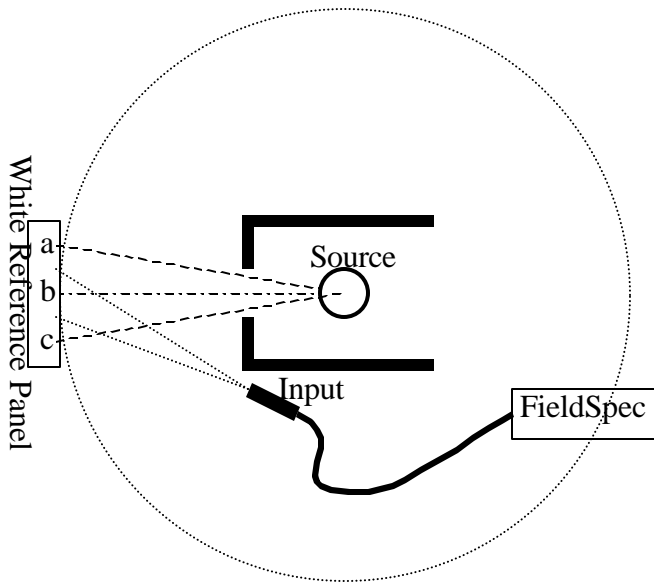


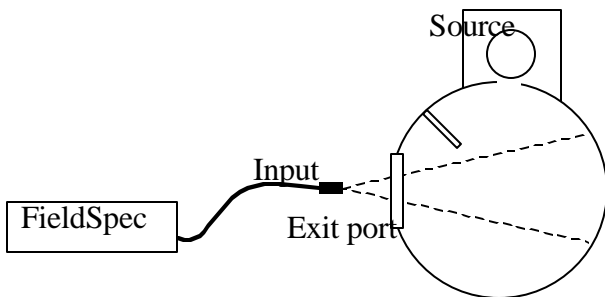
**Panel or Sphere Approaches for Radiance Calibrations**

There are two ways to generate Radiance calibration files for FieldSpec Pro. One method uses a Panel, and the other method uses an Integrating Sphere.

In the 'Panel' method, the illumination from a NIST traceable 'Irradiance Source' falls onto a nearly 100% reflectance, diffuse panel (White Reference Panel). Per NIST the panel is located 50 cm away from the source. This is far enough away that the Flux density, or Irradiances at points **a** and **c** differ insignificantly from the Irradiance at point **b**. This also means that the distances from the Source to points **a** and **c** are insignificantly different from the distance, **D** from the Source to point **b**. The NIST traceable certificate provides the Source Irradiance values at point **b** for distance, **D**. The spectrometer input views an area safely within **a** and **c**. The source enclosure contains black baffles and apertures to prevent light from bouncing off surfaces in the calibration room (such bouncing light could contribute sources of error).



The second approach uses an integrating sphere, for which the Certificate provides Radiance Data for full Field-of-View (FOV) seen by the input Foreoptic through the Exit Port.



The FieldSpec Pro RCALC software calculates Radiance for each channel as follows:

$$L = \frac{BSEunit\#cal\#.REF * LMPunit\#cal\#.ILL * DN * IGr}{\pi * Niunit\#cal\#.RAW * IG}$$

where:

L = Radiance of Sample Measurement in Watts/meter<sup>2</sup>/nanometer/steradian

BSEunit#cal#.REF = Reflectance Data of Certified Panel

LMPunit#cal#.ILL = Irradiance Data of Certified Source

Niunit#cal#.RAW = RawDN Data of Bare Fiberoptic viewing Certified Source. (8i for 8 Deg Foreoptic, and 1i for 1 Deg Foreoptic)

DN = Raw DN Data of Sample Measurement

IGr = Integration Time &/or GainFactor of Niunit#cal#.RAW

IG = Integration Time &/or GainFactor of Sample Measurement

GainFactor = 2048/Gain

Integration times are used for the photodiode array region and Gains are used for the SWIR regions. Exact Gains are used (Exact Gains can be seen using ViewSpec Pro).

