metrology (the 15 interferometers)
- the real time acquisition of several signals (bragg angle, crystal positions, fast jack position, ...)

The Speedgoat machine is directly connected to a windows computer using an ethernet cable. A “Bliss Speedgoat Server” is running on this windows computer in order to provide a bridge between Bliss and Speedgoat.

2 Power On and Off Procedure

In order to restart the DCM (after a long shutdown for instance):

- Power on the hardware (see Section)
- Start the speedgoat program
- Start the Bliss session and perform all the

The procedure to “power off” the DCM is explained in Section 2.

2.1 Turning ON all the Hardware

All the hardware can be turned on:

- Interferometers (Attocube and/or QuDIS)
- PEPU
- IcePAP and Aerotech controller
- SSI2V
- PI E-505 amplifiers
- Speedgoat

2.2 Starting the Speedgoat Server

Connect to the Windows computer directly connected to the Speedgoat and run the `BLISS SPEEDGOAT SERVER` program on the desktop.

A terminal window should be displayed, with the last line being:

```
Serving XPC speedgoat on tcp://0.0.0.0:8200
```

This means the server is correctly launched and that Bliss will be able to communicate with the Speedgoat.

2.3 Initialize some Speedgoat variables from Bliss

There are certain things that should be initialized in the Speedgoat program:

- Interferometer offsets
- Synchronization of Fast Jack steps with the IcePAP
- Feedback controllers
- Calibration of the metrology

The **first** command to use regarding the DCM is `dcm.calib.restart_all()` which does the following:

1. Turn off the regulation and online metrology calibration
2. Home the fast jacks
3. Synchronize the Fast Jack steps between the IcePAP and the Speedgoat
4. Move the DCM to 10 degrees with fix exit. At this position reset the online metrology ($r_x = 0$, $r_y = 0$ and $d_z = \frac{d_{\text{offset}}}{2 \cos \theta}$)
5. Turn on the online metrology calibration

After that, if the calibration files of the online metrology are still valid, they can be loaded with:

```
Python  
dcm.calib.interf.load(lut="rx", radix="calib_rx_name")  
dcm.calib.interf.load(lut="ry", radix="calib_ry_name")  
dcm.calib.interf.load(lut="dz", radix="calib_dz_name")
```

Otherwise, the calibration procedure explained in Section 3 can be done.

The Fast Jacks can be calibrated using `dcm.calib.fjs.build("calib_name")` and regulation filters can be loaded with `dcm.regul.load("controller_name")`.

The DCM is now ready to be used.

2.4 Shutting down the DCM

In order to shut down the DCM (before a long shutdown for instance):

- Move the DCM to the wanted position during shut down
- Turn off the regulation: `dcm.regul.off()`
- Turn off the PI voltage amplifiers

- Turn off the Speedgoat machine
- The Aerotech controller can be disabled as well as all the IcePAP axes
- All the other electronics can be turned off such as: SSI2V, PEPU, QuDIS/Attocube
- The Windows computer connected to the Speedgoat machine can also be turned off

3 Calibration Procedure

There are two things to calibrate in the DCM:

1. the online metrology (i.e. the interferometers) measuring the relative pose between the first and second crystals
2. the stepper motors used to move the second crystals

Indeed, the online metrology is not accurate enough to have the wanted stability of the output beam over wide range of bragg angles. This is mainly due to the fact that when changing the bragg angle, the gravity forces applied on the metrology frame are inducing some deformations affecting the measured relative pose between the crystals.

In order to calibrate this online metrology, the X-ray beam has to be used.

The second issue is regarding the position errors of the stepper motors and lead screw mechanism. If these errors are too high (i.e. exceeding the stroke of the piezoelectric actuator), the feedback control on the piezoelectric actuators will not work anymore. These errors can be calibrated using the online metrology.

Important

While the calibration of the online metrology is key to have a stable output beam, the calibration of the stepper motors is mandatory for the feedback loop with the piezoelectric actuators.

This sequential calibration procedure is shown in Figure 3.1. This means that each time the calibration of the metrology is changed, the fast jacks have to be calibrated again.



