Defence Research and Development Canada
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Enhanced target detection and identification in the Long-Wave IR using polarization

Denis Dion, D. A. Lavigne and
J. M. Thériault

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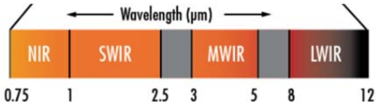
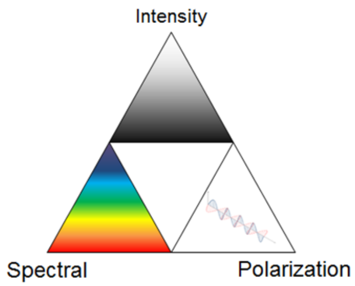
Outline

- Introduction (DRDC interests)
- Basic theory of polarimetric sensing
- Example of P-Thermal detection
- Example of P-Identification of liquids/contaminants
- Future work

DRDC interests



- Main emphasis is on HSI
  - Development and exploitation of systems
  - Experimentation
  - Development of dedicated processing algorithms
- Phenomenology studies : exploitation of polarization



Polarimetric sensing – basic theory

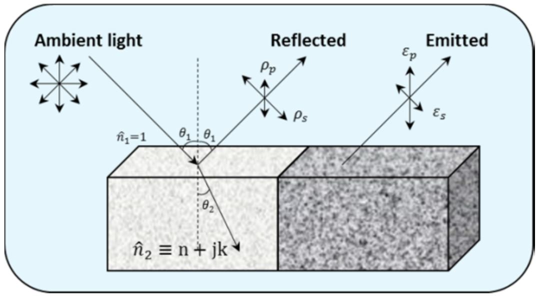
- Polarimetric signals can be described by the Stokes vector, and the *DOP/DOLP*:

$$S_0 = \frac{I_0 + I_{90} + I_{45} + I_{135}}{2}$$

$$S_1 = I_0 - I_{90}$$

$$S_2 = I_{45} - I_{135}$$

- At oblique viewing angles, a wide variety of materials polarize light



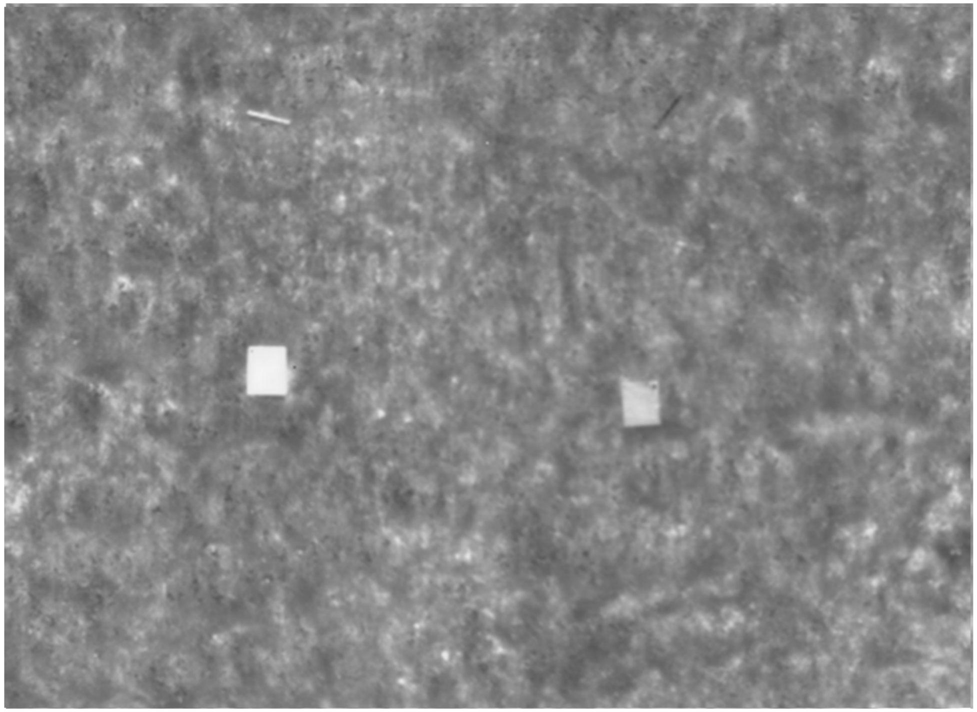
- Two radiance components can be defined:

