Spectrometer Testing:
Dark frame evaluation of StellarNet Black Comet spectrometer

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Contents

1. Scope

This document presents an evaluation of the dark current present in a StellarNet Black Comet spectrometer for potential applications in a number of research projects within the Sensors and Instrumentation Research Group and the Institute of Materials and Manufacturing.

2. Applicable Documents

[1] StellarNet Miniature Spectrometer Manual
http://www.stellarnet.us/spectrometers/black-comet-uv-vis-concave-grating-spectrometers

3. Introduction

The StellarNet Black Comet spectrometer is a robust instrument with no moving parts and is able to detect photons across a wavelength range of 190 nm - 850 nm. The spectrometer utilizes a 40 mm diameter concave grating with aberration correction to reduce comma and astigmatism found in plane grating spectrograph designs. The spectrometer design does not use any mirrors and therefore produces very low stray light levels in the UV waveband (0.02% at 435 nm and 0.2% at 200 nm) aided by the inclusion of a holographic line grating. The concave grating produces a flat field on the CCD detector creating uniform resolution over the entire range.

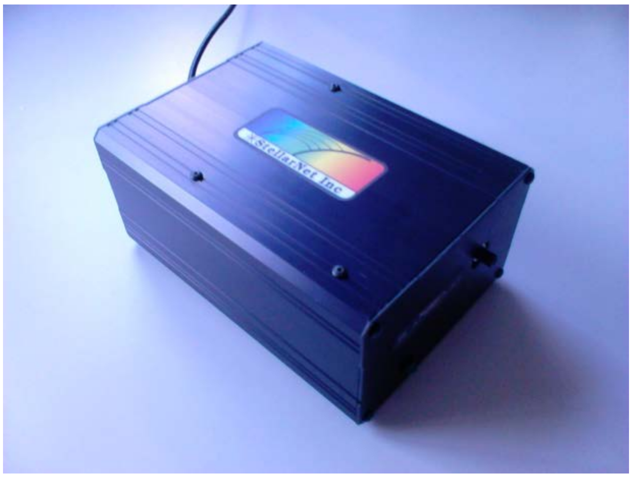


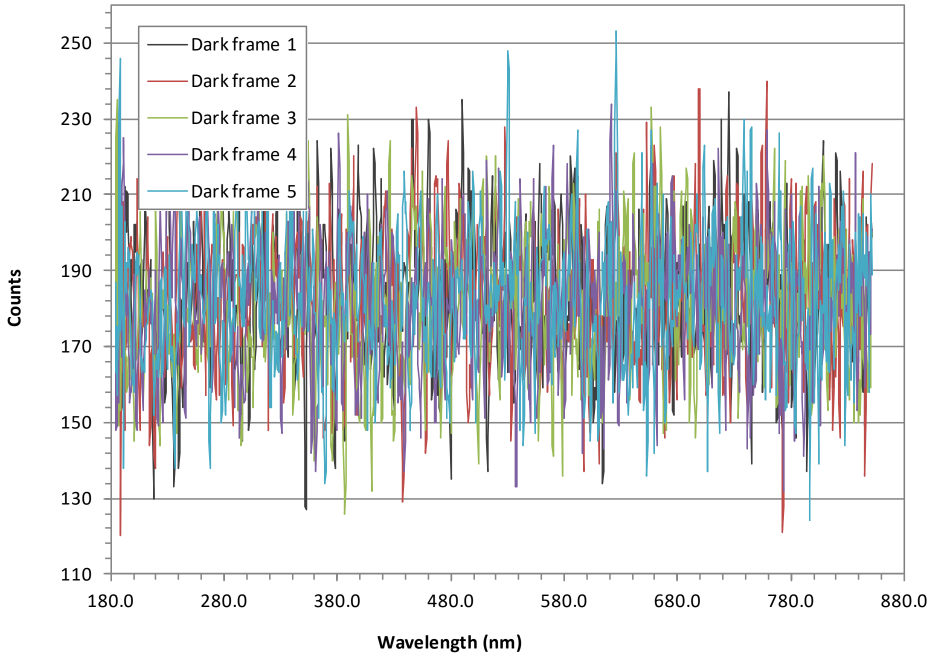
Figure 3.1 The StellarNet Black Comet spectrometer

To investigate the uniformity of the dark current in the spectrometer CCD, testing of the spectrometer was carried out in the dark (the spectrometer cap covering the entrance aperture) with the integration time and collected number of individual dark frames varied to investigate the effect of these specific parameters. The StellarNet provided software, SpectraWiz, was used to run the device and collect the data.

The StellarNet Black Comet spectrometer is serial # 16010712 and is fitted with a 100 μm wide entrance slit.

4. 180 ms integration time

The first series of tests involved setting the integration time to 180 ms and collecting individual dark frames and using the SpectraWiz software to also collect averages of multiple dark frame collections. Figure 4.1 shows a plot of 5 individual dark frames across the full spectral range of the spectrometer and across a narrower 380 nm – 480 nm band. The mean number of counts in each dark frame across the full wavelength range is shown in Figure 4.2.



