Department of Physics and Astronomy
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Bachelor Thesis in Physics
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Characterization of a multispecies imaging system

This Bachelor Thesis has been carried out by Robin Eberhard at the
Institute for Theoretical Physics in **Heidelberg**
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Characterization of a multispecies imaging system

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Abstract Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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Contents

1. Introduction

- Nothing yet…

2. Setup for high resolution imaging

2.1. Experimental requirements

- Absorption imaging
- How CCDs work
- Cooling temperatures, timescales for imaging

2.2. Camera for double species imaging

2.2.1. Comparison with the present setup

- Higher resolution
- Faster readout
- Higher quantum efficiency
- Less dark noise (to be confirmed)

2.2.2. Dark current

- Theory on Dark current
- Temperature dependent
- Logarithmic dependency
- Water cooling

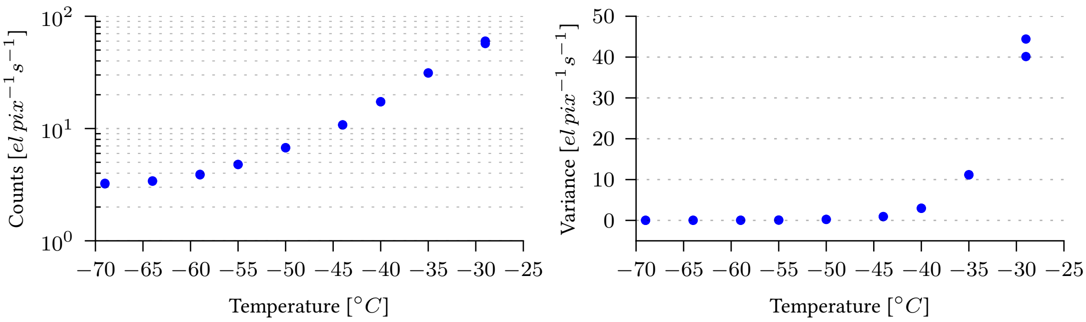

Figure 2.1.: **Dark noise** The dark noise follows a power law dependency. Since these measurements were taken without water cooling installed, deviations are visible as the temperature reaches −70 °C. The convergence to zero on the counts and their variance indicates accurate imaging when low temperatures are used. Gain in this measurement was minimal and the exposure time set to 100 s, such that dark current was the dominant noise source.

2.2.3. Readout noise

- How does pixel shifting work?

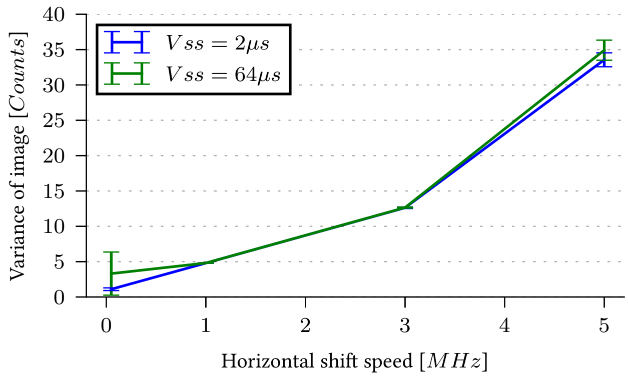

Figure 2.2.: **Readout noise** The pixels are shifted row-wise into the readout register, depending on the vertical shift speed (v_{ss}) and then moved pixel-by-pixel with the horizontal shift speed into the analogue to digital converter. Since noise reduction is important, minimal horizontal shift speeds will be used, while the vertical shift speed does not seem to affect the variance. To make the readout the dominant noise source, temperature was set to $-69\,°C$ and exposure to $10\,ms$

2.2.4. Quantum efficiency

- Little bit of theory
- Reference to Carmens' thesis

2.2.5. Pixel correlations

- Mainly the measurement (TBD)
- Some example images here maybe?

2.3. Mechanical shutter

2.3.1. Electronic setup

- A simplified circuit
- Explanation of the parts

2.3.2. Dynamical properties

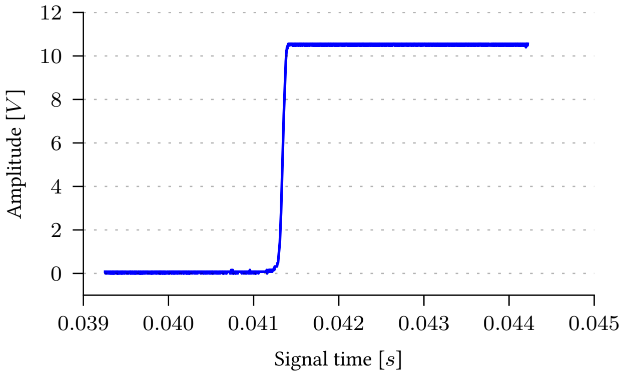

Figure 2.3.: **Shutter characterization** The dynamics of the shutter were measured using a laser with a variable horizontal offset, which is fixed in this plot, and a photodiode measuring the laser intensity. For various offsets, error functions were fitted yielding the time until the shutter opens to this offset.

