Invisible-Light Labs

User Manual - V01.02

MANUAL FOR EMILIE™ & PHILL™

Installation, operation, and troubleshooting guide

August 18, 2025

Copyright

This manual describes the operating instructions for EMILIE™ . An up-to-date version of this manual can be found online at invisible-light-labs.com/resources or requested via our support at info@invisible-light-labs.com .

Disclaimer of liability

This user manual is the official and original documentation of EMILIE™ . In the event of any conflict between this document and the General Terms and Conditions or individual sales contracts, the terms outlined in the General Terms and Conditions or sales contracts shall supersede this user manual.

Invisible-Light Labs GmbH shall not be held liable for injuries and/or property damages resulting from the use or misuse of its products.

Clause de non-responsabilité

Ce manuel d’utilisation est la documentation officielle et originale d’EMILIE™ . En cas de conflit entre ce document et les Conditions générales ou les contrats de vente individuels, les conditions énoncées dans les Conditions générales ou les contrats de vente prévaudront sur ce manuel d’utilisation.

Invisible-Light Labs GmbH ne saurait être tenu responsable des blessures et/ou dommages matériels résultant de l’utilisation ou de la mauvaise utilisation de ses produits.

QUICK EMILIE™ VALIDATION GUIDE

This Quick Validation Guide provides a brief procedure to validate EMILIE™ after installation or changes to the setup. For detailed instructions on how to operate EMILIE™ and advanced features, please refer to Section 5. For each measurement with EMILIE™ in this validation, make sure the optical alignment is done before recording a spectrum.

1. Record a background NEMS-FTIR spectrum of the light source with an EMILIE™ LIGHT chip .
2. Record a NEMS-FTIR spectrum of the EMILIE™ VALIDATION chip .
3. In OPUS, use the ”EMILIE-Validation-Macro-V1.mtx” macro to process the NEMS-FTIR spectrum. Drag & drop the background spectrum recorded in step 1 and the validation spectrum recorded in step 2 to the corresponding field of the macro, and press continue.
4. Verify that the polystyrene peak of the processed validation spectra at $1601.25\,\mathrm{cm}^{-1}$ falls within the range highlighted in Figure 1.

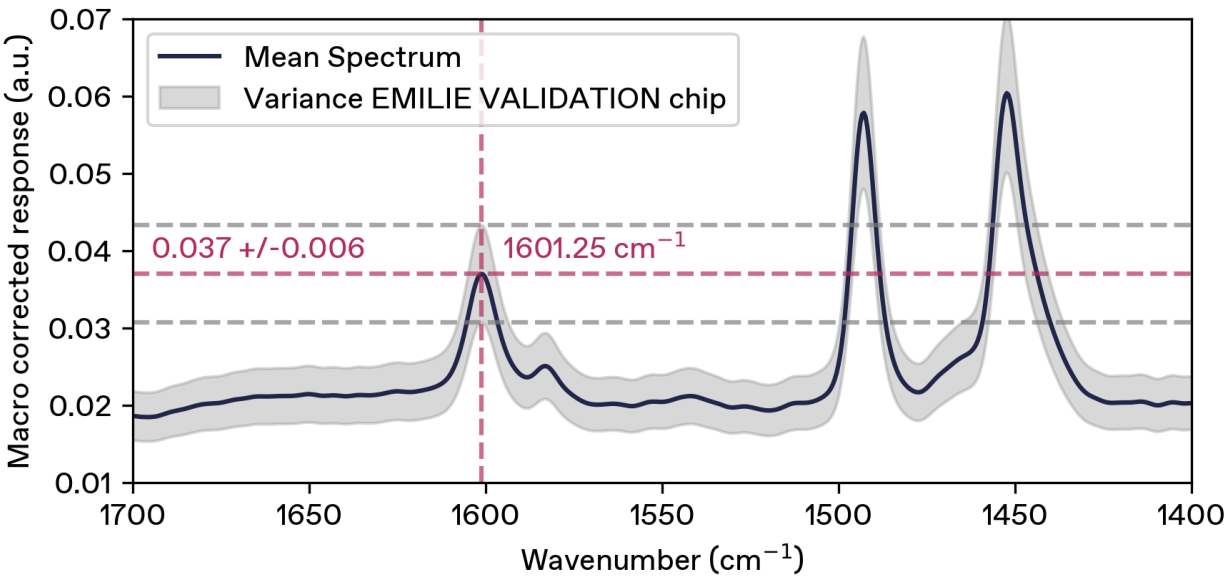


Figure 1: NEMS-FTIR spectra of an EMILIE™ VALIDATION chip after application of the ”EMILIE-Validation-Macro-V1.mtx”.

