SCIENCETECH

FTIR

Terahertz Spectrometer

Version 1.1
Jan 2017

Modular Spectral Analyzer
Material Transmission/Reflectance Spectrometer
Far-Infrared and THz Spectral Region

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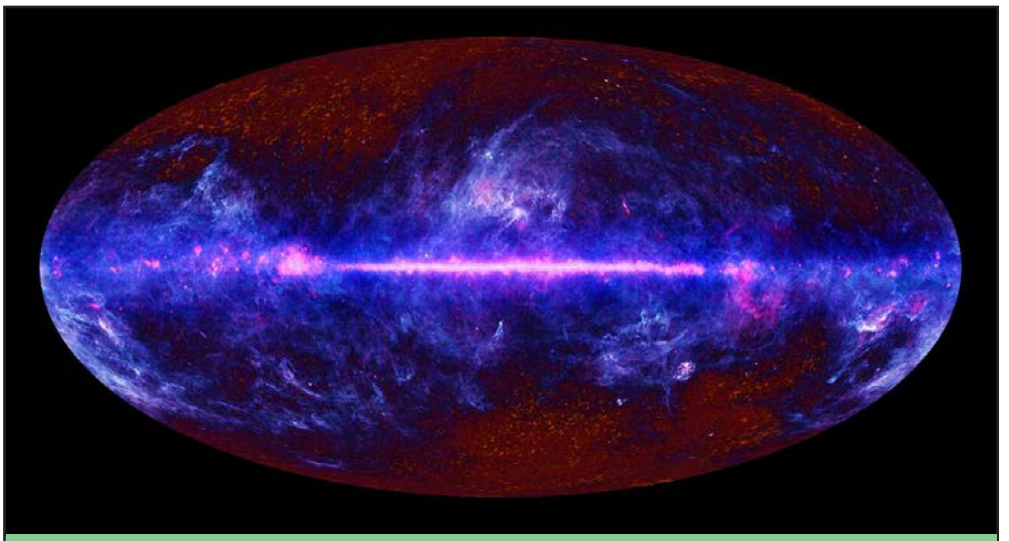
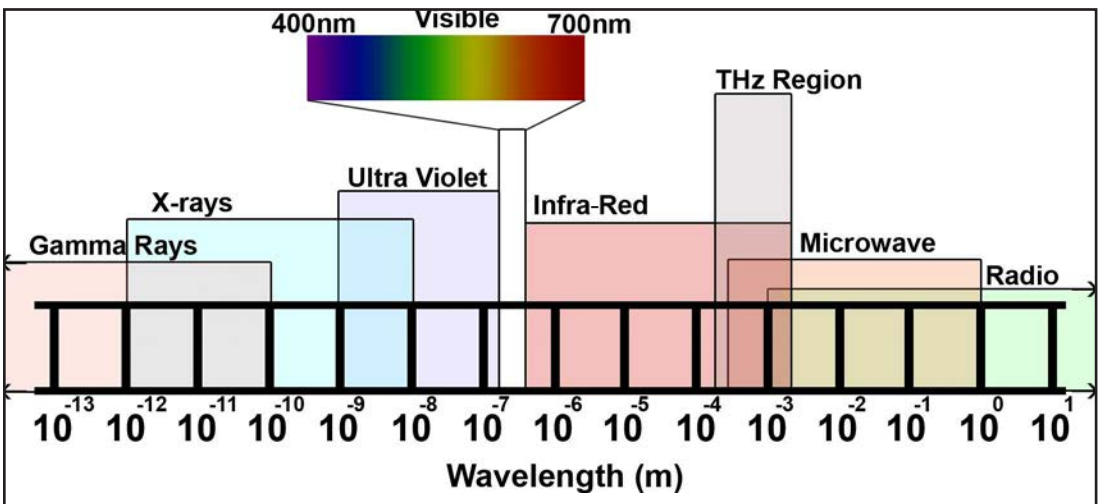


The first full-sky image of the universe's microwave radiation taken by the European Space Agency's Planck Satellite

Far-Infrared and terahertz (THz) radiation is the spectral region at the long wavelength end of the infrared and the short end of the microwave region, also known as the sub-millimeter wavelength spectral region. Recently, there has been an explosion of interest in THz applications as the radiation generated can penetrate various materials. THz light is commonly used in materials science, security, pharmaceutical compound analysis, biomedical imaging, superconducting materials, astronomy, and particle physics research.