Figure 3.1: Schematic of the calibration procedure: the stepper motors are calibrated from the online metrology (i.e. the interferometers) which is itself calibrated using the x-ray beam

3.1 Rocking curves: r_y calibration

The DCM internal metrology can be calibrated using rocking curves as at the maximum intensity, the two crystals should be parallel¹.

The procedure is the following:

¹This is not exactly true as the d-spacing of the first and second crystals may not be equal due to temperature of stress differences.

- For each bragg angle θ (i.e. energy), a rocking curve is performed. This rocking curve is usually performed in open-loop using the stepper motors. However, if required, this can be performed with the piezoelectric actuators.
- The measured r_y angle between the first and the second crystals corresponding to the maximum intensity is recorded. As we are supposing that the two crystals are parallel at the maximum of the rocking curve, the measured r_y angle corresponds to the metrology error.

Then, the obtained bragg angles $[\theta_1, \dots, \theta_n]$ and metrology angle errors $[r_{y,1}, \dots, r_{y,n}]$ can be loaded in the Speedgoat as a calibration table.

3.2 Focused scan: r_x and r_y calibration

In order to calibrate the angular errors of the DCM online metrology, the setup of Figure 3.2 can be used. The KB is tuned to focus the source on the detector².

Let's use for following notations:

- d the distance between the source and the DCM in meters
- p_v (resp. p_h) the distance between the source and the vertical (resp. horizontal) KB in meters
- q_v (resp. q_h) the distance between the vertical (resp. horizontal) KB and the detector

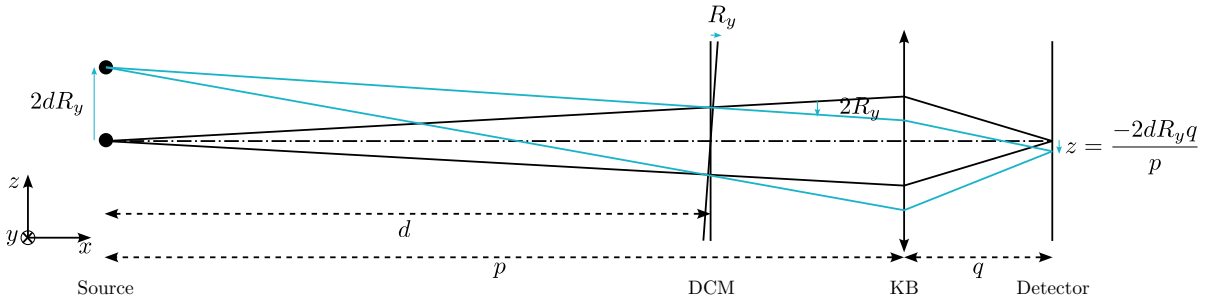


Figure 3.2: Schematic of beamline layout with Source, DCM, KB and detector (side view). A slit can be added between the DCM and the KB to reduce the possible errors induced by vertical shift of the beam induced by the DCM.

Let's now compute the relation between relative angles between the primary and secondary crystals and the shift of the focused beam on the detector.

A DCM parallelism error of R_y induces a beam deviation of $2R_y$ and a shift on the detector:

$$z = \frac{-2dR_yq_v}{p_v} \quad (3.1)$$

Therefore, from a shift z on the detector, the parallelism error R_y can be calculated:

$$R_y = -z \frac{p_v}{2dq_v} \approx -0.678z \quad (3.2)$$

²Note that the detector is not in the focal plane of the KB, but where the source is imaged (slightly behind the focal point).

with R_y in radians and z in meters.

A DCM parallelism error of R_x induces a beam deviation of $-2R_x \sin(\theta)$ with θ the bragg angle. The corresponding shift on the detector is:

$$y = \frac{-2R_x \sin(\theta)q_h}{p_h} \quad (3.3)$$

Therefore, from a shift y on the detector, a the parallelism error R_x can be calculated as follows:

$$R_x = -y \frac{p_h}{2d \sin(\theta)q_h} \quad (3.4)$$

with R_x in radians and y in meters.

Important

The idea is therefore to scan the energy in closed-loop mode (i.e. the piezo are controlled in such a way that the crystals are parallel as measured by the interferometers) and to measure the motion of the focused beam. From the Bragg angle and the y (resp. z) motion of the focused beam on the detector, the R_y (resp. R_x) calibration of the DCM online metrology can be computed from Equation (3.2) (resp. (3.4)).