**P** converts the Irradiance Data to radiance

unit# = the FieldSpec Pro serial number, for example 4010

cal# = the new single digit calibration number, for example 3

• For this instructional paper, the unit number (unit#) 4010 and new calibration number (cal#) 3 will be used as examples.

• All unit numbers should be four digits. If your unit number is only three digits, use an underscore \_ for the fourth digit of the unit number.

When using the Integrating Sphere approach there is no White Reference Panel. So, these Data should all be set to 1 (see Section C).

Also, when using the Integrating Sphere approach, the certified Radiance Data must be converted to Irradiance by multiplying each value by **P**.

**Irradiance Calibrations**

To generate 180° full hemispherical Spectral Irradiance Calibration files the plane of a 180° Remote Cosine Receptor (RCR) Foreoptic input is placed at the same position as the plane of the White Reference Panel at point **b** for distance **D**. When the user selects the RCR option in the FieldSpec software, RCALC knows to leave out **P** and BSEunit#cal#.REF Panel Reflectance and calculate Spectral Irradiance, E in Watts/meter<sup>2</sup>/nanometer for each wavelength channel as follows:

$$E = \frac{\text{LMPunit\#cal\#.ILL} * \text{DN} * \text{IGr}}{\text{COSunit\#cal\#.RAW} * \text{IG}}$$

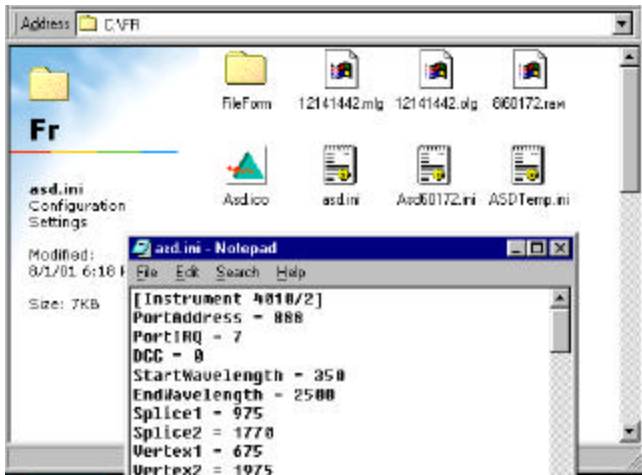
Integrating Spheres are impractical for Irradiance Calibrations. Integrating Spheres are designed and calibrated to a limited FOV, which in most cases would not include the full 180° necessary for a full hemispherical RCR Foreoptic. Also, the Foreoptic would have to be placed just inside the exit port, which would produce reflections back into the Sphere.

**Calibration Warm-up**

Turn on the FieldSpec Pro spectrometer and allow 90 minutes ‘warm-up’ before collecting \*.RAW files for calibration.

**Adjustment of FieldSpec Pro INI File and Shortcut**

1. Find the file called ASD.INI in the directory C:\FR. Double click on the file. It should open in Windows Notepad.



2. The first line of the INI file reads as follows: [Instrument unit#/cal#]. Since the Radiometric calibration will be changing, type in the next number for the cal#. So, for the example shown above, change [Instrument 4010/2] to [Instrument 4010/3]. Close the INI file and Save the changes.



3. Find the FR.EXE shortcut on your desktop. Right-click on this short cut. In the Cmd Line change the last digit, which is the cal# to the new calibration number, which for this example this would be 3. Click **OK**.