QUICK EMILIE™ MEASUREMENT GUIDE

This Quick Start Guide provides a brief overview of how to acquire NEMS-FTIR spectra using EMILIE™ . For detailed instructions and advanced features, please refer to Section 5.

1. Switch off the vacuum pump and vent the system.
2. Remove the lid of the EMILIE™ vacuum chamber.
3. Remove the contact bridge and place it in the parking position on the inner surface of the vacuum chamber lid.
4. Remove the dummy chip from the sample holder.
5. Load the desired chip, paying attention to proper orientation.
6. Place the contact bridge back in position.
7. Press the connection test button to verify that the electrical connection is established. A green light indicates a intact membrane.
8. Place the vacuum chamber lid back into place and start the vacuum pump. Once the pump speed reaches 1500 Hz the chamber is operational.
9. Select the desired preset from the drop down menu in PHILLharmonics and click ”Apply”.
10. Ensure that ”Auto apply parameters” and ”Auto apply offset” checkboxes are checked.
11. Wait until the target temperature is reached and the temperature field becomes green.
12. Click ”Run” to start the frequency finder. If the checkbox ”Auto apply parameters” was checked, the mode with the highest amplitude is automatically locked, showing the frequency plot in the ”Results” step. Watch out for the flags ”Input overflow”, and ”Output Overrange” above the frequency plot and act accordingly (see Section 5.2.3).
13. Open the OPUS software and confirm that the FTIR system is functioning correctly, as indicated by the green light in the bottom-right corner of the interface.
14. For launching a measurement, use the basic operation settings in Table 8.
15. Open the settings for ”Step Scan” in the ”Measure” tab in OPUS, by clicking on the icon with the small green foot  .
16. Switch to the ”Advanced” tab of the ”Step Scan” and load the ”EMILIE-Standard-StepScan-Res4cm-5MIN-SQ.XPM” settings file provided online at invisible-light-labs.com/resources .
17. Start the step scan spectrum acquisition by switching to the ”Basic” tab and pressing ”Start Step Scan Modulation Measurement”.
    (a) If the ”Output Overrange” flag is triggered during the measurement, increase the ”Output Range” in the text box below the results step. Click the ”Calculate Offset” button and restart the step scan.

CONTENTS

1 ABOUT THIS MANUAL

1.1 Validity & declaration of conformity

This manual describes the assembly, function, and operation of EMILIE™ in conjunction with the devices listed in Section 3.4. This manual provides important information for the safe use of the products EMILIE™ and PHILL™ . The document shall remain valid, provided that no changes are made to the product.

The declaration of conformity can be found at invisible-light-labs.com/resources

1.2 Target group

These operating instructions are aimed at all persons performing the following activities on the product:

- Transportation
- Setup & Installation
- Usage and operation
- Decommissioning
- Maintenance and cleaning
- Storage or disposal

The work described in this document is only permitted to be performed by persons with the appropriate technical qualifications or who have received training on the devices directly from Invisible-Light Labs GmbH . In case technical assistance is required, contact Invisible-Light Labs GmbH at: info@invisible-light-labs.com

1.3 Abbreviations

FTIR	Fourier Transform Infrared Spectroscopy
GUI	Graphical User Interface
IR	Infrared Radiation
NEMS	Nanoelectromechanical System
PC	Personal Computer
PCB	Printed Circuit Board
THz	Terahertz
TEC	Thermo-Electric Controller

2 GENERAL SAFETY INFORMATION (ENGLISH)

This manual uses the following risk level classifications. Carefully read all instructions and safety information before beginning installation. Keep this manual available for future reference. Always follow the provided instructions and safety guidelines to minimize the risk of personal injury or property damage.

DANGER

Immediately pending catastrophic danger

Indicates an immediate danger that could result in death or serious injury.

WARNING

Potential pending fatal danger

Indicates a potential pending danger that could result in death or serious injury.

CAUTION

Potential pending minor danger

Indicates a hazardous situation that could result in minor injuries.

NOTICE

Danger of damage to property

Highlights a situation that could result in damage to the device or property.

ⓘ Highlights additional useful information.

2.1 Intended use

EMILIE™ is a NEMS accessory for FTIR spectrometers in the field of research and development. EMILIE™ is intended for indoor use by trained scientific personnel under the operation conditions listed in 3.2. The intended use includes compliance with local safety, accident prevention, and general technical regulations.

The intended use also includes strict observance of all safety, installation, operation, repair and maintenance instructions included in this manual.

