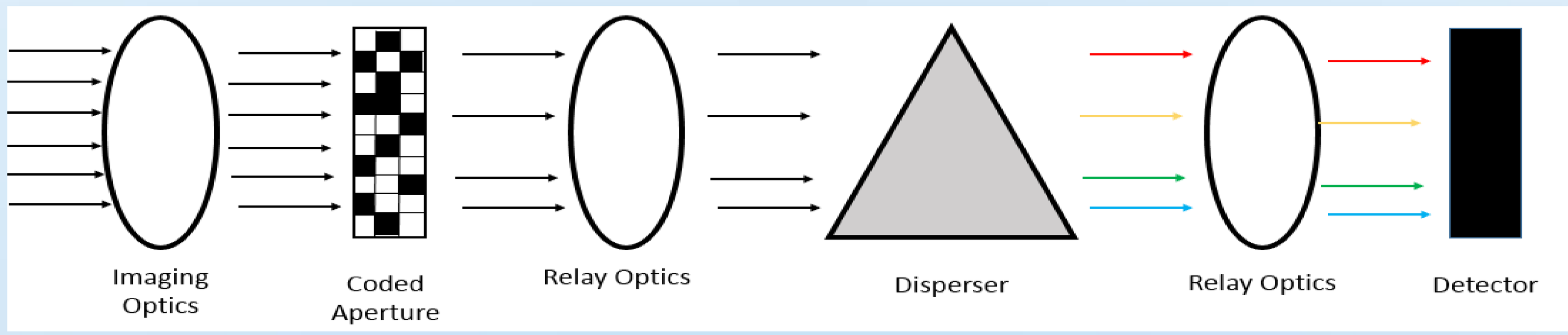
Enhanced CASSI Snapshot Imager Using Dual Prism Dispersion

Objective: Achieve A Tuneable-Spectral-Channel Snapshot Imaging System Using Dual-Prism

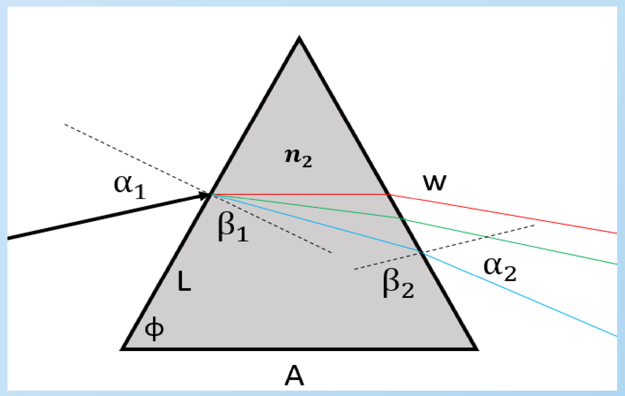
Introduction

- Coded Aperture Snapshot Spectral Imaging (CASSI) has been proposed as a snap shot multispectral imaging system capable to acquire spectral and spatial information simultaneously.
- The system exploits the theory of compressive sensing to recover spatial and spectral information through the multiplex of coded data obtained by a coded aperture mask. Current CASSI system utilises either a single equilateral prism or double Amici prism as the dispersion optics.
- Limitations of current CASSI system: The spectral wavelengths of the system are fixed due to the non-linear dispersions in the single prism/Amici.
- Proposed: a dual-prism for the CASSI which provides a tuneable-spectral-channel snapshot imaging system.
- The spectral wavelengths can be tuned by adjusting the air gap between the dual prisms.
- Aberrations due to chromatic, spherical and astigmatism will be dealt with in the future work.

