Updated Investigation of PLIF for use by COBRA

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What is PLIF

- Planar Laser Induced Fluorescence
- A PLIF system works by using a laser to fluoresce a specific tracer (like acetone) in a flow field
- The fluorescence can then be captured by a camera
- The intensity values can then be used to determine density of the tracer in the flow field
- The PLIF chamber is used to understand the density and shape of gas as it comes out of the gas puffer
- The gas puffer is used for some COBRA experiments so for those measurements to be accurate we need to know how the gas behaves initially

How Should PLIF Behave?

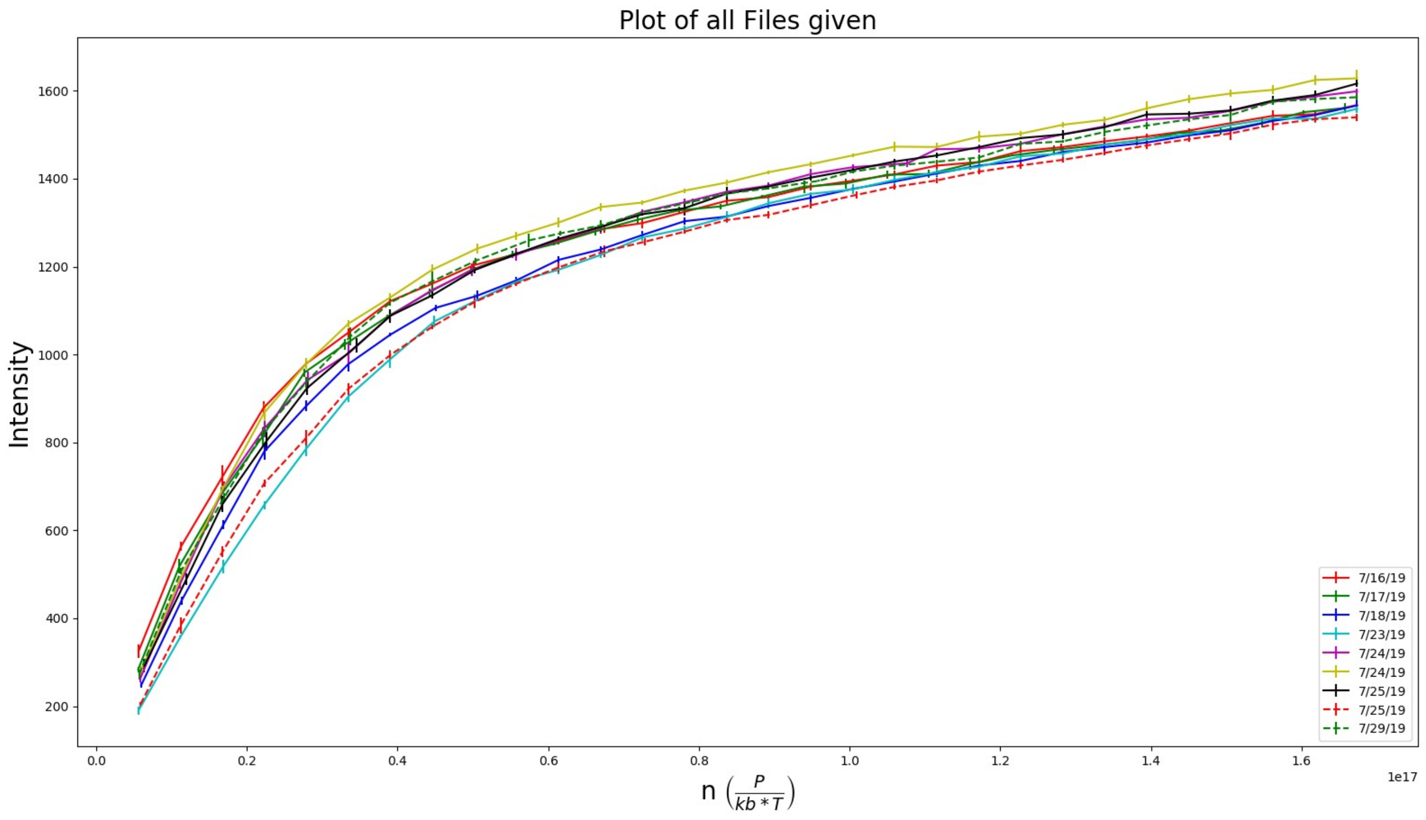
- Equation: $S_f = \frac{E_p}{A_{las}} \cdot gB \cdot N_{abs} \cdot f_{v'J'} \cdot \frac{A}{A+Q} \cdot n_c$
- S_f is the recorded fluorescence signal per volume
- All variables in the equation are constant for our PLIF system except N_{abs} which is the number density of the tracer (Acetone)
- This formula suggests that the fluorescence signal should be linearly related to the number density of Acetone

Issues prior to Investigation

- Unresolvable at low density
- Intensity appears to not scale linearly with pressure
    - The density of a shot depends on the pressure that the reference shot was taken at
    - Acetone% could be changing
    - Systematic error?
- How does injected density scale with plenum pressure
- Non trivial differences in intensity with same pressure in the chamber between runs

