High Frequency UHV Mechanical X-Ray Beam Chopper

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Abstract

An in vacuum mechanical chopper has been designed and built to perform X-ray Absorption Spectroscopy (XAS) experiments with operating liquid electrochemical cells at the NAPP end station of ALBA Synchrotron (BL24, CIRCE Beamline). While operating the liquid electrochemical cell, in order to separate the weak currents induced by the X-ray absorption process at the working electrode in contact with the liquid electrolyte (total electron yield signal or TEY) from the faradaic current stablished between the electrodes when applying a bias, the incoming beam must be chopped at a certain frequency (ω) and then, by means of a lock in amplifier, the signal at this frequency ω can be extracted and measured. The in vacuum chopper developed at ALBA can operate at variable frequencies and when inserted in the X-ray beam path, produces pulses with a certain frequency ω, therefore modulating the TEY signal. This new chopper design, improves previous designs which used piezo-actuated choppers constrained to work at fixed oscillating frequencies [1].

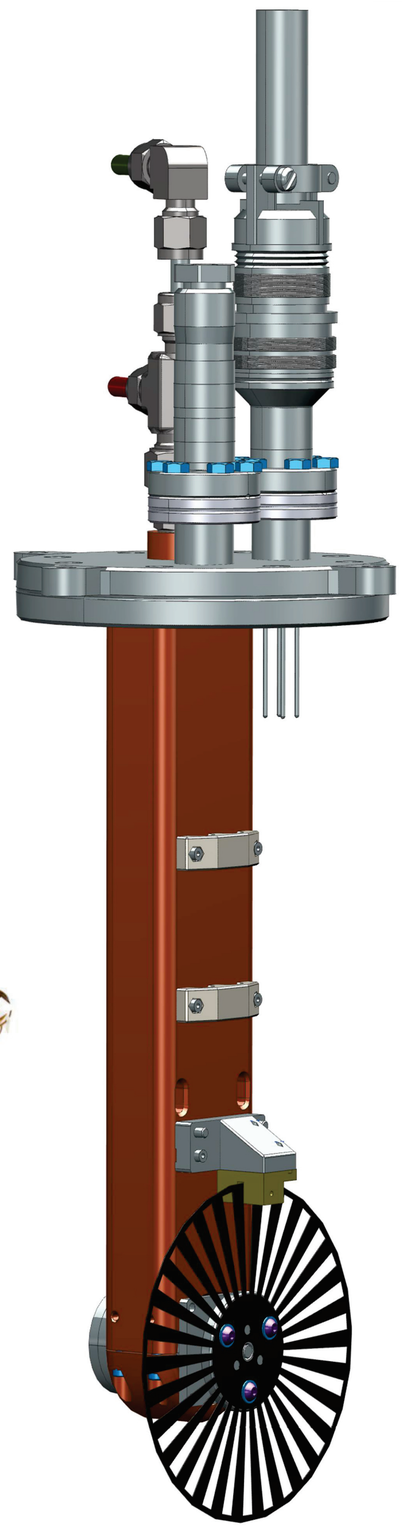
The design consists of a slotted disk that spins around an axis by means of an UHV stepper motor. A LED and photodiode based UHV sensor ensures that frequency drifts do not affect the measurements. The motor is hold by an internally water cooled OFHC support, which allows long duration experiments at high speeds without stopping.

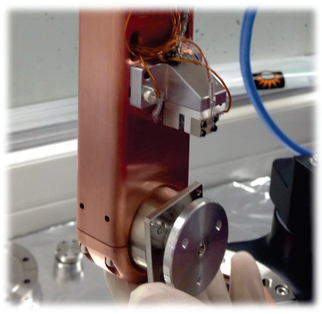
[1] Velasco-Velez et al, *Science* **2014**, 346, 831–834

Design Description

The chopper consists of a slotted disk that spins by means of an UHV stepper motor.

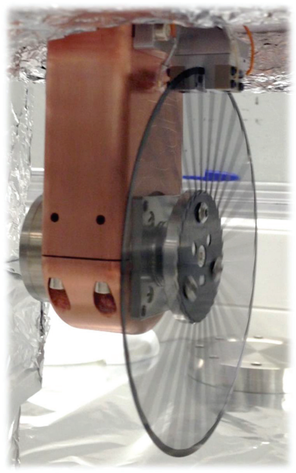
- Located downstream the M3 mirror of the NAPP branch at BL24, CIRCE.
- Rigid and stable structure with levelling elements.
- Motorized linear motion to enable in-out translation.



