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DESIGN OF MONOCHROMATIC AND WHITE BEAM FLUORESCENCE SCREEN MONITORS FOR XAIRA BEAMLINE AT THE ALBA SYNCHROTRON

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Abstract

XAIRA, the hard X-ray microfocus beamline at ALBA, includes three monochromatic fluorescence screens and one water cooled white beam monitor in its layout, mounting respectively YAG:Ce and polycrystalline CVD diamond as scintillator screens. All monitors share the same design scheme, with a re-entrant viewport for the visualization system that allows reducing the working distance, as required for high magnification imaging. The scintillator screen assembly is held by the same CF63 flange, making the whole system very compact and stable. The re-entrant flange is driven by a stepper motor actuated linear stage that positions or retracts the screen with respect to the beam path.

To cope with high power density (18,6 W/m2) on the white beam monitor 100 µm-thick diamond screen, an InGa-based cooling system has been developed. The general design of the new fluorescence screens, to be used also in other ALBA´s upcoming beamlines, with particular detail on the water-cooled white beam monitor, is described here.

INTRODUCTION

This paper reviews the design of the Fluorescence Screen Monitors (FSM) of XAIRA, the microfocus Macromolecular Crystallography (MX) beamline at ALBA. Two types of FSM have been developed: the water-cooled White Beam Fluorescence Screen (FSWB) and the Monochromatic Fluorescence Screen Monitor (FSM1 and FSM2), which mount respectively as scintillator screen polycrystalline CVD and YAG:Ce.

Due to the high heat flux deposition (18,6 W/m2) on the FSWB screen, FEM analysis has been performed to optimize the cooling design, adopting InGa contact interface to enhance heat transmission.

The design has been conceived to produce a compact and stable instrument to be used as a standard FSM in future beamlines.

TECHNICAL SPECIFICATIONS

From an optical point of view the design of the FSM must comply with the following specifications:

- Beam envelope in each FSM should represent ~25% field of view (FOV) to allow severe beam misalignment.
- Partial beam transmission through diagnostic device is not required.
- Each beam dimension should be made at least of 100-200 pixels to allow identification of beam shape pathologies.
- Two different configurations of screen-imaging system are proposed for FSWB or FSM1 and FSM2 (Fig. 1).

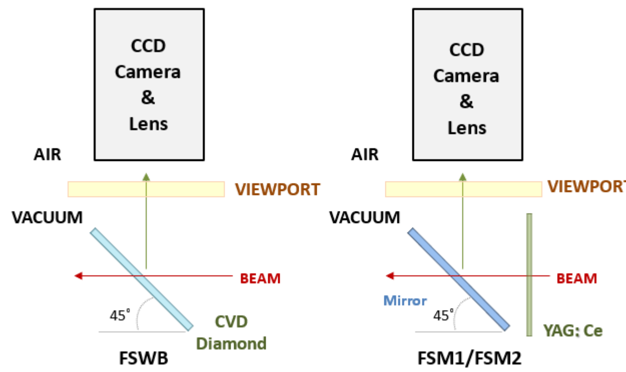

Figure 1: Geometrical configurations of the FSMs.

Both camera-lens system and fluorescence screen support should be mounted on the same moving DN63 CF flange, maximizing compactness and imaging system stability.

SYSTEM DESCRIPTION

General Description

The camera-lens system and the sensible scintillator screen are mounted on a common moving re-entrant flange. This flange is assembled on a DN63 CF welded bellow that is actuated by a linear moving stage consisting on a high precision ball screw, high precision linear guideways and low backlash stepper motor. Finally, the system is controlled with absolute encoder feedback. (Fig. 2).

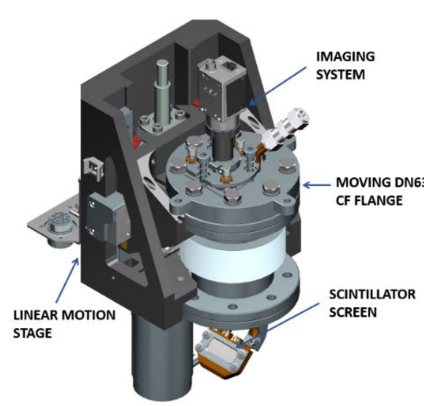

Figure 2: FSWB assembly.

