How to acquire XMCD spectra

ASSOCIATE LABORATORIES

Dedicated to linear and circular dichroic measurements of magnetic and non magnetic samples, DEIMOS beam-line has been optimized to provide high beam stability and sample sensitivity with very fast switching rate of the polarisation.

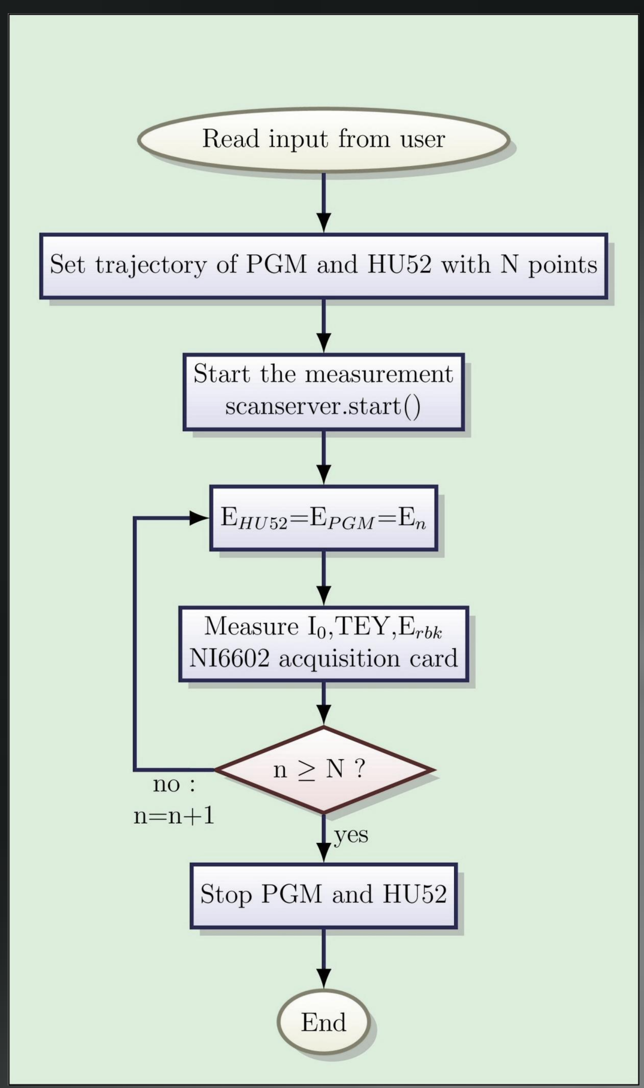
X-rays dichroic spectra

A dichroic spectrum is the result of the comparison between 2 absorption spectra taken with different light polarisations and/or different sample states. The most common are:

- **XMCD** (x-ray magnetic circular dichroism) where circular polarized light is used on sample showing non zero net magnetization. The magnetic state of the sample is flipped by applying a magnetic field.
- **XLD** (x-ray linear dichroism) where linear polarized light is used on sample with an anisotropic charge distribution. In some cases this charge anisotropy can be related to magnetism and XLD can be used to probe samples magnetic properties (**XMLD**).

Because we are comparing absorption spectra the stability in energy and the stability with time are critical issues.

