ARCoptix ANIR

Fourier Transform Spectrometer
An ARCoptix Product

Installation and Operation Manual

Document Number ARC-00000-000-02-0310

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GROUP
COMPANY

Ocean Optics offers the most comprehensive, innovative and high-quality line of modular spectroscopy tools in the world. We have partnered with ARCoptix (**www.arcoptix.com**) to offer their ARCoptix ANIR FTS spectrometer to work with our SpectraSuite Spectrometer Operating Software. We invite you to contact us at Ocean Optics, Inc. (see front cover for contact information) or ARCoptix S.A. with any technical questions, comments, or applications inquiries. ARCoptix can be contacted at the following location:

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About This Manual

Document Purpose and Intended Audience

This document provides the user of ARCoptix ANIR Series FTS Spectrometers with instructions for setting up, and performing experiments with their spectrometer.

Document Summary

Chapter	Description
Chapter 1: *Introduction*	Contains descriptive information about the ARCoptix Spectrometer and how sampling works. It also provides a list of system requirements, interface options, and shipment components.
Chapter 2: *Installing the Spectrometer*	Provides hardware and software installation instructions.
Chapter 3: *Using the Spectrometer*	Describes how to use operate the spectrometer with SpectraSuite software.
Chapter 4:*Troubleshooting*	Contains recommended steps to isolate and correct common problems.
Appendix A: *How the ARCoptix ANIR Works*	Discusses Arcspectro ANIR technology.
Appendix B: *Specifications*	Contains technical specifications for the ARCoptix ANIR Series Spectrometer.

Product-Related Documentation

You can access documentation for Ocean Optics products by visiting our website at **http://www.oceanoptics.com**. Select Technical → Operating Instructions, then choose the appropriate document from the available drop-down lists. Or, use the Search by Model Number field at the bottom of the web page.

Detailed instructions for SpectraSuite Spectrometer Operating Software is located at: **http://www.oceanoptics.com/technical/SpectraSuite.pdf**.

Upgrades

SpectraSuite software updates will be available from Ocean Optics, Inc. from our Software Downloads web page: **http://www.oceanoptics.com/technical/softwaredownloads.asp.**

Occasionally, you may find that you need to make a change or an upgrade to your system. To facilitate these changes, you must first contact Customer Support to obtain a Return Merchandise Authorization. Please contact Ocean Optics for specific instructions when returning a product.

Warranty

This product is covered by a limited 1-year warranty that starts 30 days after purchasing hteh spectrometer. Using the equipment in a manner not specified by this manual may impair the protection provided by the equipment. Information in this document is subject to change without notice and does not represent a commitment on the part of ARCoptix S.A. or Ocean Optics, Inc. No responsibility is assumed by ARCoptix S.A. for the use of this software, hardware or other rights of third parties resulting from its use. The software described in this document is furnished under a license agreement and may be used or copied only in accordance with the terms of the agreement. The user may make a single copy of the software for archival purposes.

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BUYER'S SOLE AND EXCLUSIVE REMEDY UNDER THIS WARRANTY IS THAT THE SELLER EITHER AGREES TO REPAIR OR REPLACE, AT SELLER'S SOLE OPTION, ANY PART OR PARTS OF SUCH PRODUCTS THAT UNDER PROPER AND NORMAL CONDITIONS OF USE, PROVE(S) TO BE DEFECTIVE WITHIN THE APPLICABLE WARRANTY PERIOD. ALTERNATELY, SELLER MAY AT ANY TIME, IN ITS SOLE DISCRETION, ELECT TO DISCHARGE ITS WARRANTY OBLIGATION HEREUNDER BY ACCEPTING THE RETURN OF ANY DEFECTIVE PRODUCT PURSUANT TO THE TERMS SET FORTH HEREIN AND REFUNDING THE PURCHASE PRICE PAID BY BUYER.

Place of Service

Seller shall use its best efforts to assist buyer to resolve all warranty related issues through Ocean Optics technical support as soon as reasonably practicable after notification by the Buyer of a possible defect. However, the Seller reserves the right to require the Buyer return the Product to Seller's production facility, transportation charges prepaid, when necessary, to provide proper warranty service.

Effective Date

The effective date of this warranty shall begin on the date of shipment/date of invoice, whichever is later. Products are warranted to be free from defects in materials and workmanship for parts and labor for 1 year with the exceptions indicated below:

Limitations

Products are warranted to be free from defects in materials and workmanship for parts and labor for 1 year with the following exceptions:

- Any components of the system that are in direct contact with corrosive materials are warranted to be free from defects in materials and workmanship at time of delivery but cannot be further warranted due to the unknown nature of the use of the product.
- Consumable items such as lamps, cuvettes and optical filters are excluded from this warranty. If a lamp undergoes a catastrophic failure (e.g., no light at all) within 90 days of shipment from the factory, it will be replaced at no charge.
- Loss, damage, or defects resulting from transportation to the Buyer's facility, improper or inadequate maintenance by Buyer, software or interfaces supplied by the buyer, unauthorized modification or operation outside the environmental specifications for the instrument, use by unauthorized or untrained personnel or improper site maintenance or preparation.
- The sole and exclusive warranty applicable to software and firmware products provided by Seller for use with a processor internal or external to the Product will be as follows: Seller warrants that such software and firmware will conform to Seller's program manuals or other publicly available documentation made available by Seller current at the time of shipment to Buyer when properly installed on that processor, provided however that Seller does not warrant the operation of the processor or software or firmware will be uninterrupted or error free.
- Products that have been altered or repaired by individuals other than Ocean Optics personnel or its duly authorized representatives, unless the alteration or repair has been performed by an authorized factory trained service technician in accordance with written procedures supplied by Ocean Optics.
- Products that have been subject to misuse, neglect, accident, or improper installation.

The warranty herein applies only to Products within the country of original delivery. Products transferred outside the country of original delivery, either by the Seller at the direction of the Buyer or by Buyer's actions subsequent to delivery, may be subject to additional charges prior to warranty repair or replacement of such Products based on the actual location of such Products and Seller's warranty and/or service surcharges for such location(s).

Chapter 1

Introduction

Overview

The heart of an ARCoptix ANIR FTS Spectrometer is an interferometer module that contains a micromechanical device, actuation and driving electronics. Additionally there is a laser based feedback system to control the motion of the micromechanical device. Dedicated optical components bring the light onto the surface of the interferometer mirrors, as well as fibers for in-coupling and out-coupling of light.

The interferometer module is packaged in a friendly cover including the detection board, all necessary electronics with the A/D converter and the USB data transfer. The instrument is USB powered.

Figure 1-1

In Figure 1 − 1, the Fourier transform is based on the lamellar grating concept. One distinguishes the input for the optical fiber for bringing the light to the spectrometer. The whole spectrometer is low consumption. Data transfer to the computer and powered supply are done by the USB plug.

Benefits of the ARCoptix ANIR Spectrometer

The concept of lamellar grating interference (LGI) leads to a drastic simplification of the assembly and alignment tolerances. Because of the use of the LGI, a different type of actuation could be used, making the whole device extremely compact. In fact, there is no need of placing a beamsplitter in the light path. To assure highest precision, a low power laser is used to control of the position of the scanning system.

Thanks to micromechanics technology and to the LGI concept, this instrument could have been made compact enough to be portable and, because of the principle, easily upgradeable to any much larger wavelength ranges. The limitation in wavelength range is not due to the concept, but due to the photodetector that is used. In the standard model the detection of the interferogram is carried with one single InGaAs photodiode. A single photodiode instead of a CCD line leads to lower noise and cost-effective detection solutions, particularly in the near-IR. In addition, the choice of available detectors is much larger than CCD and it is therefore easier to dedicate a detector to specific needs. There is no risk of defective pixels as it is generally the case for conventional NIR spectrometers using arrays of photodiodes.