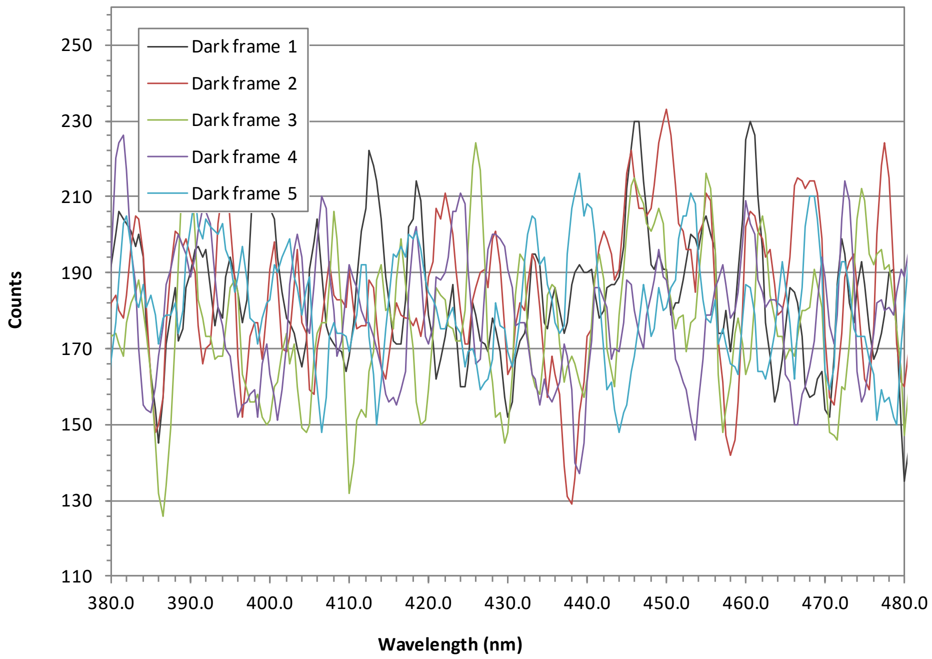


Figure 4.1 180 ms integration time individual dark frames

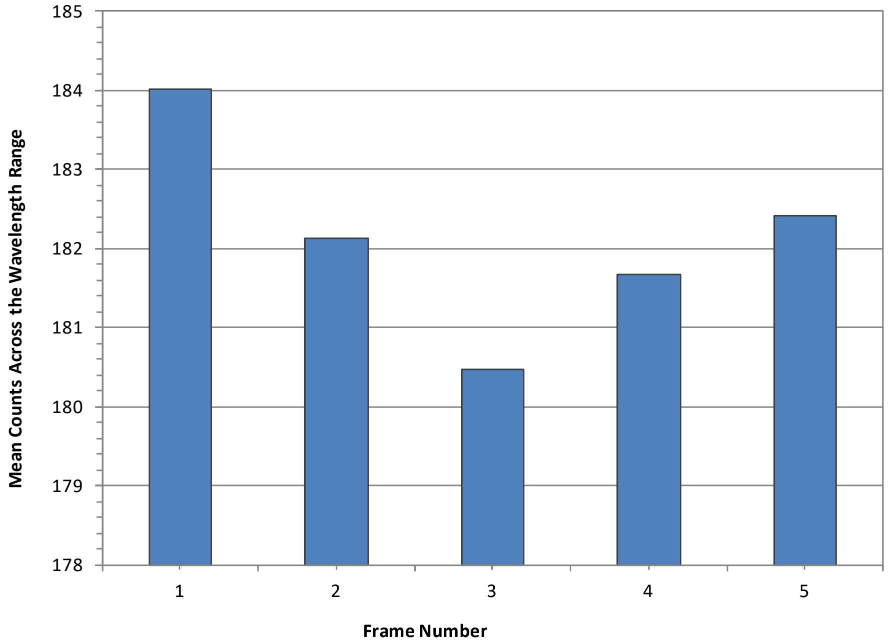
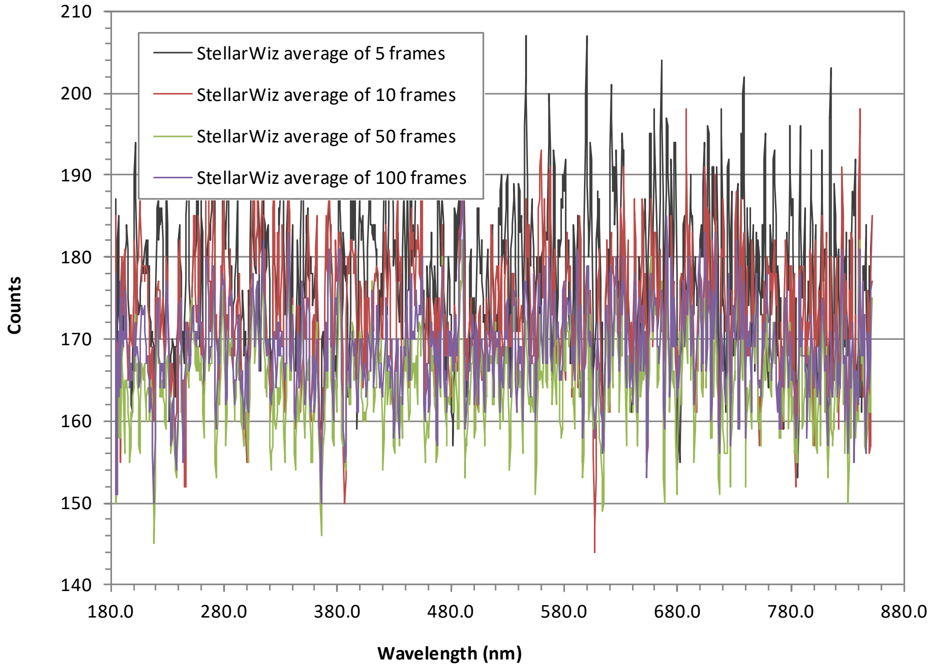


