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ADVANCED TECHNOLOGIES


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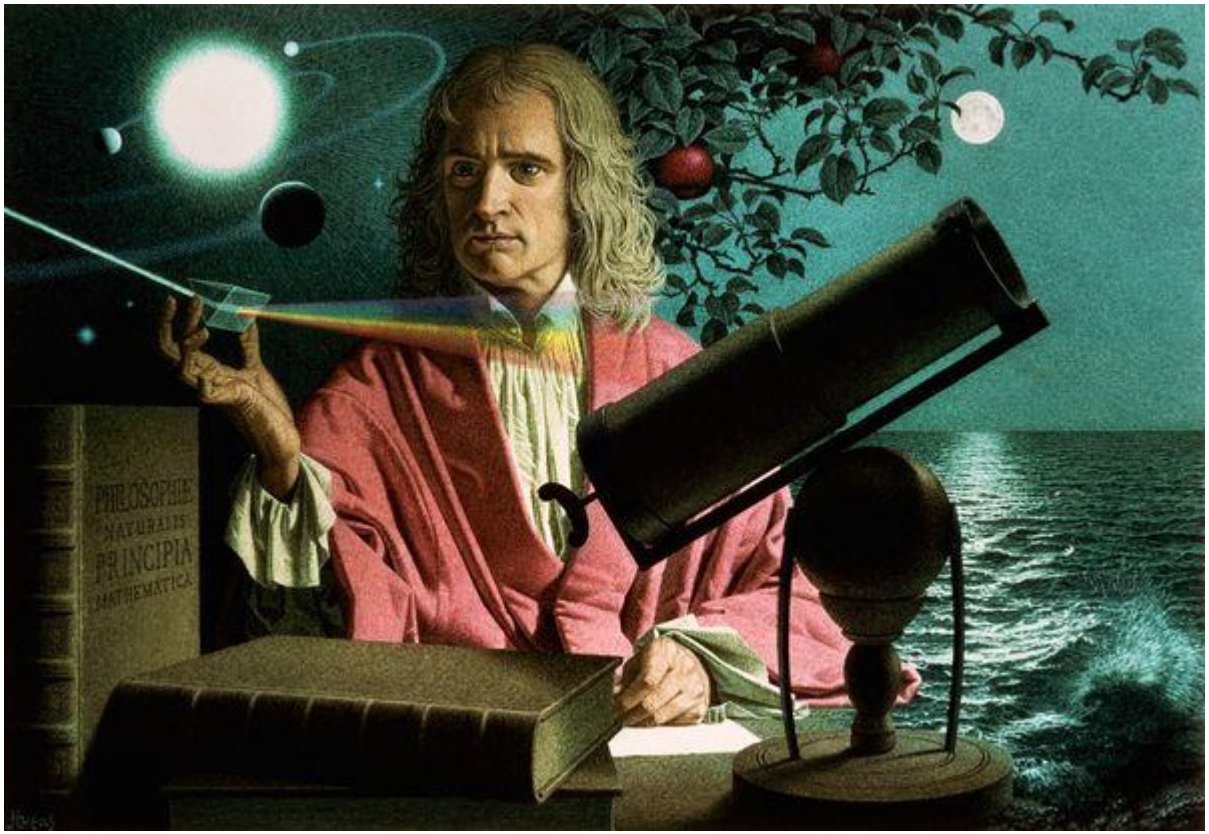
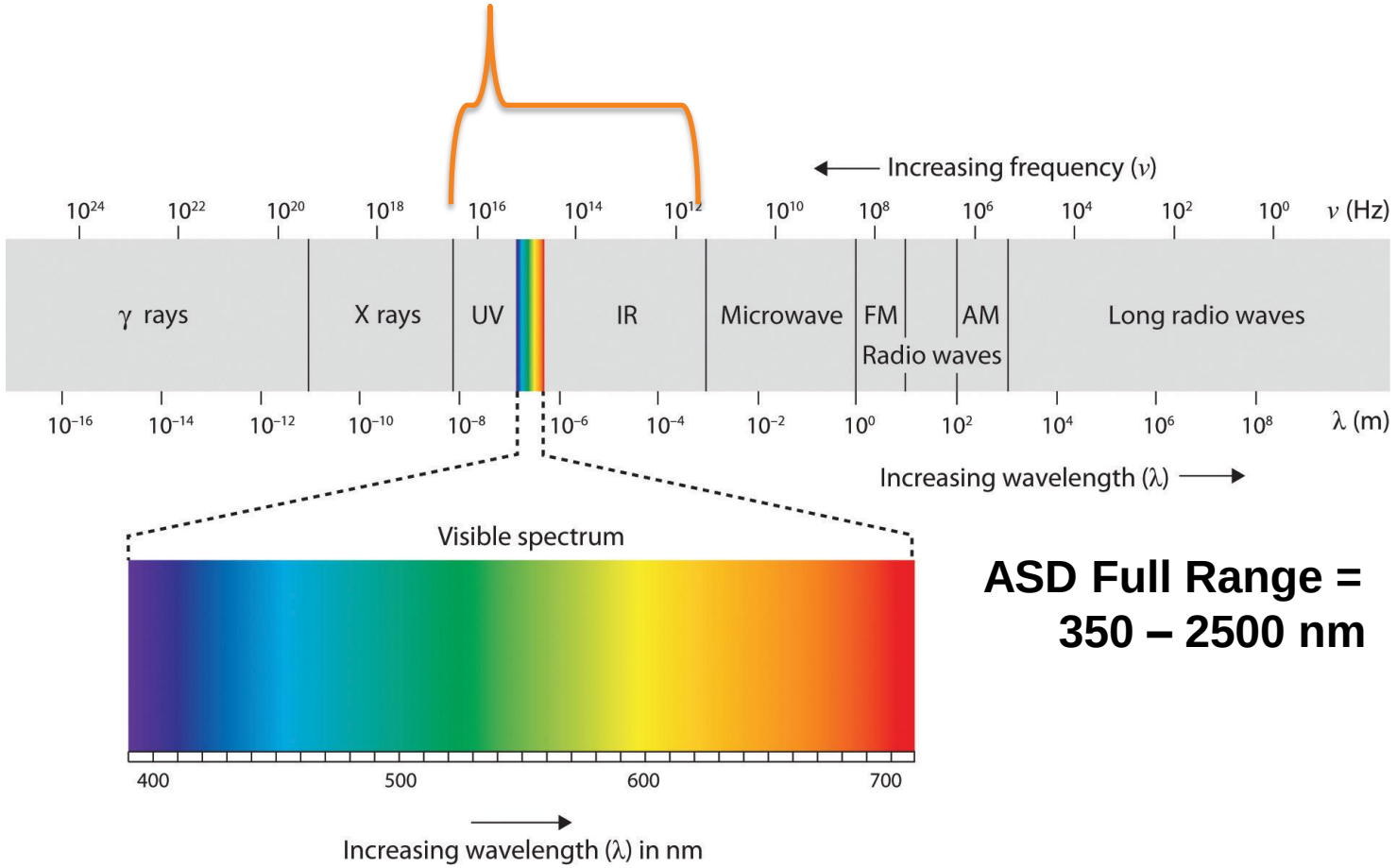
What is an optical spectrometer /spectroradiometer?



Optical spectrometer/spectroradiometer measures light properties in the optical region.

(Optical: controllable by lenses, mirrors, prisms, and fiber optics.)



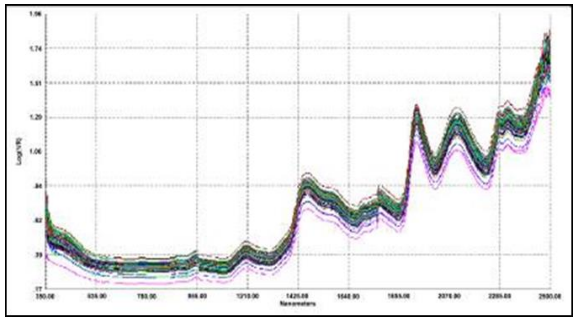
ASD Full Range = 350 – 2500 nm

Why use NIR?

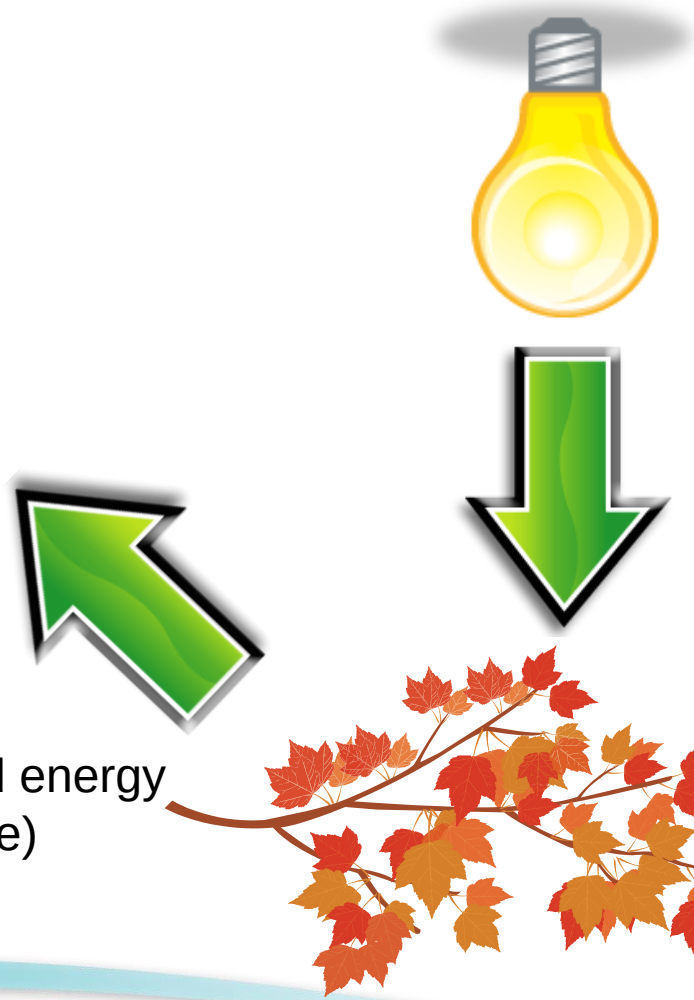
Why use NIR?