Step-by-step scan

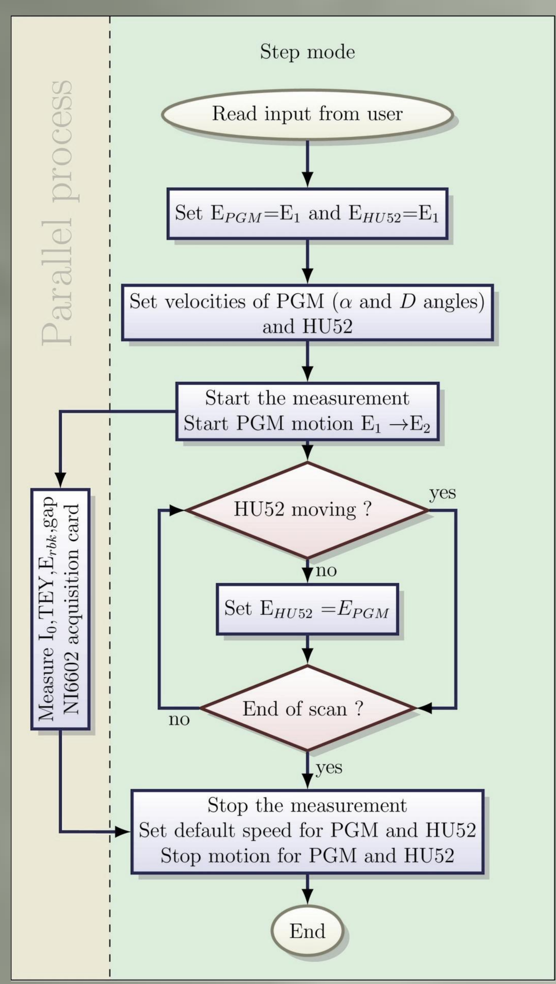


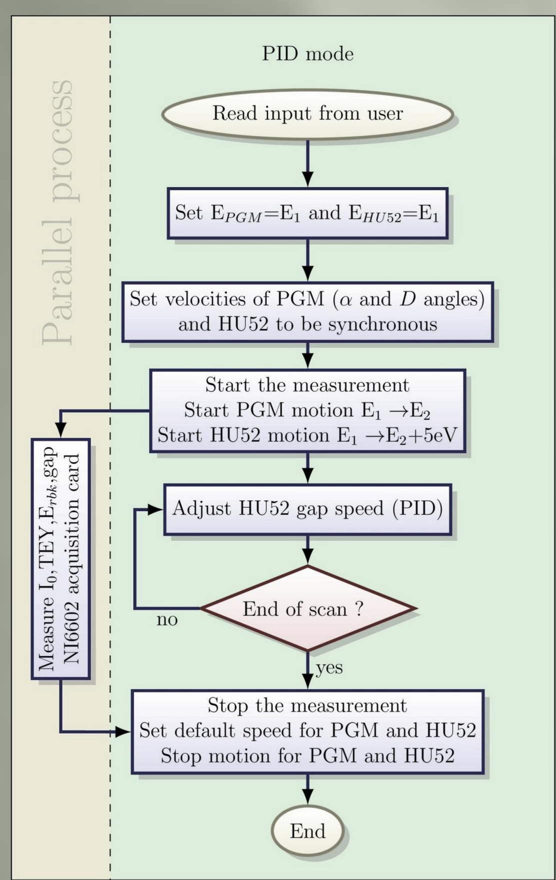
There are 2 typical ways to acquire a dichroic spectrum:

- record a complete spectrum, then flip the polarisation or the sample state and record the 2nd spectrum. In this configuration the challenge is to reduce the time needed to take one spectrum.
- At each point in energy of the absorption spectrum flip the light polarisation or the sample state. The challenge is to perform this flip at the highest rate possible.

Continuous energy scan: *TurboScan*

The standard way to acquire a spectrum is to perform a **step-by-step scan** where after each small displacement of the actuators (undulator and monochromator motors) the acquisition of the sensors (motors position and sample measurement) is performed before moving to the next displacement until the final position is reached. The drawback of this method is the **large scan duration** caused by the dead-times induced by all the small displacements.
In a **continuous scan** (or **scan-on-the-fly**) a single actuator displacement is done while during this displacement the sensors, actuator(s) position and sample measurement are synchronously recorded. This method allows for shorter acquisition time (no dead-times)and smoother data acquisition because there is only one single displacement.





HARDWARE ISSUES

- A continuous scan in energy implies the synchronization of several motors:
  - **Monochromator** (working in the Petersen mode): 2 rotations of the gratings and the mirrors
  - **Undulator**: gap

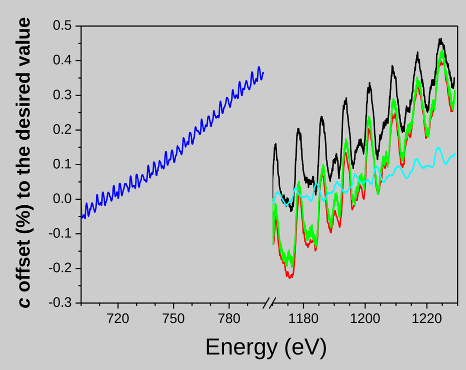
  The encoders of these 3 motors are re-read on the counting card to allow a synchronous reading of the actuators and the sensors (pico-amperemeter+ V to F converter).
- The minimum speed of the undulator has been decreased by a factor 100 to be compatible with the typical acquisition time.