Figure 4.2 Mean number of counts in sequentially collected dark frames

Figure 4.3 shows data corresponding to the average of 5, 10, 50 and 100 collected dark frames, the averaging being carried out by the SpectraWiz software. Once again, the figure shows data for the whole of the available spectral range and a narrower 380 nm – 480 nm band.



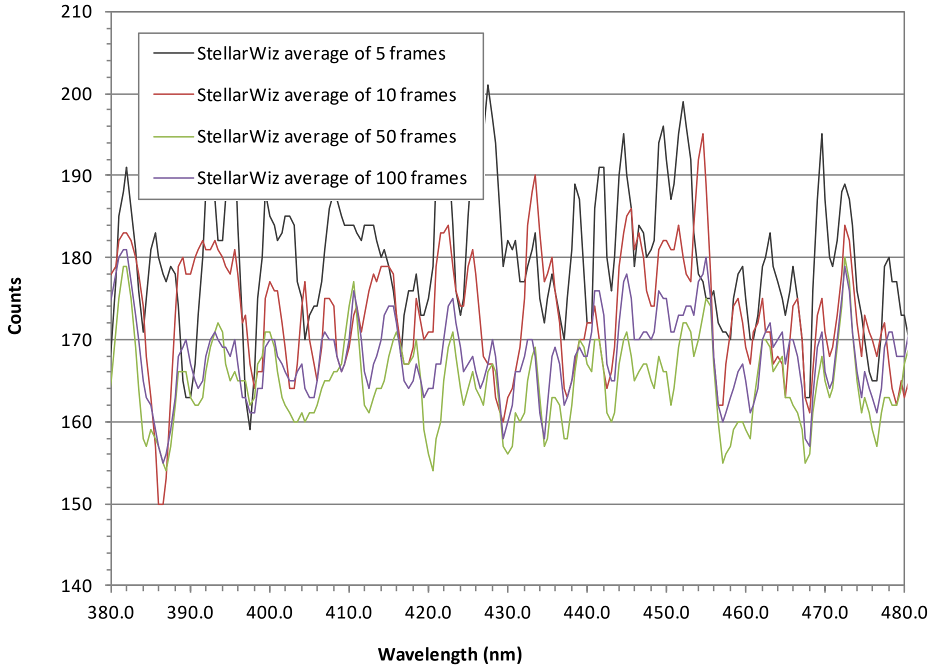


Figure 4.3 180 ms integration time averaged dark frames

Figure 4.4 shows two average of 10 dark frame data sets but collected a number of days apart. Although there is a noticeable difference in the mean signal level from one data set to the other, it should be noted that this is small compared to spectral data collected on 21/01/16 when collecting photons from deuterium and halogen light sources (SL5-DH UV-VIS Light Source). Data from the 21/01/16 testing is shown in Figure 4.5 for comparison, the peak counts in the combined spectrum being above 40000 for the same 180 ms integration time.

