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CYGNUS SOURCE EMISSION

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Key Acknowledgments:
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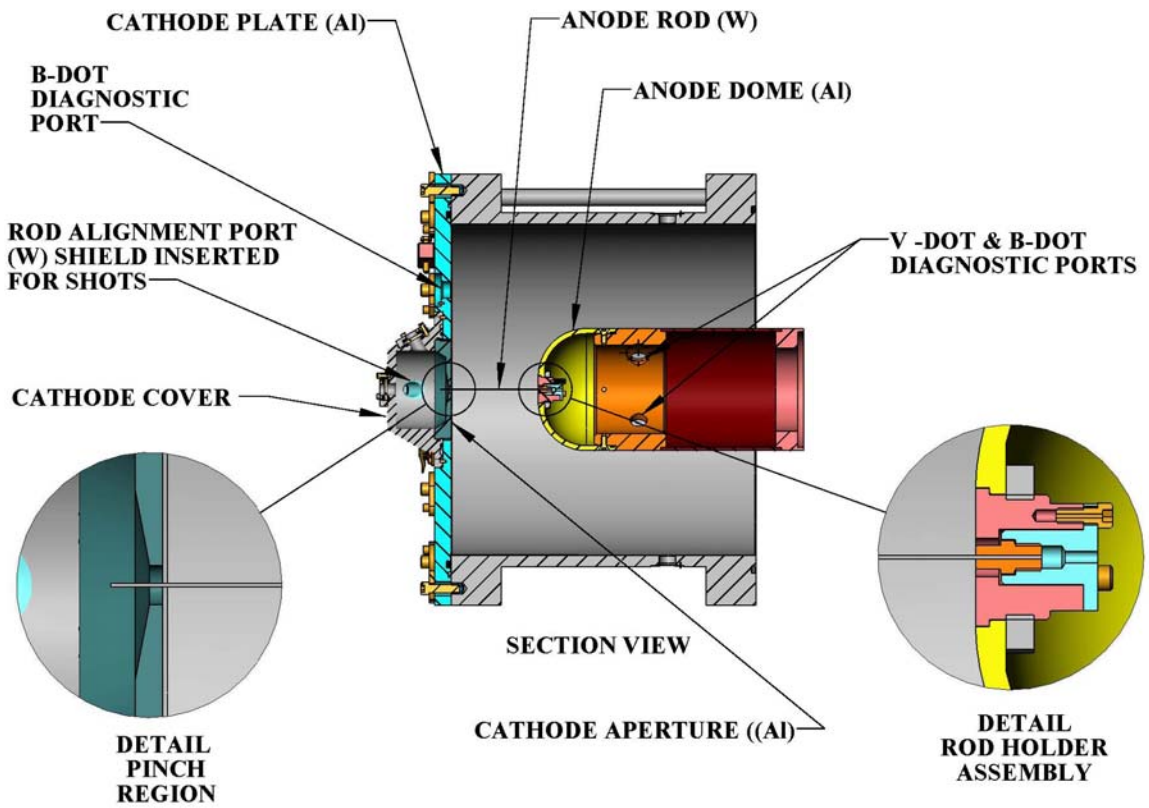
Overview of Rod Pinch Diode

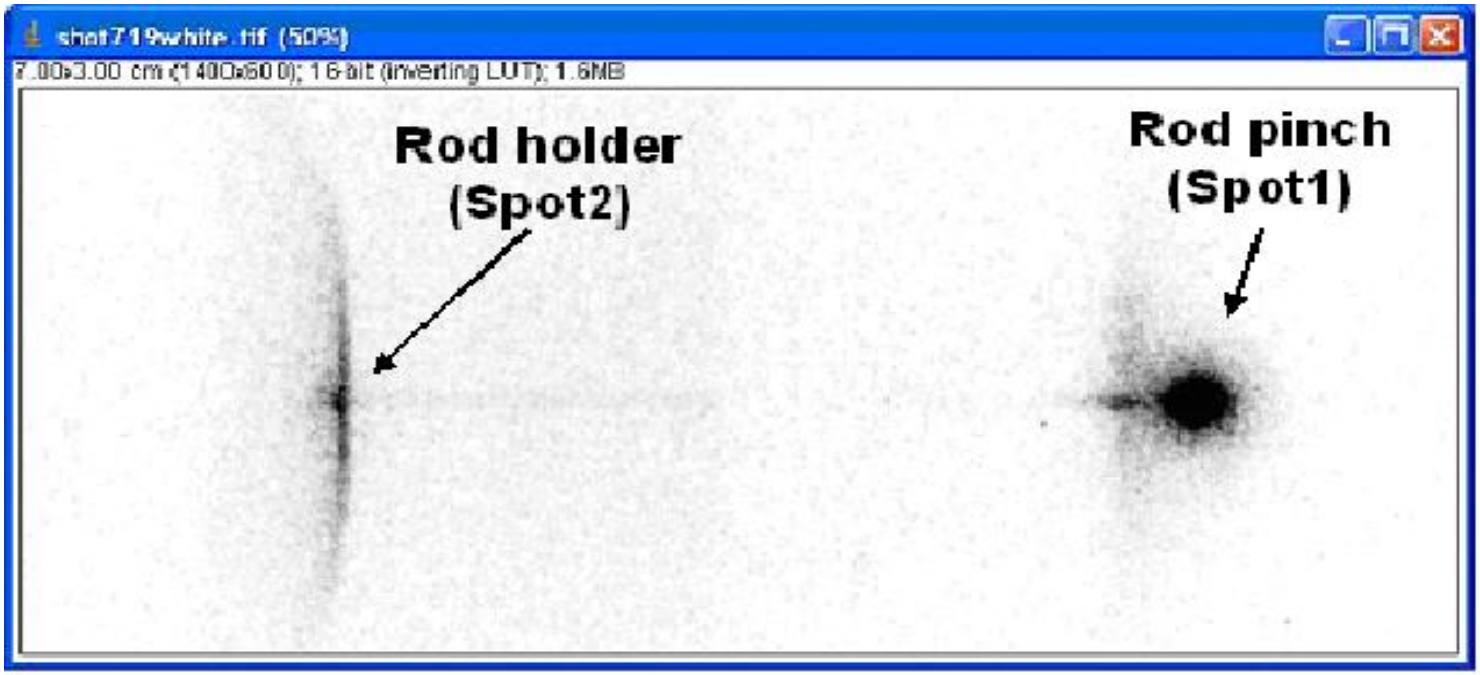
The rod pinch diode on the Cygnus machines uses an end point energy of 2.25 MeV. It is capable of high-resolution flash radiography with a pulse length of 50 ns. The diode consists of a 0.75 mm diameter Tungsten (W) tapered anode rod which extends 10 mm through a 9 mm diameter 3mm thick aluminum (Al) aperture. The majority of the current in the electron beam is created on the edges of the cathode aperture and when properly configured, the electrons will self insulate, travel down the extension of the rod, and pinch onto the tip of the rod.

