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DESIGN OF A RADIATION TOLERANT, INDEXING PROFILE MONITOR FOR THE LCLS ELECTRON BEAM*

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Abstract

The Linac Coherent Light Source (LCLS) electron beam can damage YAG:Ce scintillation screens. After one year of use, the existing profile monitor has diminished fluorescence of the screen. The decrease in performance has resulted in distorted beam images which can compromise the acquired data. Scheduling a YAG screen replacement is difficult, resulting in weeks of diminished performance. We have developed a unique profile monitor that incorporates multiple YAG screens (Ø40 mm, 50 um thick) and methods to reduce device downtime. This device uses unique geometry to direct coherent optical transition radiation (COTR) away from the optical path, which preserves the high resolution beam image. We are presenting the operational requirements, device design and installed device operational results.

INTRODUCTION

The profile monitor upstream of the electron beam dump is used to image the beam after passing through a transverse accelerating radio frequency (RF) cavity situated 30 meters upstream [1]. The LCLS electron beam, with an intensity range of 1.5-2.0 pC per pulse at 120 Hz, damages the YAG:Ce after one month of usage. Retracting the YAG screen when not in use increases the lifespan of the screen to 10-12 months but damage still occurs. Even if damage is not visible, beam tests have shown that fluorescence in a localized area is diminished which greatly compromises the useable data from the beam image. Using a green-orange filter and a blue light, instead of the usual UV light, this damage can be seen as a dark discoloration on the YAG screen. The shape of the damage matches the beam profile which is elongated vertically due to the upstream bend magnets (Figure 1).

One solution is to replace the YAG screen after one year of usage but this is costly and inconvenient. Replacing the YAG screen requires shutting the beam off for 8 hours which is problematic. This paper describes the key components of the updated profile monitor that improve the service interval period, serviceability and operation.

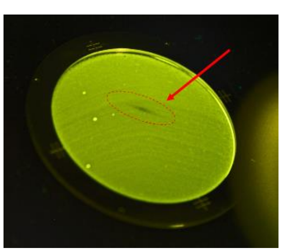

Figure 1: Photo of YAG with indicated damage.

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DESIGN REQUIREMENTS

The first requirement of the upgraded profile monitor was multiple YAG screens to increase the service interval period. The second requirement was to allow immediate operation after installation to reduce user downtime. This second requirement dictates that the new device use the proven geometry which successfully directs the OTR away from the optics path. To further decrease the potential for damage, the third requirement was that the device not fail into the beam during a power failure. The fourth requirement was to have easily removable YAG scintillators and a fifth requirement was to assess damage in situ.

Motion

Having the device near the electron beam dump prohibits the use of motors with onboard electronics or optical encoders which are susceptible to radiation. We chose a guided, double-acting pneumatic actuator because it achieves the required maximum stroke of 134.6 mm with a compact design (Figure 2). The actuator is sized to overcome the combined vacuum, spring and gravity force of 250 N while providing adjustable velocities to minimize shock to the YAG screens. Since compact pneumatic actuators don't exist with four positions, a manually adjusted hard stop is used to set the YAG screen location (Figure 2). This feature makes it quick and easy to change to the next YAG screen and simplifies the control scheme to two positions.

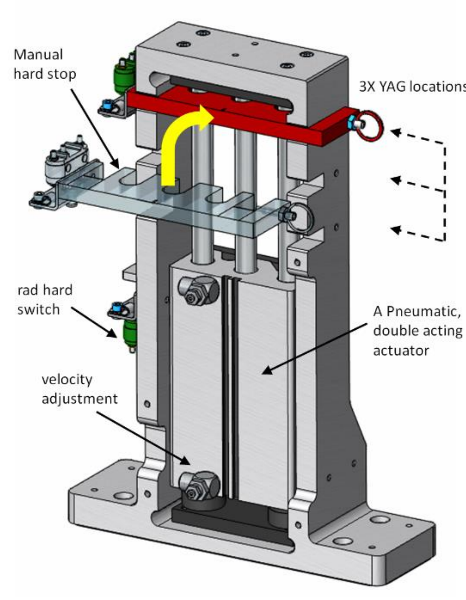

Figure 2: Actuator assembly using a 2-position pneumatic actuator to achieve 4 total positions.

The orientation of the YAG screens with respect to the beam is controlled by attaching the YAG array assembly to a fixed, UHV compatible linear guide mounted inside the chamber (Figure 3). Having the YAG array assembly on a fixed linear path reduces the repeatability and precision requirements of the actuator.