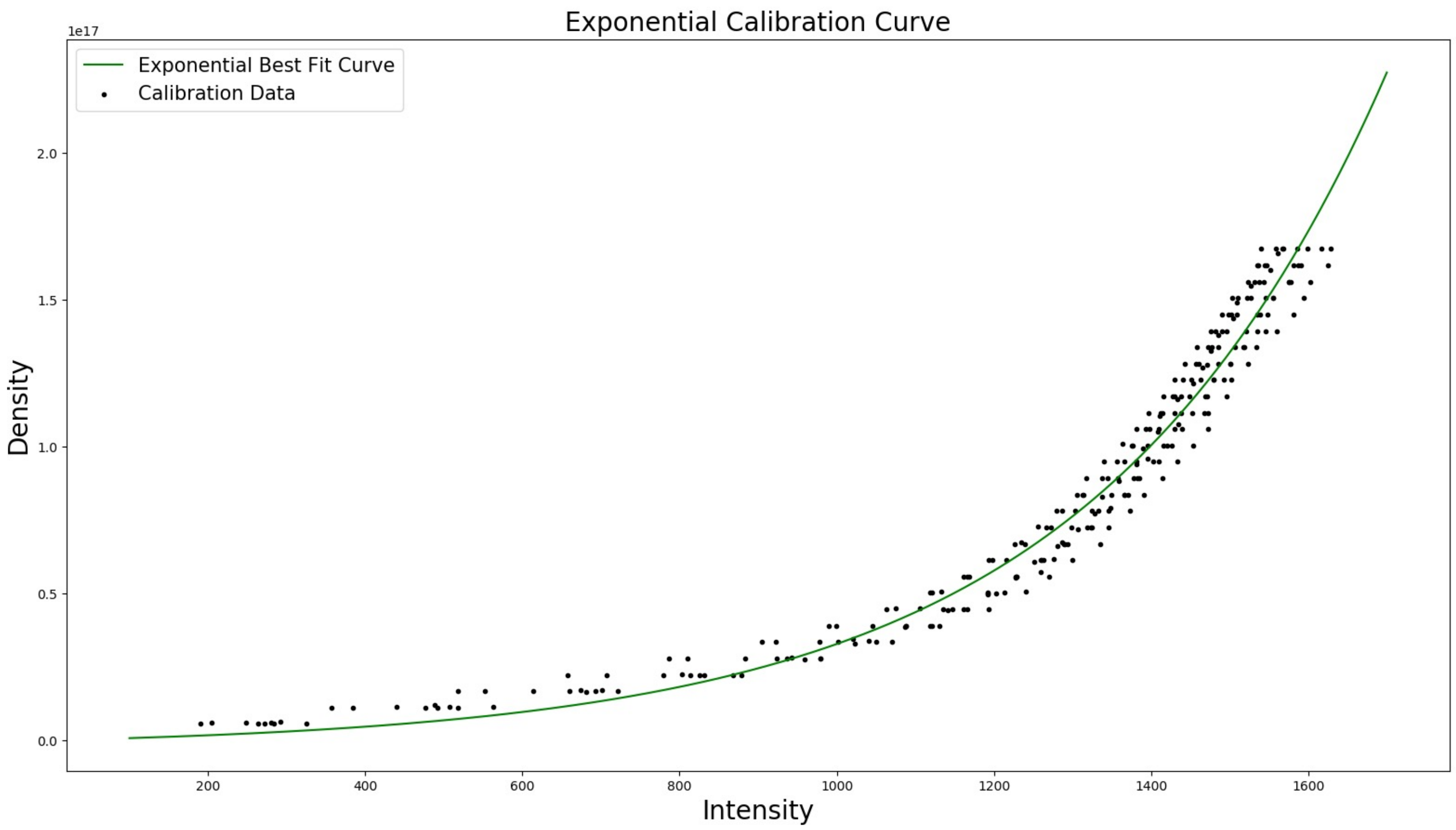
Linearity of PLIF

- Previously I found that density scaled exponentially with intensity not linearly
- This was found by doing calibration sweeps from around .1 to 3 torr in steps of .1 torr, the average intensity values in the path of the beam were then calculated at each pressure and plotted vs pressure over multiple days
- This figure also shows that there is a large day to day difference in the PLIF system



Exponential Calibration method

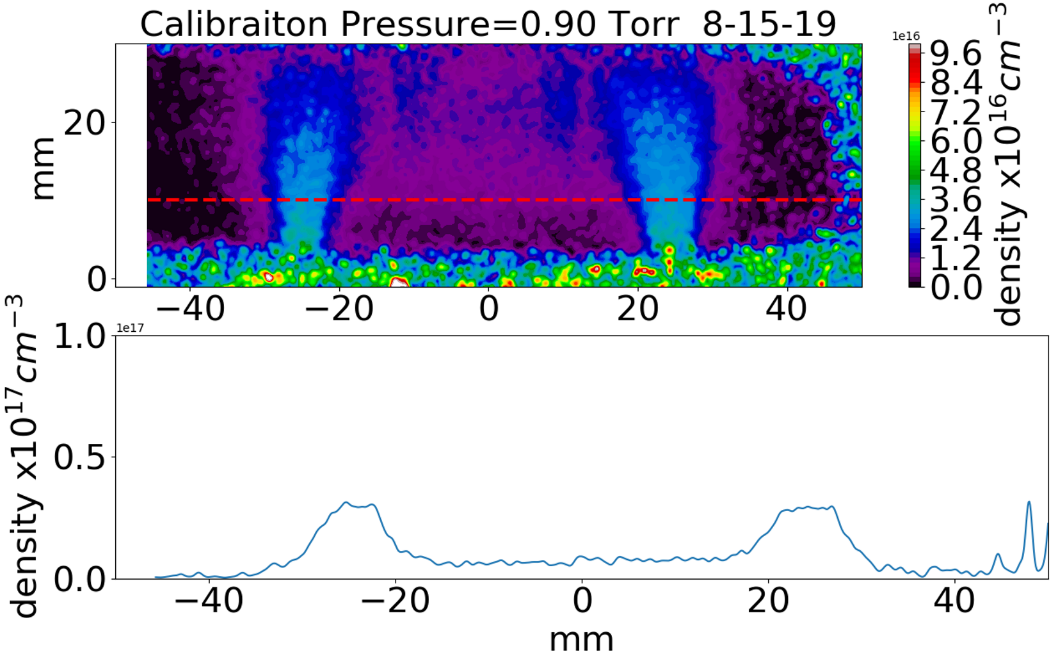
- Due to the exponential relationship, if intensity is given, an exponential calibration curve is needed to get accurate data
- This figure has all the data points for the previously shown sweeps and an exponential best fit curve for the data points