$$L_n = \frac{\varepsilon_n L_t + \rho_n L_{src}}{2}$$

where ***n*** stands for the ***s*** and ***p*** components

Wideband thermal detection

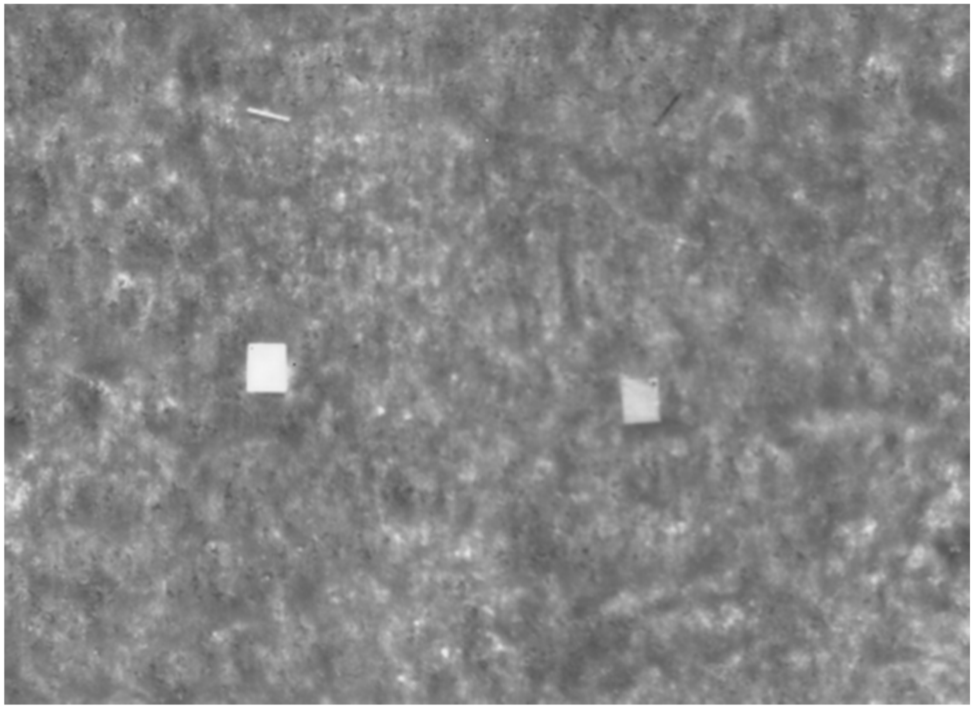
Can be severely degraded during ‘’Thermal cross-over’’ periods



MWIR time sequence, Oct 2015

Thermal detection

Can be severely degraded during ‘’Thermal cross-over’’ periods



MWIR time sequence, Oct 2015

Experimental setup

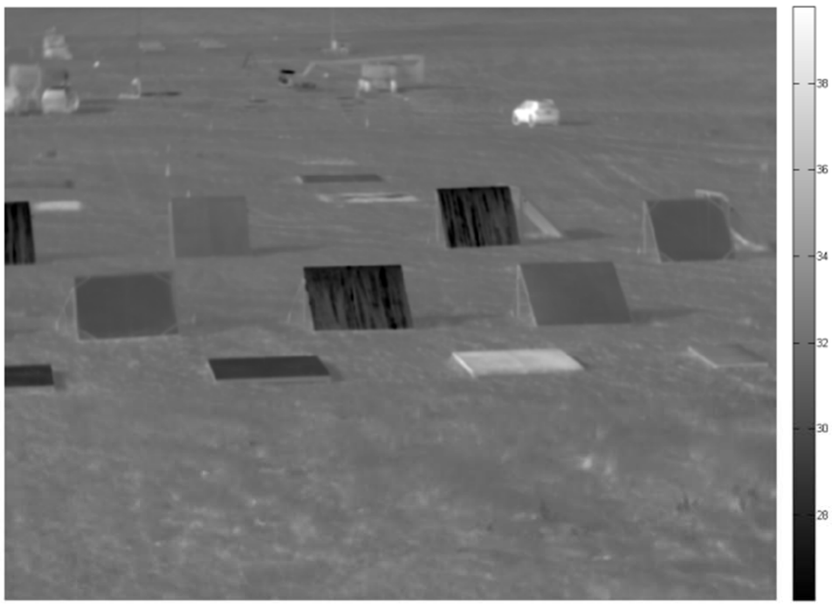
- Polarimetric sensors installed on a scissor lift, 7.5 m above the surface