Rod Pinch Diode Assembly



Problem

The Cygnus machines are unique x-ray sources used to take high resolution radiographs. As evidenced by the radiograph, a second source of x-rays appear at the rod holder. This second x-ray source creates blur, reducing image clarity which negates the original intent of a high resolution source.



Experiment Overview

- The theory is that some free electrons are creating a second bremsstrahlung source at the rod holder or the rod holder is an indirect source as a result of the rod pinch (spot1) x-rays hitting the rod holder materials (scatter).
- Two possible solutions
  1. Identify and eliminate any unwanted electron source feeding the rod holder area.
  2. Reduce the foot print of the rod holder assembly and substitute rod holder materials with ones which are less dense.

Experiment Overview I

The first condition-locate and eliminate the unwanted source of electrons. Possible sources are as follow:

- **Aluminum cathode plate**
- **Aluminum cathode aperture (square edge)**
- **Aluminum or Stainless Steel B-dot diagnostic housings on cathode plate and surrounding area**
- **Aluminum cathode aperture (upstream radiused edge)**

The materials listed in the first three items will be anodized to inhibit any electrons born off of their surfaces. The forth item will be addressed by putting a radius on the cathode aperture on the upstream side and anodizing the upstream side and aperture.

Experiment Overview II

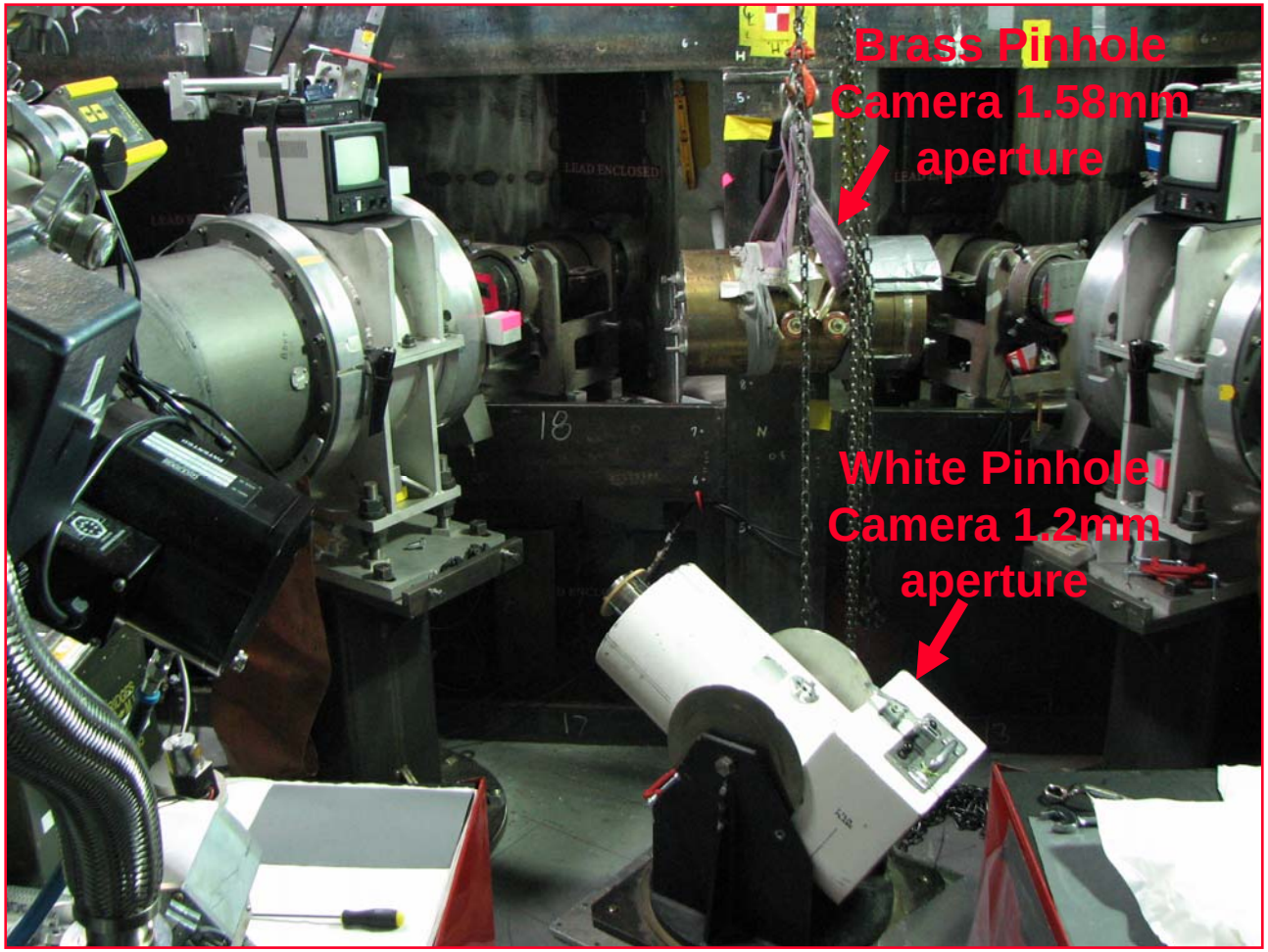
The second condition-reducing scatter created by the spot1 x-rays hitting the rod holder materials will be addressed by substituting existing rod holder materials with materials with a lower Z and reducing the cross sectional areas. The existing rod holder assembly consists of three stainless steel pieces and a graphite holder which screws into the three piece stainless assembly. The stainless steel assembly has a 17 cm^3 cross sectional area and Z=26. This Stainless Steel assembly will be replaced with an Aluminum disk with a 2.35cm^3 cross sectional area and Z=13. The existing graphite rod holder will be used for each case. The standard Tungsten rod is friction fit into the graphite rod holder.

