Visible Spectroscopy using Compressive Sensing

Ian Storer, Department of Engineering
Advisor: Dr. David J. Starling, Department of Physics
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Introduction

Spectroscopy is a useful technique in the sciences because it allows one to reliably identify unknown substances. Due to the precision required, modern spectrophotometers can exceed the $5,000 mark for standard commercial products. Additionally, typical spectrophotometers have large footprints and slow acquisition rates. To that end, our objective was to implement a modern and unique imaging technique known as compressive sensing that can both decrease acquisition time and cut cost.

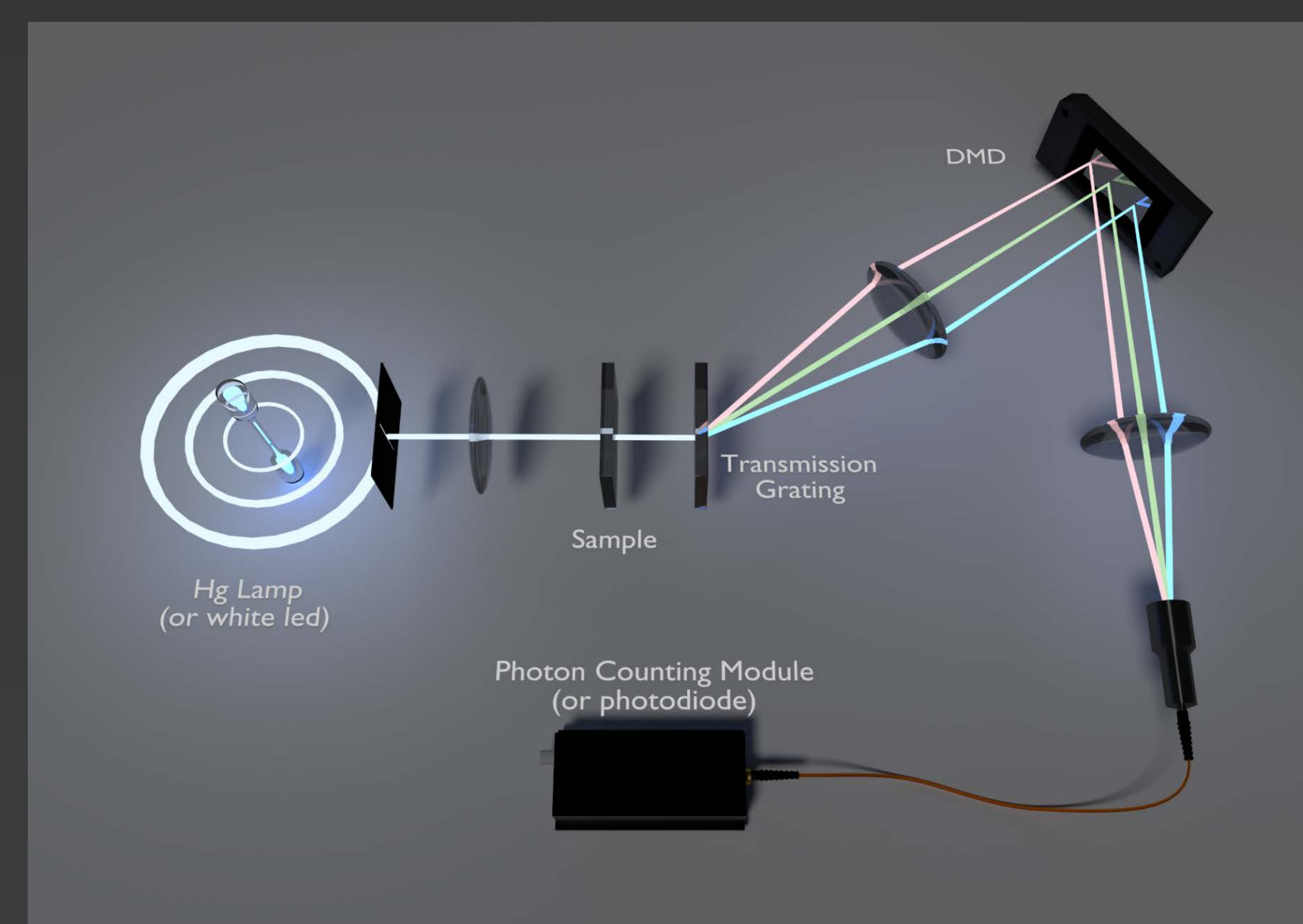
Data Analysis

Compressive sensing is a way to compress an image (**u**) while the image data (**f**) is acquired. This is done by solving an underdetermined linear system with an assumption:

$$\min \sum_i |D_i \boldsymbol{u}| \quad \text{such that} \quad \boldsymbol{f} = A\,\boldsymbol{u}$$