**Create an INTERP Directory**

4. In the main FieldSpec directory, for example, C:\FR (for FieldSpec Pro FR) create a new folder called INTERP. Inside this new INTERP directory, insert the file Interp.exe (contact ASD for a free copy of this file if

you don't already have it). According to the instructions below and the appropriate Appendixes, you will also be eventually adding all the following files so that the entire list of files in the INTERP directory will be as follows:

- Interp.exe
- InterpBSE Shortcut
- InterpLMP Shortcut
- BSEunit#cal#.TXT
- BSEunit#cal#.REF
- LMPunit#cal#.TXT
- LMPunit#cal#.ILL

**Create BSEunit#cal#.TXT**

5. For the Panel Approach, find the White Reference Panel Calibration Certificate of Wavelength versus Reflectance. Create a two column Tab Delimited ASCII TXT file for Wavelength in **Nanometers** and Reflectance in **Percentage**, similar to the following table (do NOT include any headers – just data only):

250	98.5
300	98.5
350	99.2
400	99.1
450	99.0
500	99.2
550	99.1
600	99.1
650	99.1
700	99.1
750	99.1
800	99.2
850	99.2
900	99.3
950	98.8
1000	99.0
1050	98.9
1100	99.4
1150	98.8
1200	98.9
1250	98.9
1300	98.9
1350	98.7
1400	98.5
1450	98.7
1500	98.6
1550	98.7
1600	98.4
1650	98.3
1700	98.5
1750	98.5
1800	98.2
1850	98.3
1900	98.1
1950	97.8
2000	97.3
2050	96.1
2100	95.3
2150	94.8
2200	96.4
2250	96.8
2300	96.1
2350	95.1
2400	94.7
2450	94.7
2500	93.8
2550	93.8

If your Reflectance Data is written as 'Reflectance Factor' decimal fractions, such as 0.985, be sure to convert them to percentages, such as 98.5.

Always start your Data at least one step below the starting wavelength of your FieldSpec Pro and one step above the stopping wavelength. You can check these start and stop values using ViewSpec Pro, or just use 250 – 2550 nm as a general safe range. If you don't have Data for the entire range, just repeat the last available value.

For the Sphere Approach, simply set all the Reflectance Data to 100% as follows:

250	100.0
300	100.0
350	100.0
400	100.0
450	100.0
500	100.0
550	100.0
600	100.0
650	100.0
700	100.0
750	100.0
800	100.0
850	100.0
900	100.0
950	100.0
1000	100.0
1050	100.0
1100	100.0
1150	100.0
1200	100.0
1250	100.0
1300	100.0
1350	100.0
1400	100.0
1450	100.0
1500	100.0
1550	100.0
1600	100.0
1650	100.0
1700	100.0
1750	100.0
1800	100.0
1850	100.0
1900	100.0
1950	100.0
2000	100.0
2050	100.0
2100	100.0
2150	100.0
2200	100.0
2250	100.0
2300	100.0
2350	100.0
2400	100.0
2450	100.0
2500	100.0
2550	100.0

**IMPORTANT:** Always start your Data at least one step below the starting wavelength of your FieldSpec Pro and one step above the stopping wavelength. You can check these start and stop values using ViewSpec Pro, or just use 250 – 2550 nm as a general safe range. If you don't have Data for the entire range, just repeat the last available value.

- Save this White Reference Panel TXT file in the directory C:\FR\INTERP, named as BSEunit#cal#.TXT with the appropriate unit and calibration numbers. In the example used in this paper, the unit# is 4010 and the new cal# is 3. So, for this example, the file would be named: BSE40103.TXT. After finishing the next Section on creating LMPunit#cal#.ILL, convert BSEunit#cal#.TXT into BSEunit#cal#.REF using the ASD FieldSpec Pro Interp.exe program, as described in Appendix A. Be sure to change the file type to Reflectance using ViewSpec Pro.

