

LBNL-BELLA Center Monoenergetic Photon Source Experiments

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This document outlines measurements made by Idaho National Laboratory (INL) staff at the Berkeley Lab Laser Accelerator (BELLA) Center. Measurements of a mono-energetic Thomson photon beam were made with various INL instruments. The photon beam was generated by a laser-plasma accelerator system. This project is referred to by the name Laser Wake. Key Lawrence Berkeley National Laboratory (LBNL) personnel involved include Liona Fan-Chiang, Cameron Geddes, Anthony Gonsalves, Robert Jacob, Tobias Ostermayr, and Hai-En Tsai.

Measurements

1. Dose Measurements

Dose measurements were done using a RadCal model 1515 with an 10x5-0.6 ion chamber. The ion chamber was mounted to a ThorLabs 300 mm linear translation stage so that remote movement of the ion chamber was possible. A picture of the ion chamber mounted on the translation stage is shown in Figure 1

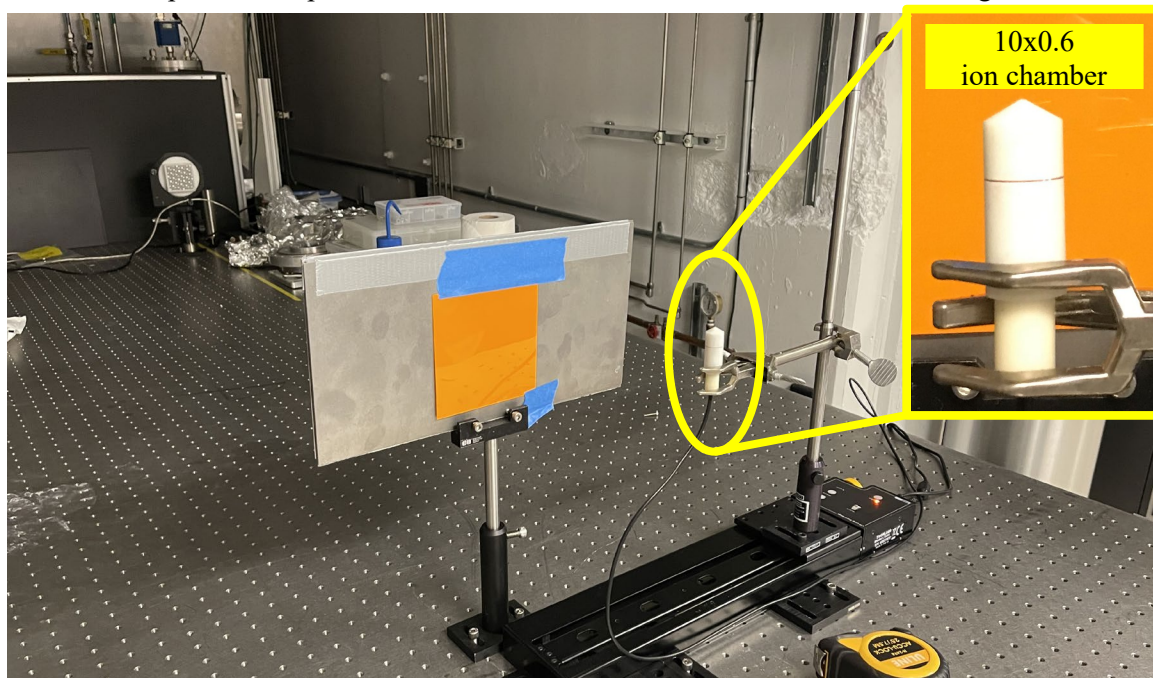


Figure 1 RadCal ion chamber (outlined in yellow) on translation stage. Also shown is an orange square of radiochromic film taped to a tungsten plate.

The RadCal and ion chamber combination have a specified integrated dose range from 0.01 mR to 420 kR. The specified noise is 0.02 R/min. This was the first time measuring the direct in-beam dose and it was anticipated that the selected ion chamber model would have been appropriate. However, as measurements were made, the dose rates were much lower than anticipated. Moving forward, a more sensitive ion chamber with less noise would be recommended.

The RadCal unit can be operated in two modes, instantaneous and integrated dose rate modes. The instantaneous dose rate mode proved to be too noisy. Therefore, the integrated dose mode was used. Then the averaging of the dose, over time, was used to measure the rate. This was accomplished by curve fitting the dose profile, then measuring the rate of change to the fit.

2. Novo Radiograph Measurements

A Novo digital radiograph detection system was used for beam imaging. This system was used to measure the beam profile and quality. The system produces images that are 16.73 by 13.66 inches (2878 x 2350 pixels) with depth of 16 bits.

Various inspection items were used for image quality measurements. RadCal dose measurements were made in conjunction with collected images, for dose calibration of the radiographs.

The method used to make the measurements with the Novo system, was to take one or more sequential exposures with the same exposure time. Then average all the images together in post processing. A dark image i.e., exposure with no beam, was also taken with the same exposure time, and in the same configuration. This image was then used to subtract the background from the averaged images. All post processing of images was done using ImageJ created by the National Institute of Health (NIH).

3. Radiochromic Film

Radiochromic film was used for beam imaging. This was used in various configurations and locations. The dose intensities were too weak given the limited exposure times the results did not give any quantifiable change in the film. Figure 1 shows a picture of radiochromic film (orange) taped to a tungsten plate and prepared for irradiation.

4. Photon Energy Measurements & Indium Foil Activation

Comments on photon energy and indium foil will be addressed in a separate memo.
LBNL Photon Source, In-beam Spectra and Indium Foil Activation – CCN 250168

INL Experimental Detectors & Hardware

- RadCal Model 1515 with 1550 converter and 10x5-0.6 ion chamber
- ThorLabs 300mm translation stage
- Ortec Transpec high-purity germanium (HPGe) detector
- Novo portable digital x-ray system with a NOVO-22W panel detector
- Radiochromic film

Commercial and Off the Shelf Software Used

- National Instrument's LabVIEW was used to control and communicate with the RadCal and ThorLabs translation stage.
- Ortec Maestro was used to control and communicate with the Ortec Transpec HPGe
- Novo's Touch Pro Software was used to control and acquire radiograph images.
- ImageJ from the National Institute of Health was used for image processing.



Figure 2 LBNL-BELLA Control Room. Constant beam monitoring and adjustment is required for beam creation and optimization.

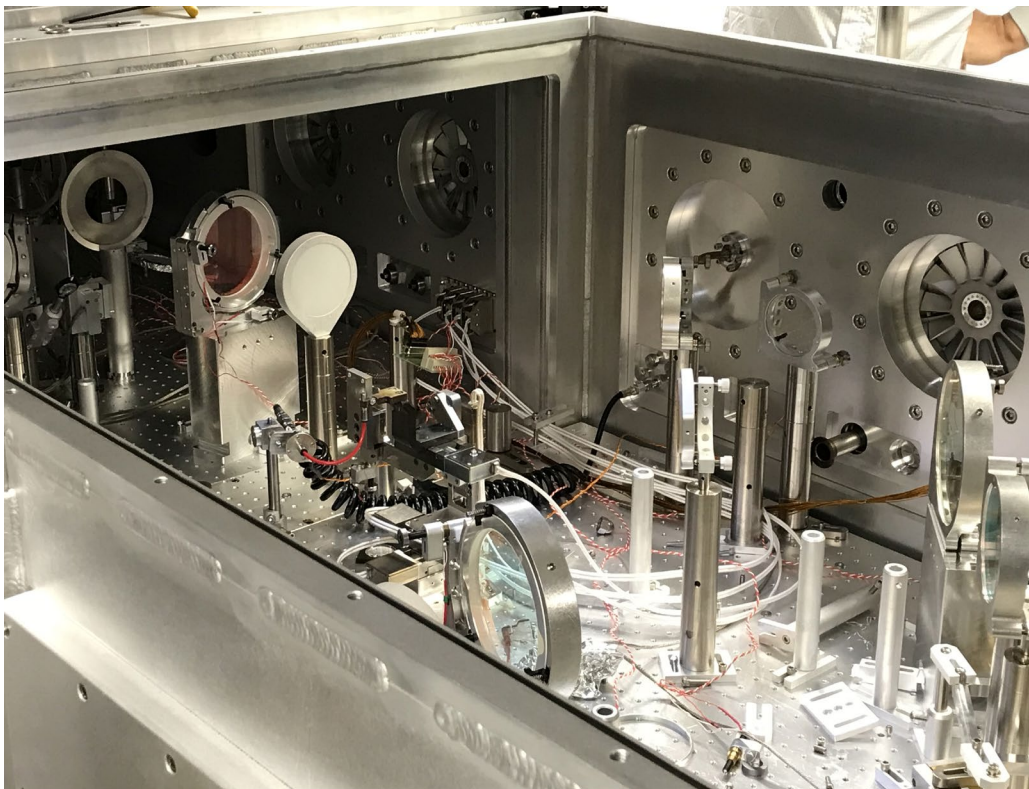


Figure 3 Some of the system components.

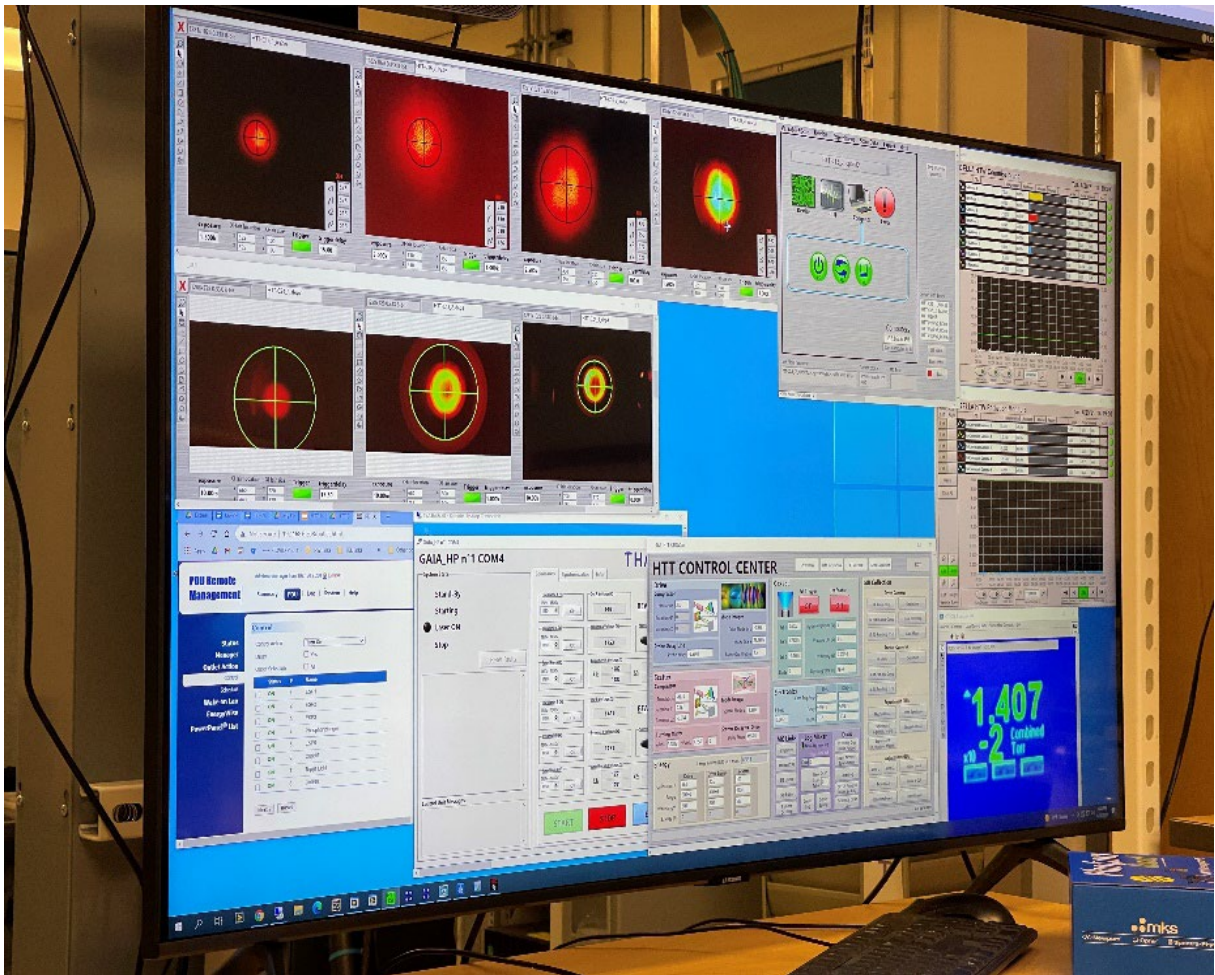


Figure 4 A picture of a control room monitor. This is used by the BELLA operators to adjust system parameters and to monitor current system conditions.

Startup issues - Monday June 28th

It took most of Monday to get the system tuned to create a bremsstrahlung beam. Just after the system was tuned, an earthquake occurred causing a misalignment of the laser system, and damaging the system components. This damage paused the experimental process until repairs could be made. One of the components that was damaged is shown in Figure 6. This picture was taken about halfway through refurbishment of the component, which took many hours.

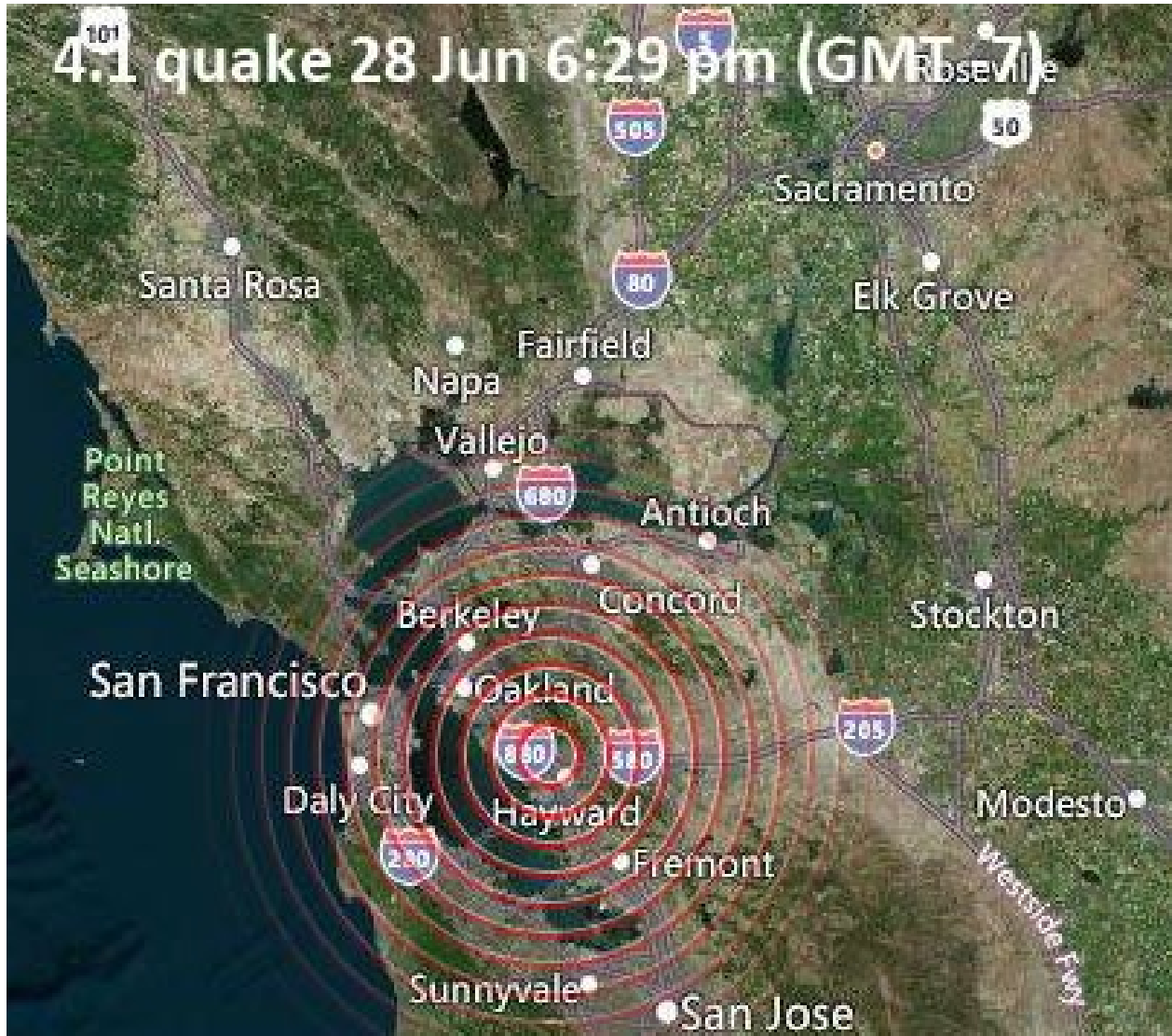


Figure 5 Origin of earthquake. <https://www.volcanodiscovery.com/earthquakes/quake-info/6304095/quake-felt-Jun-29-2021-Near-San-Francisco-California-USA.html>

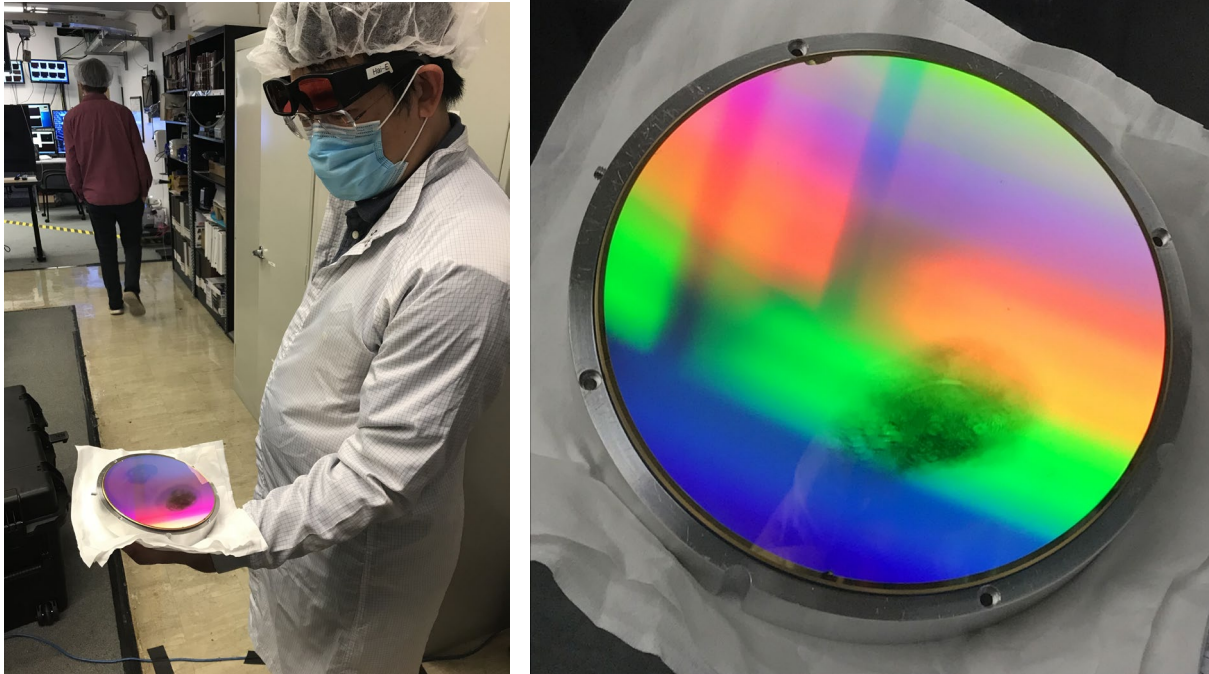


Figure 6 One of the components damaged by the earthquake.

1. Dose Measurements

1.1 Initial dose on film with tungsten shield. *Ref. 20210629 AC*

- Source: 1 Hz Bremsstrahlung
- RadCal position: centered in beam at position 150 mm
- Peak dose rate at 1 Hz: 2375 mR/Hr (background rate subtracted)
- Peak dose rate at $\frac{1}{2}$ Hz: 1106 mR/Hr (background rate subtracted)

Figure 8 shows the accumulated dose (upper) and dose rate (lower) plots. The dose rate plot is derived from the accumulated dose by fitting, smoothing, and differentiating to calculate the rate. The time axis is in Mountain Standard Time (MST).