System Models

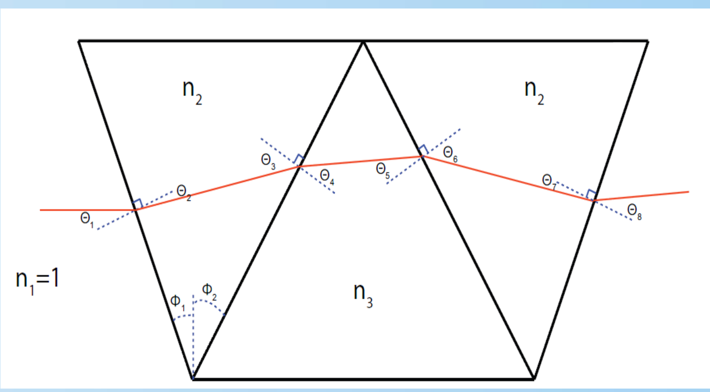


Schematic of Single Disperser CASSI system



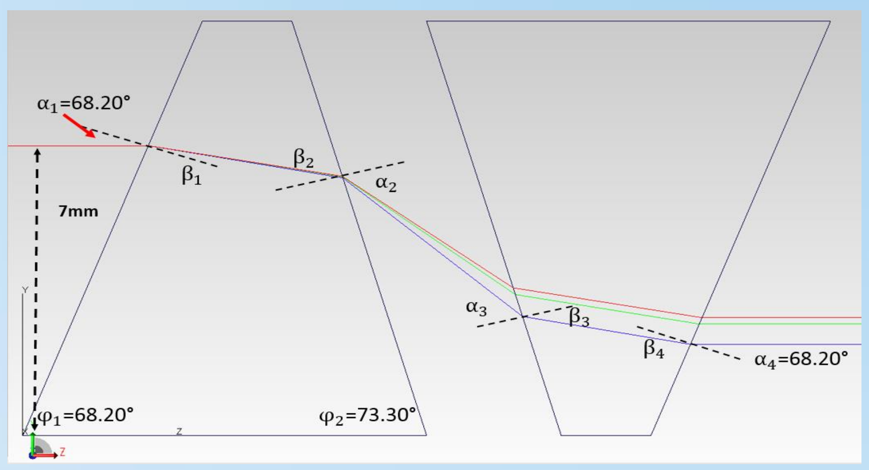
Single Equilateral Prism:

- Simply follows Snell's law
  $n_1 \sin(\alpha) = n_2 \sin(\beta)$
- Optical axis are not on-axis



Double Amici Prism:

- Central wavelength is undeviated through the prism
- Missing spectral channels in reconstruction



Dual-Prism:

- Incident angle = Exit angle
- Adjustable air gap
- Fewer prisms and Less light propagation loss
- Refractive Relationships inside prism

$$\sin(\alpha_1) = n_2 * \sin(\beta_1)$$

$$\beta_2 = 180° - \varphi_1 - \varphi_2 - \beta_1$$

$$\sin(\alpha_2) = n_2 * \sin(\beta_2)$$

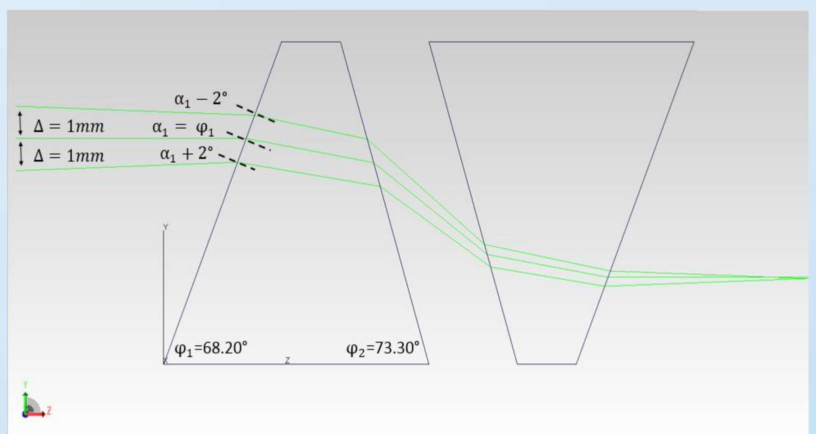
$$\alpha_3 = \alpha_2$$

$$\sin(\beta_3) = \sin(\alpha_3)/n_2$$

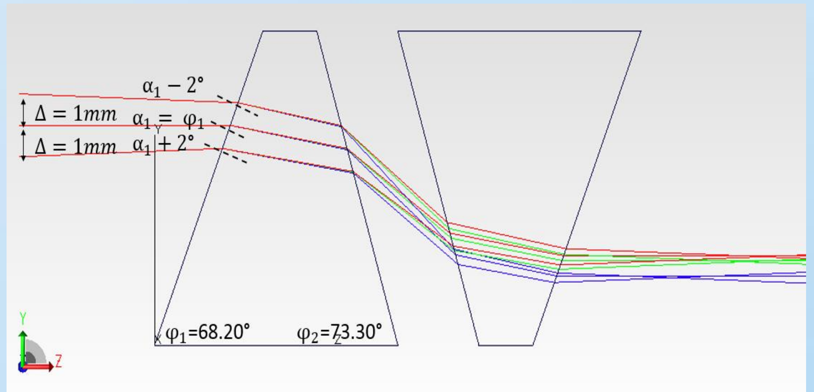
$$\beta_4 = 180° - \varphi_1 - \varphi_2 - \beta_3$$

