GEMINI

INTERFEROMETER

USER TECHNICAL MANUAL

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Subject to change without notice

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Contents

1. Introduction

1.1 Brief Description

The GEMINI Interferometer is an ultra-stable interferometer, capable of generating two delayed and phase-locked replicas of the input light. The relative delay τ between these two replicas can be controlled by the user via software with extremely high reproducibility and phase stability (<1 attosecond, corresponding to $<\lambda/1000$ in the visible spectral region). This feature is made possible thanks to the employed common-path geometry, that makes the device completely insensitive to external noise and vibrations. The GEMINI Interferometer is thus the ideal product for generating a pair of replicas of the incoming light with an interferometric stability. The device works over a broad spectral range (from the Ultraviolet to the Near and Mid-Infrared) and it is also compatible with ultrashort few-optical-cycle pulses.

1.2 Information, Warnings and Safety Instructions

1.2.1 Hazardous Voltage

The Controller Module can generate high output currents at high voltages. They may cause serious or even lethal injury if used improperly. Therefore, the equipment should only be operated by personnel, which is adequately trained and educated to prevent any improper use. Please follow general accident prevention rules:

- Never touch any part that might be connected to an output with a high voltage.
- Do not connect products from other manufacturers to the output connectors.
- Never use equipment that is damaged in any way.
- The Controller Module contains no user serviceable parts. Never open the case. Procedures which require opening the case must only be carried out by authorized, qualified and trained personnel.

Output connectors with dangerous signals are labelled with the following symbol:

***Figure 1**: "Caution, risk of electric shock" symbol.*

1.2.2 Unpacking

Please be careful when unpacking the GEMINI Interferometer and the Controller Module. Inspect the products for signs of damage and only use equipment that shows no signs of damage. In case of any damage, contact NIREOS for replacement. Please save all packing materials in case you would like to transport or ship the product again.

1.2.3 Laser safety

Please be always careful and wear laser safety glasses when using the GEMINI Interferometer with laser radiation, as there could be some back reflected or scattered light exiting from the input or output apertures.

1.2.4 Installation Instructions

The Controller Module must be installed horizontally with 3 cm air circulation area behind the ventilator. Insufficient air flow can cause overheating, which can result in a limited functionality of the controller.

1.2.5 Connection Instructions

Never use any other connecting cables than the connecting gear that you obtained from NIREOS. Never use any third-party adapters or cables. This can cause failure or malfunction.

The system is NOT hot-pluggable. Always make sure to power down the device before connecting or disconnecting any plugs. The only exception to this is the USB or Ethernet cables which may be removed or attached during operation.

NOTE: Please be careful in handling the GEMINI Interferometer. Always check the cable for possible signs of wear or damage. In case of any damage, contact NIREOS for replacement.

2. Setup and Adjustments

2.1 Hardware

2.1.1 Connections

- Connect the Controller Module to the 12V AC adapter;
- Connect the Controller Module to the computer with the USB cable;
- Connect the Controller Module to the GEMINI Interferometer with the DSUB-15 cable

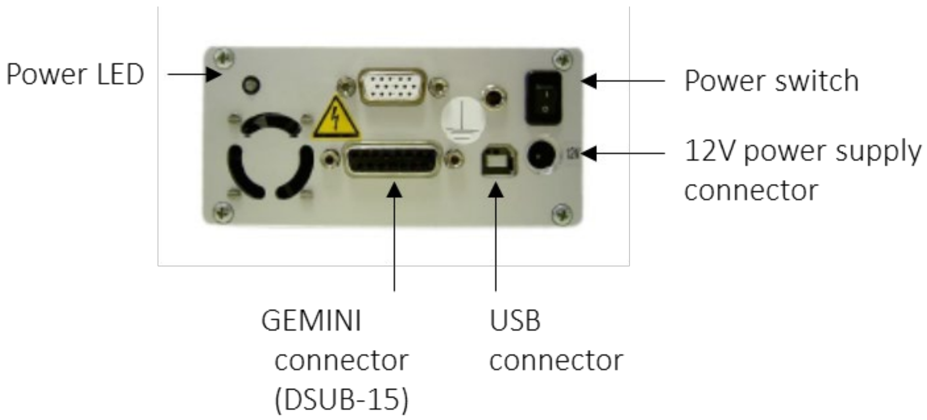


Figure 2: Picture of the Controller Module showing the connections.