- Non-destructive measurements
- Little or no sample prep
- Readings in milliseconds
- Ease of operation
- Accurate and precise

Collecting Reflectance/Transmittance Spectra



The ratio of the reflected energy of the Spectralon panel to the reflected energy of the sample creates a spectrum



Total energy falling on the sample (Irradiance)

Reflected energy (Radiance)

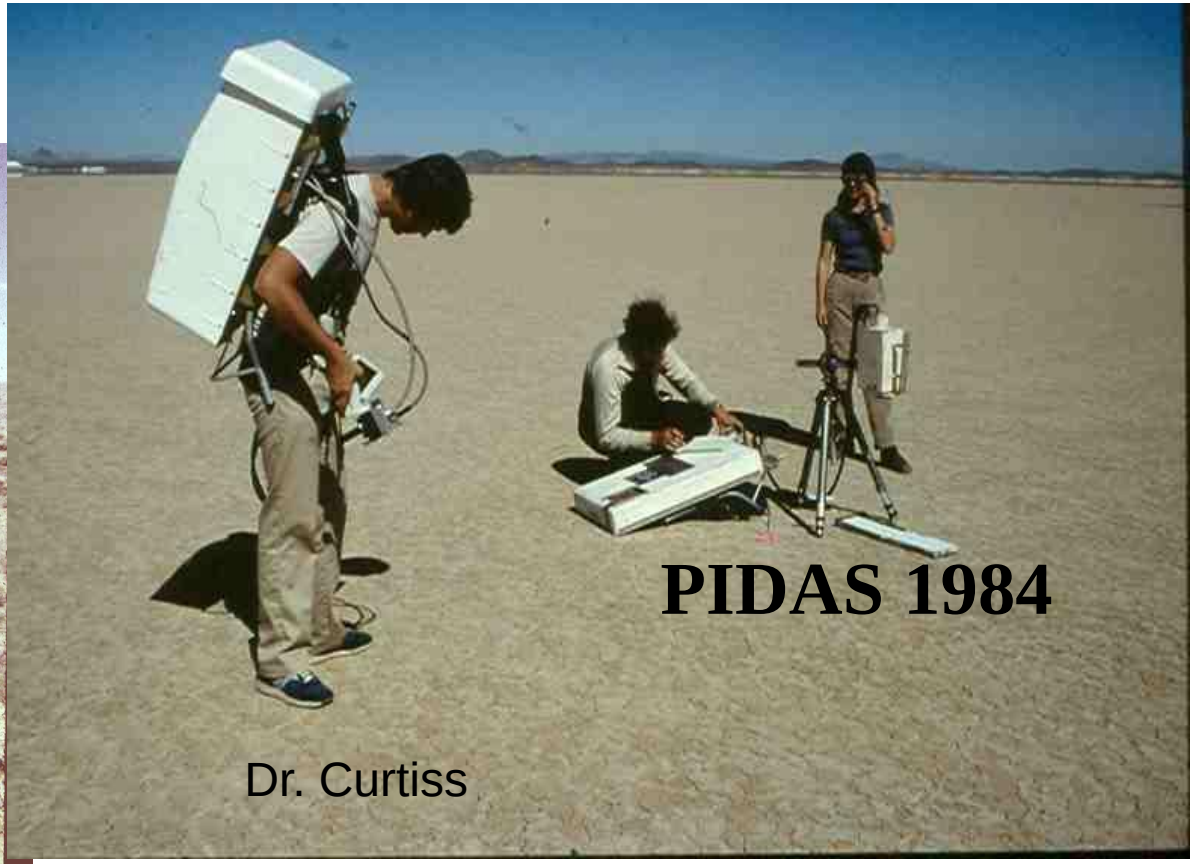
ASD history and products

Alexander Goetz **Brian Curtiss**

- **Founded in 1990 by Drs. Alexander Goetz and Brian Curtiss to meet demanding portable instrumentation needs for Remote Sensing**
- **Developed worldwide reputation for portable, robust, high speed spectrometers & spectroradiometers**
- **Over 3500 units in use in over 70 countries**

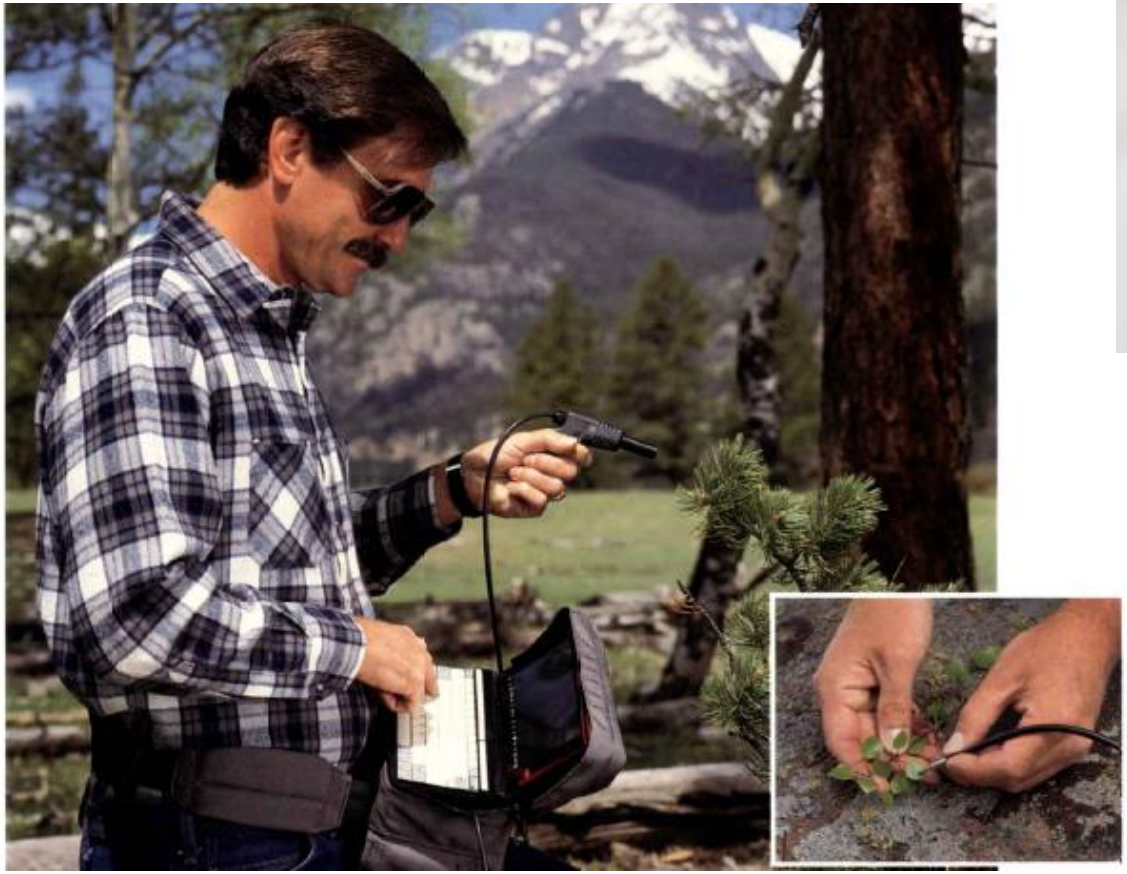
Goetz and Curtiss early research in portable spectrometry (before ASD)