As a result, this instrument is unrivaled and perfectly suited for detection in transmission like measurement of gases and liquids. In particular, the absorption signatures of gases are measured with high accuracy. The instrument is capable of recording 2 spectra per second but needs more time for processing so that an effective measurement time results that might be larger.

The spectrometer provides a number of important benefits including the following:

- Laser controlled interferometer
- Choice of resolution
- Different amplification levels
- Data acquisition in 500 ms with an effective measurement time of 5 s
- A minimum power requirement - The spectrometer is driven by a standard USB 2.0 port of a personal computer.
- The performance is unaffected by stray light
- The system is compact and lightweight.

The spectrometer is typically employed as a part of a system that includes a source and a sample holder (a cuvette holder or a reflectance sphere). As an example, the spectrometer can be used with the Tungsten Halogen Light Source and the Holder for 1-cm cuvettes. The source and cuvette holder or reflectance sphere are acquired separately. As an alternative, the spectrometer can be directly connected to the source to obtain the spectrum provided by the source).

The ARCoptix Near-Infrared Spectrometer can be used in a broad range of applications including

- Portable Field Measurements
- Laboratory Analyses
- Industrial Process Control

Product Description

The ARCoptix ANIR spectrometer is a lamellar grating spectrometer that combines the advantages of Fourier Spectroscopy with micromechanics technology. The first gives exciting optical features while the second leads to miniaturization and reliable operation. A lamellar grating interferometer is a grating that operates in the zeroth order. This particular type of apparatus was invented by Strong [J. Strong, and G. A. Vanasse, "Lamellar grating far-infrared interferometer", J. Opt. Soc. Am. 50, 113-118 (1960). A scheme of the principle is illustrated in the Fig. 1.2 below.
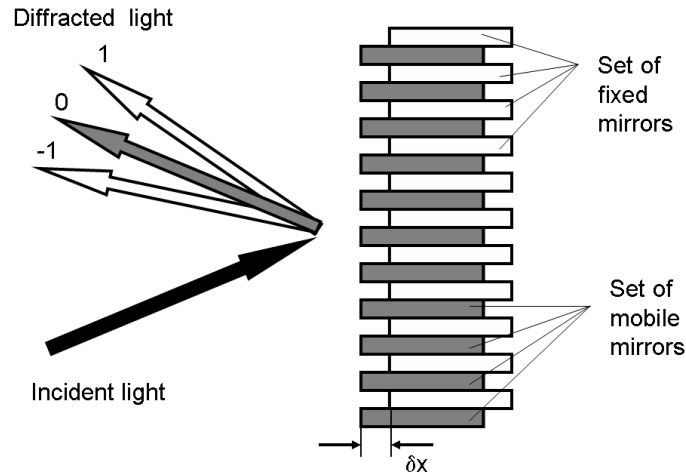
Figure 1-2

Figure 1- 2 shows the principle of operation of a LGI. Incoming light is reflected back by a series of fixed and mobile mirrors acting as a grating and generating a diffraction pattern. To obtain the interferogram one records the modulation of the zero order in function of the motion of the mobile mirrors. The path difference (or depth of the grating) δx is an important parameter and given by the distance between the fixed and the mobile mirrors.

Contrary to the Michelson interferometer that splits wave amplitudes at the beamsplitter, the lamellar grating interferometer divides the wavefront. At the grating, the wavefront is divided such that one half of the beam is reflected from the front facets (fixed mirrors in Fig. 1 - 2) and one half from the back facets (mobile mirrors in Fig. 1 - 2). The distance between the two series of mirrors determines the optical path difference (OPD) δx between the two parts of the wave. The enormous advantage of this configuration, compared with a Michelson interferometer, is the absence of a beamsplitter. Indeed, any additional micro-optical component is a limitation in the particular case of micro-sized spectrometers. In general, this type of spectrometer is used for wavelengths larger than 100 μm; below, the tolerances are too tight for most machine shops.

The ARCoptix ANIR (Near Infrared) Fiber Optic Fourier Transform Spectrometer connects to a notebook or desktop PC via a USB 2.0 port. It does not require an external power supply. The ARCoptix ANIR and the electronics share a single housing.

The ARCoptix ANIR can connect via the USB 2.0 port to any PC that uses a Windows XP/Vista operating system and has spectrometer operating software installed and configured for use with your ARCoptix ANIR.

An EEPROM memory chip in each ARCoptix ANIR spectrometer contains calibration coefficients, coefficients, and the serial number unique to each spectrometer. ARCoptix spectrometer operating software reads these values from the spectrometer.

The ARCoptix ANIR has two input connectors:

- FSMA receptacle that accepts a fiber optic cable with a standard SMA-905 connector
- USB port that connects to a USB host via a standard USB cable

Models Available

The following ARCoptix ANIR spectrometer models are available form Ocean Optics:

	ANIR 0.9-1.7	ANIR 0.9-2.6	ANIR 2.0-4.5
Spectral Range	900-1700 nm	900-2600	2000-4500
Signal to Noise	>1:1000	>1:1000	>1:1000
Detector Type	InGaAs	InGaAs	MCT

Items Included with Shipment

Important information and documentation accompany your ARCoptix NIR spectrometer shipment.

This includes:

❑ Packing List – The packing list is located inside a plastic bag attached to the outside of the shipment box (the invoice is mailed separately). The items listed on the packing slip include all of the components in the order. The packing list also includes important information, such as the shipping and billing addresses, as well as any components on back order.

❑ Software CD – Each spectrometer order comes with the Software & Technical Resources CD. This disc contains Ocean Optics software and manuals for software operation, spectrometers, and spectroscopic accessories. Documentation is provided in Portable Document Format (PDF). You need Adobe Acrobat Reader version 6.0 or higher to view these files.

Installing the Spectrometer

Overview

You must install the SpectraSuite spectrometer operating software application prior to connecting the ARCoptix ANIR spectrometer to the PC. The ARCoptix spectrometer operating software installs the drivers required for Windows to communicate with the ARCoptix ANIR. If you do not install the software first, the system will not properly recognize the ARCoptix ANIR.

If you have already connected the ANIR Spectrometer to the PC prior to installing the software, consult Chapter 4: *Troubleshooting* for information on correcting a corrupt installation.

Follow the steps in this section to interface the ARCoptix ANIR Spectrometer via the USB port to a desktop or notebook PC.

To connect the ANIR Spectrometer to a PC via the USB port, the PC must be running the XP/Vista operating system. *You also must have administrator privileges in order to run the installation package*.

Installation Overview

Spectrometer installation consists of the following main tasks:

► *Procedure*

1. Install SpectraSuite spectrometer operating software on the destination computer. See the *SpectraSuite Spectrometer Operating Software Installation and Operation Manual* (refer to *Product-Related Documentation*) for more information on installing SpectraSuite.

2. Install SpectraSuiteHub.msi on the destination computer. This is a bundled utilities Windows service that provides access to the spectrometer. See *ARCoptix Software Installation* for more information.

3. Reboot the system.

4. *After* installing all software files, connect the spectrometer to your computer using the USB cable (USB-CBL-1) that came with the ANIR Spectrometer. See *Hardware Installation* for more information.

Note

Windows XP users may encounter a **Hardware Installation** warning window regarding Windows XP driver testing. Click the **Continue Installation** button at this screen, as this is an expected warning.

ARCoptix Software Installation

The ARCoptix spectrometer can only be controlled via ARCoptix's proprietary driver. Thus, a compatibility layer (SpectraSuiteHub.msi) is necessary to allow SpectraSuite communicate with this driver.