Sciencetech is a pioneer in THz spectroscopy, having supplied its SPS-200 Far Infrared FTIR for over 10 years to the sub-millimeter wavelength research communities in astronomy and particle physics. Recently Sciencetech has upgraded its SPS-200 into the superior commercial grade SPS-300/SPS-400 THz spectral analyzer and spectrometer. The European Space Agency, which used the SPS-300 to calibrate the detectors for its Planck/Herschel Mission to analyze the origins of the universe, deserve our thanks for their support in making this possible.



The Electro-Magnetic Spectrum

Model SPS-300/SPS-400 Far Infrared THz FTIR

The SPS-300/SPS-400 is Sciencetech's latest modular polarizing Fourier Transform Spectrometer (FTS), designed specifically to operate in the far infrared or THz spectral region (operating at wave- lengths from 5µm to 5000µm, 0.06 to 60 THz or 2cm^{-1} to 2000cm $^{-1}$). Standard FTS and FTIR systems are based on the Michelson configuration; however, the SPS-300/SPS-400 can also function using the Martin-Puplett configuration, which provides polarization division for a significantly wider band pass when measuring normal transmissions, and has improved signal to noise for circular and linear dichroism measurements.

The modularity of the SPS-300/SPS-400 allows a higher degree of versatility when compared to other similar systems. Our internal source, external input and dual output ports enable the user to configure the SPS-300/SPS-400 as a far-infrared/THz light source spectral analyzer (by attaching an external bolometer detector) or as a materials transmission and reflectance spectrometer (with an external light source, a sample chamber and detector).

The SPS-300/SPS-400 also comes with both a 125mm wire grid polarizing beam splitter and a Mylar beam splitter. The grid polarizer beam splitter allows the user to operate in polarizing Martin-Puplett mode, covering a wider range than the standard Michelson mode which uses the Mylar beam splitter.

THz Scanning Services

Thanks to Sciencetech's pioneering role in establishing terahertz technology, we have founded one of the world's most technologically advanced FTIR labs. The McMaster Application Laboratory, with the co-operation of McMaster University and their leading-edge terahertz researchers, allows Sciencetech to provide spectral analysis and scanning services on various materials in solid, liquid and gas form. Both transmission and reflectance measurements can be taken in the spectral range 20µm to 3.3mm. Scanning services typically take between three to five days, excluding transportation times. Please contact the Special Development Group for additional details at: sales@sciencetech-inc.com

SPS-300 FTIR

The base system of the SPS-300 includes:

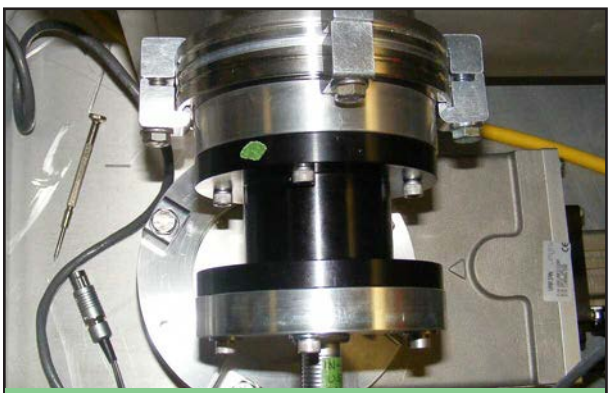
- Stainless steel vacuum rated housing
- Motorized roof mirror alignment system
- Mylar beam splitter for Michelson mode operation
- 75W ultra quiet Hg arc lamp source
- Servo motor chopper
- A wire grid polarizing beam splitter for polarizing Martin-Puplett mode. (An input polarizer and either a rotating or fixed position analyzer are also required for Martin-Puplett mode.)
- Vacuum gauge
- Host PC with SPS control software
- Arc lamp power supply and igniter