Dr Goetz



First ASD product: Personal Spectrometer II 350-1050 nm

1990

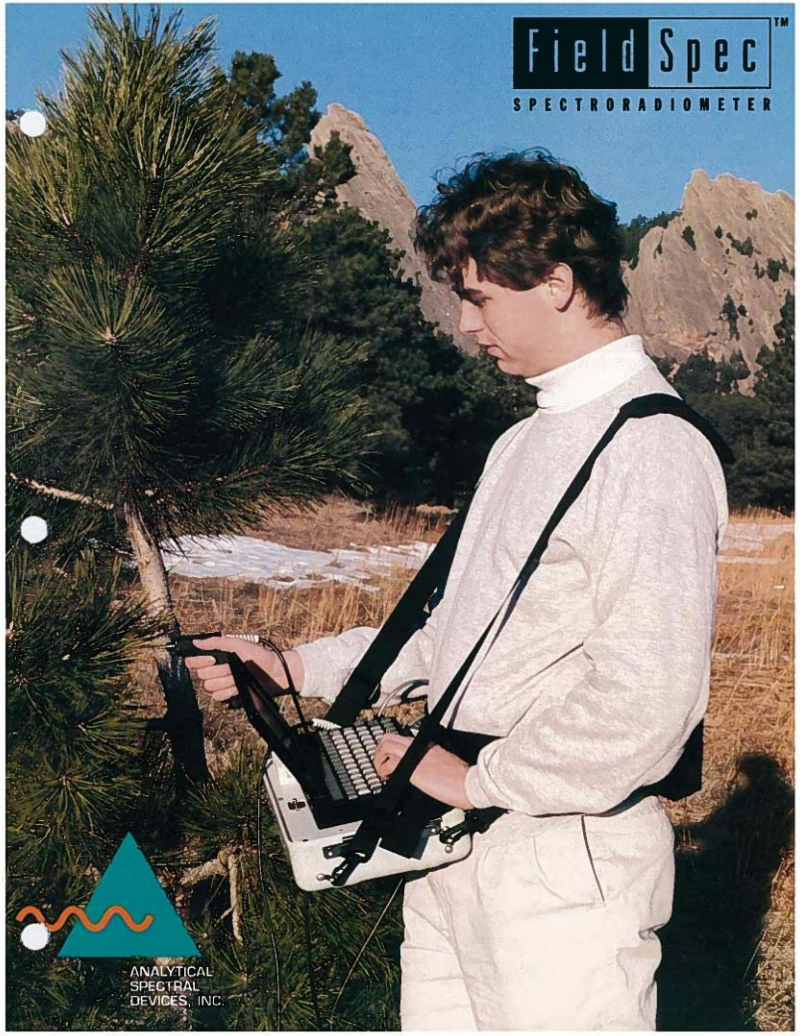


LabSpec® [original] Spectroradiometer 350-1050 nm

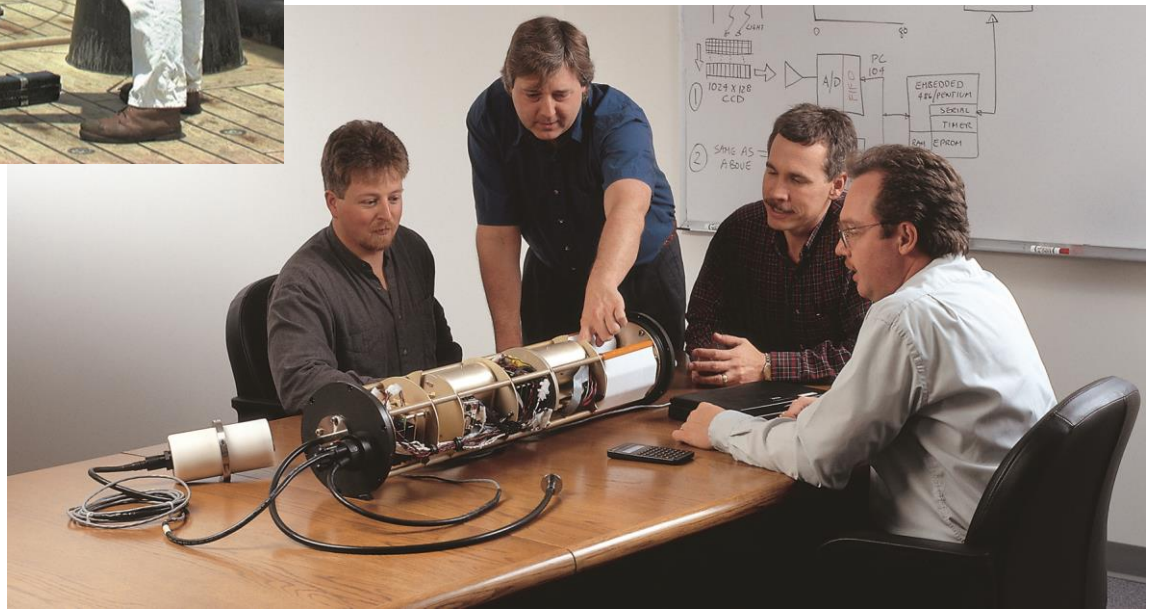
Winter 1992

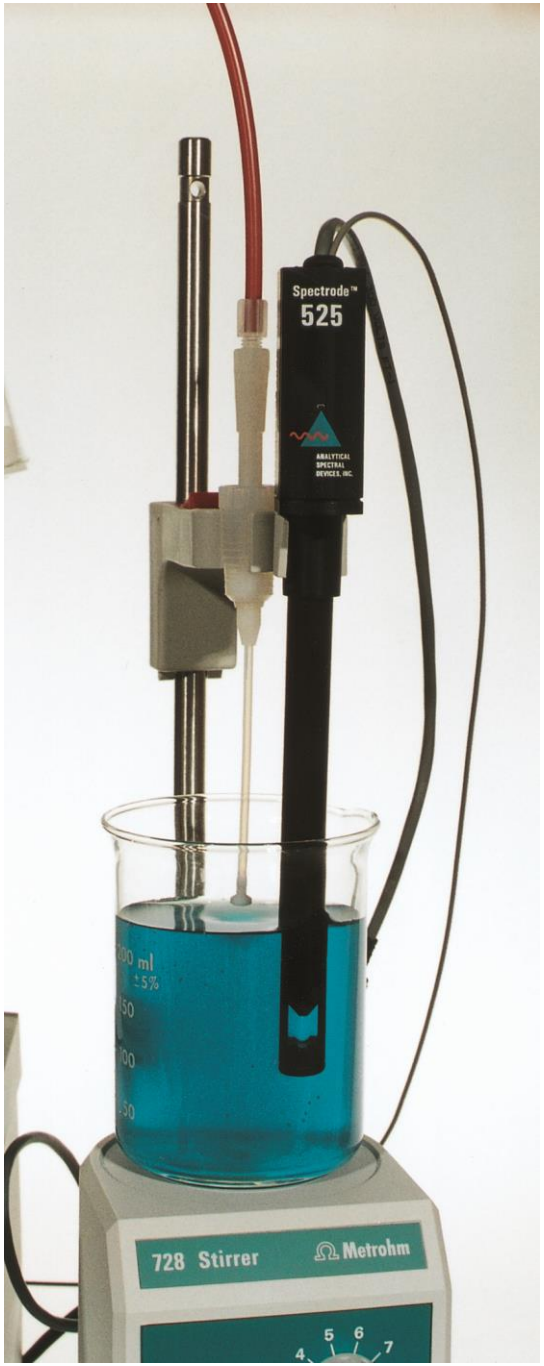
FieldSpec® Classic Spectroradiometer
350-2500 nm
or
350-1050 nm

Winter 1992



SeaSpec® Spectroradiometer 350-1050 nm

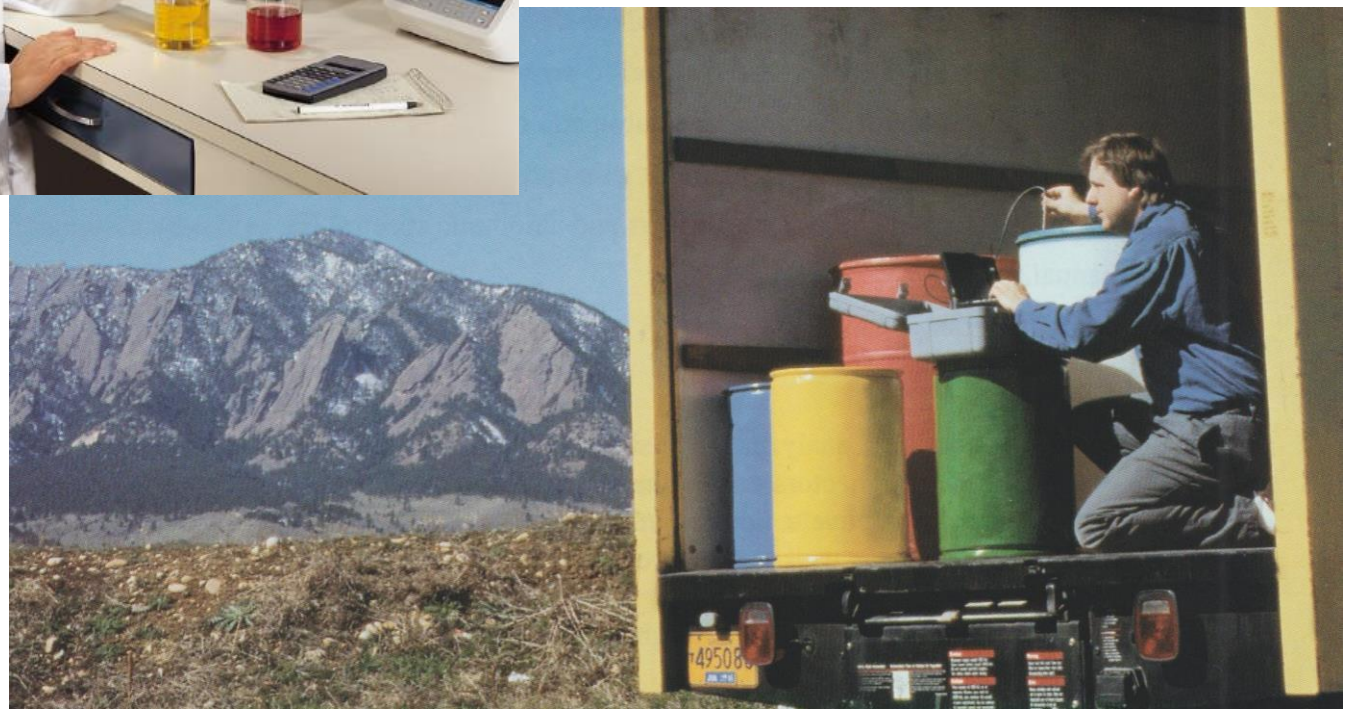




Spectrode
525 nm

For photometric titration

FieldSpec Chem Spectrometer 350-2500 nm



FieldSpec HandHeld [original] 325-1075 nm

2003

TerraSpec Examiner/Explorer Spectrometer 350-2500 nm

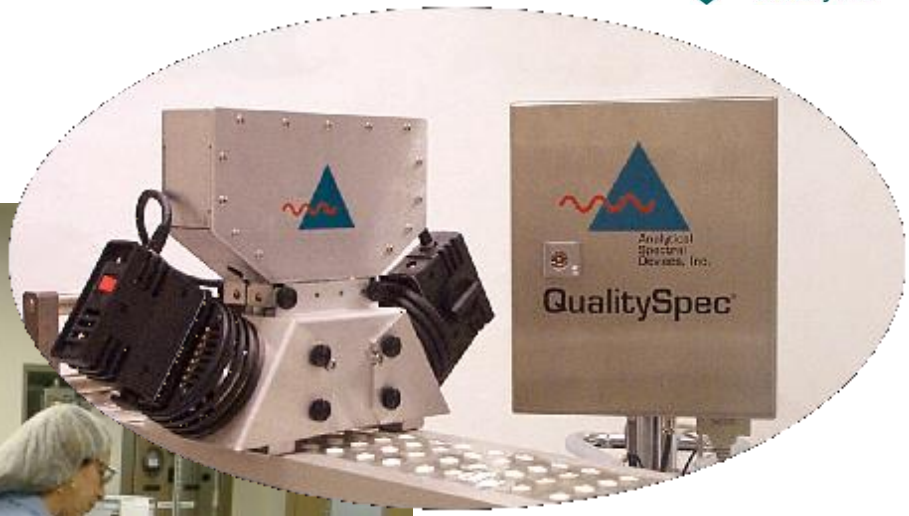
September 2006

LabSpec® 2500/2600/5000/5100 Spectrometer
350-2500 nm or 350-1050 nm

September 2006

AgriSpec® * Spectrometer 350-2500 nm

RxSpec® * & QualitySpec® 7000 On-line Spectrometers



**QualitySpec KB*
Spectrometer
350-2500 nm**

RxSpec 700Z Spectrometer 350-2500 nm

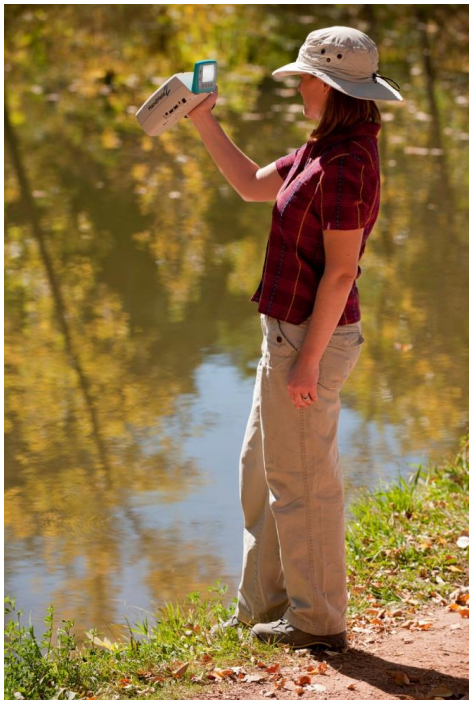
FieldSpec 3 Spectroradiometer 350-2500 nm or 350-1050 nm

Fall 2006

HandHeld 2 (325-1075 nm)

Fall 2010

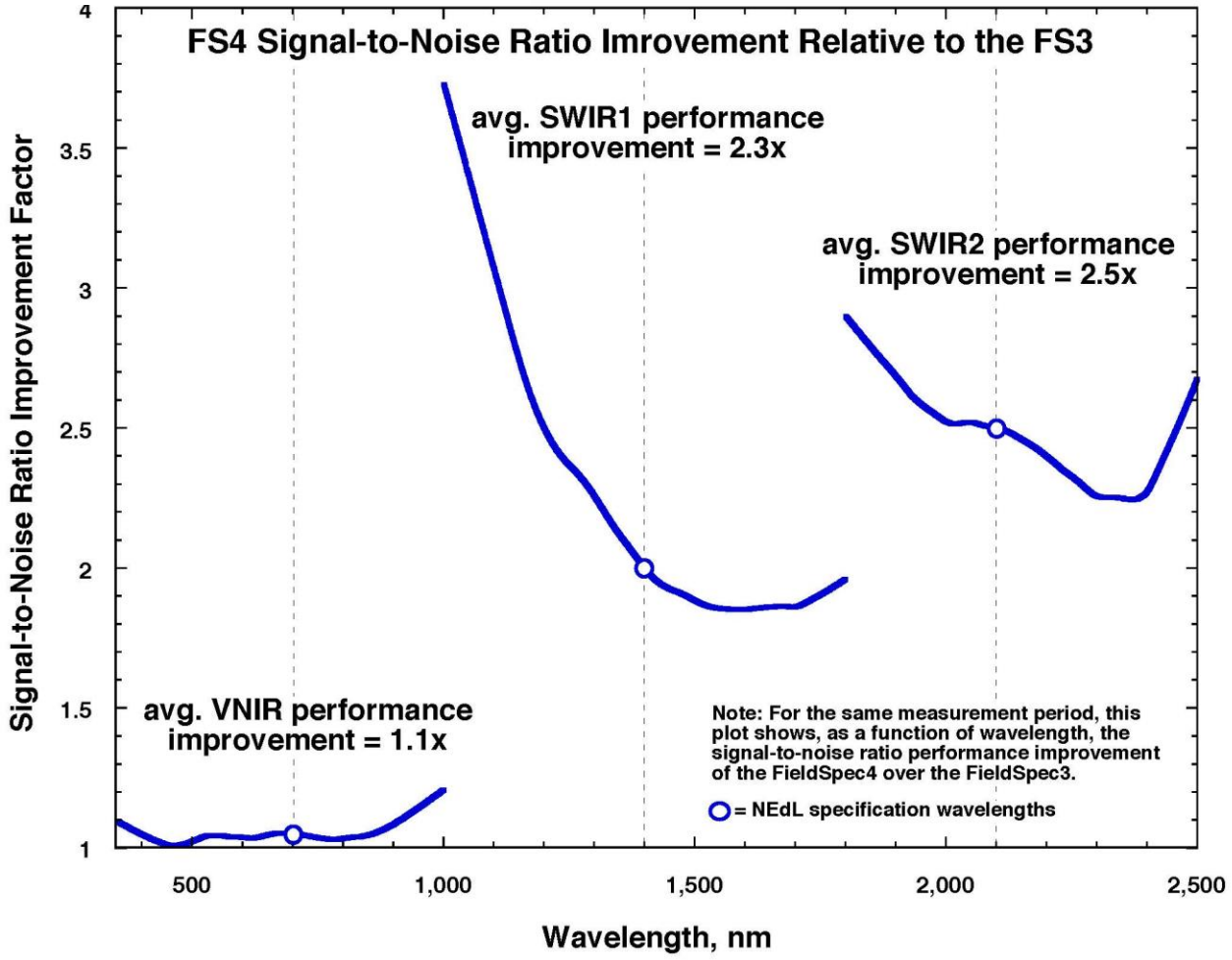
- Reflectance, Transmittance, Radiance, Irradiance
- Battery powered, field portable
- On-board, tilting display for spectrum display
- Local push-button operation
- Internal file storage of up to 2,000 spectra
- Scan over 325 – 1075 nm in 8.5 ms (selectable)
- ASD Proprietary Driftlock ™
- Standard 25 Deg Field-of-view
- Targeting: Integral red laser
- Weight: 1.2 kg (2.6 lbs) (w/batteries)