These calibration tables are then loaded in the Speedgoat.

3.3 Unfocused scan: d_z calibration

Now that the DCM online metrology has been calibrated for the angles, it can now be calibrated for the relative distance between the primary and secondary crystals.

To do so, a position detector is directly measuring the output beam of the DCM (no optical elements between the DCM and the detector). It is preferred that that position detector is as close as possible to the DCM to be less sensible to angular motion of the beam.

An energy scan is performed with the feedback control enables (which ensures that the crystals are positioned perfectly regarding the metrology measurement). During the energy scan, the bragg angle θ as well as the vertical motion of the beam on the detector $d_{b,z}$ are measured.

The DCM online metrology errors d_z can then be computed from the bragg angle θ and the vertical motion of the beam on the detector $d_{b,z}$:

$$d_z = \frac{d_{b,z}}{2 \cos \theta} \quad (3.5)$$

3.4 Fast Jack Calibration

There are mainly two types of errors induced by the fast jacks:

- errors in the lead screw pitch. This is usually below $1 \mu m$ per mm

- other lead-screw errors: period of 1 mm and amplitude of $\pm 1\ \mu\text{m}$
- micro-stepping errors: period of $5\ \mu\text{m}$ and amplitude of $\pm 300\ \mu\text{m}$

As the piezoelectric actuators have a very limited stroke ($\approx \pm 5\ \mu\text{m}$), the fast jack errors must to be calibrated to be below the piezoelectric actuator stroke in order to be able to use feedback control.

These errors can be calibrated using the online metrology ³.

The procedure is the following:

- An open-loop fix exit scan is performed with the IcePAP
- The steps generated by the IcePAP (i.e. the wanted position) for the three fast jack are recorded as well as the motion of the three fastjacks as measured by the online metrology.
- A calibration table is then computed which maps the wanted position of each fast jack to the corresponding step at which this wanted position is attained
- The calibration table can then be loaded in the IcePAP

The expected errors of the calibrated fast jacks are $\approx \pm 500\text{ nm}$. This means that without the feedback control (i.e. without using the piezoelectric actuators), the expected maximum parallelism error in r_x and r_y is $\approx \pm 3\ \mu\text{rad}$.

³This can be done without the X-ray beam (only the online metrology is required).

4 Bliss guide for DCM

4.1 `yml` configuration file

5 Bliss commands - Summary - FAQ

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How to start with a fresh configuration?

The complete “restart” procedure of the DCM is described in Section 2.

The quick and easy command to initialize the DCM is `dcm.calib.restart_all()`.

After that, it is possible to enable the regulation (with `dcm.regul.on()`) and start making some scans.

How to modify/load calibration files?

All the calibration files related to the DCM online metrology are located in `/data/id**/inhouse/DCM/CALIB/INTERF/`.

Files in this folder are constructed in the following ways:

- **name:** `<calib_name>_<crystal_name>_<rx/ry/dz>.dat`. For instance `calib_4_5kev_Si111_rx.dat`.
- **content:** two columns (separated by a space) First column is the bragg angle in degrees and the second column is the correction to add in nano-radians or nano-meters. It can have as many lines as wanted.

These files can be created/modified as wanted as long as they fulfil the above requirements.

My regulation is now working, what should I do?

When you try to do `dcm.regul.on()` and the regulation does not work (`dcm.regul.state()` gives `Off`), you can try the following:

- Verify that the errors are not too high using `dcm.regul.error()`. This displays the errors of the three fast jack that should be below $\approx 5 \mu m$ for the regulation to work.
- If the error is too large, then the calibration of the fast jack should be redone using `dcm.calib.fjs.build()`. Go back to the wanted DCM position, and verify that in that case, the fast jack positions are not

too high using `dcm.regul.error()` (it should be below $\approx 1 \mu m$). After that, `dcm.regul.on()` should work.

- If it still does not work, try to load less “aggressive” regulation filters using `dcm.regul.load("filter_name")`. The list of available regulation filters are located in `/data/id**/inhouse/DCM/CALIB/REGUL/`. Once the new filter parameters are loaded, test the regulation with `dcm.regul.on()`.
- If that still does not work, there might be a hardware problem.