

Design of a CTIS for use in the long-wave infrared

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Outline

- Introduction to new device
- Describe how it is different
- Layout
- Details about components
- Go into detail about the design of a specific component.
- Review
- Questions

Introduction



What is a CTIS?

- **Computed**
- **Tomographic**
- **Imaging**
- **Spectrometer**

The goal of CTIS is to extract as much information as possible from the light coming from an object.

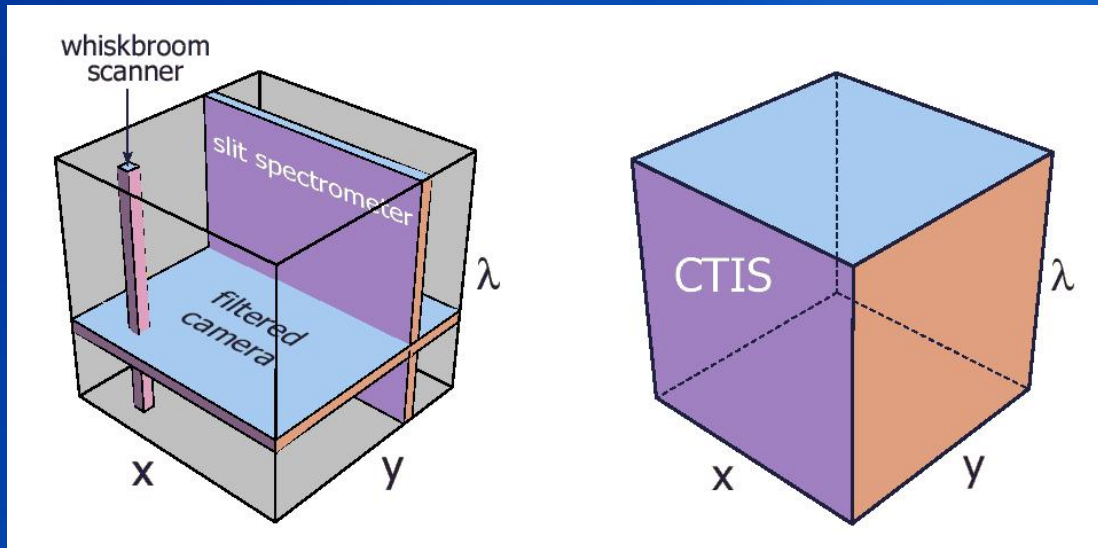
Description



A CTIS system is basically a camera that captures wavelength data for each spatial pixel in an image.

Will show detailed layout later on.