SOFTWARE ISSUES

In house solution developed using the *Tango* tools:

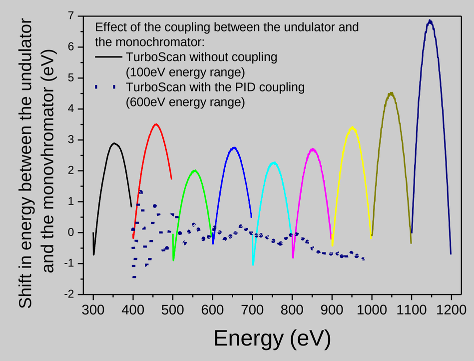
- Scan definition: the trajectories (position and speed) are determined according to the users' requirements (energy range, integration time and total time).
- The 3 trajectories (2 monochromators' rotations and the undulator's gap) are launched. Possibility to couple dynamically the undulator energy to the monochromator energy using PID loops to control the speed of the undulator during the displacement.
- The trajectory in energy dynamically reconstructed allowing for live visualization of the acquisition.

Critical parameters / criteria to obey



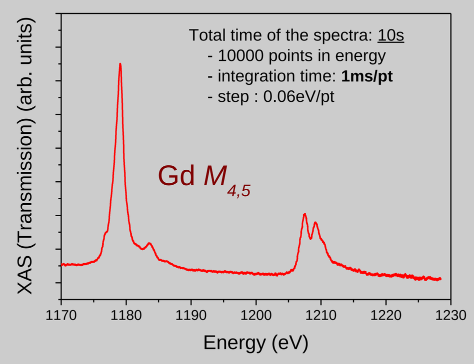
***cff* factor constant (Petersen criteria)**

Discrepancy between the *cff* factor and its ideal value lower than 0.5%.



Good coupling mono & undulator

Shift in energy between undulator and monochromator less than 7eV (1eV with the dynamic coupling).



Fast acquisition time

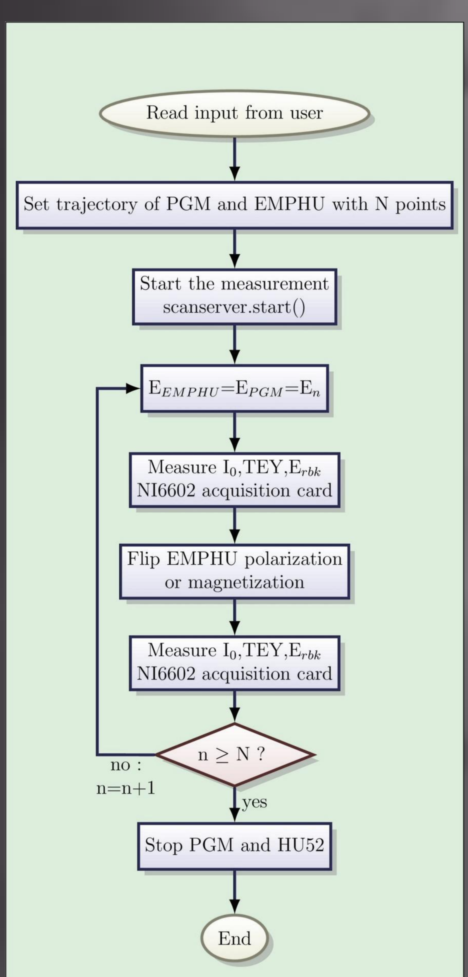
Typical time for a *TurboScan* ~2-3 minutes to compare to ~25 minutes for a step-by-step scan.