Recommended external components:

- Vacuum pump system to maintain 10^{-3} Torr
- vacuum inside SPS-300
- Recirculating water cooler
- Detector, lock-in amplifier and GPIB card
- Spectral Analyzer configuration components
- Materials Spectrometer configuration components
- Sample chamber

Internal Source and Output Ports

The SPS-300/SPS-400 has a built-in 75W Hg arc lamp for use as a broadband THz source as well as two output ports. One output port produces a focused output beam for mating to a detector while the other produces a collimated output beam for mating to an external sample chamber.
Normally, only the focused detector port is used in Spectral Analyzer configuration, while only the output external sample chamber port is used in Materials Transmission/Reflectance Spectrometer configuration; however, with an extra beam splitter both can be used at the same time. The extra ports are also sealed to prevent leakage and maintain a vacuum within the system.



An SPS-300 output port with a detector

Vacuum Environment

The SPS-300/SPS-400 FTIR is able to support a 10 Torr vacuum environment in its optics chamber to minimize the spectral absorption effects of atmospheric water vapour.
The chamber's output ports are built with ISO 100 vacuum rated flanges to make coupling vacuum rated custom sample chambers and detectors possible. Mounting holes are provided for coupling of external light sources to the SPS-300/SPS-400 input port.
While the SPS-300/SPS-400 can operate in a vacuum environment, the equipment required to produce the vacuum is sold separately as an upgrade option.

Main Hardware Features

- Modular design for use as far-infrared, THz spectral analyzer or materials spectrometer
- Dual polarizing Martin-Puplett and Michelson interferometer configurations, depending on beam splitter used
- Industry's finest 4µm Mylar grid beam splitter for polarizing Mode
- Supports external third party light sources and detectors
- Supports external custom designed sample chambers
- Standard precision step and integrate mode
- Large 100mm gold coated optics
- Wide 2~2000cm^{-1} (5µm~5mm) spectral range
- 0.12cm^{-1} resolution for standard model with 50mm stage
- 0.02cm^{-1} for high resolution model with 300mm stage upgrade
- Vacuum sealed housing supporting pressures down to 10 Torr^{-3} to eliminate spectral effects of atmospheric water vapour.

Optics

Our exclusive wire and polarizing beam splitters are designed specifically for the FTIR and are nearly 100% efficient for all wavelengths down to the cut-off frequency set by the grid separation of 4µm.
The system also features large gold coated 100mm optics for high light throughput. A high precision translating stage, large roof mirrors, and large input/output off-axis paraboloids to support a 7.6cm (3") diameter output beam.
The SPS-300/SPS-400 uses a chopper in step and integrate mode. The chopper blade can be replaced with a polarizing chopper blade for Martin-Puplett mode. In rapid scan mode the chopper blade is held stationary in the open position.
The SPS control software and hardware allow the user to change the frequency of the chopper and set the chopper to the open or closed position without having to open the main chamber.

Host PC and Software

A PC with flat screen monitor is supplied as the host computer with the SPS-300/SPS-400 control software fully installed and operational. A copy of the software is also provided on CD. The SPS- 300/SPS-400 control software is a LabView based application that operates on a Windows PC. An executable version of the software is supplied so the user does not require the LabView development environment.
Although Sciencetech only supports the Windows version of the SPS-300/SPS-400 control software, a Mac-OS version is also available through a third party vendor.

Modular LabView VI Structure

Users may add application specific LabView virtual instruments (VI's) without recompiling the SPS-300/SPS-400 software. This is useful for experiment automation where scanning operation needs to be integrated with external features (sample chambers, light sources, temperature controllers, magnetic field sweeps, etc.)

Scanning and Processing Modes

The SPS-300/SPS-400 generates an interferogram by taking multiple detector readings as a mirror translates across a known distance. In the standard Step and Integrate Mode, the mirror stops at a prescribed position for each detector reading.
By stopping, the detector can take long readings for a better signal-to-noise ratio, and the relationship beween the detector reading and mirror position is known to a precise degree.
The software is capable of simultaneous scanning and data analysis. The SPS-300/SPS-400 software runs in its own Window and is undisurbed by other Windows applications running in the background. Automated data acquisition can be achieved with simple command scripts, useful for organizing unattended automated measurements.