FieldSpec 4
350–2500 nm

January 2012

- Reflectance, Transmittance, Radiance, Irradiance
- Battery powered, field portable
- Complete scan over 350 – 2500 nm in 0.1 seconds
- Built-in ruggedized fiberoptic cable input (1.5 m standard) with 25 Deg Field-of-view
- Wireless WiFi interface 802.11g
- Backpack
- Interface with ASD Probes
- ENVI can import ASD binary files directly
- Weight 5.44 kg (12 lbs)

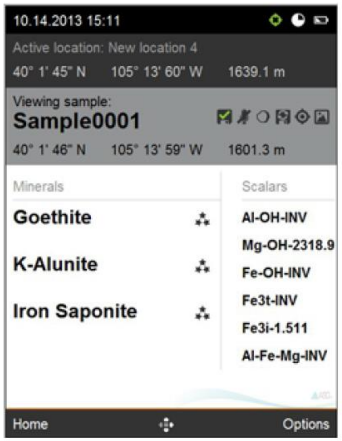

FS4 Signal-to-Noise Ratio Imrovement Relative to the FS3
avg. SWIR1 performance improvement = 2.3x
avg. SWIR2 performance improvement = 2.5x
avg. VNIR performance improvement = 1.1x
Note: For the same measurement period, this plot shows, as a function of wavelength, the signal-to-noise ratio performance improvement of the FieldSpec4 over the FieldSpec3.
= NEdL specification wavelengths
Signal-to-Noise Ratio Improvement Factor
Wavelength, nm
4
3.5
3
2.5
2
1.5
1
500
1,000
1,500
2,000
2,500

LabSpec 4/ 4 i / Bench Spectrometer 350-2500 nm

- Reflectance, Transmittance
- Battery powered, field portable (except benchtop model)
- Complete scan over 350 – 2500 nm in 0.1 seconds
- Wireless WiFi interface 802.11n or Ethernet
- Interface with ASD Probes
  (i model includes an internal broad-spectrum halogen li
- Weight 5.44 kg (12 lbs)

TerraSpec 4 Spectrometer 350-2500 nm

2013



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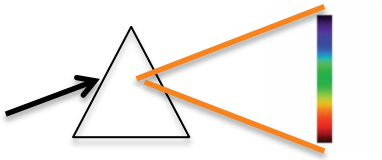
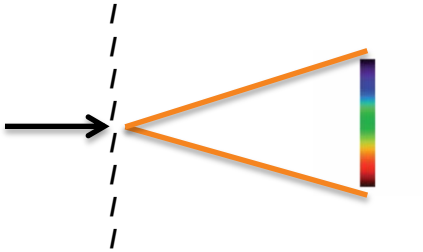
TerraSpec Halo and QualitySpec® Trek Spectrometers 2013, 2014

- Spectral Reflectance 350 – 2500 nm
- Battery powered, field portable
- Height x Width x Depth: 31 x 10 x 30 cm, (12.3 x 4.0 x 11.7 in)
- Weight with battery 2.5 kg, (5.5 lbs); Weight without battery 2.0 kg, (4.3 lbs)
- On-board GPS, voice audio recorder for sample descriptions.
- Languages English, Spanish, Chinese
- A single fully charged battery outputs for 4 to 6 hours depending on audio
- On board Spectral storage of ~7300 spectra w/o audio, ~300 with audio (recommend syncing after every 1000)
- Manager allows for 10 GB limit for each project.
- Halo only: Library spectra for 130 minerals, mineral prediction and scalar calculation based on reflectance spectra.

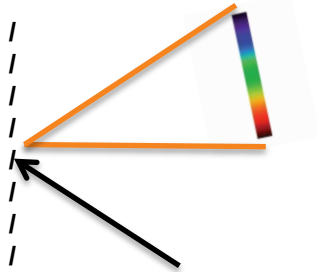
Methods of interrogating light as a function of wavelength or frequency



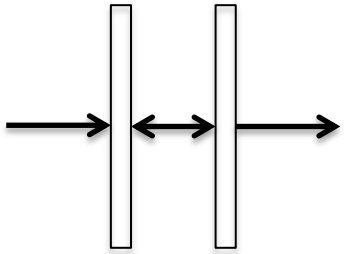
Prism



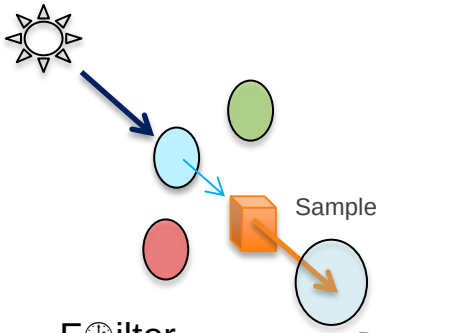
Transmissive diffraction grating



Reflective diffraction grating **(ASD is this type)**



Interferometer

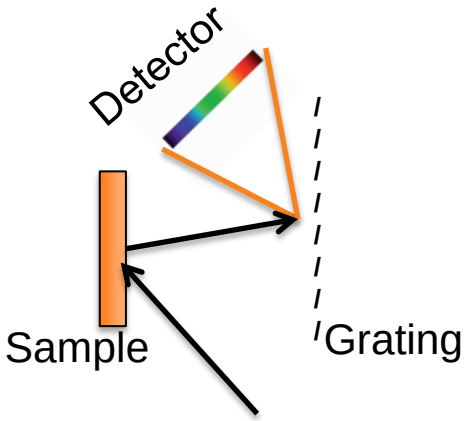


Filter

Film

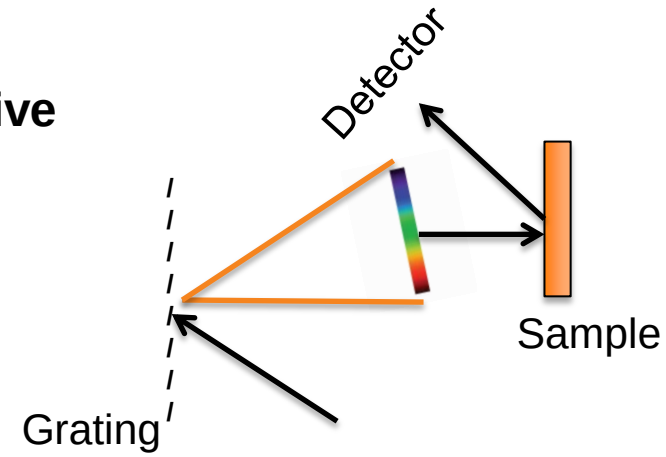
Instrument approaches

Post-dispersive
(ASD is this type)



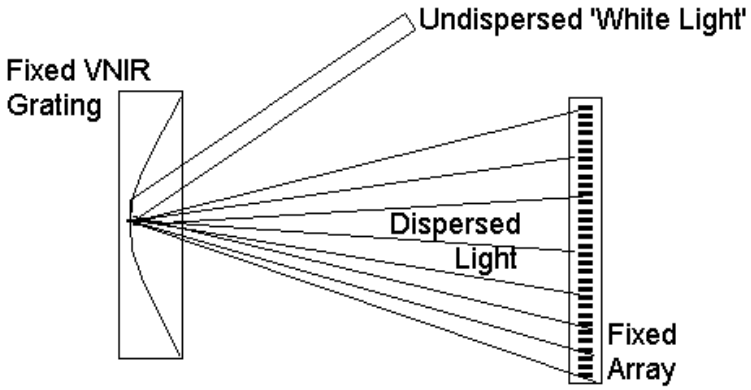
White light reflected off of
or transmitted through sample,
then dispersed.