You can install the SpectraSuite-Hub on any 32-bit Windows computer. Typically you will install it on the same computer on which SpectraSuite was installed, but this is not a requirement. If you choose to install the SpectraSuite-Hub on a remote computer (any computer other than the one on which SpectraSuite was installed), you must modify the Windows firewall settings. See *Modifying Windows Firewall Settings* for more information.

Installing SpectraSuite-Hub Software

The ARCoptix spectrometer requires version 3.0, or later, of the Microsoft .NET framework. On some systems, it may be necessary to install this version.

.NET Framework 3.0

If your PC does not have the required version of the .NET framework, the SpectraSuite-Hub installer will detect this and remind you to install the .NET framework before proceeding:
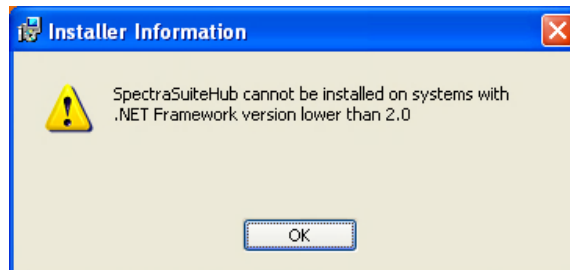
To install the required version of the .NET framework, click OK on this prompt or double-click on the dotnetfx3setup.exe installer utility in the directory containing the SpectraSuite-Hub installer. Follow the on-screen prompts. This file is also available from Microsoft **here.**

► *Procedure*

1. Run the SpectraSuiteHub.msi software installer (located on your Ocean Optics Software & Technical Resources CD and also available on our website at **http://www.oceanoptics.com/technical/softwaredownloads.asp** as SpectraSuite/ARCoptix Driver Installer).

2. The installer will verify if your system has a version of the .Net Framework already installed. If so, you will see the first setup wizard screen. Click **Next**. If not, follow the instructions in the note above.

3. Follow the prompts for the SpectraSuiteHub Setup Wizard.

4. When requested by the wizard, connect the spectrometer to the computer's USB port using the supplied USB cable. See *Hardware Installation* for more information.

5. Click **Finish** on the SpectraSuiteHub Setup Wizard.

6. The ARCspectro ANIR Setup Wizard appears.

Note

If the ARCspectro ANIR Setup Wizard does not appear automatically, go to C:\Program Files\Ocean Optics\SpectraSuiteHub and double click on the file ARCspectro ANIR 1.5b Installation Package.exe. Then follow the on-screen instructions.

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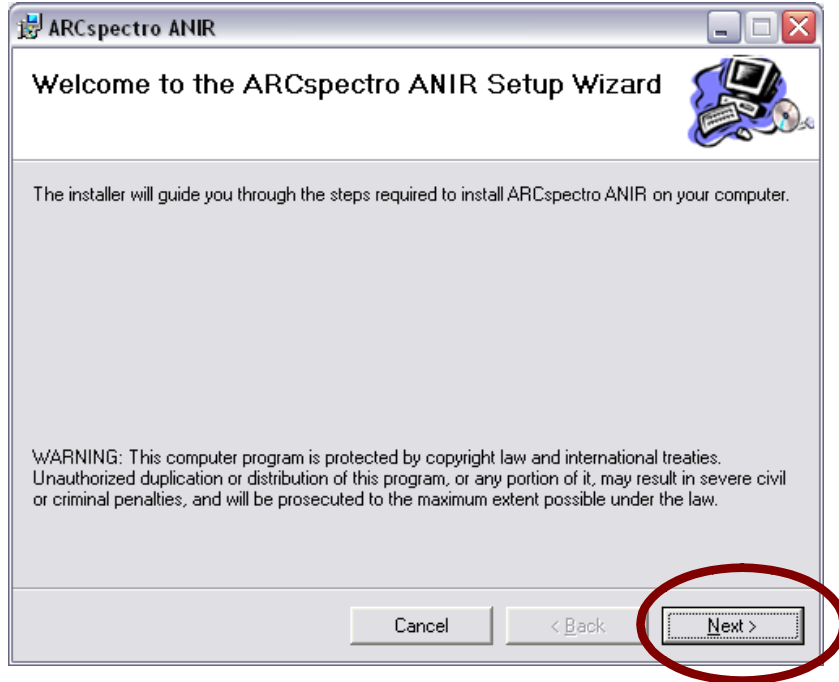
7. The **Select Installation Folder** screen appears. Choose the installation directory and press **Next**.
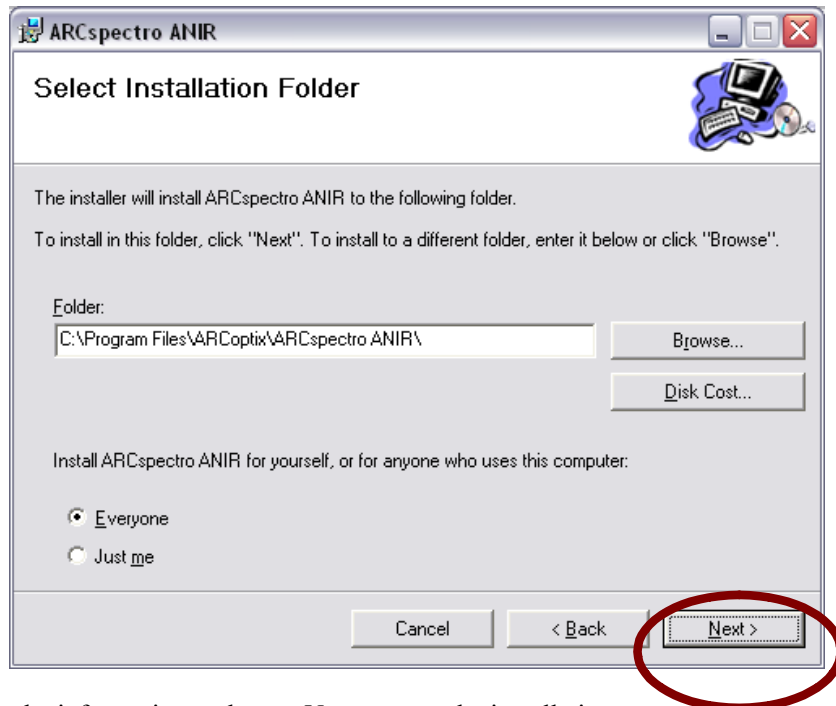
8. Verify the information and press **Next** to start the installation.
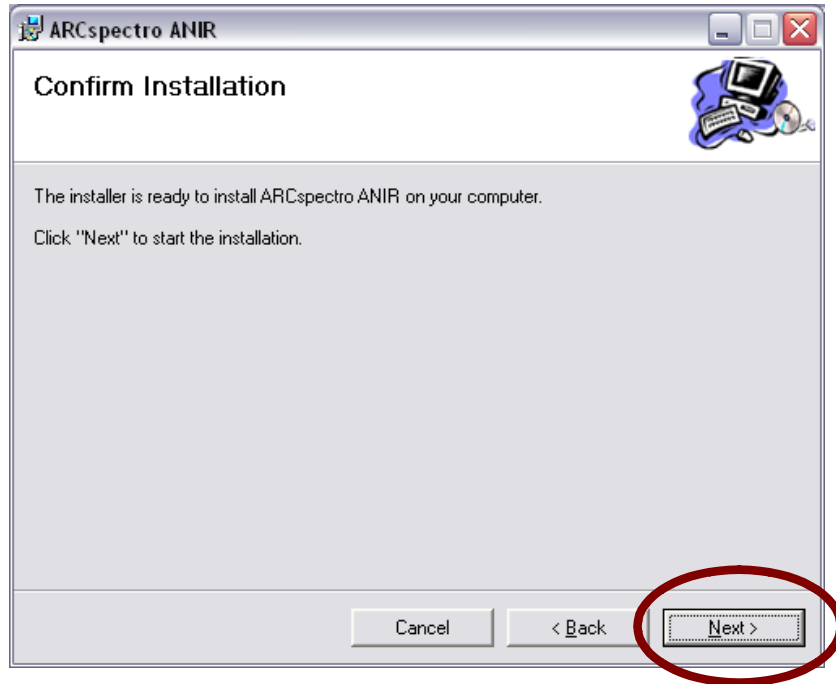
9. The installer will install the necessary files for the software.
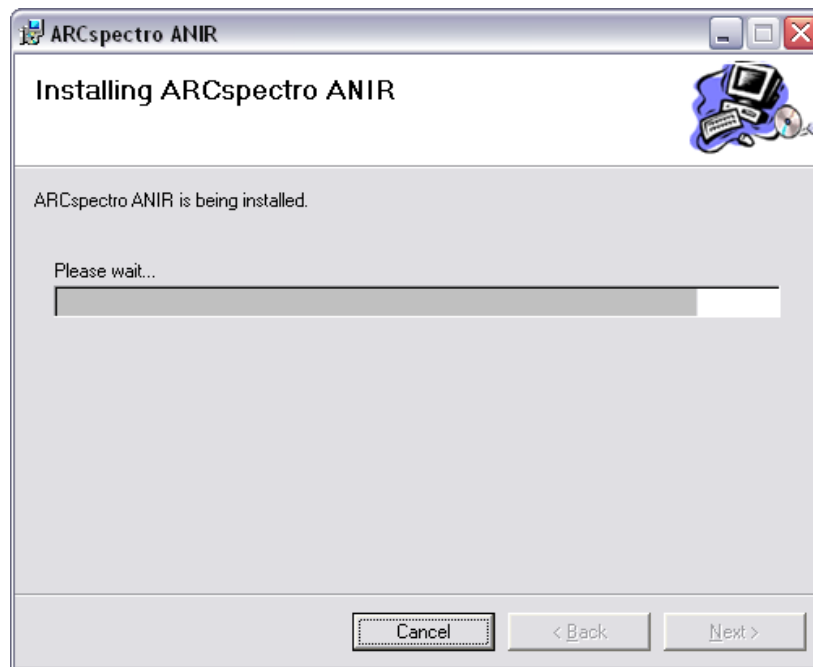
10. The device drivers installation will then start automatically. Disconnect the spectrometer if is connected to the computer and press **OK**.
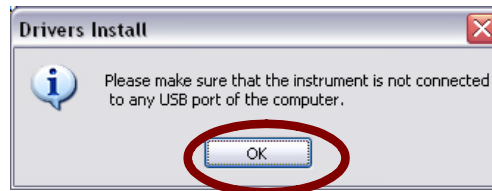
11. When Window's Device Driver Installation Wizard window appears, press the Next Button.