Main Software Features

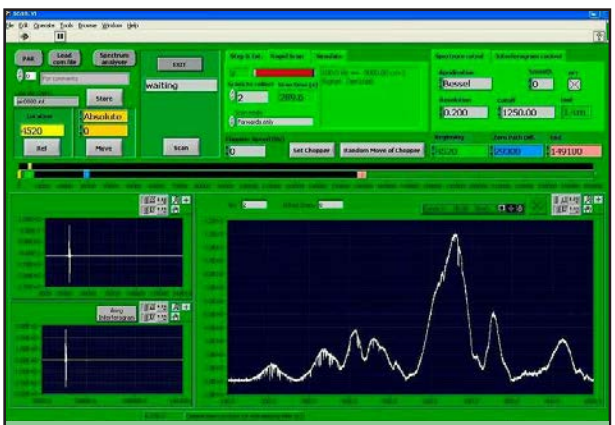
- "Step and Scan" operation
- Data acquisition and automatic log-keeper
- Data stored in ASCII format text files for easy importation into other data analysis software
- Multitasking for simultaneous scan and analysis

Data Processing and Manipulation

- Phase correction by Mertz-Forman method
- Apodizations: Bessel, boxcar, cosine, triangular
- Digital filtering of the rapid scan signal
- Add, subtract, normalize, multiply (interfero grams or spectra)
- Average and standard deviation (interferograms or spectra)
- Fitting of data by user-specified functions:
- functions are analytically specified and new
- functions are automatically saved on the hard
- drive for easy retrieval

Display

- Fast Scan Mode: display of interferogram, spectrum and the relative sigma of the spectrum
- Step and Integrate Mode: display of interfero gram and contents of lock-in amplifier buffer
- Display of spectra, interferograms, ratios, fit results and other data
- Print selected data

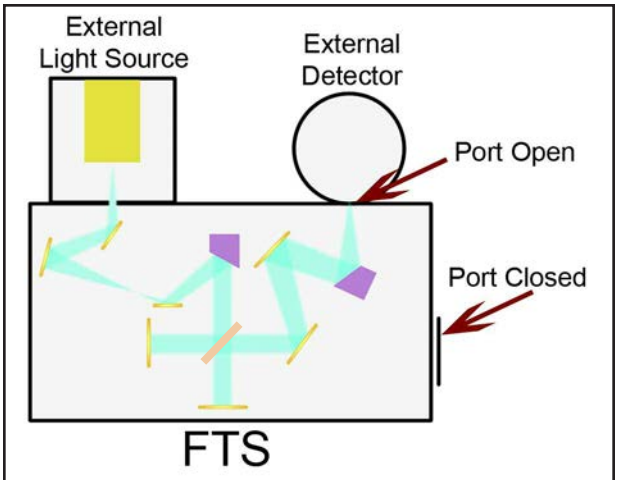


A screenshot of the SPS-300 Software

Depending on which optional components are selected, the SPS-300 can be configured into the following:

Spectral Analyzer

The SPS-300/SPS-400 is used as a spectral analyzer by mounting an external THz light source at the external input port, and an external THz detector at the condensing beam output port.
Sciencetech provides multiple detector options: a room temperature pyro-electric detector, a room temperature DTGS detector, and a helium cooled bolometer. A user can also choose to attach a third party detector to the output port.