Spectrometer Comparison



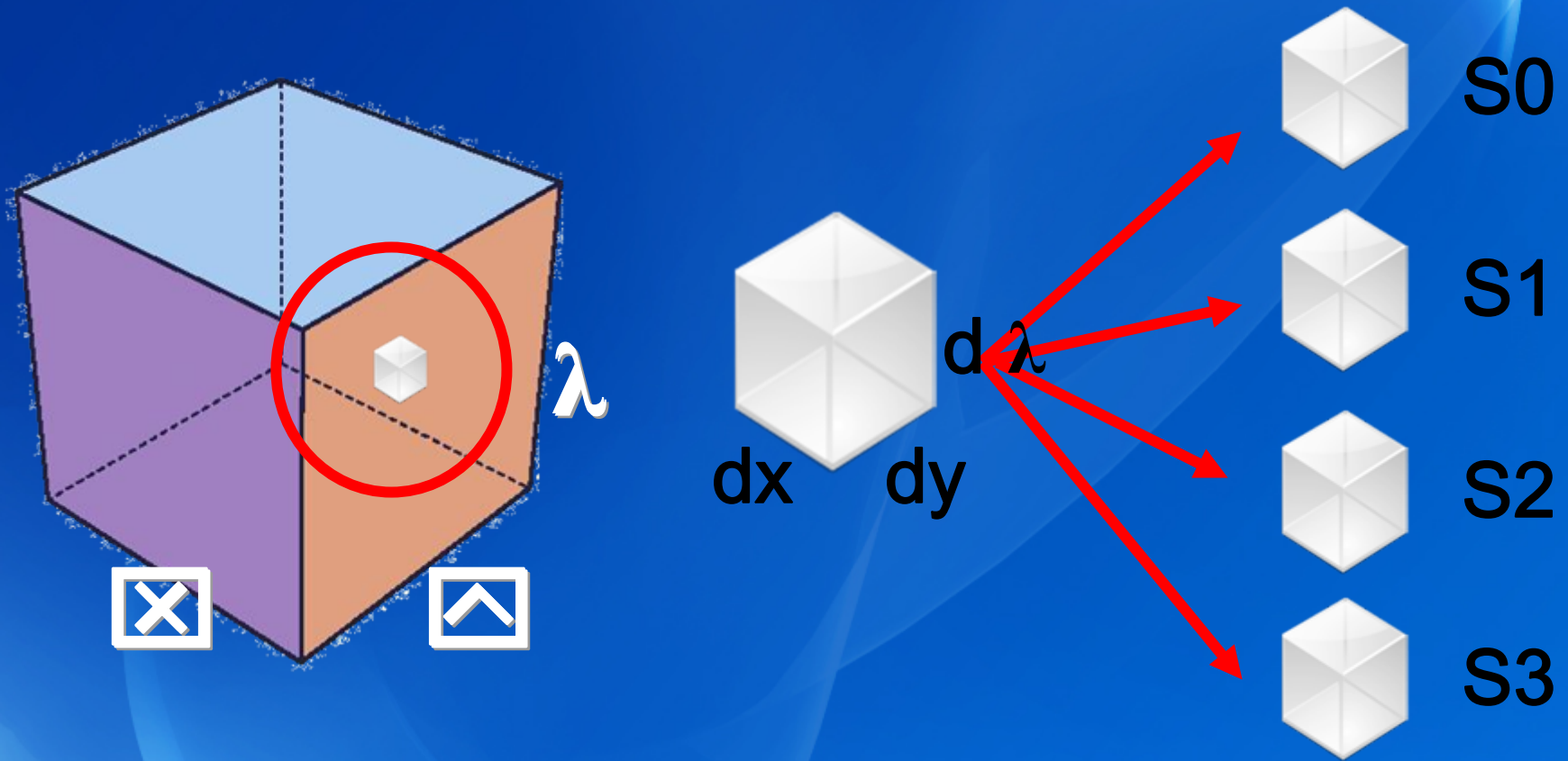
CTIS does NOT require any scanning. It is able to acquire the entire data cube in a single integration time.

Benefits of ctis

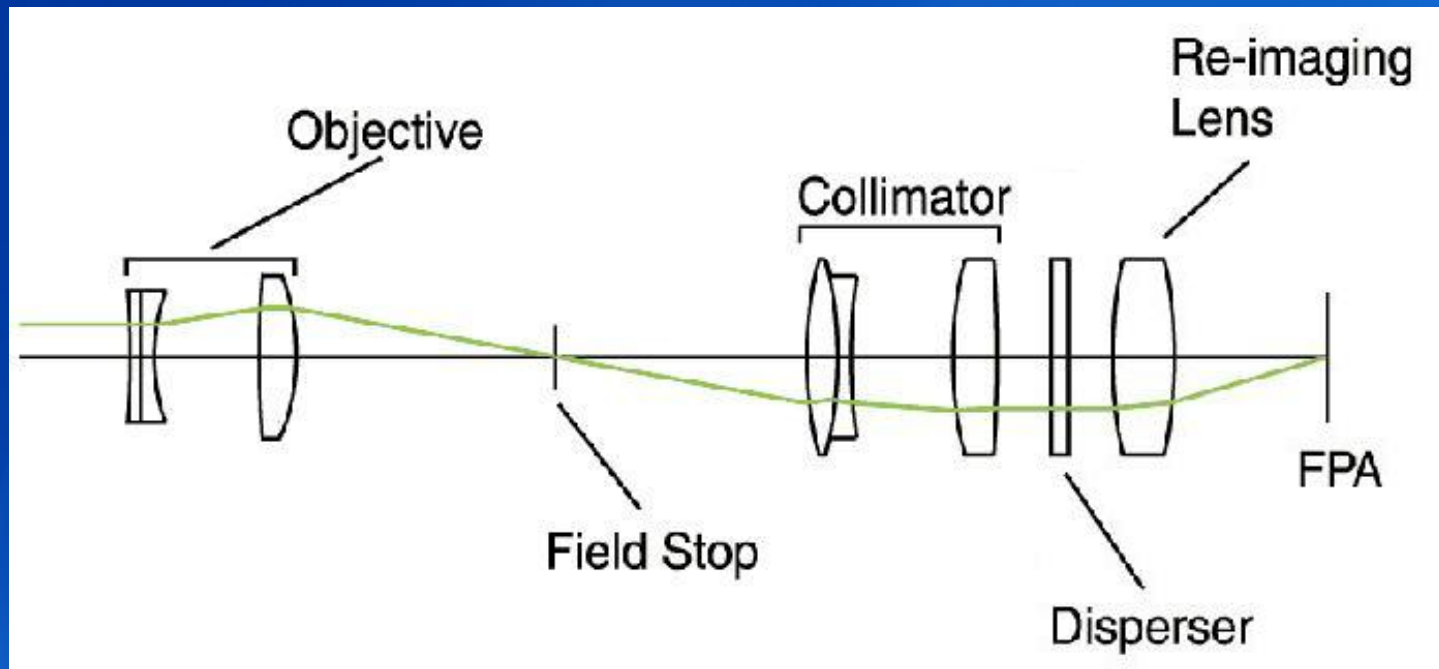
- It is an imaging spectrometer that requires no scanning
- Contains no moving parts
- Captures all data in a single integration time.
- Can analyze things that quickly change in time, without the artifacts normally introduced by scanning instruments.