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Motion Stage

The conceptual design of motion stage is shared among the different monitors, existing only small differences to adapt different ranges and, in the case of FSM1, to comply with the tight geometrical constraints at the beamline. All the standard components (high precision ball screw, recirculating linear guideways, low backlash stepper motors, absolute encoder and limit switches) are common (Fig. 3).

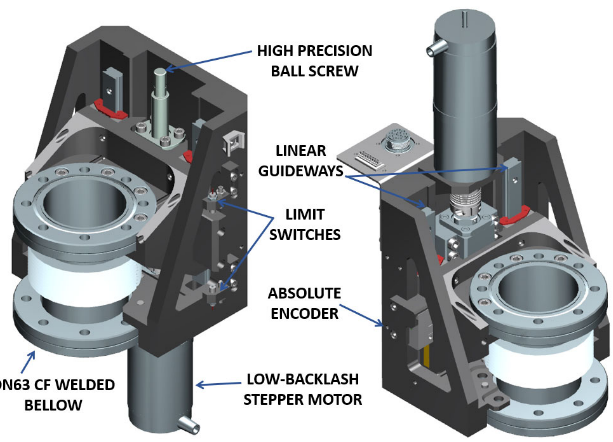

Figure 3: Motion stage assembly. FSWB and FSM2 arrangement (left), FSM1 arrangement (right).

Scintillator Screen and Imaging System

As previously commented, the optical arrangement of the scintillator screen (direct incidence or mirrored) depends on the X-ray beam monitor type (white or monochromatic) (Fig. 1). Apart from this, all the monitors share the same design scheme, with a re-entrant viewport for the visualization system, which allows reducing the working distance (WD) to the minimum.

The imaging system is equipped with a manual tilt alignment stage that allows correcting small angular deviations between the scintillator screen and lens (Figs. 4 and 5). In addition, the assembly of the imaging system the tilt alignment stage is accurately mounted on the moving flange by means of kinematical mount arrangement.

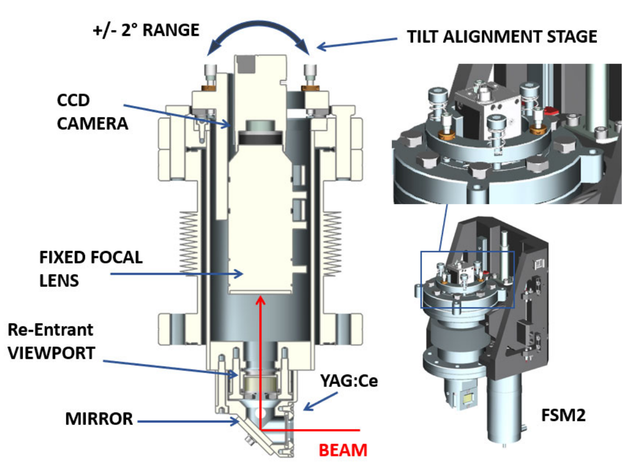

Figure 4: Imaging system and scintillator screen arrangement for monochromatic FSM2.

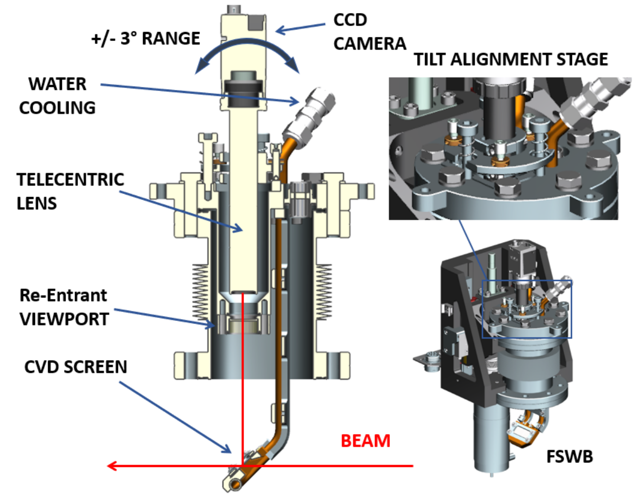

Figure 5: Imaging system and scintillator screen arrangement for monochromatic FSWB.

FSWB Cooling Design

For the FSWB monitor, a water-cooling system has been designed to cope with the power and power density of the pink beam at the exit of the first mirror. With a thin 100 µm thick CVD diamond screen, total absorbed power is 116.8 W while the peak power density is 18.56 W/mm^2.

The conventional election of Indium foil as thermal interface layer between CVD screen and copper substrate was quickly discarded due to its insufficient thermal performance. Instead, a more efficient InGa cooling system has been developed to manage these demanding heat conditions (Fig. 6).

