OPTIMIZING QE OF CCD BY MODIFYING BLACKCOMET DETECTOR

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Abstract. Charge-Coupled Device (CCD) is a type of image sensor technology used in digital cameras, video cameras, and various scientific and industrial applications to capture and convert light into electronic signals. Such sensors offer several advantages, including high sensitivity to light, low noise levels, and good image quality with high dynamic range. They are commonly used in applications that require precise and high-quality imaging, such as astronomy, microscopy, and spectroscopy. However, there are many ways to improve and optimize the role of CCD sensors in spectroscopy, and this could have a significant impact on the sensitivity, safety, and accuracy of measurements.

1. Introduction

One of the ways of optimization of a CCD (Charge-Coupled Device) sensor involves improving its performance in various aspects such as sensitivity, noise reduction, dynamic range, resolution, and overall image quality. One of the common techniques used for optimizing CCD sensors is enhancing the sensor's quantum efficiency (QE) to improve its sensitivity to light. The way we process the data can also affect the QE of CCD detector. It is essential to make sure that we have used appropriate data processing techniques, such as using background subtraction or noise reduction techniques, which will ultimately give us one opportunity to improve the signal-to-noise ratio.

One of the ways of optimizing a CCD (Charge-Coupled Device) sensor involves improving its performance in various aspects such as sensitivity, noise reduction, dynamic range, resolution, and overall image quality. Khajishvili et al. [1] investigated the estimation of signal-to-noise ratio (SNR) of a CCD camera for OD medium, highlighting the importance of optimizing CCD performance. Gomidze et al. [4] discussed the problems related to fluorescence excitation spectra, emphasizing the significance of addressing these issues in CCD sensor design. Gomidze et al. [3] conducted 3D fluorescence spectroscopy to study the distribution of bioparticles, highlighting the need for improved CCD performance to enhance data quality.

Furthermore, research by Khajisvili et al. [2] focused on 3D fluorescence spectroscopy of liquid media via the internal reference method, highlighting the importance of optimizing CCD sensitivity for accurate measurements. Groom et al. [5] developed a quantum efficiency model for a thick back-illuminated astronomical CCD, contributing to the understanding of CCD performance optimization. Prasad and Sinha [6] provided a comprehensive review of signal-to-noise ratio in CCD imaging systems, highlighting the significance of noise reduction techniques for improved performance. Kumar et al. [7] discussed optimizing the signal-to-noise ratio of CCD cameras for quantitative optical microscopy, emphasizing the role of data processing techniques.

Considering the impact of data processing techniques, it is crucial to utilize appropriate approaches such as background subtraction and noise reduction techniques to enhance the signal-to-noise ratio [6]. These techniques, combined with advancements in CCD design and optimization, contribute to improving the overall image quality and quantum efficiency of CCD sensors.

One of the impotent problem is the "Noise Reduction". By addressing this problem, we can improve the signal-to-noise ratio (SNR) of the BlackComet detector.

To decrease the SNR of the BlackComet detector, applying specific code that allows changing the quantum efficiency (QE) of the CCD sensor can be beneficial. By optimizing the QE, which affects the sensitivity of the detector to light, we can enhance the overall performance and reduce the noise in the captured images.

In addition to data processing, implementing efficient image processing algorithms is another crucial aspect. Techniques such as background subtraction, flat-field correction, or deconvolution can effectively reduce noise and enhance the signal-to-noise ratio of the detector. By optimizing these algorithms and incorporating them into the data processing pipeline of the BlackComet detector, we can achieve improved image quality and more accurate measurements.

2. Experiment and program overview

The experimental part of our research is performed on the detector BlackComet produced by StellarNet, which includes a CCD sensor. Black Comet spectrometers are equipped with high-performance CCD sensors with excellent sensitivity and low noise over a wide wavelength range. These detectors feature a thermoelectric cooling system to reduce noise levels and increase stability. This is why these detectors are ideal for applications such as absorption/transmission spectroscopy, fluorescence spectroscopy, and Raman spectroscopy.

One of the techniques to optimize the characteristics of the CCD sensor of the BlackCommet detector is to manage the hardware capabilities in software. However, it is important to note that optimizing the CCD sensor code of the BlackCommet detector is a complex task that requires deep knowledge of both the detector and the programming language used. Below is one of the codes specially developed for our detector (BlackCommet) and whose purpose is to clean and process the detrended spectra by comparing them with the reference spectra. The code is presented in the Mathematics language of the wolfram software package:

```
(* Load the CCD image *)
ccdImage = Import["path/to/image.fits"];
(* Perform background subtraction *)
background = MedianFilter[ccdImage, 5];
backgroundSubtracted = ImageSubtract[ccdImage, background];
(* Perform flat-field correction *)
flatField = Import["path/to/flatfield.fits"];
flatFieldCorrected = ImageMultiply[backgroundSubtracted, 1/flatField];
(* Perform deconvolution *)
psf = Import["path/to/psf.fits"];
deconvolved = ImageDeconvolve[flatFieldCorrected, psf];
(* Display the results *)
ImageCollage[{ccdImage, backgroundSubtracted, flatFieldCorrected, deconvolved}]
```

In this code, we first loaded the spectral image formed by the CCD sensor using the import function. We then performed background subtraction by calculating the median of the image using the MedianFilter function and subtracting it from the original image using the ImageSubtract function.

Next, we performed flatfield correction by loading a flatfield image using the Import function and multiplying it by the background-subtracted image using the ImageMultiply function.

Finally, we performed deconvolution by loading the point spread function (PSF) using the import function and deconvolving the flat field corrected image using the ImageDeconvolve function.

The results were then displayed using the ImageCollage function, which created a composite image showing the original image formed by the CCD sensor, the background subtracted image, the flat-field corrected image, and the deconvolved image.

3. Results

Obtained images allowed us to obtain the graph of SNR dependence on path length and detector integration time.

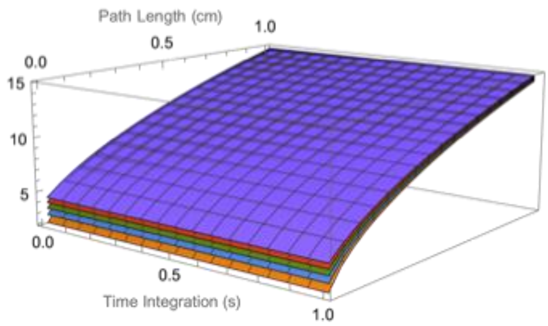

Fig. 1. SNR three-dimensional dependence on beam path length and detector integration time, when the concentration is c=0.01 mol/L, and molar absorption coefficient ε=20000 L/(mol*cm)

Conclusions

- Decreasing of SNR of BlackComet detector is possible by applying specific code, which allows change of the QE of the CCD of the detector.
- The way we process the data can also affect the QE of our detector. It is essential to make sure that we have used appropriate data processing techniques, such as using background subtraction or noise reduction techniques, which will ultimately give us one opportunity to improve the signal-to-noise ratio.

- Implementing efficient image processing algorithms can help reduce noise and improve the detector's signal-to-noise ratio. This may include techniques such as background subtraction, flat-field correction, or deconvolution.

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