. . .and still more

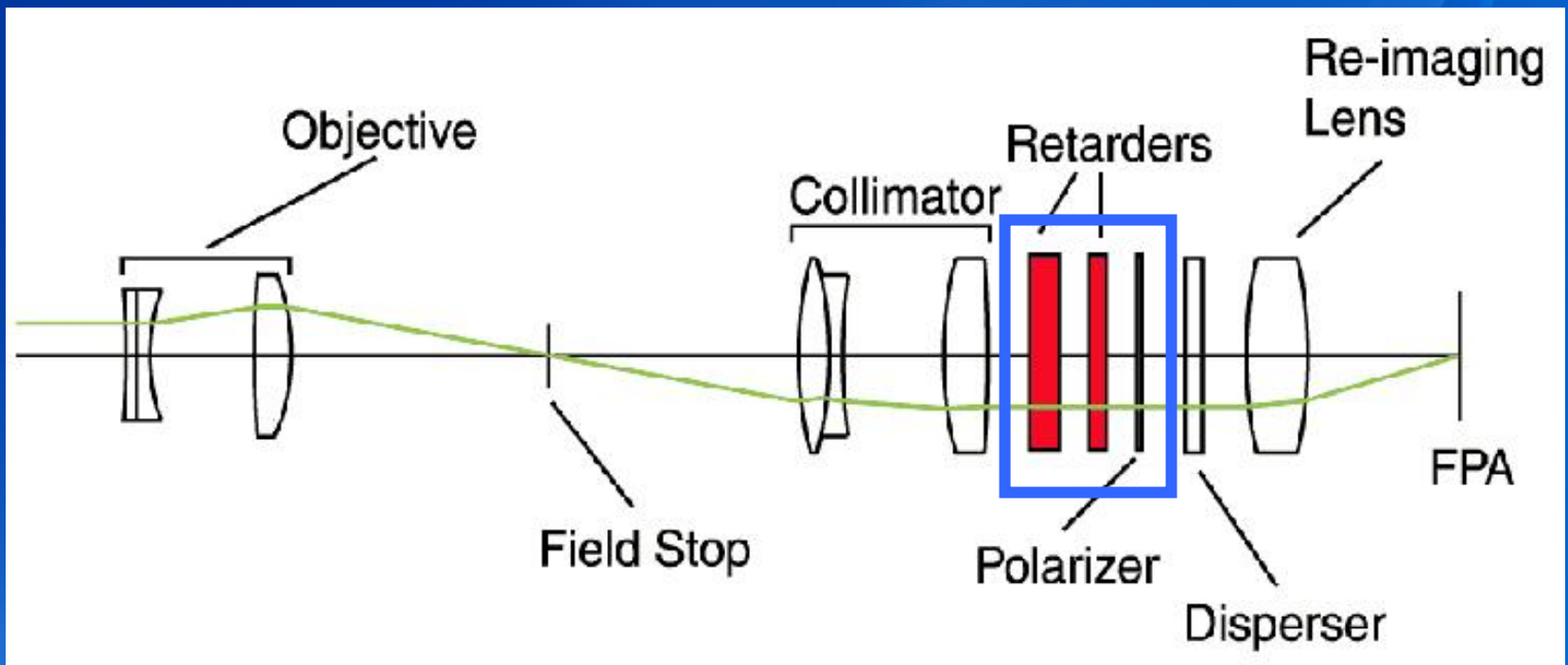
Polarization data acquired for each voxel