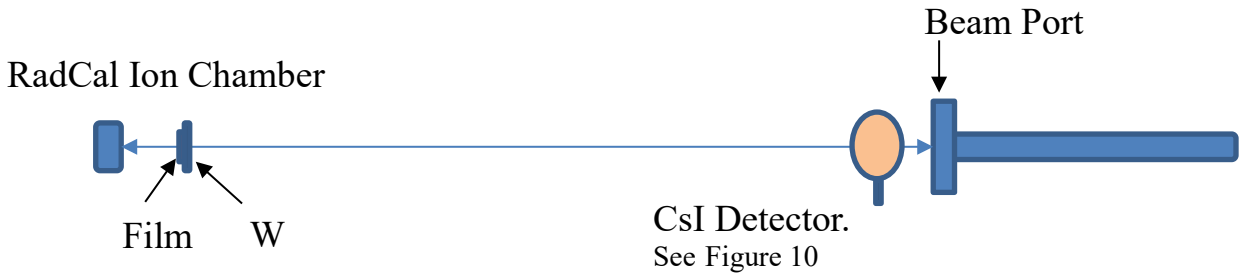


Figure 7 Diagram of setup and components. Measurement 1.1

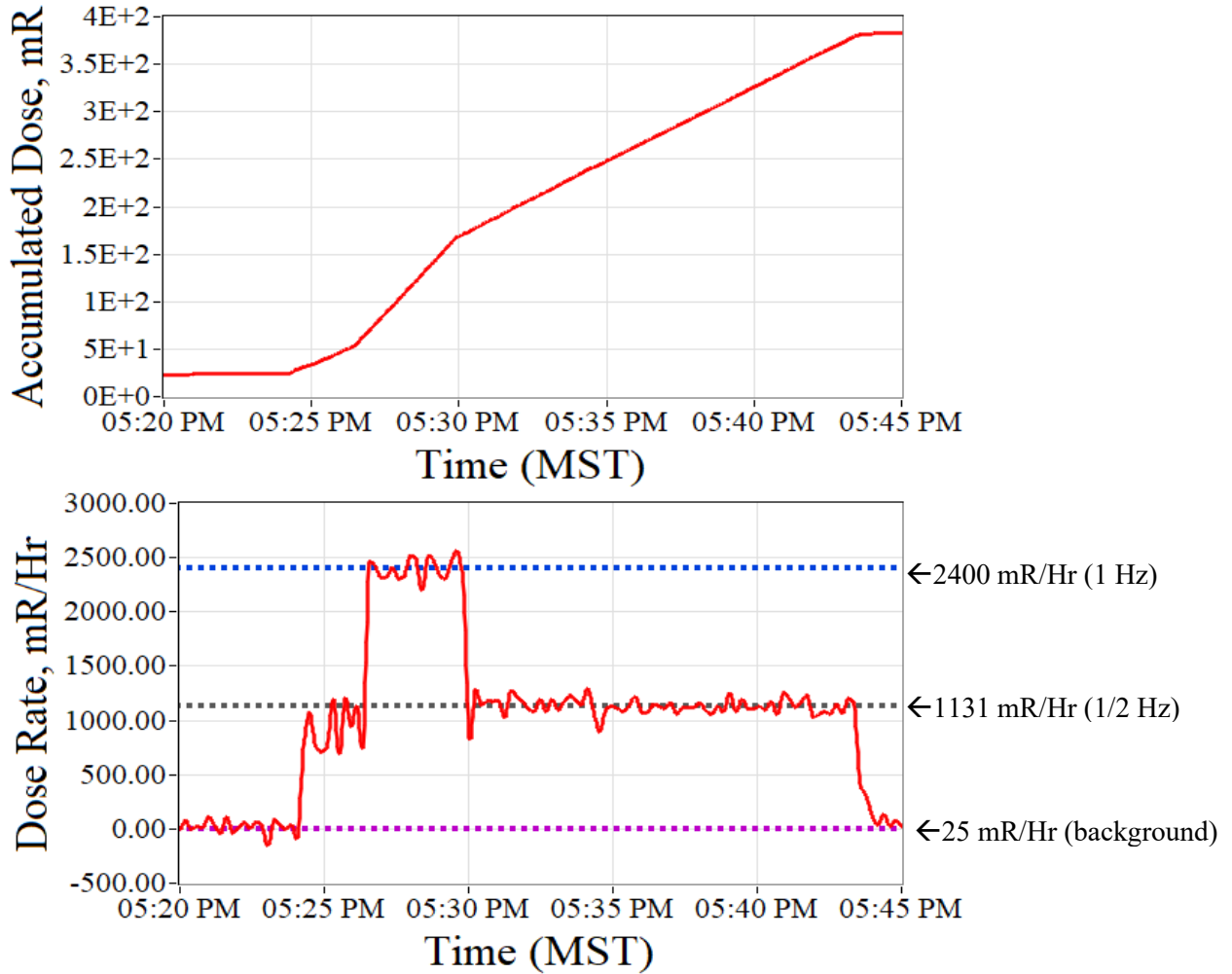


Figure 8 RadCal dose and rate plots at 1 Hz and 1/2 Hz Bremsstrahlung beam. Measurement 1.1

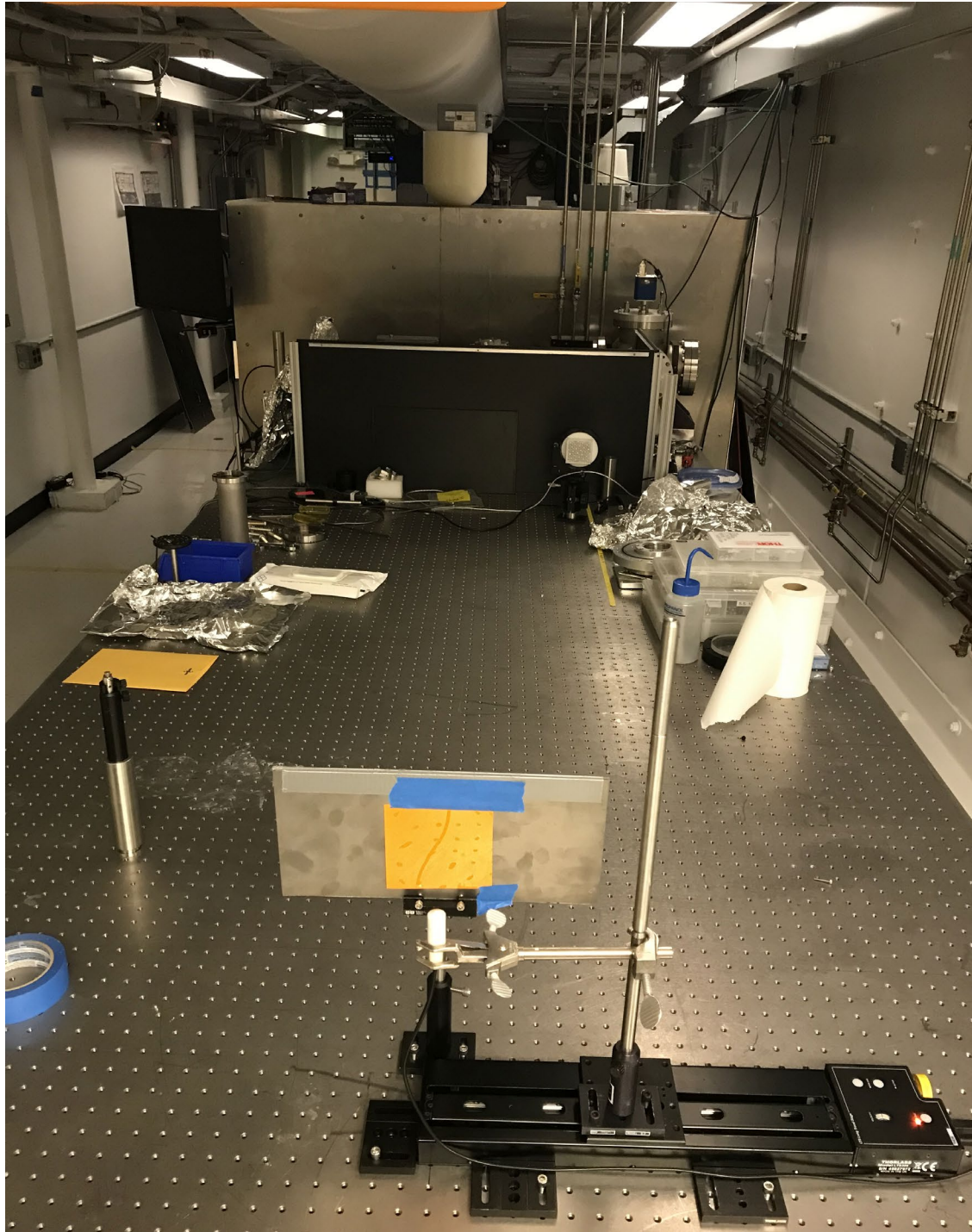


Figure 9 Setup of the RadCal dose measurement 1.1 with radiochromic film. The black box in the back, houses the CSI detector setup. Inside details can be seen in Figure 10.

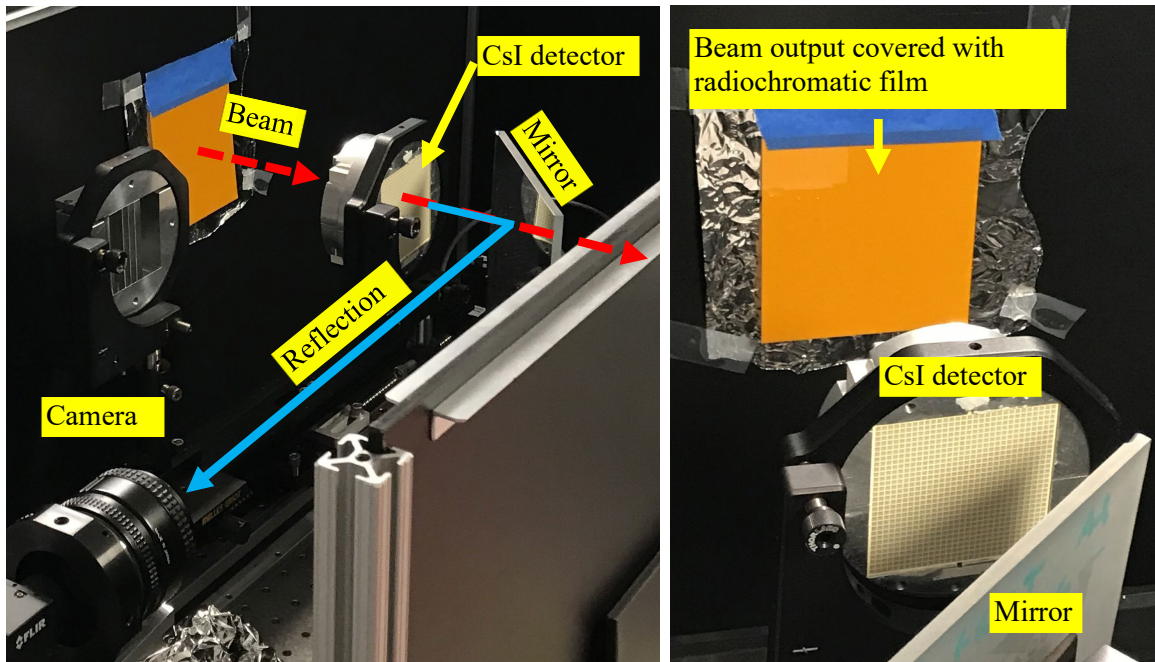


Figure 10 Pixilated CsI detector setup. The detector is setup in beamline a mirror and camera is used to measure the scintillation light. Setup is enclosed in a box to reduce ambient light. This detector is monitored in the control room.

1.2 Measure Bremsstrahlung beam dose profile through tungsten, film, and CsI detector. *Ref. AD position 0 background and AE 0.5 mm/s scan*

- Source: 1 Hz Bremsstrahlung
- RadCal scan: 300 mm to 0 mm (centered) at a speed of 0.5 mm/s
- Peak dose rate: 2011 mR/Hr (background rate subtracted)
- Dose rate profile Full Width Half Max (FWHM): 86.7 mm

This is the same setup as measurement 1.1 and can be seen in Figure 9.



Figure 11 Diagram of setup and components. Measurement 1.2

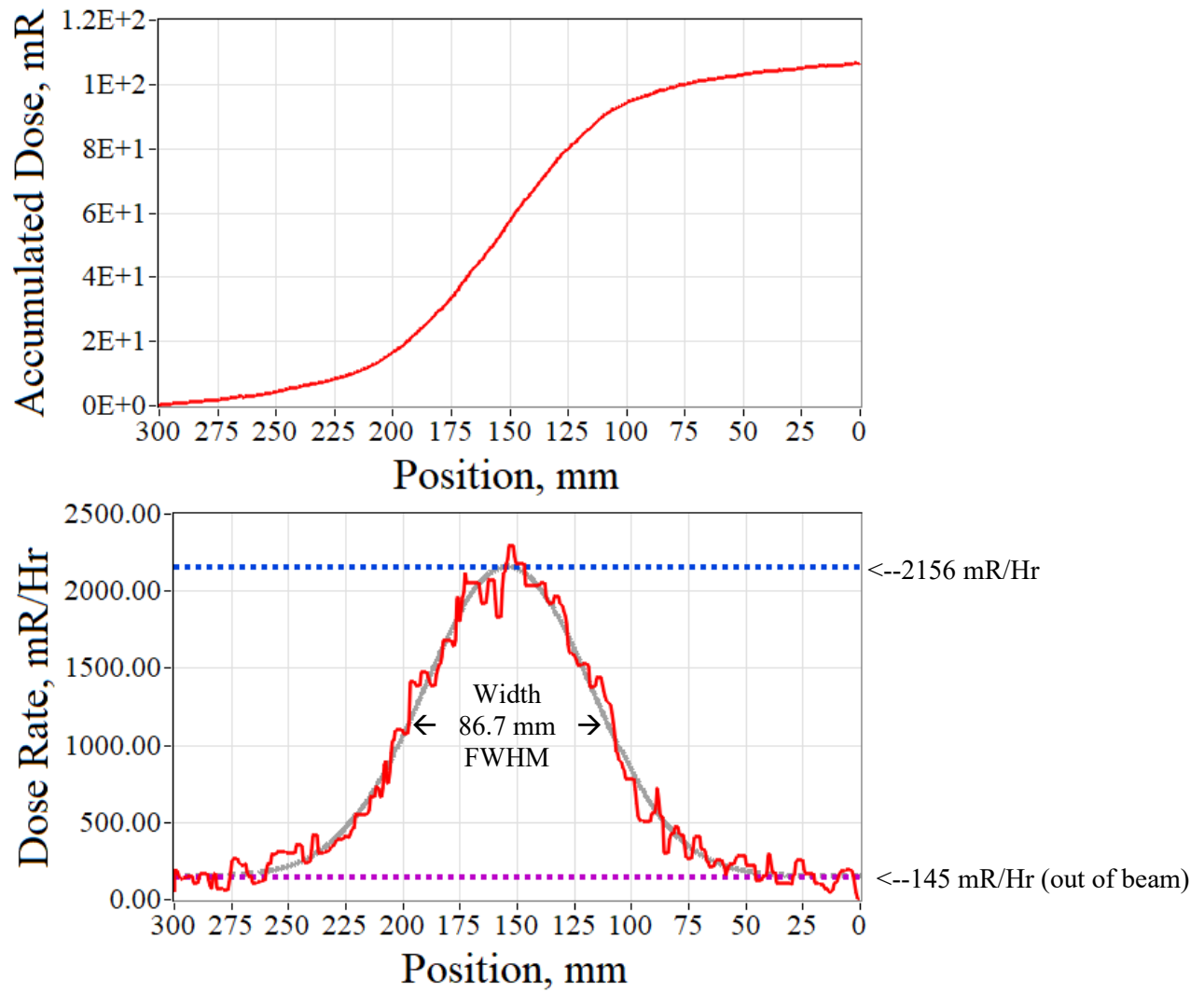


Figure 12 Bremsstrahlung beam profile dose rate plots. Measurement 1.2

1.3 Measure Bremsstrahlung beam dose profile with only CsI detector. Tungsten & film removed. *Ref. AF.*

- Source: 1 Hz Bremsstrahlung
- RadCal scan: 300 mm to 0 mm (centered) at a speed of 0.5 mm/s
- Peak dose rate: 456 mR/Hr (baseline subtracted)
- Dose rate profile width (FWHM): 82.0 mm

This is a repeat of the beam scan in measurement 1.2 with the removal of the tungsten plate. The peak dose rate goes down significantly as well as the background.

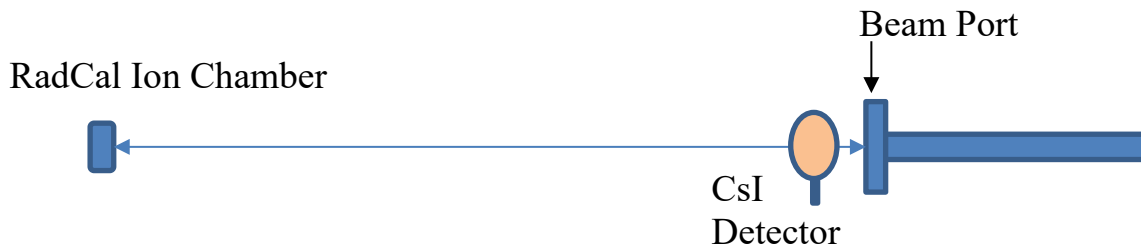


Figure 13 Diagram of setup and components. Measurement 1.3

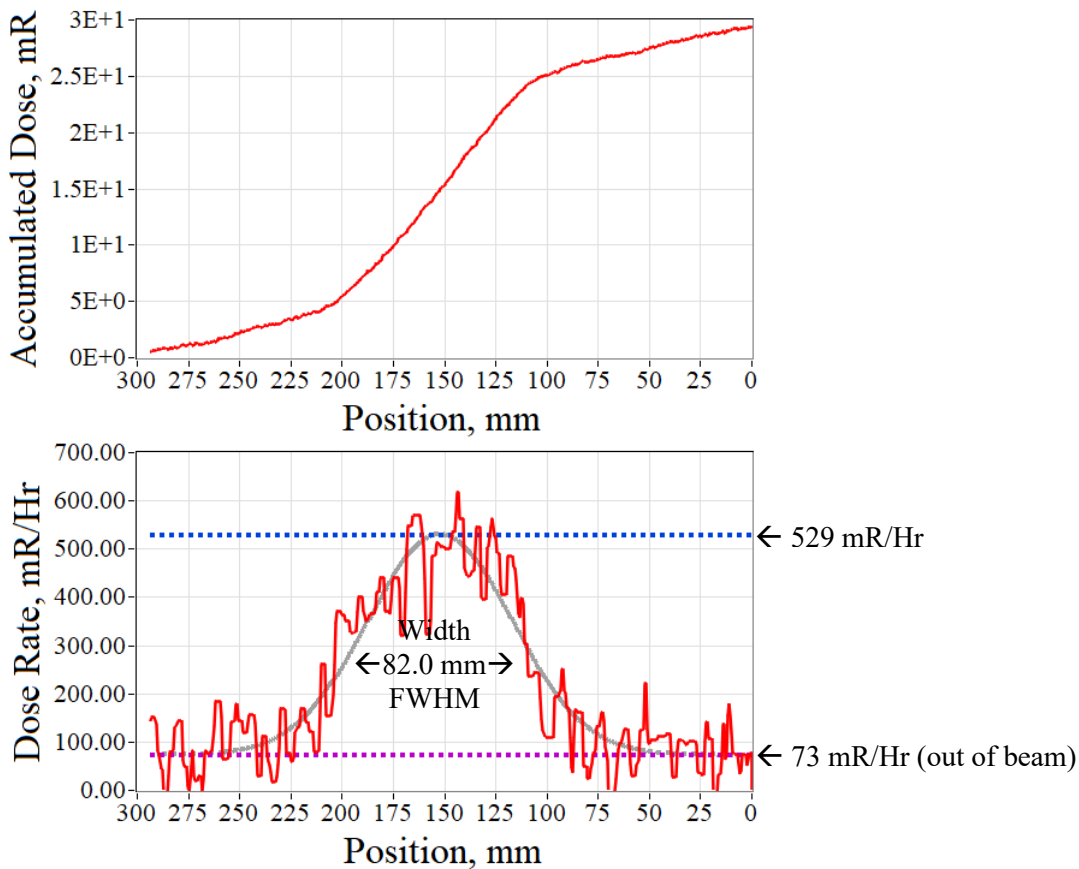


Figure 14 Bremsstrahlung beam profile dose rate plots. Measurement 1.3

1.4 Measure Bremsstrahlung beam dose profile with CsI detector Removed. *Ref. AG.*

- Source: 1 Hz Bremsstrahlung
- RadCal scan: 300 mm to 0 mm (centered) at a speed of 0.5 mm/s
- Peak dose rate: 1068 mR/Hr (baseline subtracted)
- Dose rate profile width (FWHM): 81.3 mm

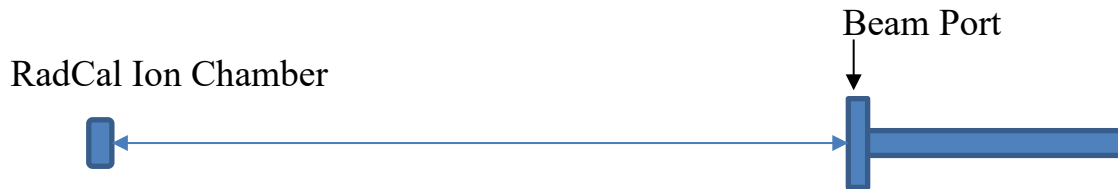


Figure 15 Diagram of setup and components. Measurement 1.4

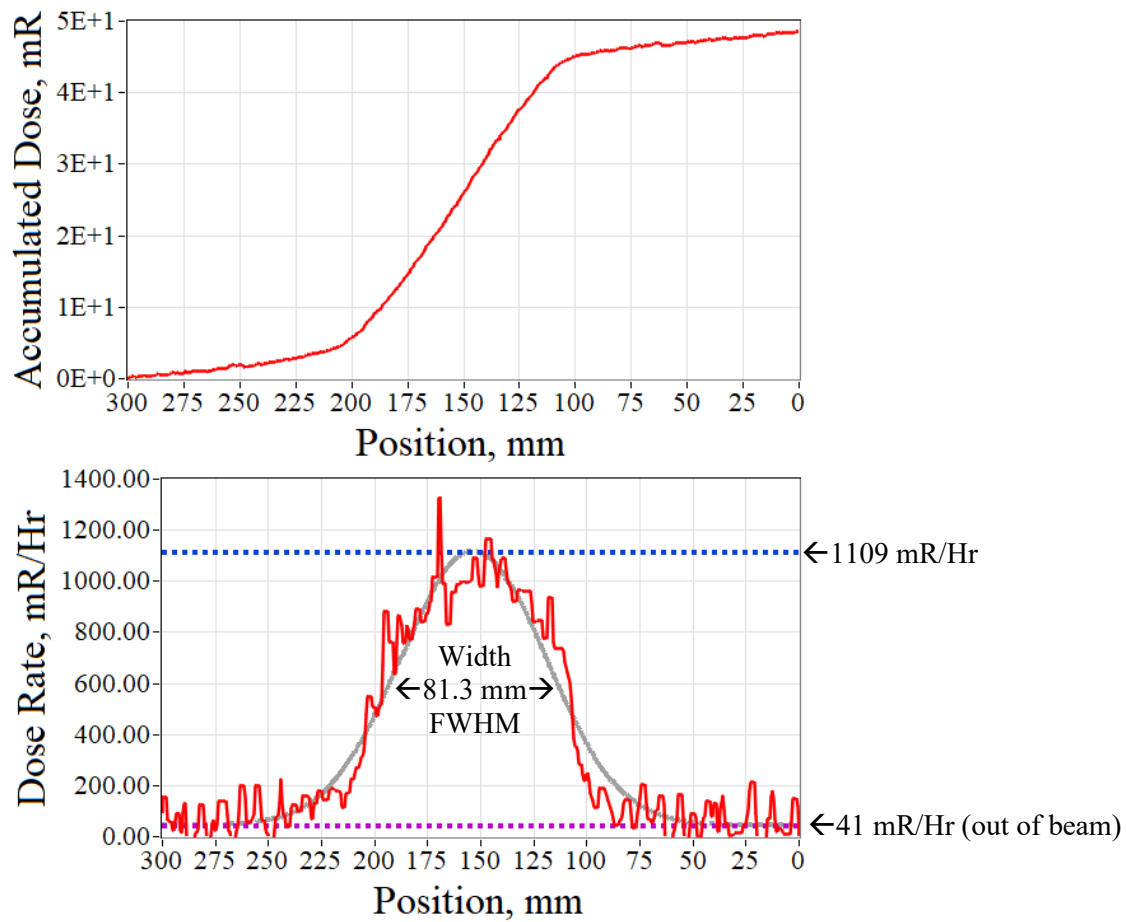


Figure 16 Bremsstrahlung beam profile dose rate plots. Measurement 1.4

1.5 Dose with lead shielding & Transpec HPGe. *Ref. AI*

- Source: 1 Hz Bremsstrahlung
- CsI detector has been removed
- RadCal position: centered in beam at position 150 mm
- Dose with 8" of lead: 10 mR/Hr (background rate subtracted)
- Dose with 6" of lead: 10 mR/Hr (background rate subtracted)
- Dose with 4" of lead: 12 mR/Hr (background rate subtracted)
- Dose with 4" of lead with Transpec HPGe: 11 mR/Hr (background rate subtracted)

Different thicknesses of lead were stacked in front of the beam, to give an idea of beam attenuation as a function of the shielding. The lead was placed as close as possible to the beam output. Figure 18 shows the lead configuration of 8, 6, & 4 inches. This was done in preparation for measurements with the Ortec HPGe Transpec detector.

