ISBN: 978-3-95450-229-5 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2020-MOOB02



# ALBA BL20 NEW MONOCHROMATOR DESIGN

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*Abstract*

LOREA Beamline (BL20) at ALBA Synchrotron is a new soft X-Ray Beamline dedicated to investigate electronic structure of solids by means ARPES technique. Optical design has been developed in-house so as most of beamline core opto-mechanics like monochromator. The design made for LOREA is based on a Hettrick-Underwood grating type that operates without entrance slit. Experience cumulated over years allowed to face the challenge of designing and building UHV Monochromator. The large energy range of LOREA (10-1000 eV) requires a device with 3 mirrors and 4 gratings with variable line spacing to reduce aberrations. Monochromator most important part, gratings system, has been carefully designed to be isolated from external disturbances as cooling water, and at the same time having high performances. Deep analytical calculations and FEA simulations have been carried out, as well as testing prototypes. The most innovative part of Monochromator is gratings cooling with no vacuum guards or double piping that are well-known source of troubles. Heat load is removed by cooper straps in contact with a temperature controller device connected to fixed water lines. In addition, motion mechanics and services (cabling, cooling) are independent systems. Designs involved give high stability (resonance modes over 60 Hz) and angular resolution below 0,1 µRad over 11 deg range. On mirrors side, it has been used gonio mechanics from MIRAS [1] plus an eutectic InGa interface between cooling and optics to decouple them. Grating and mirror holders are fully removable from main mechanics to be able to assembled at lab measuring to achieve the best fit. Instrument has been already assembled and motions characterization or stability measurements are giving expected results matching with specifications.

## GENERAL DESCRIPTION

LOREA is a 10-1000 eV soft X-Ray beamline to study the electronic structure of solids by Angle Resolved Photo-Emission Spectroscopy (ARPES). Core level photoemission, resonant photoemission and X-Ray absorption spectroscopies are accessible in the entire energy range.

The whole design of the monochromator, which includes a novel cooling design of the gratings, has been fully developed at ALBA. The BL20 Monochromator is based on a Hettrick-Underwood geometry with 3 spherical mirrors (SM) and 4 plane varied line-spaced (VLS) gratings to cover the entire energy range of LOREA.

Optics and mechanics work at ultra-high vacuum (UHV) regime. It is considered a big circular vacuum chamber for gratings plus one of the mirrors and two additional chambers for remaining two mirrors. An extra chamber contains part of the gratings pitch mechanism, Fig. 1.

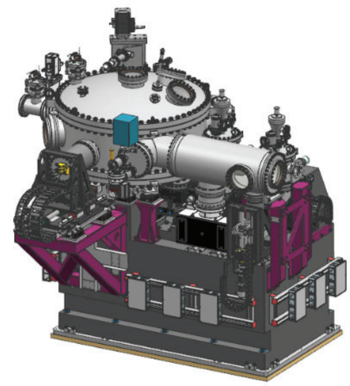

Figure 1: External view of BL20 Monochromator.

## GRATINGS MECHANISM

The gratings mechanics, which can locate up to five gratings, consists on a frame that can be moved transversally to the beam to select the suitable grating. This frame is mounted on an oscillating second frame that produces gratings pitch and it is commanded by a sine arm of 1 m long.

The entire mechanism is placed in vacuum, except the actuator of the sine arm. Two welded bellows, one of them connected to the support and thus standing all the force, compensate the vacuum force on the actuator. The vertical actuator, guided by cross roller linear guides consist on a preloaded satellite roller screw with roller recycling spindle that provides high stiffness and small pitch. Between the sine arm that describes an angular trajectory and the actuator that is lineal, there is a connecting rod with two doubled-ended flexural pivot bearings to reduce as much as possible rolling elements. Figure 2 shows full system.

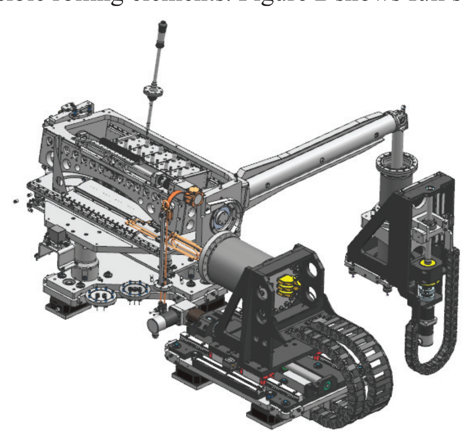

Figure 2: Gratings system design.

Regarding transversal motion, an UHV motor, vacuum adapted guides and spindle are installed, mounted directly on the pitch frame. As grating cooling lines are not linked

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directly to the optics, there is an extra actuator called services motion. This motion is in charge to move cooling fixed water circuit and the main cabling installed. Services motion is placed out of vacuum and has preload ball recirculating spindle and guides. It moves together with UHV grating exchange motion as a pseudo-motor. For the pitch motion, there are two angular absolute encoders to remove the residual eccentricity of mechanics.

Figure 3 shows the different motions that are involved at gratings mechanics. Grating holders are in the middle in grey color. Red colored parts are the pitch frame plus sine arm. In green color, the services motion fully decoupled, and in blue, the parts of pitch frame support.