12. If the installer informs you that the drivers have not passed the Windows logo, please ignore the message and press **Continue Anyway**.

13. When the drivers are installed, press **Finish**.

14. This completes the installation of the Arcspectro ANIR. Press **Close** to connect the Instrument.

15. Now you need to connect the device to your USB 2.0 port. The following window will appear automatically. Select "**Install the software automatically (Recommended)**" and press the **Next** button.

16. If the installer informs you that the drivers have not passed the Windows logo, please ignore the message and press **Continue Anyway.**
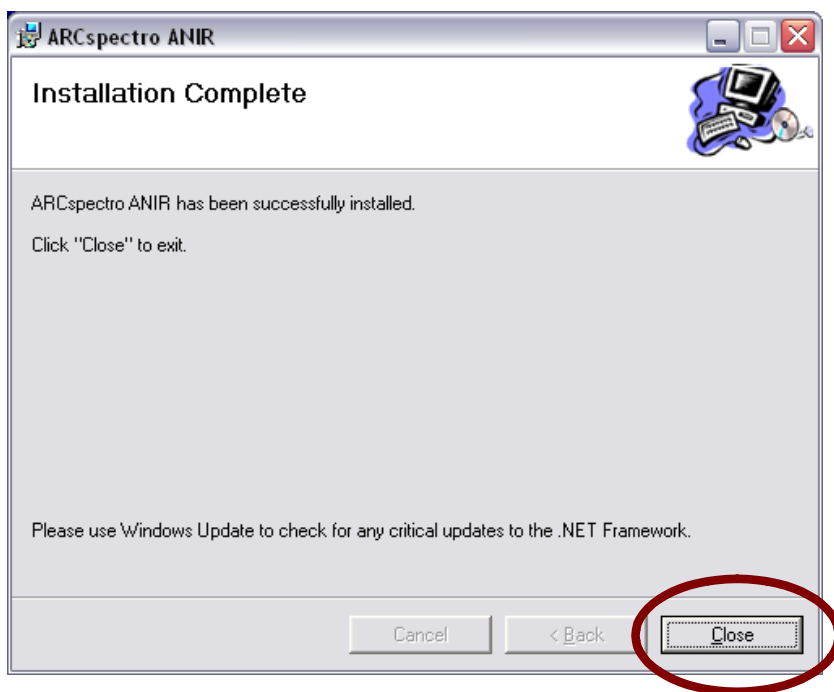
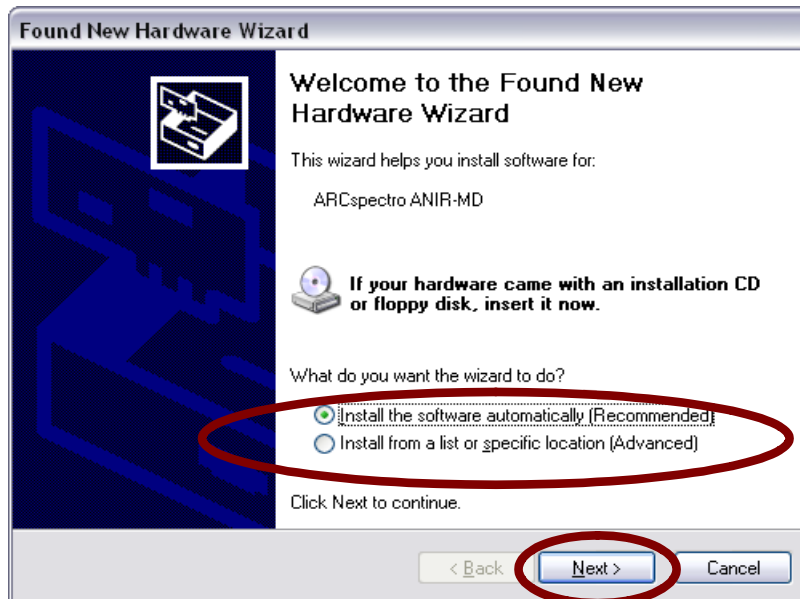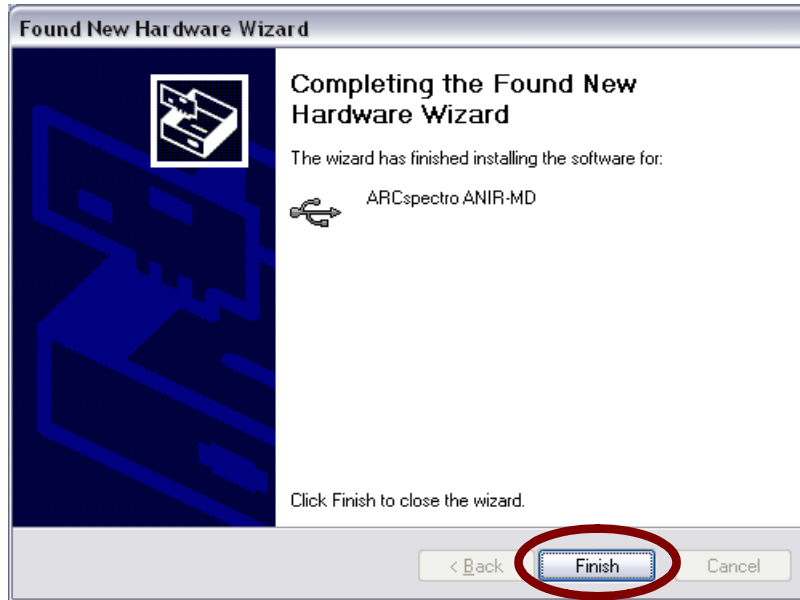17. The device is now ready to be used. Press **Finish**.

