GENERAL ATOMICS
AND AFFILIATED COMPANIES

LA-UR-05-3092

Evidence of fractionation in beta-layered DT solid layers

by

John D. Sheliak, General Atomics
James K. Hoffer, Drew A. Geller, LANL ESA-TSE
and Evan R. Mapoles, LLNL

presented at the

High Average Power Laser Workshop

sponsored by the

U. S. Naval Research Laboratory's
High Average Power Laser Program (HAPL)
hosted by

Lawrence Livermore National Laboratory

Livermore, CA, June 20-21, 2005

Los Alamos
NATIONAL LABORATORY

ESA-TSE
Engineering Sciences and Applications Division
Tritium Science & Engineering

Evidence of fractionation in beta-layered DT solid layers*

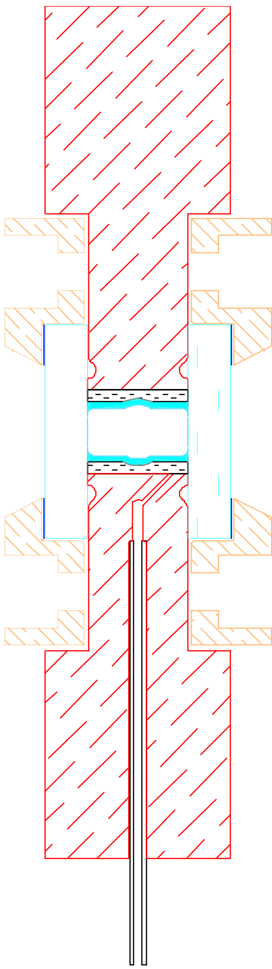
John D. Sheliak - General Atomics
James K. Hoffer, **Drew A. Geller** - Los Alamos National Laboratory
Evan Mapoles - Lawrence Livermore National Laboratory

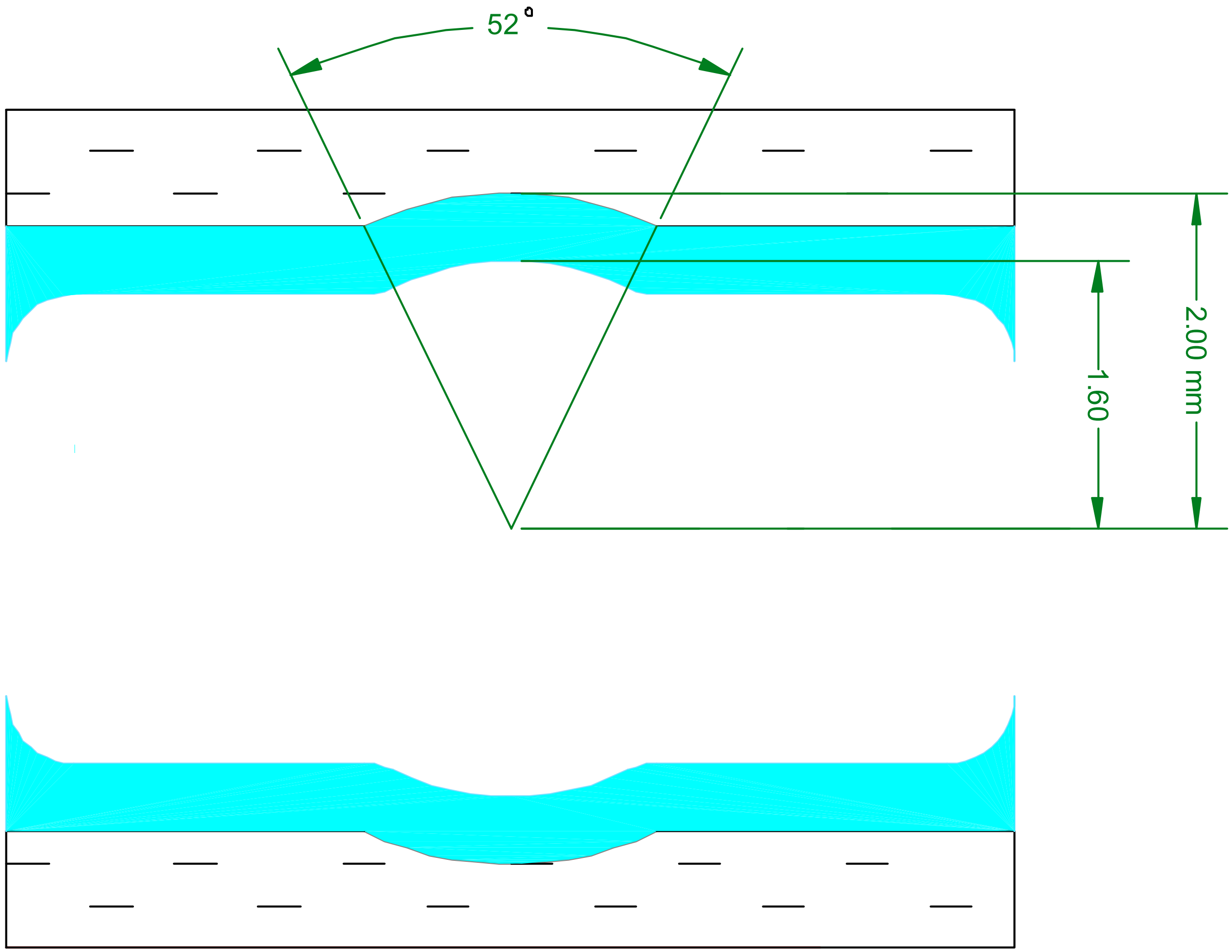
ABSTRACT

Fractionation of 50-50 D/T, (a ternary mixture of 25% D_2, 50% DT and 25% T_2 molecules) into tritium-rich and deuterium-rich regions can occur during the processes of condensation, freezing, and/or solid redistribution (beta-layering) and is of concern to both ICF and IFE communities. Fractionation could occur radially, resulting in a D_2-rich layer at the solid-vapor boundary that might impact the ignition of the 'hot-spot.' Fractionation might also occur vertically following rapid freezing and the initial beta-layering equilibration. In a sphere-cylinder geometry, the inside edge of the spherical solid DT ice segment and the outer edge (i.e., the inside diameter of the spherical sapphire undercut) are both visible in the same image and it is possible to directly measure the mode 1 offset of the ice. If vertically oriented, a significant mode 1 could be interpreted as a sign of fractionation. In solid DT layering experiments performed inside a sapphire hemisphere, we cooled two separate solid layers to 8.7 K and recorded self-illumination with one-hour-long time exposures. The intensity distribution of the light is a direct measure of the spatial distribution of tritium atoms and can be compared with distributions calculated for differing amounts of fractionation.

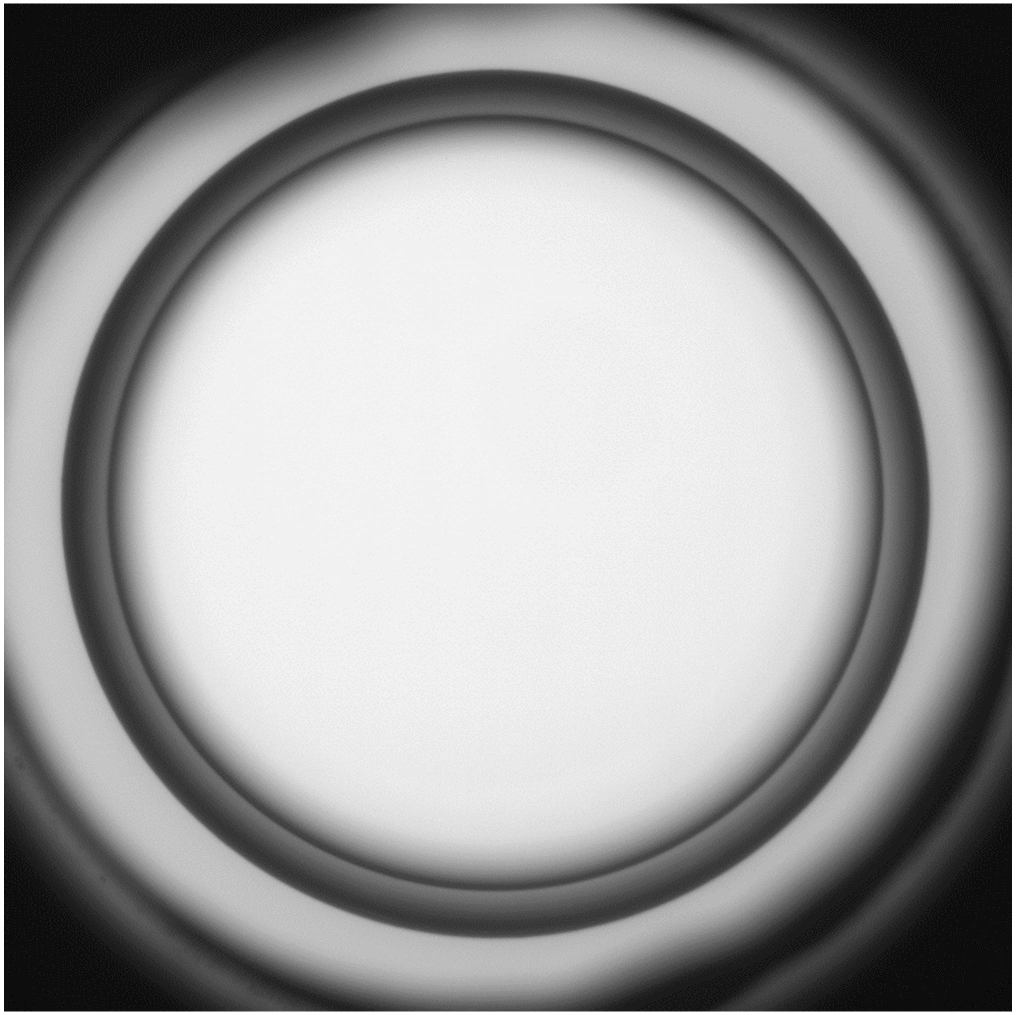
* **Work supported by contract to the U. S. Naval Research Laboratory High Average Power Laser (HAPL) Program.**