**Create LMPunit#cal#.TXT**

- For the Panel Approach, find the Lamp Standard Spectral Irradiance Calibration Certificate of Wavelength versus Spectral Irradiance. Create a two column Tab Delimited ASCII TXT file for Wavelength in **Nanometers** and Spectral Irradiance in **MicroWatts/centimeter<sup>2</sup>/nanometer**, (micro = 10<sup>-6</sup>) similar to the following table (do NOT include any headers – just data only):

250	0.0194
260	0.0343
270	0.0569
280	0.0896
290	0.1350
300	0.1970
310	0.2790
320	0.3810
330	0.5120
340	0.6680
350	0.8590
360	1.0800
370	1.3400
380	1.6400
390	1.9700
400	2.3500
450	4.7800
500	7.9600
555	11.9000
600	15.1000
654.6	18.6000
700	21.0000
800	24.6000
900	25.7000
1050	24.7000
1150	22.7000
1200	21.6000
1300	19.4000
1540	14.1000
1600	13.1000
1700	11.3000
2000	7.5300
2100	6.6700
2300	5.1500
2400	4.4700
2500	3.9200
2550	3.9200

For the integrating Sphere Approach, find the Lamp Standard Spectral **Radiance** Calibration Certificate of Wavelength versus Spectral Radiance. Convert the Spectral **Radiance** Data to Spectral **Irradiance** by multiplying each Radiance Data Value by **P**. Then, also apply any corrections necessary so that the Wavelength Data is in nanometers and the Spectral Irradiance Data

is in **MicroWatts/centimeter<sup>2</sup>/nanometer** (micro =10<sup>-6</sup>). Create a two column Tab Delimited ASCII TXT file for Wavelength and Spectral **Irradiance** similar to the previous table (do NOT include any headers – just data only).

**IMPORTANT:** Always start your Data at least one step below the starting wavelength of your FieldSpec Pro and one step above the stopping wavelength. You can check these start and stop values using ViewSpec Pro or just use 250 – 2550 nm as a general safe range. If you don't have Data for the entire range, just repeat the last available value.

- Save this Lamp Standard Spectral Irradiance TXT file in the directory C:\FR\INTERP, named as LMPunit#cal#.TXT with the appropriate unit and calibration numbers. In the example used in this paper, the unit# is 4010 and the new cal# is 3. So, for this example, the file would be named: LMP40103.TXT.

**Convert TXT files with Interp.exe**

- According to the instructions in Appendix A, convert BSEunit#cal#.TXT into BSEunit#cal#.REF and LMPunit#cal#.TXT into LMPunit#cal#.ILL. Save BSEunit#cal#.REF and LMPunit#cal#.ILL in the main FieldSpec directory, for example, C:\FR.

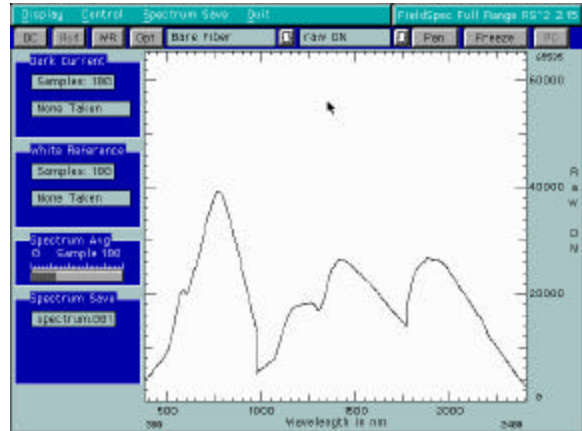
Remember to change the BSEunit#cal#.REF format to Reflectance using ViewSpec Pro after running InterpBSE.exe.

The default format for Interp.exe is Irradiance, so there is no need to make any additional changes after running InterpLMP.exe.

**Create of Foreoptic Response Files**

- For the Panel Approach, fix the FieldSpec Pro Bare Fiber Input so that it does not interfere with the illumination of the Panel, and so that its FOV is well within points a and c on the Panel.
- For the Integrating Sphere, fix the FieldSpec Pro Bare Fiber Input at an appropriate position for viewing the exit port on the integrating sphere. The field-of-view of the fiber input should be full with the view of the inner wall of the sphere, and the probe should be just far enough outside the sphere so that no light reflects from it back into the sphere (actual distance depends on the exit port size).
- Open either FieldSpec Pro FR or FieldSpec Pro VNIR Software, depending on which one you are calibrating to.
- Under the menu Control and Adjust Configuration, set Dark Current Averaging and Spectrum Averaging to an appropriately high number, such as 100. Set the