The objective was to attenuate the beam to a level where the Transpec detector is not overwhelmed and/or damaged but still had a measurable signal above background. The highest attenuation was measured first with 4 bricks of lead (8 inches). The dose rate was measured with the RadCal, and then shielding was reduced and remeasured.

The Transpec was put on beam centerline and a measurement with the Transpec detector was made with four inches of lead. Figure 19 shows a picture taken of the lead shielding from behind the Transpec, and a picture of the Transpec from the beam's perspective. A 600 second passive (beam off) measurement and 600 second active (beam on) measurement was made with the Transpec.

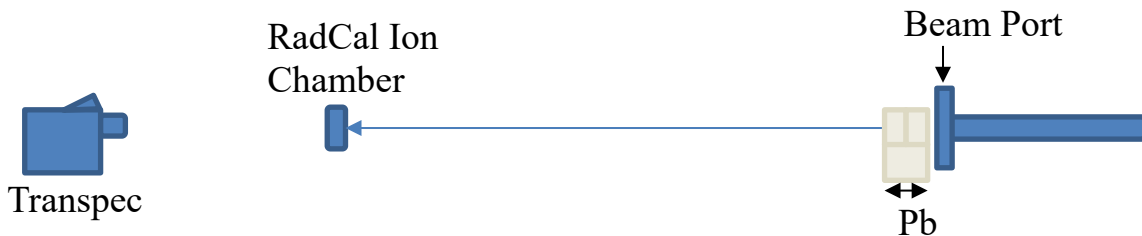


Figure 17 Diagram of setup and components. Measurement 1.5

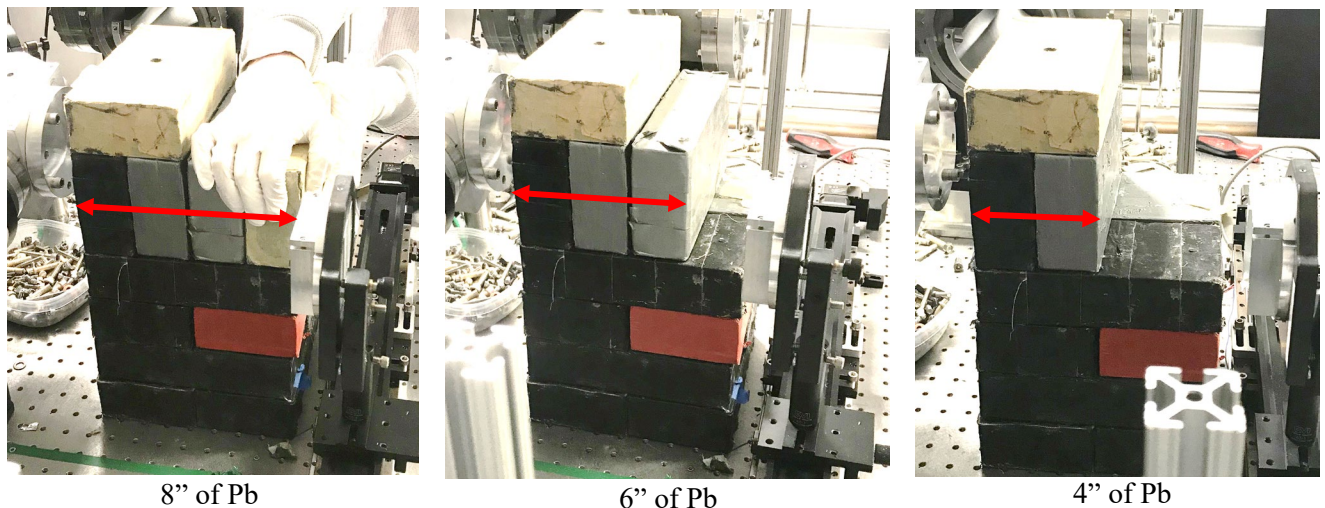
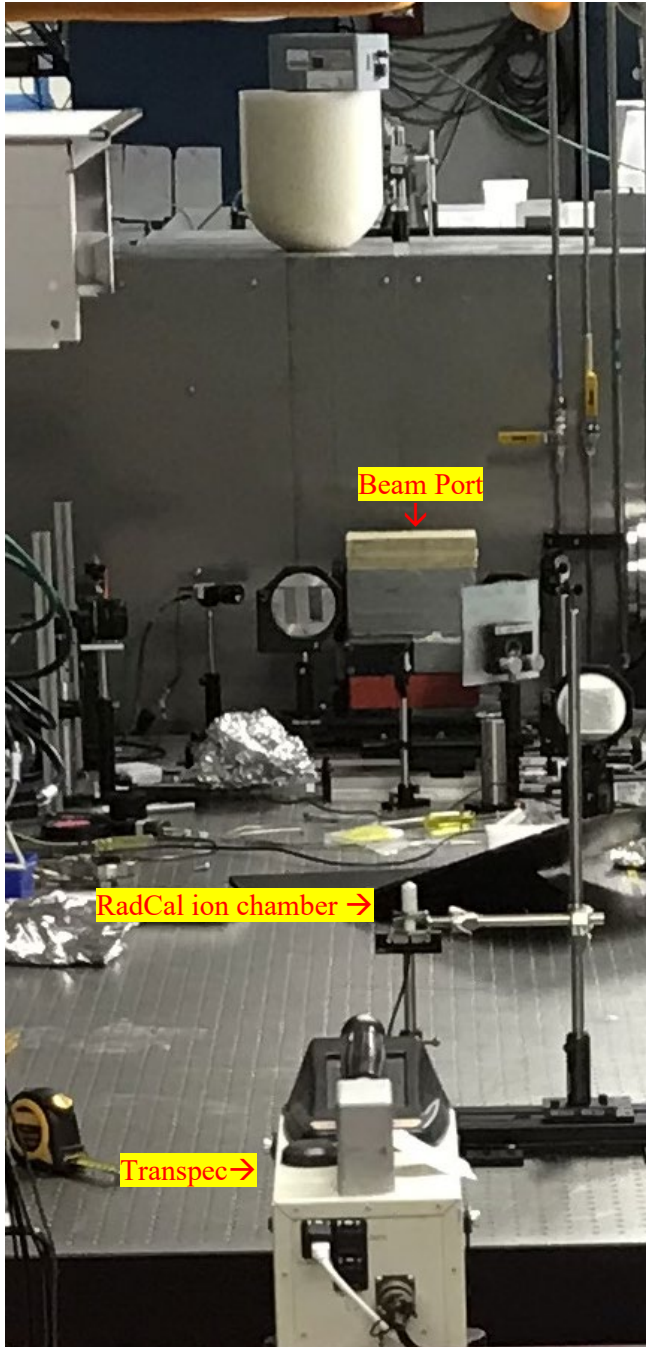
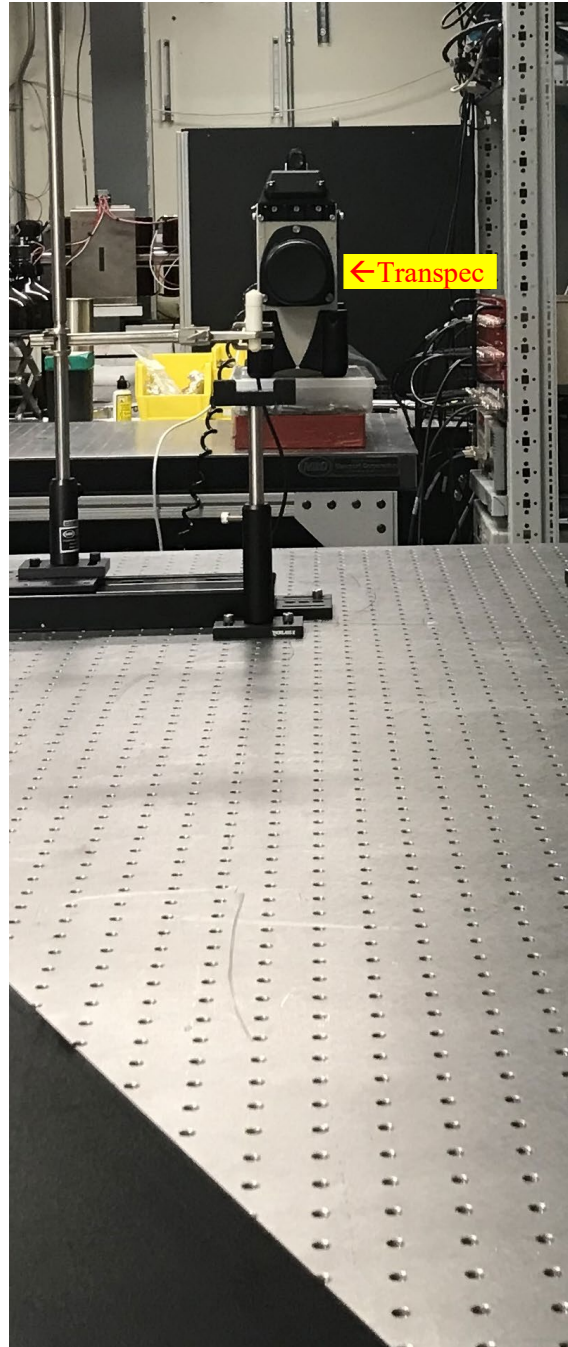


Figure 18 Lead configurations in front of the beam.



The view from behind the Transpec, towards the beam.



The beam's view of the Transpec.

Figure 19 Ortec HPGe Transpec measurement of the bremsstrahlung beam.

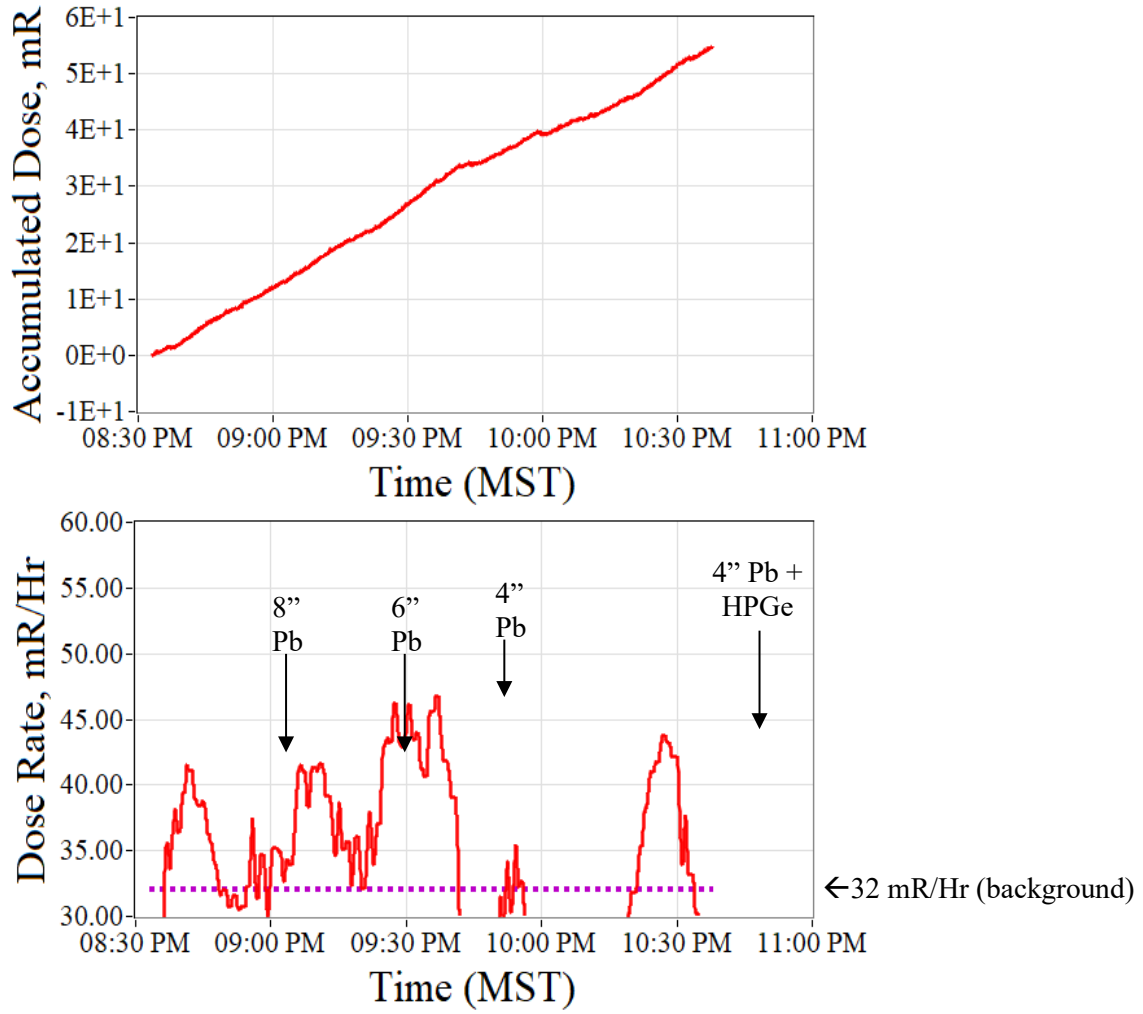


Figure 20 Bremsstrahlung dose rate plots with 8, 6, & 4 inches of lead.

1.6 Dose with lead shielding, Transpec HPGe & Indium foil. *Ref. AK*

- Source: 1 Hz Bremsstrahlung
- CsI detector has been removed
- RadCal position: centered in beam at position 150 mm
- Dose with 4" of lead with Transpec HPGe: 17 mR/Hr (background rate subtracted)
- Transpec HPGe Measurement made 20210630AD

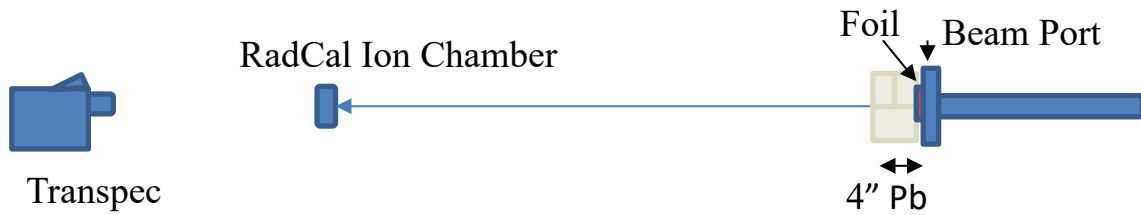


Figure 21 Diagram of setup and components. Measurement 1.6



Figure 22 Beam output window with Indium foil and radiochromatic film.

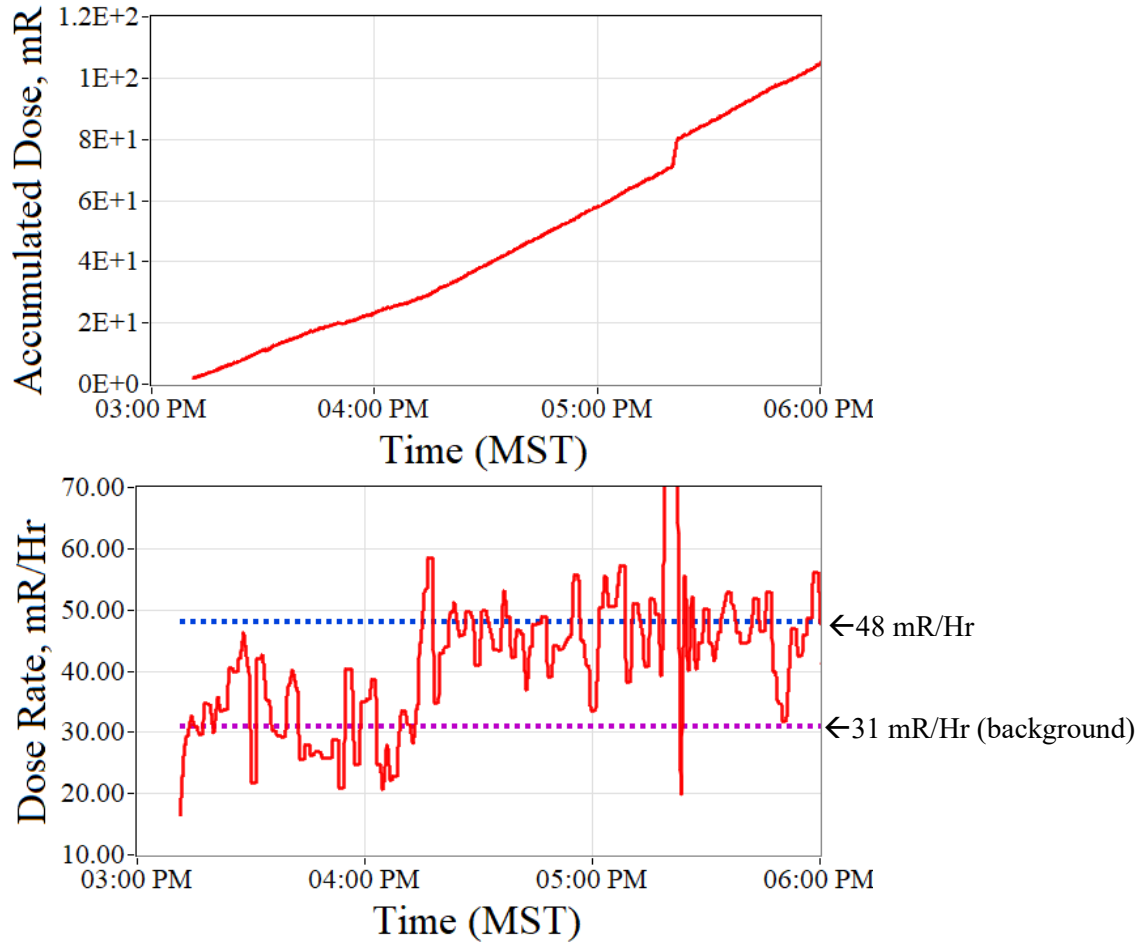


Figure 23 RadCal dose rate plots with 4" of lead and Indium foil. Measurement 1.6

1.7 Initial Thomson Photon Dose with CsI detector. *Ref. AL*

- Source: 1 Hz Thomson Photons
- Indium foil is flipped up out of the beam and lead has been removed.
- RadCal position: centered in beam at position 150 mm
- Dose rate: 22 mR/Hr (background rate subtracted)

Source is tuned for producing monoenergetic Thomson photons. This experiment measures the photon beam dose rate with the RadCal. The observed dose rate was much lower than the Bremsstrahlung source. The dose rate plot in Figure 25 shows the beam turning on at ~6:19 PM. The dose rate starting and ending at zero is an end effect of the median filter used to smooth the data.



Figure 24 Diagram of setup and components with Thomson photons. Measurement 1.7

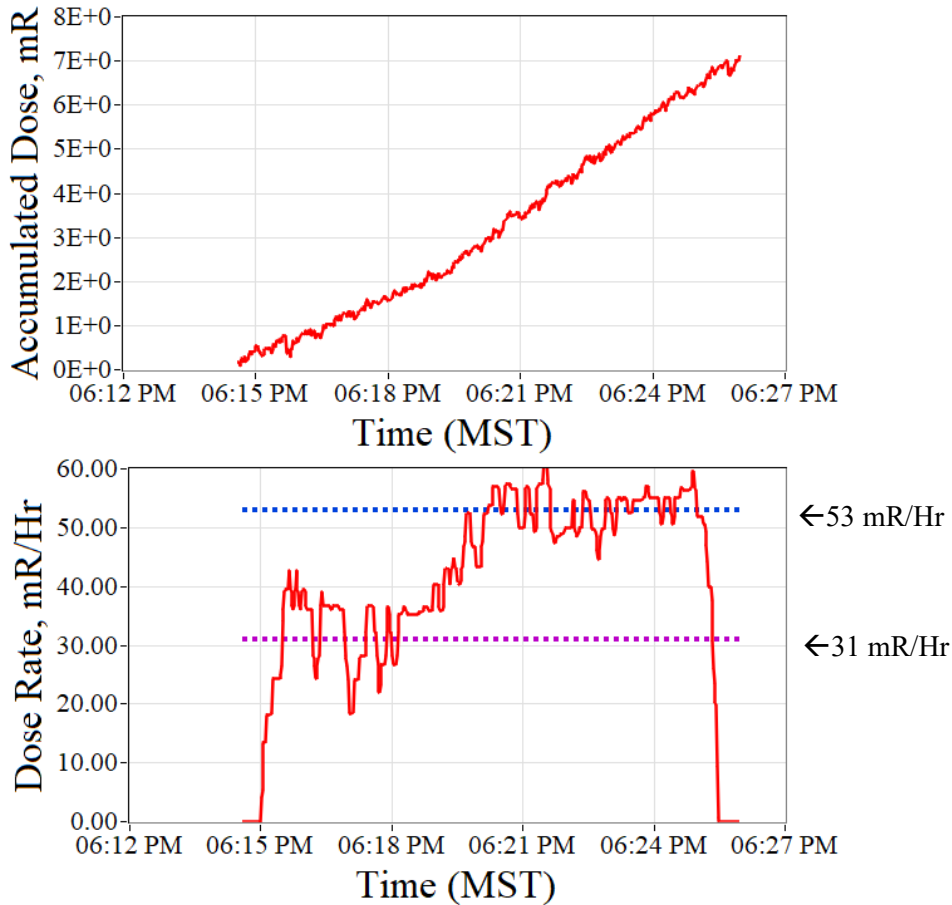


Figure 25 RadCal dose rate plots of Thomson photon beam. Measurement 1.7

1.8 Thomson Photon Dose Profile with CsI detector. *Ref. AM*

- Source: 1 Hz Thomson Photons
- RadCal scan: 300 mm to 0 mm (centered) at a speed of 0.5 mm/s
- Peak dose rate: 20 mR/Hr (background rate subtracted)
- Too noisy for width measurement.

A measurement of the Thomson photon beam was attempted but the beam profile was not noticeable from background. The translation time across the beam needs to be lengthened for more averaging of the signal. This can be accomplished by slowing down the speed of the translation stage. See measurement 1.10.