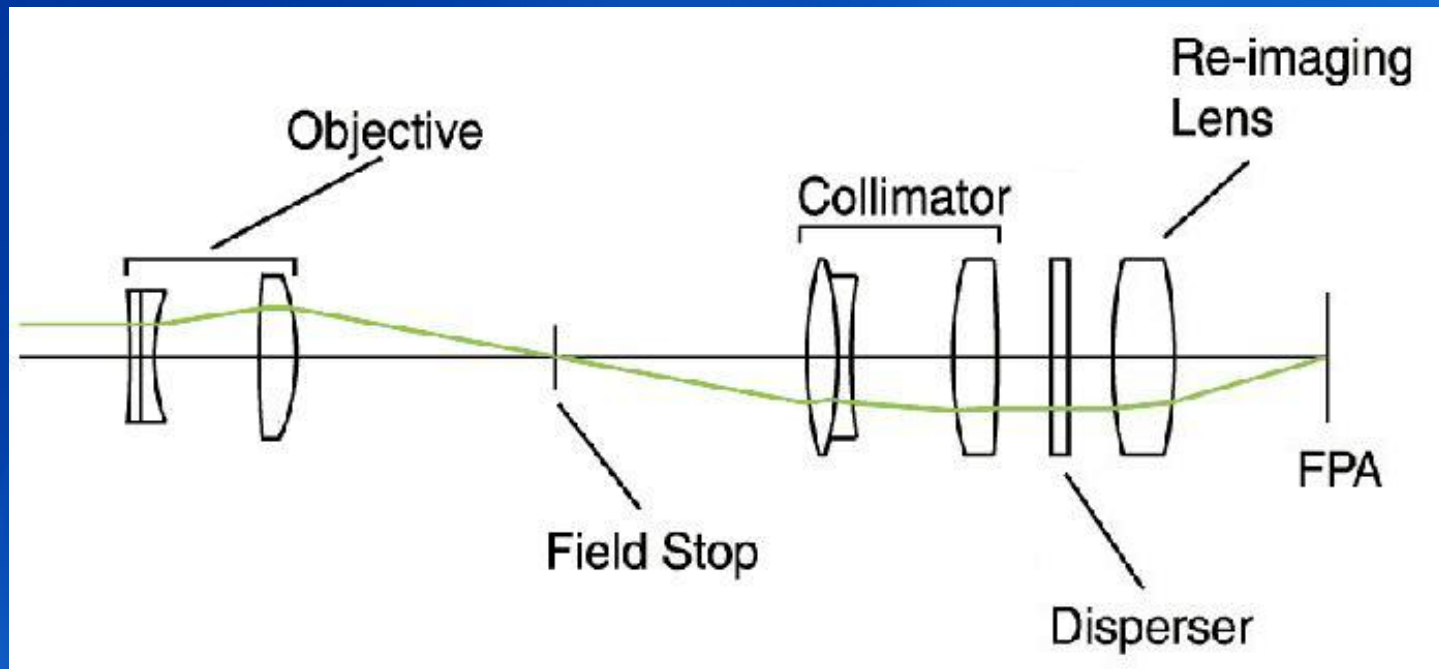
layout



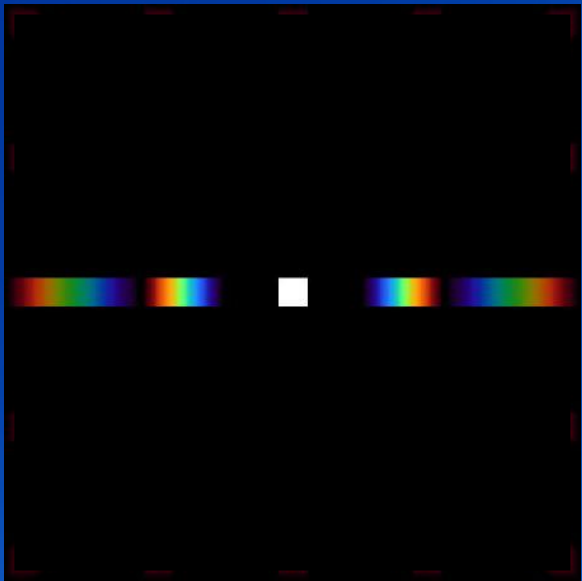
Layout with polarization components



Analysis of components

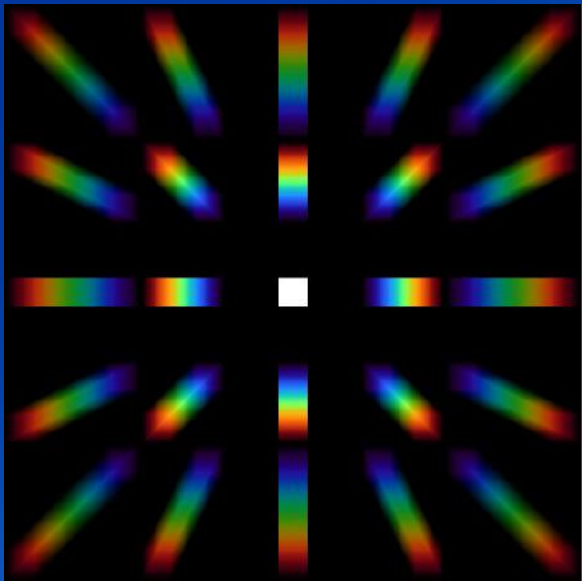


Diffraction Grating



With a blazed grating you can shape the individual grooves of a grating to control the amount of light sent into a particular diffraction order.