Our sapphire sphere-cylinder enables us to view spherical cavity, cylindrical bore, and DT solid layer surface; but none are par focal with one another

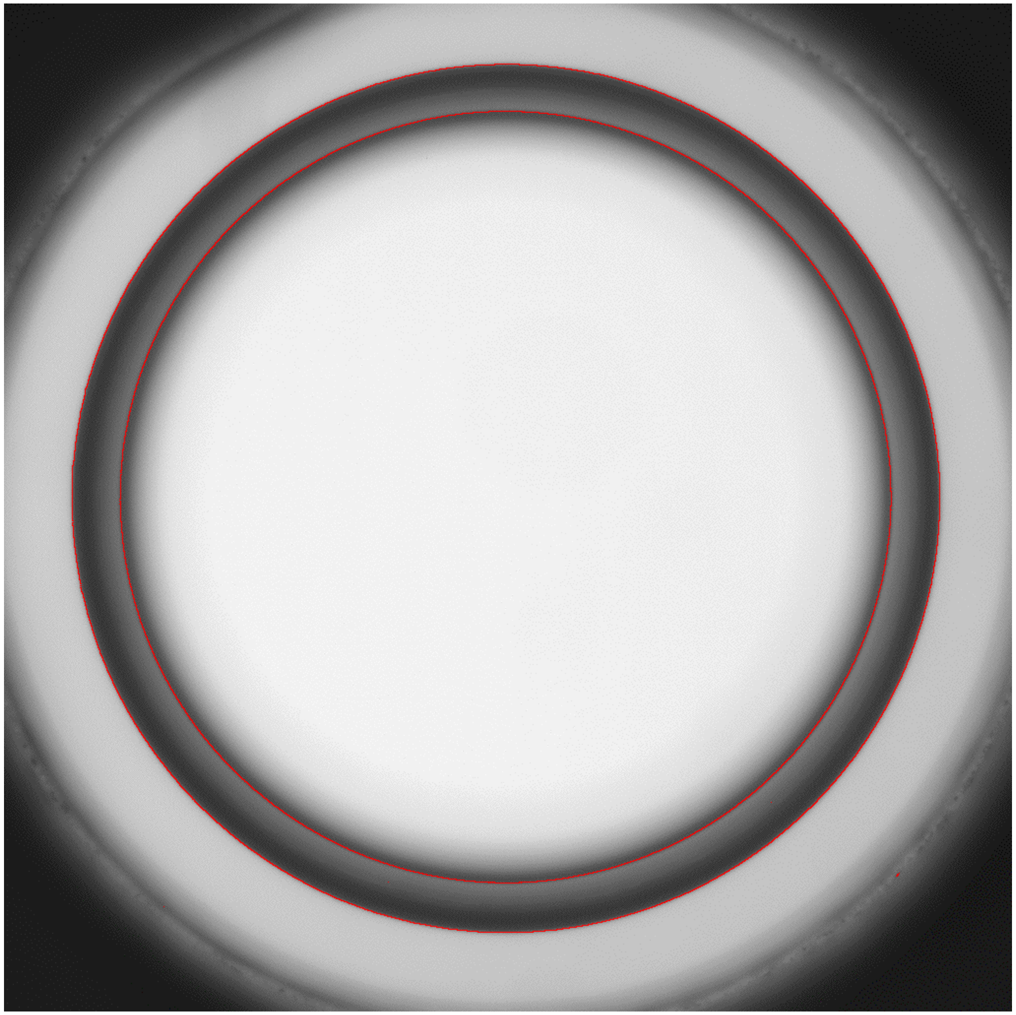




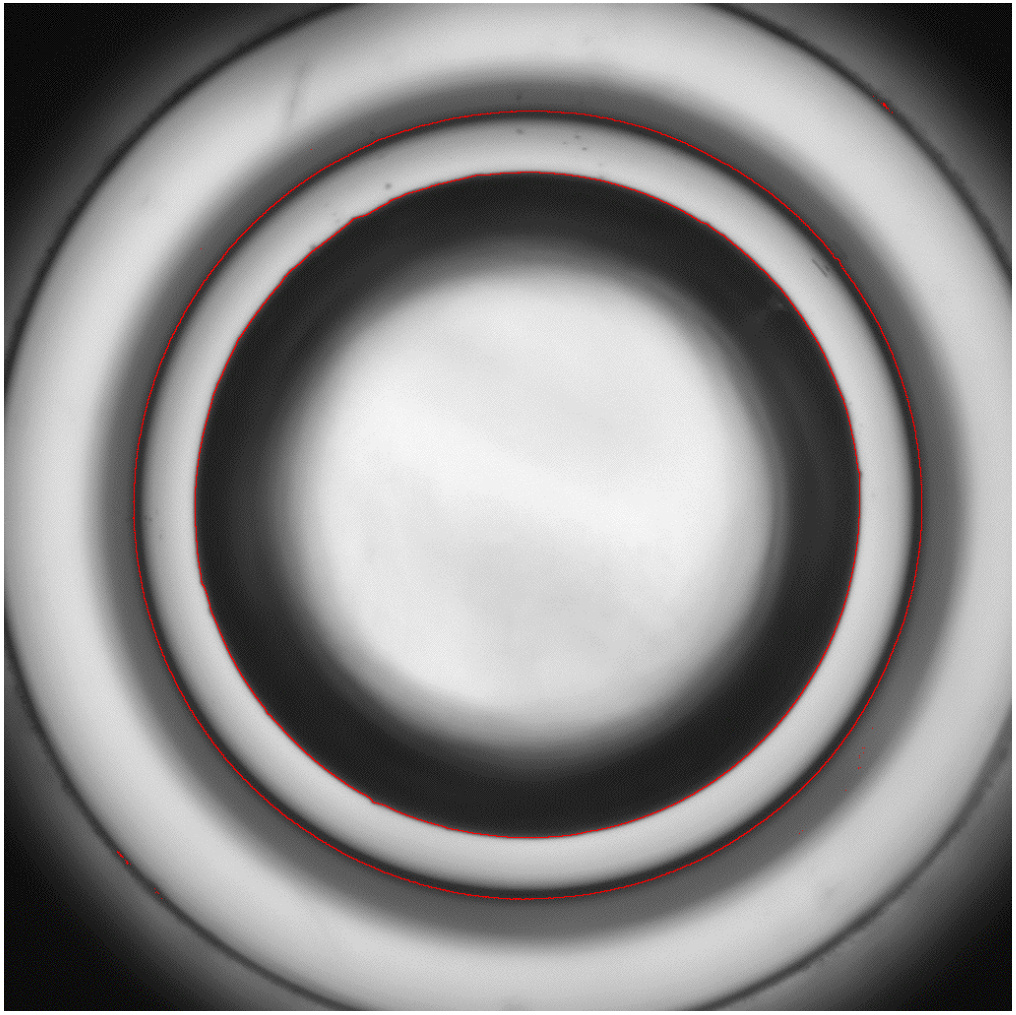
The spherical cavity edge and the cylindrical bore edge are both visible but not par focal in this empty sphere-cylinder image



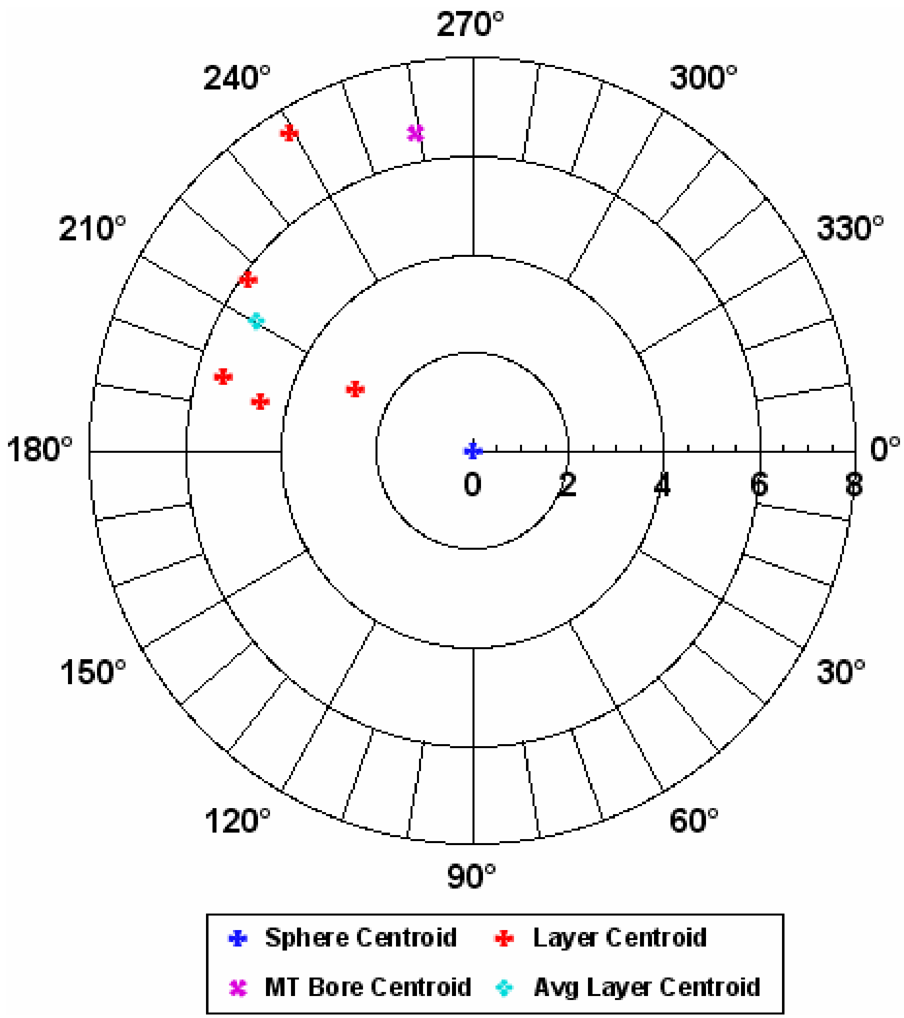
Using the empty sphylinder image, we first find the centroid for the cylindrical bore and that of the spherical cavity.