Experiment Matrix

Test	No changes	Anodized Cathode plate	Anodized B-dots	Anodized cathode aperture (anodized on the upstream side)	Anodized cathode aperture with (anodized and aperture radius on the upstream side)	3mm thick aluminum holder (graphite stick out)	3mm thick aluminum holder (graphite flush)
Baseline	X						
Mod1		X					
Mod2		X	X				
Mod3		X	X	X			
Mod4		X	X		X		
Mod5		X	X			X	
Mod6		X	X				X

Goal: eliminate electron source or reduce the amount of unwanted x-rays

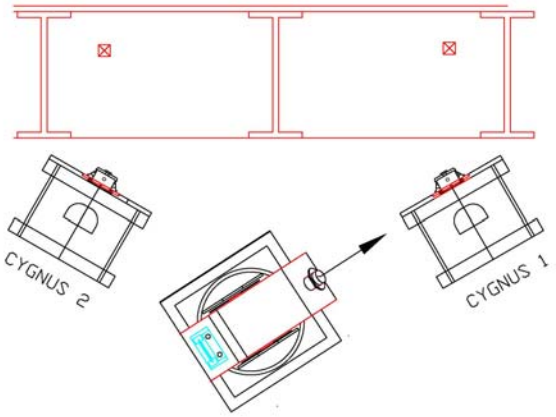
White and Brass Pinhole Cameras viewing Cygnus 2



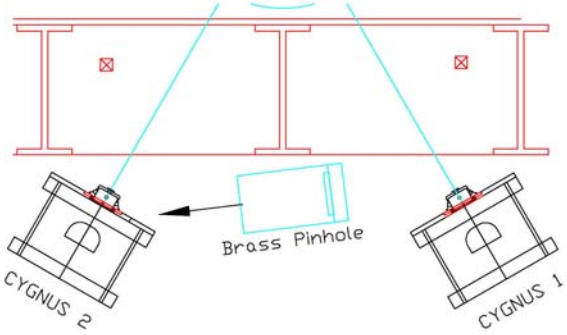
White camera is rotated to view Cygnus 1

Pinhole Camera Location drawings

Top View

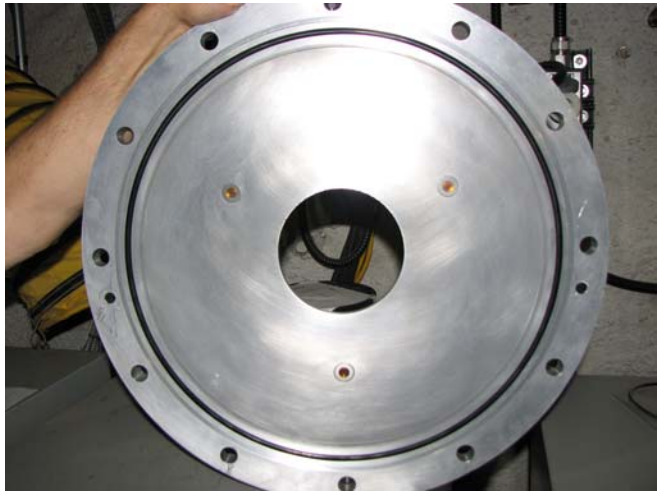


White Pinhole camera viewing Cygnus 1

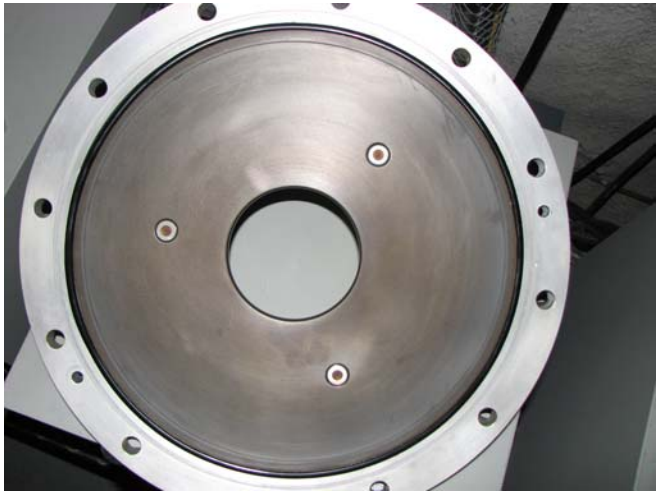


Brass Pinhole camera viewing Cygnus 2

Anodized parts

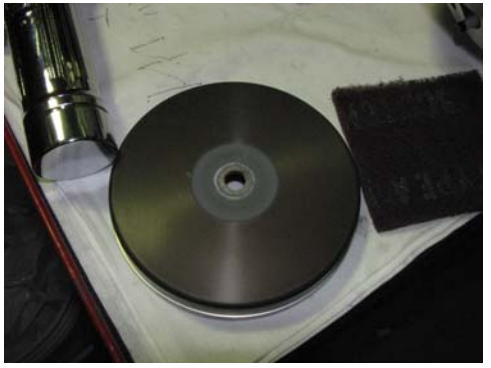


Possible source Al cathode plate & B-dots



Anodized Al cathode plate & B-dots

Possible source Al diagnostic port plug



Anodized Al cathode aperture (after shot)

White and Brass Pinhole Camera Details

Machine	Pinhole camera	Aperture/ focal length	Degrees off Normal	Elevation angle	Distance From Machine
Cygnus1	White	1.2mm 40.64cm	1º	27.3º	69.85cm? 27.5’
Cygnus1	White	1.2mm 40.64cm	3º	32º	50.8cm? 20’
Cygnus2	White	1.2mm 40.64cm	3º	32º	47.31cm? 18.625”
Cygnus2	Brass	1.58mm 31.5cm	37º	0º	41.91cm? 16.5”?

Fujifilm BAS-MS Image Plates

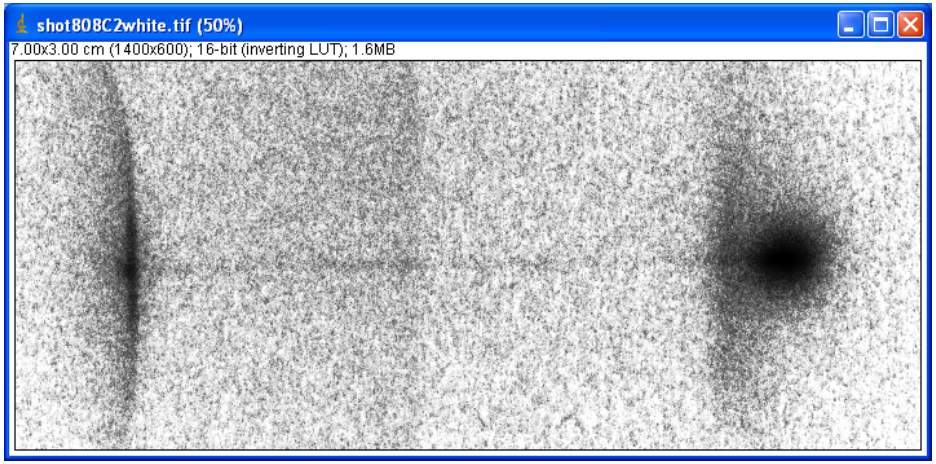
The BAS-MS, like all Imaging Plates, has a flexible polyester base coated with highly dispersed barium fluorohalide phosphor crystals ($BaF(Br,I):Eu^{2}+$). When a radioactively labeled sample is exposed to an IP, the energy from that sample is transferred to the phosphor crystals, and stored as trapped electrons. In short, the electrons become trapped to form 'F-centers' in the BaF(Br,I) matrix. Scanning the exposed IP with a He-Ne laser (633nm) releases the trapped electrons and photons at about 400nm. This process is known as photo-stimulated luminescence. The blue light emitted is collected to produce the digitized image.