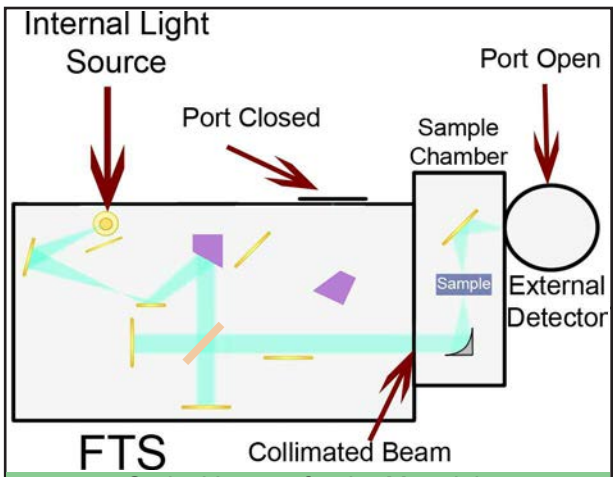
Optical Layout for the Spectral Analyzer Configuration

THz Circular/Linear Dichrosim Spectrometer

In polarizing mode operation, the SPS-300/SPS-400 can also be used for transmission, circular dichroism, and linear dichroism investigations with a good signal-to-noise ratio. The measurement of vibrational circular dichroism (VCD) below ~600 cm is a modern experimental challenge.
Polarization-division interferometry is considered to be the most efficient approach for these measurements. A crucial component for successful applications of this interferometry is the beam splitter that divides the incoming beam according to polarization.
The Sciencetech large area FIR grid polarizers consisting of metallic lines deposited on a mylar substrate are effective beam splitters for the 500cm-1~ 2.0 cm-1 frequency range.

Materials Transmission / Reflectance Spectrometer

The SPS-300/SPS-400 is used as a materials transmission/reflectance spectrometer by mounting an external sample chamber at the collimated beam output port and an external THz detector at the sample chamber detector output port.
For example, the SPS403 sample chamber and detector allows both transmission and reflectance measurements. The source is the broadband Hg arc lamp inside to the SPS-300/SPS-400 body.
As well, other types of broadband THz sources such as a globar or Gunn oscillator can be mated to the external input light port. Please note that the SPS-300/SPS-400 base system does not include these additions.



Optical Layout for the Materials Spectrometer Configuration

IMPORTANT NOTE

Some additional components are necessary for any of these specialized configurations.
The SPS-300/SPS-400 can be configured as a THz spectral source analyzer by inputting the source through the external input port and mating to an external bolometer detector at the output port, or it can be configured as a THz materials spectrometer using the internal source and mating to a sample chamber with detector at the output port.
Please contact our sales department at sales@sciencetech-inc.com for further details.

Spectral Range

The SPS-300/SPS-400 Spectral Range (both Standard and High Resolution Models) is 2 to 2000cm^{-1} (5µm to 5mm or 60GHz to 60 THz). Although the SPS-300/SPS-400 optics can cover a spectral range from 2 to 2000cm-1, the practical range is generally limited by the source and detector combination used. For example, the 2cm-1 low wavenumber spectral range cutoff can only be obtained with a high powered source such as that of a synchrotron entering through the external light source port and a 1.7K helium cooled bolometer detector. Using the internal Hg arc lamp provided, the low wavenumber spectral range cutoff is limited to approximately 4cm-1 using the bolometer. This low wavenumber cutoff increases to about 8cm-1 with a 4K helium cooled bolometer and the internal Hg arc lamp.
At the high wavenumber end, the grid spacing of the polarizer is the limiting factor. Since Sciencetech uses a close pitch 4µm grid polarizer, compared to other polarizers of 12.5µm or 25µm pitch, the SPS-300/SPS-400 is capable of reaching 2000cm^{-1} if the detector and source allow. More commonly the cutoff is closer to 1000cm^{-1}.

Resolution

Standard: 0.12cm^{-1} with 5cm translation stage **High**: 0.020cm^{-1} with 30cm translation stage

The resolution quoted for the SPS-300/SPS-400 is not the theoretical limit as determined by the length of the roof mirror translating stage, quoted by some manufacturers.
Abrupt stopping of data collection at the ends of the interferogram produces oscillations in the Fourier transformed spectrum (that look like “feet” at the sides of strong lines). Sciencetech uses an “apodization” function which multiplies the interferogram by a factor that goes to zero smoothly at the scan ends - but this degrades the resolution somewhat. Although there are several alternatives, we quote the resolution for Bessel apodization, which is degraded by 1.904 from the theoretical limit. In general, resolution is given by:

$$\text{Resolution} = A/(2x2x0.80xL)\ [\text{cm}^{-1}]\ ,$$

where L = stage length [cm] , A = Apodization factor
0.80 is the zero path location factor (zero is 20% from the translation stage end position)

Four different apodizations can be selected on the SPS-300/SPS-400 software, each with its own factor affecting the resolution:

Bessel: A = 1.904 **Boxcar**: A = 1.207 **Cosine**: A = 2.000 **Triangular**: A = 1.772

The recommended apodization for the very far infrared and THz domains is the Bessel function.