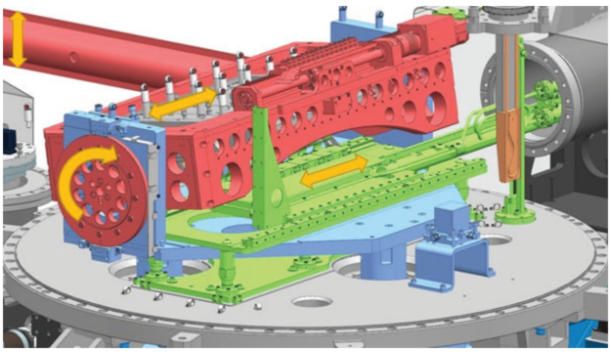

Figure 3: Motions involved at grating system.

The entire system rests on a big natural granite that is the support for all mechanics (seen at Fig. 1).

## GRATINGS HOLDER

Each grating is mounted on an independent holder that can be disassembled from mechanics to be adjusted at lab (Fig. 4). It consists in two base plates. One is fixed to be connected on the frame. And the second, it is adjustable where the grating is clamped. There are three micrometer screws for the fine adjustment. Pitch and roll angles can be adjusted during operation through vacuum screwdriver. Also fixed to mobile base with the grating, there are three fiducial marks always accessible to have a reference of the mirror. The holder also supports two symmetric OFH cooper cooling pads. These pads, decoupled from the cooling pipes, also hold the protection chin guard.

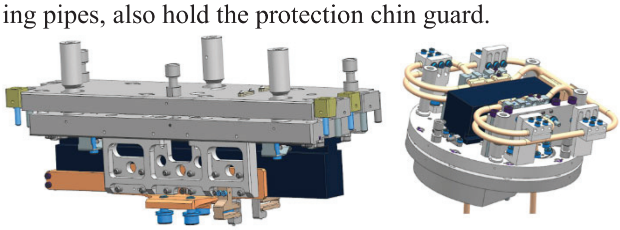

Figure 4: Gratings holder, left. Mirrors holder, right.

## GRATINGS COOLING

In this design, doubled vacuum piping has been avoided. Cooling line is a single cooper pipe without any intermediate joint fixed at services actuator. Between pads placed at optics and cooling lines, flexible OHF Copper multi foil straps are used. Figure 5 shows final assembly of straps.

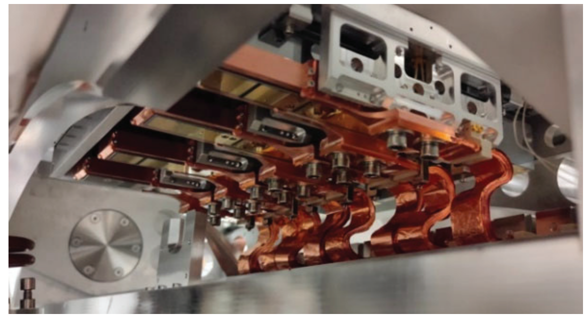

Figure 5: Cooling final design. Straps working "S" shape.

In order to avoid the rise of equilibrium temperature at optics caused by the distance between the heat source and the cooling pipes, a Peltier module is placed between water pipes and straps [2]. The Peltier module, applying an electrical current produces a ΔT between faces. The objective is to maintain the hot side of Peltier at 23 deg and adjust the temperature of the cold side in order to keep optics at a constant temperature also of 23 deg.

To prove this concept, a protype was produced. It consisted on a silicon substrate including copper pads, straps and Peltier modules with cooling water lines, all in vacuum. A heater simulated the heat load and thermocouples were used as temperature sensors. One of them closed the control loop of Peltier current. Tests have been performed increasing the heat load at the silicon to see the thermal response of the system. The 400 mA corresponds to 4 W, maximum power expected. Figure 6 shows tests results.

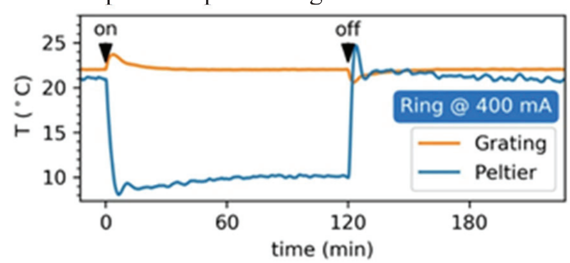


Figure 6: Gratings cooling prototype results.

Orange line corresponds to silicon temperature and blue line, the cold side of the Peltier. At ON point, heater starts to give power increasing temperature. Also, the control starts to put current to the Peltier drooping the temperature of the straps. The dynamic response is quite fast, the stabilization time is around 9 minutes with a ΔT of 1,7 deg. After set point is reached (23 deg), the temperature is maintained very stable via modulating the Peltier current. Once the load is removed, OFF point, the inertia of the system is continuing cooling down the mirror. Then, the polarity of Peltier is inversed acting as a heater to recover temperature.

The prototype validated the concept of Peltier modules and flexible cooper straps to allow the relative motion and also decouple from vibrations due to water-cooling flow.