Adjusting the YAG location within the chamber is achieved by a simple coupler rod that has RH threads on one end and LH threads on the other. Rotating the coupler CW pulls the YAG array upward and rotating the coupler CCW pushes the YAG downward. Once the desired location is reached hex nuts are used to lock the coupler in place.

The first location on the YAG array assembly is a large ring to allow the beam to pass through when the device is not being used (Figure 3). Power is applied to the system to insert the YAG screen into the beam. This configuration ensures that the device fails out of the beam if power is lost.

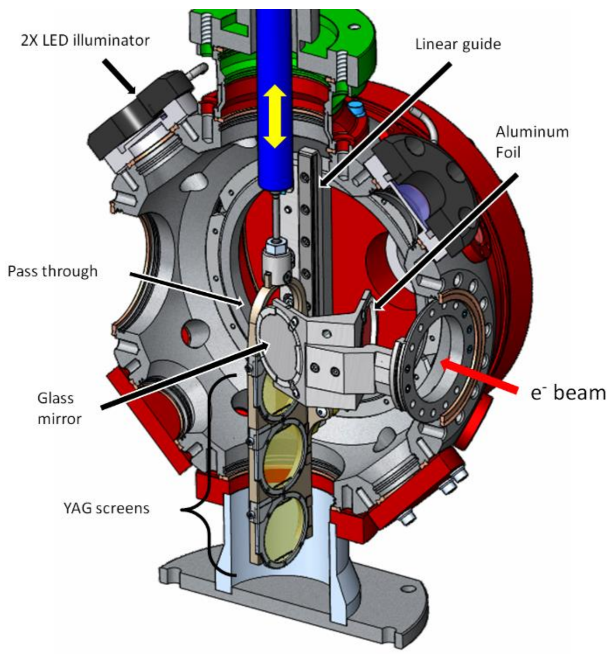

Figure 3: Isometric cross section of vacuum chamber showing internal components.

Optics

The typical configuration of a YAG screen orthogonal to the beam axis with a 45° foil (in front or behind) creates coherent optical transition radiation (COTR) that is directed into the camera [2]. This light obscures the higher resolution beam image that is created when the electron beam impinges upon the surface of the YAG screen. The optics inside the chamber was designed to address this issue by placing the YAG at 3° relative to the electron beam axis. This orientation effectively redirects the OTR away from the camera optics (Figure 4, top). To maximize the horizontal effective width and eliminate the need for a larger diameter, the foil is placed at 22.5° to the beamline with a glass mirror added to reflect the resulting image to the camera (Figure 4, bottom). The large YAG, foil and mirror ensures that no beam reflections on the frames show up on the camera image. Furthermore, the configuration allows for easy access to the YAG screens during replacement and keeps the existing optics box location.

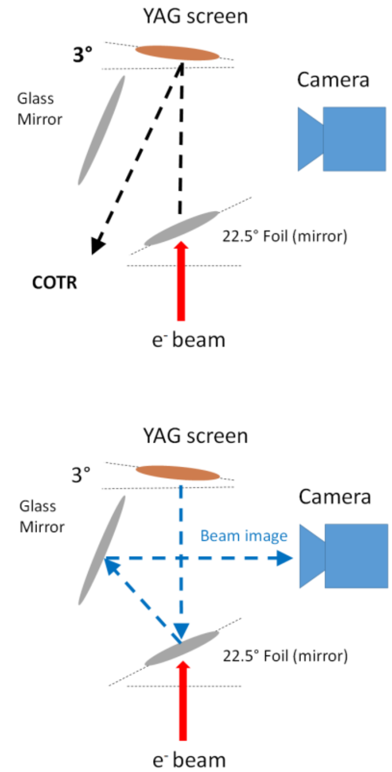

Figure 4: Orientation of YAG screen to direct COTR away from optical path to camera (top). Optical path of beam image to camera (bottom).

YAG:Ce Screen & Foil

A large YAG is required to image the transversely kicked beam and accommodate for beam jitter and slight misalignment of the beam. The large diameter allows for the addition of a chromium scale, located at the top and bottom center of the YAG screen, which is used to assist with focusing the camera on the YAG surface. This feature eliminates the need for an additional target location used only for setting the focus. With a YAG screen bonded to a keyed circular aluminum frame, the orientation of the YAG is consistent during actuation, installation and replacement. Scribe marks on the frame are used as reference markers for the camera orientation and are used to determine the initial focal distance. The YAG screen and frame cartridge design reduces the service time since they are easily inserted and removed and held in place with a screw and spring clip.