Modifying Windows Firewall Settings

If you installed the SpectraSuite-Hub on a remote computer (i.e., any computer other than the one on which SpectraSuite was installed), Windows Firewall settings must be modified to allow SpectraSuite to access the SpectraSuite-Hub. Normally the install script will do this automatically. However, if the script is unable to do this, you must manually add the SpectraSuiteHub program to the list of the firewall's exceptions.

► *Procedure*

To modify firewall setting on a Windows Vista computer,

1. Open the Windows Control Panel.

2. Click on the Windows Firewall icon (classic view) or select Security | **Windows Firewall**.

3. Click on the **Change settings** link.

4. Click on the **Exceptions** tab.

5. Click on the **Add program** button.

6. Browse to **C:\Program Files\Ocean Optics\SpectraSuiteHub.** Highlight SpectraSuiteHub.exe and click **Open**.

7. Click **OK** until the Windows Firewall dialog box(es) are all dismissed.

Configuring the ANIR Spectrometer

The ARCoptix ANIR spectrometer has to be used with the included software when connected to the USB port. There is no particular configuration process. The calibration is included in the software and cannot be changed.

Hardware Installation

Before use the spectrometer must be installed in a measurement setup with the other devices. In addition to the spectrometer (connected to a computer running SpectraSuite) you need the following components:

- 2 fiber optic cables
- Sample holder or probes
- Fiber-coupled lamp (Halogen, preferably 20 W)

The figure below shows a typical transmission set-up. Yours may differ depending on what you are measuring and the type of measurement being taken.
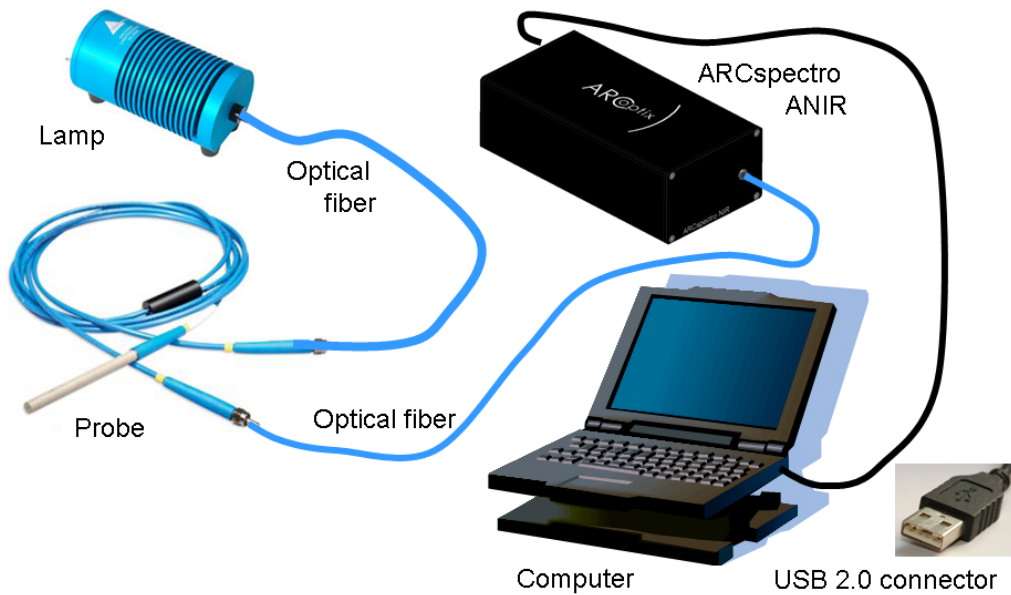
Using the Spectrometer

Overview

Once you have installed the proper software and connected the spectrometer to the desired hardware, you are ready to take measurements. This chapter provides information on running the SpectraSuite-Hub service and starting SpectraSuite when using an ARCoptix ANIR spectrometer. SpectraSuite functions specific to the ARCoptix ANIR spectrometer are also discussed. However, general SpectraSuite operation is covered in the main *SpectraSuite Spectrometer Operating Software Installation and Operation Manual* (see *Product-Related Documentation*).

Starting the SpectraSuite-Hub Service

The SpectraSuite-Hub service must be running before SpectraSuite can access the ARCoptix ANIR spectrometer. Normally, this service is started automatically when you boot your Windows system. However, if it is necessary to manually start or stop the SpectraSuite-Hub service, use the SpectraSuite-Hub Service Controller utility to do this.
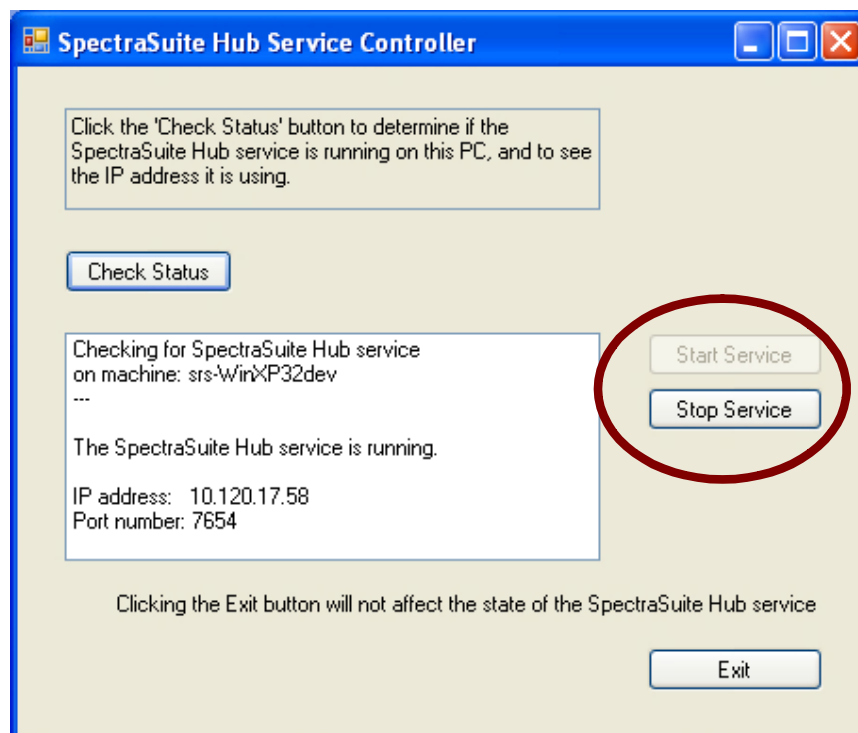
If you are running on Vista, read the section below on how to start the Controller utility. Otherwise, to start this utility, double-click on the desktop icon labeled **SpectraSuite Hub Controller**. There is also an item in the Start Menu within the SpectraSuiteHub folder labeled **Shortcut to SpectraSuiteHubLocator.exe**.

You can click the "Check Status" button to verify that the SpectraSuite-Hub has been installed and is started. **It also displays the IP address and port number currently used by the SpectraSuite-Hub.** You will need this IP address and port number later on when you run SpectraSuite.

Use the **Start Service** and **Stop Service** buttons to start and stop the SpectraSuite-Hub service.