Images were recorded using Fujifilm BAS-MS Image plates.
The plates have 16-bit gray scale.

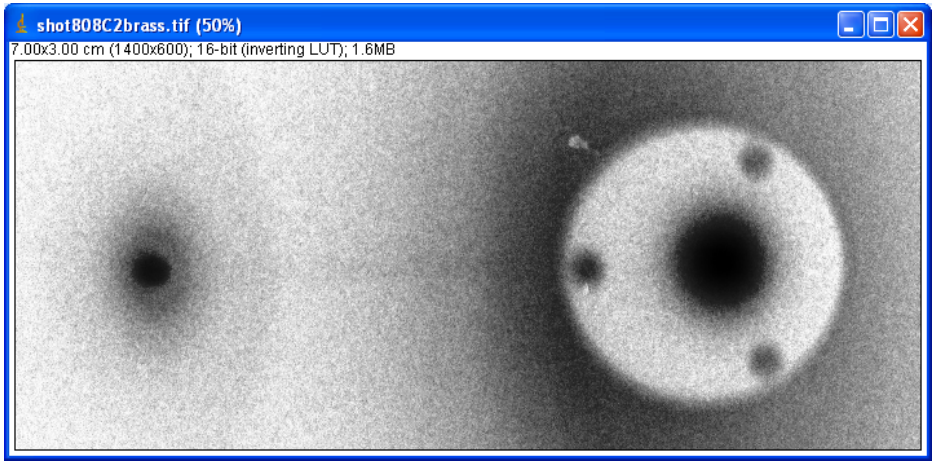
FUJIFILM FLA7000 Fluorescent Image Analyzing System

- **The image plates were read using the Fujifilm FLA7000 Fluorescent Image Analyzing system**
- **The settings used:**
  1) **Sensitivity: s4000 – Voltage levels to the photo multiplier tubes which controls reading sensitivity.**
  2) **Pixel size: 50um – Scanner resolution**
  3) **Latitude: L5 –Dynamic range (2 ranges available L5- 16 bit or L4-8 bit)**

Sample Radiographs
White and Brass Pinhole Images



White 3º off normal viewing Cygnus 2



Brass 37º off normal viewing Cygnus 2. Note there is a ½”W shield in front of rod tip

Analysis Software

NIH image is a public domain image processing and analysis program for the Macintosh. It was developed by the research services branch of the National Institute of Mental Health (NIMH), part of the National Institute of Health (NIH). ImageJ, also in the public domain, is a Java program inspired by Image that runs on any platform. ImageJ version 1.410 software was used to analyze the pinhole images. The imageJ software can be downloaded at http://rsb.info.nih.gov/ij/

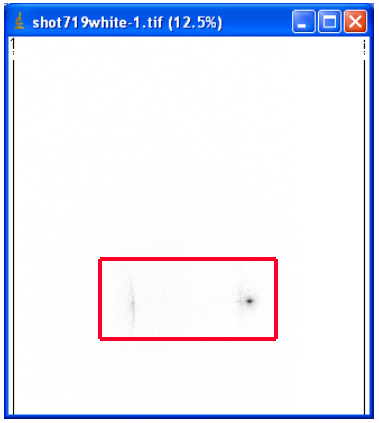
Overview of Measurements, Analysis Software and Process

- It is desired to have a quantitative unit of measure to characterize the performance of each experiment; therefore, a figure of merit (FOM) was established and is defined as the ratio of the average intensity of the rod pinch region to the average intensity of the rod holder region.
- It is desired to use consistent techniques when comparing one image to another; therefore, a rectangular area was defined for scanning a region of interest and centered about the maximum point of each area.
- It is desired to smooth the data by using minimally intrusive methods to remove fluctuations in the data. To accomplish this the Gaussian Blur filter routine in ImageJ was utilized.

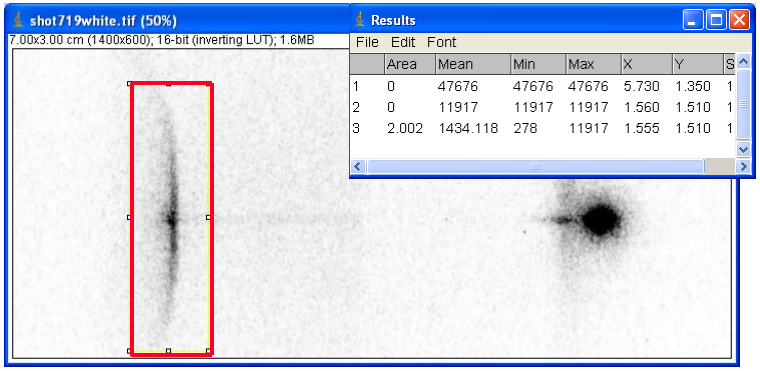
Steps of the Measurement Process

1. The scanned image is cropped using a rectangle (7.00 cm wide by 3.00 cm high).
2. The cropped image is smoothed using the ImageJ Gaussian Blur filtering routine with a Sigma radius of 4.00.
3. The peak points in the areas of interest are found and the locations are saved.
4. Pre defined rectangles are centered about the peak point location of each area which was recorded in the previous step.
5. The intensity averaged over the rectangular area is recorded and the FOM is calculated.
6. Plots of the data are created using Microsoft Excel.