2.2 Hazardous chemicals

DANGER

Danger of death or poisoning due to contact with or inhalation of hazardous chemicals

Observe substance-relevant safety measures when analyzing hazardous chemicals with EMILIE™. During normal operation, the vacuum pump releases gases and vapors into the air. In analyses involving toxic media, there is a risk of poisoning that could cause injury or death.

- Comply with applicable regulations regarding the handling of toxic substances.
- Always read the safety datasheet of the analyte before analysis. Take into account the toxicity and volatility of the analytes.
- Always verify the pictograms on the containers of analytes before analysis.
- Safely vent toxic process gases to an appropriate exhaust.
- Affix corresponding warning labels at the appropriate location when necessary.

2.3 Electronic safety

DANGER

Danger of death from electrocution

PHILL™ is powered via an external 5 V DC power supply (minimum 4 A) and must not be connected directly to mains voltage. The EMILIE module receives power and control signals exclusively through the Sub-D cable connection to the PHILL unit and is not directly powered from the mains. The power supply provided with PHILL™ is an IEC 60601-1 approved 2 x MOPP rated DC/DC converter. Unspecified and unapproved power supplies or an incorrect voltage may damage the device, prevent proper operation, cause serious injury or even death.

- Only use the power supply provided with the unit or supplied by Invisible-Light Labs GmbH specifically for this unit.
- Do not use in wet or humid environments.
- Ensure the AC adapter is connected to the correct mains voltage as indicated on the rating label.

2.4 Vacuum safety

DANGER

Risk of an electric shock, severe injury, or death

Failure to comply with the vacuum pump manufacturer's instructions can lead to an electric shock, severe injury, or death.

- Comply with all safety, installation, operation, repair, and maintenance instructions included in the manual provided by the vacuum pump manufacturer.

DANGER

Danger of death or poisoning due to inhalation of hazardous chemicals

During normal operation, the vacuum pump releases gases and vapors into the air. In analyses involving toxic media, there is a risk of poisoning that could cause injury or death.

- Comply with applicable regulations regarding the handling of toxic substances.
- Safely vent toxic process gases to an appropriate exhaust.

WARNING

Risk of equipment damage or severe injury

- Use only original accessories and vacuum products approved by the pump manufacturer or Invisible-Light Labs GmbH .
- Avoid the presence of loose parts inside the vacuum chamber.
- Do not operate the pump unless the lid of EMILIE™ is closed.

2.5 Purge gas safety

DANGER

Risk of asphyxiation due to lack of oxygen

EMILIE™ can be purged with clean dry air or nitrogen. The EMILIE™ purge box is not sealed. Using nitrogen for purging EMILIE™ can lead to oxygen depletion. Non-observance of applicable safety standards and guidelines for the use of nitrogen purging systems may lead to asphyxiation.

- High nitrogen gas concentrations in an enclosed area can cause asphyxiation! Only use with nitrogen purge gas in well-ventilated areas and ensure that an adequate oxygen concentration in the air is maintained at all times.
- Consult the FTIR manufacturer manual for further information on the appropriate purge supply, maximum pressure, and flow rate for your specific device. Never exceed the recommended maximum pressure and flow rate when purging EMILIE™ .

2.6 Laser safety

WARNING

Potential risk of eye damage due to laser products

EMILIE™ does not contain a laser. However, as EMILIE™ is designed for operation with FTIR spectrometers, the user is advised to check the spectrometer manufacturer's laser safety instructions before operation. EMILIE™ is only allowed to be operated in conjunction with laser class 1 or class 2 products, according to IEC 60825-1:2014 and ANSI Z136.1.

- Verify the laser class of the spectrometer before installing and operating EMILIE™. Only operate EMILIE™ in conjunction with laser class 1 or 2 products.
- Do not look into the light beam of the spectrometer or light emitted from the central chip holder.

2.7 Magnetic field safety

DANGER

Magnetic field

EMILIE™ contains magnets that create a magnetic field within the vacuum chamber and vacuum chamber lid.

- Pacemaker wearers stay back 15 cm from the EMILIE™ vacuum chamber and vacuum chamber lid.
- Metallic tools and components may be influenced by the magnetic field within EMILIE™ 's vacuum chamber, potentially causing them to be pulled towards the magnets. Exercise caution when handling metallic components in the vicinity of the vacuum chamber to prevent damage to internal components.

2.8 Burn prevention

WARNING

Risk of burn injury on hot surfaces

EMILIE™ contains a Peltier element capable of regulating surface temperatures up to 80°C.