Other Specifications

Optics:
Large 100mm beam optics coated for maximum infrared reflection, Fast f/2.35 off-axis paraboloid condensers for high light throughput, 90°±3” roof mirrors, Martin-Puplett optical configuration.

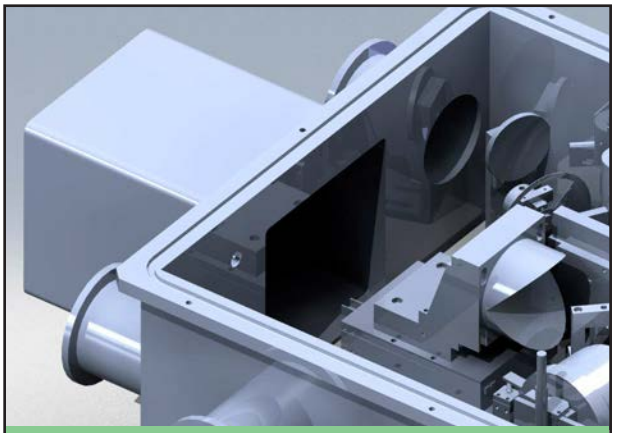
Body:
Stainless steel housing capable of maintaining 10^{-3} Torr.

Source:
Internal 75W Hg arc lamp (water cooled) with external DC stabilized power supply and igniter.
Controls:
Motorized alignment for roof mirror (tilt, rotary shear, lateral shear) to fine tune interference at the beam splitter
Grid Polarizer Beam Splitter:
2µm lines with 4µm pitch aluminum onMylar substrate.

High Resolution Upgrade

The standard SPS-300/SPS-400 has a 50mm translating stage, which can provide resolutions to 0.12cm^{-1}. The high-resolution upgrade option extends the translating stage to 300mm, allowing the SPS-300/SPS-400 to achieve a resolution of 0.020cm^{-1}. Due to the increased stage length, an extension to the vacuum sealed body accommodates the extra travel.

The 300mm stage has a built-in encoder that provides the absolute position of the translating roof mirror to the SPS-300/SPS-400 host computer. This encoder has been individually calibrated at the factory using a laser interferometer for accurate positioning.



Extended Stage for Hi-Res Upgrade

Rapid Scan Mode

Two scanning modes are provided with the system: “Step & Integrate mode” and “Rapid Scan mode”. “Step & Integrate mode” is preferred as lock-in and chopper are enabled or a pulsed source is measured. The control software sets the mirror position via firewire commands and acquires the corresponding detector data via lock-in amplifier’s GPIB interface. Detector data acquisition coordinates with the translating roof mirror position. The user selects an integration time per step between 1 and 10 seconds and it takes about 1 second to move the stage to the next position and restart averaging so this mode takes longer in measurement than in rapid scan mode. However this mode has the advantage of avoiding noise peaks by choosing a proper chopper modulation frequency.

In “Rapid Scan mode”, the roof mirror moves continuously and does not stop at each reference position for detector data acquisition. An interferogram is generated immediately after the mirror completes its translation. The user selects the scanning period between 15 and 60 seconds. Due to this fast scanning speed, this mode is usually recommended to be used for continuous sources instead of modulated or pulsed sources.

In Martin-Puplett polarizing mode, “Rapid Scan mode” works only with a fixed polarization beam splitter placed at the output beam (or with the polarizing chopper in a non-rotating position at the output) while the “Step & Integrate mode” works also with a rotating polarizing chopper. For additional information or questions regarding different scanning modes contact us at sales@sciencetech-inc.com.