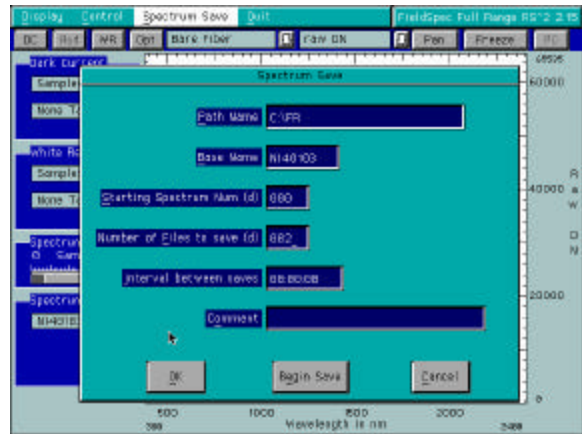
foreoptic to Bare Fiber and the collection mode to Raw DN.



- For FieldSpec Pro FR Software: Optimize, and collect Dark Current.

For FieldSpec Pro VNIR Software: Set the integration time according to the Manual, and collect Dark Current.

- In the Spectrum Save menu assign the basename Niunit#cal# to the file you are about to save (in this example Ni40103). Set the Starting Spectrum Num to 000, Number of Files to save to 2 and click on Begin Save.



- Two spectra will be saved as Niunit#cal.000, and Niunit#cal.001 (in this example Ni40103.000, and Ni40103.001)
- Rename Niunit#cal.000 as Niunit#cal#.RAW (in this example, Ni40103.RAW). This .RAW Foreoptic Response file should already be in the main FieldSpec directory. If it is not, go ahead and put it there now. For example, C:\FR.
- Verify that the calibrations are correctly installed and properly working by making some measurements with the FieldSpec Pro in Radiance (RAD) mode with the proper foreoptic selection.

19. For other foreoptics, attach them properly and repeat this Foreoptic Response File Procedure with the following base file names: 8iunit#cal# for the 8 Deg, and, 1iunit#cal# for the 1 Deg, COSunit#cal# for the ASD Full Sky Irradiance Remote Cosine Collector (180 Deg Cosine Collector can only be done by Panel Approach).

Units are displayed and stored as follows:

Wavelength: **nanometers**

Radiance: **Watts/meter<sup>2</sup>/nanometer/steradian**

Irradiance: **Watts/meter<sup>2</sup>/nanometer**

**APPENDIX A: INTERP**

A1. If you haven't done so already, create a directory named INTERP inside the main FieldSpec directory. For example, C:\FR\INTERP

A2. Place the following files into the directory INTERP:

Interp.exe (contact ASD if you don't already have this file).  
BSEunit#cal#.TXT  
LMPunit#cal#.TXT

In this example:  
BSE40103.TXT  
LMP40103.TXT

**Of course, use the correct unit# and cal#.**

A3. Create a short-cut for Interp.exe and rename the short-cut InterpBSE.  
Create another short-cut for Interp.exe and rename this short-cut InterpLMP.

A4. For Field Spec Pro FR:

Right-click on the shortcut InterpBSE and change the Cmd line and Working lines to read as follows:

Cmd line: C:\FR\INTERP\INTERP.EXE -i BSEunit#cal#.TXT BSEunit#cal#.REF 350 1 2151  
Working: C:\FR\INTERP

In this example:  
Cmd line: C:\FR\INTERP\INTERP.EXE -i BSE40103.TXT BSE40103.REF 350 1 2151

**Of course, use the correct unit# and cal#.**

Click-on **OK**.

For FieldSpec Pro VNIR:

FieldSpec Pro VNIR software, VNIR.EXE comes as standard with either a FieldSpec Pro VNIR instrument or as an additional .EXE option with FieldSpec Pro FR instruments.

