Testing Pixelink Camera: Linearity of Gain and Exposure

The linearity of the pixelink camera was tested on the trapped atomic cloud. The test conditions were:

Getter Current: 6.78 A (low Rb pressure, threshold around 6.0 A)
Ion pump current: 1.45 μA

Test: Image cloud and vary the exposure time.

Model: The intensity of the image should increase linearly with the exposure time.

DATA:

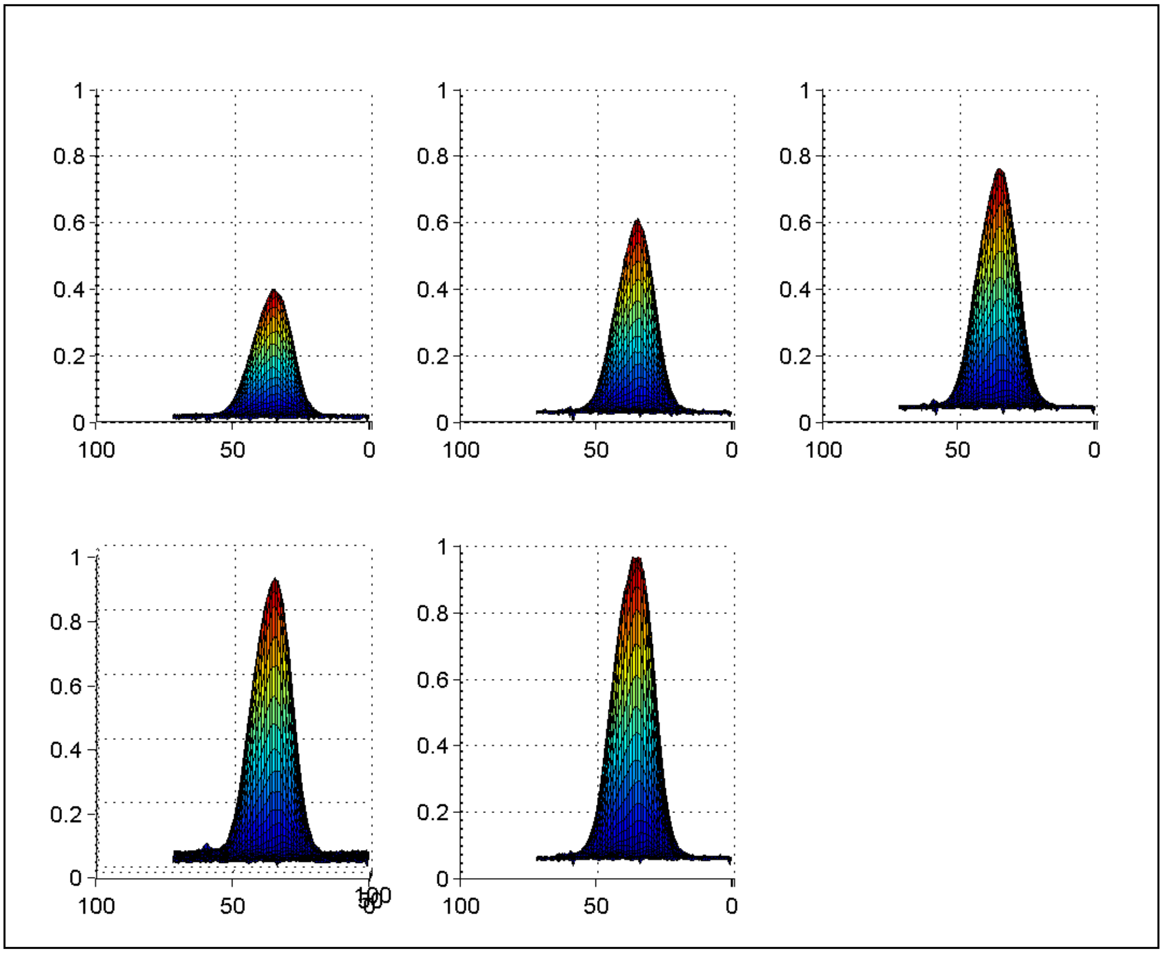


Figure 1. False colour image of ^{87}Rb atoms in BCIT MOT. The exposure times for each of the images were 10 ms, 15 ms, 20 ms, 25 ms, and 26.8 ms, respectively. These images were 72 x 72 pixels.