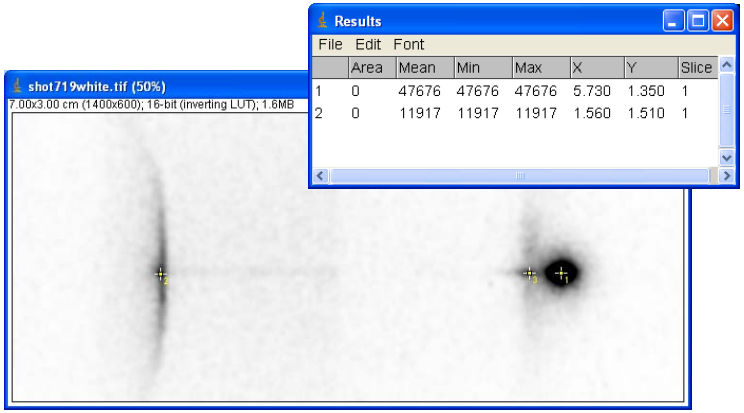
Example Steps of ImageJ Measurement Process



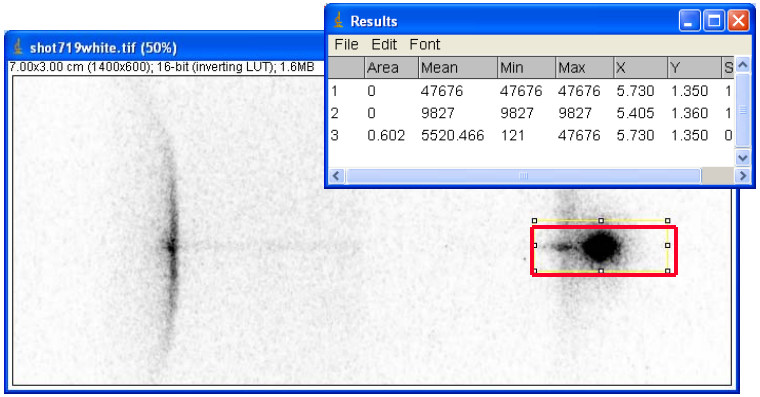
(1) Scanned Raw Image



(4) Pre defined rectangle centered about spot2(Rod Holder area) Peak Point and the mean is recorded