- Do not touch the chip or its holder with your fingers before, during, or after operation to prevent burn injuries.
- Use tweezers when handling the chip.
- Wear personal protective equipment if necessary.

2.9 Wet environment safety

CAUTION

Dry Clean Environment Use Only

EMILIE™ and PHILL™ are intended for use exclusively in dry, controlled indoor environments such as laboratories or cleanrooms. Operation in wet or outdoor environments is not permitted. Moisture can cause corrosion, short circuits, and other malfunctions in electronic devices. Using in a wet or humid environment could lead to reduced performance, damage, and failure, and potentially lead to safety risks. Use EMILIE™ and PHILL™ in a dry clean environments only to avoid moisture-related risks, such as short circuits, component damage, and electric shock.

- Use in dry environments only. Avoid contact with water or other fluids.

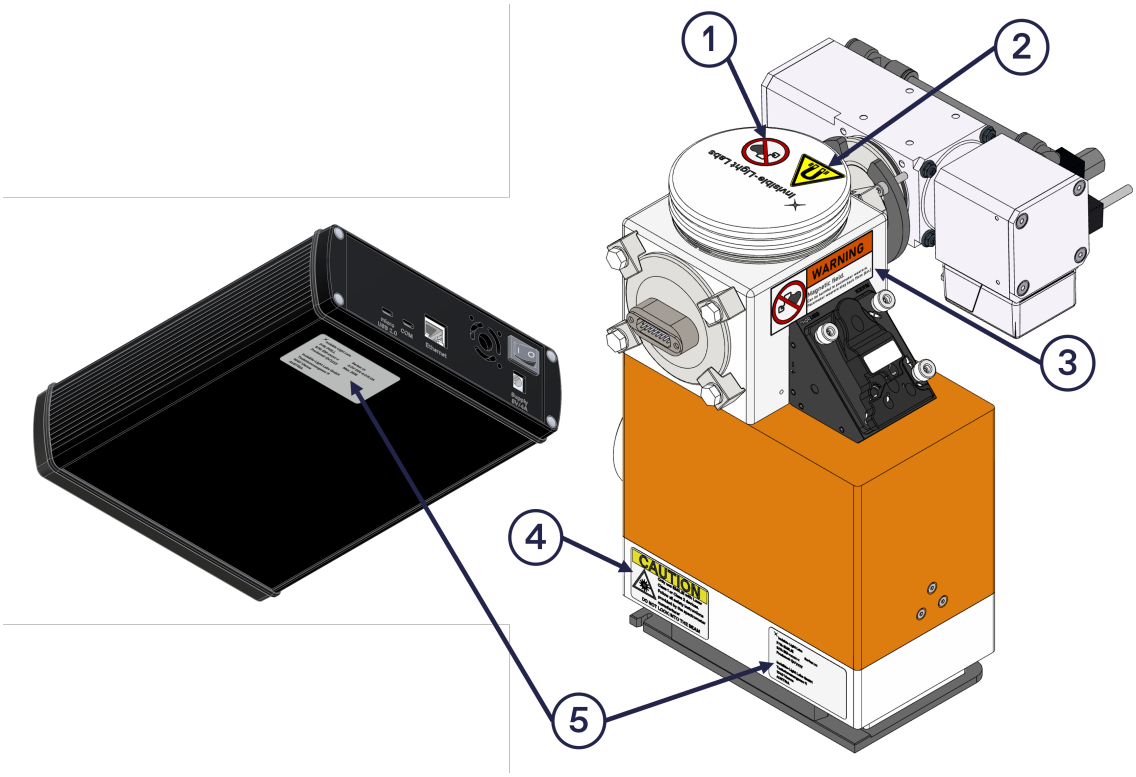
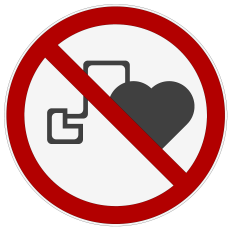


Figure 2: Position of warning and product labels: (1) pacemaker warning, (2) magnetic field warning, (3) descriptive pacemaker warning to keep 15 cm/6 inch distance, (4) laser safety warning to only use the device with Class 1 or 2 light sources, (5) product label on EMILIE™ and PHILL™

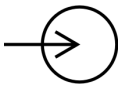
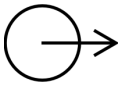
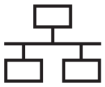
2.10 Warning signs description

Table 1: Description of each warning label found on EMILIE™ , specific location is described in Figure 2

Sign	Description
	Magnetic field warning pictogram, location: EMILIE™ lid.
	Pacemaker-wearer warning pictogram, location: EMILIE™ lid.
 	WARNING: Magnetic field. Can be harmful to pacemaker wearers. Pacemaker wearers stay back 15 cm (6 inch). Location: Side of EMILIE™ above the kinematic mirror mount. Language: English and French.
 	CAUTION. Only use EMILIE™ with laser Class 1 or Class 2 devices. Follow all safety instructions provided by the spectrometer manufacturer. DO NOT LOOK INTO THE BEAM. Location: EMILIE™ backside. Language: English and French.