Vacuum Operations Upgrade

The standard SPS-300/SPS-400 housing is itself vacuum grade and can maintain a 10^{-3} Torr vacuum environment. The vacuum upgrade contains all of the necessary parts for vacuum operation including: seals, valves, gauges, and port covers. With a typical roughing and turbomolecular pump, the SPS-300/SPS-400 can reach a vacuum of 10^{-5} Torr .

In addition to removing virtually all particles from the SPS300/SPS400 the amount of acoustic noise is greatly reduced when the vacuum operation is active. Initial quality testing of the vacuum is also included in the base upgrade price.

Turbomolecular Pump for Ultra-vacuum oper.

Sample Chamber

This external transmission/reflectance sample chamber can be mated to the output port of the SPS-300/SPS-400 FTIR for use as a Materials Spectrometer. This sample chamber allows small samples to be studied in both transmission and reflectance modes.

The sample chamber can be totally isolated from the SPS-300/SPS-400 vacuum environment by a sealed polyethylene window or optional vacuum gate at its input port (output port of the SPS) enabling the user to change samples without upsetting the SPS-300/SPS-400 vacuum housing. The sample chamber can be operated independently in vacuum or in atmospheric conditions, using reflective aspheric optics with gold coating for far infrared and THz operation; also, a motorized flipping mirror inside the sample chamber allows the user to select between transmission and reflectance modes with ease.

All optics are pre-aligned and focused for a specific detector prior to shipment for easy installation.

Sciencetech can also customize a sample chamber to meet your specific needs: send your inquiries to sales@sciencetech-inc.com

Optical Layout for SPS300 Sample Chamber

Peltier and Helium Cooled Options

The peltier and helium coolers are available to maintain the temperature of the sample holder. For these options, a water cooling loop inside the sample chamber is also required. This water cooling loop can be connected to the same water re-circulating system as the main SPS-300 body or though a separate independent cooler such as the Sciencetech Model 160-REC water recirculator.

Water Recirculating Cooler

160-REC Water Recirculating Cooler

This cooling system is an external unit designed to dissipate up to 700W of heat through a dual fan cooled radiator system, which is enough to cool low wattage water cooled arc lamp housings, IR water filters, cooled PMT housings, and electric motors operating in a vacuum environment.

It is temperature adjustable with a sensor to monitor the real-time temperature of the device and has a back lit LCD which displays the current temperature in either Celsius or Fahrenheit. The desired temperature can be adjusted by setting the cooler's internal radiator fan speed, which is also displayed.

If the current temperature wanders above a "warning" preset value, an alarm will go off. The temperature is monitored by a thermo sensor wire which can be embedded in the device whether it be an arc lamp housing, IR water filter housing, cooled PMT housing, or electric motor operating in a vacuum environment.

DTGS Detector

This is a room temperature based far-infrared detector for use with SPS-300/SPS-400 THz FTIR spectrometers. This detector option includes the DTGS detector wi th a mounting flange (The dual phase lock-in amplifier, required for improved signal-to-noise ratio, is sold separately and is required for several other detectors). The detector can be mounted directly to the SPS-300/SPS-400 body at the detector port, or on the Modular Sample Chamber.

Liquid Helium Cooled and Hot Electron Bolometer

Liquid Helium Cooled Bolometers are far more sensitive than room temperature DTGS or Pyro-Electric detectors in the far-infrared/THz spectral region. However, they are more expensive and delicate to operate, as liquid helium is required.

This detector option includes a customized silicon composite bolometer, pre-amplifier electronics, a helium dewar and interface flange to the SPS-300/SPS-400. The helium dewar cools the detector to 4.2K or 1.7K (depending on version purchased) for high sensitivity. In the 1.7K version an added helium pump connected to the dewar is required. In Rapid Scan Mode, the bolometer interfaces to the AD board, and in Step and Integrate mode it interfaces to the lock-in amplifier which in turn has a GPIB interface.

If this bolometer is purchased separately from the SPS-300/SPS-400, a lock-in amplifier data acquisition system is required.