Figure 26 Diagram of setup and components with Thomson photons. Measurement 1.8

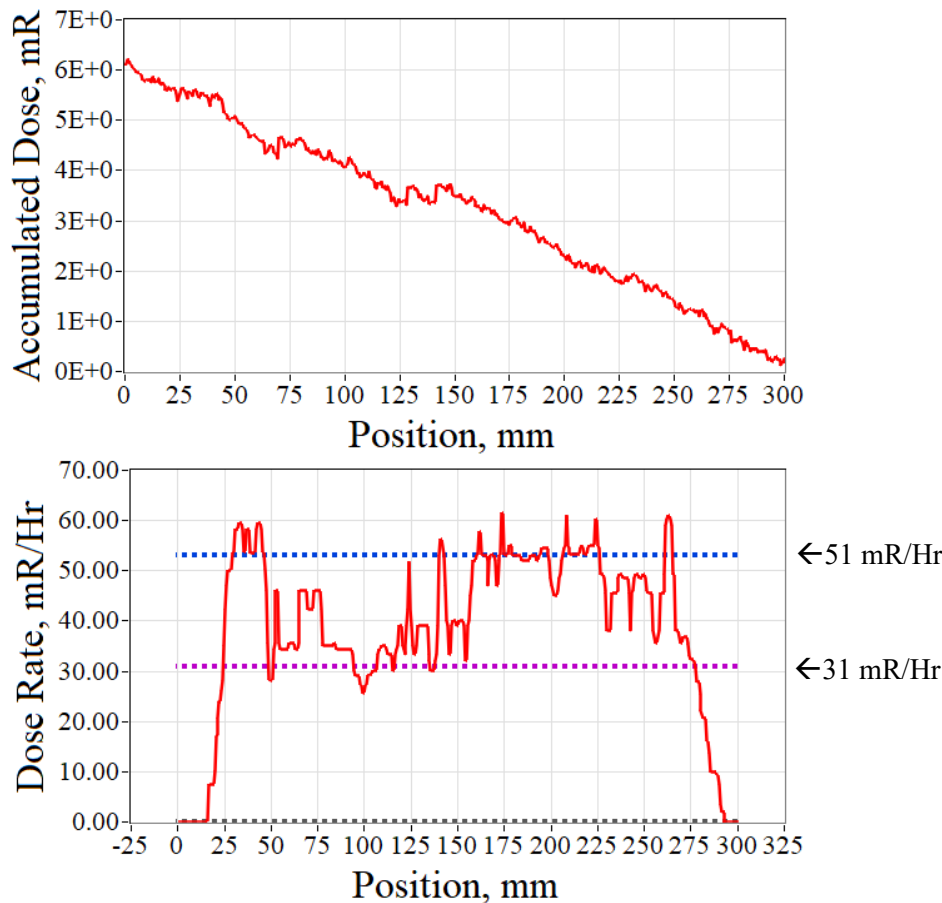


Figure 27 Thomson beam profile dose rate plots. Measurement 1.8

1.9 Thomson Photon Dose (no CsI detector). *Ref. AN*

- Source: 1 Hz Thomson Photons
- RadCal position: centered in beam at position 150 mm
- Dose rate: 39 mR/Hr (background rate subtracted)



Figure 28 Diagram of setup and components with Thomson photons. Measurement 1.9

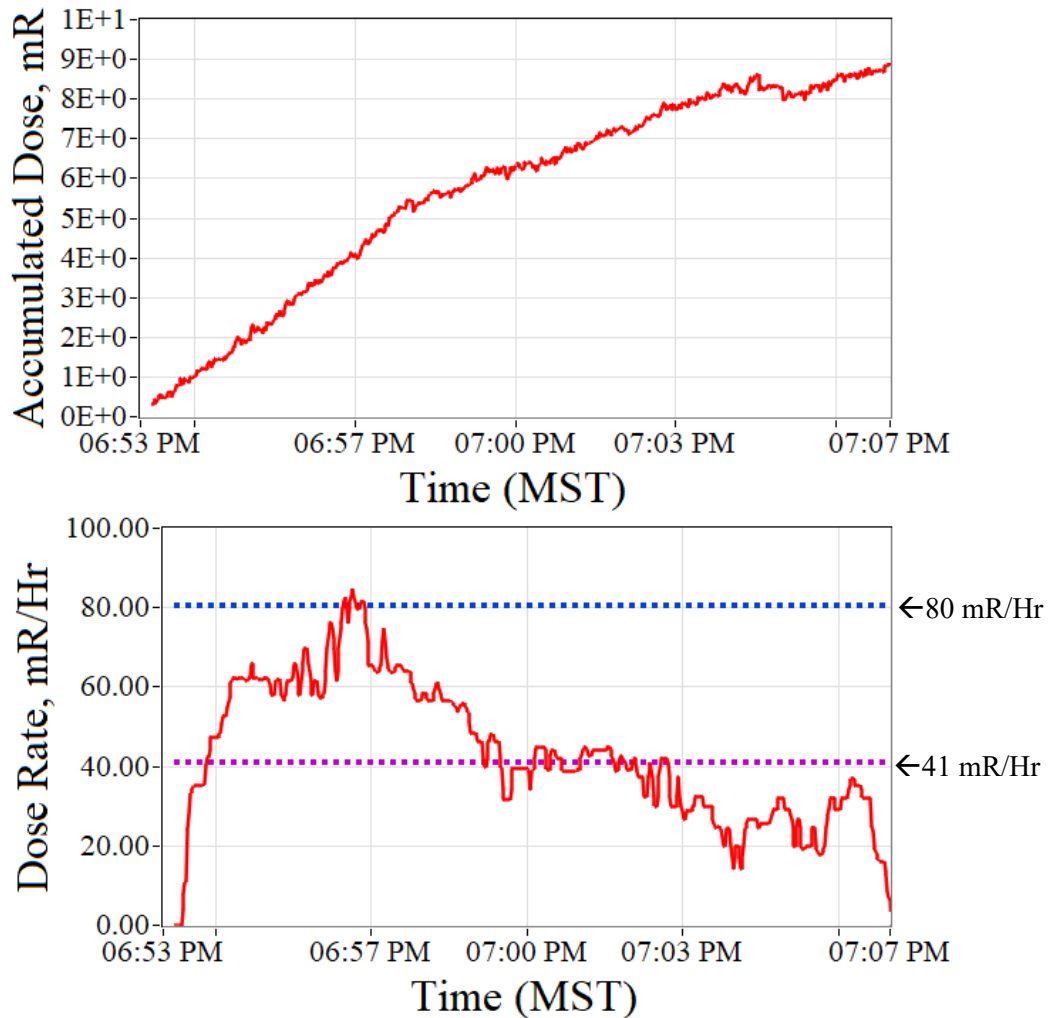


Figure 29 Thomson beam profile dose rate plots. Measurement 1.9

1.10 Thomson Photon Dose Profile. *Ref. AO*

- Source: 1 Hz Thomson Photons
- RadCal scan: 75 mm to 225 mm (centered) at a speed of 0.04 mm/s
- Peak dose rate: 37 mR/Hr (background rate subtracted)
- Dose rate profile width (FWHM): 63.1 mm



Figure 30 Diagram of setup and components with Thomson photons. Measurement 1.10

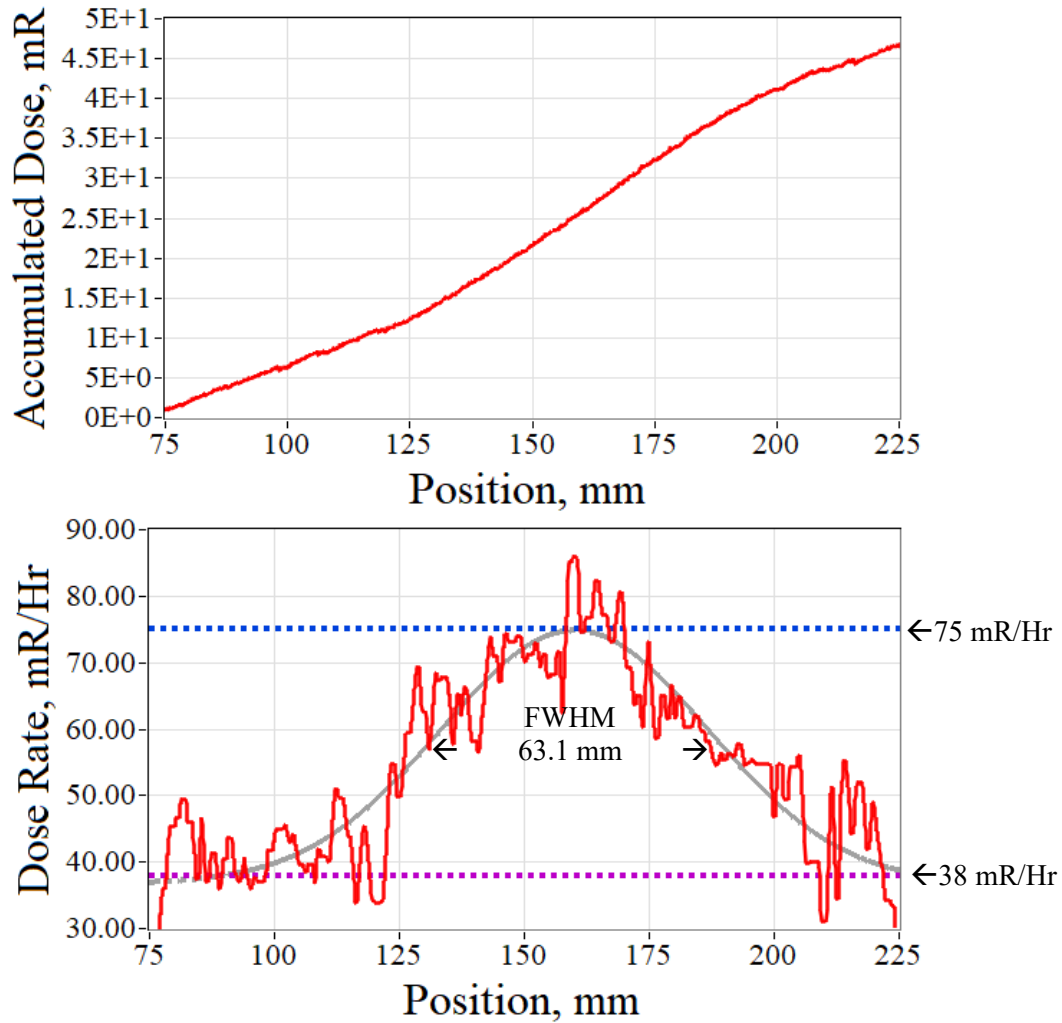


Figure 31 Thomson beam profile dose rate plots. Measurement 1.1

1.11 RadCal background measurements.

Table 1 This table shows the passive backgrounds and calculates the mean background value

Background Measurements	Dose mR/hr
AC	25.33
AI	22.48
AJ	25.9
AK	27.1
AL	26.02
AN	23.32
AR	21.2
AT	28.21
AT	27.18
Mean	25.9
Standard Deviation	2.228656795

2. Novo Radiograph Measurements

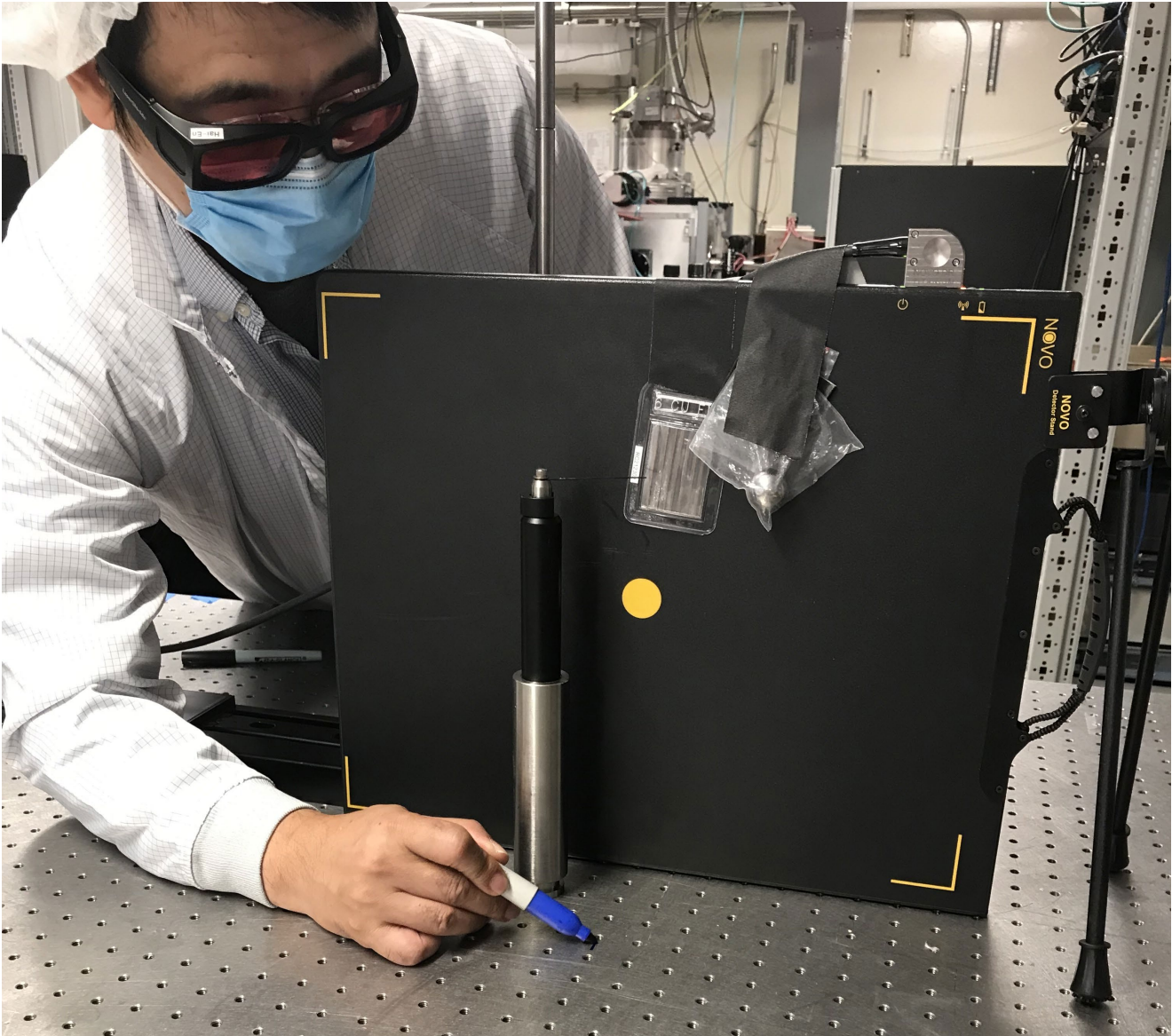


Figure 32 Setup and positioning of the NOVO digital radiography panel. Front side.

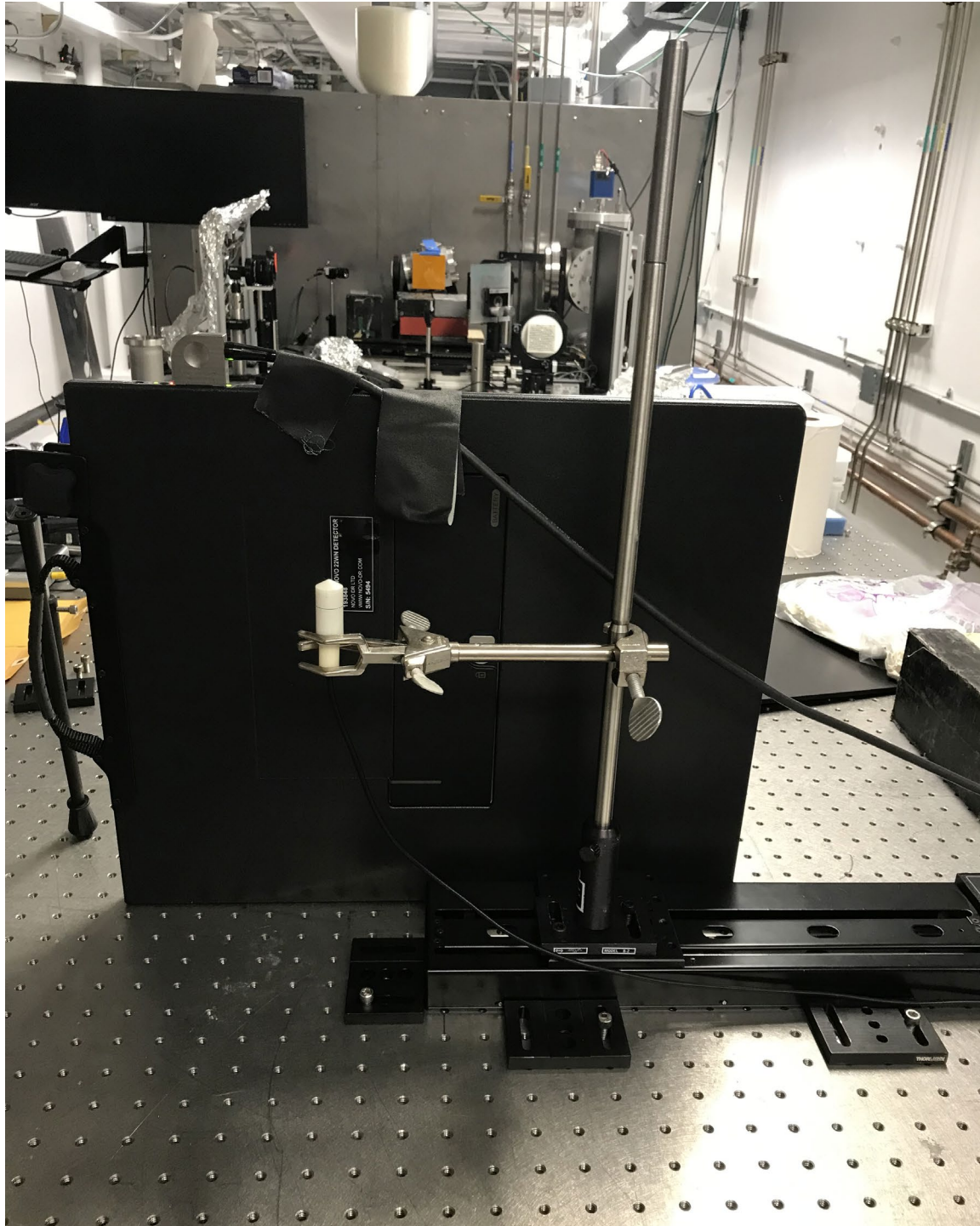


Figure 33 The backside of the NOVO detector. The detector is placed in front of the RadCal ion chamber.



Figure 34 Top view of the NOVO detector and ion chamber.

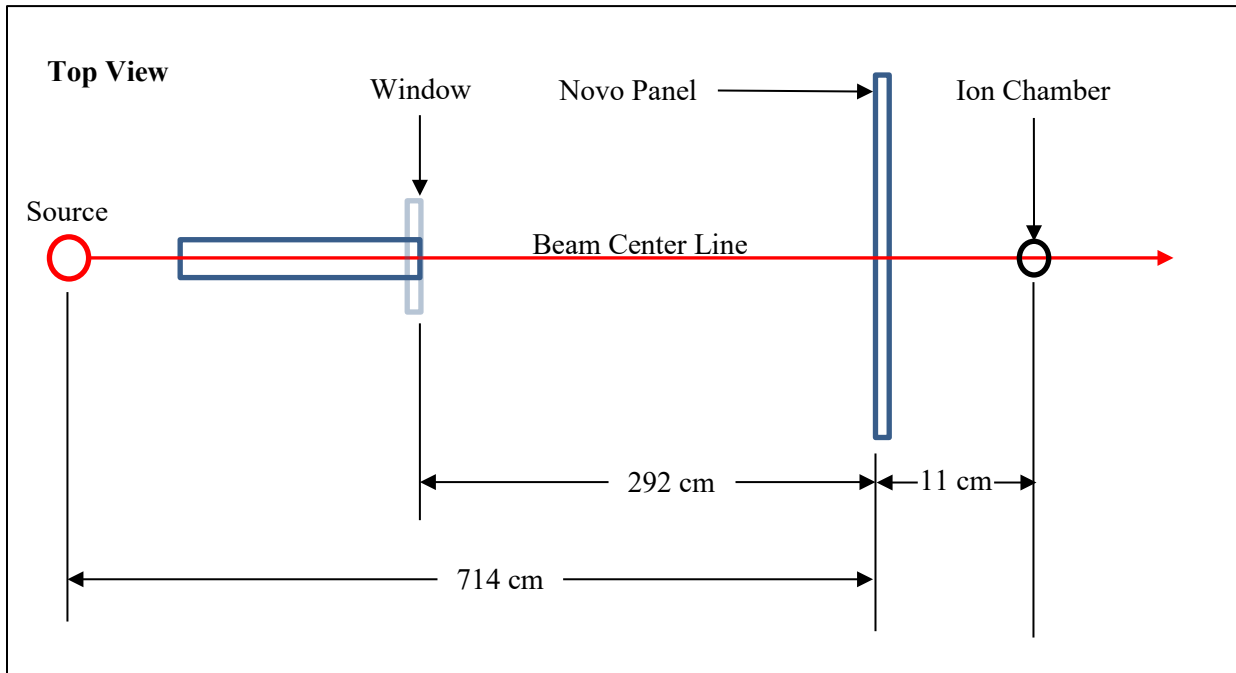


Figure 35 Illustration of experimental setup. Not to scale.

2.1 Thomson Photon Imaging *Ref. AP-AQ*

- Source: 1 Hz Thomson Photons
- Image Quality Indicator (IQI): 6 CU EN
- RadCal Position: 150 mm behind Novo
- Novo exposure time: 175 seconds (average of 2 images)
- Dose rate: 25.98 mR/Hr (background rate subtracted)
- Beam is nominally 3.17" or 80.5 mm in diameter

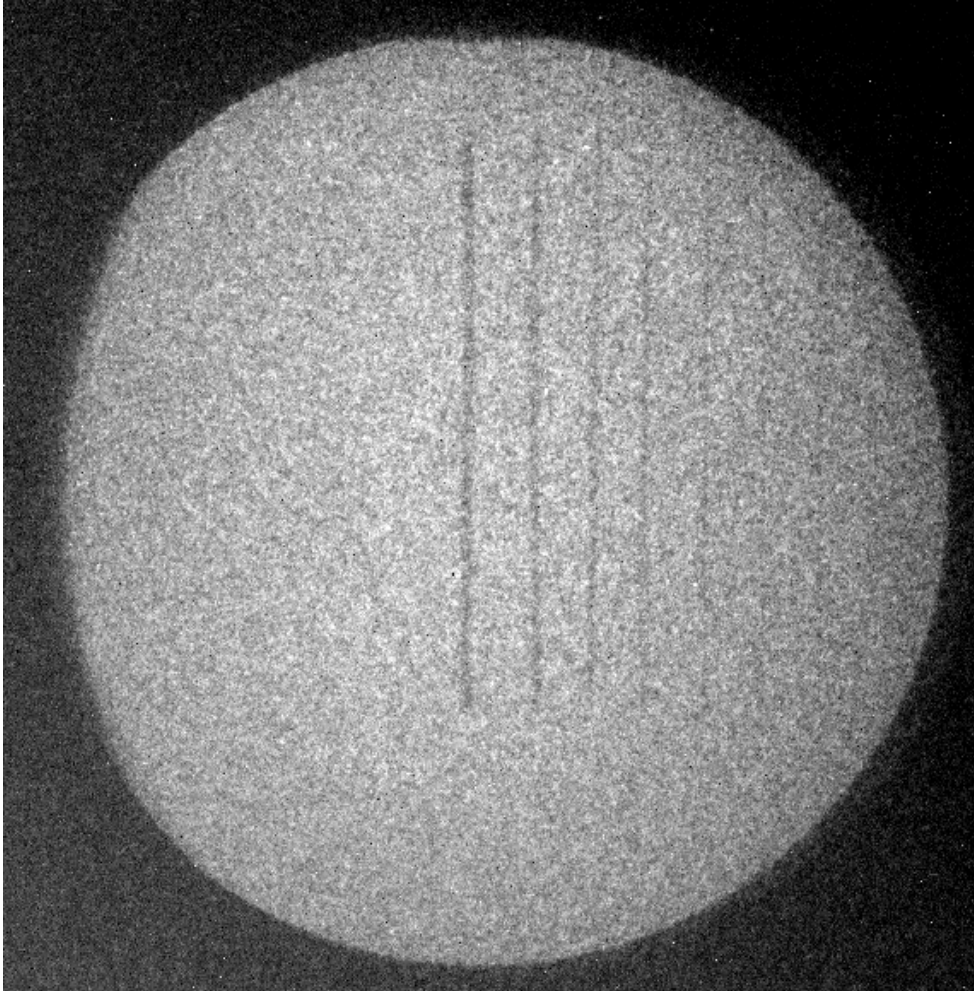


Figure 36 NOVO radiograph of a one wire IQI using a monoenergetic photon source.