Exponential Calibration Code in PYTHON

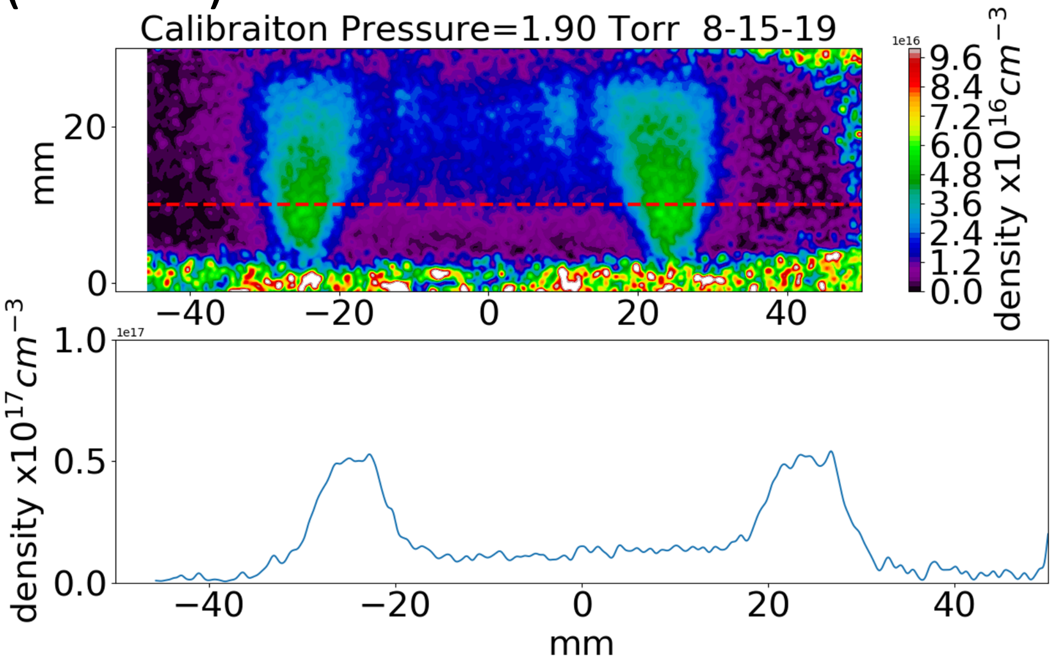
- Input calibration chamber pressures - P_{cal} [scalar]
- Input room temperature - T [scalar]
- Calculate calibration number density - $n_{cal} = \frac{P_{cal}}{k_B T}$ [scalar]
- Import and average 5 vacuum shots - I_{vac} [array]
- Import calibration images in groups (usually 5), subtract I_{vac} from each, then average the groups together - $I_{cal} = \frac{\sum_{n=1}^{5}\left(I_{cal_n} - I_{vac}\right)}{5}$ [array]
- Repeat last process for shot data - $I_{shot} = \frac{\sum_{n=1}^{5}\left(I_{shot_n} - I_{vac}\right)}{5}$ [array]
- Take I_{cal} and find average intensity in the path of the beam for each group - A_{cal} [scalar]
- Fit n_{cal} and A_{cal} for each group to the equation $n_{cal} = a \cdot \left(e^{\frac{A_{cal}}{b}} - 1\right)$ with fitting parameters a, b
- For every pixel in I_{shot} apply the above equation to get a number density at that pixel - N_{shot} [array]

Same Shot Group (5 shots)