NOTE: Remember to install horizontally the Controller Module, with 3 cm air circulation area behind the ventilator.

2.1.2 Mechanical Mounting

If needed, there are 4 threaded holes (M6 threads) to screw 4 posts to the GEMINI Interferometer, that can be thus clamped and locked on an optical table. For more details regarding the position of the threaded holes, please go to Section 3.3 “Mechanical Drawings”.

NOTE: Please always handle with care the GEMINI Interferometer. Sudden movements or shocks can cause a misalignment or break of the optics inside the device.

2.1.3 Optical Alignment

- POLARIZATION
  The first optical element inside the GEMINI Interferometer is a polarizer oriented at 45°. For the best performance, it is recommended to enter with a beam linearly polarized and having the direction of polarization parallel to the *polarization line* (in yellow in the Picture below), in order to maximize the light throughput. Inside the GEMINI, the 45° polarized light is divided into two replicas, one with vertical polarization and one with horizontal polarization, that are delayed by τ. At the output of the GEMINI, another polarizer oriented at -45° projects the two delayed replicas onto the same state of polarization.

NOTE: Never enter with a beam having perpendicular polarization with respect to the direction represented by the line on the front face. In that case, the total throughput of the device would be close to 0%.

Figure 3: *Picture of the front face of the GEMINI.*

2.1.4 Optical Features

- <u>RELATIVE DELAY τ</u>

  Depending on your version of the GEMINI Interferometer, the introduced delay between the two generated replicas of light can be:

  - **Symmetric** ("SYM"). The moving replica is scanned in time in a symmetric way around the "time zero". The delay τ can be varied from –T to T.

  - **Asymmetric** ("ASY"). The moving replica is scanned in time in an asymmetric way around the "time zero". The delay τ can be varied from –δT to 2T (approximately).

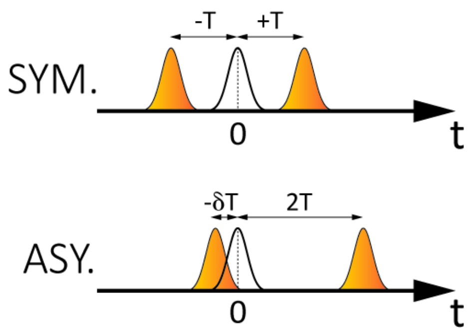


***Figure 4**: Possible delay configurations. Top: "SYM" configuration; bottom: "ASY" configuration.*

NOTE: Please check the table in Section 3.1 "Technical Data" for more quantitative details.

2.1.5 How to properly find TIME ZERO?

NOTE: Please note that the GEMINI Interferometer (and the provided software examples as well) is already calibrated and set with the correct TIME ZERO when shipped. However, sudden movements or shocks during the shipment can cause a slight change of TIME ZERO. This paragraph explains how to find (or to check) the correct position of TIME ZERO.

There are 3 different ways to properly find the correct τ. In all these three methods, a broadband light source (coherent or incoherent) must be transmitted through the GEMINI Interferometer.

- <u>Using a spectrometer</u>

  Measure the light exiting the GEMINI with a spectrometer. In this configuration, the spectrometer measures the spectral interference between the two replicas delayed by τ. If τ≠0, then the measured spectrum is characterized by spectral fringes, which gets larger as the delay τ goes to zero. This effect is shown in Figure 5 for two different values of τ (15 fs and 150 fs). When τ = 0, the measured spectrum does not show spectral fringes.