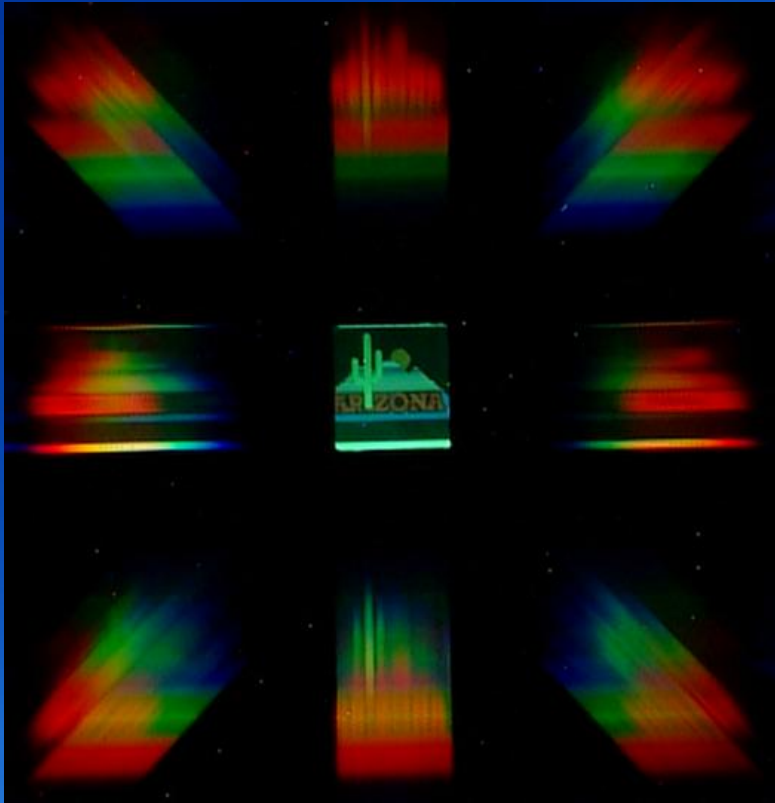
CTIS Disperser



The CTIS disperser is basically just a two-dimensional blazed grating.

Designed using algorithms for Computer Generated Holography.

Resulting Output From FPA



This is an example of the output from a visible CTIS. The “zero order” shows original object.