- $D_i \boldsymbol{u}$ is the difference between element i and $i+1$ of $\boldsymbol{u}$.
- Solved in Matlab with TVAL3
  - **T**otal **V**ariation minimization by **A**ugmented **L**agrangain and **AL**ternating directing **AL**gorithms
  - Data set 1: white light from LED
  - Data set 2: transmitted light through sample

Compressive Sensing Experimental Setup



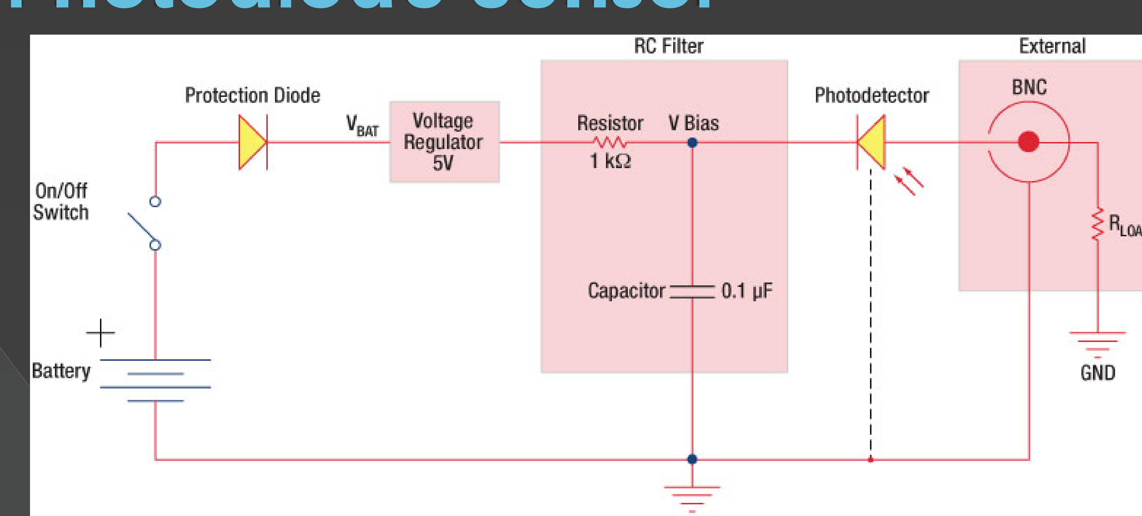
Light source: LED or mercury lamp

DMD: Digital Micromirror Device