← Old

Old →

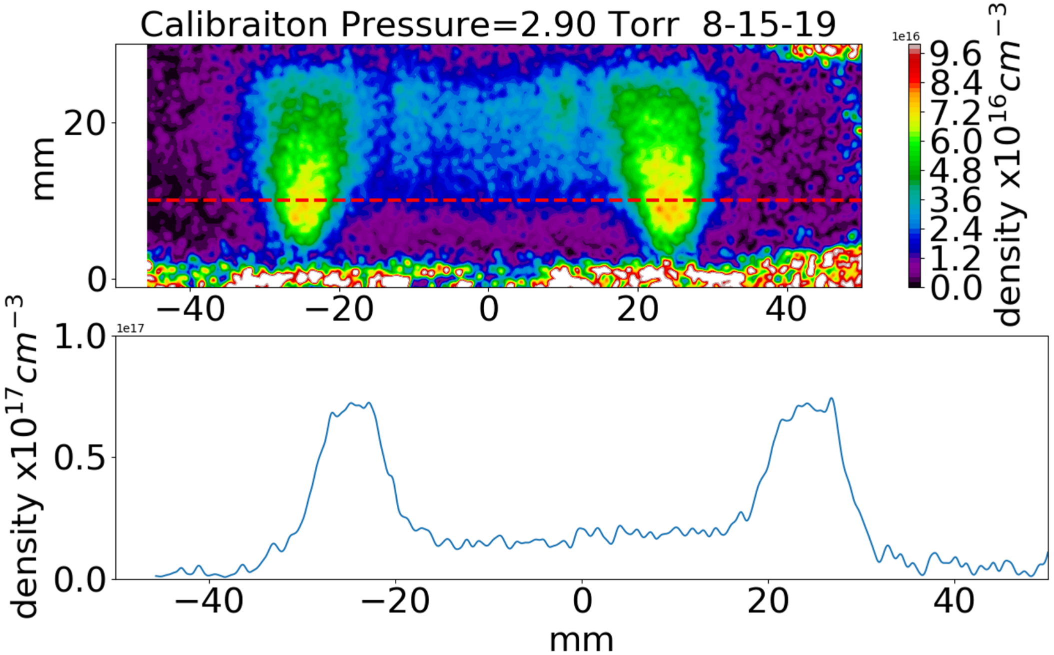


Pressures:

Outer - 3

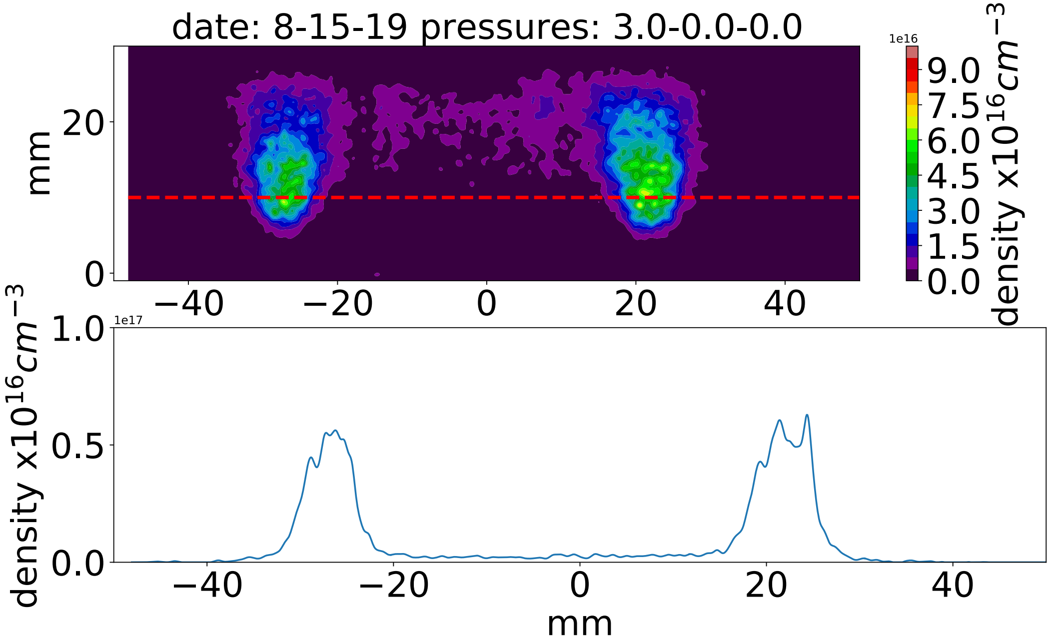
Inner - 0

Center - 0

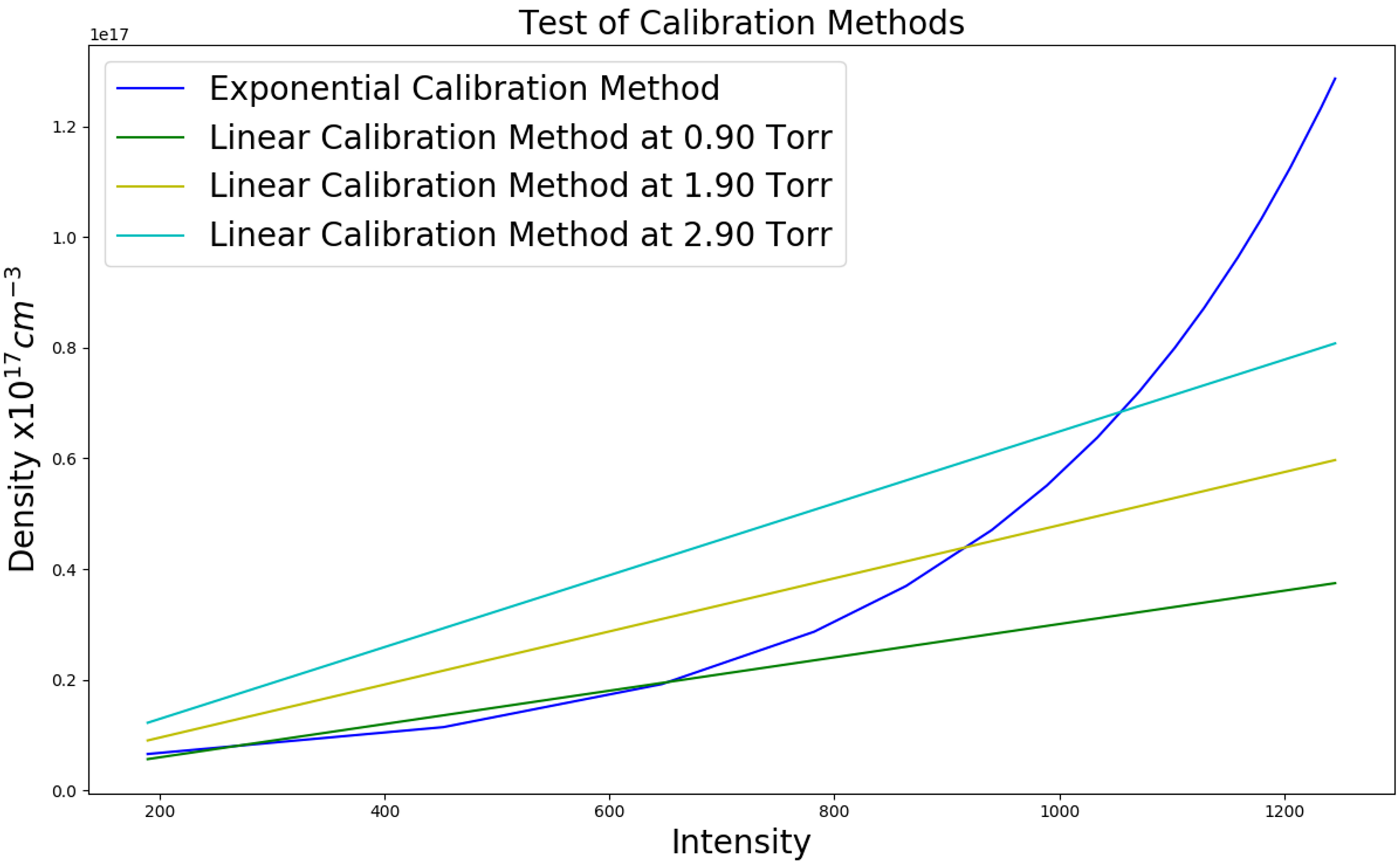


← Old

New →

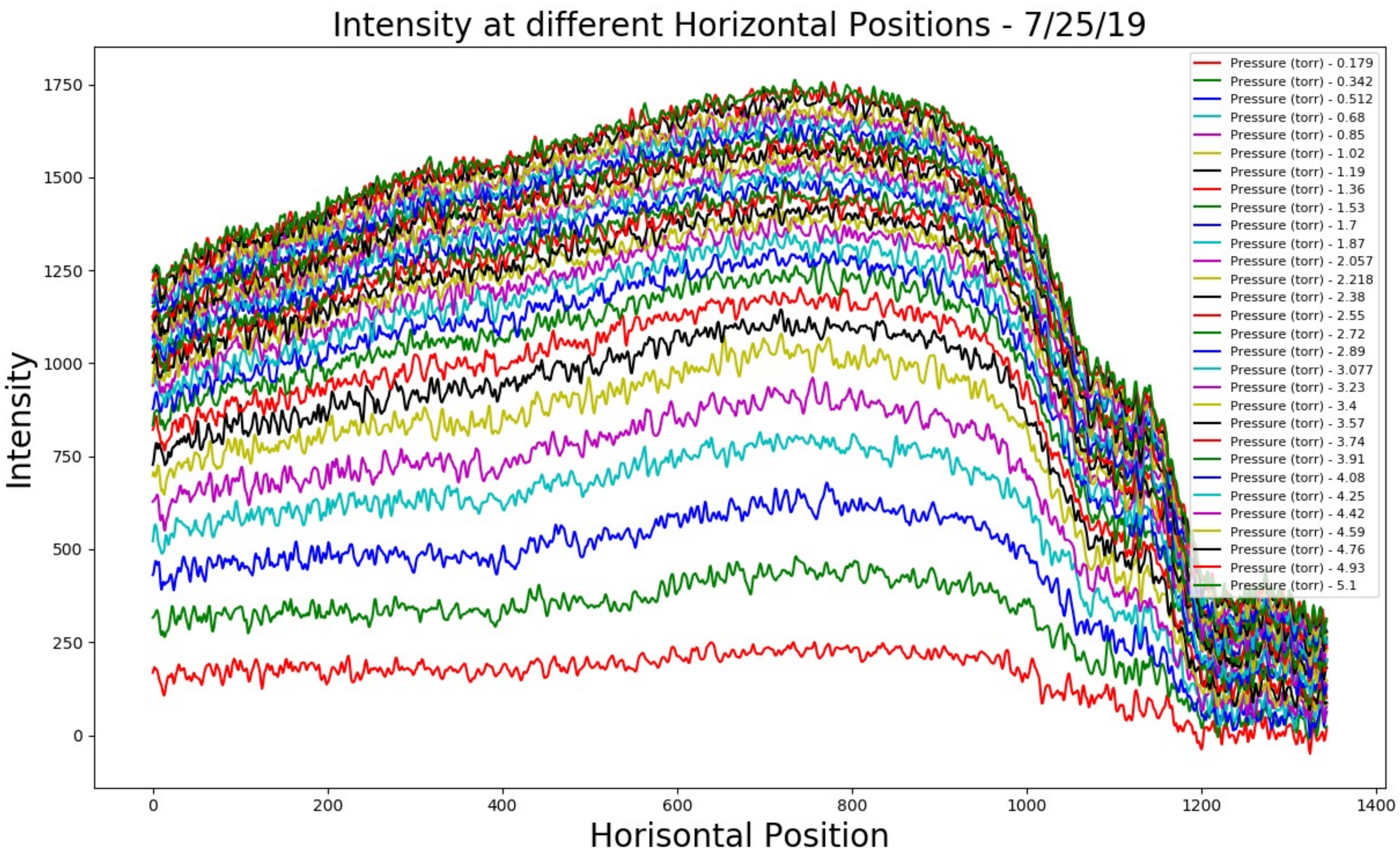


Difference In Density between the Old and New Calibration Methods



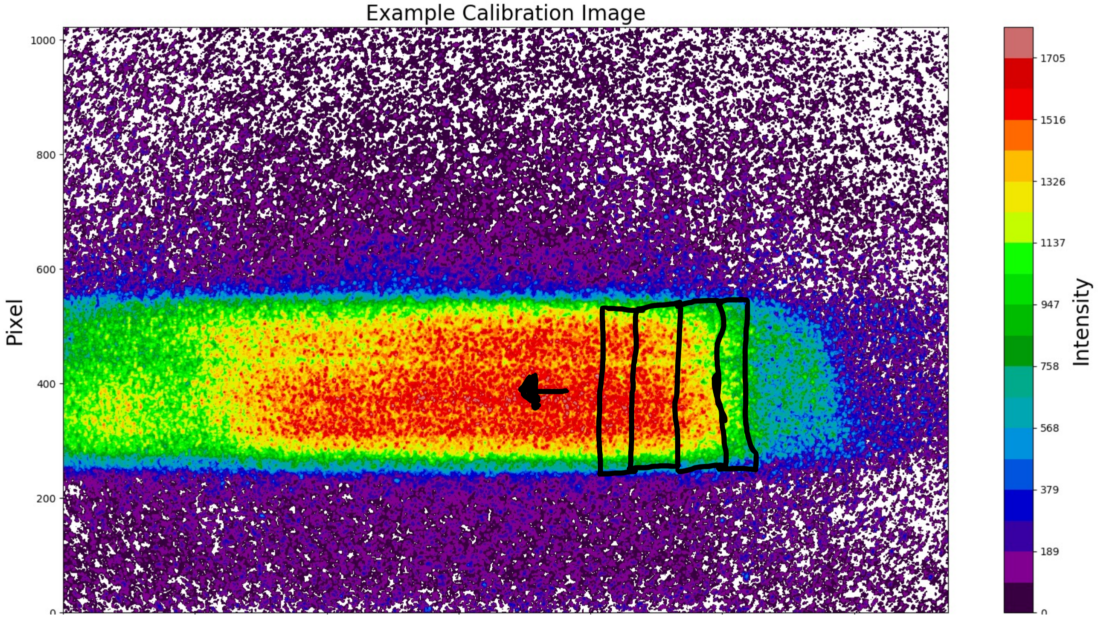
Intensity Not Continuous Along Beam Path