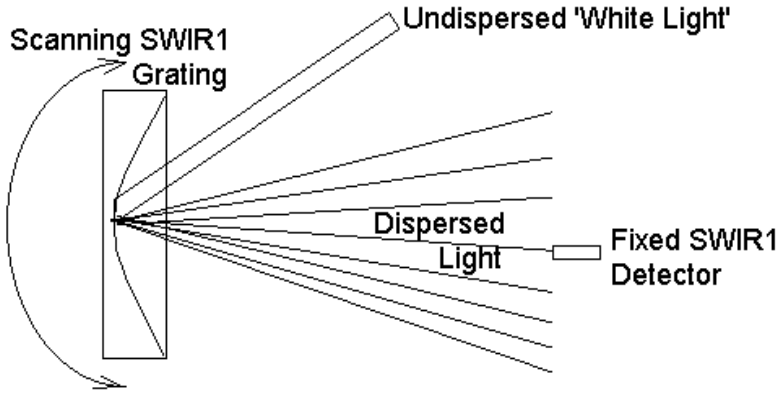
Pre-dispersive

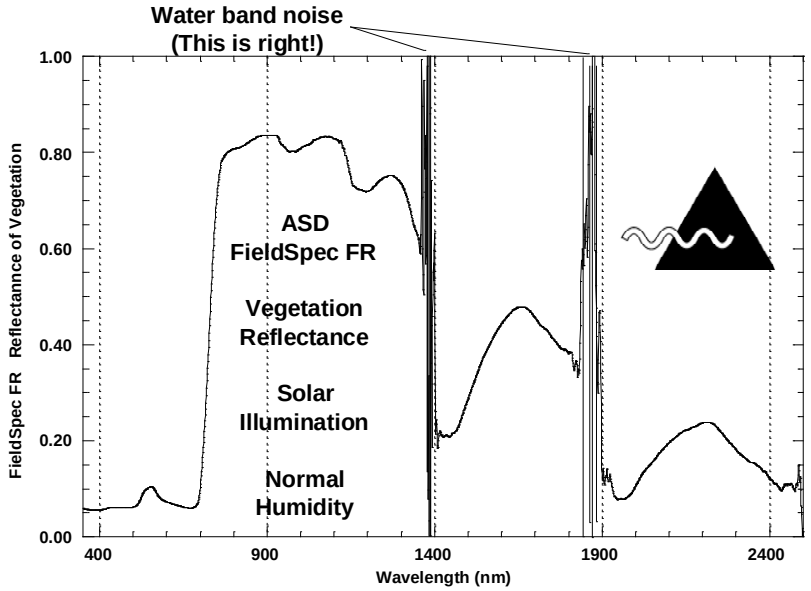


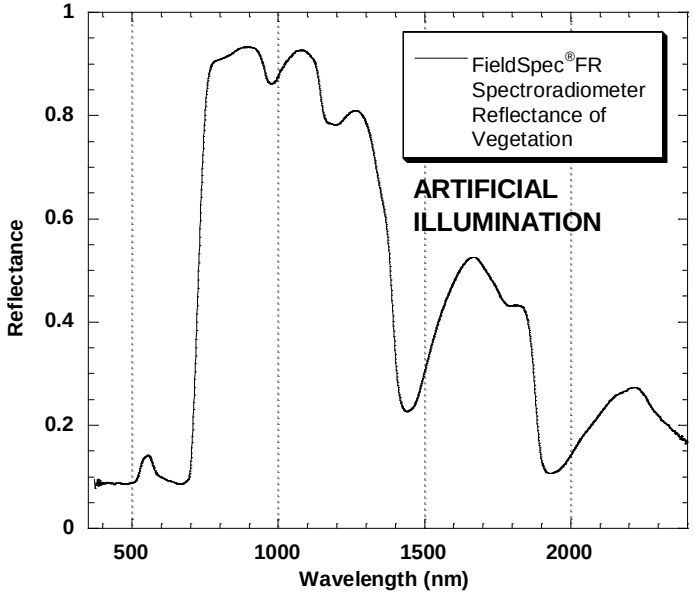
White light is dispersed,
then reflected off of
or
transmitted through sample.

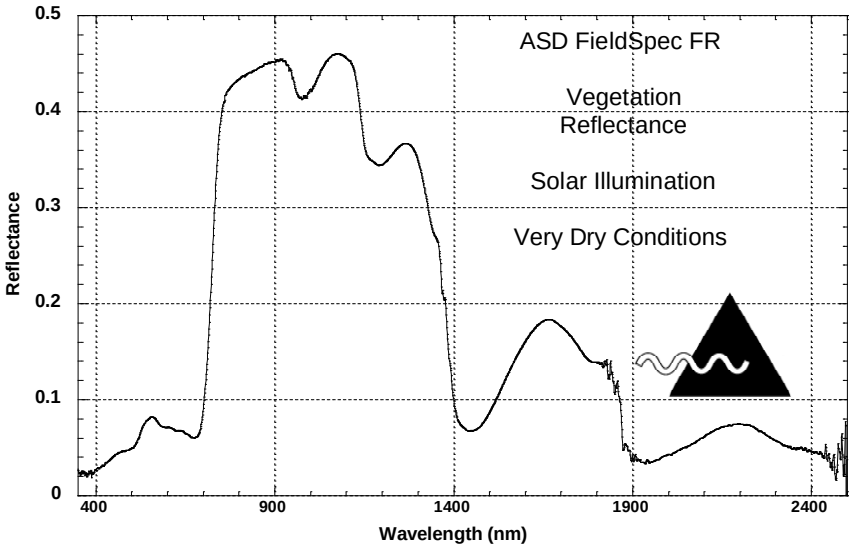
Arrays and scanners



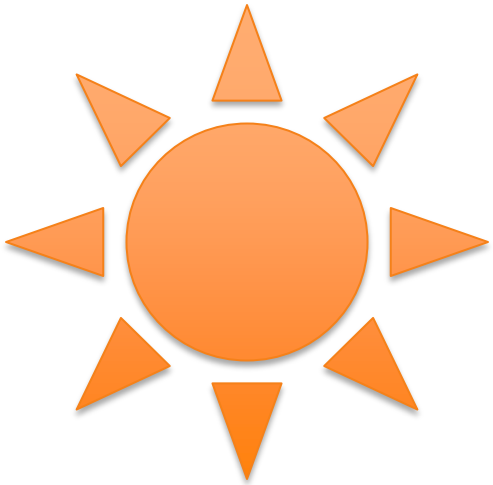



Water band noise
(This is right!)
FieldSpec FR Reflectannce of Vegetation
1.00
0.80
0.60
0.40
0.20
0.00
400
900
1400
1900
2400
Wavelength (nm)
ASD
FieldSpec FR
Vegetation
Reflectance
Solar
Illumination
Normal
Humidity

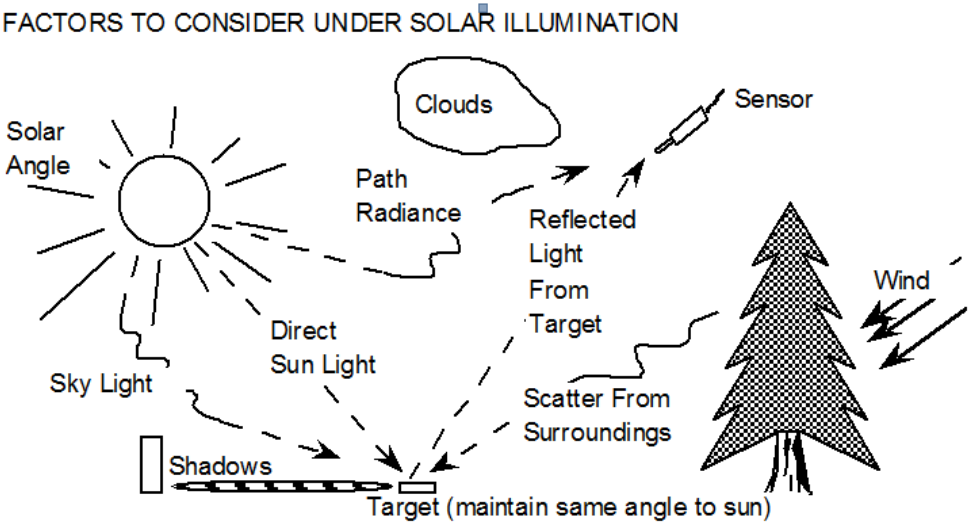

Reflectance
1
0.8
0.6
0.4
0.2
0
500
1000
1500
2000
Wavelength (nm)
FieldSpec® FR
Spectroradiometer
Reflectance of
Vegetation
ARTIFICIAL
ILLUMINATION


Reflectance
0.5
0.4
0.3
0.2
0.1
0
400
900
1400
1900
2400
Wavelength (nm)
ASD FieldSpec FR
Vegetation
Reflectance
Solar Illumination
Very Dry Conditions

Measurements under solar illumination



Measurements under solar illumination



Are you tired of waiting for that “perfect day” to collect your field spectra?

Do you want to collect more accurate reflectance spectra?

FieldSpec® Dual Software

What is FieldSpec Dual?

ASD's FieldSpec Dual software works with your existing FieldSpec systems to synchronize collection of white reference and target measurements:

- collect spectra under less than perfect atmospheric conditions
- collect more accurate spectra

The Problem

- Rapidly changing atmospheric conditions pose one of the greatest obstacles to the collection of accurate field-collected reflectance spectra using solar illumination

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- Field measurements collected in illumination conditions that are inconsistent with the associated reference measurement cannot be reproduced or correlated to imagery with any degree of certainty

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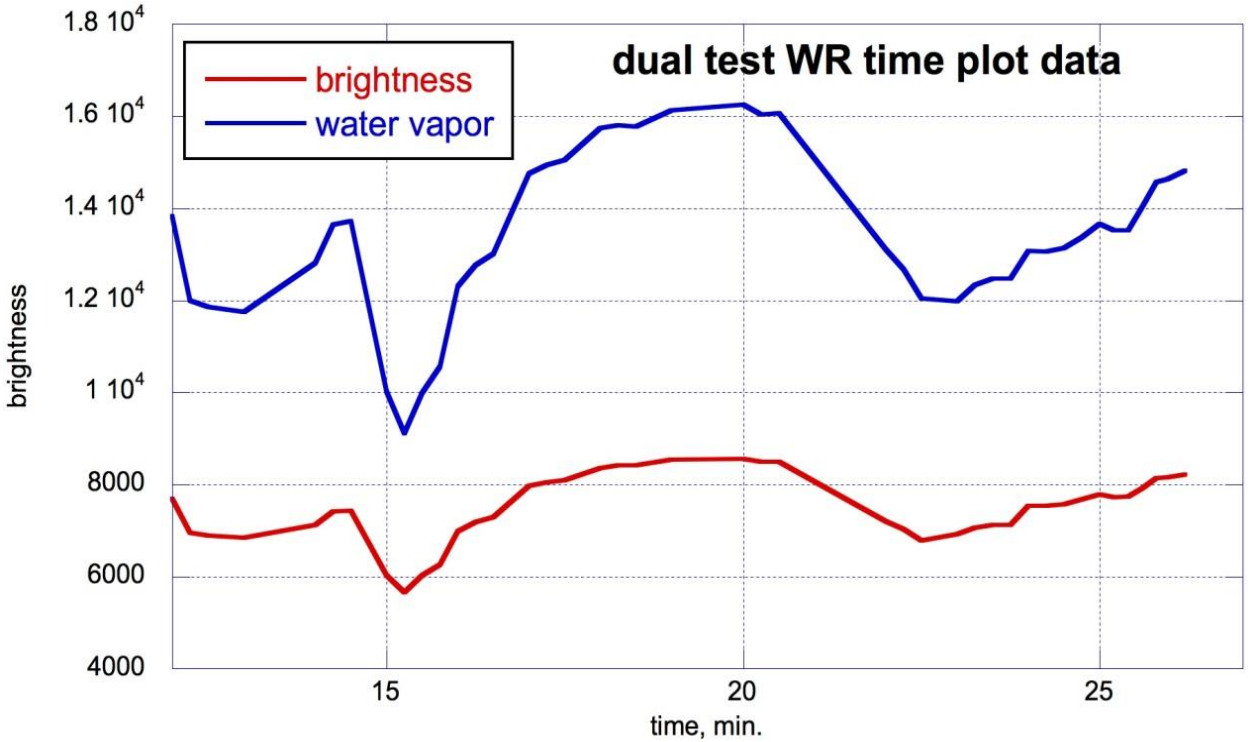
- Rapidly changing atmospheric conditions pose one of the greatest obstacles to the collection of accurate field-collected reflectance spectra using solar illumination
- Field measurements collected in illumination conditions that are inconsistent with the associated reference measurement cannot be reproduced or correlated to imagery with any degree of certainty
- Traditionally field work is limited to days with favorable atmospheric conditions, often incurring additional and often unbudgeted project costs waiting for good weather.

Example — Conditions

- Sunlight intensity varied by ~30% and water vapor absorption by ~45% over the 15 minute sample measurement period
- Without FieldSpec Dual, it would not be possible to collect accurate field reflectance spectra under these conditions



Variation in overall brightness (an average of the 450-800 nm range) and water vapor absorption (an average in the vicinity of the 1200 nm water vapor absorption feature).