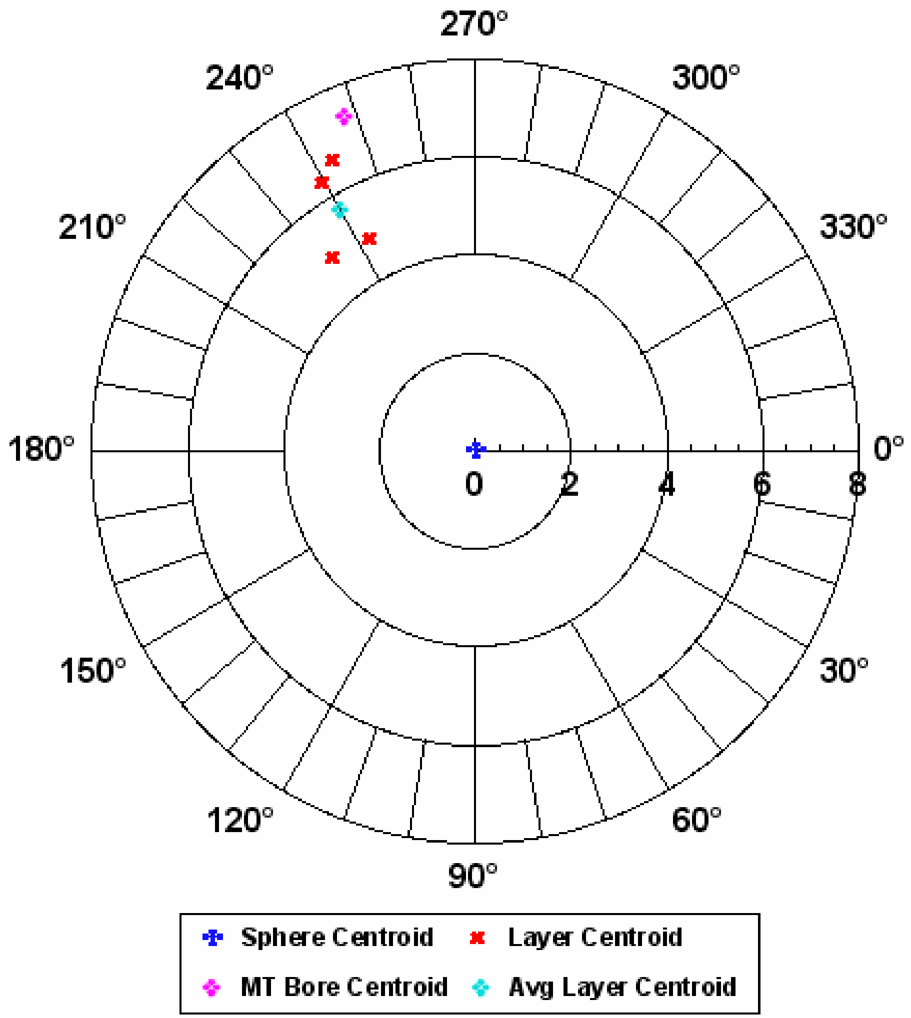
Using a layered cell image, we next find the centroid for the DT solid layer and the sphylinder cylindrical bore



Finally we compute the DT solid layer P1 (magnitude, phase) relative to the sphylinder spherical surface - this graph shows data for the unpolished sphylinder

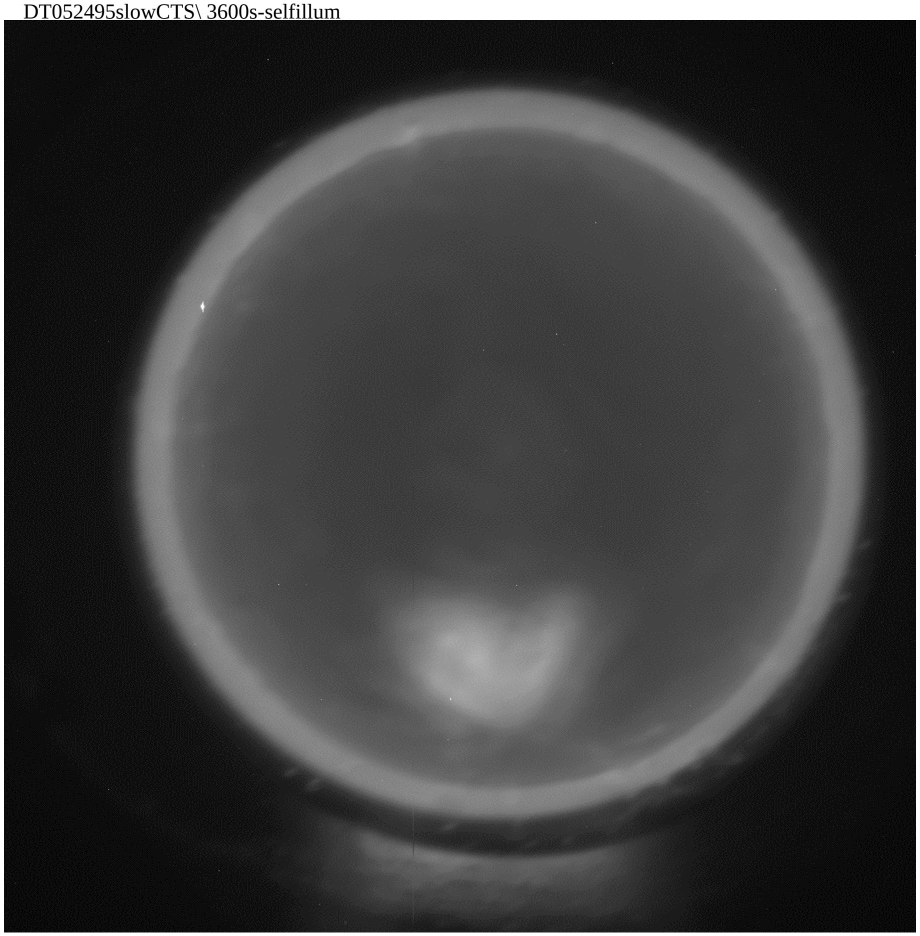


We use the same process to determine solid layer P1 for our polished sphere-cylinder data shown here



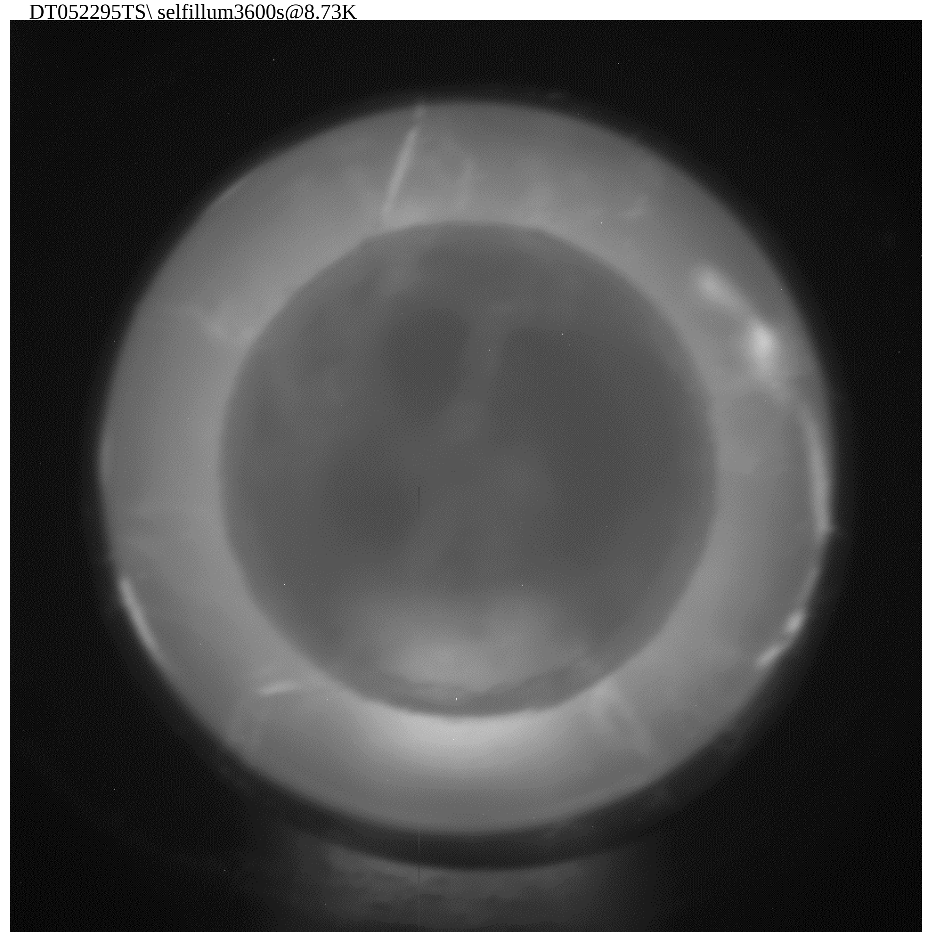
Self-illumination of 2 solid DT layers inside a sapphire hemisphere : 60 minute exposures @ T< 10 K