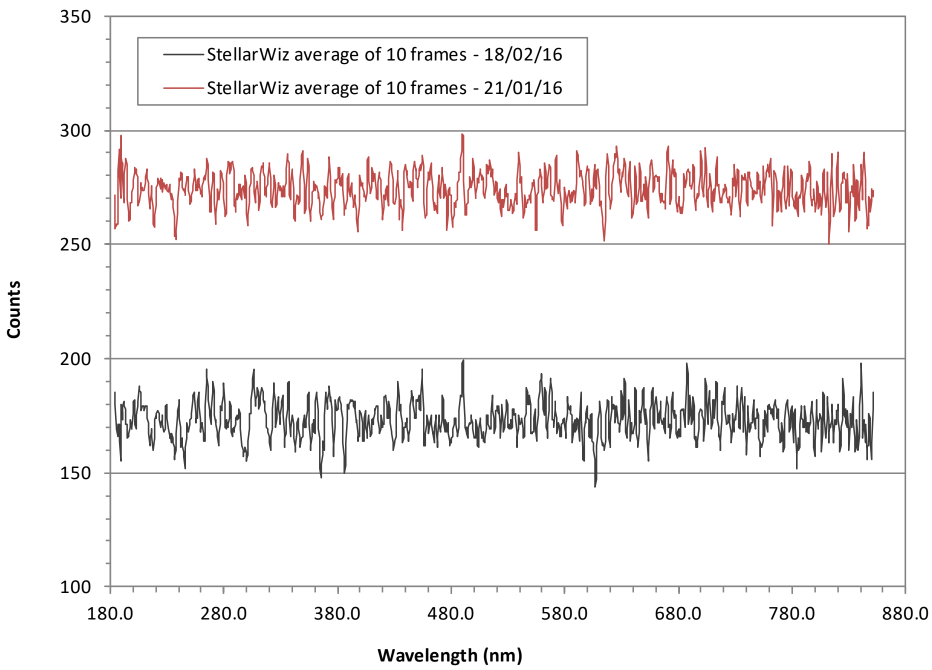


Figure 4.4 180 ms integration time averaged dark frames

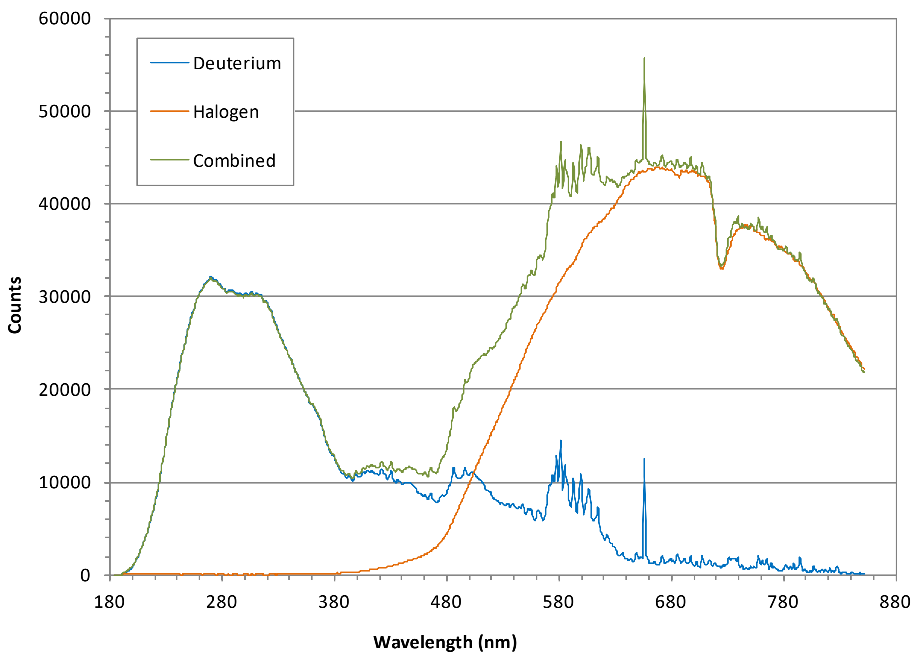


Figure 4.5 Collected light source spectra with 180 ms integration time

5. Varying integration time

The second series of tests involved setting different integration times and collecting a single dark frame of data and an average of 100 dark frames in each case. Figure 5.1 shows individual dark frames collected with integration times of 1 ms, 10 ms and 100ms, while Figure 5.2 shows collected averages of 100 dark frames at each of the same three integration times.