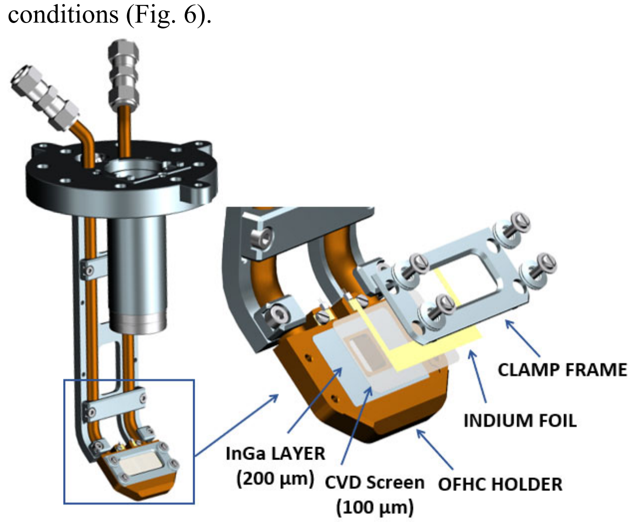

Figure 6: FSWB Cooling Flange and detail of the CVD diamond screen clamping design.

SIMULATIONS

A coupled thermal and mechanical FEA calculation has been conducted with ANSYS Workbench software to assess the temperature distribution and maximum induced stresses and deformations (Figs. 7 and 8). In addition to the more standard simulation assumptions the following criteria has been considered:

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- The thermal Contact Conductance (TCC) between CVD Screen-InGa-Copper substrate is assumed to be 10^5 W/mm^2.
- Contact between CVD screen, copper substrate and clamp are considered to be sliding with 0.2 of friction coefficient [1].
- For 35x21x0.1 mm CVD polycrystalline screen a value of 350 MPa has been adopted as fracture stress after conservative evaluation of data available in bibliography [2].
- Principal stress will be used as failure criteria for CVD polycrystalline screen since diamond is a brittle material [1].

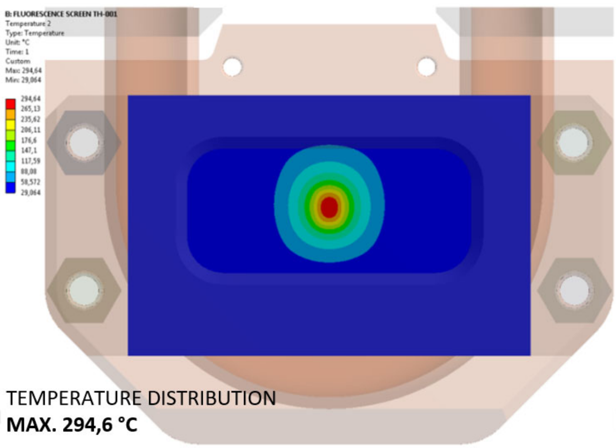

Figure 7: Temperature distribution on diamond screen.

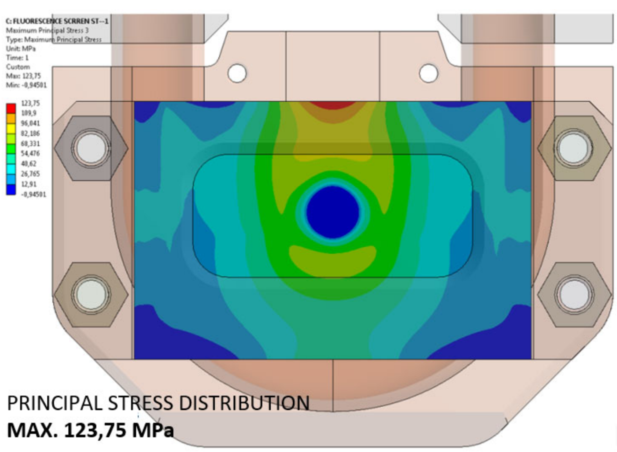

Figure 8: 1st principal stress on diamond screen.

CONCLUSIONS

Two types of Fluorescence Screen Monitors have been developed for XAIRA, the microfocus MX beamline at ALBA, currently under construction. The beam monitors have a compact design that aims to be adaptable to a wide range of X-ray beamlines and become standard at ALBA light source facility.

The Fluorescence Screens are currently being assembled and tested, their installation at XAIRA beamline is being scheduled during forthcoming months.

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