



GEMINI

INTERFEROMETER

TIME-RESOLVED EMISSION SPECTRUM (TRES) MANUAL

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This manual is continuously updated by our staff to help our customers to use the GEMINI interferometer at the top of its potential. You can always find the latest version of this manual at **www.nireos.com/downloads**

We made our best to assure that the manual is clearly written and does not contain errors, but we are aware of possible imperfections. Please contact us at info@nireos.com in case you spot an error or in case you find hard to understand some parts of the manual.

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Contents

1. Introduction	3
2. Principle of Operation	3
3. List of Supported TCSPC system (Alphabetical Order).	4
4. Front Panel.....	5
4.1 Single Movement Panel	5
4.2 FT Parameters panel	6
4.3 STATUS panel.....	6
4.4 STEP SCAN panel.....	7
4.5 TCSPC System Parameters and Status panel	8
5. Matlab Processing Scripts	8
5.1 Gemini_HISTOGRAM_script	9
Measurement parameters:	9
5.2 Gemini_MAP_script.....	9
Measurement parameters:	9
6. Configuration Files	10
a) *_parameters_int.txt.....	10
b) *_parameters_scale.txt.....	10
c) *_parameters_cal.txt.....	10

1. Introduction

This manual aims to show a step-by-step example of how to properly acquire Time-Resolved Emission Spectrum (TRES) maps with the NIREOS GEMINI Interferometer using the LabVIEW programming language. The described application is based and tested on LabVIEW 2019 (32 bit), although similar code can be written with any previous and future LabView versions with slight variations. The application is released as an executable or a distribution source code folder depending on the Time-Correlated-Single-Photon-Counting (TCSPC) system and/or the user choice. The main file is *NIREOS Complete Example *_#.vi*. The * indicates the specific TCSPC system. The # symbol indicates the GEMINI controller type. **All the remaining necessary functions and calibration files must be present in the same folder as the main file.**

This manual is intended for users with previous knowledge of the principle of Fourier transform spectroscopy, TCSPC Systems, and the GEMINI interferometer operating principle. See the Theoretical Manual for a detailed explanation.

All the processing codes to retrieve the light spectral information are the results of years of research in the Fourier Transform spectroscopy field and have been tested and applied to a great variety of scientific applications. Please have a look at www.nireos.com to see the wide applicability of this device.

2. Principle of Operation

The measurement principle is simple, the GEMINI performs a scan and for each step drives the TCSPC board to acquire a single histogram with a user-selected collection time. This histogram sequence is organized in a 2D matrix (TCSPC time axis vs Interferometer Position) and is defined as the “Interferometric MAP”. During the scan, this map is progressively built and displayed in the “Interferometric MAP” panel in the bottom right part of the front panel. In this manual, we refer to this map together with the corresponding temporal and spatial axis as the RAW interferometric data. After the scan, a Fourier Transform converts the interferometric map into the TRES map, displayed in the “TRES (preview)” panel. The RAW data can be saved at the end of the scan for further advanced processing. The “Mean Interferogram” panel displays the cumulative mean of the RAW data while its corresponding spectrum is displayed in the “Mean Spectrum” panel.

3. List of Supported TCSPC system (Alphabetical Order).

Becker & Hickl GmbH:

- SPC-130-EMN (Tested).
- SPC-150 (Tested).
- All SPC family board (Compatible).

PicoQuant:

- PicoHarp300 (Tested).
- TimeHarp260 (Tested).
- HydraHarp400 (Tested).