Starting the SpectraSuite-Hub Controller Utility on Vista

When starting the SpectraSuite-Hub Controller task, you must run it with *Administrator* privileges. If you do not have the required permissions, you will see the following error message: "**System.InvalidOperationException: Cannot open SpectraSuiteHub service on computer '.' --> System.ComponentModel.Win32Exception: Access is denied**".

To run the SpectraSuite-Hub Controller with Administrator privileges, right-click on the shortcut icon or the **Start Menu** item for the Controller and choose **Run as administrator**. The User Account Control pop-up window may appear requesting permission to run this task. Respond by clicking **Allow**.

Note

If you only wish to check the status of the SpectraSuite-Hub service, you do not need to run the SpectraSuite-Hub-Controller task with Administrator privileges. Administrator privileges are only necessary if you intend to start or stop the SpectraSuite-Hub service.

Using SpectraSuite

Once you have installed the SpectraSuite-Hub service, ensured it is in the "started" state, and plugged in the ARCoptix ANIR spectrometer to the computer running SpectraSuite, you can control the spectrometer and view spectra using the SpectraSuite application.

► *Procedure*

1. Start SpectraSuite.

2. From the menu, select **Spectrometer | Network Spectrometer**.

3. Click on the **ARCoptix spectrometer** radio button. The following window appears:
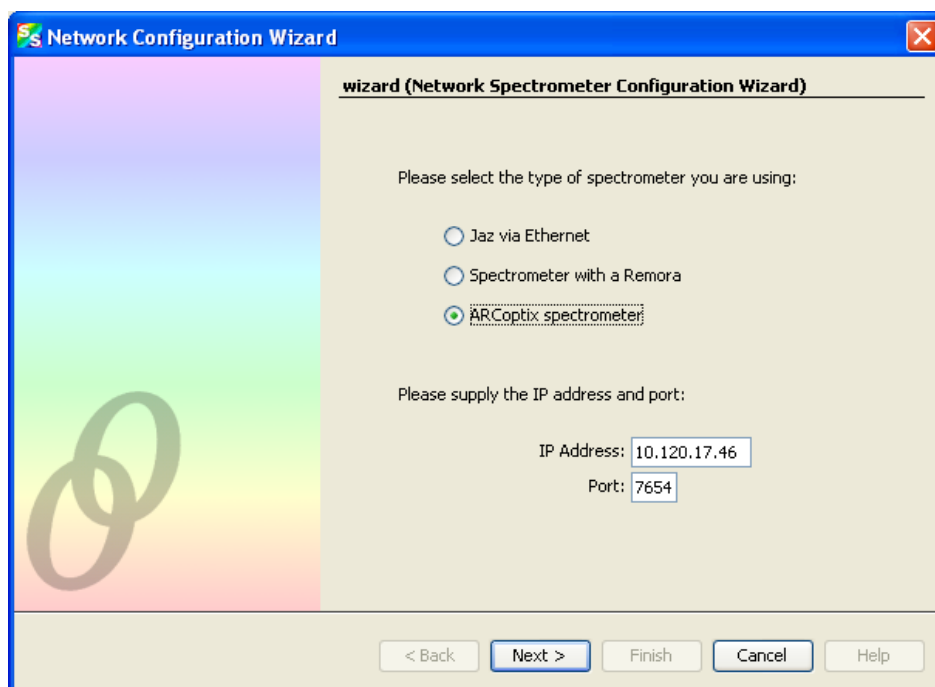
4. Enter the IP address and port number of the ARCoptix ANIR spectrometer.
   You can determine the IP address and port number by running the SpectraSuite-Hub
   Controller utility on the computer attached to the ARCoptix ANIR spectrometer. See *Starting
   the SpectraSuite-Hub Controller Utility on Vista* for information on how to obtain these
   numbers. When finished, click **Next**.
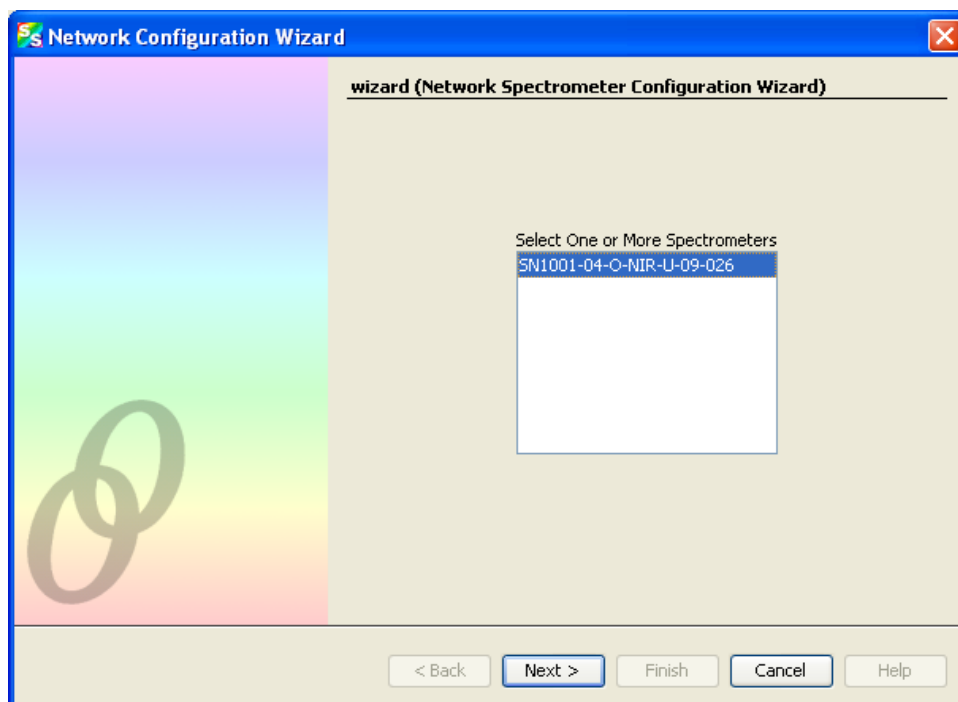
5. Highlight the serial number of the spectrometer you wish to view. Then, click **Next**.

6. Click **Finish**. The icon for the ARCoptix ANIR spectrometer now appears in the **Data Sources** pane.

7. Right-click on the ARCoptix ANIR icon and choose **Spectrum Graph**.

Note

The ARCoptix ANIR spectrometer requires several seconds to acquire each spectrum.

Gain Setting

The ARCoptix ANIR spectrometer does not use an **integration time** setting to control its operation. However, the spectrometer does have a unique setting called Gain you can use to accomplish a similar purpose. Scans-to-average and boxcar averaging are supported by the ANIR.

You can set the gain to one of four values: low, medium, high, and extreme.

► *Procedure*

To set the gain on your ARCoptix ANIR spectrometer:

1. Right-click on the ARCoptix ANIR icon and choose **Spectrometer Features**.

2. Click on the **Gain** tab.

3. After selecting the desired gain setting, be sure to click **Update Now**.

Shutting Down

When you shut down SpectraSuite, it is not necessary to shut down the SpectraSuite-Hub service. The service will remain idle in the background waiting for SpectraSuite to restart.

Chapter 4

Troubleshooting

Overview

The ARCoptix ANIR Spectrometer is an instrument that is designed for use in a laboratory or field application with a minimum amount of maintenance. Since it is normally used with a source and cuvette holder, we describe the maintenance and troubleshooting with respect to the entire system. The user should refer to the documentation provided with the integrating sphere or source and sample holder, as it is very possible that the problem is in one of these components, rather than the spectrometer.

Maintenance

The ARCoptix ANIR requires a minimum amount of maintenance. If necessary, the unit can be wiped clean with a damp cloth. The lamp in the source should be replaced on a periodic basis as described in the documentation provided with the source. Typically, the lamp life is 1000-2000 hours, but this time is dependent on the lamp and the degree of noise that can be tolerated in the spectrum.