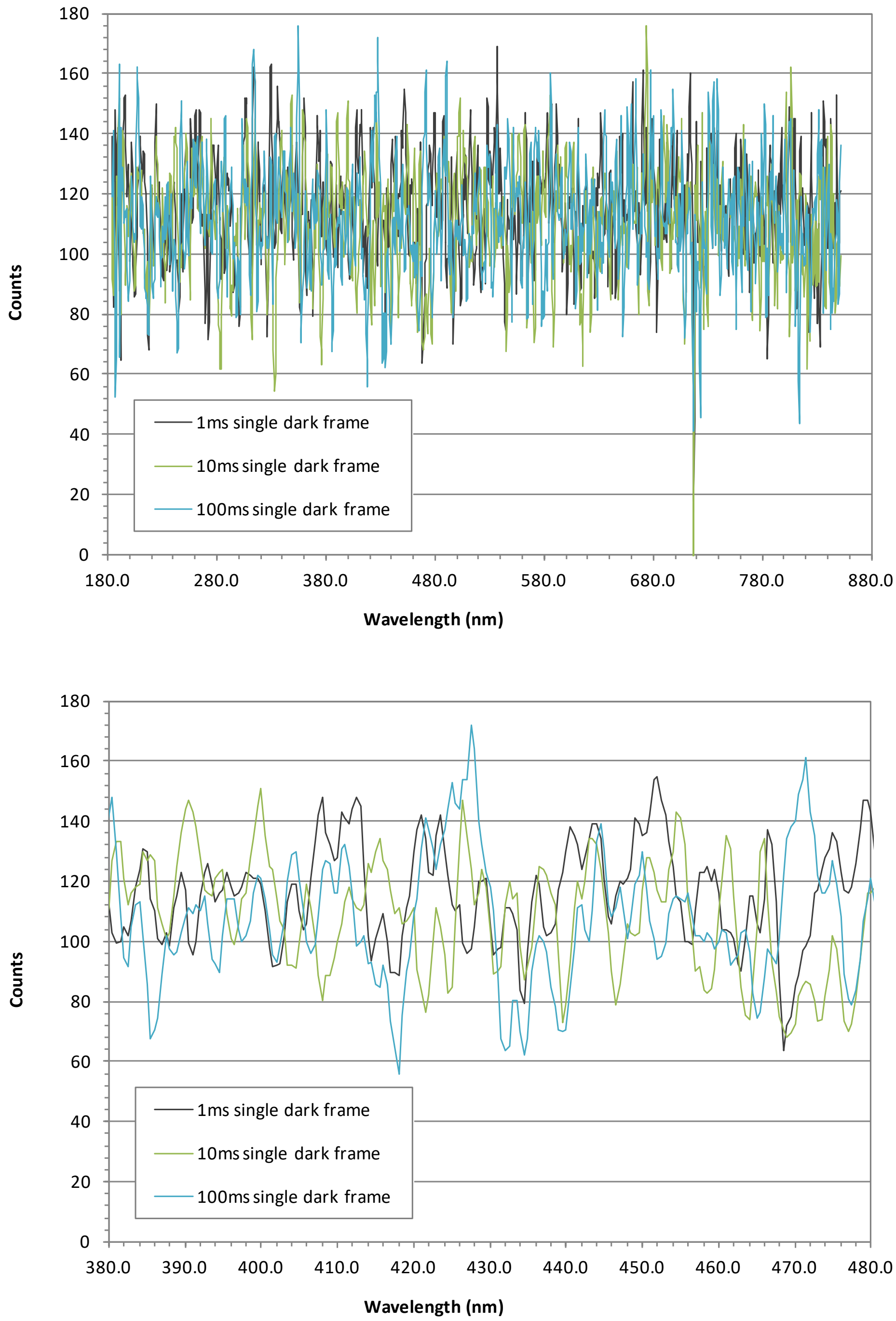


Figure 5.1 Individual dark frames collected with different integration times

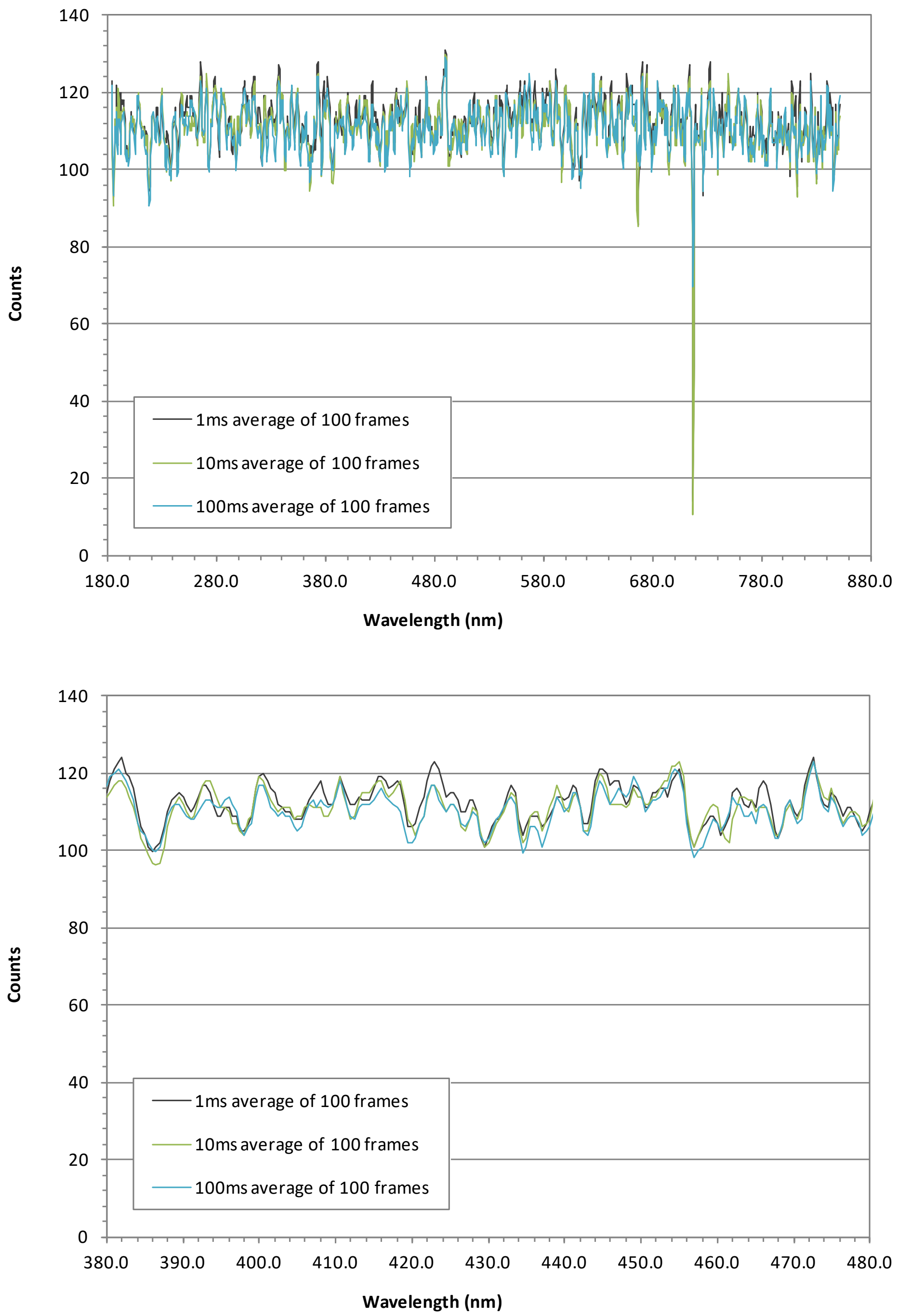


Figure 5.2 Averages of 100 dark frames collected with different integration times

Another data set containing an average of 1000 dark frames at an integration time of 50 ms was obtained and is shown in Figure 5.3. Part of this dataset is shown in Figure 5.4 alongside the corresponding data from Figure 5.2 for comparison.