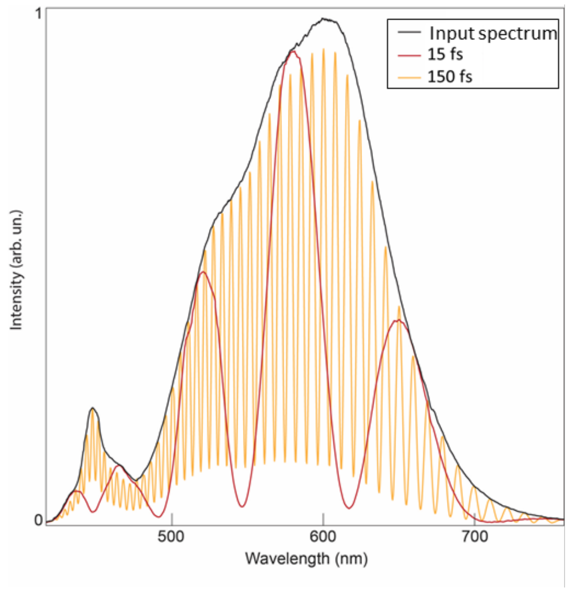


Figure 5: Spectrum of the light exiting the GEMINI measured at different values of τ (15 and 150 fs), together with the spectrum of the input light to the interferometer.

- <u>Using a photodiode</u>
  Measure the light exiting the GEMINI with a single-pixel photodiode while scanning the delay τ via software (the delay can be controlled by moving the motorized positioner by a few millimetres). Associate to each position of the motor (in mm) the corresponding signal acquired from the photodiode. The result is the so-called interferogram (shown in Figure 6) as a function of the position of the motor (which is proportional to τ). If the light has a sufficiently broad spectrum, the centre of symmetry of the interferogram clearly indicates the exact TIME ZERO position.

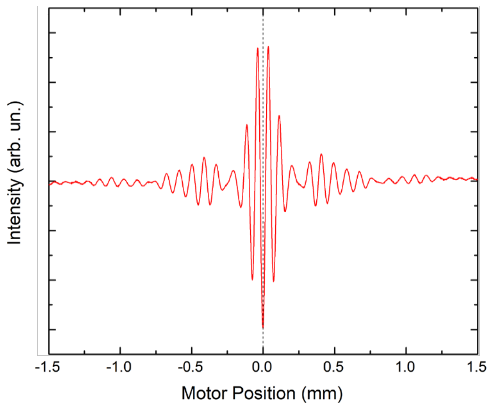


Figure 6: Interferogram of a broadband light exiting the GEMINI measured with a single-pixel detector.

- By eye

  If the input light has a broad spectrum (such as a halogen lamp, a standard LED, or even the spotlight of the mobile phone), the TIME ZERO can be found simply by looking at the light spot transmitted by the GEMINI. When τ is far away from 0, the spot has the same colour of the incoming light. When τ approaches 0, spatial fringes start to appear (see Figure 7(a)). When getting closer to τ=0, the contrast of the fringes increases (Figure 7(b)). TIME ZERO corresponds approximately to the position with higher contrast of the fringes (see Figure 7(c)). The three panels of Figure 7 are real pictures obtained by using a LED as an input illumination.

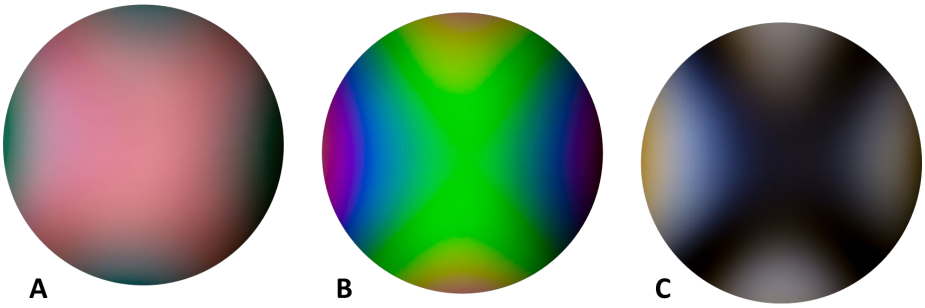


Figure 7: Pictures of the light spot transmitted by the GEMINI at different values of τ.