The profile of these data through the x-axis were taken and fit to a Gaussian shape. The results were:

Table E1. Gaussian Fit to Cloud Profile vs Camera Exposure Time

Exposure (ms)	Background	Amplitude	Center (pixels)	Width (pixels)
10	0.016	0.38	35.8	9.8
15	0.032	0.57	35.9	9.5
20	0.044	0.728	36.35	9.7
25	0.057	0.88	36.3	9.5
26.8	0.054	0.92	36.6	10.3

Table E2. Scaled Amplitude vs Scaled Exposure Time

Exposure Time / (10 ms)	Amplitude / 0.38
1	1.00
1.5	1.50
2	1.92
2.5	2.32
2.62	2.42

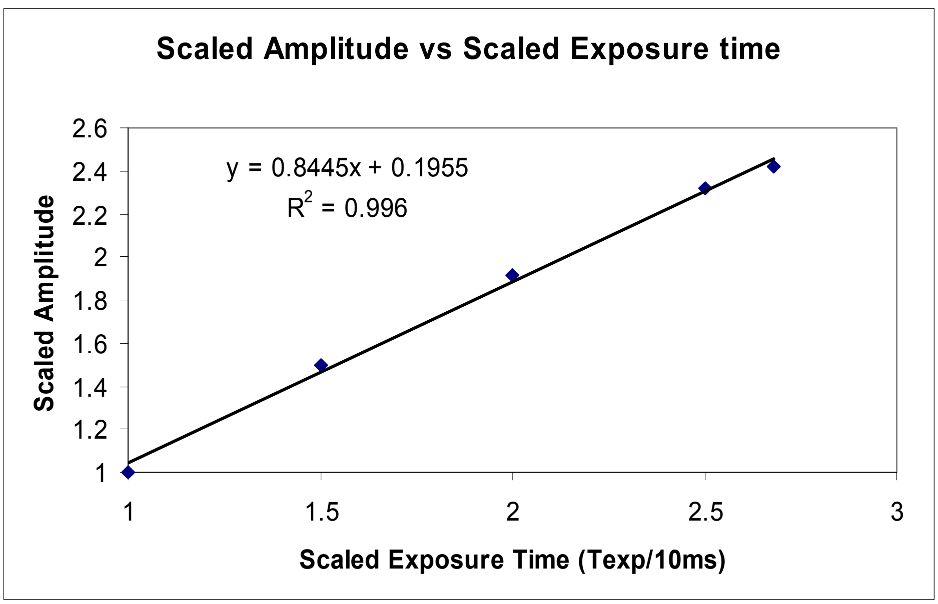


Figure 2. Rubidium Cloud Intensity Maximum vs exposure time. These have been scaled to the minimum exposure time and minimum amplitude.

Results: The amplitude of the cloud increases linearly with the exposure time but the slope of the scaled data is not 1.0. There is a 16% reduction in the slope with the observed data along with an offsetof 0.20, instead of 0.00. This may be due to the lasers drifting over the length of time used to acquire the data. During the several minutes recording, the repump laser had drifted, resulting in a lower overall signal.

Gain Linearity Test:

Model: The gain specified on the pixelink interface is in dB. Namely,

$$Gain(dB) = 20dB \cdot \log\left(\frac{V}{V_0}\right) \qquad \text{(G.1)}$$

or linear gain is:

$$Voltage\ Gain = 10^{-\left[\frac{Gain(dB)}{20dB}\right]} \qquad \text{(G.2)}$$

Once again the cloud was imaged using the pixelink camera, this time the gain setting was adjusted between exposures and this test was carried out over a much shorter time scale (less than 2 minutes).