Wire # 6 7 8 9 10 11 12

Figure 37 Photograph of the 6 CU EN IQI.

Table 2 One wire IQI wire dimensions.

Wire #	Wire Diameter	
	mm	inches
6	1.00	0.0393
7	0.80	0.0315
8	0.63	0.0248
9	0.50	0.0196
10	0.40	0.0157
11	0.32	0.0126
12	0.25	0.0098

2.2 Thomson Photon Imaging *Ref. AP-AQ*

- Source: 1 Hz Thomson Photons
- Image Quality Indicator: 6 CU EN and 1" steel sphere
- RadCal Position: 150 mm behind Novo
- Novo exposure time: 175 seconds (averaged of 12 images)
- Dose rate: 25.98 mR/Hr.
- All 7 wires can be seen. Wire sizes range from 1.00 mm to 0.25 mm.
- Photon beam intensity varied +/- 20%. See Figure 41.

The IQI imaged in Figure 38 is a 1 wire copper 6EN IQI standard. This standard published by the European committee for standardization. For more information see: <https://ndtsupply.com/en-462-1-iso19232-1-wire-iqi-s.html>

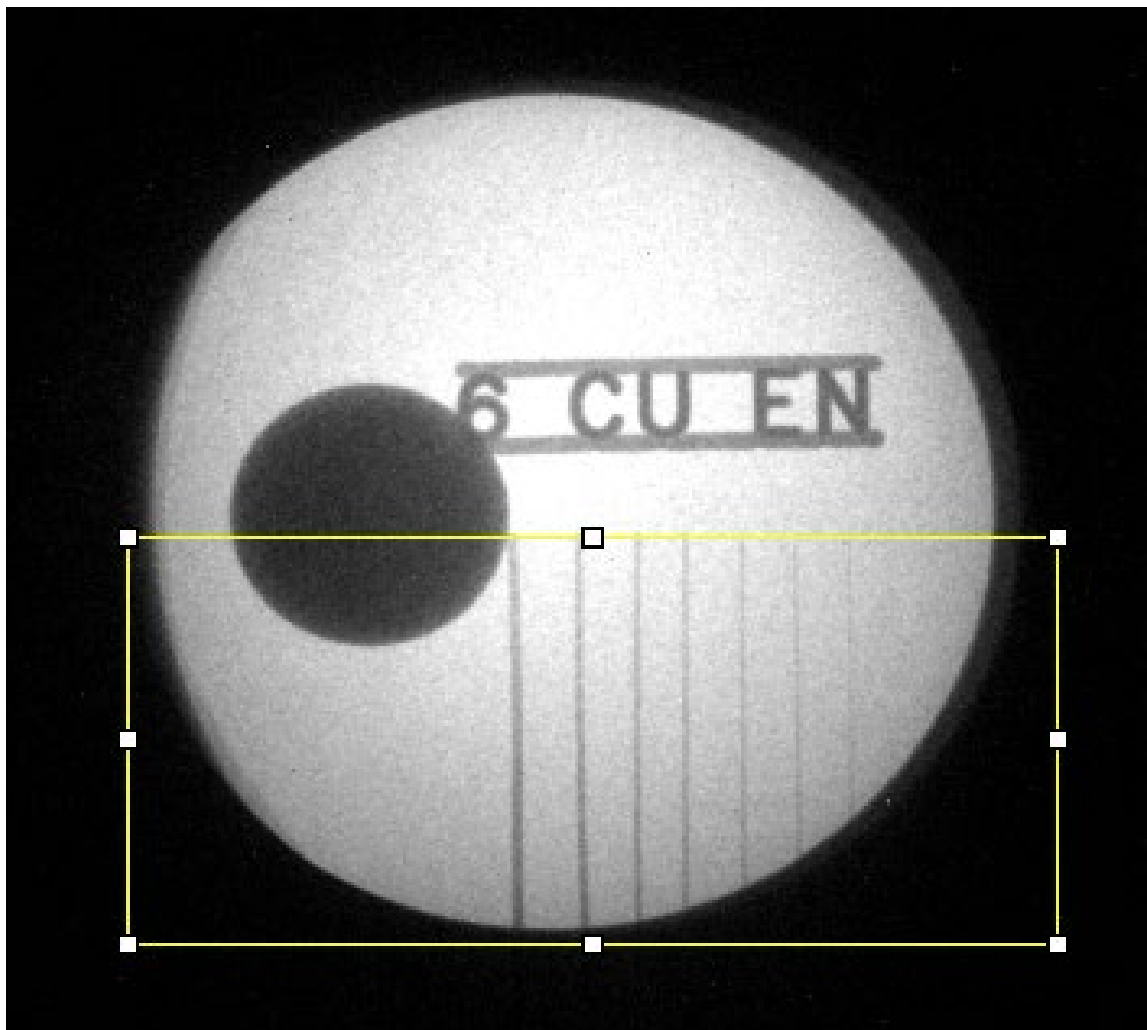


Figure 38 NOVO radiograph image of the monoenergetic photon beam with a 1-inch steel calibration sphere and one wire IQI standard (6EN ISO19232-1 Wire) in the beam. This image is the average of 12 images and has been background subtracted. The profile of the area in yellow is shown in Figure 39.

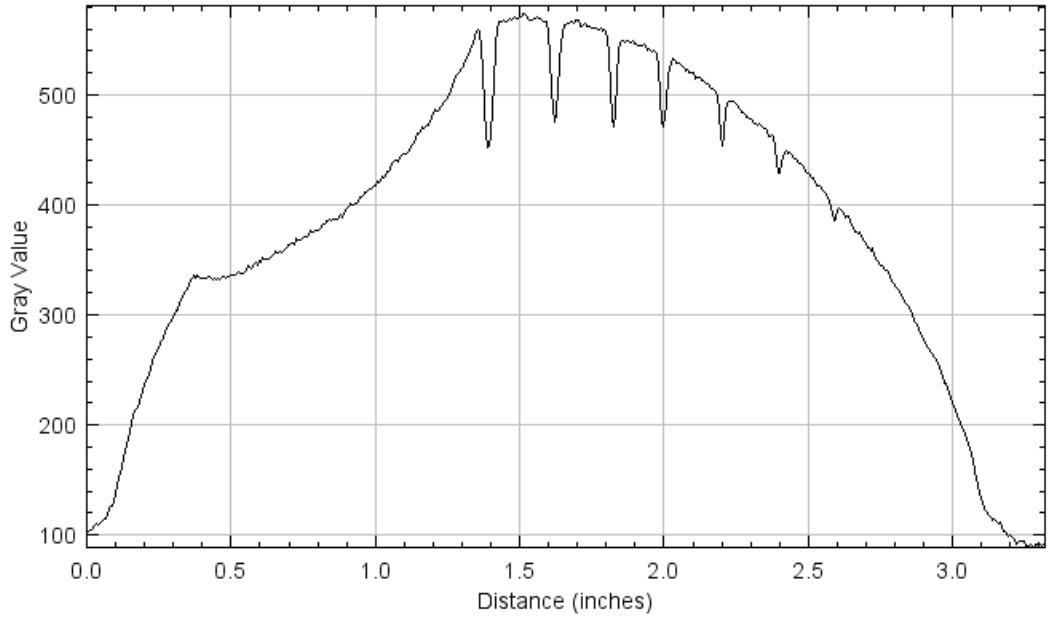


Figure 39: Profile of a 6EN wire standard (See Figure 38). All seven wires are clearly seen. The wires range from 1 mm to 0.25 mm in diameter. Table 2 shows the one wire IQI details.

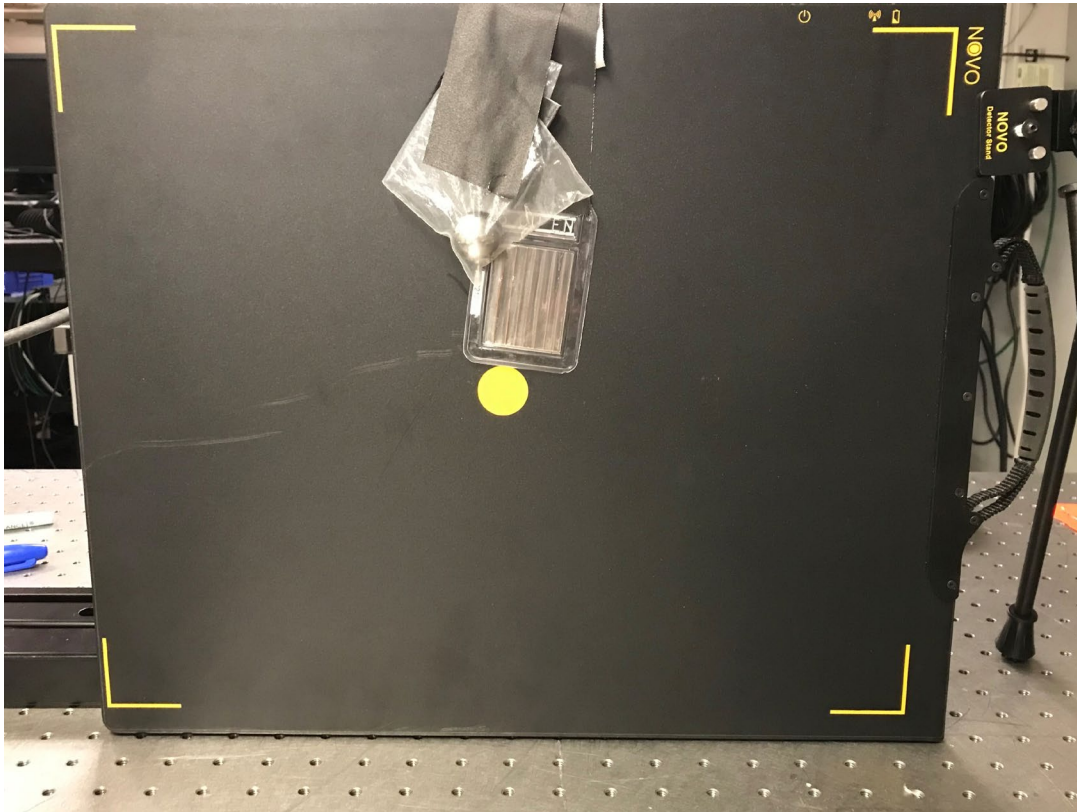


Figure 40 Photograph of the 6 CU EN IQI with and 1-inch steel sphere taped to NOVO panel.

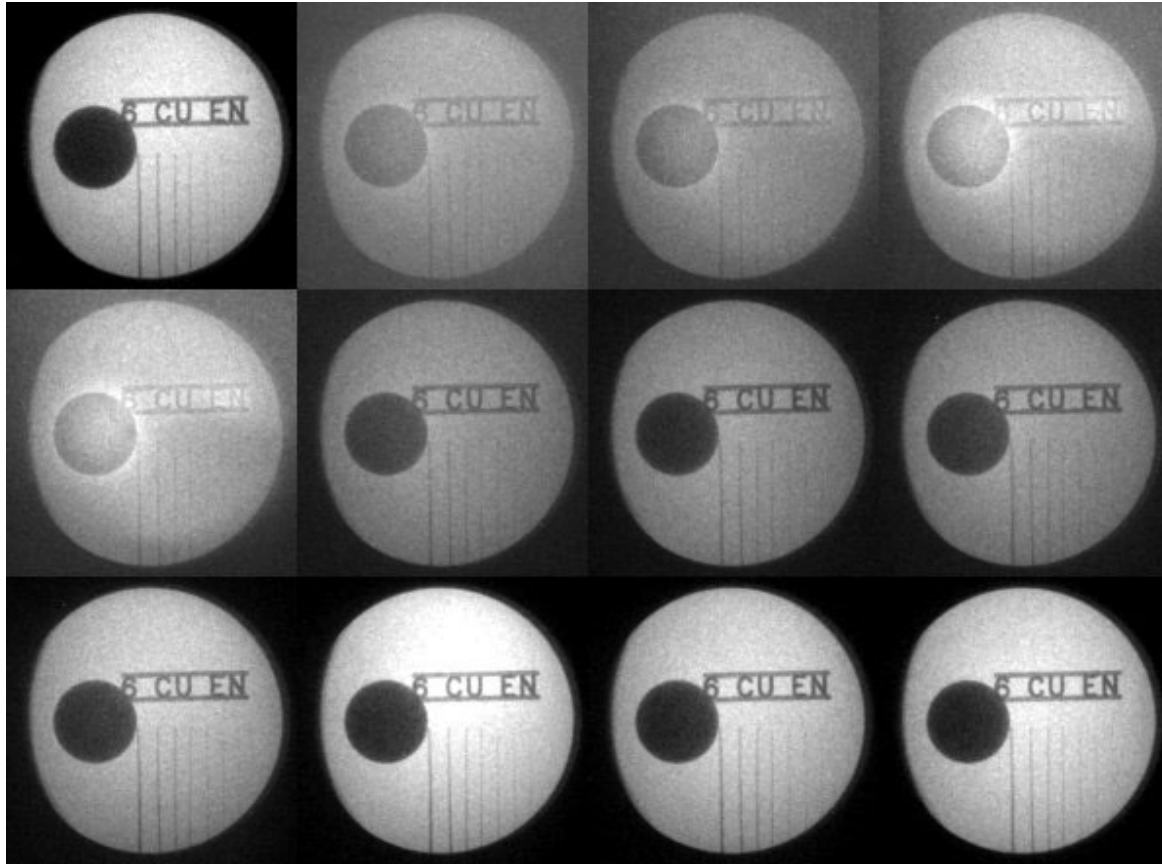


Figure 41 Twelve images, each of 175 second exposures, used to make the average image seen in Figure 38. The beam intensity is fluctuating. Beam fluctuation could be due to the fact that the Csl detector has been moved out of the beam and drift compensations cannot be made.

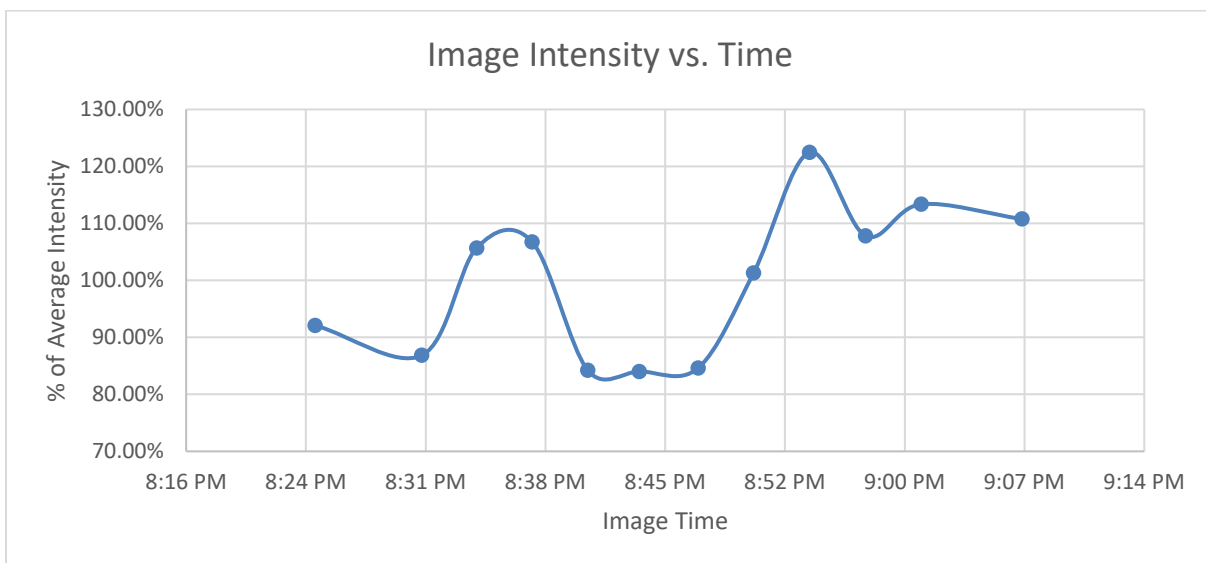


Figure 42 Photon beam intensity variation over ~50 minutes. The intensity is calculated by the maximum pixel value over the beam area.

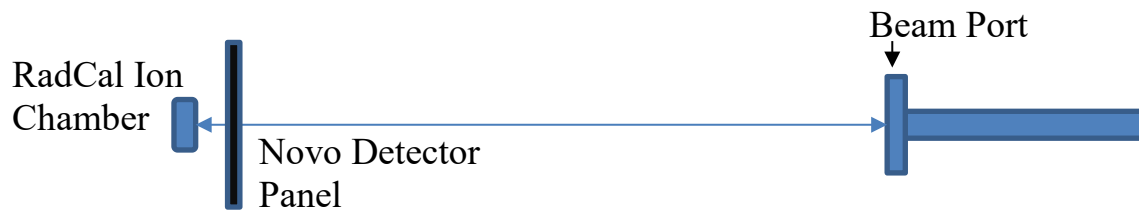


Figure 43 Diagram of setup with NOVO panel and components.

2.3 Bremsstrahlung Radiation Exposure *Ref. AS*

- Source: 1Hz, single pulse
- Image Quality Indicator: 6 CU EN and 1" steel sphere
- RadCal Position: 150mm behind Novo
- Novo exposure time: 10 seconds

The checkerboard pattern is intrinsic to the detector panel and can only be seen on a very low-level exposure. Dose rates for short exposures do not register above background. Dose rates for Figure 47, Figure 48, and Figure 49 do not register above background.

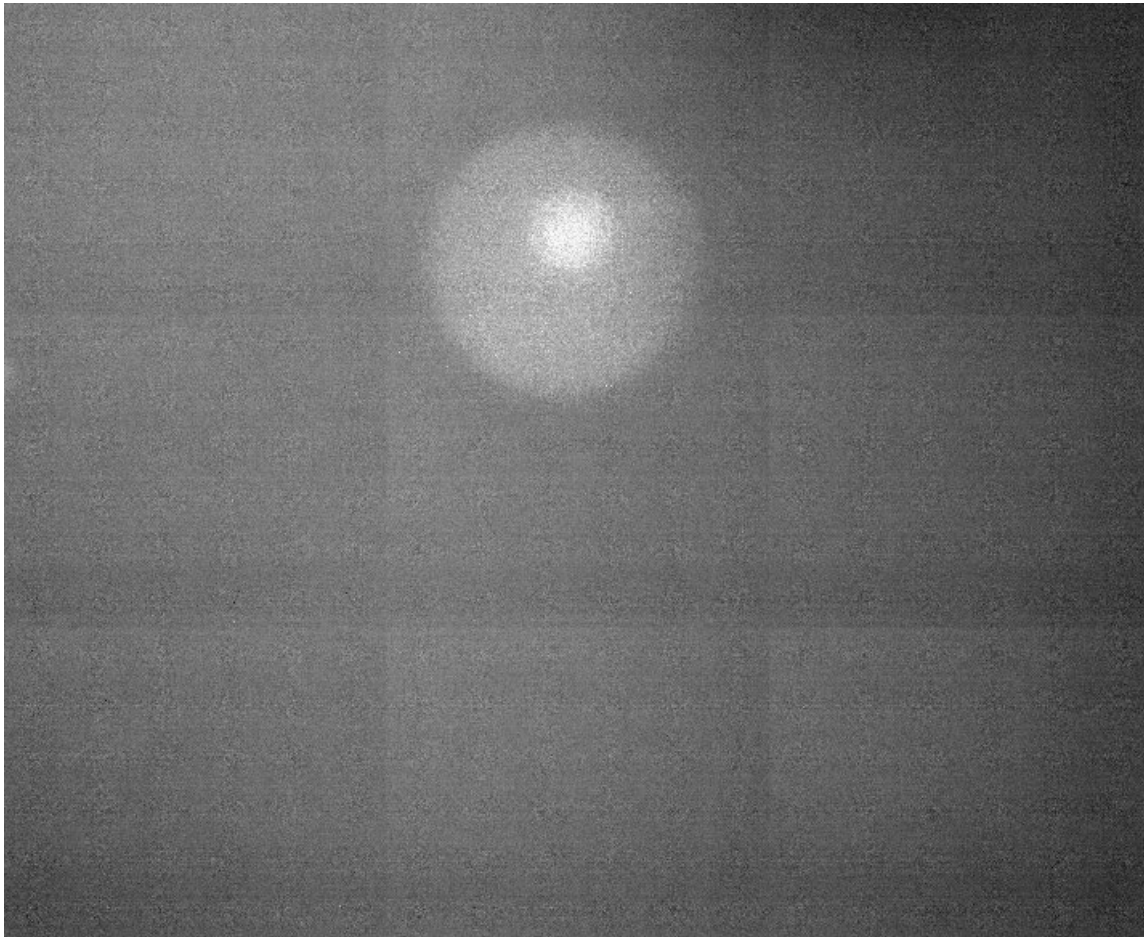


Figure 44 Bremsstrahlung Exposure:10 second, 1 pulse. The checkerboard pattern is intrinsic to the detector and can only be seen because of the very low exposure time.