Swabian Instruments GmbH

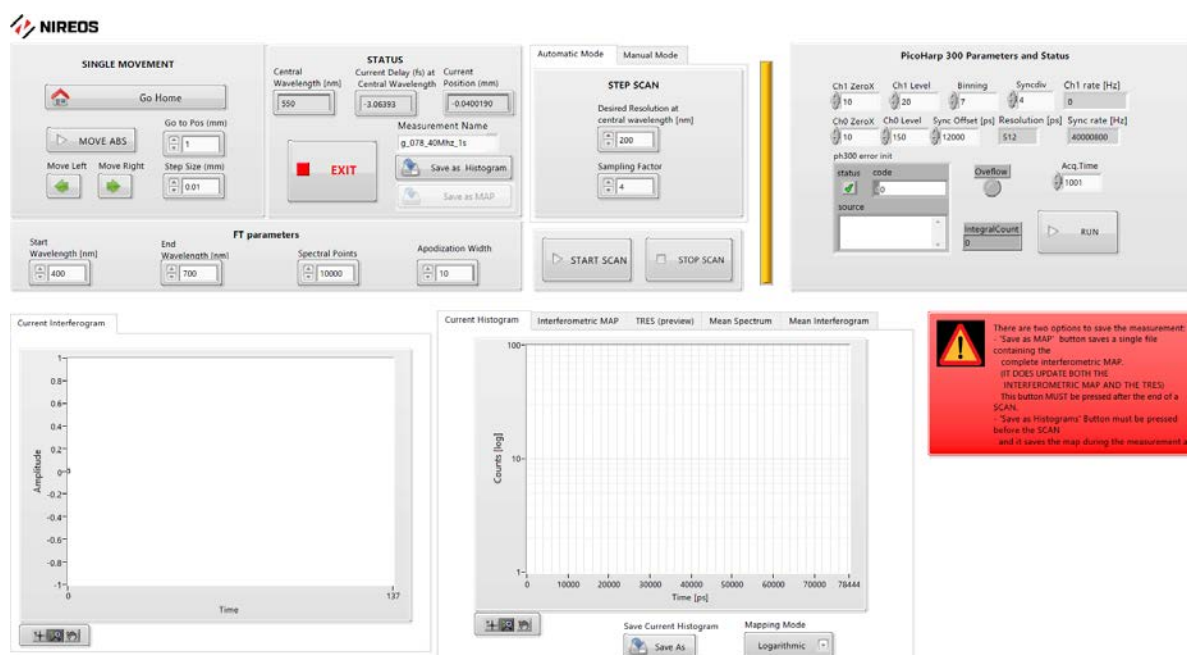
- Time Tagger 20 (Tested).
- All Time Tagger boards (Compatible).

Universal Quantum Devices

- Logic16 (Tested)

We are always prone to widen our portfolio of supported devices. If you are interested to have support for a TCSPC not listed here. Please contact us at info@nireos.com.

4. Front Panel



4.1 Single Movement Panel

By using the control buttons in this panel, it is possible to move the positioner to the desired positions.

- “Go Home” moves the positioner to the defined “home position”. Each time you run the software; the positioner always moves to the defined “home position” first. *NB. The ‘home position’ is the position of the interferometer where the interferometric delay is set to zero. The GEMINI interferometer is shipped with the right “Home position” and in general there is no need to manually change its value.*
- “MOVE ABS” performs an absolute movement to the desired position indicated in the Go to Pos (mm) numeric control. The absolute movement is performed with respect to the “Home position”.
- “Move Left” performs a negative relative movement with respect to the actual current position of the positioner. The amount of movement is selected in the Step Size (mm) numeric control.
- “Move Right” performs a positive relative movement with respect to the actual current position of the positioner. The amount of movement is selected in the Step Size (mm) numeric control.

The total travel range of the positioner is:

S version	L version
12 mm	31 mm

4.2 FT Parameters panel

In this panel, the user can select the spectral parameter of the measured light spectra as computed by a Fourier Transform (FT) of the measured signal.

- “Start Wavelength” selects the shortest wavelength of interest of the measured light.
- “End Wavelength” selects the longest wavelength of interest.
- “Spectral Points” selects the number of spectral points of the output spectra.
- “Apodization Width” defines the standard deviation (normalized to the scan edges) of the gaussian apodization window. The apodization window is multiplied to the acquired signal before the FT is performed.

NB. In FT-spectroscopy the maximum scan length defines the spectral resolution (see *Theoretical Manual* for more details).

NB. *Start Wavelength* and *End Wavelength* parameters do not affect the spectral transmission of the GEMINI interferometer. The settings above set only the computed output spectra parameters.

4.3 STATUS panel

This panel shows the actual status of the interferometer and lets the user save the RAW interferometric map to be processed with the Analysis software as described in the TRES analysis manual.