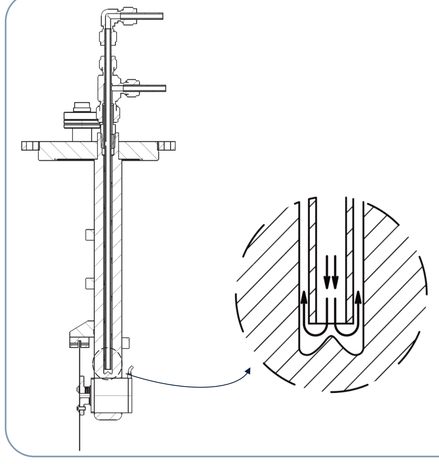


UHV sensor based on a LED and a phodiode to ensure speed stability

Phytron VSS.32.200.1,2 UHV Stepper Motor



Thorlab´s UHV compatible slotted disk



- Motor hold by a OFHC support with internal water recirculation to cool down the stepper motor.
- Minimum gap between water and motor maximizes the heat exchange capacity.

Specifications

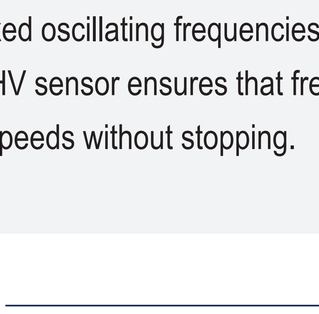
- High and stable rotation speed above 1 kHz continuously for hours.
- Controlled and variable frequency.
- Fully UHV compatible (10^{-9} – 10^{-10} mbar).
- In-out motion in order to remove it from the beam path.
- To allow the synchronization with the chopped electron yield current by means of a lock-in amplifier.

Design Simulations

Thermal Calculations

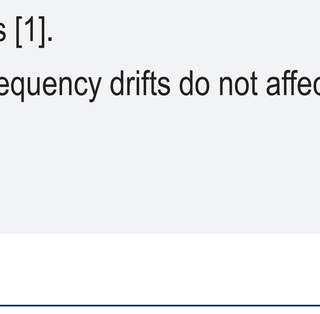
Boundary Conditions:

- *Pmotor = 15 W*
- *Twater = 23 ˚C*
- $K_{conductance}$ *= 2000 W/m².˚C*
- *In vacuum*



T_{max} = 31,4 ˚C

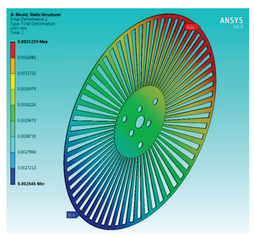
v_{water} = 3m/s



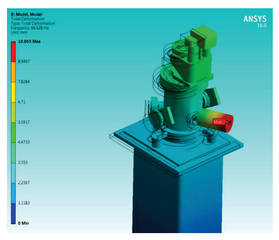
T_{max} = 35,7 ˚C

v_{water} = 0,5m/s

Static & Vibrational Analysis

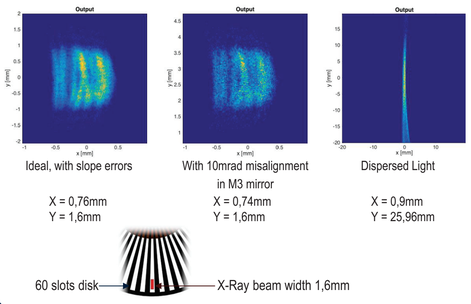


Maximum deformation of 3µm



1st mode at 66,6 Hz

Ray tracing at chopper position

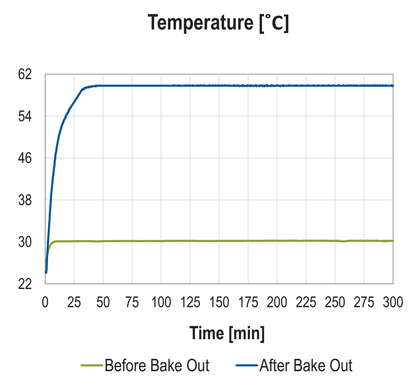


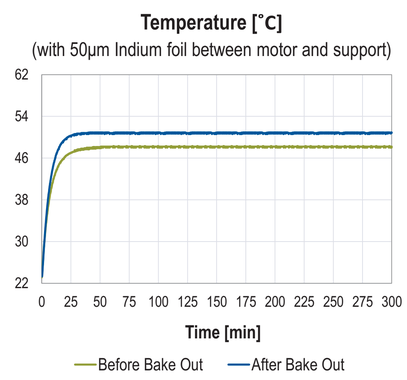
Ideal, with slope errors
X = 0,76mm
Y = 1,6mm

With 10mrad misalignment in M3 mirror
X = 0,74mm
Y = 1,6mm

Dispersed Light
X = 0,9mm
Y = 25,96mm

Test & Results





- *2.000 rpm*
- T_{water} *= 23,5 ˚C*
- Q_{water} *=3 l/min*
- *In vacuum*

- Cooling capacity is lost with the bake out.

✓ Possible to work beyond stepper motor manufacturer temperature limitations and over the speed specified by the catalogue for hours uninterruptedly in UHV.

N. González & C. Colldelram, "Dispositivo de corte de haces de radiación en entornos de vacío", Spanish Patent and Trademark Office, No. U201630988, Aug. 1, 2016

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