2.11 Graphical symbols used on products

Table 2: Overview of connector symbols and their international standards

Description	International Standard	Symbol
Input terminal	IEC 60417	
Output terminal	IEC 60417	
Direct current terminal	IEC 60417	
Ethernet communication port	IEC 60417	
Universal Serial Bus (USB) communication port/plug	ISO 7000	

2.12 Waste disposal

Dispose of all waste products (chemicals, infectious and radioactively contaminated substances etc.), such as used EMILIE™ nanoelectromechanical sampling and sensing chips , according to the prevailing laboratory regulations. Detergents and cleaning agents must be disposed of according to your local special waste regulations.

Regulations from the European Parliament and the Council concerning electric and electronic devices mandate compliance with the WEEE Directive, necessitating the affixation of the crossed-out wheeled bin symbol on our products. This directive is designed to encourage the collection and recycling of equipment.

Recycle packaging materials according to local regulations.

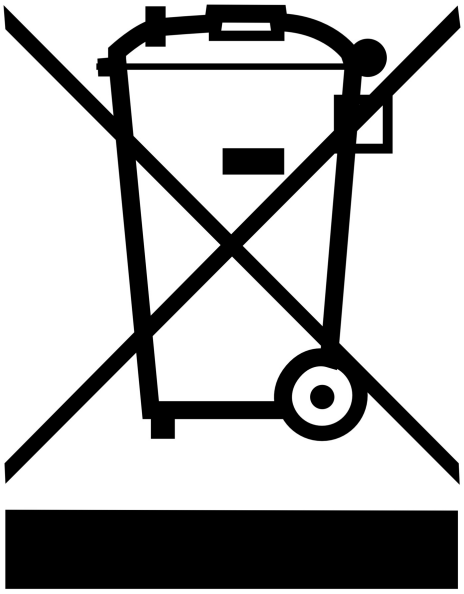


Figure 3: This symbol affixed to Invisible-Light Labs products or its packaging means that the product should not be disposed of with household waste. It is mandatory to dispose of the waste separately from the municipal waste stream according to local regulations. The correct disposal of the end-of-life equipment will help prevent potential negative consequences for the environment and human health. Recycling them responsibly promotes the sustained reuse of material resources.

2 CONSIGNES DE SÉCURITÉ (FRANÇAIS)

Ce manuel utilise les classifications de niveaux de risque suivantes. Veuillez lire attentivement toutes les instructions et les consignes de sécurité avant de commencer l'installation. Conservez ce manuel à disposition pour référence ultérieure. Suivez toujours les instructions et les consignes de sécurité fournies afin de minimiser les risques de blessures ou de dommages matériels.

DANGER

Danger direct et imminent

Indique un danger direct et immédiat pouvant entraîner la mort ou des blessures graves.

AVERTISSEMENT

Danger potentiel imminent

Indique un danger imminent pouvant entraîner la mort ou des blessures graves.

ATTENTION

Danger potentiel imminent

Indique un danger imminent pouvant entraîner des blessures légères.

AVIS

Risque de dommages matériels

Signale une situation susceptible d'endommager l'appareil ou les biens.

ⓘ Met en évidence des informations supplémentaires utiles.

2.1 Usage prévu

EMILIE™ est un accessoire NEMS pour spectromètres infrarouge à transformée de Fourier (IR-TF) utilisés dans le domaine de la recherche et du développement. EMILIE™ est destiné à une utilisation à l'intérieur par du personnel scientifique qualifié, dans les conditions d'utilisation décrites dans la section 3.2. L'usage prévu comprend le respect des réglementations locales en matière de sécurité, de prévention des accidents et de réglementations techniques générales.

L'usage prévu inclut également le strict respect de toutes les instructions de sécurité, d'installation, d'utilisation, de réparation et de maintenance contenues dans ce manuel.