DT052495slowCTS\ 3600s-selfillum



108 m-thick layer @ 8.9 K

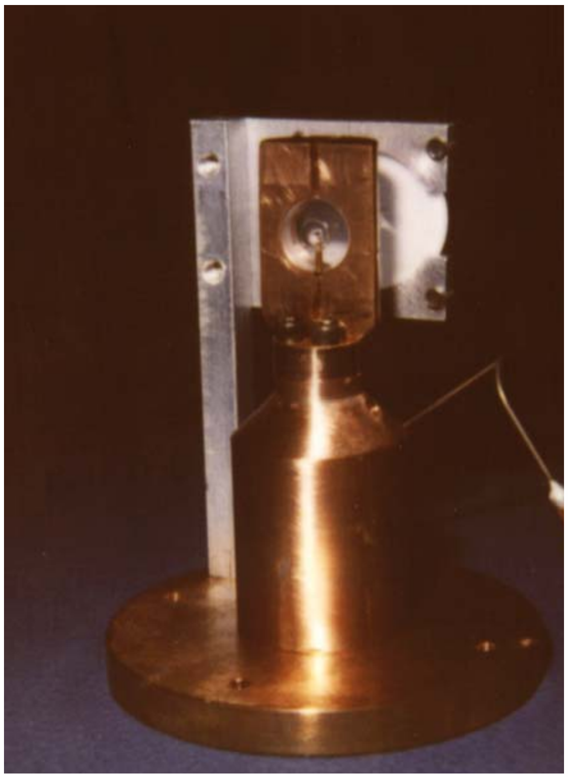
DT052295TS\ selfillum3600s@8.73K



318 m-thick layer @ 8.73 K

We dubbed this effect ‘self-phosphorescence.’ It is the result of light being emitted as atomic species (D’s and T’s ionized by beta emission) recombine to form molecules. The ionization is a result of tritium decay, thus the light reflects where the tritium atoms are.

Sapphire Hemisphere Photo & Diagram Showing Location of Fill-Line Sections Relative to Observed Surface



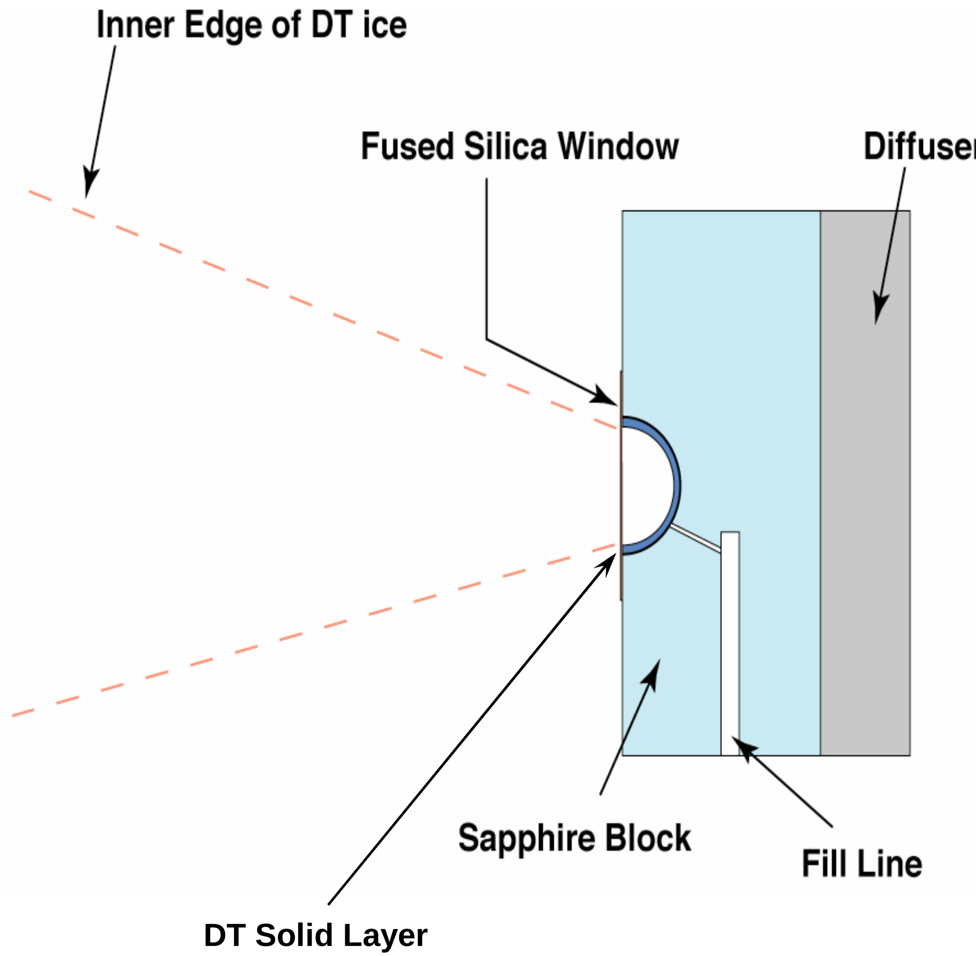
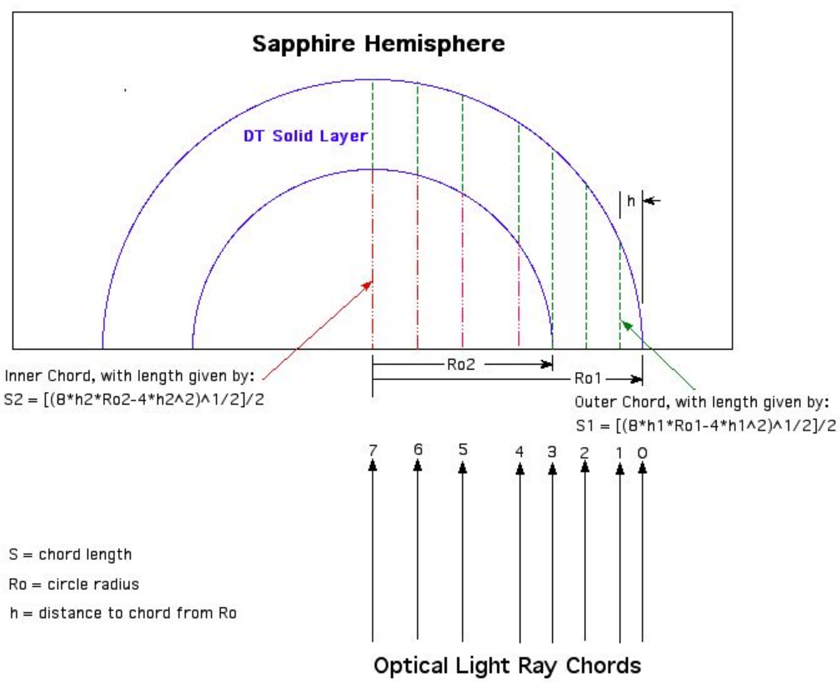
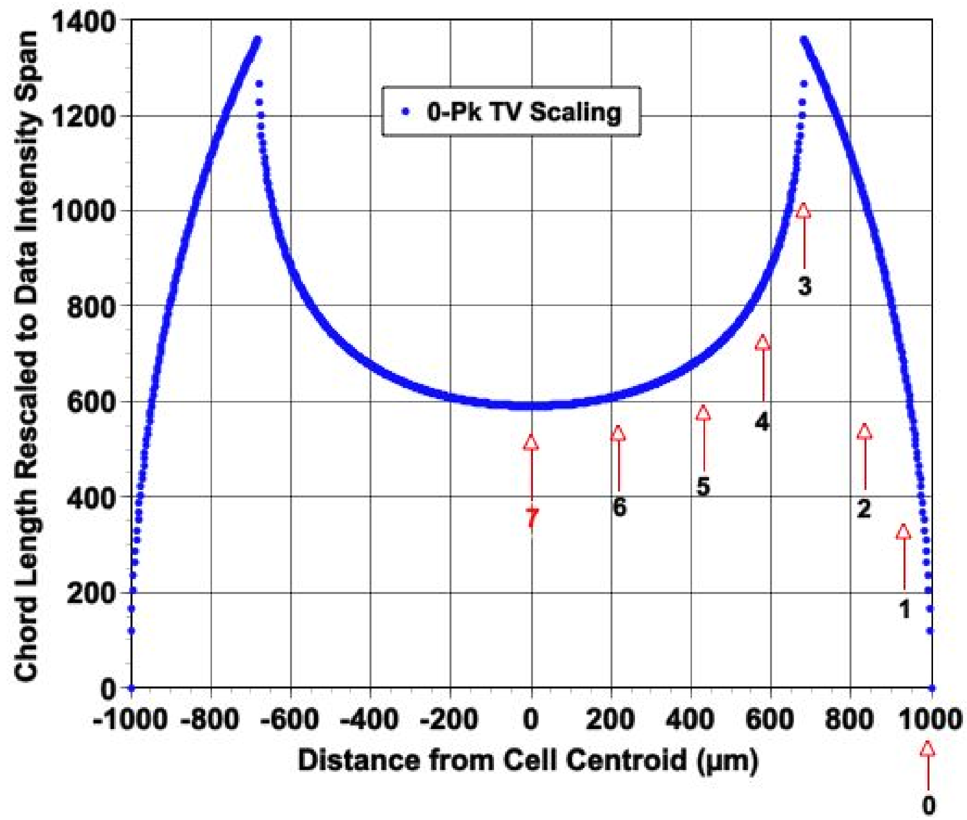