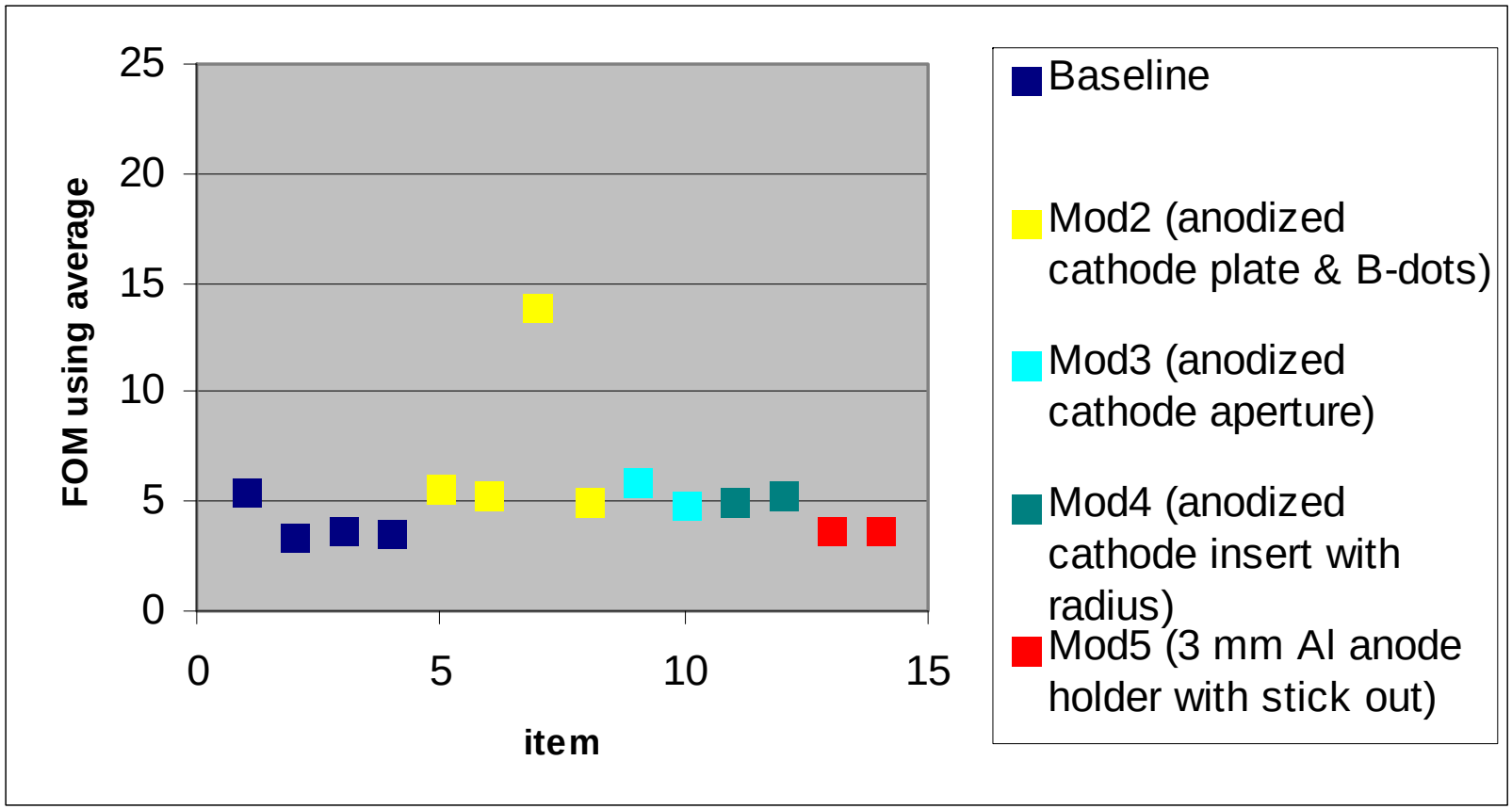


(2,3) Image cropped and filtered. peak points located and recorded



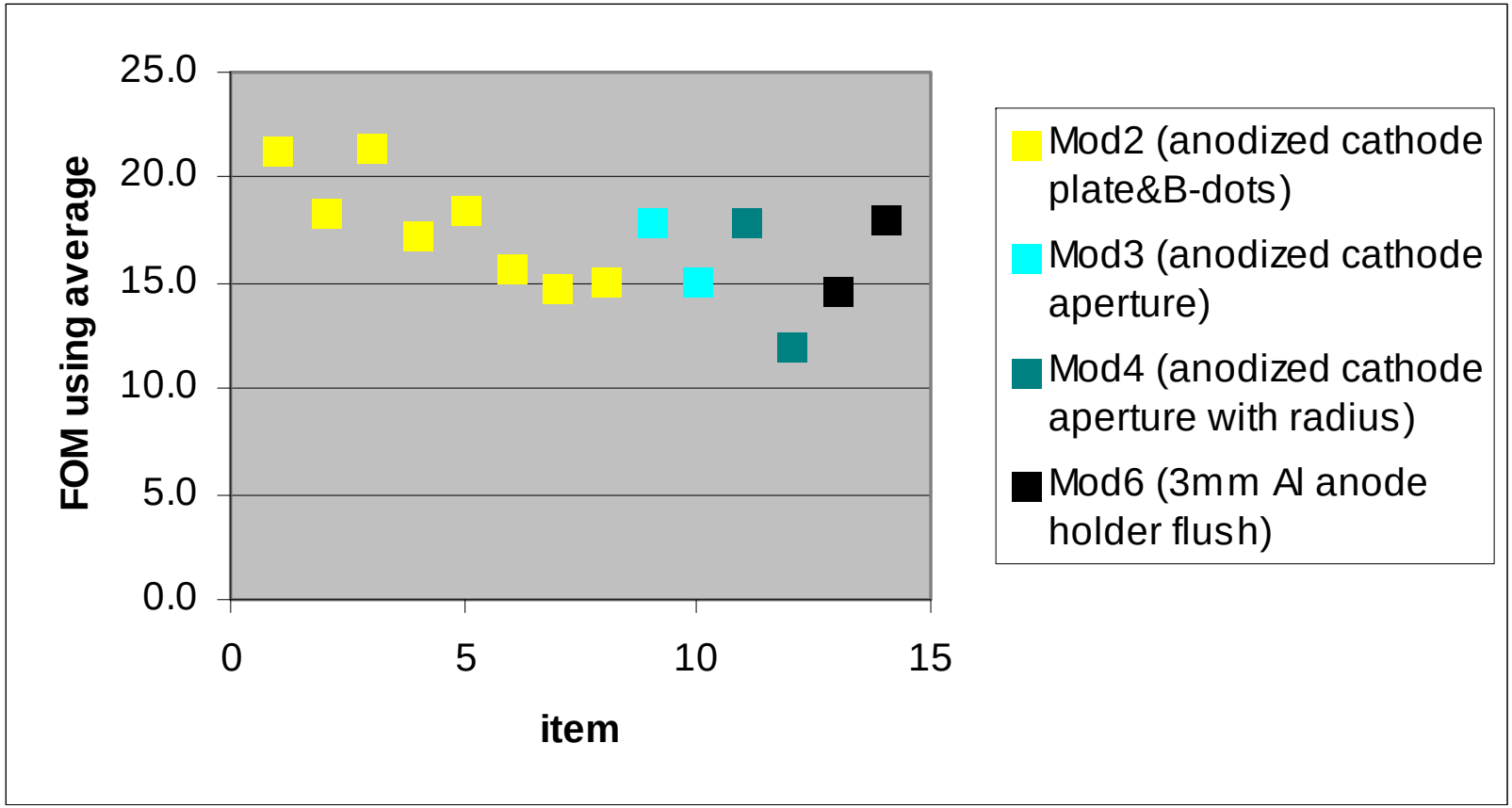
(4) Pre defined rectangle centered about spot1(Rod Pinch area) Peak Point and the mean is recorded

Results
Cygnus 1 White Camera 1º off Normal



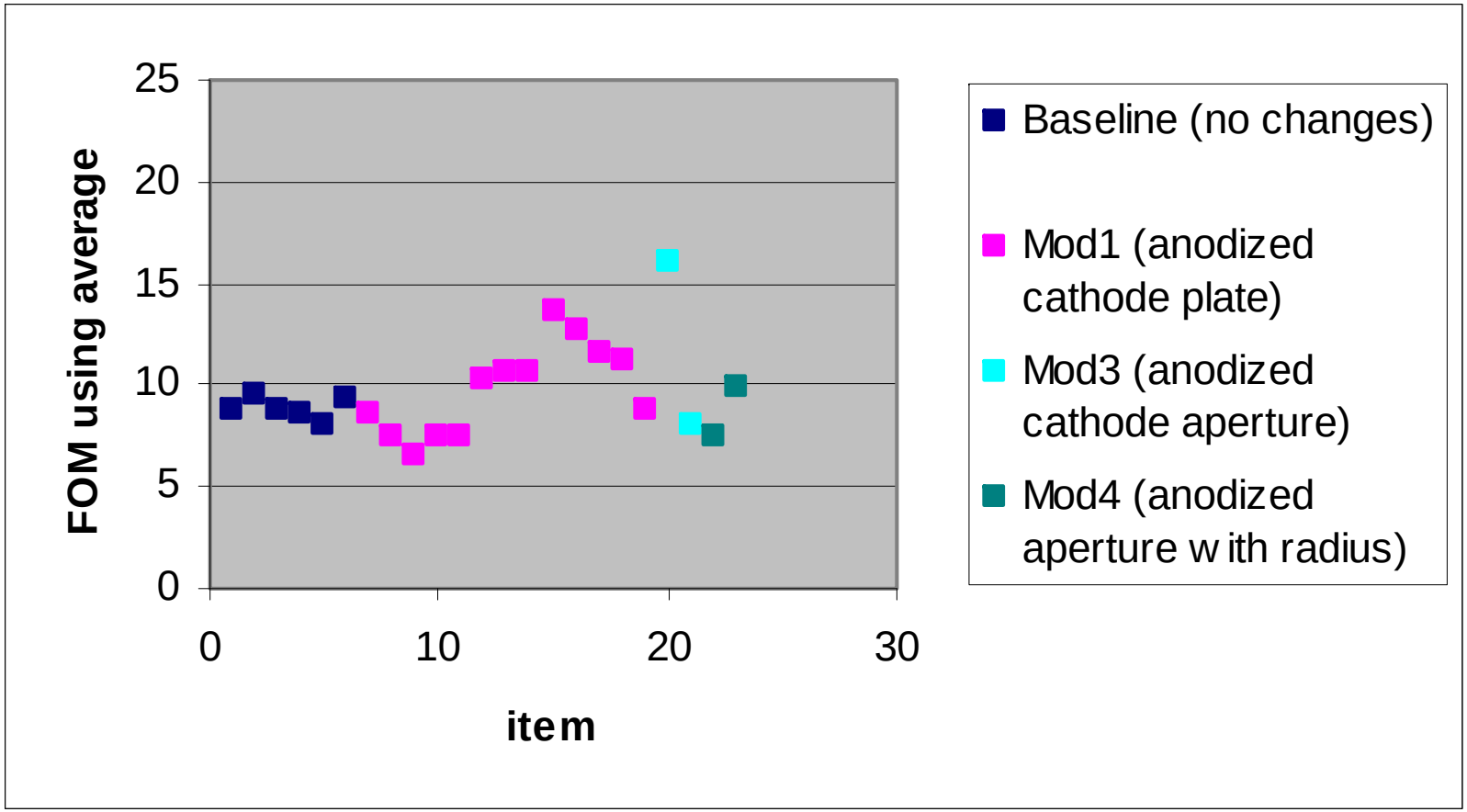
The FOM is the calculated intensity average of the two locations, spot1 and spot2