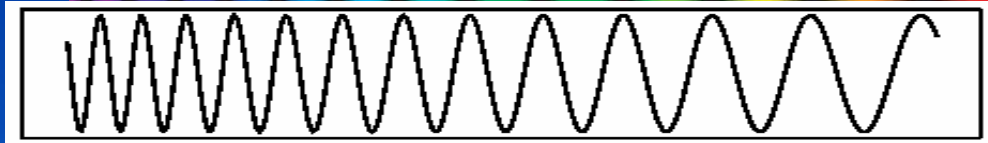
The CTIS uses techniques from tomography to reconstruct the spectral data.

How can we get polarization data?

flat spectrum



channeled spectrum



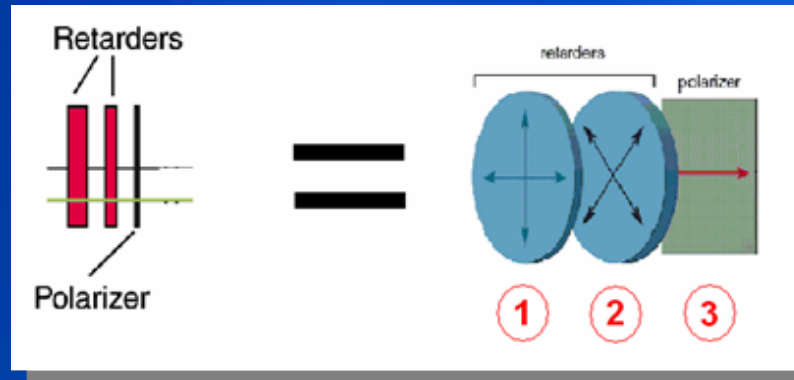
We can modulate the polarization data onto the spectrum using a technique called “Channeled Spectropolarimetry.”

Stokes Vectors

$$\mathbf{s} = \begin{pmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \end{pmatrix} = \begin{pmatrix} I_{total} \\ I_0 - I_{90} \\ I_{45} - I_{-45} \\ I_{rc} - I_{lc} \end{pmatrix}$$

Using Stokes vectors we can conveniently model the electric field of light passing through the system.

Mueller matrices



$$\mathbf{s}_{\text{out}} = \underbrace{\begin{pmatrix} 1/2 & 1/2 & 0 & 0 \\ 1/2 & 1/2 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}}_{\textcircled{3}} \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(\delta_2) & 0 & -\sin(\delta_2) \\ 0 & 0 & 1 & 0 \\ 0 & \sin(\delta_2) & 0 & \cos(\delta_2) \end{pmatrix}}_{\textcircled{2}} \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos(\delta_1) & \sin(\delta_1) \\ 0 & 0 & -\sin(\delta_1) & \cos(\delta_1) \end{pmatrix}}_{\textcircled{1}} \begin{pmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \end{pmatrix}$$

By using Mueller Matrices for each of the elements we can find the electric field output of the system.

Intensity distribution

$$s_{\text{out}} = 1/2 \begin{pmatrix} s_0 + s_1 \cos(\delta_2) + s_2 \sin(\delta_1) \sin(\delta_2) - s_3 \cos(\delta_1) \sin(\delta_2) \\ s_0 + s_1 \cos(\delta_2) + s_2 \sin(\delta_1) \sin(\delta_2) - s_3 \cos(\delta_1) \sin(\delta_2) \\ 0 \\ 0 \end{pmatrix}$$

$$2I(\sigma) = s_0 + s_1 \cos(\delta_2) + s_2 \sin(\delta_1) \sin(\delta_2) - s_3 \cos(\delta_1) \sin(\delta_2)$$