Image of the empty 2 mm diameter sapphire hemisphere at 20 K just prior to DT filling for beta-layering experiments

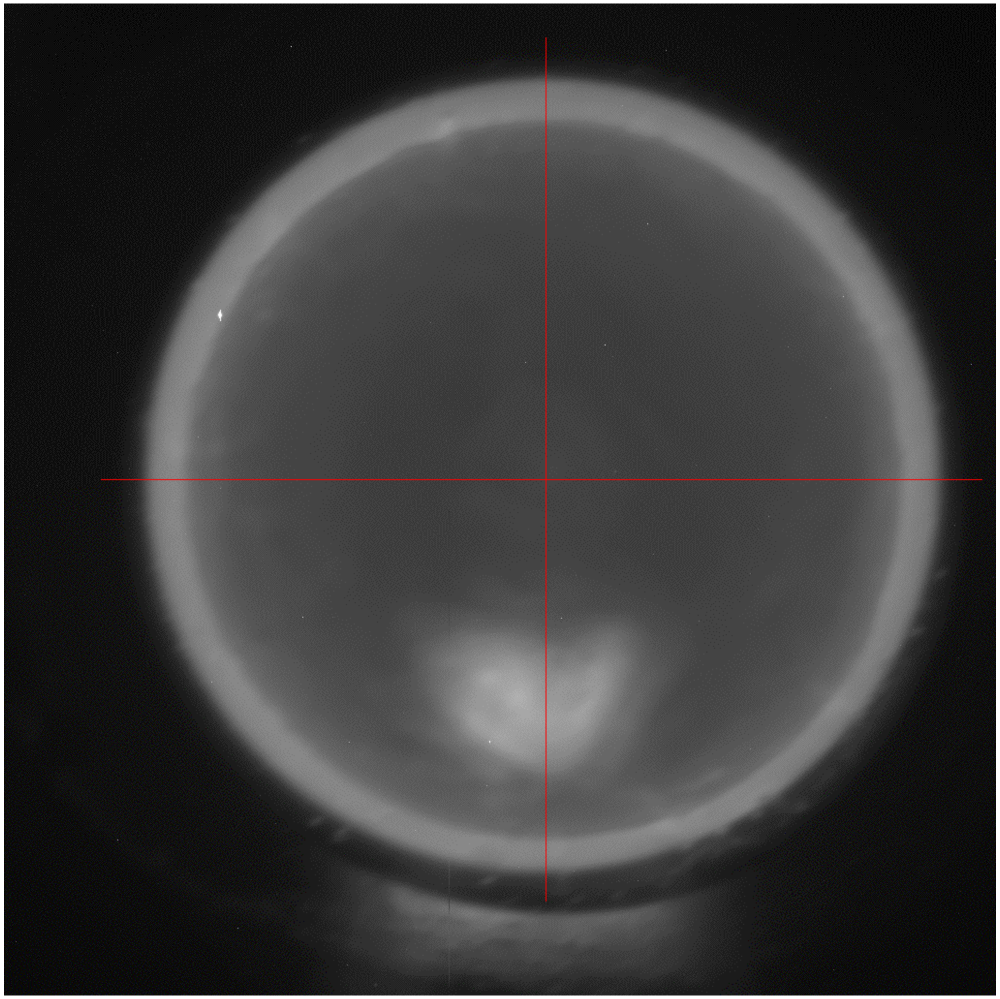
Light intensity for self-illuminated DT solid layers is expected to scale linearly with DT solid chord length for a uniform DT distribution, so that a theoretical plot can be drawn





Inner surface chord is subtracted from outer surface chord beginning at the inside surface radius

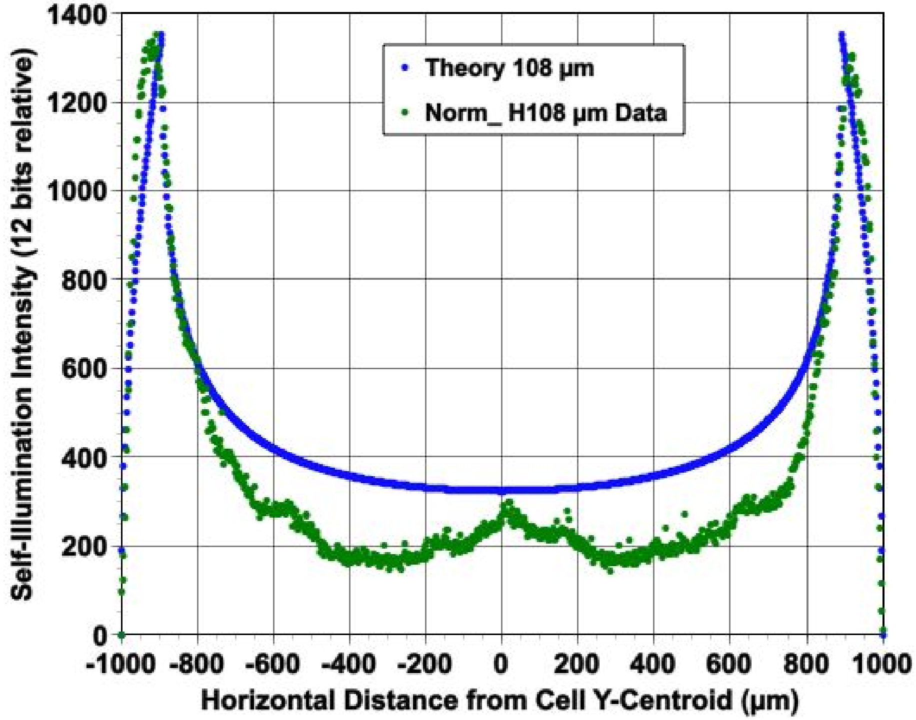
Vertical and horizontal light intensity distributions are measured using lines drawn through the cell centroid, shown in red for this 108 μm self-illuminated solid DT layer at 8.9 K