- “Central Wavelength” indicator shows the current middle wavelength of the spectral range defined in the FT parameters panel.
- “Actual delay (fs) at Central Wavelength” indicator displays the current delay of the GEMINI interferometer as computed for the central wavelength. Differently from Michelson’s interferometer, for each position of the GEMINI interferometer, each wavelength of the input light experiences a different delay.
- The “Actual position (mm)” indicator shows the current position of the interferometer in millimeters. The current position is defined with respect to the “Home position” corresponding to position: 0 mm.
- The “EXIT” button is used to disconnect the interferometer and stop the software.
- Measurement Name: Name of the file to be saved. The files are automatic saved in the Measurement folder and they are organized in sub-folders by date and time.
- Save as MAP: This button saves three files containing the raw measurement data:
 - “* MAP.txt”: Is a 2D matrix (TCSPC time axis vs Interferometer Position) containing the histogram sequence, one histogram for each interferometer step.
 - “* POS.txt”: Array containing the sequential positions in millimeters of the interferometer
 - “* TIME.txt”: TCSPC temporal axis in picoseconds.

This saving mode is not recommended for long scans with a high number of samples. In this case, please use the Save As Histogram mode.

- Save as Histogram: Recommended saving mode. For each position of the interferometer, the measured histogram is saved sequentially in single files. The temporal and Position axis are saved at the end of the scan.

This saving mode is recommended for long scans with a high number of samples. In this mode, the measured data is not held in memory, but it is saved during the measurement, preventing RAM saturation. After the scan, since the measurement file is not in memory (RAM), the TRES map is not calculated and the “Interferometric MAP”, “TRES (preview)”, “Mean Spectrum”, and “Mean Interferogram” panels are not updated.

4.4 STEP SCAN panel

This section is used to perform step scanning of the interferometer. The user can choose between two modes of operation. In *manual mode*, the user can define all the scan parameters (not recommended). In *automatic mode*, the scan parameters are defined based on the user-selected spectral resolution at the central wavelength.

Manual Mode (not recommended):

- “Start (mm)” and “End (mm)” define the travel range of the scan in millimeters with respect to the “home position”.
- “Number of Steps” defines the number of steps of the scan.
- “Waiting Time” defines the time (in milliseconds) during which the positioner does not move between one step and the other. The software automatically waits for the specific TCSPC system integration value. The “Waiting Time” value is added to the latter increasing the total stopping time of the interferometer. The default value is zero.

Automatic Mode (recommended): in this operation mode all the parameters are chosen automatically based on the user-defined spectral resolution and the selected spectral range parameters (see “Start Wavelength [nm]” and “End Wavelength [nm]”).

- The “Desired resolution at central wavelength [nm]” numeric control sets the resolution at the central wavelength of the spectral band defined by the user. This control sets automatically the scan range of the interferometer.
- The “Sampling Factor” defines the minimum number of points per period of the interferogram. This control sets automatically the number of steps of the scan. The sampling factor is defined with respect to the shortest wavelength of the input signal. The shortest wavelength is defined by the user with the “Start Wavelength” numeric control.

It is very important to choose the “Start Wavelength” and “End Wavelength” to fit the expected light spectrum to optimize the scan parameters, the measurement time, and signal quality.

- The “START SCAN” button starts the scan.
- The “STOP SCAN” button stops the scan.

4.5 TCSPC System Parameters and Status panel

This panel contains the TCSPC parameters, indicators, overflows, and errors. These parameters are specific for the used TCSPC board and their complete descriptions are available in the specific manuals provided by the TCSPC manufacturers and are beyond the scope of this manual. The typical parameters are:

- Acquisition time: The histogram collection time in seconds
- Overflows: This flag is on when the TCSPC board detects overflows.
- IntegralCounts: The cumulative number of counts of the current histogram.
- Binning: The binning factor to use.
- Channel thresholds: Channel Voltage threshold.
- Channel Zero Levels: Zero levels in Volts for the specific channels.
- Channel Offsets: Offset in picoseconds applied to the specific channel (TCSPC dependent).
- Channel Rates: Current Rate in Hz.
- “RUN”: the run button starts the continuous (oscilloscope) mode acquisition of the TCSPC histograms. The histogram is displayed in the “Current Histogram” tab in the Front Panel’s bottom part. This mode is very useful to align and optimize the signal at the detector. While continuously acquiring the histograms, the GEMINI can be moved by acting on the Single Movement Panel parameters. Moving the interferometer across the zero position (hence, where the interferometric modulation is higher) might help to optimize the interferometric contrast (maximizing the signal variation as a function of the interferometer position).

