

Measuring the Density of Laser-Cooled Atoms

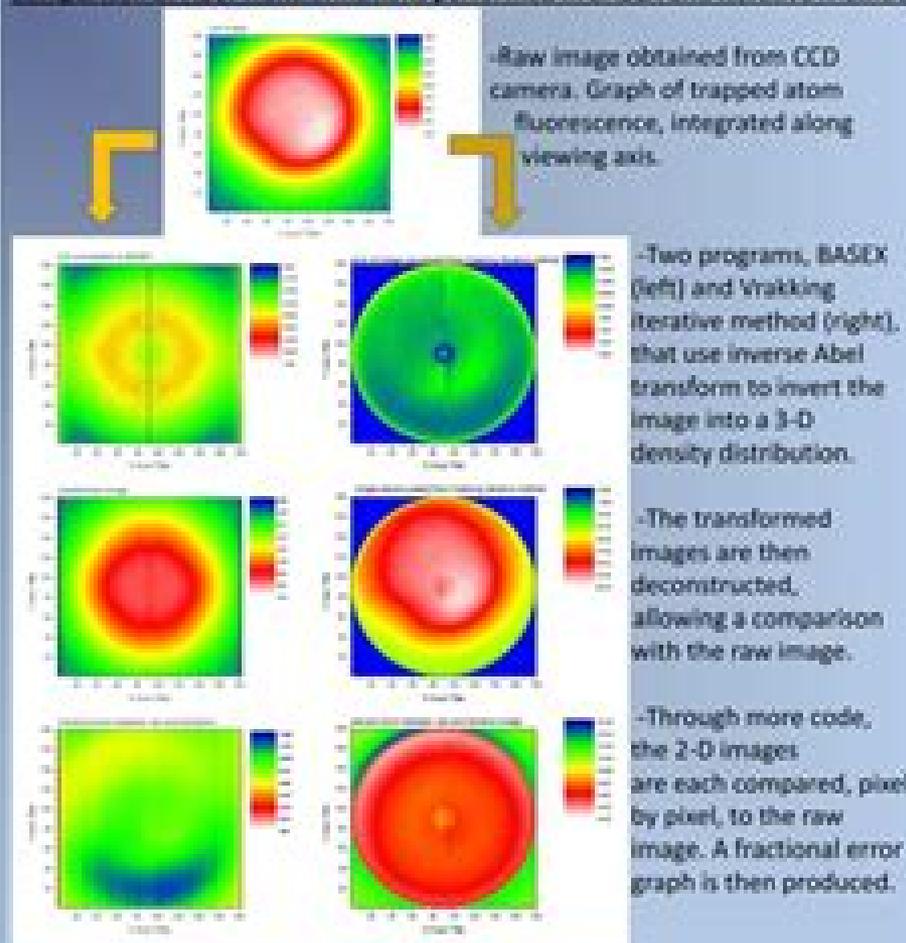


Cameron Cook, Larry Weaver, Brett DePaola

116 Cardwell Hall, Department of Physics, Kansas State University, Manhattan, KS, 66506-2604, USA

Motivation: Coherent excitation in cold collision processes depends delicately on the density of the atomic objective. The density of atoms cooled and trapped in a MOT (magneto optical trap) typically depends on position in the chamber. The goal is to find a method that will measure this density quickly, accurately, and in a fashion that is reproducible.

Comparison of Abel Transformations performed in BASEX and Iterative Method



Camera Calibration

Spatial: At a distance of r cm from the viewing port, the camera measures about 60 pixels per mm.

Intensity: By relating the power of a calibration laser to observed pixel values, the relationship follows:

$$P = \frac{N \cdot S \cdot C}{k \cdot F(G)}$$

where P is laser power as measured by a power meter, N is the attenuation of a neutral density filter (ND3.0), S is the shutter speed fixed by the user, C is the sum total pixel count of the entire image, k is a constant defined below, and $F(G)$ is the gain function of the camera.

There was a linear relationship between the shutter speed on the camera and the pixel count measured on the computer.

The camera's gain function was measured to be exponential in the gain value set by the user. This equation is:

$$F(G) = y_0 + Ae^{G/x}$$

Results

For $F(G)$, several computer images were compared in intensity for specific gain values. After plotting pixel count and gain, the exponential curve shown above was observed. The following parameters were determined: $y_0 = -19.7$ with an error of: $\Delta y_0 = 13.3$

$$A = 74.0$$

$$\Delta A = 14.2$$

$$x = 293.2$$

$$\Delta x = 31.3$$

For a gain of 603, this gives $F(G) = 508.64$ and a propagated error, $\Delta F(G) = 169.73$. Solving for k when laser power is 77.4 mW (x2mW), shutter speed is set at 40, sum total pixel count is 1361276, and a measured camera lens attenuation of 8.13%, we obtain $k = 1.16 \cdot 10^7$ counts per mW. The propagated error is dependent on the error in power and $F(G)$; so $\Delta k = 0.35 \cdot 10^7$ counts per mW. The fractional error, $\frac{\Delta k}{k}$, equals 0.30.

Knowing this, one may determine the intensity of spontaneous emission in photons per second that the camera detects. Using the lifetime of the upper state, $\tau = 25.63 \text{ ns}$, and the solid angle of the camera, $\frac{\Delta \Omega}{4\pi r^2}$ at a distance r from the MOT, one may determine the number of excited

atoms that the camera senses using $n_{\text{exc}} = \frac{I \cdot C \cdot 2 \cdot 4\pi \cdot r^2}{k \cdot F(G) \cdot \Delta \Omega}$

where C is the pixel count from the transform images.

Acknowledgements

We would like to thank Richard Lammiman, Hyounguk Jang, and Yusef Nourbham for their technical support and expertise.

THE MISSOURI JOURNAL OF LASER COOLING AND TRAPPING (LJLCT)



Funding: AFOSR F49620-98-1-0028
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