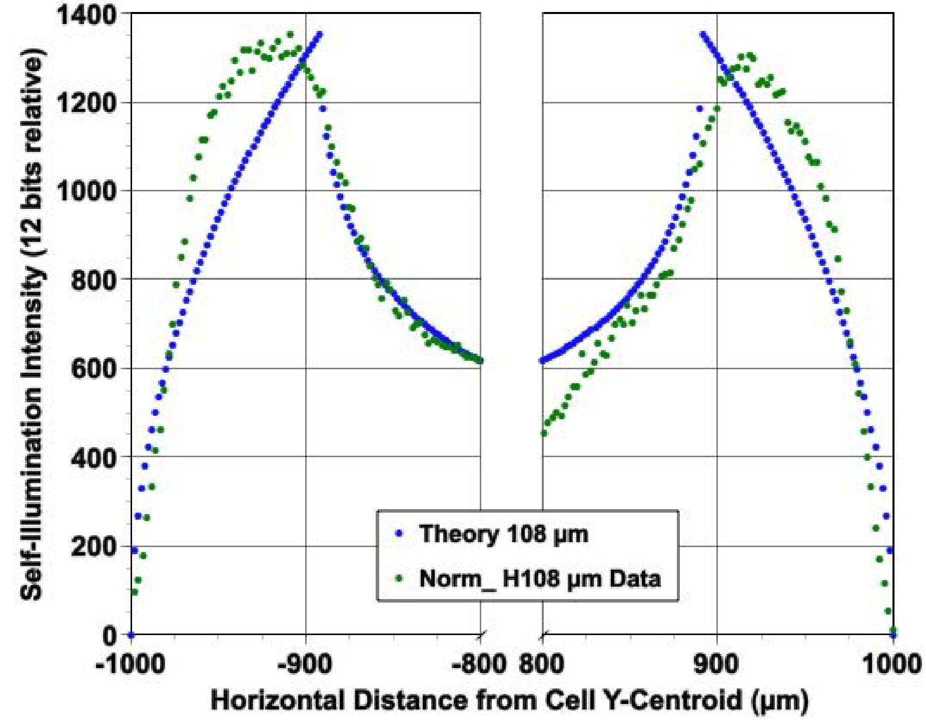


GENERAL ATOMICS

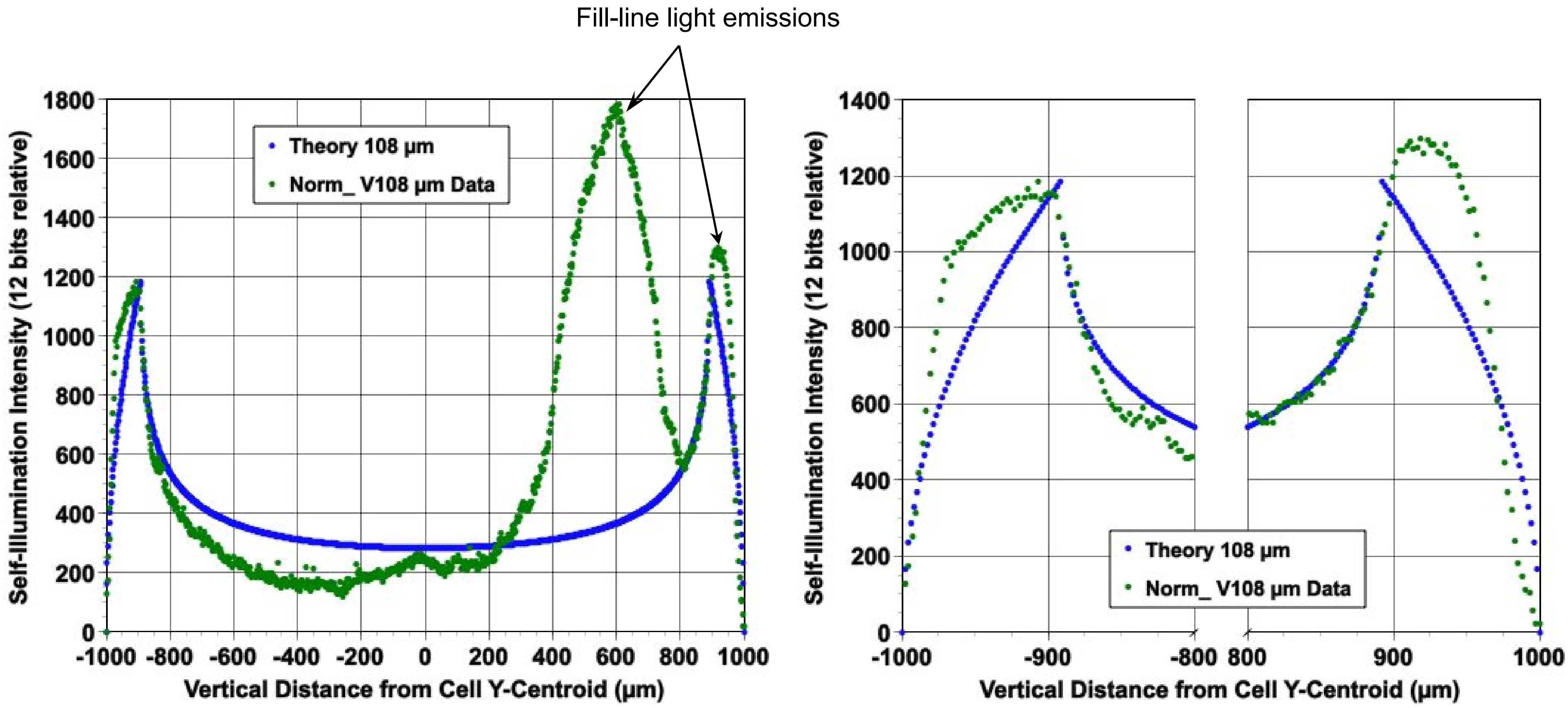
Los Alamos
NATIONAL LABORATORY

The horizontal line-out light intensity data for the 108 µm solid layer tracks the expected curve quite well; but it may show some evidence of minimal radial fractionation

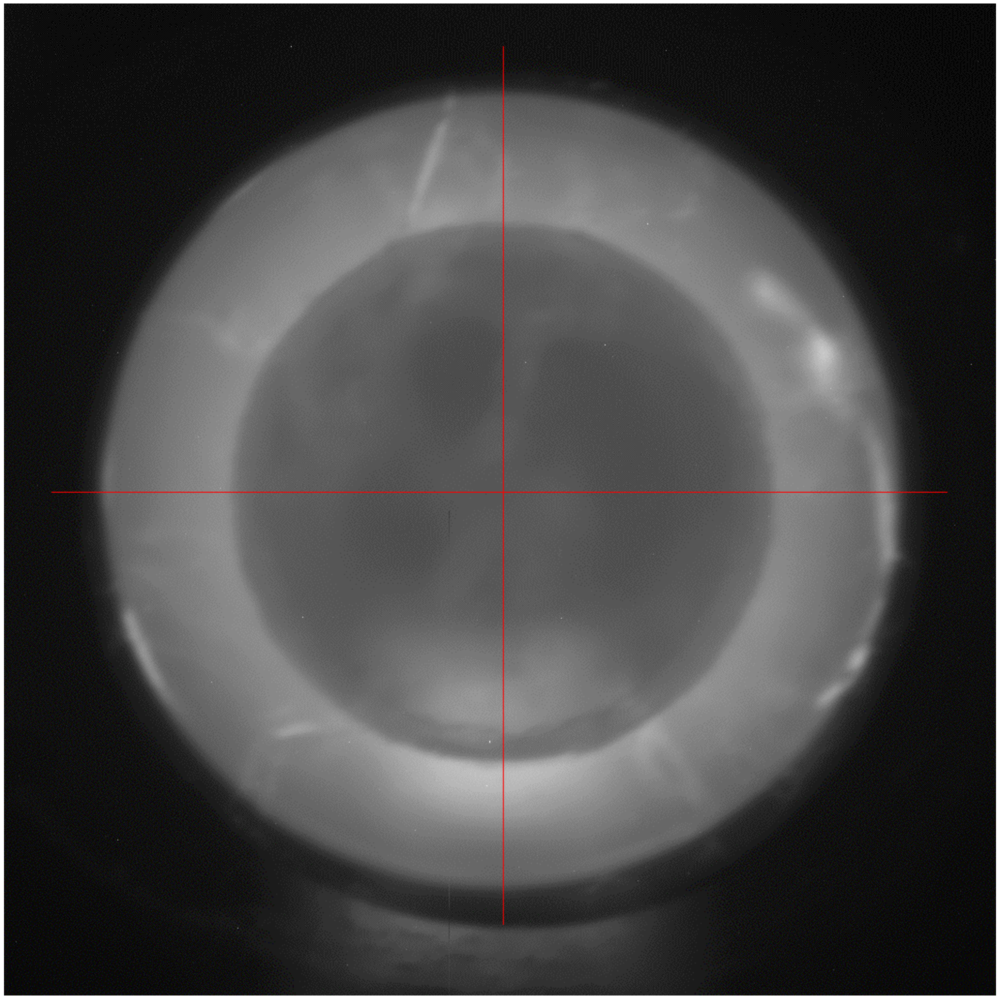




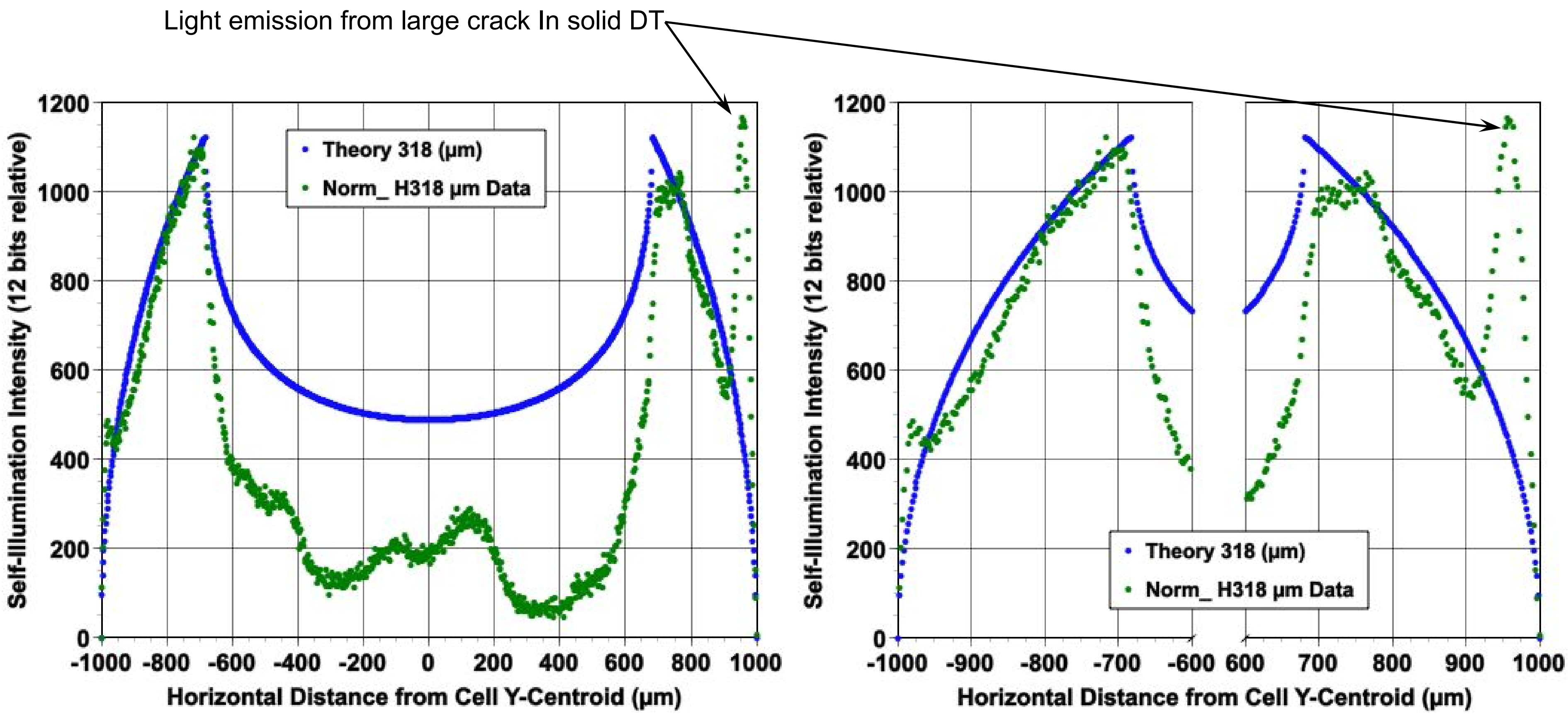
The vertical light intensity data for the 108 µm solid layer also tracks the expected curve quite well, but is heavily influenced by the brightness of light emission from inside the fill line