5. Matlab Processing Scripts

This section aims to show the working principle of the scripts used to retrieve the TRES. The main scripts are *gemini_HISTOGRAM_script.m* and *gemini_MAP_script.m*. These scripts were developed and tested in MATLAB R2018b. All the remaining necessary scripts and files **must** be placed in the same folder as the main scripts (See 6). The user should set some parameters before running the script, they will be detailed in the next sections. Eventually, the code will plot the 2D TRES map of the measurement.

5.1 Gemini_HISTOGRAM_script

This script shows how to retrieve the time-resolved emission spectrum (TRES) from the interferometric histograms measured by the GEMINI interferometer. *This script works with measurement saved with the “Save as Histogram” button in the LabVIEW acquisition program.*

Measurement parameters:

Before running the script the user should set:

- “start_wave”: select the shortest wavelength of interest of the measured light.
- “end_wave”: select the longest wavelength of interest.
- “sample”: select the map’s number of spectral samples.
- “apodization_width”: defines the standard deviation of the gaussian apodization window. This apodization window is multiplied to the acquired signal before the Fourier Transform is performed.

N.B. *start_wave* and *end_wave* parameters do not affect the spectral transmission of the GEMINI interferometer. The settings above set only the computed output spectra parameters.

Once it is run a dialog window appears that allows the user to navigate the directory to find the interferometric histogram files map saved from the TRES LabVIEW program. The user is prompted to select the file of the first interferometric histogram, which is named “0000_*_MAP.txt”, the remaining histograms are loaded by default.

At the end of the process, this script plots the 2D TRES map as a function of time (x-axis) and Wavelengths (y-axis).

5.2 Gemini_MAP_script

This script, in the main script that must be run. It shows how to retrieve the time-resolved emission spectrum (TRES) from the interferometric map as measured by the GEMINI interferometer. *This script works with measurement saved with the “Save as MAP” button in the LabVIEW acquisition program (see).*

Measurement parameters:

Before running the script the user should set:

- “start_wave”: select the shortest wavelength of interest of the measured light.
- “end_wave”: select the longest wavelength of interest.
- “sample”: select the number of samples of the map.
- “apodization_width”: defines the standard deviation of the gaussian apodization window. The apodization window is multiplied to the acquired signal before the FT.

N.B. *start_wave* and *end_wave* parameters do not affect the spectral transmission of the GEMINI interferometer. The settings above set only the computed output spectra parameters.

Once it is run a dialog window appears that allows the user to navigate the directory to find the interferometric map file map saved from the GEMINI LabVIEW program. The user should select the measurement file, which is named “*_MAP.txt”.

At the end of the process, this script plots the 2D TRES map as a function of time (x-axis) and Wavelengths (y-axis).

6. Configuration Files

The GEMINI interferometer is calibrated and configured when it is shipped. To work properly, the previously described applications and scripts need a few configuration files that **must** be present in the same main folder, namely:

a) *_parameters_int.txt

This file contains the interferogram of a highly temporal coherent source such as a He-Ne laser sampled over the whole scan range of the GEMINI interferometer. The file is composed of two rows. The first one contains the position axis and the second one the interferogram values at the correspondent positions.

b) *_parameters_scale.txt

This file contains the scale parameter of the positioning system and it is used to find the physical zero position of the interferometer.

c) *_parameters_cal.txt

This file contains the conversion table from the spatial frequency (mm^{-1}) to the wavelength domain (nm) and it is used to calibrate the spectral axis. The user can add or modify any of the entry and the software will automatically consider the change to compute the spectral axis.

Please note that these files are device-dependent.