- Target panels were clustered in 3 rows providing incidence angles of 36, 51 and 80 degrees

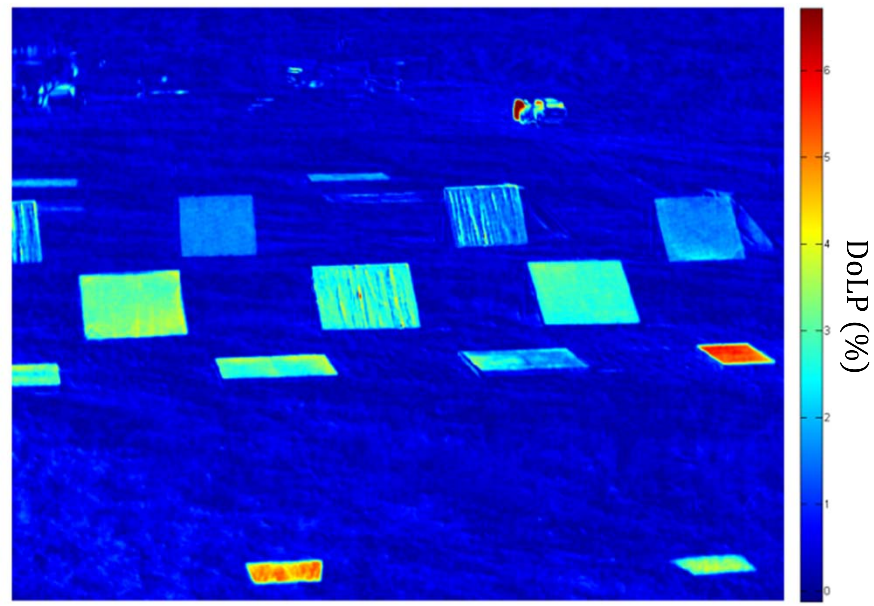
LWIR measurements

Sofradir (ATOM 1024) mounted with rotating polarizers

LWIR radiance



LWIR DOLP



P - Identification of contaminants

Based on material's ***s*** and ***p*** reflectivities

P-iCATSI

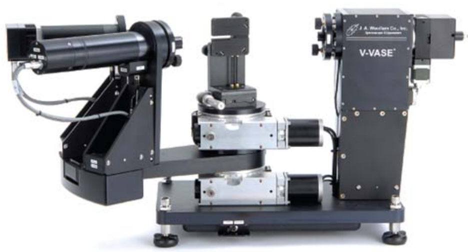
- 4-port LWIR FTIR (8 – 13 µm)
- Two 1x16 arrays
- Resolution (target) : 1 mrad
- Simultaneous recording of ***s*** and ***p*** spectra
- Spectral bin: 16 cm-1
- Real-time processing analysis

Processing

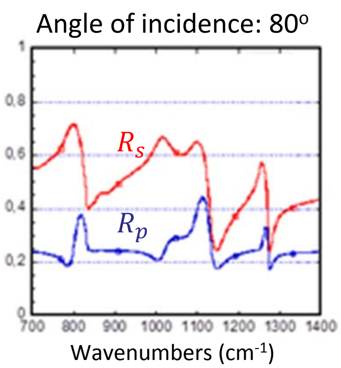
- Infer ***s*** and ***p*** reflectances from the measured ***s*** and ***p*** radiances
- A Generalized Likelihood Ratio Test (GLRT) algorithm is applied against archived optical parameters for the ***s*** and ***p*** components

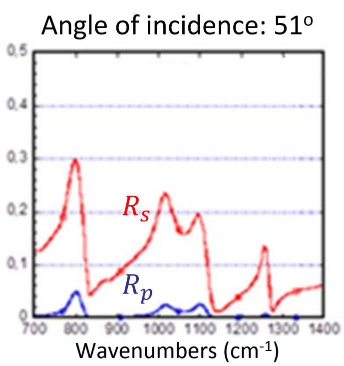
Measurement of material optical quantities