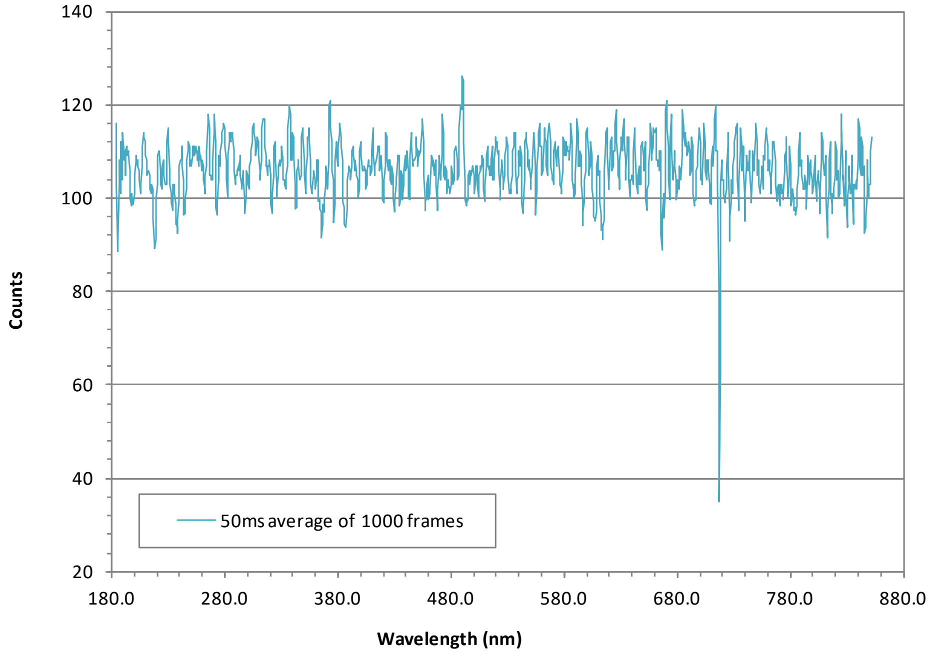


Figure 5.3 Average of 1000 dark frames collected with 50 ms integration time

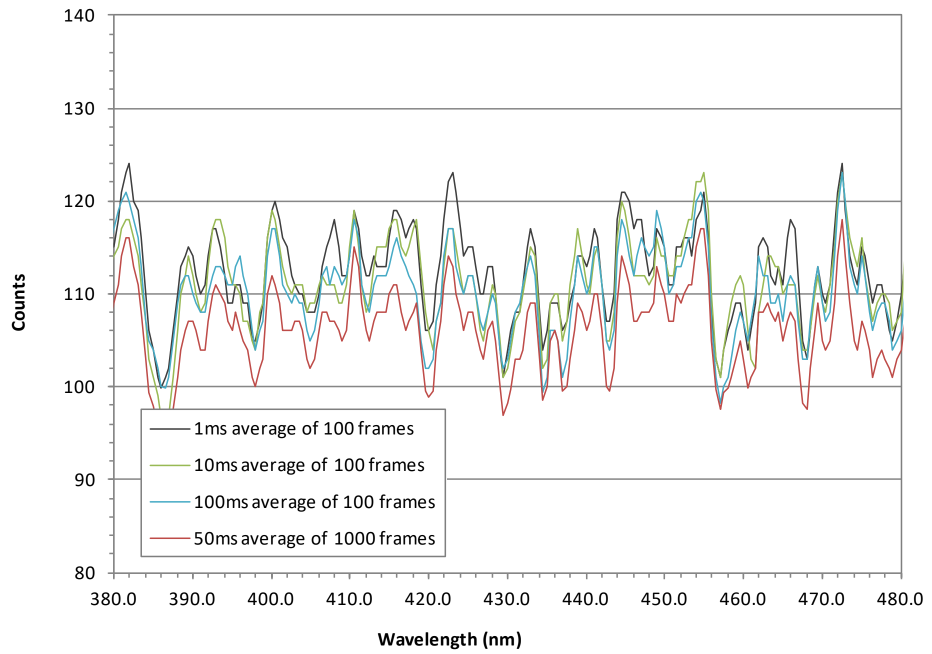


Figure 5.4 Comparison of varying integration time data sets from 380 nm - 480 nm

Increasing the integration time further resulted in a software timeout when trying to collect an average of 100 frames so only individual dark frames were obtained at longer integration times of 1000, 2000, 5000, 10000, 20000, 50000 ms and at the maximum possible integration time allowable by the system of 65535 ms. The resulting data sets are shown in Figure 5.5 along with corresponding data sets collected at the previously investigated 1, 10 and 100 ms integration times.