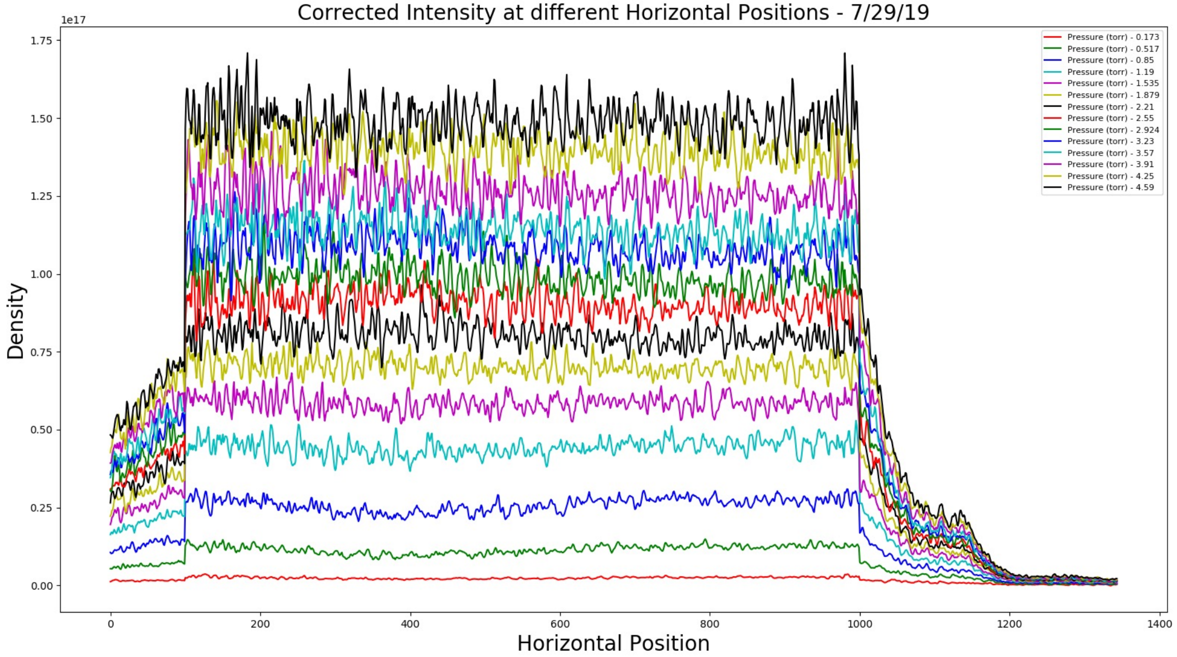
- Also, I found that in the calibration images, intensity is not constant in the horizontal direction parallel to the beam path (but is in the vertical direction perpendicular to the beam path)
- This looks like it could be due to laser attenuation but based on attenuation length, not the case