Table G1. Cloud Fitting Parameters for Various Gain Settings

Gain (dB)	Background	Amplitude	Center (pixels)	Width (pixels)
0	0.016	0.37	36.4	9.5
1.5	0.043	0.44	36.3	9.5
3.1	0.0588	0.54	36.1	9.6
4.6	0.0823	0.64	36.2	9.7
6.1	0.0823	0.75	36.2	9.6

Table G2. Scaled Signal to Linear Voltage Gain

Gain (dB)	Linear Voltage Gain	Scaled Signal Amplitude
0	1.00	1.00
1.5	1.19	1.19
3.1	1.43	1.46
4.6	1.70	1.73
6.1	2.02	2.03

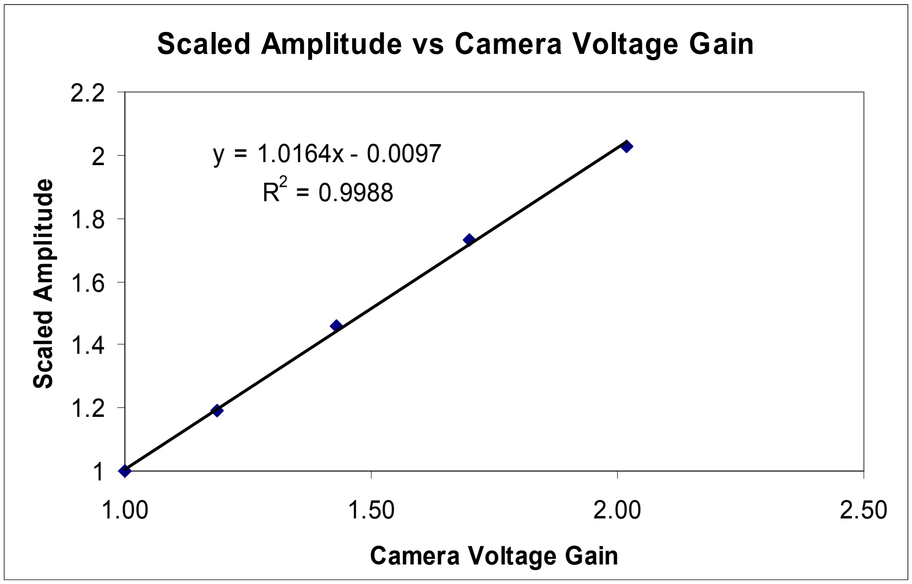
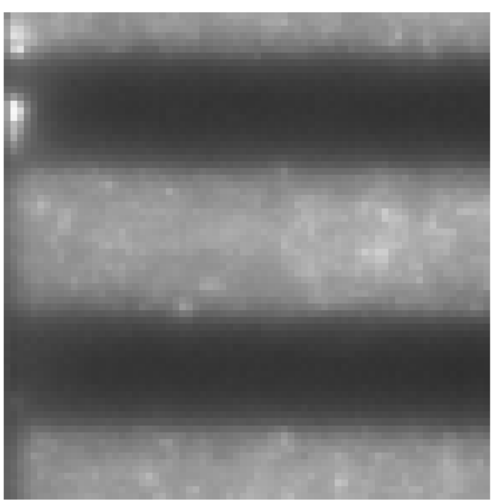


Figure 3. Scaled Amplitude of ^{87}Rb cloud as a function of the Pixelink camera voltage gain.

Results: The cloud image amplitude increases linearly with the voltage gain applied to the camera signal, as expected. As can be seen the slope of the scaled signal versus gain is 1.02 and the intercept is 0.01, in good agreement with the expected values of 1.00 and 0.00. The camera appears to be behaving well, as long as the image is kept away from the saturation value.