Figure 5.5 Individual dark frames collected with different integration times up to the maximum possible setting

Looking at the integration time data further, Figure 5.6 shows the average counts per bin across the full wavelength range of the spectrometer for the different integration times studied.

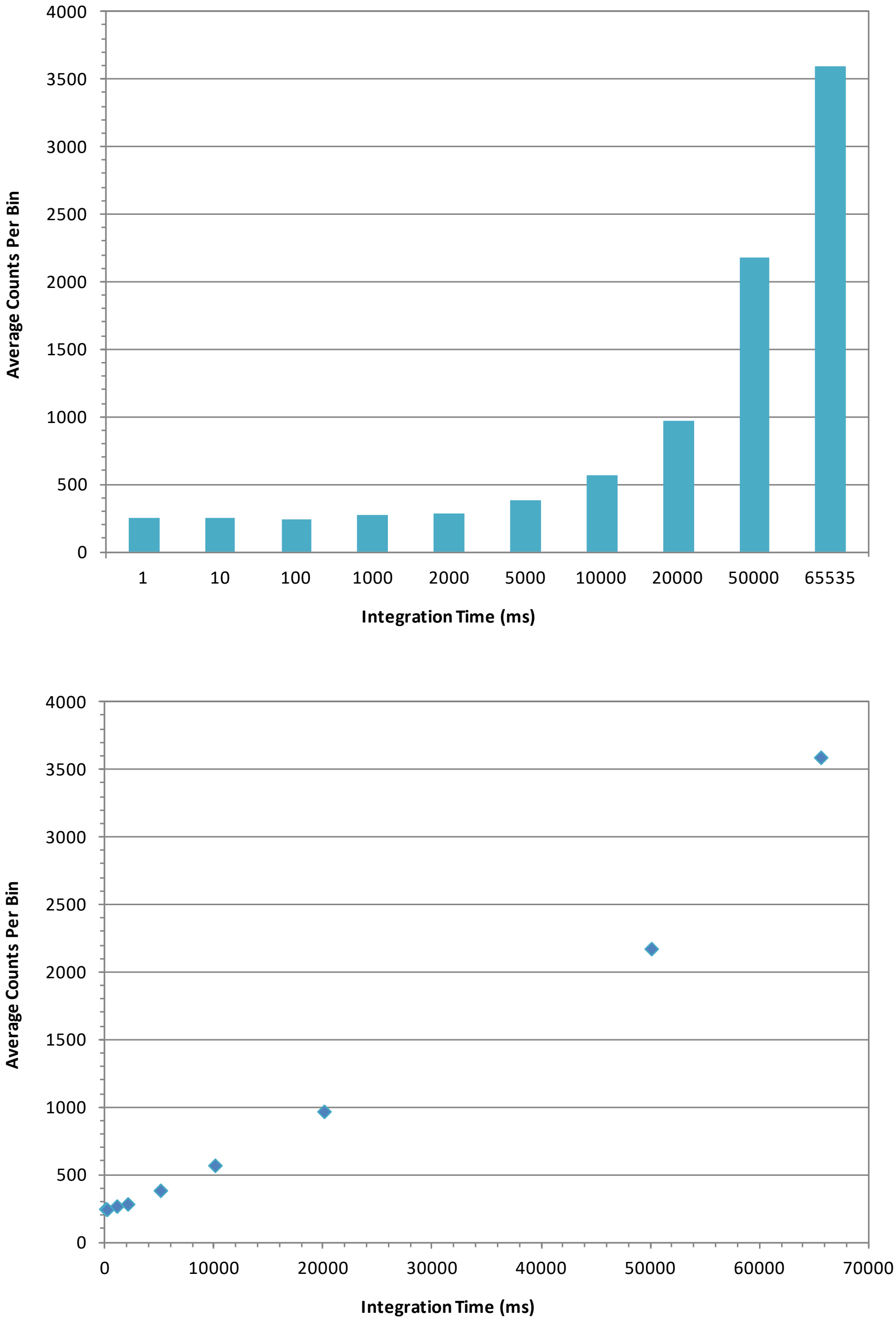


Figure 5.6 Average counts per wavelength bin vs. integration time

Figure 5.7 shows the data for integration times of 100, 1000, 10000, 20000 and 50000 ms including a linear fit to each data set.