Sample: calibrated filters or unknown

Detector: single photon or intensity

Photodiode Sensor



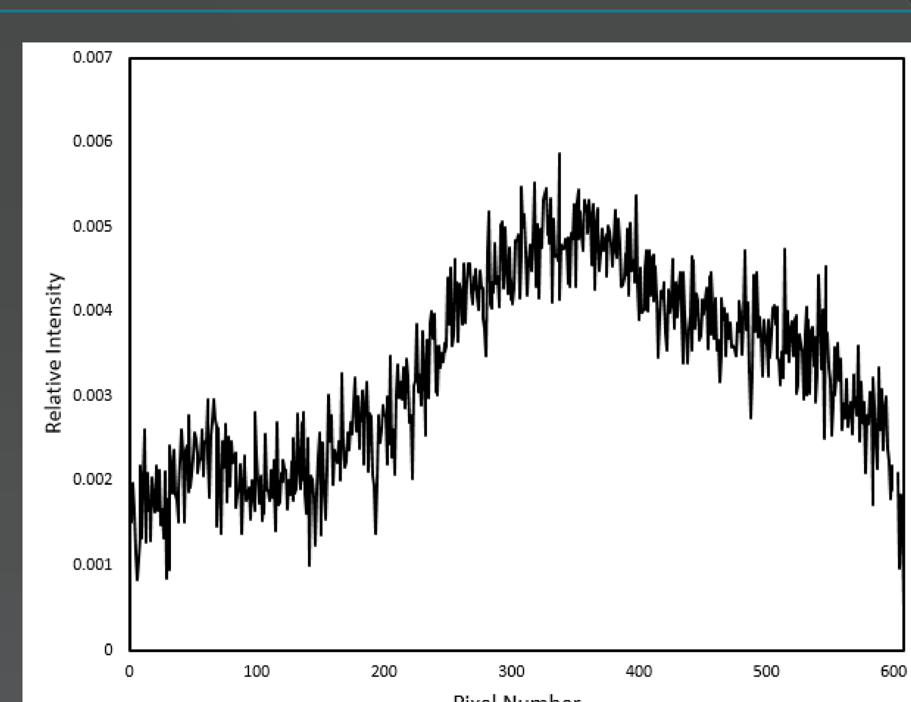
(source: thorlabs.com)

- Passive components
- Measures less than 120 nW
- Large area (13 mm²)
- Sends data to data acquisition (DAQ) board

Future plans: switch to single photon detector

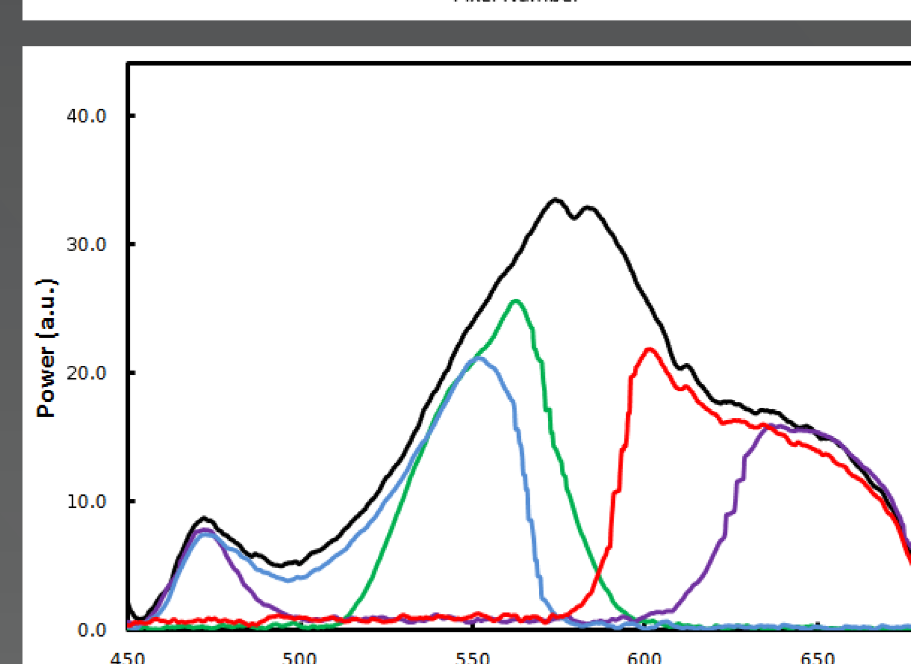
Raster Scanning

- Standard technique
- Moving slit
- Acquisition time: 121.6 s
- Low signal to noise ratio
- Commercial cost: $5000+