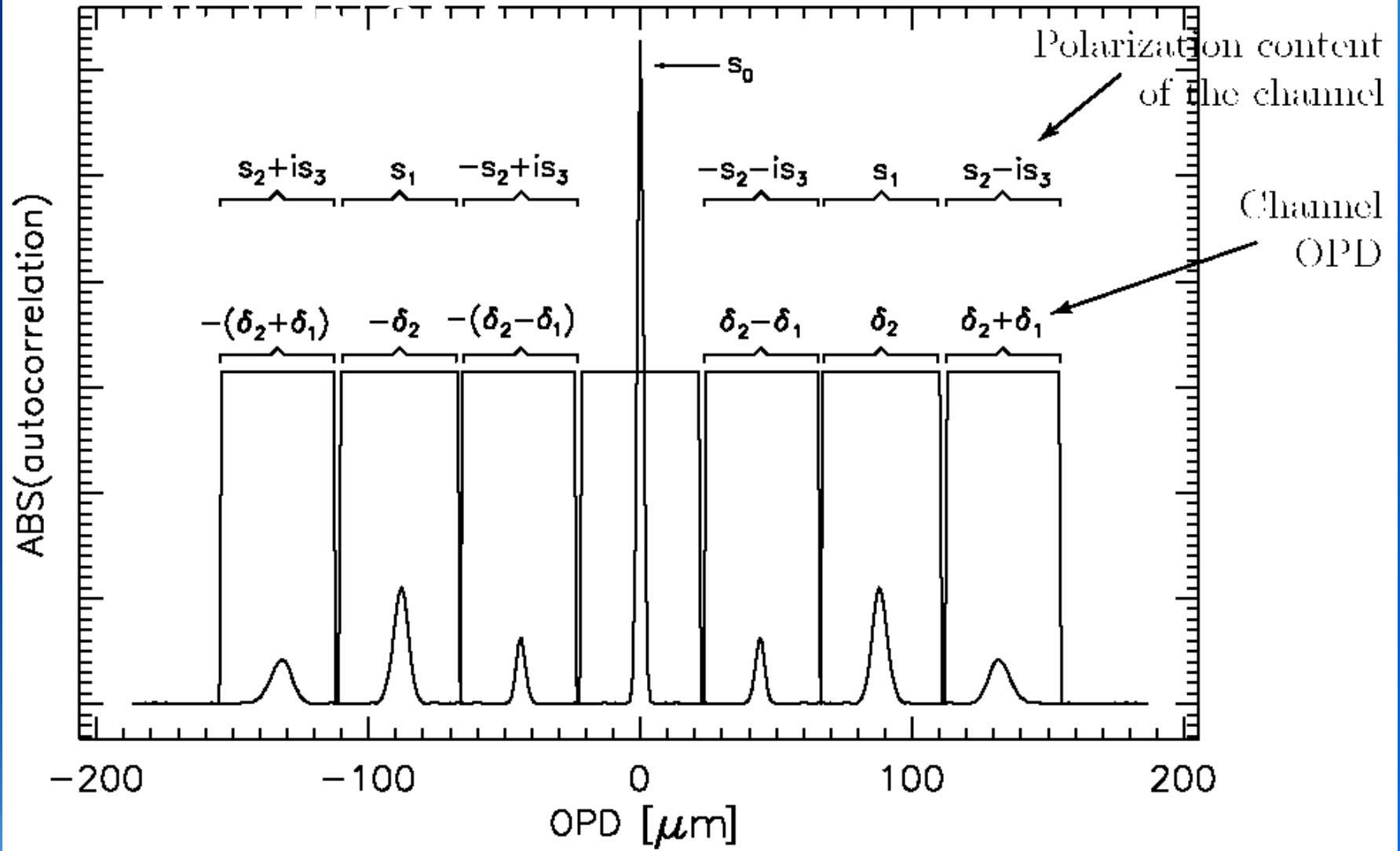
math

We know that the intensity output is a combination of sine and cosine terms based on the polarization of the light. Can rewrite the equation using the Euler formula to get...

$$I(\sigma) = \frac{1}{2}s_0 + \frac{1}{4}s_1(e^{i\delta_2} + e^{-i\delta_2}) + \frac{1}{8}[(s_2 - is_3)e^{i(\delta_2+\delta_1)} + (s_2 + is_3)e^{-i(\delta_2+\delta_1)} + (-s_2 - is_3)e^{i(\delta_2-\delta_1)} + (-s_2 + is_3)e^{-i(\delta_2-\delta_1)}]$$

We can see that the modulation is composed of seven different frequency terms or frequency “channels.” Can see the channel separation by taking the Fourier Transform.

OPD SPECTRUM



reconstruction

- To reconstruct the polarization data across the spectrum, multiply by an appropriate windowing function that reduces the “ringing” in the spectrum and inverse transform.
- Choice of windowing function is important but does not eliminate ringing problem. To get reasonable data can truncate the edges of the spectrum.

Demo



Review

- CTIS systems are unique in the fact that they can acquire x, y, and wavelength data without any scanning.
- Can be modified to capture polarization data
- Captures all data in a single integration time with no moving parts.
- Can analyze things that quickly change in time, without the artifacts normally introduced by scanning instruments.

Questions