appendix image

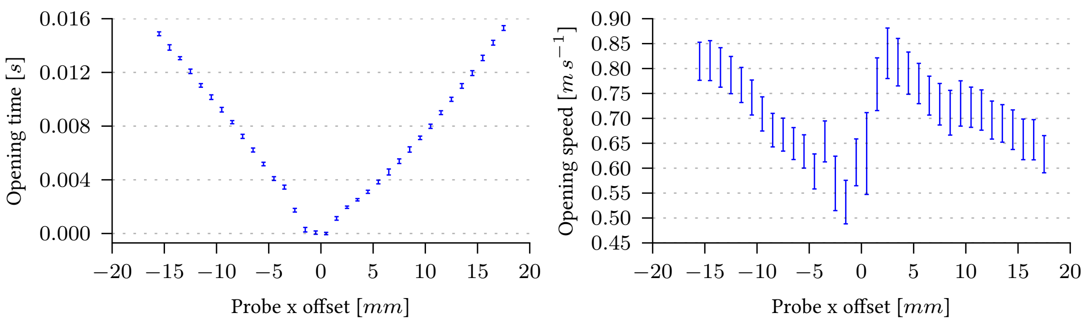

Figure 2.4.: **Sample dynamics** Opening velocity was measured using the beam diameter and the time the shutter needed to transverse it. It is noticable, that the opening velocity on the right side is faster at first than on the left side. This is due to the structure of the shutter, as can be seen in [Appendix image of shutter]. The overall opening speed on the other hand is not affected by this and seems to be linear with the offset.

2.4. Mask for the CCD sensor

2.4.1. Fast kinetics mode

- Why it is good
- Shifting timescales

2.4.2. Frequency response of an imaging system

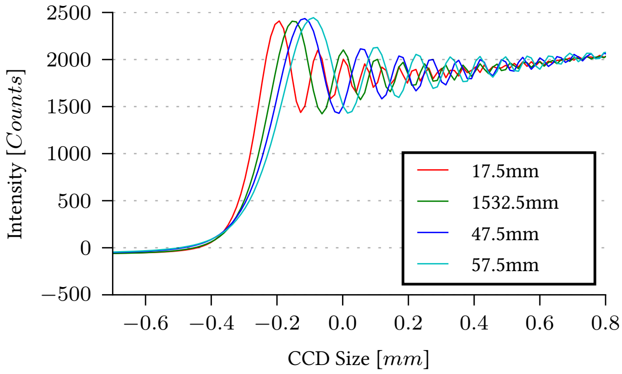

Figure 2.5.: **Distance dependant diffraction** A slit was placed on a moving platform and diffraction was measured for various offsets. The diffraction frequency rises as the distance gets closer to the CCD. As soon as the frequency is of the order of one pixel, the diffraction is unnoticable, therefore higher frequencies, or closer slit positions are preferred.

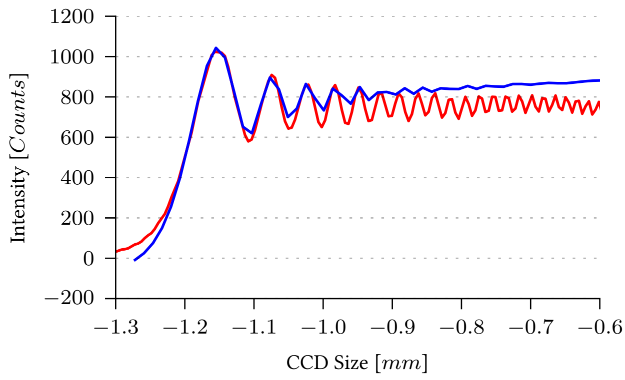

Figure 2.6.: **Diffraction measurement** In order to characterize the diffraction on the CCD, a slit was placed as close as possible. The parameters were then measured as distance $d = 10.9\,\mathrm{mm}$, opening $a = 2.5\,\mathrm{mm}$ using a ruler, and wavelength $\lambda = 852\,\mathrm{nm}$ from the laser specifications. The blue curve is the experimental data, while the red curve was fitted, leaving distance and opening free. They were found to be $d' = (11.0 \pm 0.3)\,\mathrm{mm}$ and $a' = (2.470 \pm 0.013)\,\mathrm{mm}$, which is in close agreement.

2.4.3. Optimization of the masking setup

- Custom slit properties

3. Testing the camera: Superfluids

- Theory on superfluids
- Spin population profile
- Measurement

4. Conclusion and outlook

A. Acquisition sequence

B. Testing software

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