Intensity not Horizontally Continuous

- To correct for this, in the area where the shot data is, I started taking smaller columns of 10-20 pixels in width and calibrating those columns individually, which was able to correct for the drop in intensity in the horizontal direction
- Before adjusting for horizontal inconsistency, the left and the final plot images were asymmetrical, but introducing the columns has helped

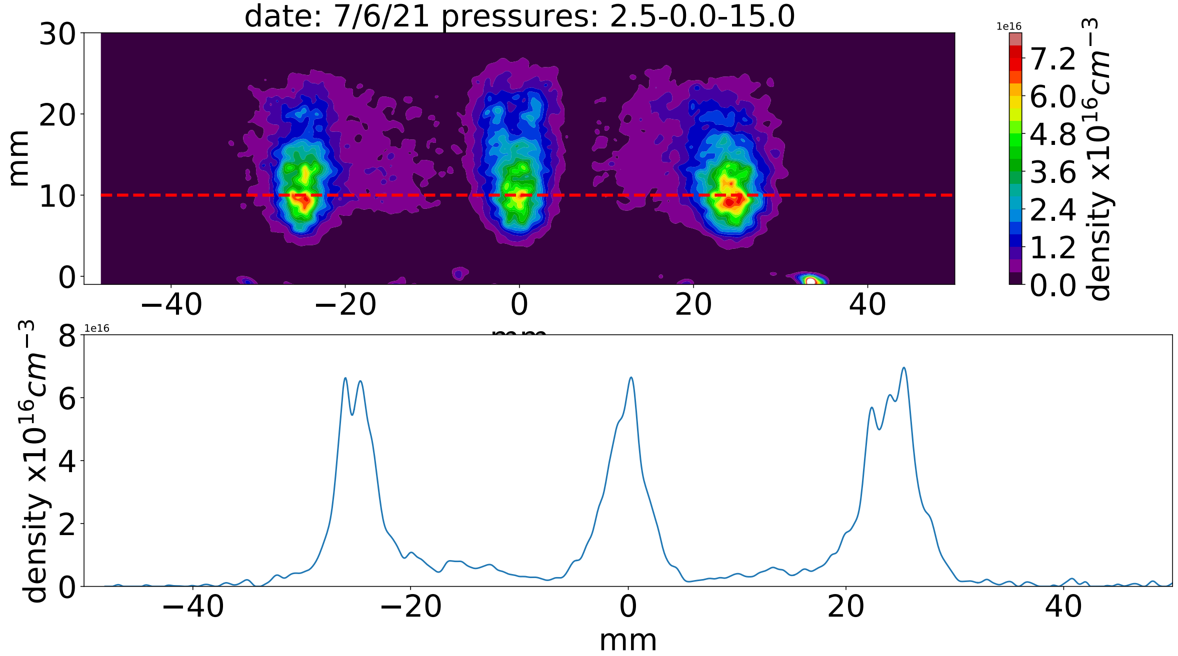


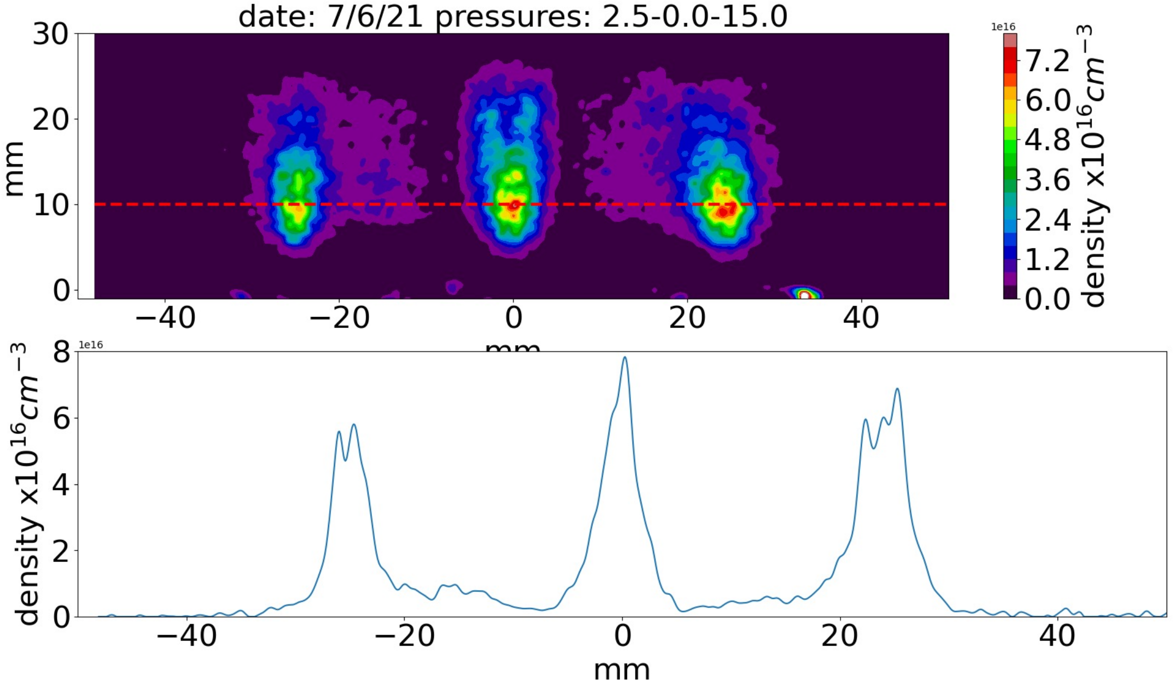


Difference between calibrating in columns and not:

- There is not a large difference between the two implementations, but the columns method reduces previously seen asymmetry