2.1.6 Example: Optical Alignment for Fluorescence Measurements

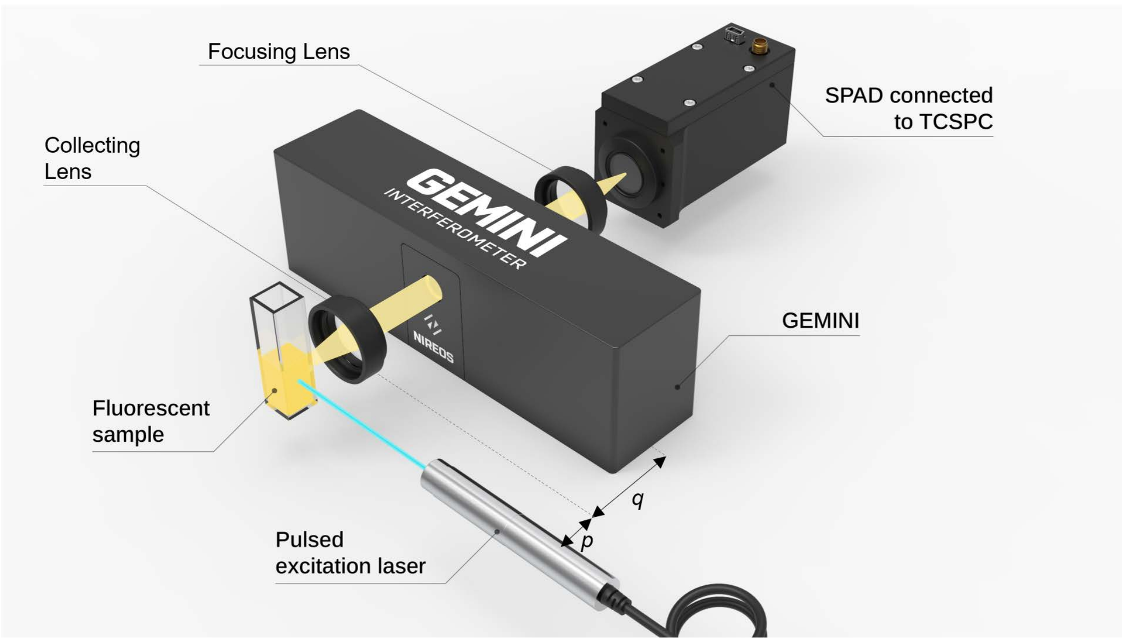


Figure 8: Experimental Setup showing how to use GEMINI in Fluorescence Experiments.

Figure 8 shows an example of experimental setup in which GEMINI Interferometer coupled with a single-pixel detector (such as a SPAD or PMT) is used to measure the fluorescence signal emitted by a fluorescent sample.

The following procedure allows to properly align the optical elements together with GEMINI and the detector, in order to optimize the experimental conditions and obtain the best results.

STEP 1: Align the excitation laser, so that the beam (represented in blue in Figure 8) excites the fluorescent sample. If needed, a lens (not present in Figure 8) can be used to focus the light into the sample.

STEP 2: Collect the fluorescent signal (represented with a yellow beam in Figure 8) with a collecting lens, with focal length f. Approximately, as a first alignment, place the collecting lens at a distance p greater than f from the sample ($p=f+\delta$), so that the image of the sample is formed at a distance q from the collecting lens, following the equation: $1/p+1/q=1/f$.

STEP 3: Place GEMINI Interferometer after the collecting lens, in such a way that the image of the excited sample lies inside the interferometer. If possible, slightly adjust the position (distance p) of the collecting lens in order to maximize the throughput of light out of the GEMINI Interferometer.

STEP 4: Place a focusing lens after the Interferometer to focus the light inside your detector.