Step-by-step scan with a flip at each step in energy *FlipScan*

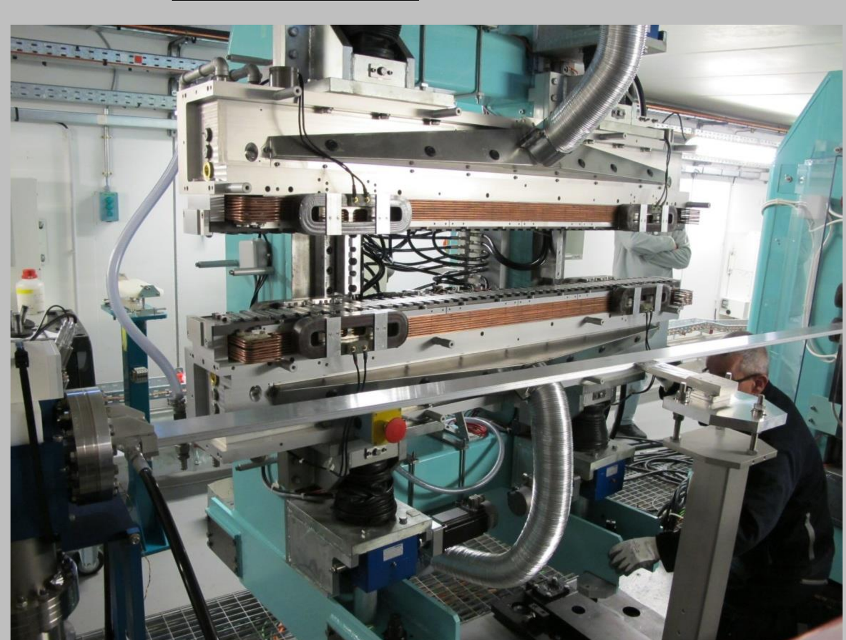
In such a **step-by-step scan** the light polarization (CR / CL) or the magnetization (+H / -H) is flipped at each point in energy.

To optimize the time consumption for this type of measurement 2 instrumental developments have been necessary:

- EMPHU-65: an undulator able to flip the light polarization at a rate of 5Hz.
- MilleK: an electromagnet to flip the magnetization (2T) at high rate. The present rate is ~1Hz, but 10Hz are possible with pre-charge power supply; still to be developed.



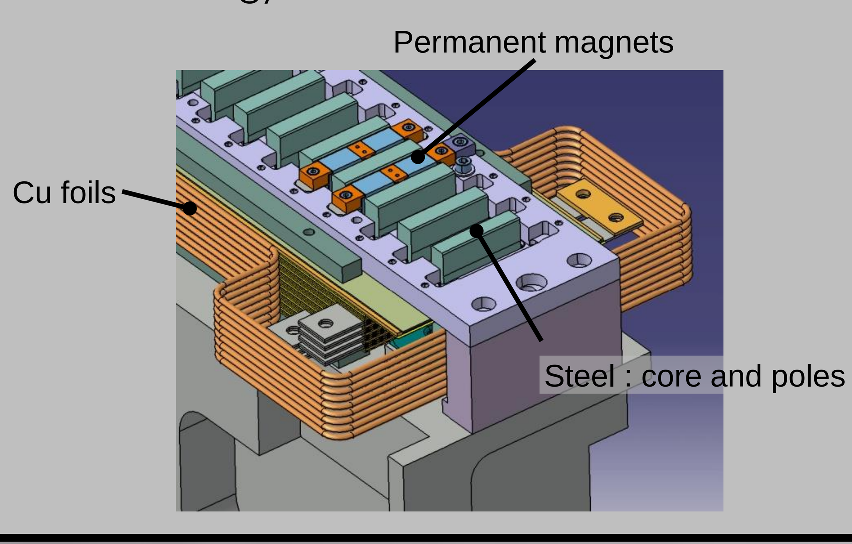
EMPHU-65



5Hz current flipping rate (≡ circular polarization flipping rate).

Permanent magnet: NdFeB magnets

Coils: 25 layers of copper sheets stacked together (16 with current and 9 with cooling)



Electro**M**agnet/
Permanent magnet
Helical
Undulator

MilleK

- 2T electromagnet (split coils) with *in situ* bore.
- Flipping rate around 1Hz (depends on the field).
- Temperature range: 10-1000K.
- Compatible with all the *in situ* facilities.