2.2 Consignes de sécurité en lien avec les substances chimiques dangereuses

DANGER

Risque de décès ou d'empoisonnement dû au contact ou à l'inhalation de produits chimiques dangereux

Respectez les mesures de sécurité relatives à la substance lors de l'analyse de produits chimiques dangereux avec EMILIE™. En fonctionnement normal, la pompe à vide libère des gaz et des vapeurs dans l'air. Dans les procédés impliquant des substances toxiques, il existe un risque d'intoxication susceptible de provoquer des lésions ou la mort.

- Respectez la réglementation en vigueur concernant le traitement de substances toxiques.
- Lisez toujours la fiche de données de sécurité de la substance à analyser avant l'analyse. Tenez compte de la toxicité et de la volatilité des substances à analyser.
- Vérifiez toujours les pictogrammes figurant sur les contenants des substances à analyser avant l'analyse.
- Évacuez les gaz de procédé toxiques en toute sécurité par une conduite de refoulement.
- Apposez les étiquettes d'avertissement correspondantes à l'endroit approprié si nécessaire.

2.3 Consignes de sécurité en lien avec les composantes électroniques

DANGER

Danger de mort en cas d'électrocution

PHILL™ est alimenté par une alimentation externe de 5 V CC (minimum 4 A) et ne doit pas être connecté directement au secteur. Le module EMILIE reçoit les signaux d'alimentation et de commande exclusivement via le câble Sub-D de connexion à l'unité PHILL et n'est pas directement alimenté par le secteur. Le bloc d'alimentation fourni avec PHILL™ est un convertisseur CC/CC 2 x MOPP approuvé IEC 60601-1. Les blocs d'alimentation électrique non spécifiés et non approuvés ou une tension incorrecte peuvent endommager l'appareil, empêcher son bon fonctionnement, entraîner de graves blessures, voire la mort.

- Utilisez uniquement le bloc d'alimentation fourni avec l'appareil ou fourni par Invisible-Light Labs GmbH spécifiquement pour cet appareil.
- Ne pas utiliser dans des environnements humides ou mouillés.
- Il est impératif de vérifier que l'adaptateur secteur est connecté à la tension secteur correcte, comme indiqué sur l'étiquette signalétique de l'appareil.

2.4 Consignes de sécurité en lien avec l'utilisation d'une pompe à vide

DANGER

Risque d'électrocution, de blessures graves, et de mort

Le non-respect des instructions du fabricant de la pompe à vide peut entraîner un choc électrique, des blessures graves ou la mort.

- Respectez toutes les instructions de sécurité, d'installation, d'utilisation, de réparation et d'entretien figurant dans le manuel fourni par le fabricant de la pompe à vide.

DANGER

Danger de mort par empoisonnement lié à la fuite de gaz de procédé toxiques, en l'absence de conduite de refoulement

En fonctionnement normal, la pompe à vide libère des gaz et des vapeurs dans l'air. Dans les analyses impliquant des substances toxiques, il existe un risque d'intoxication susceptible de provoquer des lésions ou la mort.

- Respectez la réglementation en vigueur concernant le traitement de substances toxiques.
- Évacuez les gaz de procédé toxiques en toute sécurité par une conduite de refoulement.

WARNING

Risque de dommages matériels ou de blessures graves

- Utiliser uniquement des accessoires et des produits d'origine approuvés par le fabricant de la pompe ou Invisible-Light Labs GmbH .
- Éviter la présence de pièces détachées à l'intérieur de la chambre à vide.
- Ne pas utiliser la pompe si le couvercle n'est pas en place sur la chambre à vide d'EMILIE™ .

2.5 Consignes de sécurité en lien avec l'utilisation d'un gaz de purge

DANGER

Risque d'asphyxie par manque d'oxygène

EMILIE™ peut être purgé à l'air sec et propre ou à l'azote. Le boîtier de purge d'EMILIE™ n'est pas étanche. L'utilisation d'azote pour la purge EMILIE™ peut entraîner une perte d'oxygène. Le non-respect des normes de sécurité et des directives applicables à l'utilisation des systèmes de purge à l'azote peut entraîner une asphyxie.

- De fortes concentrations d'azote gazeux dans un espace clos peuvent provoquer une asphyxie! Utiliser le gaz de purge à l'azote uniquement dans des zones bien ventilées et veiller à maintenir une concentration adéquate en oxygène dans l'air en permanence.
- Consultez le manuel du fabricant du FTIR pour plus d'informations sur l'alimentation de purge, la pression maximale et le débit appropriés à votre appareil. Ne jamais dépasser la pression et le débit maximum recommandés lors de la purge d'EMILIE™ .