STEP 5: After the focusing lens, find the plane where spatial interference fringes have maximum contrast. In fact, after the focusing lens, the contrast of the fringes depends on the distance from the lens itself (please refer to Figure 9 below: in case A and C, the selected plane is not at the proper distance from the focusing lens: indeed, interference fringes in these two cases show very poor contrast. Case B shows the best condition, where interference fringes show very good contrast). Place your detector so that its active area lies in this plane (case B in Figure 9).

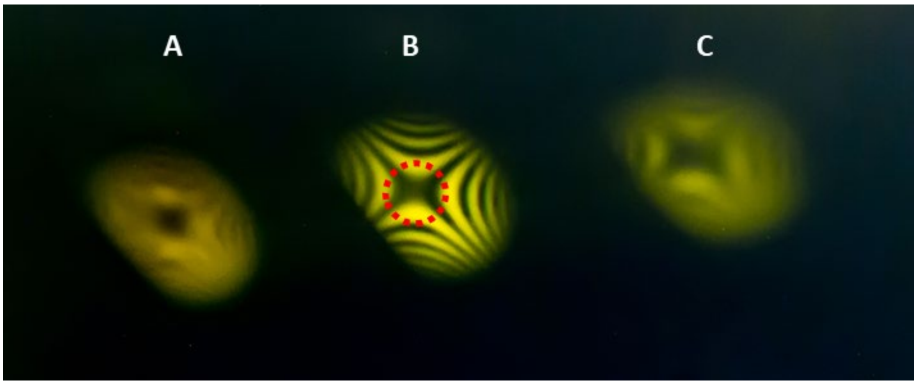


Figure 9: Three pictures of the light spot after the focusing lens, at different distances.

NOTE: In order to maximize the contrast, you can use an aperture to select the central part of the spot (as an example, please refer to the red dotted circle in Figure 9(B)).