2.4 Bremsstrahlung Radiation Exposure *Ref. AS*

- Source: 1Hz, 11 pulses
- Image Quality Indicator: Copper wire pair and 1” Steel ball
- RadCal Position: 150mm behind Novo
- Novo exposure time: 20 seconds

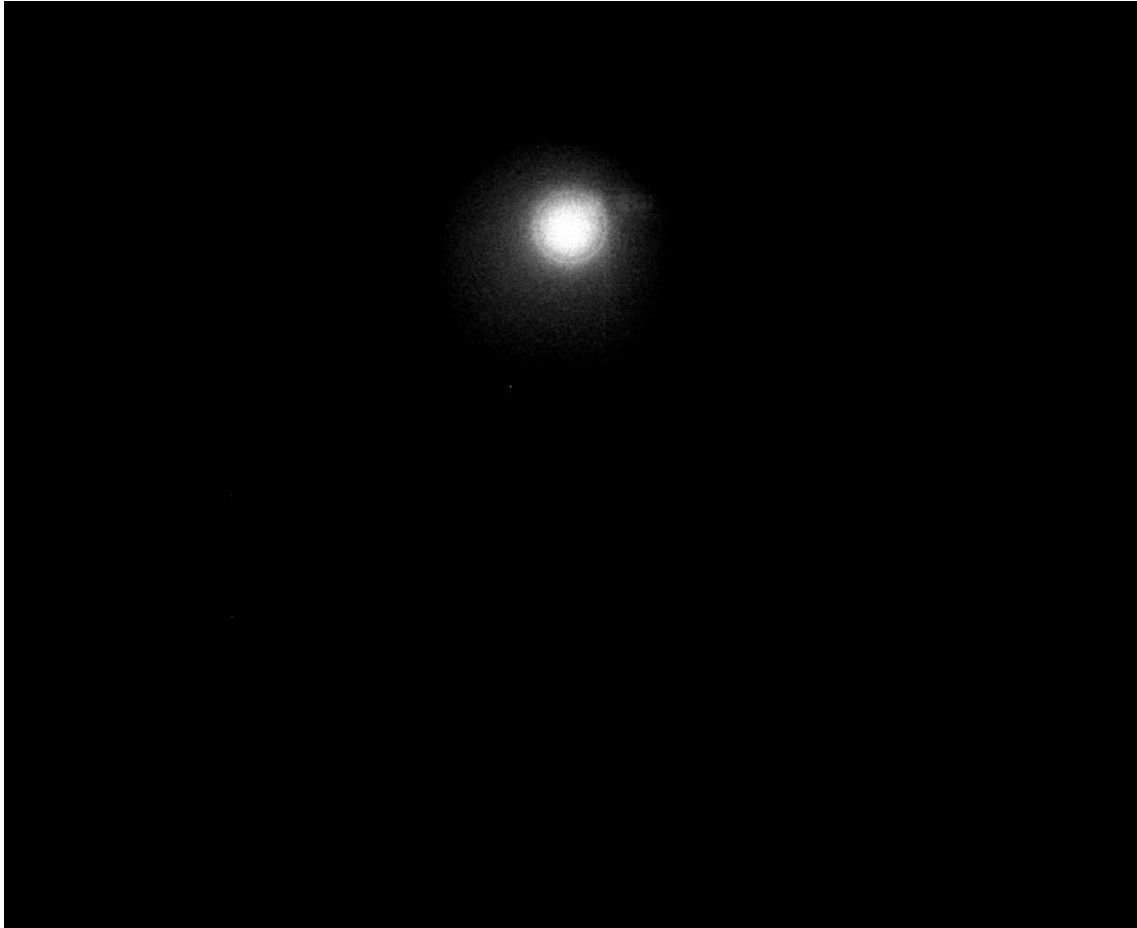


Figure 45 Bremsstrahlung exposure: 20 second, 11 pulses



Figure 46 Diagram of setup with NOVO panel and components.

2.5 Thomson Photon Imaging *Ref. AT*

- Source: 1Hz Thomson Photons
- Image: RadCal Detector
 - RadCal Position: Started at 150mm.
 - Novo exposure time: 15 seconds. Figure 47.
 - RadCal Position: Moved to 155mm
 - Novo exposure time: 15 seconds. Figure 48.
 - RadCal Position: Moved to 160mm
 - Novo exposure time: 15 & 175 seconds (average of 4). Figure 49 & Figure 50.
 - Figure 50 Dose rate: 26.64 mR/Hr at 160mm (background rate subtracted)
 - RadCal Position: Moved to 0mm
 - Novo exposure time: 175 seconds (average of 4). Figure 51.
 - Figure 51 Dose rate: 5.83 mR/Hr. at 0mm (background rate subtracted)

A background subtraction was not done on Figure 47, Figure 48, Figure 49, and Figure 50. Background images of equivalent exposures were not recorded. The bright spot in the upper right corner of the radiographs is due to background.

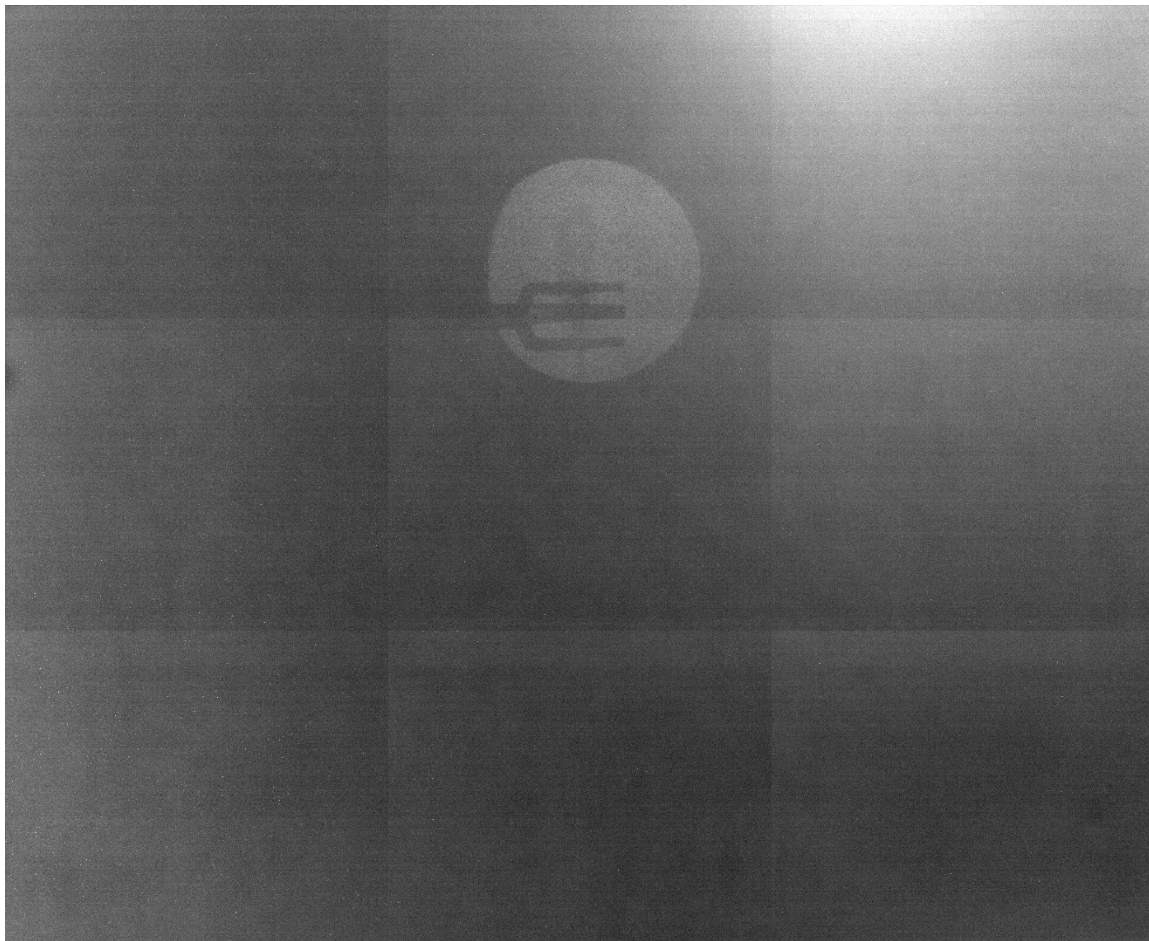


Figure 47 Thomson Photon Exposure: 15 seconds exposure of the RadCal positioned at 150 mm. The metal lab stand tines that hold the ion detector in place are visible. No background subtraction

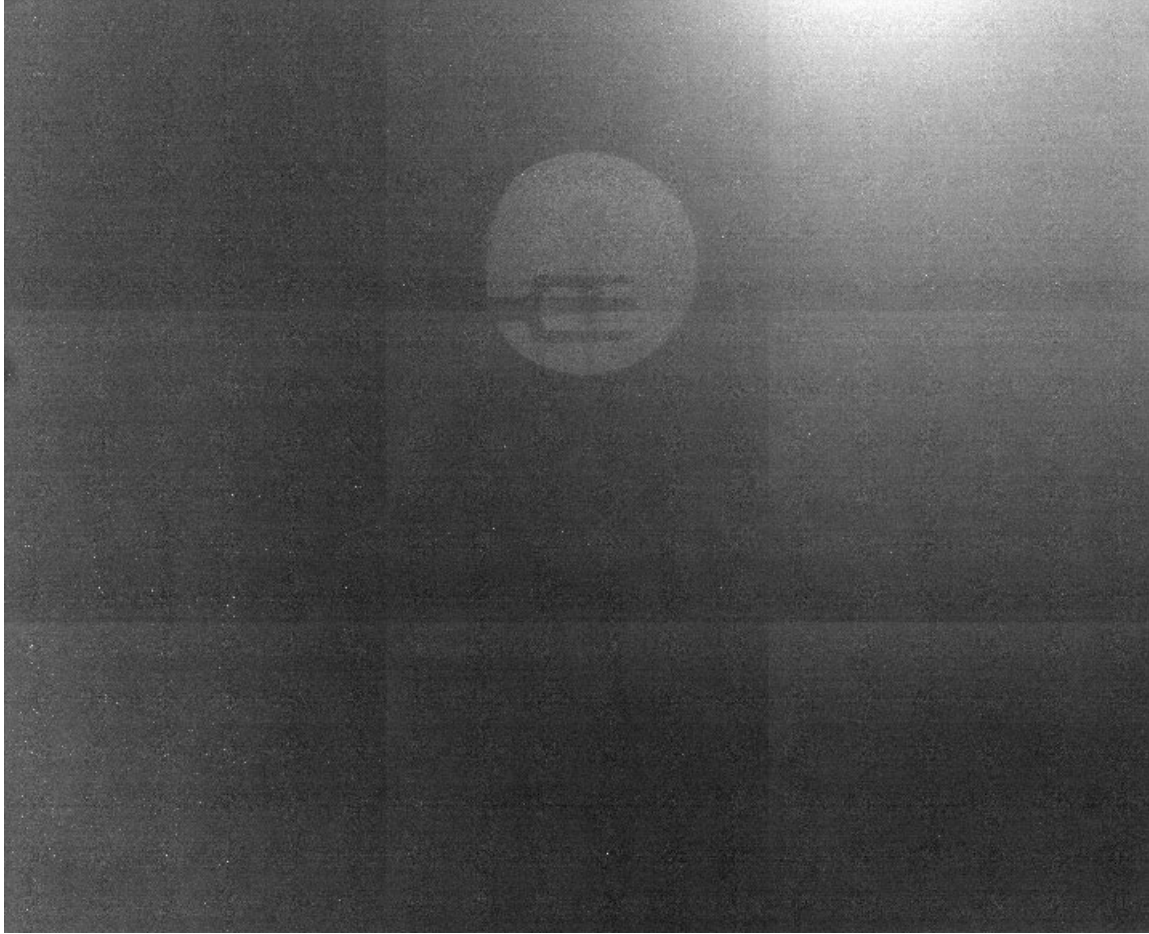


Figure 48 A 15 second exposure of the RadCal positioned at 155 mm. No background subtraction

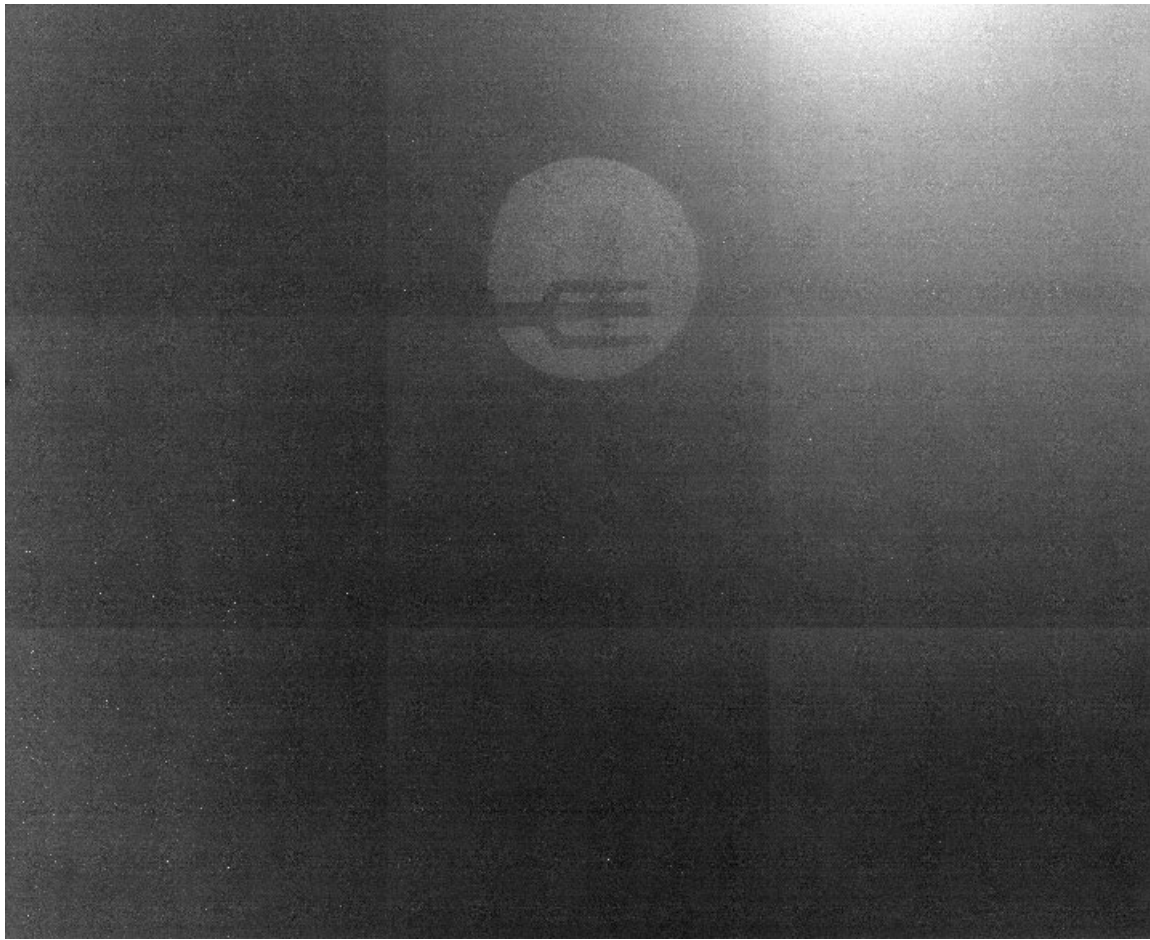


Figure 49 15 second exposure of the RadCal positioned at 160 mm. No background subtraction.



Figure 50 175 second exposure (average of 4). RadCal in center at 160 mm.



Figure 51 175 second exposure (average of 4). RadCal out of beam at 0 mm.



Figure 52 Diagram of setup with NOVO panel and components.

2.6 Thomson Photon Imaging *Ref. AU*

- Source: 1Hz
- Image: Indium foil
- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (1 image)

- Dose: 6.56 mR/Hr (background rate subtracted)

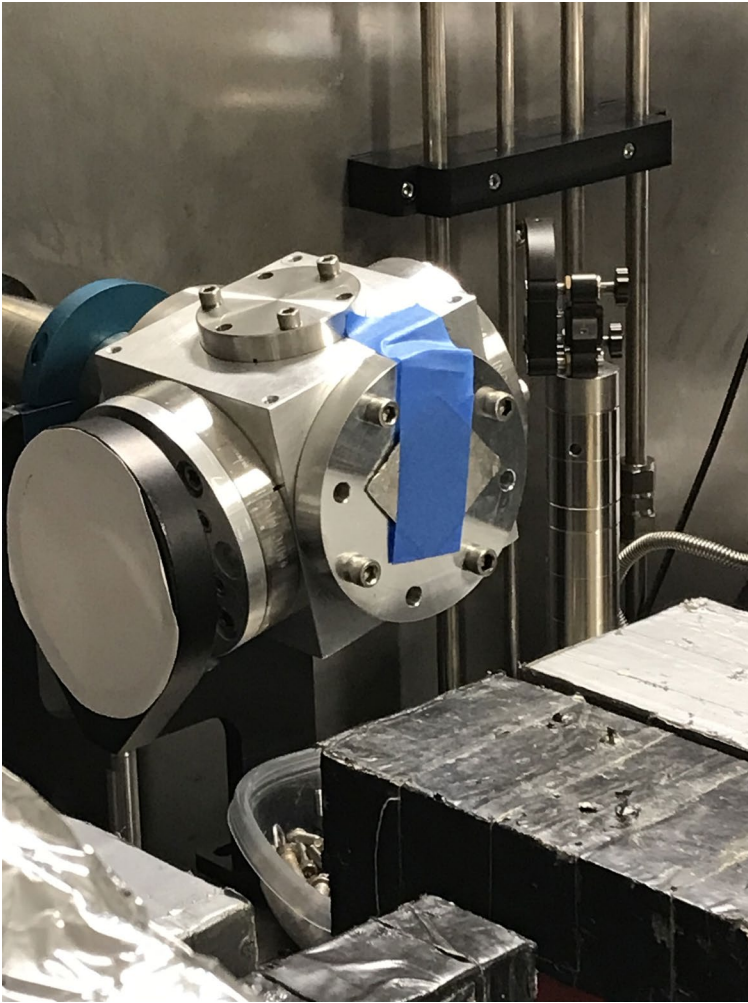


Figure 53 Photo of Indium foil taped on the beam port.

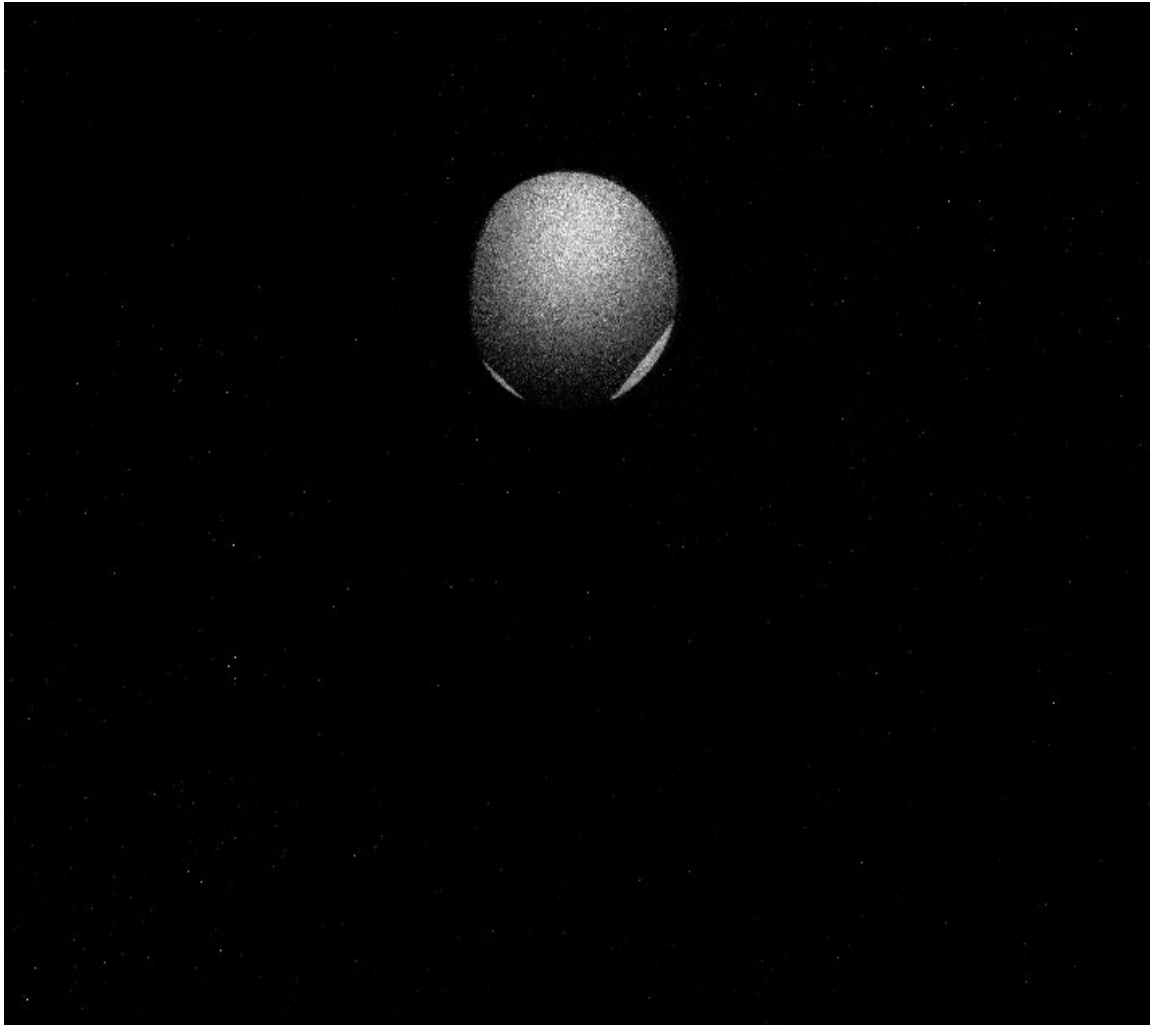


Figure 54 Thomson Photon Exposure: 175 seconds with Indium foil directly on beam port.

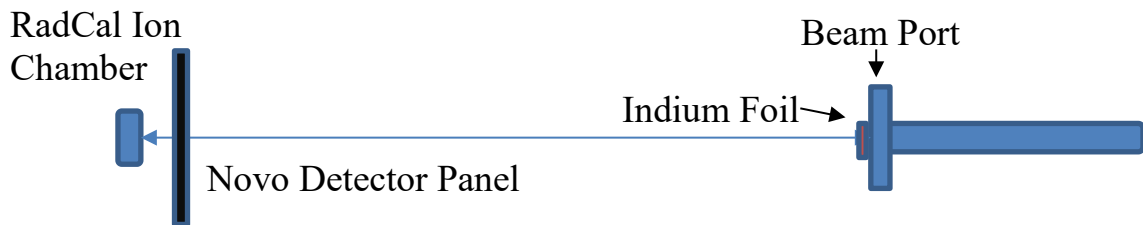


Figure 55 Diagram of setup with NOVO panel and components.