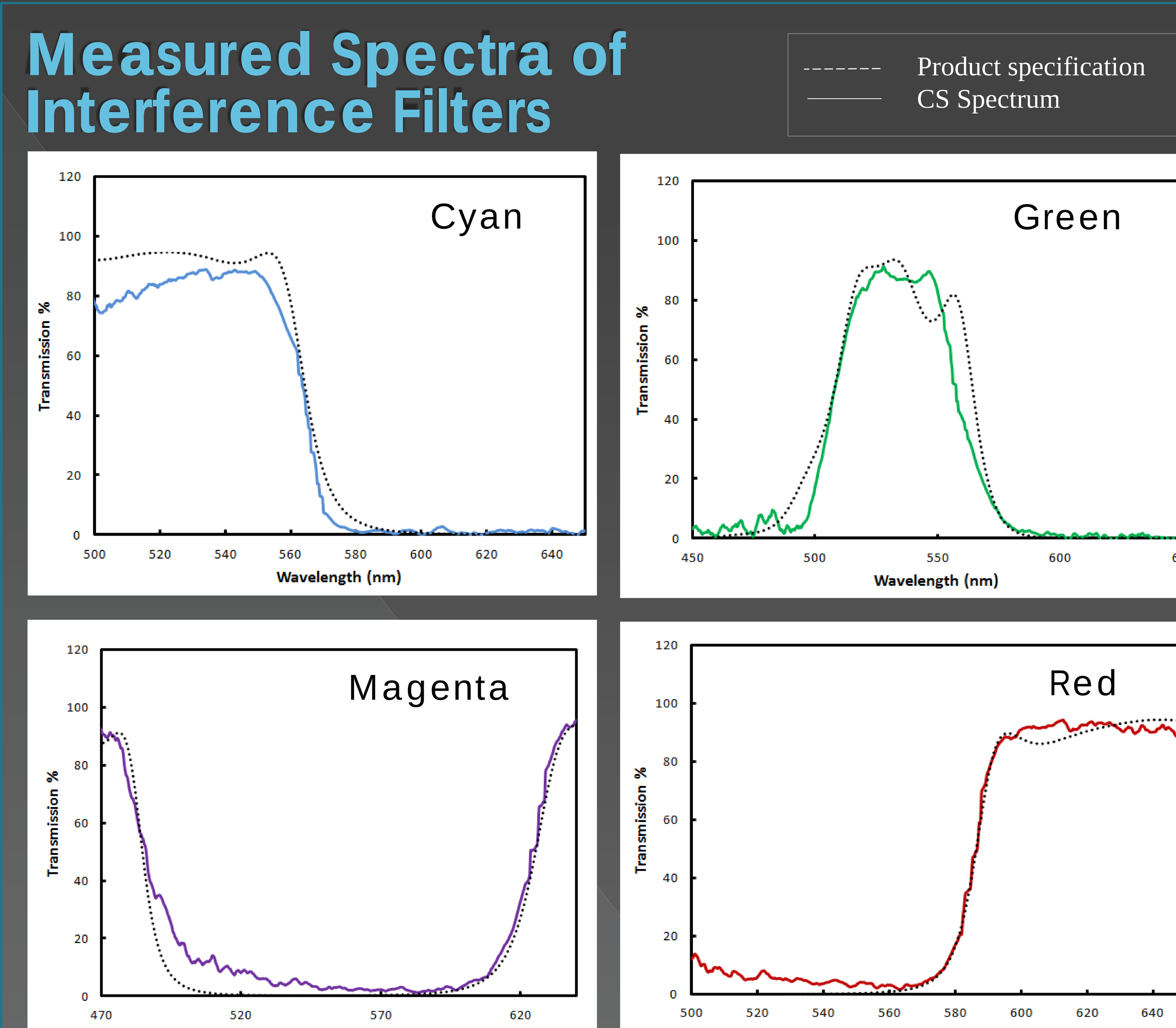


Compressive Sensing

- Novel technique
- Digital Micromirror Device (DMD) using computer generated random patterns
- Acquisition time: 10 s (12x faster)
- High signal to noise ratio
- Projected cost: $1000



Measured Spectra of Interference Filters



References

[1] Y. August, C. Vachman, Y. Rivenson and A. Stern, "Compressive hyperspectral imaging by random separable projections in both the spatial and the spectral domains," Appl. Optics **52**, 10 (2013).

[2] J. D. Batchelor and B. T. Jones, "Development of a Digital Micromirror Spectrometer for Analytical Atomic Spectrometry," Anal. Chem. **70**, 4907 (1998).

[3] L. Xua, M. A. Davenport, M. A. Turner, T. Suna, K. F. Kelly, "Compressive Echelle Spectroscopy," Proc. of SPIE **8165**, 81650E (2011).

Integration

- Slight variation with increased integration
- Detector limited