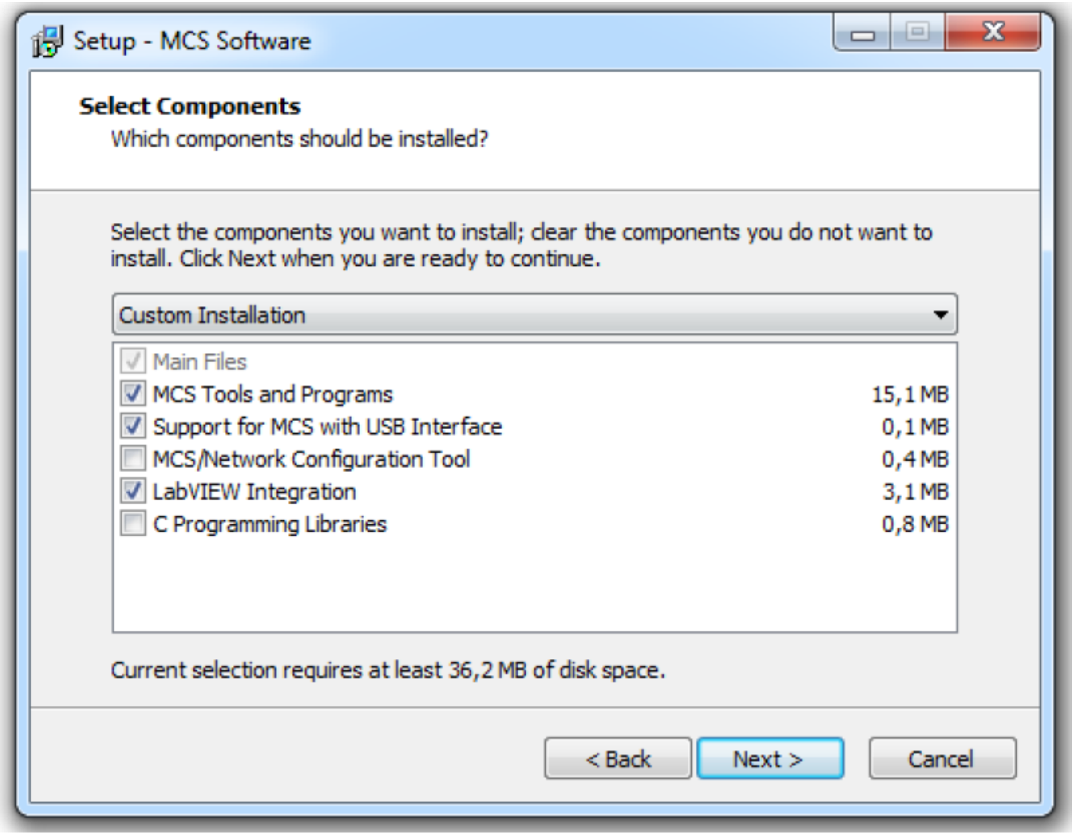
2.2 Software

2.2.1 Software Installation Guide

Please note that the positioner inside the interferometer that acts on the delay τ is from Smaract GmbH.

<u>INSTALLING MCS SOFTWARE</u>

In the NIREOS pen drive you will find a link with all the software needed to use the Controller Module and to develop your own software. Run the installer MCS_Installer in the MCS folder. In the installation you must first select the software folder where most of the files will be installed (default: C:\SmarAct). The installer allows to select different software components for installation:



- Select MCS Tools and Programs to install utilities like the firmware updater and the configuration tool.
- The installation of USB support drivers, needed for communicating with MCS devices over USB, can be disabled by deselecting the Support for MCS with USB Interface option. USB support is not needed if only MCS with RS232 interface will be used. However, if the USB support is not installed, the software will not be able to connect to MCS with a USB interface and will show errors. If the option is selected, the installer

will ask for permission to run the Usb-To-Serial driver installer at the end of the installation process. The driver can also be installed manually by running the program CDMxxxx_Setup.exe in the Drivers folder in the NIREOS pen drive.

- For developing applications with LabVIEW select LabVIEW Integration. If more than one LabVIEW version is installed, you can choose the version to install the LabVIEW commands in one of the next steps. To install additional LabVIEW versions just run the installer again and select another LabVIEW version (the other software doesn't have to be installed again). Note that the LabVIEW commands are only available for MCS devices with USB interface.
- Select C Programming Libraries to install libraries and header files for writing your own programs in C or C++ (or other languages that are compatible with the programming libraries).

WHERE FILES ARE INSTALLED

The MCS folder is inside the Smaract folder which you have selected during installation.
The Programs folder contains tools and applications for the MCS.
Documentation is installed in the Documentation folder in the MCS folder.
If LabVIEW Integration was selected in the installer, the MCS LabVIEW commands are installed in the program folder of the selected LabVIEW version and can be dragged directly from a LabVIEW commands palette into your program. LabVIEW programming examples are installed in the folder SmarAct\MCS\LabVIEW\Examples.
The software development kit (SDK) for developing programs with the MCS C API is installed under SmarAct\MCS\SDK if C Programming Libraries is selected. This path is defined in the environment variable MCS_SDK which can be used in development tools to find the SDK folder.

The installer creates shortcuts to programs and documents in the Start menu.

2.2.2 Software Examples

In the NIREOS pen drive you will find a link to useful software examples written in LabView. For more details, please read the "COMPLETE OPERATIONAL EXAMPLE (LABVIEW AND NI-DAQ)" manual.

3. Appendix

3.1 Technical Data

VERSION	S	L
Spectral range [nm]	400 - 2300 (Standard) 250 - 3500 (Ultra-broadband) 500 - 4200 (On request)	
Max. Delay τ [fs @ λ=600 nm]	-100 → 700	-100 → 2000
Delay τ Stability	< 1 attosecond	
Dimensions [mm]	176 x 44 x 54.5	
Weight [kg]	0.4	

NOTE: in step scan mode, the user can select the dwell time for each delay τ via software.