2.6 Consignes de sécurité en lien avec l'utilisation de dispositifs laser

AVERTISSEMENT

Risque potentiel de lésions oculaires dues au dispositif laser

EMILIE™ ne contient pas de laser. Cependant, comme EMILIE™ est conçu pour fonctionner avec des spectromètres IR-TF, il est conseillé à l'utilisateur de consulter les consignes de sécurité laser du fabricant du spectromètre avant toute utilisation. EMILIE™ ne peut être utilisé qu'avec des produits laser de classe 1 ou classe 2, conformément aux normes CEI 60825-1:2014 et ANSI Z136.1.

- Vérifiez la classe laser du spectromètre avant d'installer et d'utiliser EMILIE™ . N'utilisez EMILIE™ qu'avec des dispositifs laser de classe 1 ou 2.
- Ne regardez pas le faisceau lumineux du spectromètre ou la lumière émise par le support de puce central.

2.7 Consignes de sécurité en lien avec les champs magnétiques

DANGER

Champ Magnétique

EMILIE™ contient des aimants qui créent un champ magnétique dans la chambre à vide ainsi qu'à l'intérieur du couvercle de la chambre à vide.

- Les porteurs de stimulateur cardiaque doivent se tenir à 15 cm de la chambre à vide d'EMILIE™ ainsi que de son couvercle.
- Les outils et composantes métalliques peuvent être influencés par le champ magnétique d'EMILIE™ , ce qui peut les attirer vers les aimants dans la chambre à vide. Soyez prudent lors de la manipulation de composantes métalliques à proximité de la chambre à vide afin d'éviter d'endommager les composants internes.

2.8 Consignes de sécurité en lien avec la prévention des brûlures

AVERTISSEMENT

Risque de brûlure sur les surfaces chaudes

EMILIE™ contient un élément Peltier capable de réguler les températures de surface jusqu'à 80°C.

- Ne touchez pas la puce ou son support avec vos doigts avant, pendant ou après l'opération pour éviter les brûlures.
- Utilisez des pincettes de précision pour manipuler la puce.
- Portez si nécessaire des équipements de protection individuelle.

2.9 Consignes de sécurité en lien avec les environnements humides

ATTENTION

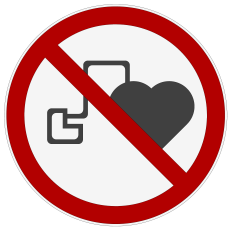
Utilisation en environnement propre et sec uniquement

EMILIE™ et PHILL™ sont destinés à être utilisés exclusivement dans des environnements intérieurs secs et contrôlés, tels que des laboratoires ou des salles blanches. Leur utilisation en milieu humide ou extérieur est interdite. L'utilisation dans un environnement humide ou mouillé peut entraîner une baisse de performance, des dommages, des pannes et potentiellement des risques pour la sécurité. Utilisez EMILIE™ et PHILL™ dans un endroit sec pour éviter les risques liés à l'humidité, tels que les courts-circuits, les dommages aux composants, et les électrocutions.

- Utilisez uniquement dans un environnement sec. Évitez tout contact avec l'eau ou d'autres liquides.

2.10 Description des panneaux d'avertissement

Table 3: Description de chaque étiquette d'avertissement affichée sur EMILIE™ , l'emplacement spécifique est décrit dans la Figure 4

Sign	Description
	Pictogramme d'avertissement concernant les champs magnétiques. Position: Couvercle d'EMILIE™ .
	Pictogramme d'avertissement pour les porteurs de stimulateurs cardiaques. Position: Couvercle d'EMILIE™ .
 	AVERTISSEMENT: Champ Magnétique. Peut être nocif pour les porteurs de stimulateurs cardiaques. Porteurs de stimulateur cardiaque, garder une distance minimale de 15 cm (6 pouces). Position: Sur le côté d'EMILIE™ , au-dessus du support du miroir cinématique. Langue d'affichage: Anglais et français.
 	ATTENTION: Utilisez EMILIE™ uniquement avec des dispositifs laser de classe 1 ou 2. Suivez toutes les consignes de sécurité fournies par le fabricant du spectromètre. NE REGARDEZ PAS DANS LE FAISCEAU. Position: surface arrière d'EMILIE™ . Langue d'affichage: Anglais et français.