2.7 Thomson Photon Imaging *Ref. AU*

- Source: 1Hz
- Image: Indium foil place on the back side of Novo panel

- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (average of 4)
- Dose: 14.54 mR/Hr (background rate subtracted)

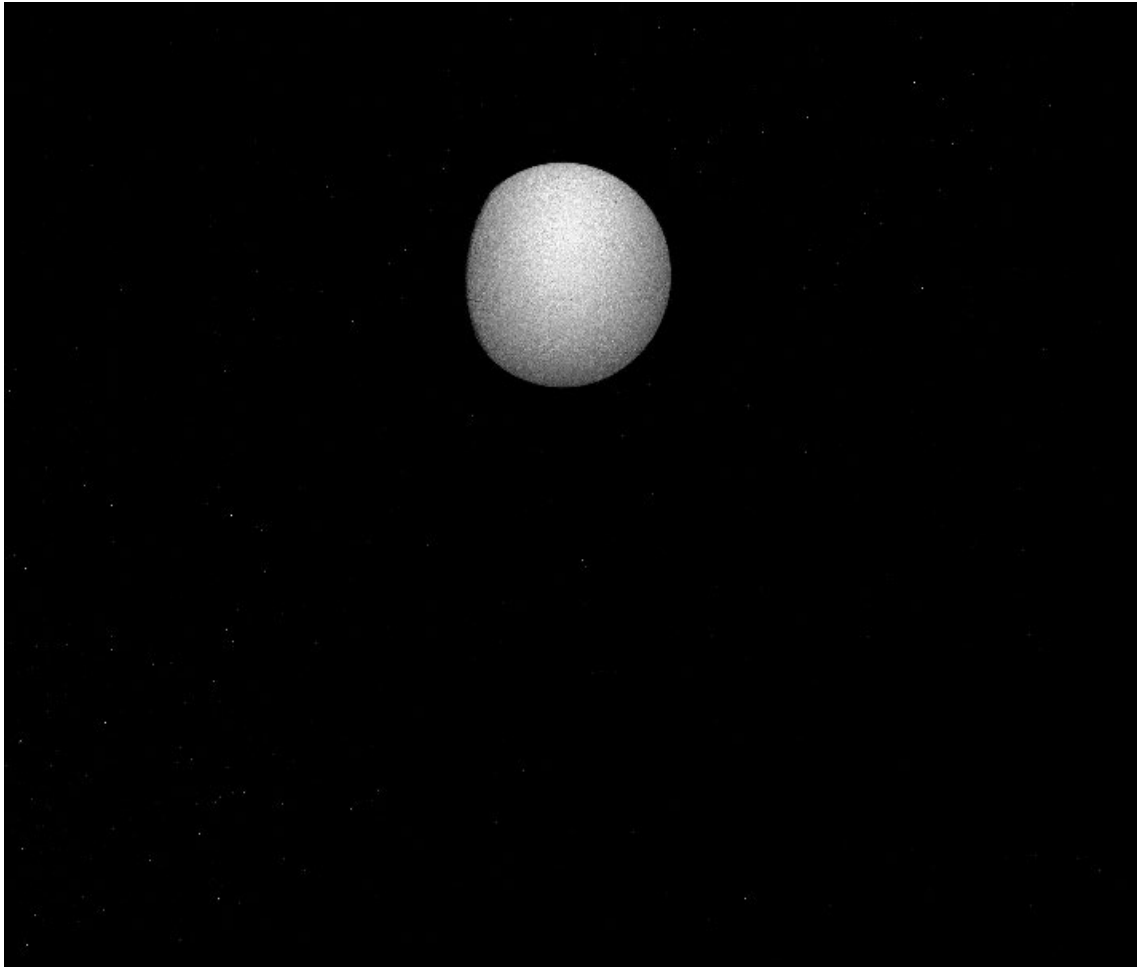


Figure 56 Thomson Photon Exposure:175 second exposure (average of 4) with Indium foil placed on the back of NOVO panel.

2.8 Thomson Photon Imaging *Ref. AU*

- Source: 1Hz Thomson Photons
- Image Quality Indicator: Step wedge centered on first step
- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (average of 5)

- Dose: 12.47 mR/Hr (background rate subtracted)

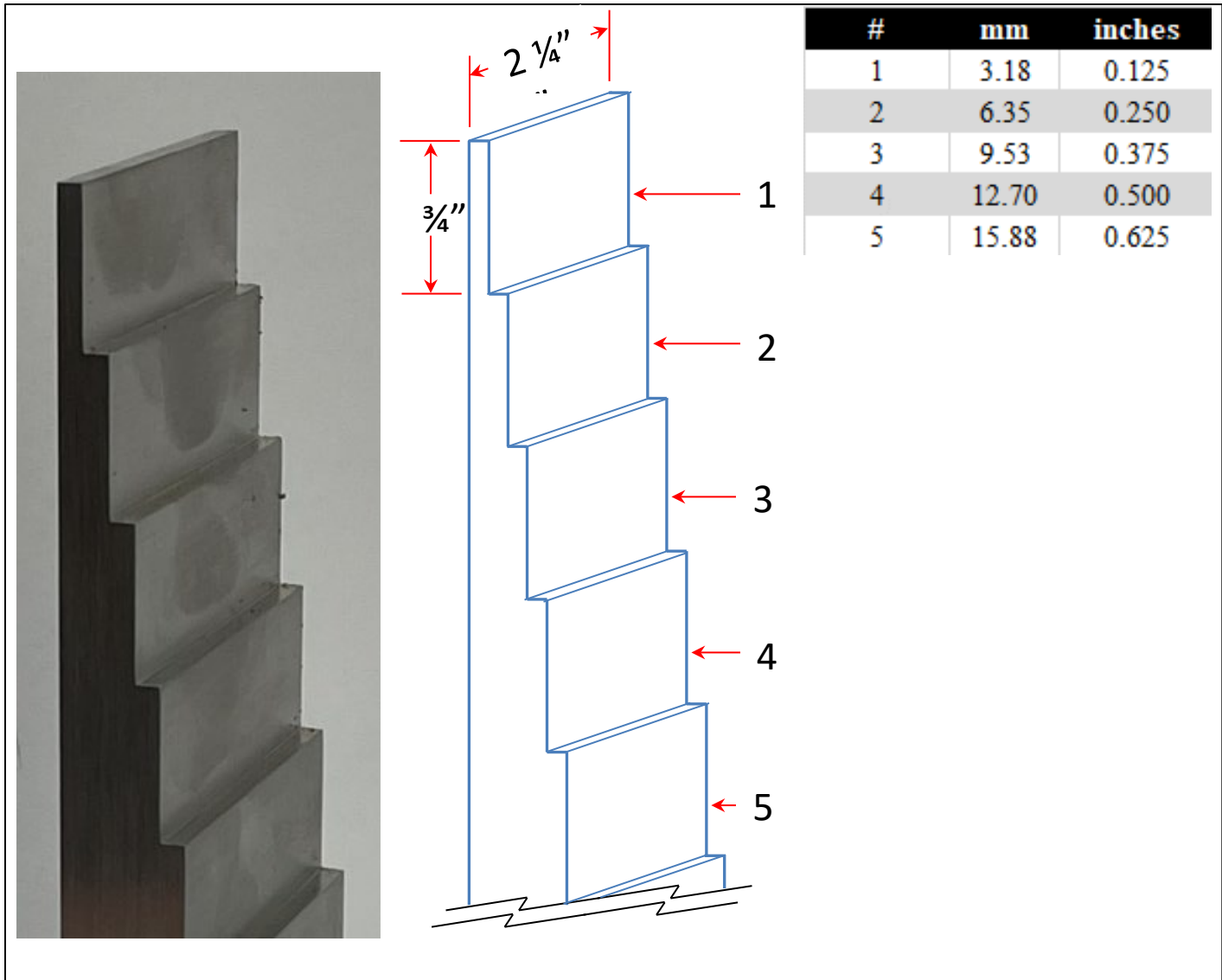


Figure 57 INL step wedge IQI. Wedge is made from 304 stainless steel. Wedge thicknesses are listed in the table.



Figure 58 Thomson Photon Exposure:175 seconds (average of 5) of step wedge. Image centered on first step.

2.9 Thomson Photon Imaging *Ref. AU*

- Source: 1Hz
- Image Quality Indicator: Step wedge centered on second step.
- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (average of 6)
- Dose: 10.66 mR/H (background rate subtracted)

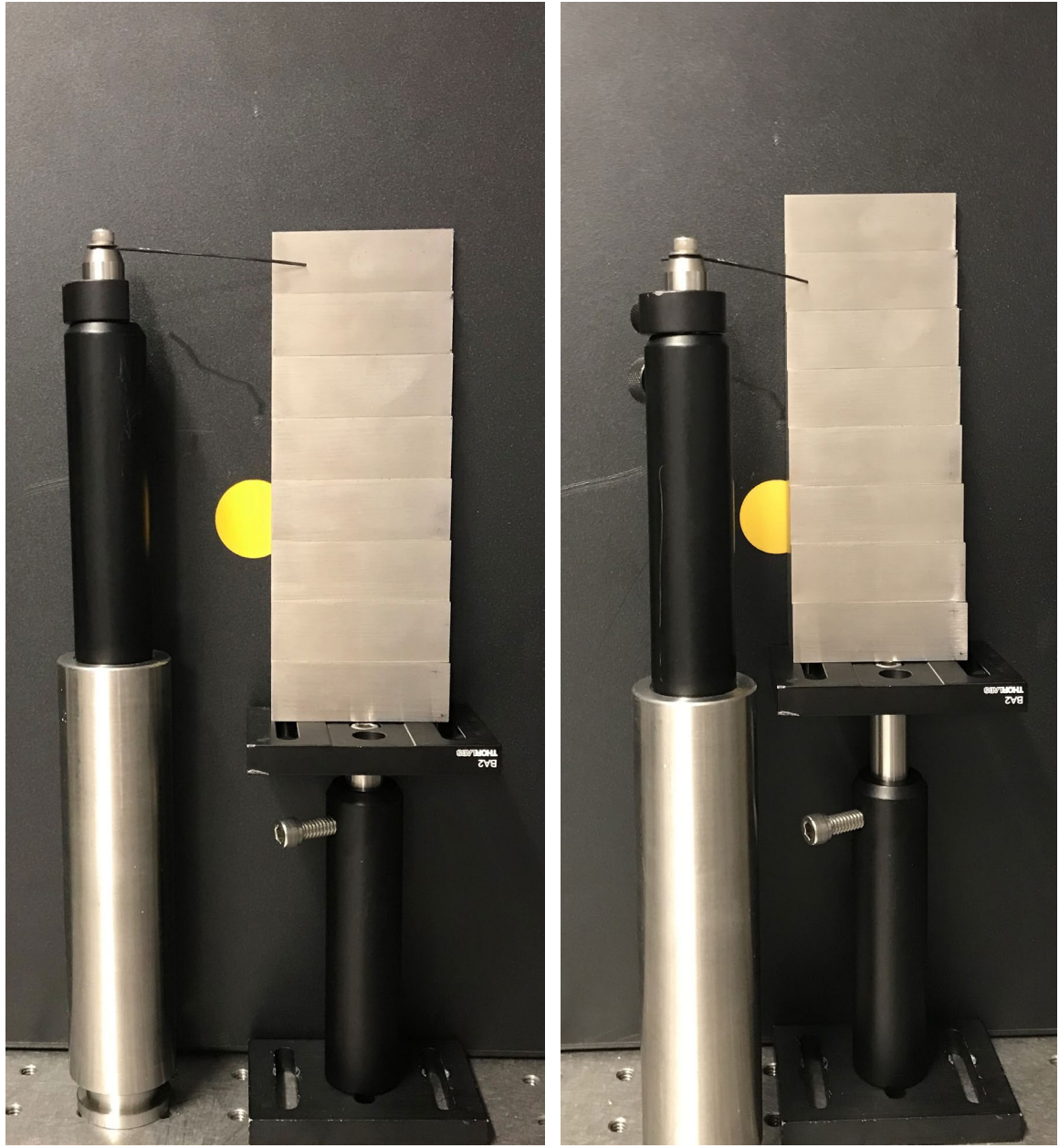


Figure 59 Pictures of the step wedge. Left: vertically centered on first step. Right: vertically centered on second step.

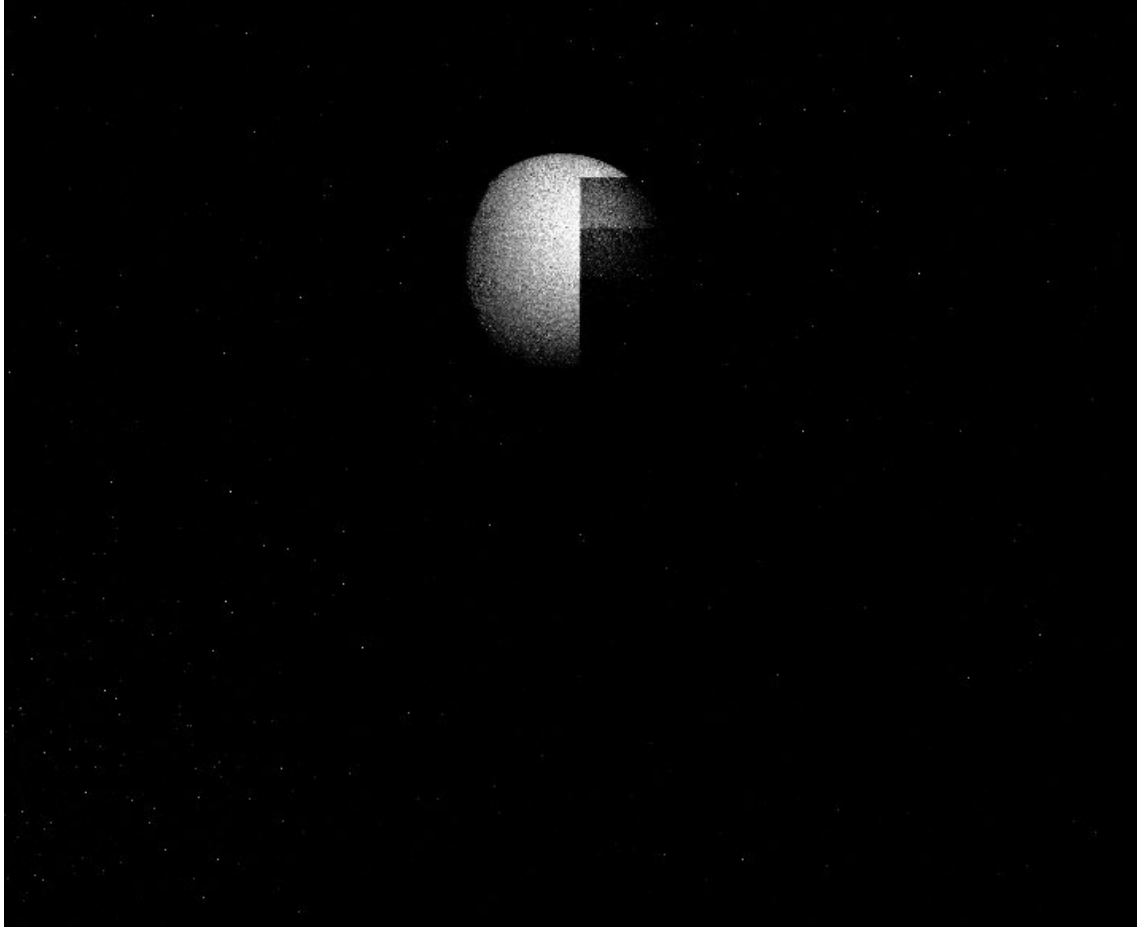


Figure 60 Thomson Photon Exposure: 175 seconds (average of 6) of step wedge. Image centered on second step.

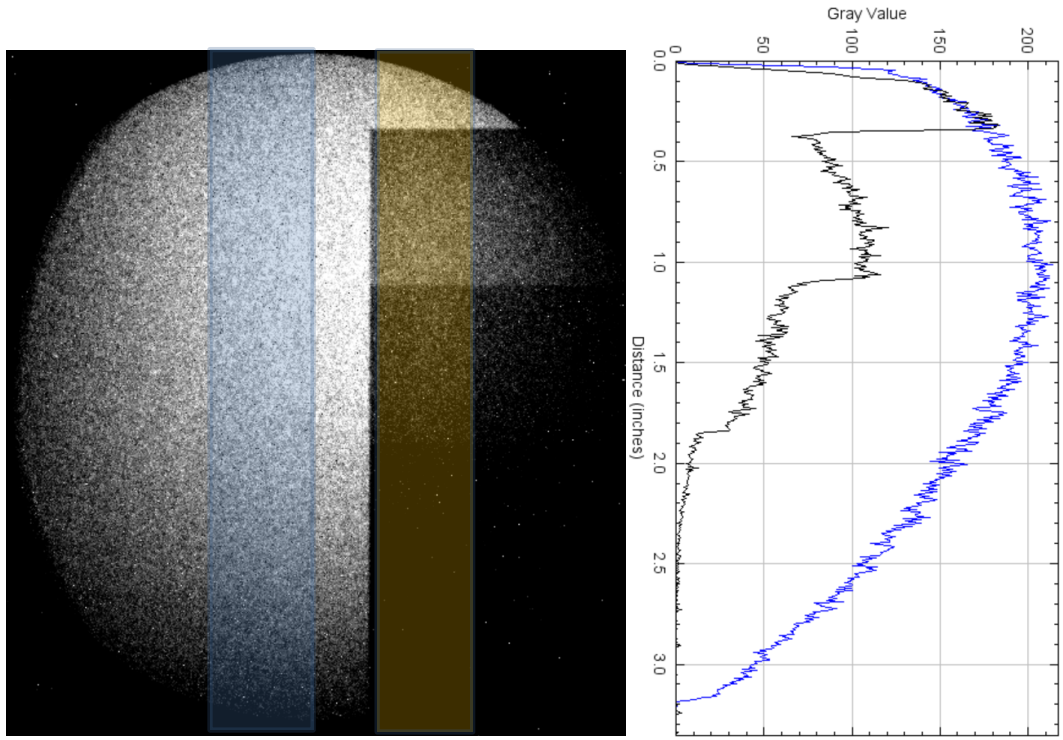


Figure 61 The image on the left is a 175 second exposure (average of 6 images) of the INL step wedge. Two regions are highlighted, one blue and one orange. The horizontal profiles of each of the highlight regions is plotted on the right. The blue line is from the blue region (in left image) and the black line is from the orange region (in the left image). The blue region position was adjusted horizontally to have a comparable background profile response to the orange region. Both regions have the same area.

2.10 Thomson Photon Imaging *Ref. AU*

- Source: 1Hz Thomson Photons
- Image Quality Indicator: LBNL step wedge
- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (average of 5)
- Beam degraded and resulted in poor image
- Dose: 10.23 mR/Hr (background rate subtracted)

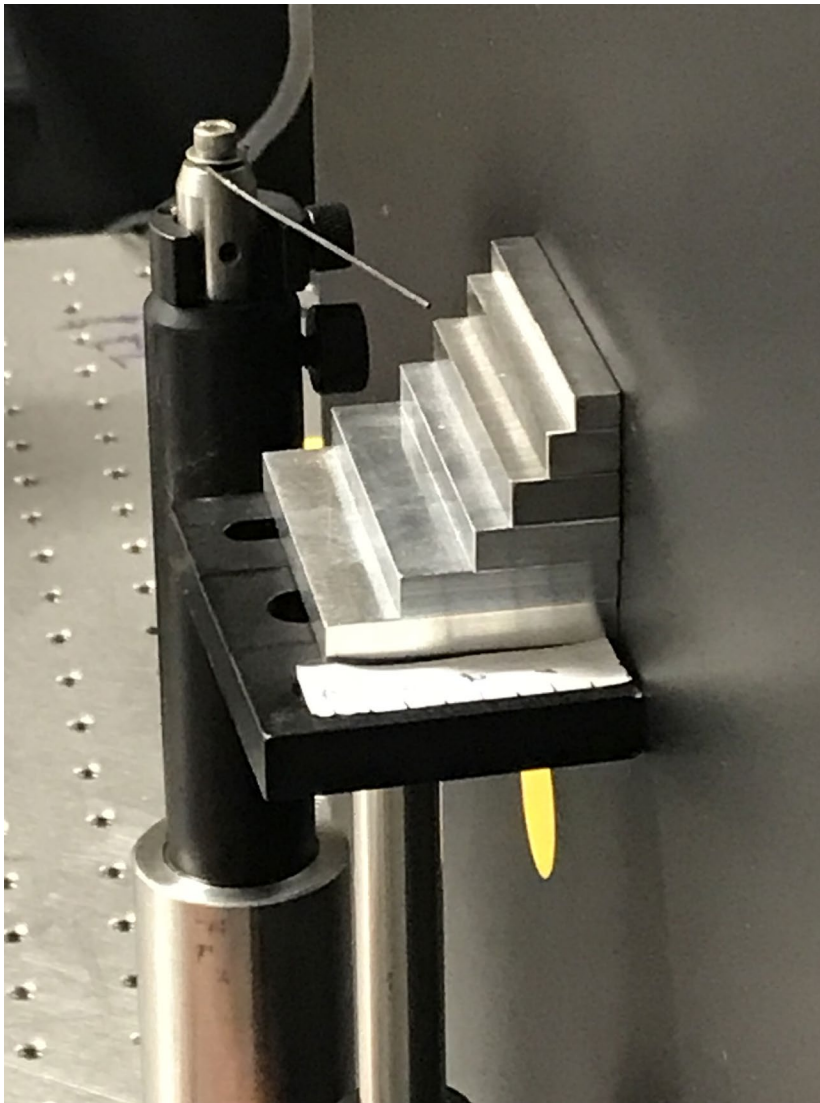


Figure 62 Photo of the LBNL step wedge.

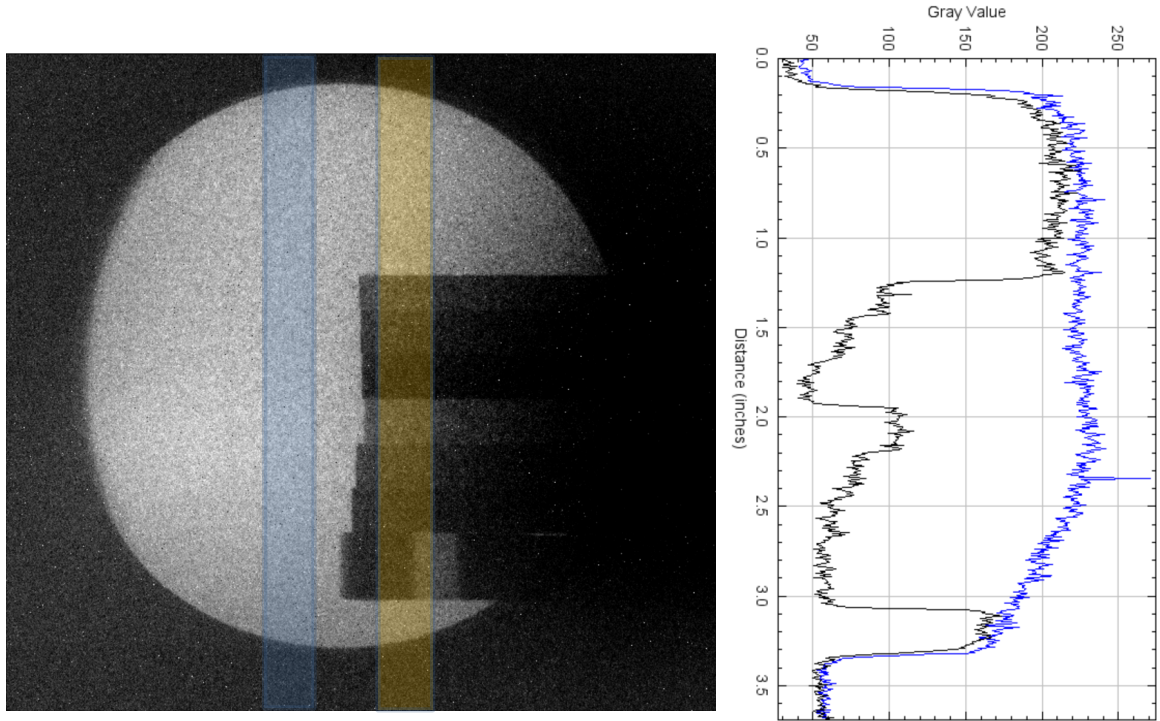


Figure 63 The image on the left is a 175 second exposure (average of 5 images) of a step wedge supplied by BELLA staff. Two regions are highlighted, one blue and one orange. The horizontal profiles of each of the highlight regions is plotted on the right. The blue line is from the blue region (in left image) and the black line is from the orange region (in the left image). The blue region position was adjusted horizontally to have a comparable background profile response to the orange region.