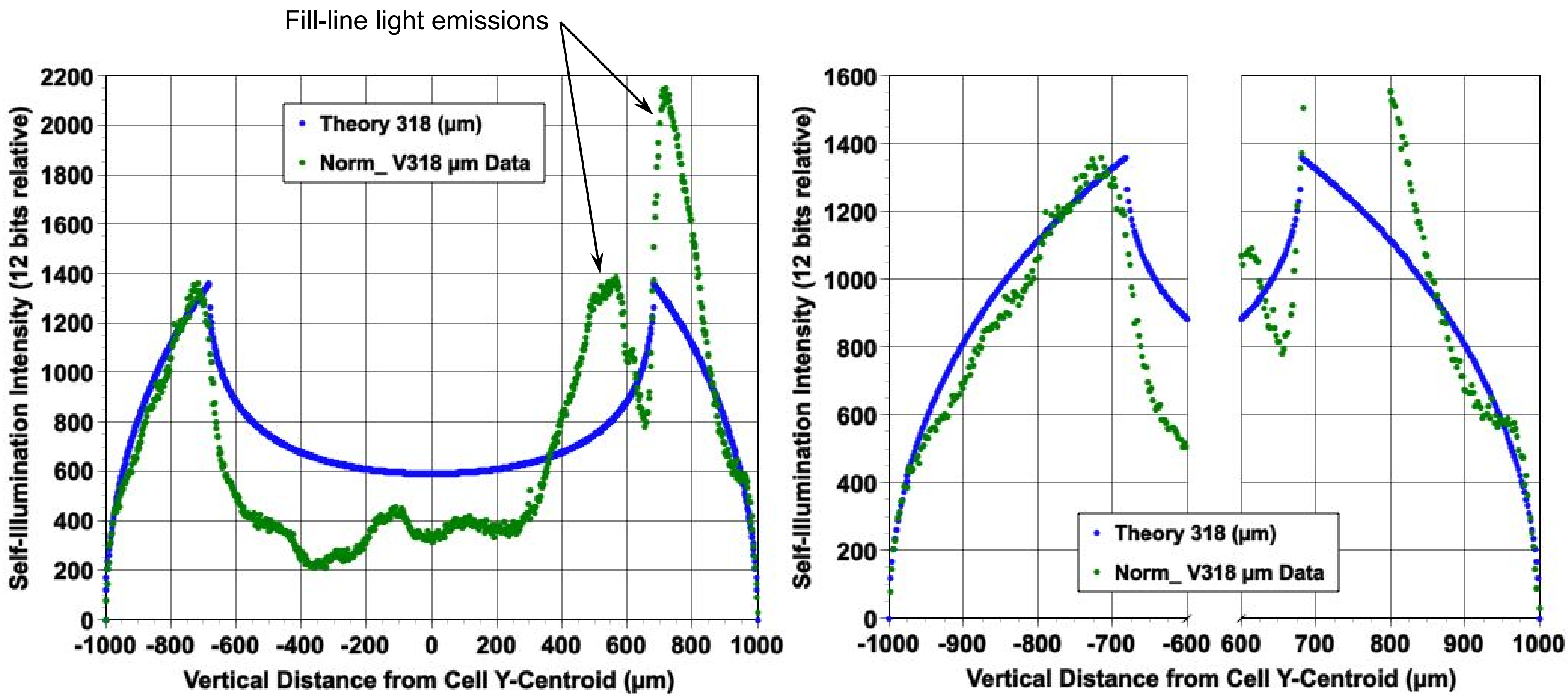
Vertical and horizontal light intensity distributions are measured using lines drawn through the cell centroid, shown in red for this 318 µm self-illuminated solid DT layer at 8.9 K



The horizontal line-out light intensity data for the 318 µm solid layer tracks the expected curve quite well, thus showing no clear evidence of radial fractionation



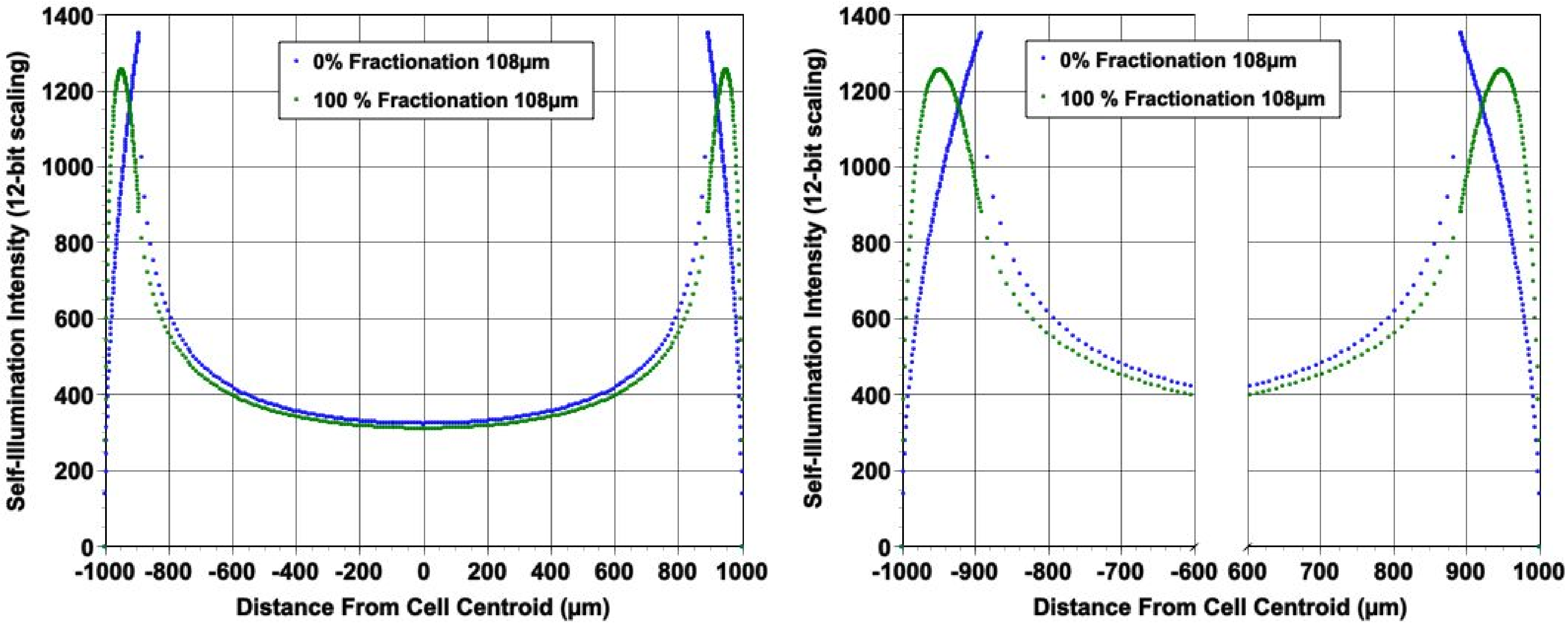
The vertical self-illumination light intensity data for the 318 μm solid layer also tracks the expected curve quite well, but is more heavily influenced by the brightness of the fill tube hole