Results
Cygnus 1 White Camera 3º off Normal



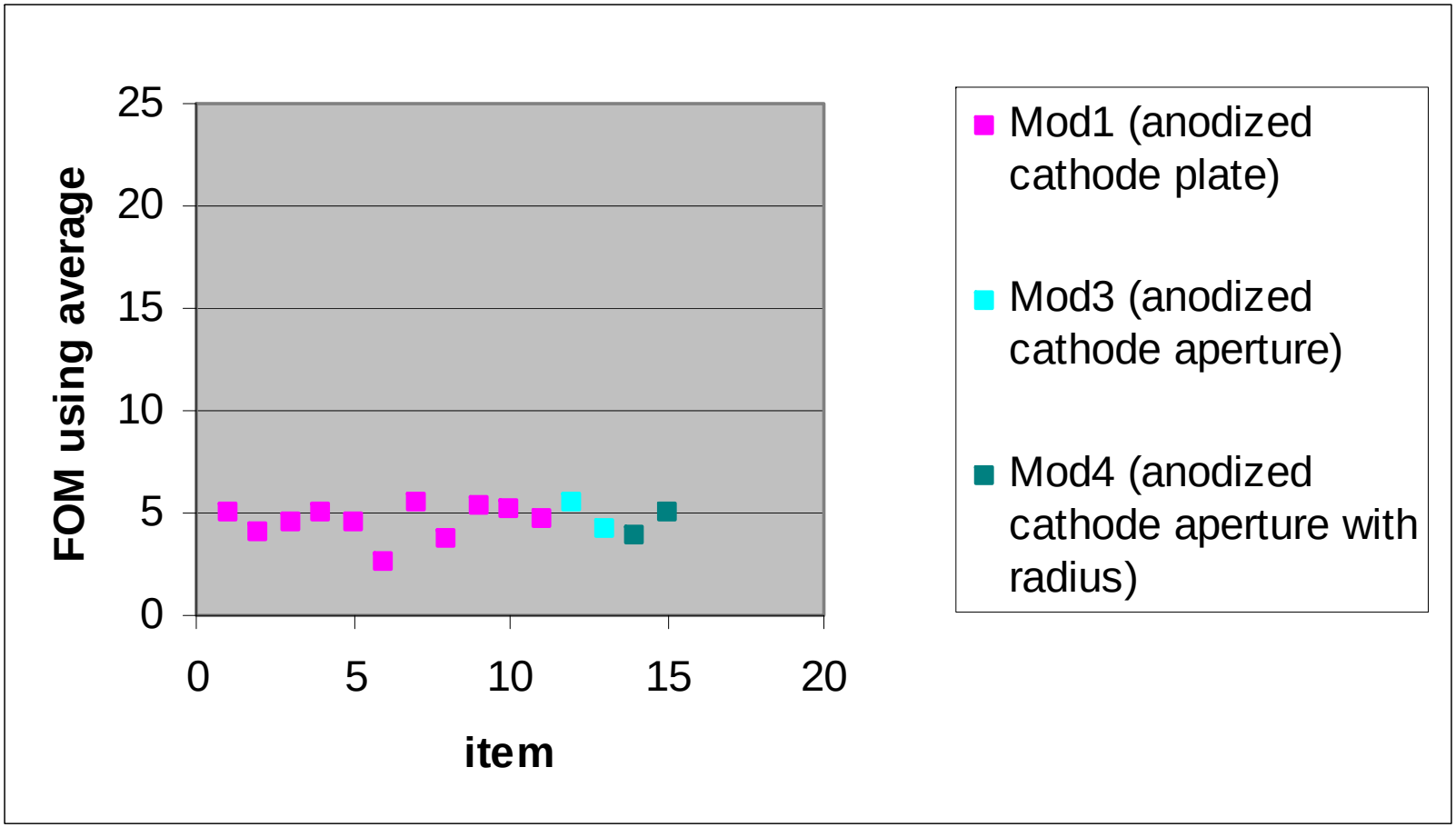
The FOM is the calculated intensity average of the two locations, spot1 and spot2

Results
Cygnus 2 White Camera 3º off Normal



The FOM is the calculated intensity average of the two locations, spot1 and spot2

Results
Cygnus 2 Brass Camera 37º off Normal



The FOM is the calculated intensity average of the two locations, spot1 and spot2