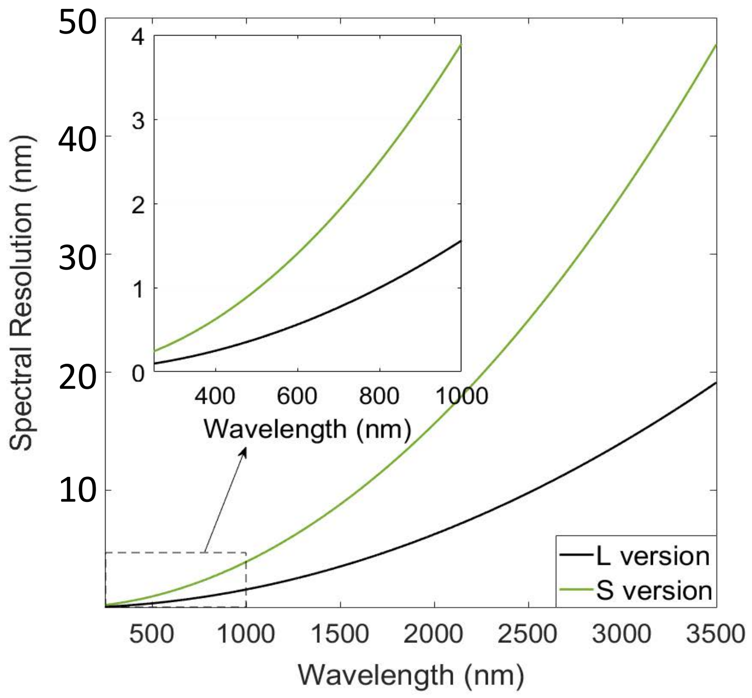


Figure 10: Maximum delay τ relative to the asymmetric (ASY) configuration achievable with the two different models (S and L) as a function of wavelength.

3.2 Available Versions and Description*

The GEMINI Interferometer is available in different versions:

GEMINI.yyy.x

- yyy: **Configuration of the relative delay τ** (**SYM**: symmetric, **ASY**: asymmetric). For more details, please see the paragraph "RELATIVE DELAY τ" in Section 2.1.3 "Optical Alignment".

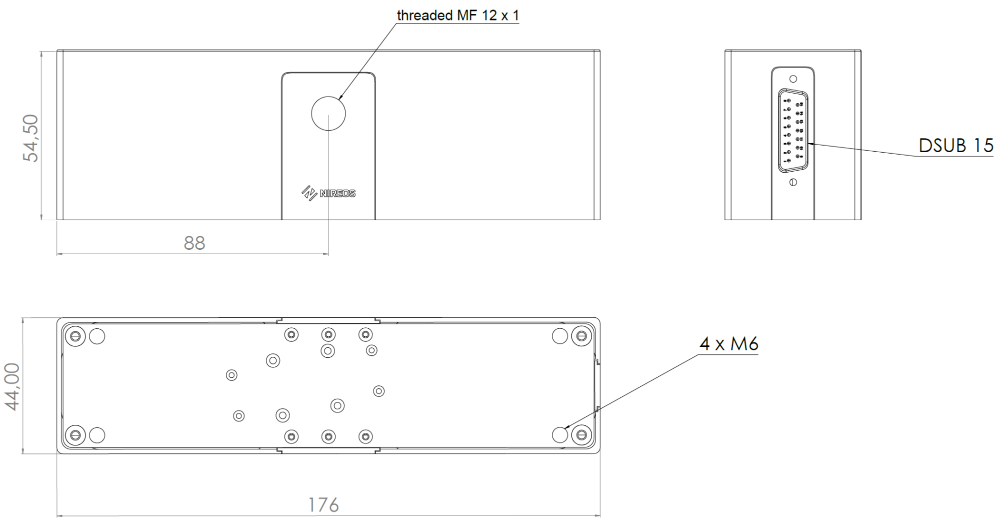
- x: **Maximum achievable relative delay τ** (**S**: small, **L**: long). For more details, please read the table in Section 3.1.

Example: GEMINI.ASY.L:

GEMINI Interferometer with "asymmetric" configuration of the delay τ, "long" maximum achievable delay τ.

** For customized products or more information, please contact NIREOS at info@nireos.com*

3.3 Mechanical Drawings



Units: mm

GEMINI Interferomter

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