Columns →

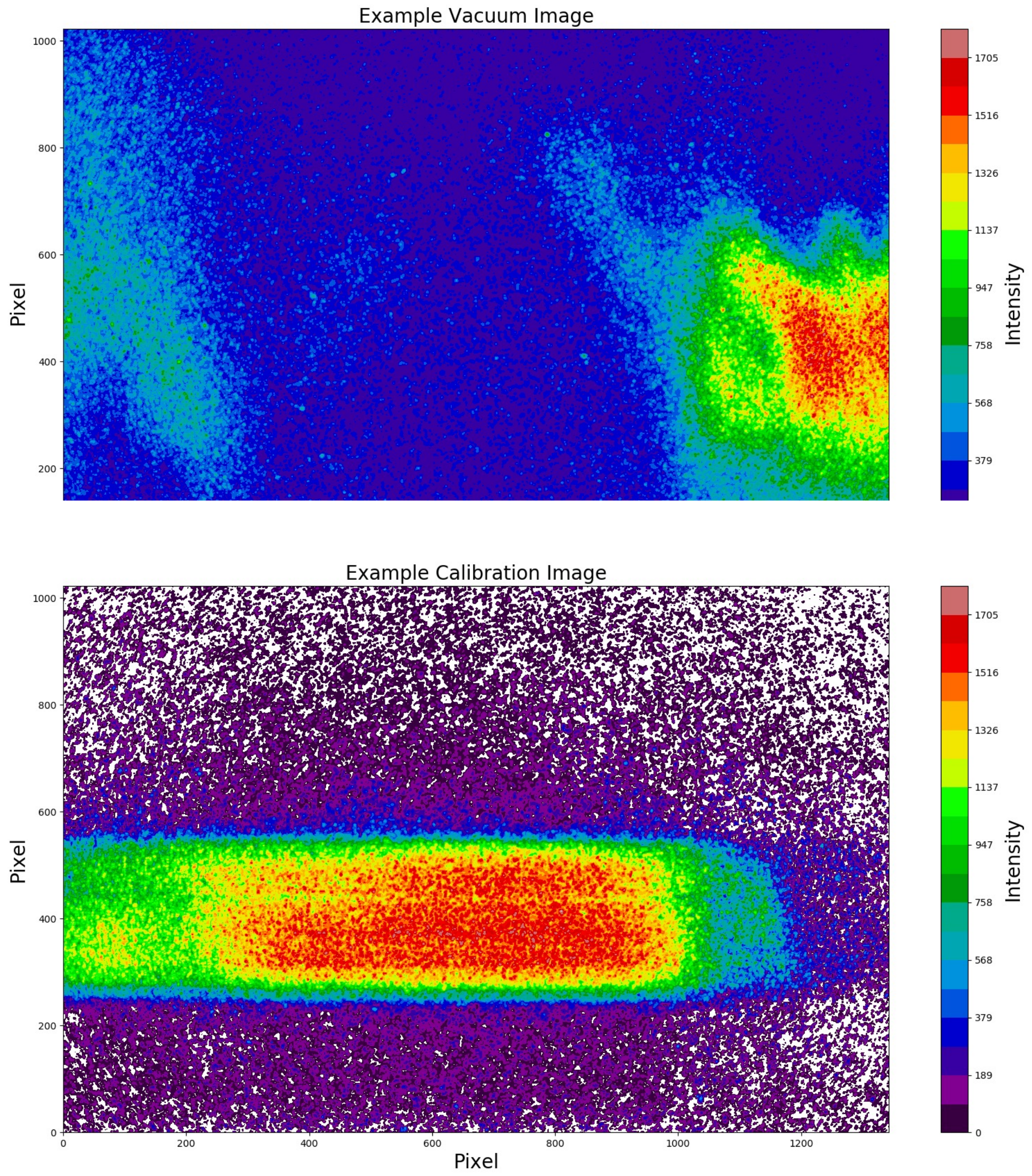




← Regular

Camera Saturation

- PLIF camera gets saturated as the measured intensity increases, which is probably what causes the exponential relationship between intensity and density
- This should not affect the calibration process because a best fit curve can still be made from the calibration data, and the curve can be used to calibrate the density of the shot data



Apparent Dependence on Working Gas

- Even after adjusting for the calibration factor for each gas on the thermocouple pressure gauge, there is a difference in the calibration curves for Argon and Neon