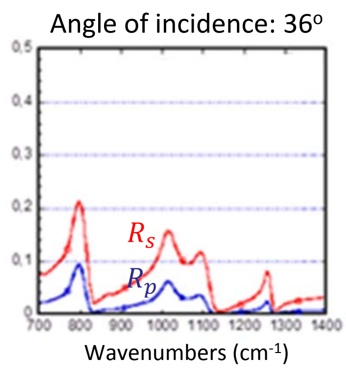
Using COTS Ellipsometers

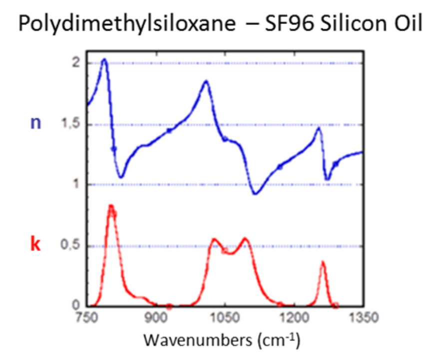


- P-Fresnel reflectances are derived from the measured amplitude and phase
- Optical constants ***n*** and ***k*** can also be estimated (after *Theriault, et al. (2016)*)





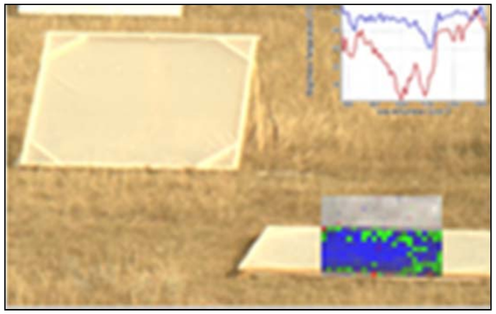




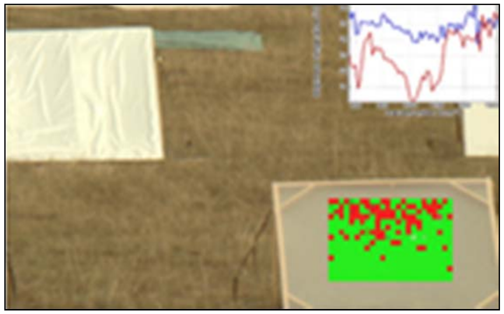
P - Identification : experimental results

ID of silicon oil at the surface of polyethylene plate

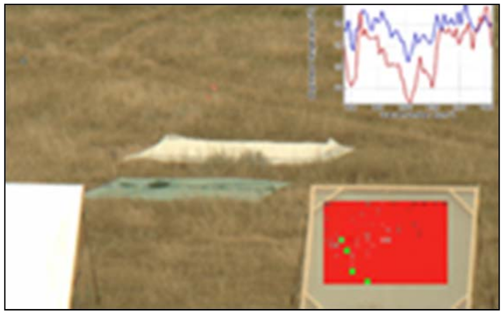
Angle of incidence: 80º



Angle of incidence: 51º



Angle of incidence: 36º



Blue : silicon at 80 deg incidence

Green: silicon at 51 deg

Red: silicon at 36 deg ;

Future work on polarization

- Continuing data collection for varying system configurations, atmospheric conditions, and scenarios of operation

- A solid modeling capability is required for a correct understanding of the P-sensing phenomenology in the atmosphere:

  - To explain observations
  - To anticipate detection performance enhancement under specific conditions
  - To help design/develop new sensing systems
  - To estimate sensor performances under scenarios that are difficult to experiment
  - To cast light on new effects

DRDC recognizes the current lack of models and is articulating new activities aimed at providing solutions

Conclusions

- In Wideband LWIR, examples were shown wherein polarization provides a solution to the frequent thermal cross-over events
- With P-iCATSI, polarization allows identification of contaminants; examples showed sensitivity to the observation angles of incidence
- DRDC recognizes the need of a compliant modeling capability for the study of P- phenomenology in the atmosphere

References

Lavigne, D.-A., Thériault, J.-M., Dion, D., Fortin, G., Breton, M., “Enhanced target detection and identification using multispectral and hyperspectral polarimetric thermal measurements ”, SPIE SPIE Security + Defence: Electro-Optical and Infrared systems – Technology and Applications, Berlin (Germany) (2018).

Thériault, J.-M., Fortin, G., Lacasse, P., Bouffard, F., and Lavoie, H., “Using linear polarization for LWIR hyperspectral sensing of liquid contaminants,” Proc. SPIE Optical Engineering + Applications: Polarization Science and Remote Sensing VI 8873 (2013)

Thériault, J.-M., Fortin, G., Lacasse, P., and Gagné, G., “Measurements of optical constants (n, k) in the LWIR,” DRDC Scientific Report DRDC-RDDC-2016-R153, DRDC Valcartier (2016).