Example — Instruments Used

The following FieldSpec instruments were used for the test:

- FieldSpec 4 Ser. No. 18147 was used as the Field Based Unit (FBU)
- FieldSpec 4 Ser. No. 18343 was used as the Mobile Unit (MU)

Example — Instrument Intercalibration

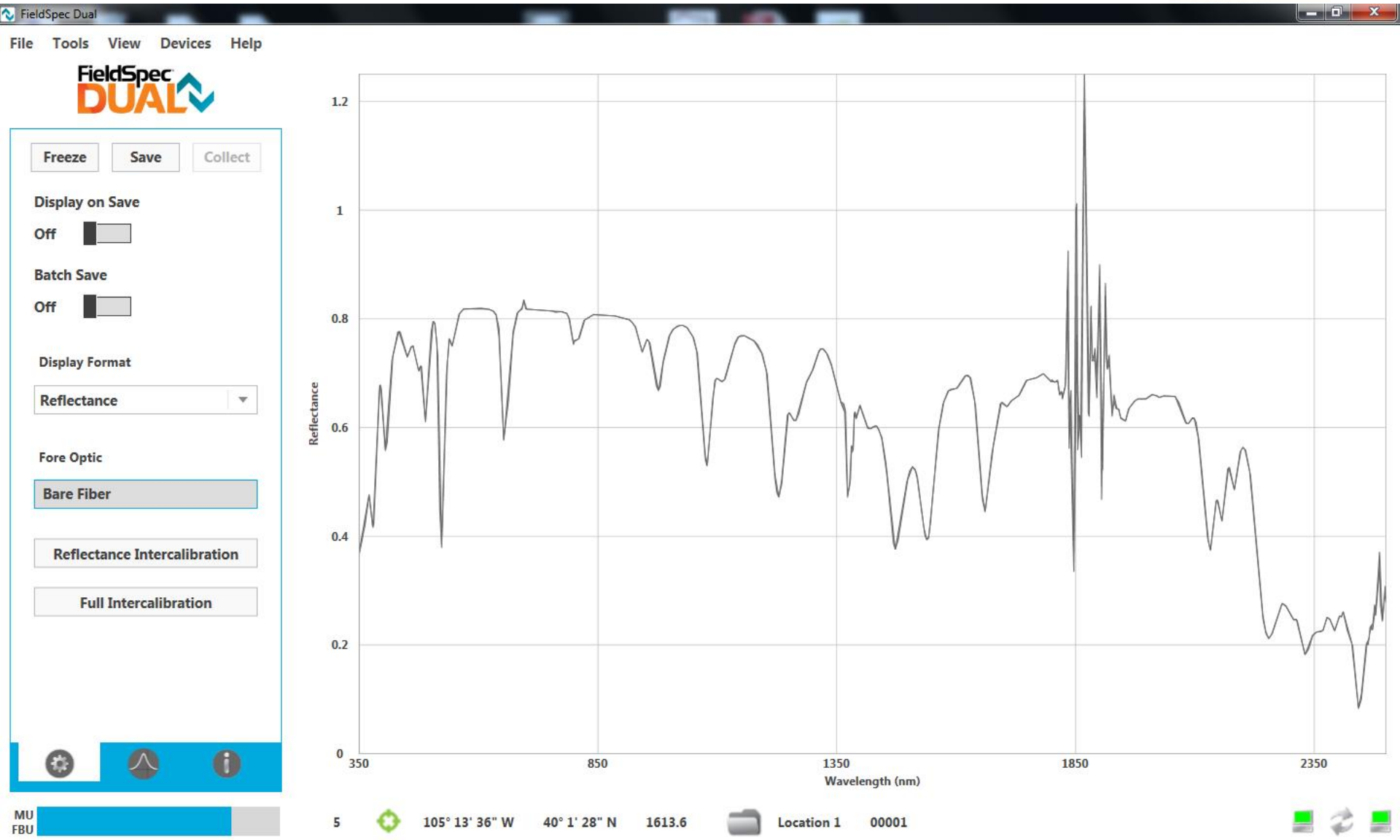
Using the FieldSpec Dual tripod mount to:

- Intercalibrate wavelength scale using the wavelength intercalibration reference puck
- Intercalibrate the reflectance scale using the white reference panel

Example — Collecting Field Spectra

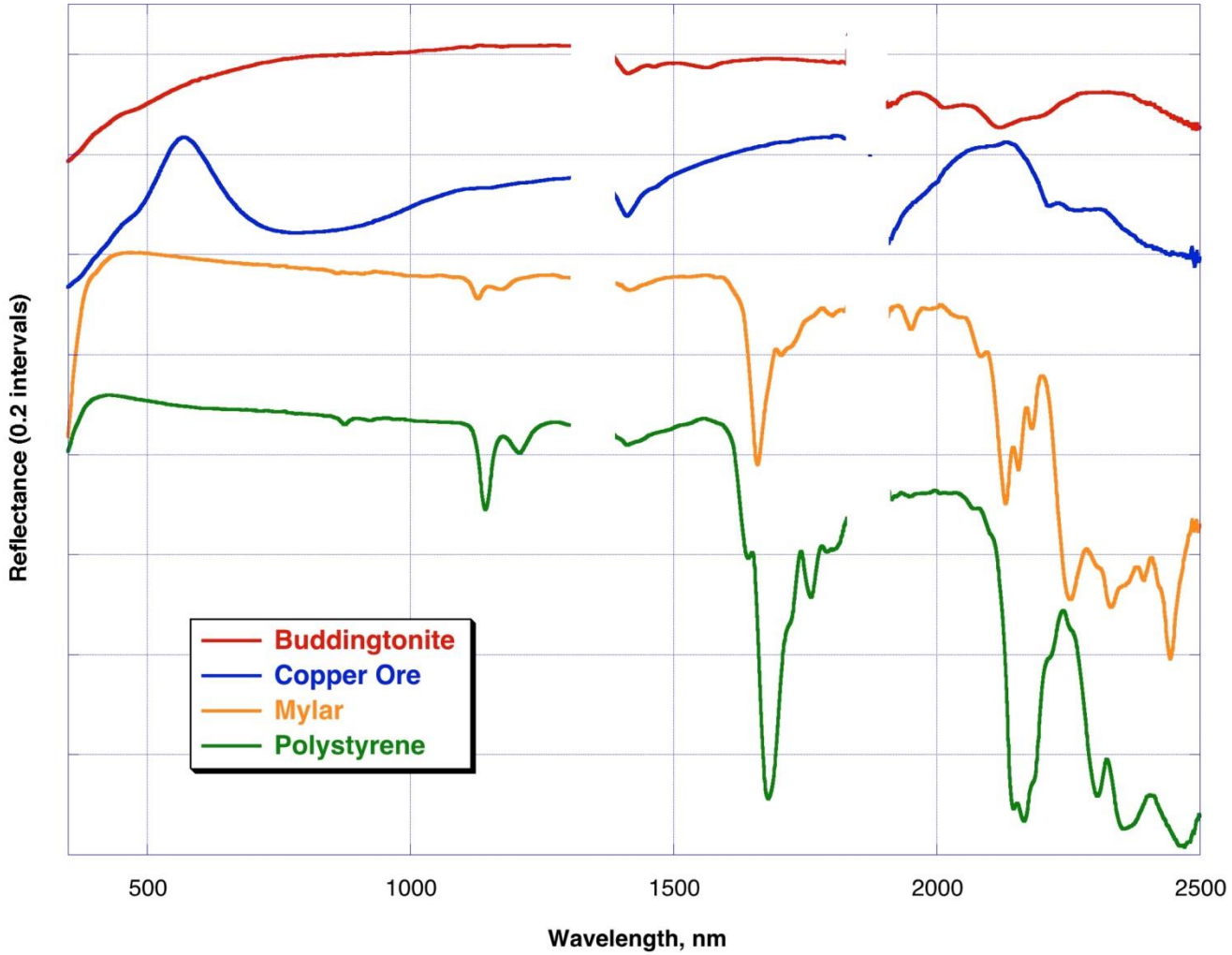
After performing the intercalibrations, the MU unit was used to view samples while the FBU remained viewing the Spectralon white reference panel. Reflectance spectra for each of the measured samples were computed as follows:

$$Refl = [\ DN\text{-}MU_{sample,\ t=i} / DN\text{-}FBU_{wr,\ t=i}\ ] * [DN\text{-}FBU_{wr,\ t=0} / DN\text{-}MU_{wr,\ t=0}\ ]$$


FieldSpec Dual
File Tools View Devices Help
FieldSpec DUAL
Freeze
Save
Collect
Display on Save
Off
Batch Save
Off
Display Format
Reflectance
Fore Optic
Bare Fiber
Reflectance Intercalibration
Full Intercalibration
MU
FBU
Reflectance
1.2
1
0.8
0.6
0.4
0.2
0
350
850
1350
1850
2350
Wavelength (nm)
5
105° 13' 36" W
40° 1' 28" N
1613.6
Location 1
00001

Example — Measured Spectra

FieldSpec Dual allows you to measure accurate field reflectance spectra under variable atmospheric conditions



The Value To Research

- By removing operator subjectivity and white reference time lags, the FieldSpec Dual system eliminates the most common source of error and inconsistencies associated with spectral measurements using solar illumination.

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- Field scientists can now calibrate and validate sensors and develop field-collected full-range spectral libraries with total confidence.

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- Field scientists can now calibrate and validate sensors and develop field-collected full-range spectral libraries with total confidence.
- Stop wasting time and $ waiting for that perfectly clear day. By providing near-simultaneous white reference/sample target measurements the FieldSpec Dual system effectively eliminates/neutralizes the need to wait for optimal weather conditions to carry out field campaigns.

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- Stop wasting time and $ waiting for that perfectly clear day. By providing near-simultaneous white reference/sample target measurements the FieldSpec Dual system effectively eliminates/neutralizes the need to wait for optimal weather conditions to carry out field campaigns.
- Dust off that old FieldSpec 3! The new FieldSpec Dual collection software system is compatible across the FieldSpec 3 and FieldSpec 4 product lines.

Product History

- 1996 – ASD released the FieldSpec VNIR-Dual – the first commercial dual spectroradiometer product to enable simultaneous upwelling and down-welling measurements:

  "Based on ASD's popular FieldSpec VNIR spectroradiometer, the two spectrometers of the FieldSpec VNIR-Dual provide simultaneous measurements of two components of the ambient light field. Because of this capability, the FieldSpec Dual UV/VNIR is rapidly becoming a standard in the oceanographic research community for the measurement of the above-water radiances necessary for the calculation of remote sensing reflectance."

- 2001 — ASD announces the FieldSpec Pro Dual VNIR
- To date, over 100 peer reviewed papers have been published that provide real world problems/solutions and use cases
- The 2015 FieldSpec Dual collection software is updated to work with ASD's FieldSpec line of field portable spectroradiometers

Eligible Products

- FieldSpec 3's serial numbers
  - 16139, 16146, 16167, 16168, 16176
  - 16178 and all subsequent serial numbers
- All FieldSpec 4's
- Technical requirements
  - Instruments are accurately calibrated
  - As long as the instruments are of the same resolution, FieldSpec 3's and FieldSpec 4's can be paired

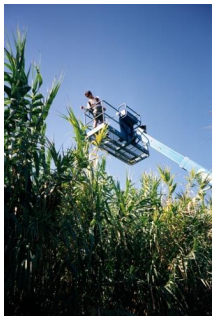
Applications

Field portable for ground truthing spectral imaging sensors

Field portable for getting to difficult access areas and targets.