If the instrument is a FieldSpec Pro VNIR, then VNIR.EXE will be in the FieldSpec Directory, C:\VNIR.

If the instrument is a FieldSpec Pro FR, then VNIR.EXE will be in the FieldSpec Directory, C:\FR.

First of all, open a VNIR spectrum file with ViewSpec Pro and View the Header Information (in this case the VNIR.exe software was in the directory C:\FR that also included FR software):

**Header Information**

C:\FR\Spectrum.001

Comment:

Instrument Number: 4010  
Calibration Number: 3

Wavelength Start: 327.88  
Wavelength Step: 1.432  
Sample Count: 10

XMin: 327.88 XMax: 1059.63  
YMin: 0 YMax: 65535

Program Version: 8.11  
File Version: 4.03  
Date Spectrum Saved: 08/06/101 at 17:48:29  
File Data Type: Raw  
Integration Time: 17

Write down the Wavelength Start, Xmin, Wavelength Step, and the number of channels. The number of channels is always 512 for FieldSpec Pro VNIR. In this example the numbers are:

327.88            1.432            512

For FieldSpec Pro VNIR Software, these Xmin, and Step will always be different from instrument to instrument.

Right-click on the shortcut InterpBSE and change the Cmd line and Working lines to read as follows:

Cmd line: C:\FR\ INTERP\INTERP.EXE -i BSEunit#cal#.TXT BSEunit#cal#.REF Xmin Wavelength Step #Channels  
In this example:

Cmd line: C:\FR\ INTERP\INTERP.EXE -i BSE40103.TXT BSE40103.REF 327.88 1.432 512

Working: C:\FR\INTERP

(use C:\VNIR instead of C:\FR if instrument is FieldSpec pro VNIR Instrument)

**Of course, use the correct unit# and cal#.**

Click-on **OK**.

- A5. Right-click on the shortcut InterpLMP and change the Cmd line and Working lines to read as follows:

For Field Spec Pro FR Software:

Cmd line: C:\FR\INTERP\INTERP.EXE -i LMPunit#cal#.TXT LMPunit#cal#.ILL 350 1 2151

Working: C:\FR\INTERP

In this example:

Cmd line: C:\FR\INTERP\INTERP.EXE -i LMP40103.TXT LMP40103.ILL 350 1 2151

**Of course, use the correct unit# and cal#.**

Click-on **OK**.

For FieldSpec Pro VNIR Software:

FieldSpec Pro VNIR software, VNIR.EXE comes as standard with either a FieldSpec Pro VNIR instrument or as an additional .EXE option with FieldSpec Pro FR instruments.

If the instrument is a FieldSpec Pro VNIR, then VNIR.EXE will be in the FieldSpec Directory, C:\VNIR.

If the instrument is a FieldSpec Pro FR, then VNIR.EXE will be in the FieldSpec Directory, C:\FR.

First of all, open a VNIR spectrum file with ViewSpec Pro and View the Header Information (in this case the VNIR.exe software was in the directory C:\FR that also included FR software):

Write down the Wavelength Start, Xmin, Wavelength Step, and the number of channels. The number of channels is always 512 for FieldSpec Pro VNIR. In this example the numbers are:

327.88            1.432            512

For FieldSpec Pro VNIR Software, these Xmin, and Step will always be different from instrument to instrument.

Right-click on the shortcut InterpLMP and change the Cmd line and Working lines to read as follows:

Cmd line: C:\FR\INTERP\INTERP.EXE -i LMPunit#cal#.TXT LMPunit#cal#.ILL Xmin Wavelength Step #Channels  
In this example:

Cmd line: C:\FR\INTERP\INTERP.EXE -i LMP40103.TXT LMP40103.ILL 327.88 1.432 512

Working: C:\FR\INTERP

(use C:\VNIR instead of C:\FR if instrument is FieldSpec pro VNIR Instrument)

**Of course, use the correct unit# and cal#.**

Click-on **OK**.

