**Specifications of Imaging Station**

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**Overview:**

The imaging station as a whole started as a concept for just a new light tight box to enable shielding of the camera as well as altering the location of the camera. The camera used has a silicon sensor that is sensitive to both neutrons and gammas. Direct interactions of this radiation saturate the incident pixel and then spreads to adjacent pixels as the energy is deposited. Further requirements came forth due to the need for running experiments in tandem with other users of the facilities; this resulted in a need to change the sample while still at power thus requiring access to the sample away from the beamline. Finally, repeatability in setup positioning was required as careful alignment of the beam is necessary. The solution to all of this was to create a mobile imaging station that housed the light tight box and stages in a way that was mobile and modular.

The fast neutrons for the beam enter the collimator very close to the reactor housing and travel the ~6.75 feet until exiting the collimator. fast neutron facility is housed within the bay of the reactor lab with a 3ft thick beam stop blocking the neutrons when not in use. For neutron imaging, this beam stop is pulled back along a set of rails to allow for the imaging equipment to be placed into the beam. Dose limits in the bay, necessity to remove the imaging equipment after use, and size constraints in how far back the beamstop could be moved all created constraints for the design. The station had to be removable yet consistent. The light tight box needed to be sufficiently large to hold shielding to attenuate scattered neutrons from the beam, yet it had to be small enough to meet requirements set by NRL staff in conjunction with dose limits. The area away from the beamline also presented other challenges with the location of a gate to prevent access to the facility and a thermal facility on the other side.

**Design:**

With all constraints and needs in mind, several iterations of designs lead to the three-piece sliding cart design. By 3 pieces, this means 3 major components that interact with each other. This design was created in CAD and as shown in the Figure 1 on the next page. Labeled as number 1 in this figure is the sliding component of the station itself; number 2 is the rolling lower piece adding the mobility component to the station; finally, number 3 is a stationary track that rigidly connects to the facility as well as the rolling piece. The stationary track sits on the same rails that the beam stop moves on, when pulled back, the user can attach the stationary track to the rails providing the secured anchor for the station. This track has two stoppers that allow for repeatable positioning of the sliding piece. The rolling cart is necessary to quickly move the bulky and heavy components from the storage area to the facility. This cart is wheeled up to the stationary track and is guided onto pins then locked into place with fasteners. Once the two lower sections are connected, the lock on the sliding component can move freely from the position away from the beam to the stoppers putting the scintillator into the beam. Having the slider enables the users to make sample changes while at power by closing the beam shutter and pulling the top section out into the bay. When the sample is prepared, the user can slide everything back into the beam and prepare the shielding for re-opening the shutter.

Diagram

Description automatically generated

Figure 1: CAD of Imaging Station

As shown above in Figure 1, there are many components on the sliding portion of the cart. The XYZ stage is placed on a plate at the bottom of the cart with the rotation stage and sample holder attached to it. This combination is used to enable the user to reach in and access the sample in the position shown in Figure 1; then, once pushed into the beam, the XYZ stage is used to align the sample with the beam. The light tight box sits atop the sliding portion of the cart. Inside the box as shown in Figure 2, the camera sits on a linear stage that enables position changes for different configurations/lenses. The beam enters the box below the scintillator moving upward along the direction of the arrow in Figure 2. A flat plane mirror mounted at 45 degrees from the scintillator directs the light to the camera. The box was designed for minimal objects being placed in the path of the beam before reaching the beam stop to reduce scatter towards the camera. The bulk of the shielding was placed on the top and right sides of the camera as the scattered neutrons from the beam stop make up the majority of the radiation field the camera sensor sees. To achieve this, 3 inches of borated high density polyethylene (HDPE) and a quarter inch of lead were placed into the primary shielding areas. The high hydrogen content in the HDPE is useful in scattering the fast neutrons and the lead is useful for the gamma ray attenuation.

Graphical user interface

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Figure 2: Top Down View of CAD Light Tight Box

The final component of the imaging station design was to reduce the dose within the reactor bay when the facility was in use. Again, borated HDPE was used as the shielding material in this case as was the practice of other shielding components for the fast beamline. Several 2 inch thick HDPE pieces are built up around the imaging station when in the beamline to keep the dose rate at acceptable levels.

**Build:**

The skeleton of the cart was all built from 1 inch T-slot as T-slot is a lightweight yet strong material that enables modifications of the cart to be made if necessary. T-slot is made from aluminum which gives minimal activation in a radioactive field. Sliders made for T-slot already exist making it an ideal component to couple all of the pieces together. A drawback of the modularity of t-slot is that the fasteners do not lock into place and could become loose over time; this can be avoided with regular checks for tightness. The light tight box was made from a 0.5 inch thick aluminum plate for mounting components. 1 inch aluminum square bars line the perimeter of the plate and act as the guide for the light tight box shroud to slide over and attach as well as prevent light from coming between the plate and should. The shroud has 3 main aluminum sheets; two bent pieces forming the sides and a top sheet all of which are fastened together by a series of overlapping right angle extrusions to prevent light leakage as shown in Figure 3 on the next page. The cables for the camera, linear slide, and cooling hoses exit out of the box from a hole that is covered by a plastic piece keeping light out of the box. All of the aluminum components of the light tight box were anodized with a black finish to reduce light scatter within the box. To the right of the light tight box in Figure 3, the holder for the rotation stage mounted to the plate on the XYZ linear stage is shown. This is the position for setting samples during an experiment.

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Figure : Front-Right of Light Tight Box Exterior

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Figure : Interior Views of Light Tight Box top-down (left) and isometric (right)

In Figure 4 above, the 3inches of borated HDPE and 0.25inch of lead is built up above and to the right of the camera. The beam travels through the scintillator and mirror to the area where the beam stop is at. Through MCNP simulation, the majority of the beam passes through to the back stop then back scatters towards the camera’s sensitive silicon sensor. A hole large enough for the camera lens was cut into the shielding material as shown in the right image of Figure 4. The camera sits on a linear stage, not visible, which is used to alter the camera position within the box for different lenses or experiment requirements. Typically, the camera is kept at the closest position the linear stage allows keeping the camera within the shielding but maximizing use of the camera sensor.

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Figure : Rear of LTB and XYZ stage components

Underneath the light tight box (LTB), there is a shelf for the linear stage controllers and assorted wires. The black boxes circled in Figure 5 above are the controllers for the XYZ stage. These must be kept on while the stages are in use and can only be turned off if the stages are at their zero positions shown in the Figure 5. Due to the constraints of the box construction and presence of the reactor wall when in use, the stages often are limited to how much they can move. In general, the “XYZMotion\_Station.py” code has artificially limited what movements can be sent to the stages. Sometimes differing experimental situations require alteration of the limits which could lead to movements into a rigid body; in this case or with an error, the stage would have to be shut off from the controller power switch. Unfortunately, this would lead to the zero point being set to the current position and possible damage to the stage if it was hit. The user can turn the controller back on and manually jog the stage back to zero positions as shown in the documentation for the XYZMotion\_Station notes using the jog buttons on the controller. Then, the user would turn the controller off again.

**Next need to talk about the stationary track placements, coupling the two tracks, putting the wires on side of shielding, putting shielding around the box.**

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