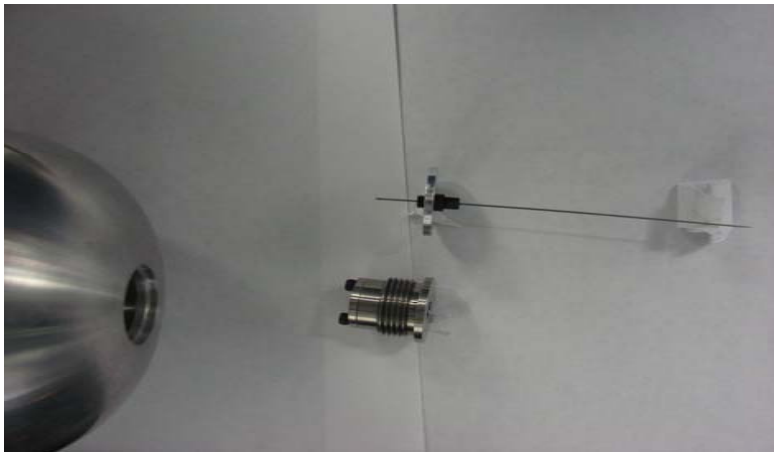
Results Table

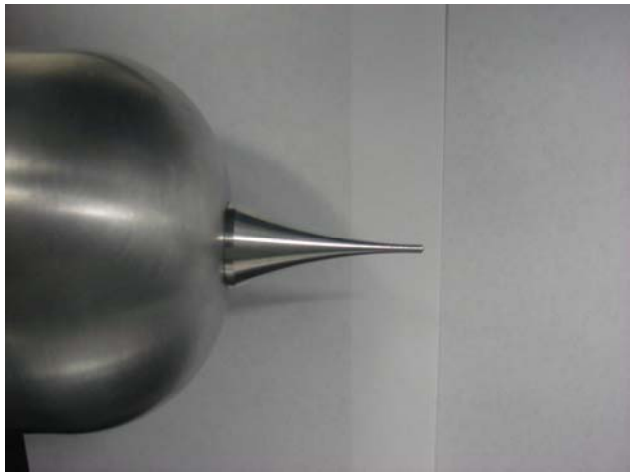
Test	Cygnus1 White 1º	Cygnus1 White 3º	Cygnus2 White 3º	Cygnus2 Brass 37º
Baseline (no changes)	4	na	9	na
Mod1 (anodized cathode plate)	na	na	10	5
Mod2 (anodized cathode plate& b-dots)	7	18	na	na
Mod3 (anodized aperture)	5	17	12	5
Mod4 (anodized aperture with radius)	5	15	9	4
Mod5 (Al holder with stick out)	4	na	na	na
Mod6 (Al holder flush)	na	16	na	na

Changing the material and surface finish (anodization) showed little effect on the FOM

Hershey Kiss Geometry

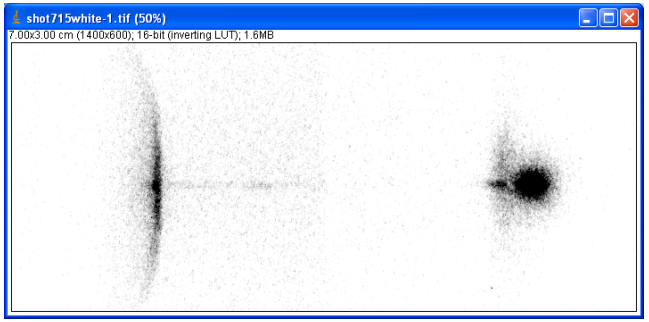
- **A second set of tests were conducted where the geometry of the rod holder was changed to move the junction of the rod to rod holder closer to the aperture. This shape resembles a Hershey kiss.**



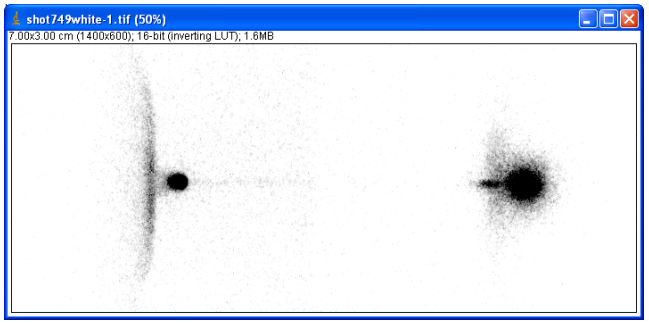


There were only two tests conducted with this geometry one holder was made of graphite and the second was made of aluminum.

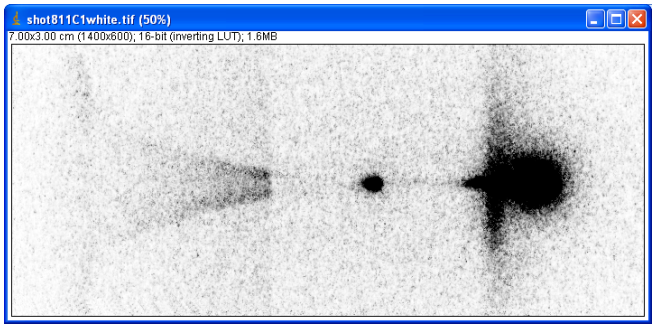
Radiographs show the main x-ray emission at the spot2 location did move with the location of the rod to rod holder interface



- Standard stainless steel rod holder



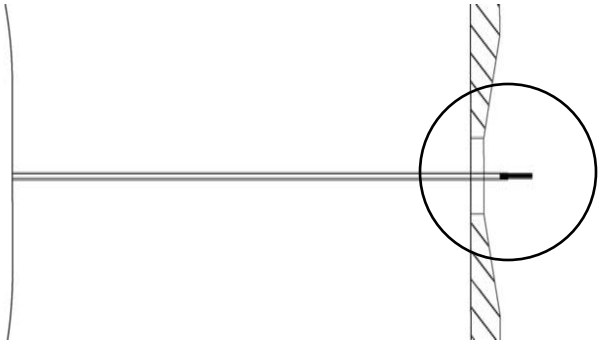
- 3mm Al rod holder graphite sticking out



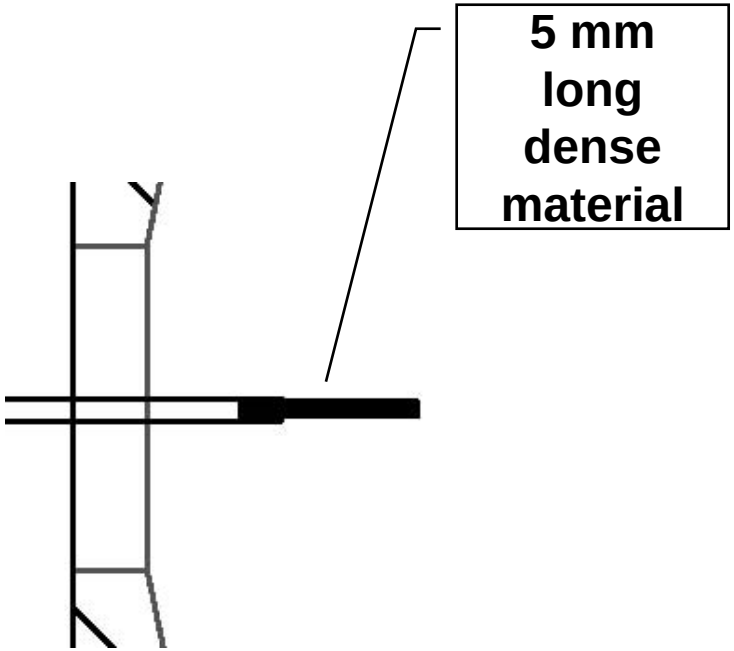
- Al Hershey kiss rod holder

Future Work

- A third set of tests are planned using a low Z hollow tube instead of a solid tungsten rod.
- Different materials i.e. Au, Pt, W, etc .5mm long will be inserted into the tip.



Hollow tube rod holder



THE END

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