- A6. Double-click-on InterpBSE. If all is well, you should see a message in a DOS window that says:

'Irradiance file BSE40103.REF successfully written.'

Close the DOS window by clicking-on the X close button in the upper right corner of the DOS window.

Move BSE40103.REF to the main FieldSpec directory, for example, C:\FR.

- A7. Double-click-on InterpLMP. If all is well, you should see a message in a DOS window that says:

'Irradiance file LMP40103.ILL successfully written.'


For FieldSpec Pro FR Software, Interp.exe has interpolated the wavelength intervals to **1 nanometer**, the Irradiance units to **Watts/meter<sup>2</sup>/nanometer**, and the format to ASD binary.

For FieldSpec Pro VNIR Software, Interp.exe has process the data to the same WaveStep interval as the Raw Data in **nanometers**, the Irradiance units to **Watts/meter<sup>2</sup>/nanometer**, and the format to ASD binary.

Close the DOS window by clicking-on the X close button in the upper right corner of the DOS window.

Move LMP40103.ILL to the main FieldSpec directory, for example, C:\FR.

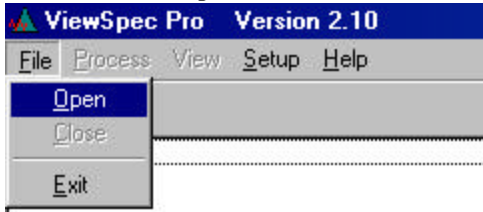


- A8. Open ViewSpec Pro from the Desktop Short-cut. ViewSpecPro

- A9. Set the **Input** and **Output** directories to the main FieldSpec directory. For example:



A10. Select **File**, and **Open**.

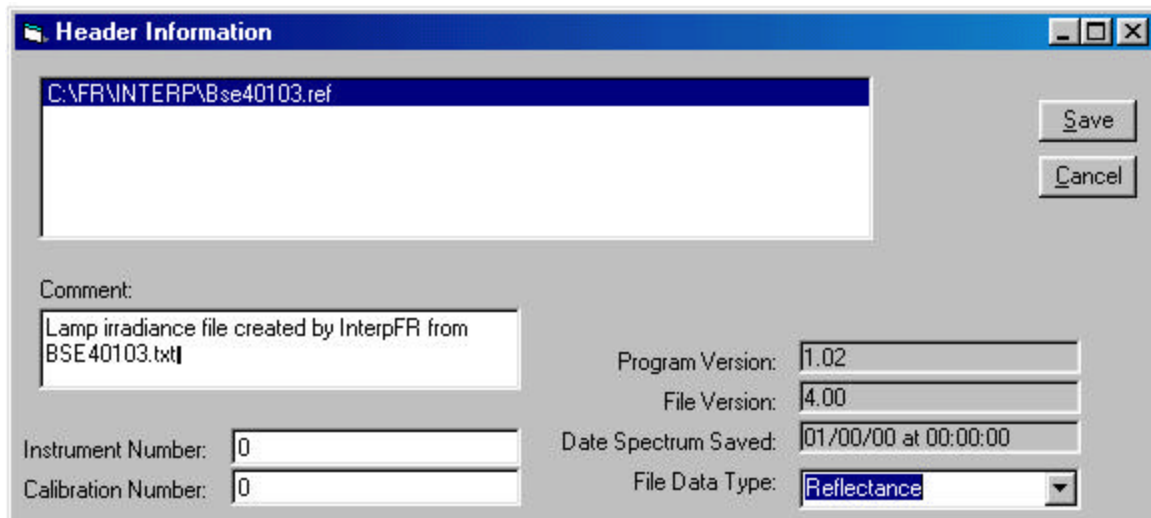


Select the file the BSE40103.REF.

Under View, select Header Info.



Change the **File Data Type** from Irradiance to **Reflectance**. Click-on **Save**.



Note: The default File Data Type of Irradiance is already selected for the Irradiance file LMP40103.ILL. So, there is no need to change the File Data Type for LMP40103.ILL.