Figure 64 Diagram of setup with NOVO panel and components.

2.11 Thomson Photon Imaging *Ref. AV*

- Source: 1Hz Thomson Photons
- Image Quality Indicator: Duplex Wire
- RadCal Position: Started at 160 mm
- Novo exposure time: 175 seconds (average of 5)
- Dose: 14.78 mR/Hr (background rate subtracted)
- Basic spatial resolution (SRb) is 0.16 mm.

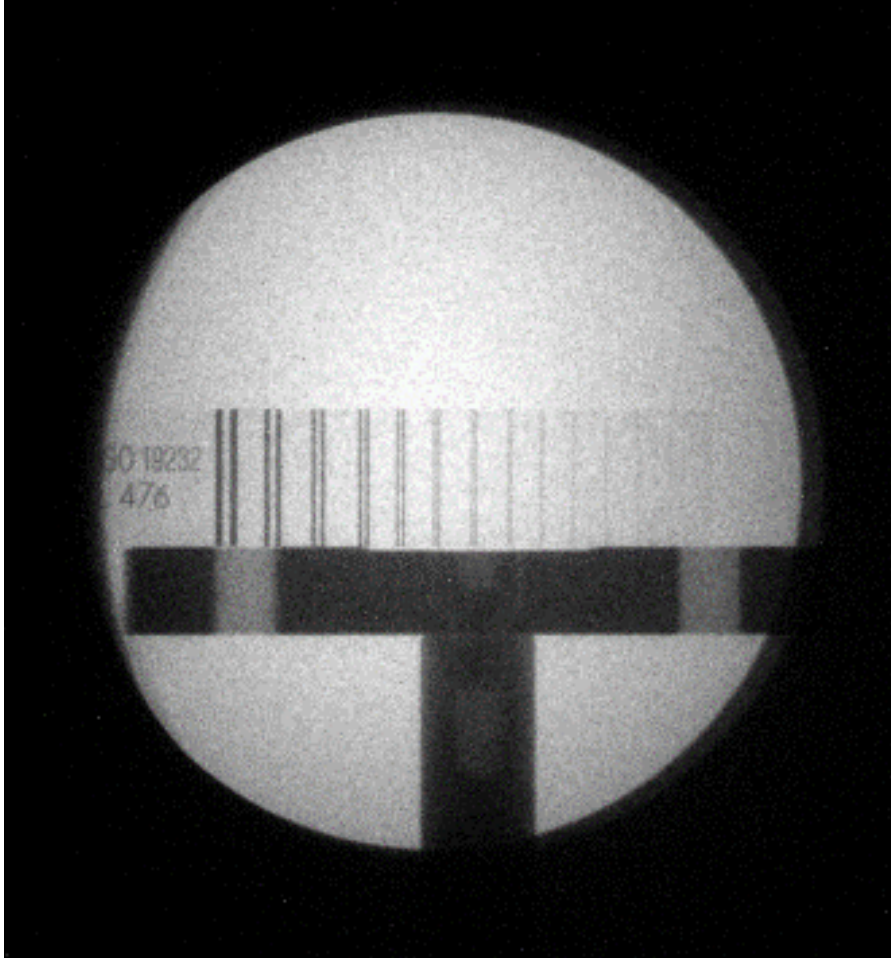


Figure 65 A 175 second exposure with an IQI Duplex wire.

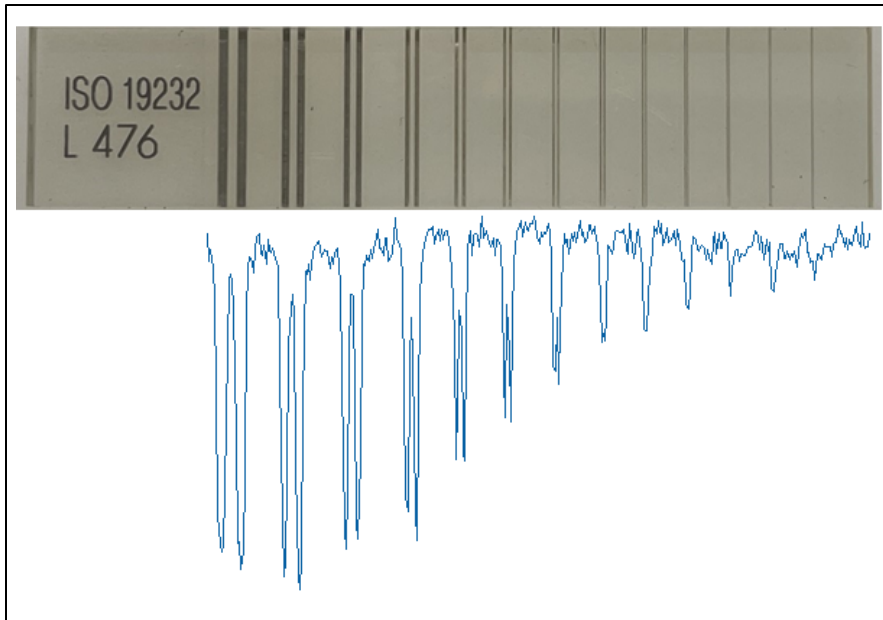


Figure 66 Picture of the IQI and a line profile that has been baseline subtracted. The largest diameter pair with a less than 20% dip is 0.160 mm in diameter. More information on the IQI can be found at this website: <https://content.ndtupply.com/assets/Uploads/Kowotest-Duplex-IQI-Penetrameter-Flyer.pdf>

2.12 Thomson Photon Imaging *Ref. AV*

- Source: 1Hz
- Image Quality Indicator: Divergent Line Pair
- RadCal Position: Started at 160mm
- Novo exposure time: 175 seconds (average of 4)
- Dose: 17.47 mR/Hr (background rate subtracted)

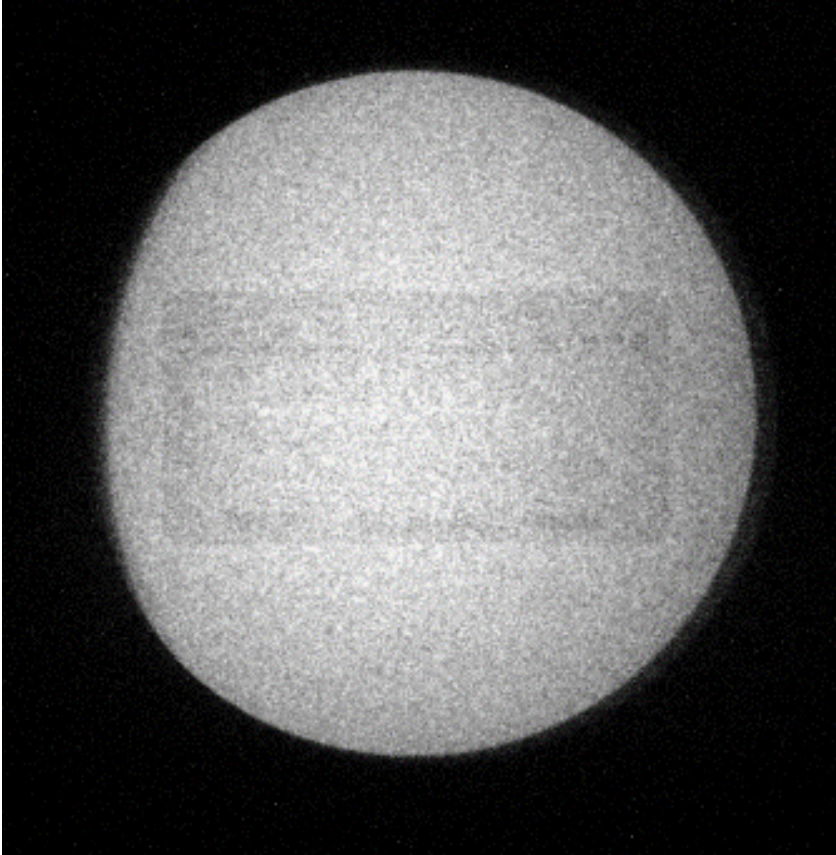


Figure 67 A 175 second exposure. IQI Line Pair Gauge, type 39.

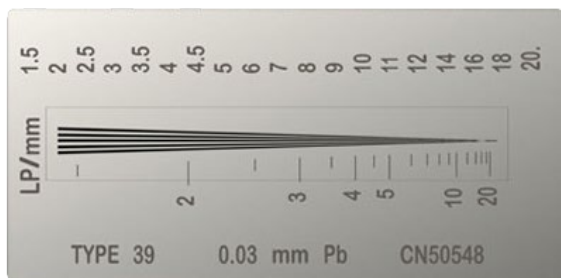


Figure 68 Photograph of IQI. Line Pair Gauge

2.13 Thomson Photon Imaging *Ref. AV*

- Source: 1Hz Thomson Photons
- Image Quality Indicator: Duplex Wire
- Magnification experiment: Line Pair held up with Tungsten cylinders. ~ 1.7 magnification.
- RadCal Position: 160mm
- Novo exposure time: 175 seconds (average of 5)
- Dose: 16.25 mR/Hr (background rate subtracted)

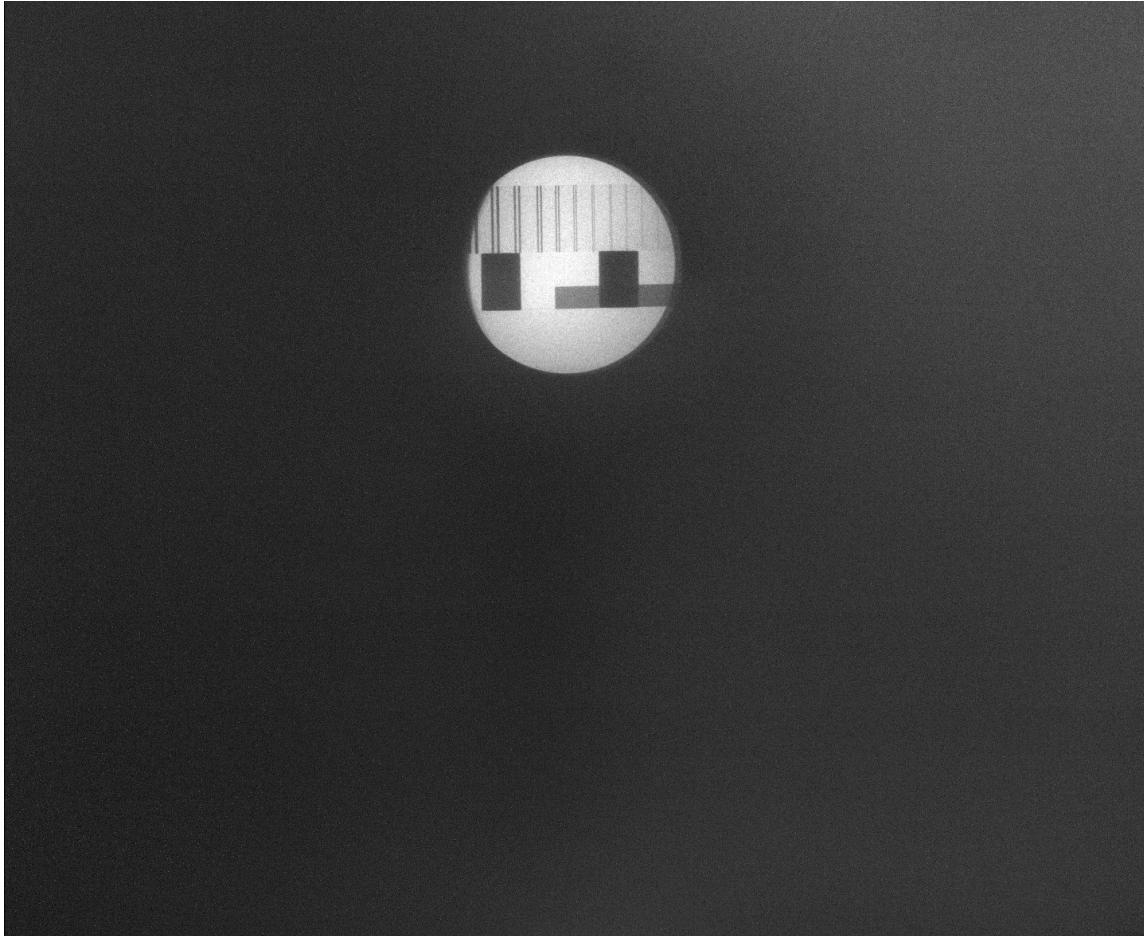


Figure 69 . A 175 second exposure (average of 5) of the duplex wire IQI. IQI was placed near the beam port window, about 3 meters from NOVO panel. This was done to measure the magnification factor and beam divergence.

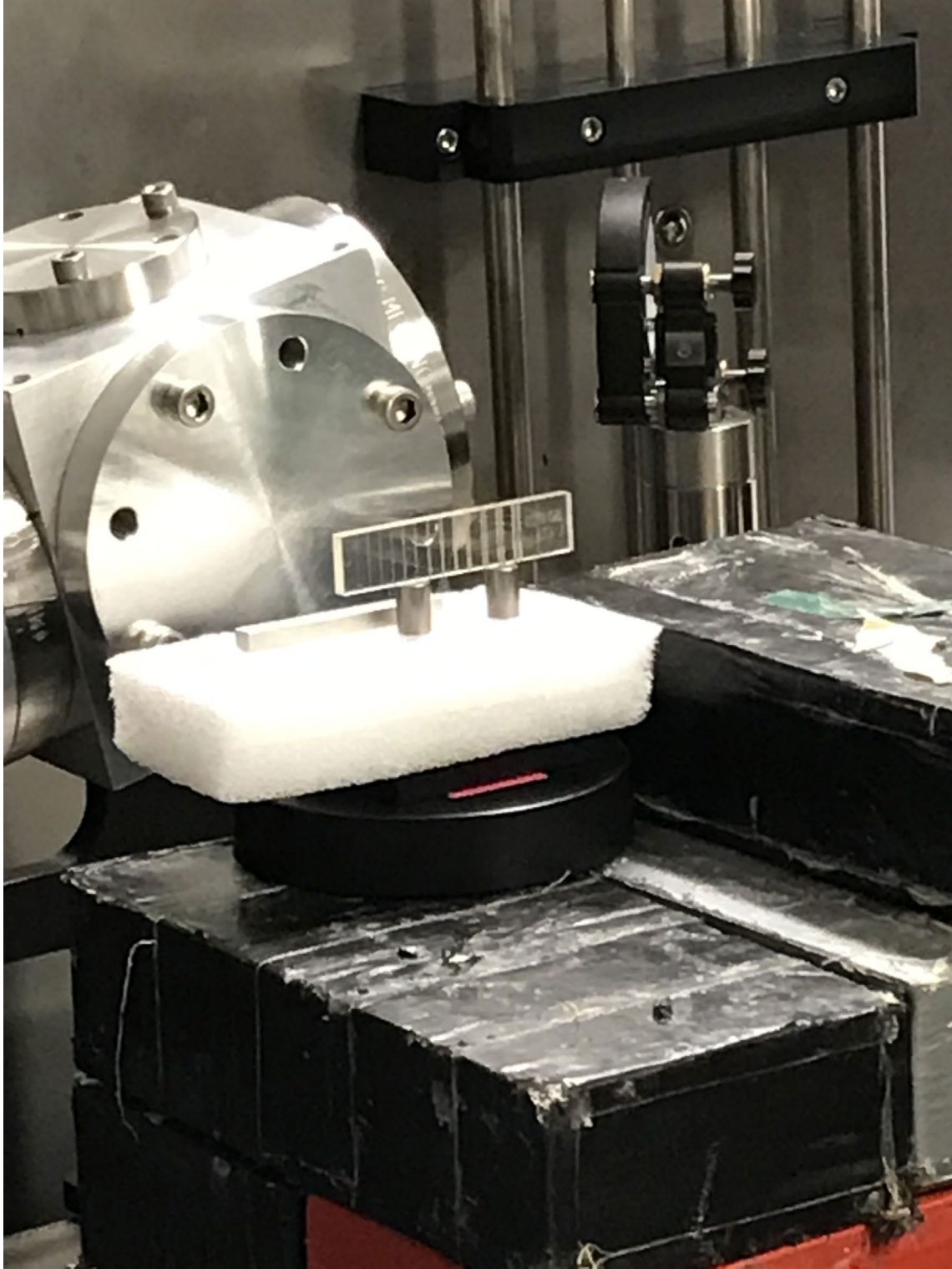


Figure 70 Photo of duplex wire IQI near beam port window.

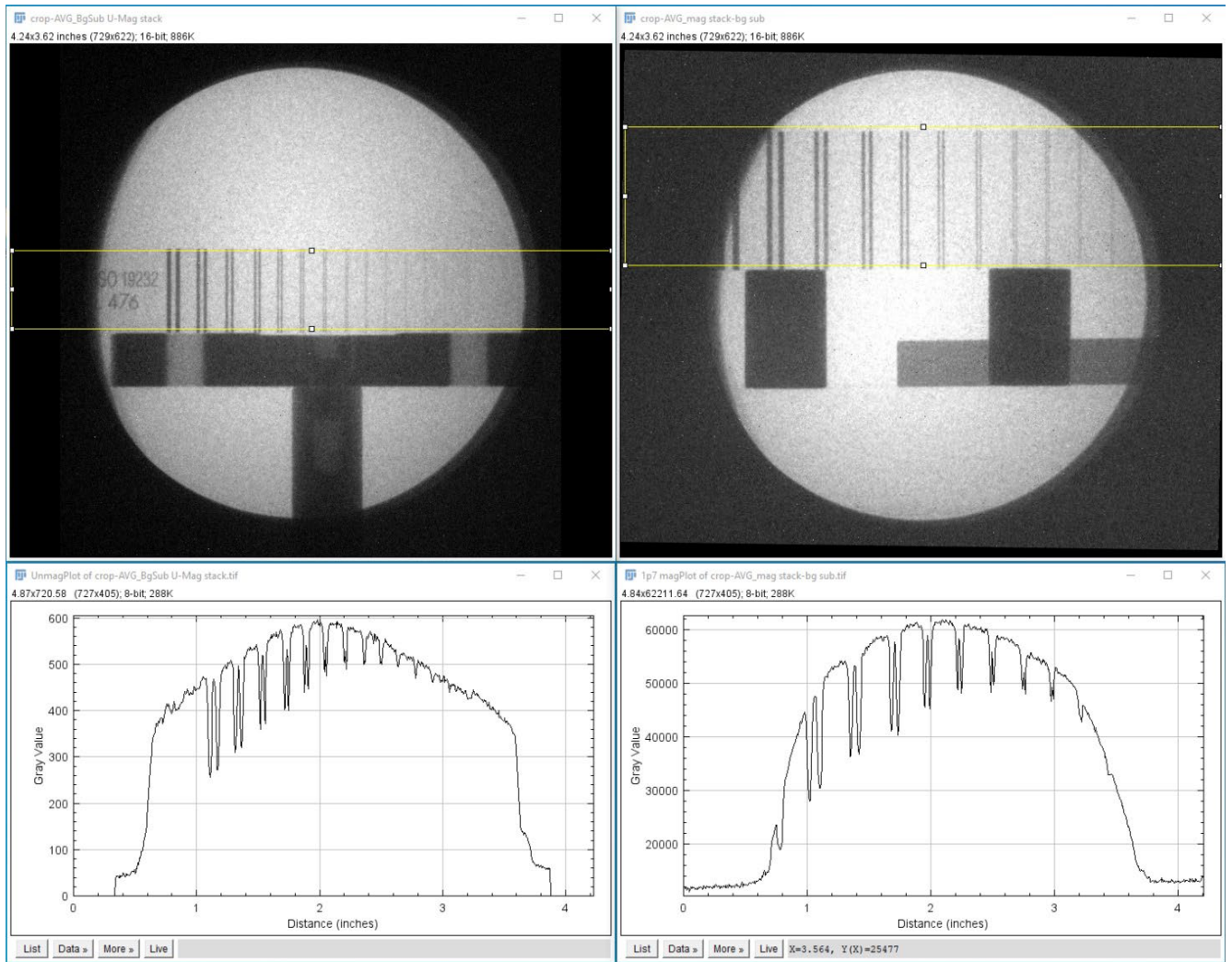


Figure 71 The image on the top left is with the IQI placed directly on the Novo detector panel and the image on the top right is with the IQI near the beam port. Magnification is ~ 1.7 times bigger. The bottom plots are image profiles across the IQIs of the top images.

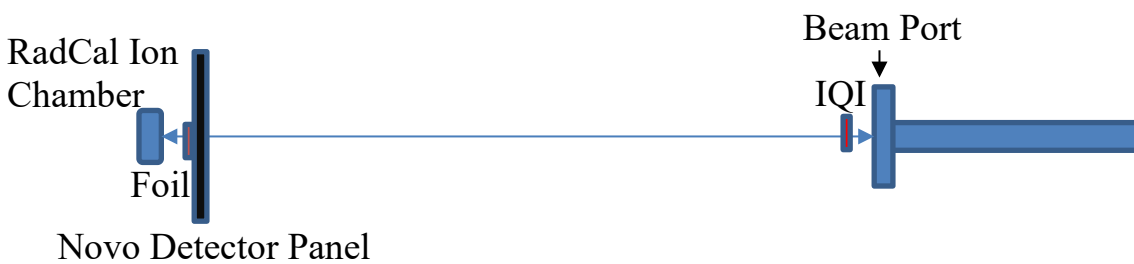


Figure 72 Diagram of setup with NOVO panel and components.

5.1 Thomson Photons with Transpec and Lead *Ref. AW*

- Source: 1Hz Thomson Photons
- Novo removed
- 4" of Pb
- 500 Second background measurement 0701AA.chn
- 500 Second beam measurement 0701AB.chn
- 40 counts difference in energy ROI
- Dose: 24.4 mR/Hr (background rate subtracted)
- Counted Indium foil overnight

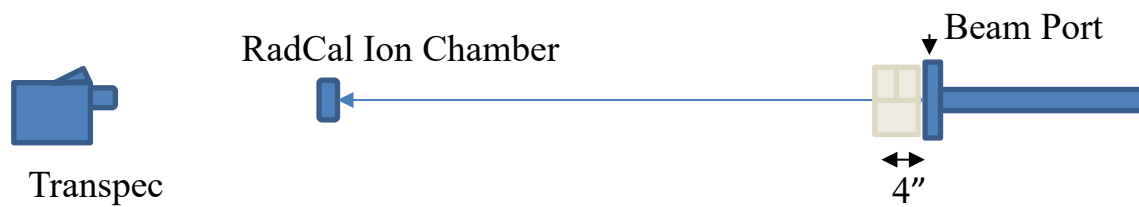


Figure 73 Diagram of setup with Transpec detector and components.