## MIRRORS MECHANISM

Mirror with holder are placed on a column mounted rigidly to a blank flange connected on a frame with curved linear guides to allow pitch motion. The center of these guides is pointing at the central axis of the mirror surface.

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Externally there is an edge welded bellow to allow motion. This scheme was used also on MIRAS at ALBA [1].

The pitch stage is mounted on custom linear stages. Two verticals for SM173 and SM176, to put them at beam height or remove it. And one horizontal, transversal to the beam for SM162, that has two optical stripes. All moving elements, spindles and guides, have preload recirculated balls. Linear stages are mounted on small granites. Every mirror is a stand-alone system and can be aligned independently. Mirrors motions are shown at Fig. 7.

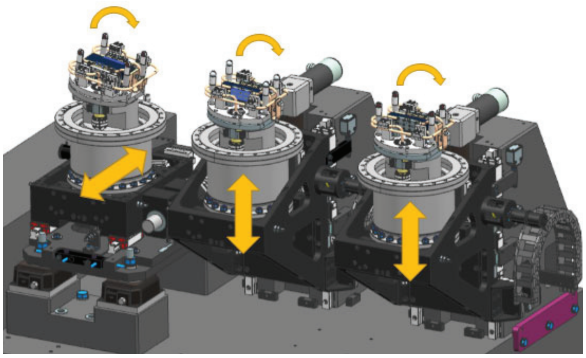

Figure 7: Mirrors motions. SM162, SM173 and SM176.

After that, the tree mirror systems are placed on the main granite support. SM162 mirror is placed at the same vacuum chamber that gratings and for SM173 and SM176 there are independent vacuum chambers.

## MIRRORS HOLDER

As gratings, each mirror is mounted on independent holders that can be disassembled from motion actuators (Fig. 4). They consist on two base plates. One is fixed and connected at the main column, and the second, adjustable via three micrometer screws, and is where the mirror is clamped. Also fixed with the mirror, there are the fiducial marks. The holder also supports symmetric cooper cooling pads with fixed cooling circuit. The protection chin guard is also fixed at holder.

## MIRRORS COOLING

The cooling water circuit is a continuous rigid cooper pipe that goes inside vacuum and it is fixed at internal mirror mechanics. The flexible lines out of vacuum absorb all the bending motion. The cooling circuit has two brazed cooper pads. There is an adjustable 0.1mm gap that is filled by a Eutectic InGa. Tests have been done to ensure a good behavior of the InGa, even during bake outs (80deg).

The solution, with no direct contact between the cooling pads and mirrors, reduces the deformations and stresses that might be introduced to the mirror when clamping. The assembly process is the following, half of the material is applied at the mirror on the surface contact and the other half is applied at copper pads. Notice that cooper pads must be nickel plated because eutectic InGa is very aggressive to cooper. After that, pads and optics must be mounted at final place controlling the gap between them. Once the gap is achieved, the cooling pad is fixed.

## MECHANICS METROLOGY

Gratings and mirrors systems metrology have been done by Renishaw ML10 interferometer and autocollimator (Tables 1 and 2).

Table 1: Gratings Mechanism Measured Performances

| Parameter | Pitch | Exchange |
|---|---|---|
| Total range | ±5.5 deg | ±150 mm |
| Resolution | 0.085 µrad/ 2 half steps | Not measured |
| Repeatability | 0.77 µrad | 23.6 µrad |
| 1st Resonance mode | 56 Hz | |

Table 2: Mirrors Mechanism Measured Performances

| Parameter | Pitch (x3) | Z (x2), X |
|---|---|---|
| Total range | ±1 deg | +40 mm/ ±10 mm |
| Resolution | 0.232 µrad/ 2 half steps | 0.998 µm/ half step |
| Repeatability | 1.39 µrad | 0.18 µm |
| 1st Resonance mode | 74 Hz | |

## CONCLUSION

A high-performance soft x-ray monochromator has been designed and built at ALBA. Water circuit is mechanically decoupled from grating pitch mechanism and Peltier cooling allows for high cooling efficiency and active stabilization of gratings temperature. Regarding mirror system, it is a high stability system. Thermal contact between cooling and mirror is enhanced via a wet interface witch also minimizes mechanical deformations of the mirror. Finally, excellent results are confirmed by metrology and first commissioning results

## ACKNOWLEDGEMENTS

The authors wish to acknowledge all those most involved in the project: Salvador Ferrer, Joan Casas, Nahikari Gonzalez, Gabriel Peña, Jon Ladrera, José Ferrer, Jordi Navarro, Karim Maimouni, Paco Trujillo, Raúl Lorenzo, Oscar Borrego, David Calderón, Lluis Ginés, Núria Martí, Igors Sics, Jordi Prat, Jose Avila, Bern Saló, Cristian Pérez, Sergio Astorga, Xavier Fariña, Fulvio Becherri, Jorge Villanueva, María José García and Arnaud Devienne.

This project is co-funded by the European Regional Development Fund (ERDF) within the Framework of the ERDF Operative Programme of Catalonia 2014-2020.

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