Caution

There are no user-replaceable parts inside the spectrometer. Do <u>not</u> take it apart.

Troubleshooting Tips

Since the ARCoptix ANIR spectrometer is employed in a system that includes a source and a sample holder or integrating sphere, all troubleshooting activities should include all components of the system. Troubleshooting can be simplified with following guidelines:

In almost all cases, there is a single cause for the problem. As an example, a noisy spectrum can be due to one or more of the following causes:

- The lamp is weak.
- The fiber optic cable does not make good contact with the spectrometer or the sample holder.
- There is an internal defect in the spectrometer.

A fundamental knowledge of the role of each component in the system is extremely useful in diagnosing the problem. It is also helpful to have spare components on hand to substitute for those in the system.

- If any aspect of the analytical conditions is to be changed, run a "before and after" test to verify that the effect of the change is well understood. Do not consider any change as trivial.

As an example, if you change the supplier of a solvent, verify that the change has no effect on the analysis.

- Run a standard (or a series of standards) on a periodic basis to verify that the system is performing properly. When abnormal data is obtained, collect the spectrum of a standard and compare the spectrum to one that was previously obtained.

- If an error message is presented, press the **Continue** button indicated on the *Error Message* dialog box. If this does not remedy the problem, turn off the spectrometer, disconnect the USB cable and then reinstall the cable.

- The following SpectraSuite error message can be caused by the Windows firewall, which blocks applications from communicating over the Internet. If this is the cause, follow the steps given in the *Modifying Windows Firewall Settings* section. This error may also occur because you have entered the wrong IP address or port number (see *Starting the SpectraSuite-Hub Service*).
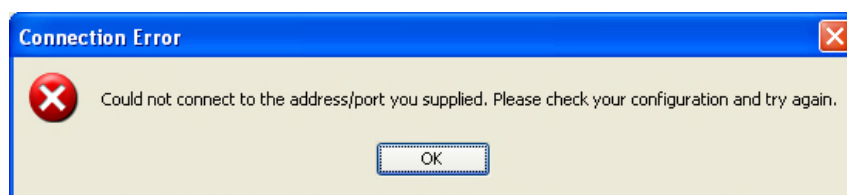
Spectrum is Noisy

Possible Cause	Comment	Suggested Solution
Lamp is weak	The lamp has a finite lifetime	Replace the lamp
The absorbance is weak or % T is very high (noisy spectrum)	The sample is too dilute or too thin	Prepare a more concentrated sample
		Use Spectrum Averaging to reduce noise
The absorbance is too strong	The sample is too concentrated or thick	Dilute the sample or reduce its thickness
Cable is loose		Check all cables for good contact
Fiber optic cable is defective		Replace fiber optic cable
Transient internal spectrometer fault		Remove USB cable and re-insert
Defect in Spectrometer		Contact Ocean Optics

No Signal

Possible Cause	Comment	Suggested Solution
USB cable is loose		Check cables for good contact
Light not on		Check light
Sample not appropriate		Use a different sample
Transient internal spectrometer fault		Remove USB cable and re-insert
Defect in Spectrometer		Contact Ocean Optics

Signal Intensity is Not Constant

Possible Cause	Comment	Suggested Solution
Fiber optic cable has shifted in position		Tape fiber optic cable to bench
Lamp is not stable	Defective lamp	Replace the lamp
Sample is not homogeneous (cuvette)		Mix sample and filter if necessary to remove particulate matter
Sample is not homogeneous (integrating sphere)		Move integrating sphere to a different region of the sample
Sample is decomposing		Replace sample
Cuvette is scratched	Always place cuvette in sample holder with same plane facing the source	Replace cuvette
Defect in Spectrometer		Contact Ocean Optics

Peak Wavelength Has Shifted

Cause	Comment	Solution
The background spectrum is not valid		Run a new background spectrum
Sample is not homogeneous		Find another region of the sample
Defect in Spectrometer		Contact Ocean Optics

How the ARCoptix ANIR Works

Overview

The ARCoptix ANIR is a miniaturized Fourier Transform Spectrometer (FTS). It is based on the principle named "Lamellar Grating Interferometer" (LGI). The active part of the LGI is driven by a micrommechanical System. A Fourier Transform Spectrometer (FTS) has distinct advantages compared to grating spectrometer in terms of throughput and Signal-to-Noise Ratio (SNR).

The principle of the LGI was invented by Strong [J. Strong, and G. A. Vanasse, "Lamellar grating far-infrared interferometer", J. Opt. Soc. Am. 50, 113-118 (1960). The implementation of the LGI using the emerging technology of micro-machining is unique.

Principle of Operation

An FTS splits the in-coming light in two beams, which are then recombined after having been shifted in phase. The output modulation of the light is recorded as a function of time and called interferogram. The interferogram contains all information about the spectra but contrary to grating spectrometers the information is encoded via a Fourier transform. To obtain the spectra the recorded data have to be Fourier transformed.

The particularity of the instrument developed by ARCoptix consists in using the so-called Lamellar Grating Interferometer (LGI) configuration to produce the interferogram. Instead of using the conventional Michelson interferometer (more precisely, the Twyman-Green interferometer) where two mirrors and a beam splitter are used, the LGI consists of a series of mirrors that from a grating as shown in Fig. A - 1.
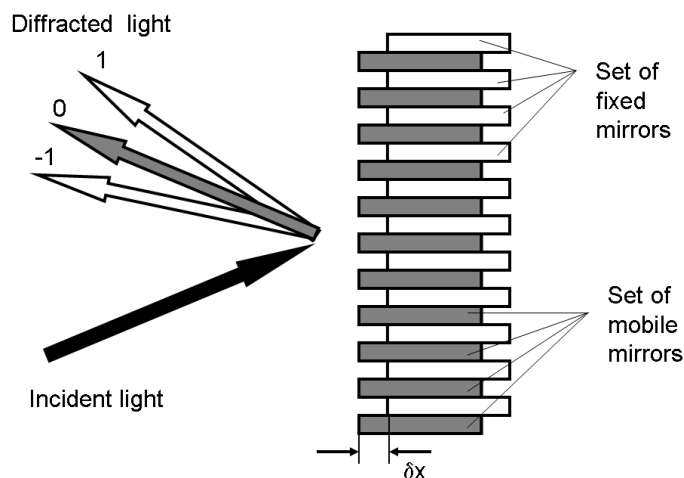

Figure A- 1. The principle of operation of an LGI

Figure A-1 shows incoming light is reflected back by a series of fixed and mobile mirrors acting as a grating and generating a diffraction pattern. To obtain the interferogram one records the modulation of the zero order in function of the motion of the mobile mirrors. The path difference (or depth of the grating) δx is an important parameter and given by the distance between the fixed and the mobile mirrors.