Setting the Camera Scale

Without adjusting the magnification of the camera, two images were taken of a ruler with 0.5 mm divisions. The results were:



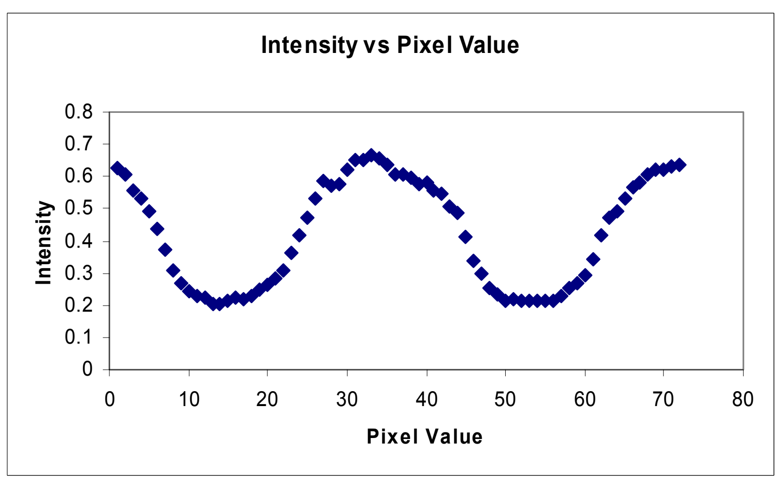


Figure 4. Image of 0.5 mm scale divisions to establish magnification. (a) shows image (b) indicates the intensity profile through the image.

Based on the intensity profile: 40 pixels = 0.5 mm

$$FWHM = \left[2 \cdot \sqrt{\ln(2)} \cdot width\right] \times \left[\frac{0.5mm}{40\ pixels}\right]$$

Using this scale we can deduce the FWHM of the ^{87}Rb atomic cloud:

Table W1. FWHM of the ^{87}Rb Atomic Cloud

Gain (dB)	Width (Pixels)	FWHM (mm)
0	9.5	0.198
1.5	9.5	0.198
3.1	9.6	0.200
4.6	9.7	0.201
6.1	9.6	0.200

Note the CMOS pixel sizes are 6.7 μm x 6.7 μm implying that 40 pixels would cover 268 μm. This provides a magnification of :

$$M = \frac{268\ \mu m}{500\mu m} = 0.54$$

(I will have to test the specifications of the zoom lens (Navitar 7000) to see if this pans out. Supposedly at 5" working distance the maximum magnification at the CMOS is around 1.1. The system supplies a 6X zoom so the range of magnifications at a 5" working distance would be from 1.1 to 0.18)

Check CMOS dimensions: 1280 x 1024 or 8.576 mm x 6.86 mm

Manufacturer's specs: 8.576 mm x 6.912 mm

Conclusions:

1. The camera provides a reasonable dependence (linear) between the exposure time and the image intensity.

$$Scaled\ Amplitude = 0.84 \cdot \left(\frac{Exposure\,Time}{10\,ms} \right) + 0.20 \qquad \text{(C1)}$$

compared to the ideal:

$$Scaled\ Amplitude = 1.00 \cdot \left(\frac{Exposure\,Time}{10\,ms} \right) + 0.00 \qquad \text{(C2)}$$

The main reason for the observed discrepancy is hypothesized to be due to the long duration over which the images were recorded (many minutes). In this time the repump laser frequency was observed to drift and may be responsible for the discrepancy.

2. The Pixelink camera (PL-A741) provides the expected linear dependence between the image intensity and the electronic gain:

$$Scaled\ Amplitude = 1.02 \cdot \left(Voltage\ Gain \right) + 0.01 \qquad \text{(C3)}$$

compared to the ideal behaviour:

$$Scaled\ Amplitude = 1.00 \cdot \left(Voltage\ Gain \right) + 0.00 \qquad \text{(C4)}$$

These data were collected over a short time period, reducing any effects due to laser frequency drift.

3. The magnification of the lens system was measured to be 0.5 mm / 40 pixels (each pixel is 6.7 μm square → 500 μm in real space to 268 μm). This gives a magnification of approximately 0.54. The FWHM of the cloud was observed to be about 200 μm.

To Do: a) Check Zoom lens against specifications
b) Look into data saving formats (.bmp images are stored in only 8 bits) to increase bit depth to 10 bits.
c) Experiment with the triggering modes of the camera.