The large YAG screen is paired with a large foil (Ø42.4 mm, 1 um thick). The prototype design had the YAG screen and foil as part of one assembly and moved as one unit. This method was not feasible for multiple YAG screens of this size due to space constraints, and thus, the solution was to keep the foil stationary and only move the YAG screen array.

Chamber

A stock spherical square vacuum chamber was chosen for its many features. The chamber has DN160 (203mm) flange ports for easy access to the foil and YAG screen and many smaller ports for testing various illumination locations (Figure 5). The groove grabber features near the ports provide various internal mounting locations not typical of vacuum chambers. This attachment method was used to mount the linear slide and foil-mirror holder assembly. Since vertical space below the device is limited, the custom base flange was designed to provide a stable mounting location and minimize the retraction distance of the YAG array.

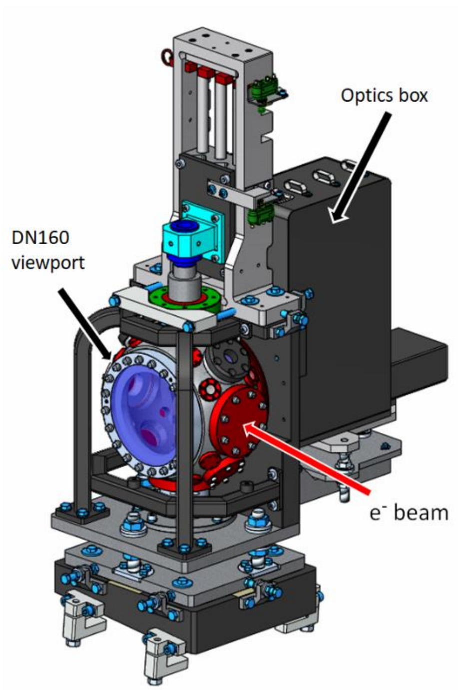

Figure 5: Model of fully assembled profile monitor.

Illumination

A dedicated light source is required to help with focusing the camera on the YAG screen surface. We chose a solution that utilizes a circular array of dimmable bright white LEDs in a compact design that mounts onto the DN40 (70 mm) CF viewport flanges. The vendor fabricated a custom version that contains bright blue LEDs which will be used for in situ inspection of the YAG screen (Figure 6, top). For in-person inspection, the YAG screen can still be viewed through the viewport when the LED illuminator is mounted to the flange.

CONCLUSION

We have designed a radiation tolerant, indexing profile monitor that has increased the service interval period from one year to three years with improved serviceability. Working with the space limitations and the existing controls system, the device was installed on the LCLS beamline in August 2017 and is currently performing better than before. Multiple features of the previous design were improved upon from multiple YAG screens with a pneumatic actuator, ease of YAG replacement, optics to mitigate OTR light and YAG inspection methods.

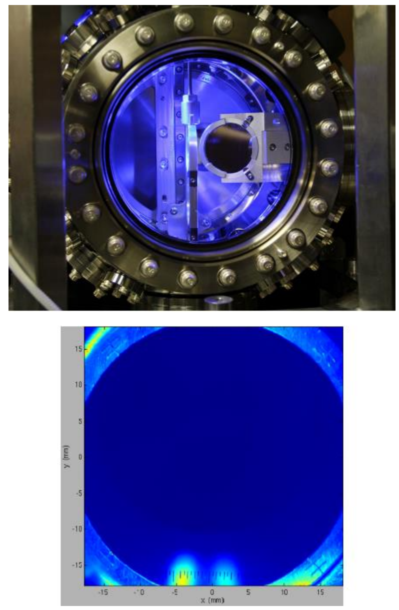

Figure 6: Photo of internal components viewed through DN160 CF viewport flange (top). Camera image of YAG screen showing scale and fiducial markings (bottom).

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REFERENCES

[1] P. Krejcik *et al.*, “Commissioning the new LCLS X-band transverse deflecting cavity with femtosecond resolution” in *IBIC2013*, Oxford, UK, Sept. 2013, pp. 308-311.

[2] H. Loos *et al.,* “Observation of coherent optical transition radiation in the LCLS linac,” in *Proc. of FEL08 Conf.,* Gyeongju, Korea, Aug. 2008, pp. 485-489.