



	Experiment title: <i>Electro-acoustic chopper for time-resolved experiments in XMCD</i>	Experiment number: <i>MI. 179</i>
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Report:

The aim of the experiment was to test an electro-acoustic chopper for time-resolved XMCD. The chopper is necessary to match the interpulse period of the X-ray pulses to the relaxation time of the magnetic excitation created by short (10-20 ns long) almost squared magnetic pulses. In relevant situation, it is required to separate the X-ray pulses by 1 μ s to let enough time for the sample to come back to its equilibrium state and thus to study the kinetic of the magnetic relaxation.

The chopper is essential if one wants to use the hybrid mode. It is necessary to select each isolated single X-ray pulse and to eliminate the "superbunches" (1/3 of the ring). This electro-acoustic chopper creates an "artificial" single bunch mode with a period of 2.82 μ s.

The chopper has been already tested with a monochromatic beam and the results are taken as a reference to analyze its efficiency when inserted in the X-ray absorption energy dispersive spectrometer.

0. Time schedule of the experiment

To test the chopper with the requirements of the XMCD on ID24, it has been necessary to install several elements with very accurate settings: a quarter wave plate on a Kappa goniometer to tune the photon helicity, the magnetic sample (which should stay in the focal plane of the beam), the micro-coil and the 2D-detector. Furthermore, the focusing polychromator has to be set across the chosen edge. All these operations have to be carried out very precisely and take a significant time: at least 6 shifts for each experiment have been allocated for the settings of these devices.

To evaluate the influence of the chopper on the XMCD signals, preliminary experiments were achieved with the single bunch mode shifts to collect time-resolved XMCD without the chopper.

We checked that a twist of the crystal of the polychromator leads to a twist of the beam after the focal point. This could not be rapidly corrected, and it has been extremely difficult to set precisely the chopper in these conditions.

1. Insertion of the device on ID 24

On ID24, the beam is energy dispersive and therefore, the first problem was to make sure that the chopper could work in the energy dispersive set-up. It was decided to insert the chopper between the sample and the detector as close as possible from the sample to select the largest energy bandpass of the beam (the sample is placed at the focus of the beam). The horizontal acceptance of the chopper is of the order of 1 mm. An energy window of ~ 50 eV could easily be selected around the edge of the magnetic compound (Gd, Tb). The electro-acoustic chopper is an energy dispersive device itself since the surface acoustic wave acts as a grating. But for an energy window of ~ 50 eV, the dispersion is negligible. We have checked with the 2D-imaging detector of ID 24 that there were no visible difference between the structure of the direct beam profile (behind the sample) and of the “acoustic” satellite.

2. Choice of the multilayer

The chopper is based on the X-ray diffraction by surface acoustic waves propagating in a multilayer mirror. One important parameter is the multilayer period and consequently the Bragg angle depending on the energy. The first idea was to increase this angle as much as possible (25 Å for the period) to reduce the footprint of the beam on the surface and hence to “properly” select the single pulses (the acoustic pulse should cover the footprint of the beam when a single pulse hits the crystal and should have completely left this zone when the following superbunch arrives). It turns out that it is much more profitable in this case to use a d-spacing of 35 Å for the multilayer. This is small enough to perform a correct selection and provides some larger separations between the acoustic satellites and the specular beam.

3. Efficiency of the chopper

The chopper has been tested in the hybrid mode which in some way accumulates the worse conditions: Very long and intense X-ray pulses (1 μ s) have to be rejected. Nevertheless, it allows to precisely quantify the efficiency of the rejection of our device.

Each single X-ray pulse is selected with an efficiency of 20 % and the superbunches rejection reaches up to 99.7 %. This rejection ratio must nevertheless be improved: The ratio between the full intensities of the single and the superbunch is of the order of 1:20 in the direct beam and reaches in the chopper’s output a value of 3.5: 1.

These results are very similar to the previous ones obtained with a monochromatic beam (8 keV).

The noise is essentially due to diffusion introduced by defects in the multilayer mirror and should therefore be partially avoided by decreasing the roughness of the substrate and by improving the quality of the interfaces.

The maximum vertical size of the beam was 80 μ m. For larger beams, the selection was no more optimal since the footprint of the beam was too large.

4. Time resolution

This time-resolved experiment is based on the “pump and probe” scheme. After the magnetic excitation (pump), the X-ray pulse (probe) hits the sample with an adjustable delay. This cycle is repeated many times to allow the low XMCD signal to be extracted from the noise, thanks to an integration detector. All the electronics involving the synchronization of these various operations have been successfully tested and implemented.

5. Perspectives

In some cases, it is necessary to increase the intensity of the magnetic pulses delivered by the micro-coils to reach the saturation of the sample. This implies an increase of both the excitation time (since the available electric power of the coil is constant) and the investigated temporal window. Practically, it is planned in the near future to extend the use of the single bunch mode and to select one pulse out of 2 (or more for samples with longer relaxation time). The ratio S/N should be much improved (- 65) since the ratio between the pulses to remove and to select is 1 in this case (instead of 20 in the hybrid mode).

It is easy to envisage that photo-stimulated chemical reactions (for example), where characteristics can fall in the 1-100 μ s range should benefit of such an optical element, namely the electro-acoustic chopper.