While in the Michelson interferometer one mirror changes its position, in the lamellar grating interferometer a series of mirrors move. The configuration does not need a beam splitter. The LGI splits the wavefront at the mirrors, contrary to the Michelson interferometer that splits the wave amplitude at the beamsplitter. The whole arrangement of mirrors performs like a grating having a variable depth. The interferogram is recorded by measuring the modulation of the zero order, reflected back by the grating, as a function of the depth of the grating. Note that there is no dispersion in the zero order. Exactly like in a conventional Michelson interferometer, the important notion, here, is the phase delay generating at the grating, which is the double of the distance between the fixed series of mirrors and the mobile ones. Figure A - 2 shows the resultant diffraction patterns for selected positions of the movable mirror grating.
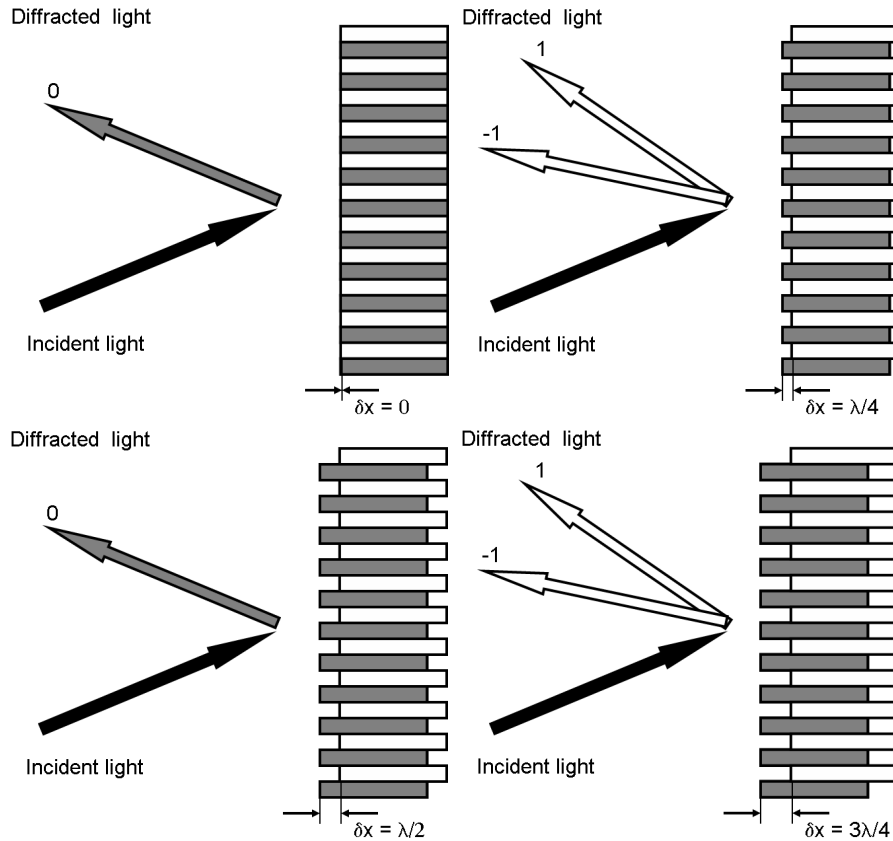
Figure A - 2.

The depth of the grating δx determines the resulting efficiencies in the different diffraction orders. For δx = 0 the grating acts like a simple mirror while for δx = λ/4 no light is found in the zero order. The effect is wavelengths depended. For each wavelengths this conditions is realized for a different δx.

The zero order intensity A for a single wavelength λ_0 can be written as a function of δx and becomes:

$$A = A_0(\lambda_0)\cos^2(\pi\,\delta x/\lambda_0) \qquad\qquad \text{Eq. A - 1}$$

The intensity is thus modulated and changes with a cosine function of the grating depths δx. The period is given by the wavelengths. If the lamellar grating is illuminated with a source containing several wavelengths of intensities $A(\lambda)$, then the interferogram is the integral over all wavelengths λ.

$$I(\delta x) = \int A(\lambda)\cos^2(\pi\delta x/\lambda)d\lambda \qquad \text{Eq. A - 2}$$

The recorded intensity $I(\delta x)$ contains information about the spectral composition of the incoming light $A(\lambda)$ that can be extracted by using a Fourier transform.

It is useful to define the contrast (or visibility) as follows:

$$C(\delta x) = I_{max}(\delta x) - I_{min}(\delta x) \,/\, I_{max}(\delta x) + I_{min}(\delta x) \qquad \text{Eq. A - 3}$$

An important measurement point is the zero path difference ($\delta x = 0$) when all mirrors are at the same positions and the grating acts as a simple mirror. At this point, all intensity values $A(\lambda)$ are added since the cosine term is maximum for all wavelengths. At the zero path difference, the contrast is maximum and equal to unity. If δx is non-zero, then the broader the spectrum of the source, the smaller the contrast. On the other hand, the narrower the spectrum (e.g. monochromatic light source), the higher the contrast.

Reference Laser

The ARCoptix NIR contains a reference laser to precisely control the position of the movable parts in the interferometer. The reference laser operates at about 635 nm and its spectra can be measured depended on the light level in the measurement channel. To check the operation of the reference laser choose the EXTREME detection gain and choose the spectral range in the graphing options.

Resolution

In Fourier spectroscopy, resolution is depending of the maximum optical path difference (i.e., phase delay) that you can achieve with the interferometer. The longer the scanning range the higher the resolution. Strictly speaking, the smallest spectral interval that can be discerned is defined as:

$$\Delta\sigma = \frac{1}{\delta x_{max}} \qquad \text{Eq. A - 4}$$

Resolution is usually defined as the smallest spectral interval multiplied by the truncation effect of a boxcar. This corresponds to the full width half maximum of a monochromatic radiation. If no apodization is used, resolution is about $1.2*\Delta\sigma$ and if a triangle apodization is used, then resolution is $1.7*\Delta\sigma$.

Detector Nonlinearity

If the detector response does not increase linearly with the illumination intensity the measured interferogram will be distorted. Every detector (or analogue/digital converter) shows some non-linearity, especially when approaching the saturation level or the detection limit of the detector. However, if detectors are used in useful range below saturation very good linearity is obtained and distortions are negligible. This has to be respected when the gain level is chosen. To high gain will increase effects of nonlinearity.

Noise

The last aspect treated in this chapter is related to the effect of noise in Fourier transform spectroscopy. The interferogram signal is always accompanied by statistical errors and we want to know their effect on the spectrum. Several types of noise and their origins will be presented in this section.

Signal-to-noise ratio

We define the Signal-to-Noise ratio (SNR) of a set of measurements as the ratio between the mean value of the signals and their standard deviation.

Types of Noise

In spectroscopy, we usually distinguish between additive noise and multiplicative noise. The first one is the noise added to the signal; the latter varies with the signal power. Previously, we have mentioned the multiplex advantage of an interferometer over a dispersive spectrometer (Fellgett advantage). This advantage occurs only for additive noise.

Additive Noise

Thermal noise (or Johnson noise) arises from thermal fluctuations of the current in the detector and is independent of the signal level. In the infrared region, photon energies are smaller than these thermal fluctuations and, therefore, detectors will mainly be limited by thermal noise.

In addition, we mention the dark-current noise, which is an additive noise as well. Photodetection devices also generate dark-current noise, which is present even in the absence of light and results from random electron-hole pairs generated thermally or by tunneling.

Multiplicative Noise

Photon noise (or quantum noise, shot noise) is associated to the electromagnetic radiation itself and is a fundamental quantity. It refers to the fluctuations resulting from the random arrival of photons at the detector. The standard deviation of these fluctuations is proportional to the square root of the number of photons arriving. Therefore, the noise power is proportional to the square root of the signal power. Photon noise is a multiplicative noise. In the near-infrared and visible region, very sensitive detectors (e.g. photodiodes) are available, which allow to approach photon-noise-limited detection. In this case, there is no multiplex advantage of the FTS over a dispersive instrument (note that the interferometer still enjoys the luminosity or Etendue advantage).

Appendix B

Specifications

Specification	Value
Resolution:	8 cm-1
500nm	0.5 nm
1000 nm	1.5 nm
1700 nm	4 nm
2600 nm	9 nm
Wavelengths accuracy	<0.5 nm
A/D converter	24 bit
Fiber optical connector	SMA 905
Optical fiber entrance	0.6 mm (Fiber core diameter)
Minimum scan time	0.5 s
Effective measurement time	<5 s (CPU dependent)
Operating voltage	5 V (USB powered)
Operating temperature	10° - 30°C
Communication interface	UBS 2.0
Software interface	Windows XP
Product dimensions	146 mm x 105 mm x 70 mm
Weight	850 g

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