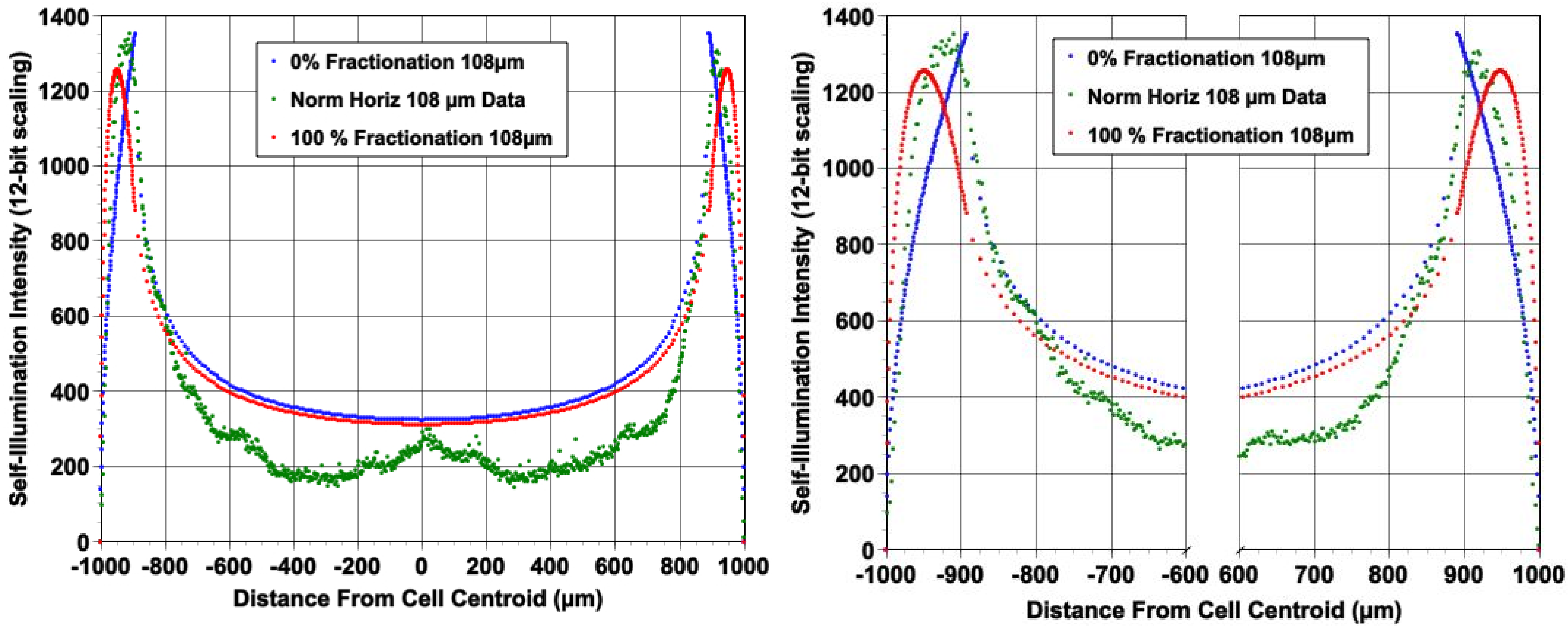
GENERAL ATOMICS

Los Alamos NATIONAL LABORATORY

Theoretical calculations of 0% and 100% fractionation for a 108 µm DT solid layer inside a 2 mm dia cell, assuming a linear radial fractionation distribution



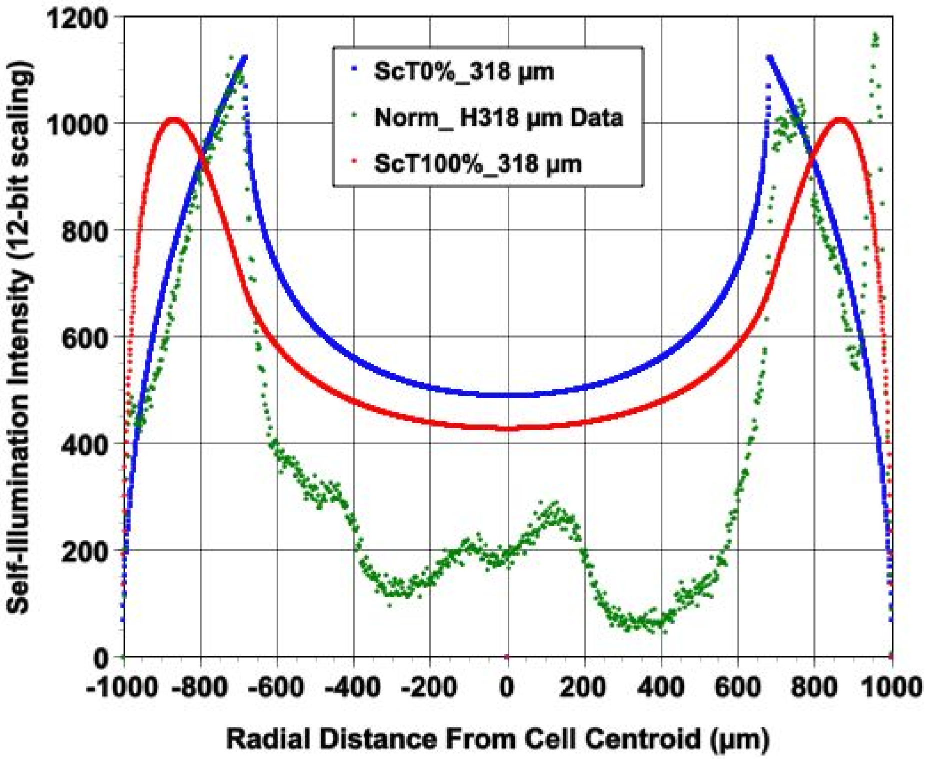
Comparison of the 0% & 100% Fractionation Calculations with the Self-Illuminated 108 μm DT solid layer data, shows some evidence of a small amount of radial fractionation

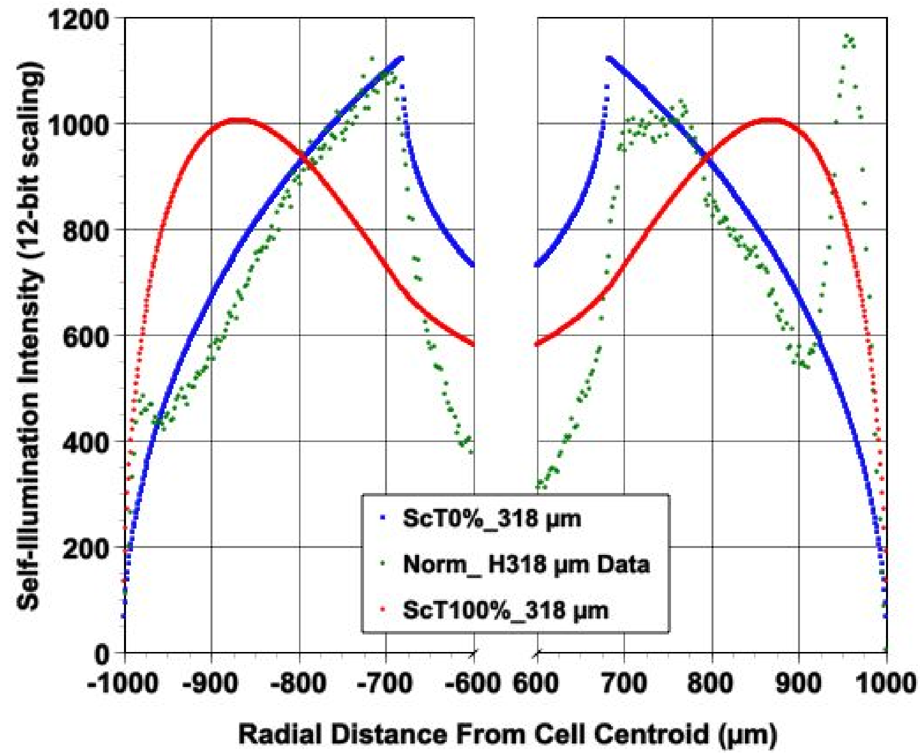


GENERAL ATOMICS

Los Alamos
NATIONAL LABORATORY

Comparison of the 0% & 100% Fractionation Calculations with the Self-Illuminated 318 µm DT solid layer data, shows little or no evidence of radial fractionation





Conclusions

- Sphere-cylinder data shows very weak evidence of vertical fractionation, but improvement in analysis technique is required to reduce measurement error.
- Hemisphere self-illumination data shows some evidence for a small amount of radial fractionation in the DT solid layer, although further study is required to determine the degree of fractionation present
- The degree of fractionation observed thus far observed is not likely to impact ignition.

Calculation process for determining the location of solid DT layer centroid relative to the sphylinder spherical surface (P1)

- **Step 1**: Locate the centroid, Cx,Cy, of sphylinder cylindrical bore and the centroid of the spherical surface from an empty sphylinder image (both are in focus)
- **Step 2**: Locate the centroid of the DT solid layer and the centroid of the sphylinder cylindrical bore from a DT layer image (both edges are visible, but the cylindrical bore is somewhat defocused)
- **Step 3**: Negate all Y centroid values - Cys (CCD 0,0 is upper left corner of CCD)
- **Step 4**: Convert all centroids (empty sphere & bore, layer and bore Cx,Cy) to µm
- **Step 5**: Compute the empty ΔCx, ΔCy (P1) of the spherical surface relative to central bore by subtracting the Cxs & Cys of the central bore from those of the spherical cavity
- **Step 6**: Compute empty sphylinder bore P1 mag, phase (relative to spherical surface)
- **Step 7**: Adjust phase to place centroid point in correct quadrant (computed phase +180)
- **Step 8**: Compute the location of the spherical surface centroid in the DT layer image, using the cylindrical bore centroid from step 2 and the empty ΔCx, ΔCy computed in step 5
- **Step 9**: Compute DT Layer ΔCx, ΔCy (P1) relative to the computed layered sphere Cx,Cy from step 8)
- **Step 10**: Compute DT Layer P1 mag, phase from ΔCx, ΔCy
- **Step 11**: Adjust phase to place point in correct quadrant (Phase +180)