Field portable to meet time limits. Need to move quickly and collect a lot of spectra within time limits; minimize changing illumination, and physical changes due to temperature and humidity changes ,etc.

Field portable for data quality. Minimize reflectance from mounting method (large vehicles would produce significant reflectance noise).


Field portable for platform flexibility.

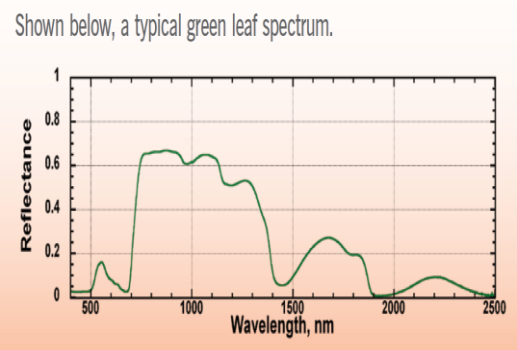

Field portable for fast in situ measurements in difficult situations

Field portable for fast in situ measurements in time sensitive exploration & production processes

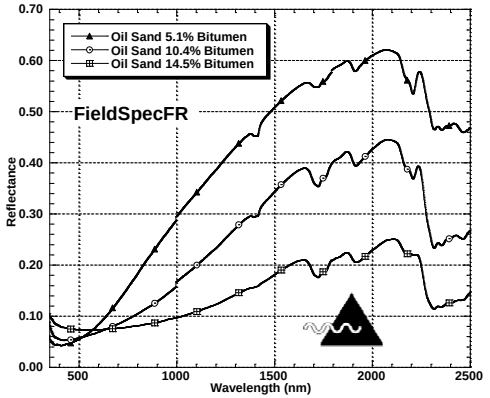
Field portable for ease of transportation around the world

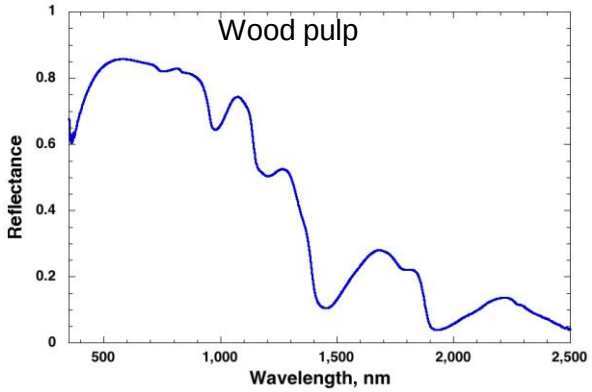
Applications…

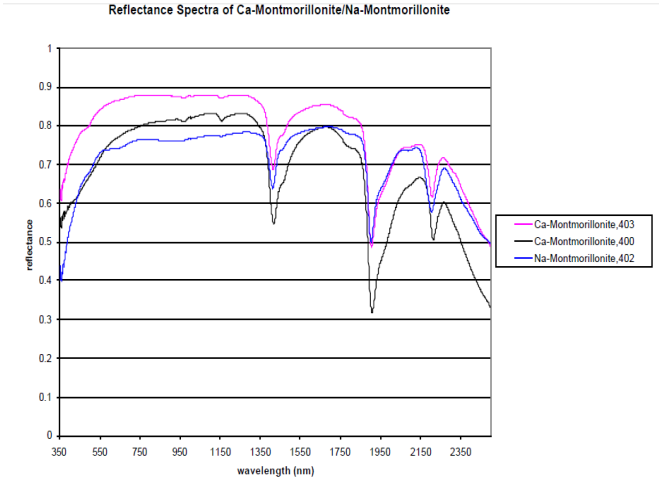
Rapid classification



Classifying many different materials in-situ in different locations. Full spectral range and many wavelength features are necessary to accommodate small differences in same material spectra and to discriminate between similar spectral features in different materials.



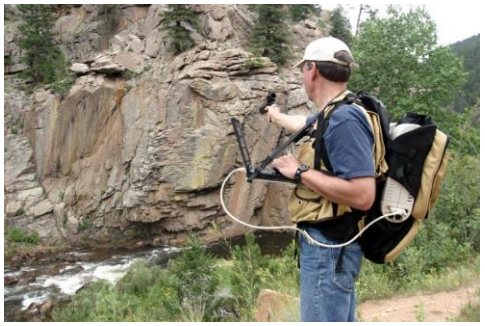




Applications…

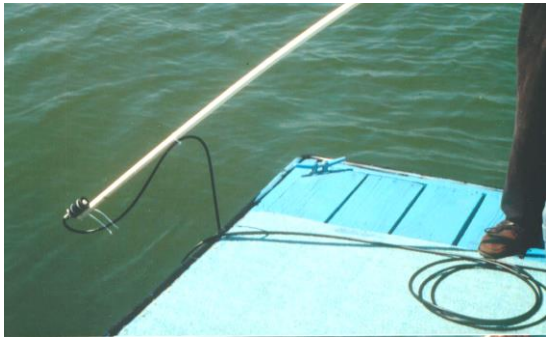
Post dispersive non-destructive in-situ

Live sample, property of interest is lost if detached.

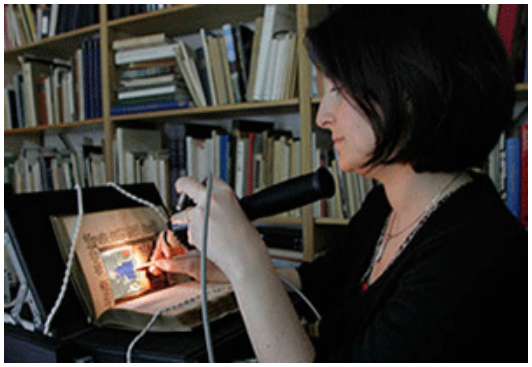


Large live sample studies.

Large samples, small sampling is not representative or not allowed.



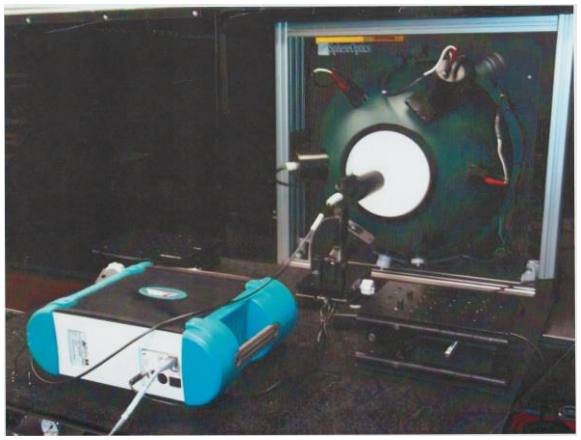
Solar illumination.



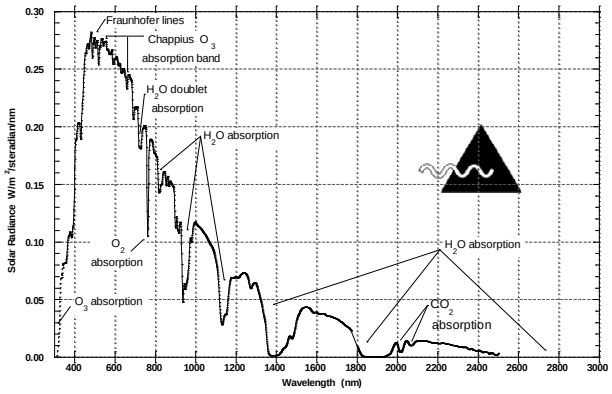
Sensitive sample. Sample cannot be removed or damaged.

Applications…

Spectroradiometry (must be post dispersive).



Measurements of large/fixed illumination devices or areas. Cannot move target, must move instrument (portable spectroradiometer).



Solar studies.

Applications… Raw material quality control

WITHOUT ASD LABSPEC 4

RAW MATERIALS VENDER
⇩
RECEIVE (-$)
⇩
QUARANTINE (-$$)
⇩
SUBSET TO LAB (-$$$)
⇩
RETURN FROM LAB
⇩ ⇩
PASS FAIL ⇨ (-$$$$$)
⇩
MIX
⇩
EA BATCH TO LAB (-$$$$$$)
⇩
RETURN FROM LAB
⇩ ⇩
PASS FAIL ⇨ (-$$$$$$$)
⇩
STOCK ⇨ SELL

WITH ASD LABSPEC 4 (and goLab)

RAW MATERIALS VENDER
⇩
~100% INSPECT ⇨ FAIL
⇩ ++$$$SAVE$$$++
PASS
⇩
RECEIVE
⇩
MIX
⇩
FINAL INSPECT EA BATCH
⇩ ⇩
PASS FAIL ⇨ (-$)
⇩
STOCK ⇨ ++$$$SELL$$$++

Some reference papers on applications

USGS Spectroscopy Lab Surface Reflectance Calibration of Terrestrial Imaging Spectroscopy Data: a Tutorial Using AVIRIS, by Roger N. Clark, Gregg A. Swayze, and others
http://speclab.cr.usgs.gov/PAPERS.calibration.tutorial/

Mineral Mapping Using Spectroscopy: From Field Measurements to Airborne and Satellite-Based Imaging Spectrometry, by Fred A. Kruse
http://www.asdi.com/getmedia/ad51d09a-42b4-4c56-b1b7-afb5b6d52bcc/Mineral-Mapping-Using-Spectroscopy.pdf.aspx

Imaging Spectrometer Data Analysis – A Tutorial, by Fred A. Kruse
http://www.hgimaging.com/PDF/Kruse_isssr94tut.pdf

Reflectance Spectroscopy Applied to Exploration for Mineral Deposits and Geothermal Systems, and to the Remediation of Mined Lands in the Great Basin of the United States, by by James V. Taranik, Wendy M. Calvin, and Fred A. Kruse
http://www.asdi.com/getmedia/1e2c6c6c-e043-4b01-b4c9-2e3309e05065/REFLECTANCE-SPECTROSCOPY-APPLIED-TO-EXPLORATION.pdf.aspx

Unveiling Mineralogical Information in Ore Deposits: The Use of reflectance Spectroscopy for Mineral Exploration in South America, by Alvaro P. Crósta
http://www.asdi.com/getmedia/4fc8b413-ebb7-42c6-af01-77bbcf2edbcc/UNVEILING-MINERALOGICAL-INFORMATION-IN-ORE-DEPOSITS.pdf.aspx

TerraSpec Halo for the Mine Geologist, by Stacey Leichliter
http://www.asdi.com/resource-center/application-notes/terraspec-halo-for-the-mine-geologist?App=Mining

Quantitative prediction of material properties using reflectance spectroscopy: A multivariate chemometrics-based approach, by Daniel A. Shiley
http://www.asdi.com/getmedia/9a42d789-1f6d-4851-a347-c6c40df5f334/Quantitative-prediction-of-material-properties-using-reflectance-spectroscopy.pdf.aspx

Field Characterization of White Micas Using the TerraSpec Halo, by Brian Curtiss
Curtis Field_Characterization_of_White_Micas_Using_the_TerraSpec_Halo

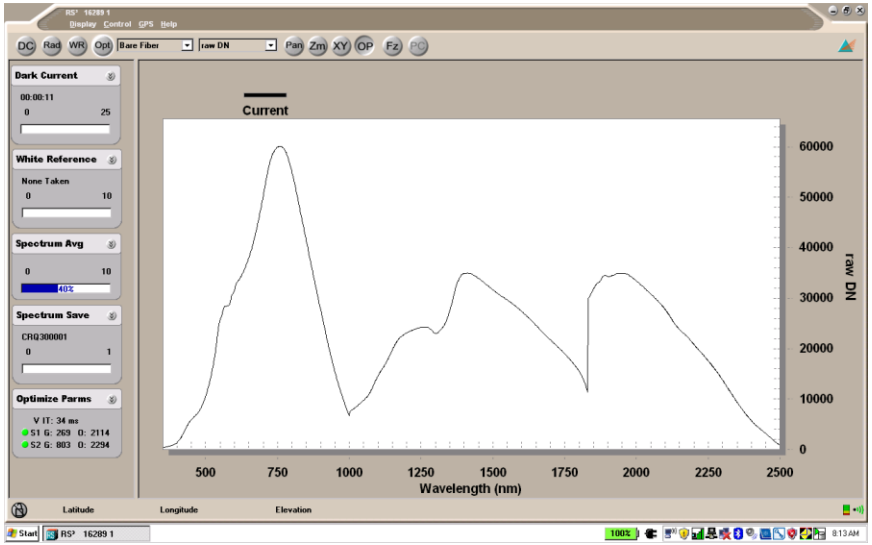
Estimation and Extrapolation of Soil Properties in the Siberian Tundra, using Field Spectroscopy
http://www.asdi.com/getmedia/d16d89aa-2da0-43fd-9750-ef07b2b12362/Estimation-and-Extrapolation.pdf.aspx

Some instrument details

ASD unique features for optimizing signal stability

Thermo-Electric (TE) cooling on the InGaAs SWIR detectors: For minimizing large changes in dark drift offset.