$$\sin(\alpha_4) = n_2 * \sin(\beta_4)$$

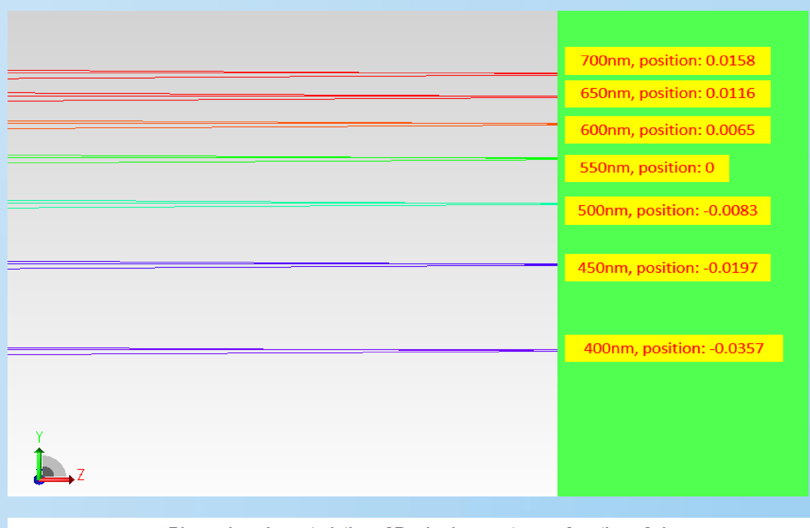
Simulations and Analysis



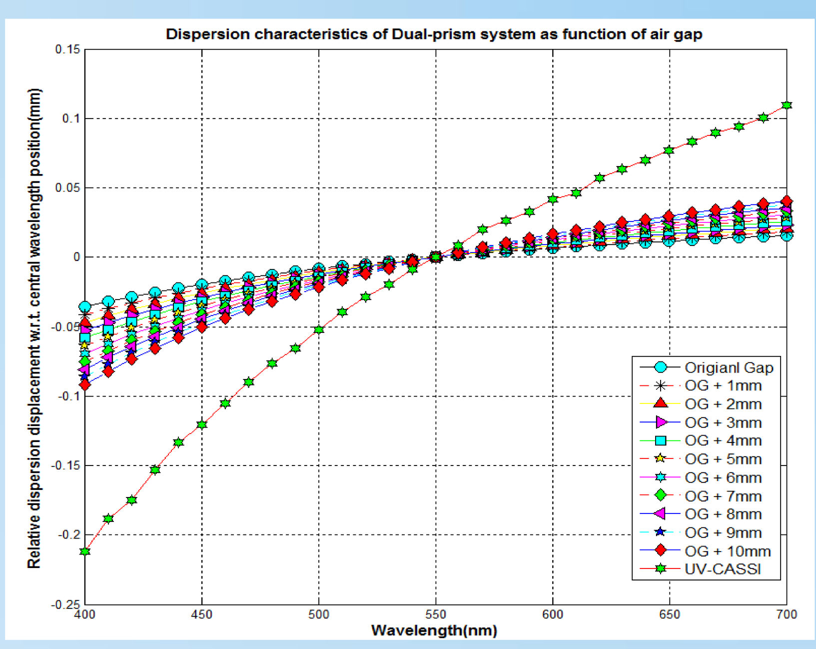
- Ray tracing of Dual-prism system in TracePro
- Three incident rays @ 550nm from 66.20°, 68.20° and 70.20° into the prism
- The interaction where three rays focus is not exactly a single point



- Ray tracing of Dual-prism system in TracePro
- Three incident rays @ 550nm, 400nm and 700nm from 66.20°, 68.20° and 70.20° into the prism
- The focal plane is not a plane due to the axis shift



- After calculations in Matlab, the system parameters are adjusted to minimise the errors in focusing
- The material is N-BK7
- $\varphi_1 = 85.90°$ and $\varphi_2 = 73.70°$
- Length of prism bottom is 7.5mm, prism height is 20mm,
- Initial air gap is 5.8484mm,
- Incident angle range 0.8°
- Central light source height is 10mm
- Height difference between sources Δ = 0.5mm



- Dispersion characteristics of Dual-prism system as function of air gap from +0mm to +10mm compared with UV-CASSI reference data.

Table shows comparison of displacement of Dual-prism System(N-BK7) with three different gaps and UV-CASSI reference data

Band	Dual-prism System Air gap + 0mm	Dual-prism System Air gap + 5mm	Dual-prism System Air gap + 10mm	UV-CASSI System
400nm	-0.0357mm	-0.0638mm	-0.0919mm	-0.2117mm
450nm	-0.0197mm	-0.0351mm	-0.0506mm	-0.1208mm
500nm	-0.0083mm	-0.0149mm	-0.0215mm	-0.0526
550nm	0mm	0mm	0mm	0mm
600nm	0.0065mm	0.0115mm	0.0166mm	0.0426mm
650nm	0.0116mm	0.0207mm	0.0298mm	0.0753mm
700nm	0.0158mm	0.0282mm	0.0406mm	0.1051mm

Conclusion

- The purpose of the proposed dual-prism design is to enhance CASSI system's image reconstruction in terms of tuneable spectral channels.
- Dual-prism system avoids anamorphic distortion of the single prism system and it utilises two prisms instead of three prisms in double amici prism system.
- The dispersion on the unit pixels of focal plane array can be adjustable through the width of air gap between two prisms to realise a tuneable-spectral-channel snapshot imaging system.
- Future work involves system optimisation and aberration reduction.

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