Liquid Helium Cooled Hot Electron Bolometer and Dimensions

Lock-In Amplifier

Sciencetech IR detectors and optical choppers are designed to work with Stanford Research Systems Lock-in amplifiers. This option includes the lock-in amplifier, all interconnecting cables to Sciencetech detector and chopper, and Sciencetech IR detector operating software.

Sciencetech's SPS-300 Terahertz Spectrometer requires a two phase lock-in amplifier for its detectors when used in polarizing Martin-Puplett mode.

Conventional lock-in amplifiers use an analog demodulator to mix an input signal with a reference signal. Dynamic reserve is limited to about 60 dB, and these instruments suffer from poor stability, output drift, and excessive gain and phase errors.

Demodulation in the LIA-830 is accomplished by sampling the input signal with a high-precision A/D converter and multiplying the digitized input by a synthesized reference signal.

This digital demodulation technique results in more than 100 dB of true dynamic reserve (no prefiltering)
and is free of the errors associated with analog instruments.

Two-Phase Digital Lock-In Amplifier

External Source Selector

Available for both the Spectral Analyzer and Spectrometer configurations, this option adds an internal motorized mirror such that an external THz source entering through the external input port can be selected instead of the internal Hg arc lamp source. The internal Hg arc lamp source is turned off when the external light source is selected.

Without this option, the only available light source is the built-in internal Hg arc lamp source.

This option is required in the Spectrum Analyzer configuration where an external source spectrum is measured. It is also required in the Materials Spectrometer configuration if the user wishes to use an external source to illuminate the sample.

Simultaneous Dual Output Ports

The SPS is typically configured to use only one output port - either the converging output for mating to a detector when the instrument is used as a spectral analyzer or the parallel output for mating to a sample chamber if the instrument is being used as a materials spectrometer.

This option allows the instrument to use both outputs simultaneously. The internal mirror that directs the parallel beam to the converging output is replaced by a large beam splitter which sends half the radiation to the converging output and the rest to the parallel output.

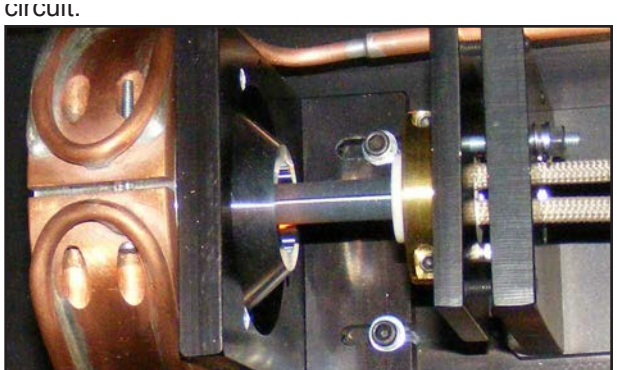
Globar Light Source

Sciencetech can supply a demountable Globar light source that can be mounted to the external light source port of the SPS-300/SPS-400 THz Spectrometer.

When the internal light source flipping mirror of the SPS-300/SPS-400 is set to the external light source port, the Globar becomes the excitation source rather than the internal arc lamp.

The Globar is enclosed in its own vacuum housing (sharing the same vacuum space of the SPS-300/SPS-400) and with water-cooling lines that interconnect to the SPS-300/SPS-400 cooling circuit.

circuit.



Internal Globar Light Source and Cooling Circut

Computer Controlled Polarized Chopper

The Sciencetech C230X-Polar variable frequency optical chopper is used with the detectors during the Polarizing Martin Puplett mode. The chopper is positioned in front of the output port just before the detector. The Polarized captures the output at 45º to the two planes of collimation.

This facilitates the retrieval of the Fourier Transform Interferogram during Martin Puplett mode.

The optical chopper is designed for high stability and broad range frequency control from 0.5Hz to 100Hz.

Price includes servo motor controller and Sci-Chopper Active-X software.

Technical Specifications

- Chopper Motor Type: DC Servo Motor
- Motor Speed: 0.5 to 100 Hz
- Blade diameter: 4” outer diameter, 3.5” aperture diameter
- Standard Aperture: 4
- Input Power: 115VAC @ 60Hz or 230VAC @50 Hz. single phase

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