ASD Proprietary Driftlock ™ (hardware and software system): For continuous update and subtraction of systematic dark offset. Without Driftlock small changes in dark offset would affect the lowest signal points of the detector.



ASD NIST traceable radiometric calibration facility

ASD NIST traceable radiometric calibration facility used for calibrating the ASD **FieldSpec** has been compared to those at both NASA-Ames Research Center and Los Alamos National Laboratory and has been found to be within 1 % of both facilities. Radiometric calibrations require a thorough understanding of energy geometries, irradiance standards, and equipment maintenance. Independent verification by world-wide recognized facilities ensures radiometric accuracy.

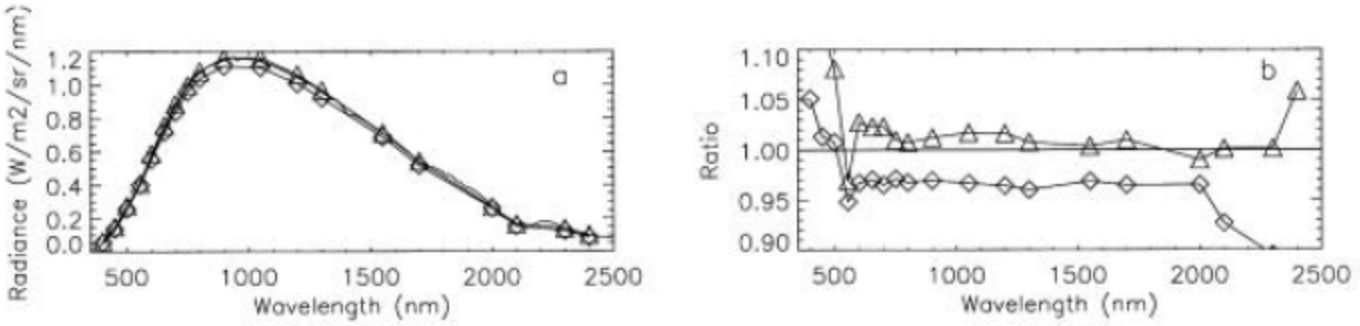


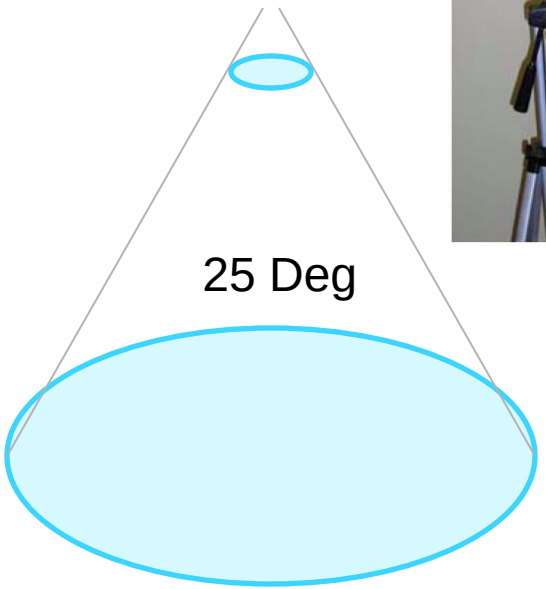
Fig. 3. (a) Radiance measured from the LANL sphere. Squares represent the NIST calibration, triangles the Labsphere calibration and the continuous curve the ASD FieldSpec. (b) Ratios of the Labsphere and NIST calibrations against the ASD FieldSpec measurement.

ASD wide field-of-view

Wider conical field-of-view (FOV) than any other similar product (25 deg full conical angle on the bare input):

Allows for very large spot sizes necessary for measurement of foliar canopies, geological faces, ground features, backgrounds, imager pixel sizes.

Conical FOV also allows for very close small spot measurements down to 1/8 inch and contact measurements.



ASD variety of accessories

ASD proprietary contact probes, fiberoptic jumper cables, in-air and underwater foreoptics, and integrating sphere interface with FieldSpec 4 and HandHeld 2. Allows for optimal flexibility and convenience in measurement approaches and field portable measurements.



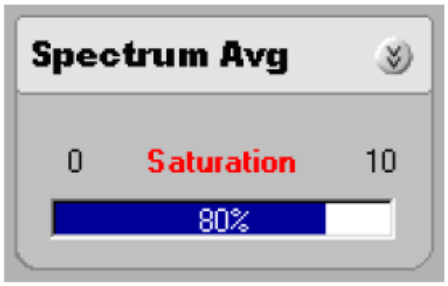


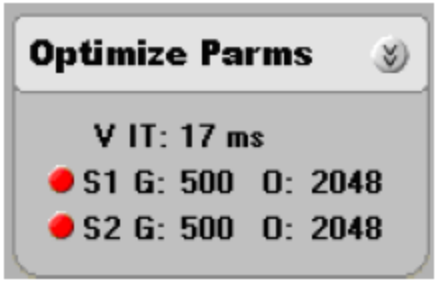


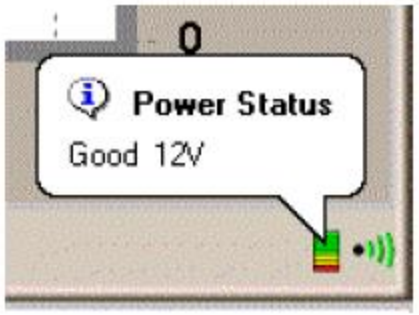
ASD proprietary Fiber Checker

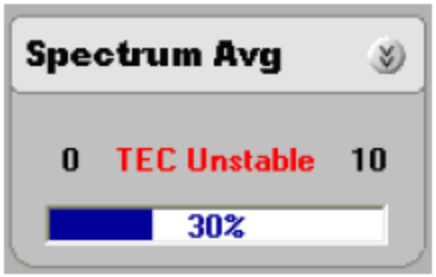
The ASD **FieldSpec 4** (350 - 2500 nm) includes ASD proprietary ‘fiber checker’ hardware and software for checking the performance of the fiberoptic cable. Routine checking of fiberoptics integrity ensures accurate data collection.

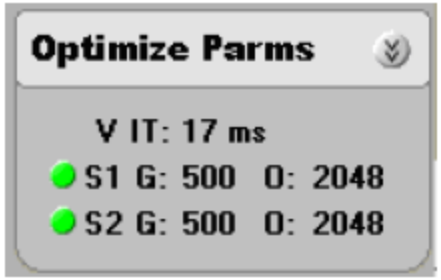
ASD on-screen instrument diagnostics.

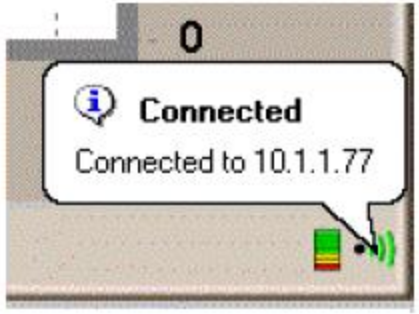






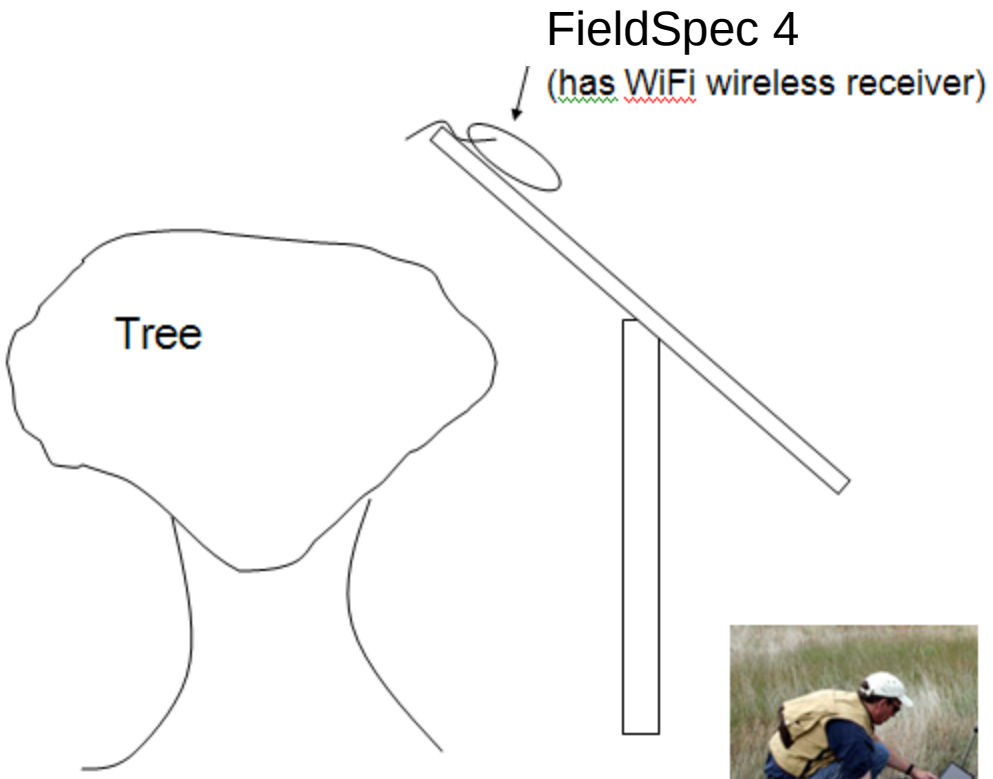






FieldSpec 4 Wi-Fi communications

FieldSpec 4 10/100Base T Ethernet and 802.11g Wireless-Wi Fi interface interface: For interface with a variety of the most recent note book computers and for control over capable networks; wireless capability is necessary for field control at a distance, reducing cable clutter, and ease of use.



User controlling FieldSpec with controller computer that has wireless WiFi (radio transmission).

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