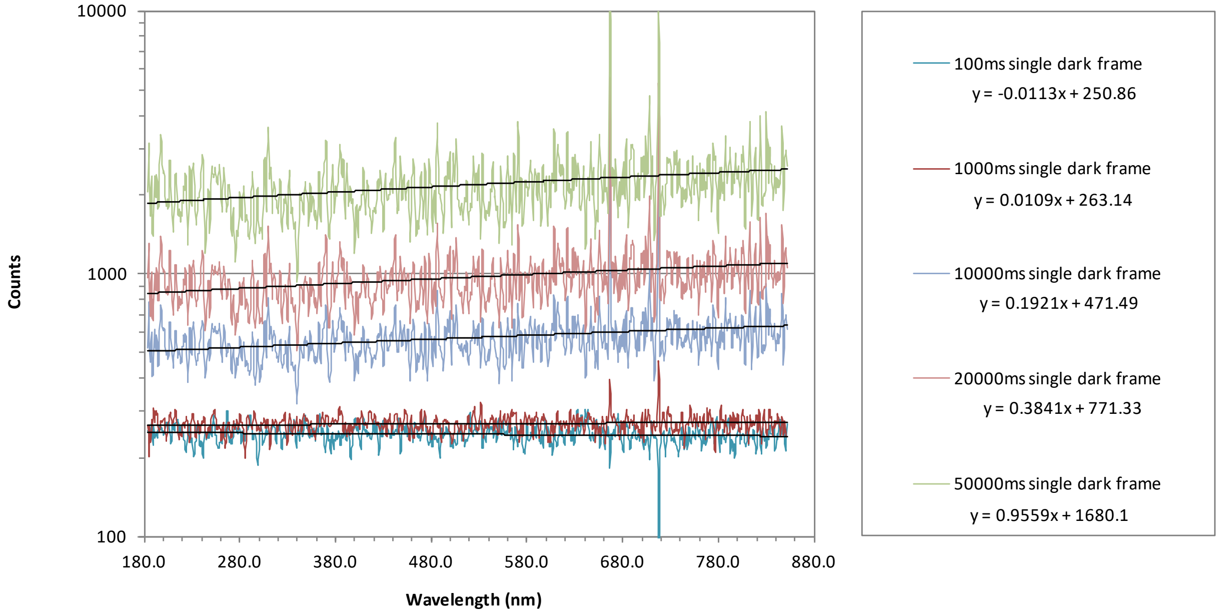


Figure 5.7 Individual dark frames collected with different integration times and corresponding linear fit for each data set

6. Discussion and Conclusions

The following observations can be made from the presented results:

- Sequentially captured spectra show a very similar mean signal level to within a few counts averaging across the full spectral histogram.

- Spectra captured after longer periods of time between measurements show a larger change in mean signal level for a given integration time, possibly due to **thermal fluctuations** between measurements or the requirement for a warm up time to allow the spectrometer to thermally stabilise:
    - a change in mean signal level of ~100 counts was seen between the 180 ms integration time data collected on 21/01/16 when compared with testing conducted on 18/02/16.

- The **dark current signal level is low** compared to measured light source photon spectra, a variation of 100 counts in dark signal being a fluctuation of around 0.25% of the peak measured counts (~40000) in a collected deuterium, halogen light source combined spectrum.

- Data collected at different integration times shows that readout amplifier noise dominates the resulting spectrum until the integration time is increased above ~2000 ms. Increasing the integration time further results in an approximately **linear increase in observed dark current with increasing integration time**.

- As integration time is increased the gradient of a linear best fit line to the counts across the spectrum increases, the count rate being proportionally higher at the longer wavelength end of the measured spectrum.

- Averaging collected datasets of 100+ dark frames reveals a **fixed dark current pattern** across the full wavelength range of the spectrometer.

- Varying the integration time reveals **fixed pattern noise spikes** in the recorded spectrum:
    - integration times <150 ms reveal a dark current dip at a wavelength of 717.5 nm.
    - integration times >500 ms reveal two significant dark current spikes at wavelengths of 717.5 nm and 666.6 nm.

7. Acknowledgments

The StellarNet Black Comet spectrometer was purchased on Brunel University London research code R33349 under an EU grant (NUMBER — 654168 — AIDA-2020) for the AIDA-2020 project (work package WP14).