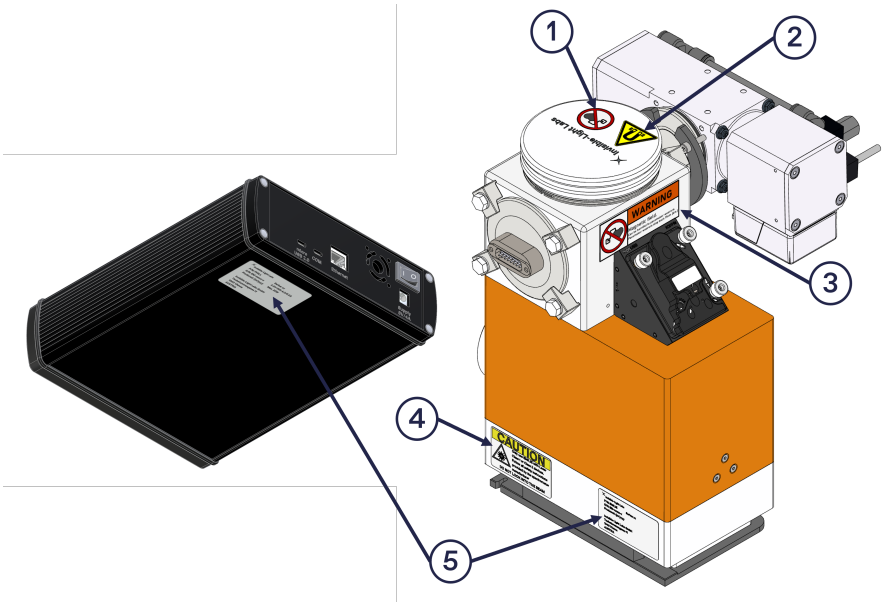
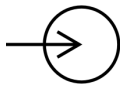
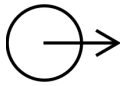
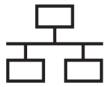


Figure 4: Position des étiquettes d’avertissement et de produit : (1) avertissement concernant le stimulateur cardiaque, (2) avertissement concernant le champ magnétique, (3) avertissement descriptif concernant le stimulateur cardiaque pour maintenir une distance de 15 cm/6 pouces, (4) avertissement de sécurité laser pour n’utiliser l’appareil qu’avec des sources lumineuses de classe 1 ou 2, (5) étiquette du produit sur EMILIE™ et PHILL™

2.11 Symboles graphiques utilisés sur le matériel

Table 4: Aperçu des symboles de connecteurs et normes internationales correspondantes

Description	Norme internationale	Symbole
Borne d'entrée	IEC 60417	
Borne de sortie	IEC 60417	
Borne de courant continu	IEC 60417	
Port de communication Ethernet	IEC 60417	
Port de communication USB (Universal Serial Bus)	ISO 7000	

2.12 Mise au rebut

Éliminez tous les déchets (produits chimiques, substances infectueuses et radioactives contaminées, etc.), tels que les puces nanoélectromécaniques d'échantillonnage et de détection EMILIE™ usagées, conformément à la réglementation en vigueur en matière de laboratoire. Les détergents et produits de nettoyage doivent être éliminés conformément à la réglementation locale relative aux déchets spéciaux.

La réglementation du Parlement européen et du Conseil relative aux équippement électriques et électroniques impose le respect de la directive DEEE, rendant obligatoire l'apposition du symbole de la poubelle barrée sur nos produits. Cette directive vise à encourager la collecte et le recyclage des équipements.

Recyclez les matériaux d'emballage conformément à la réglementation locale.

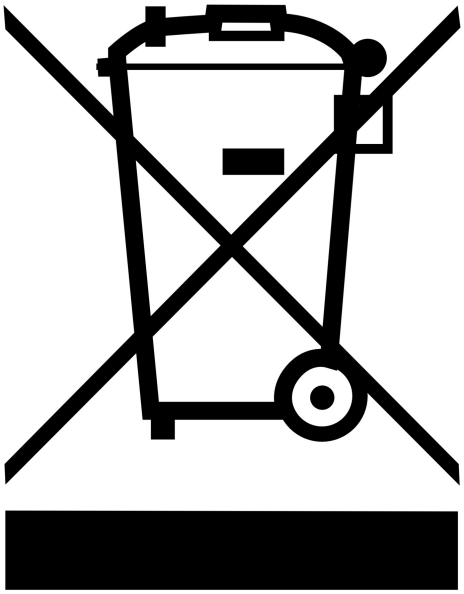


Figure 5: Ce symbole, apposé sur les produits Invisible-Light Labs ou sur leur emballage, signifie que le produit ne doit pas être jeté avec les ordures ménagères. Il est obligatoire de les éliminer séparément des déchets municipaux, conformément à la réglementation locale. L'élimination appropriée des équipements en fin de vie contribuera à prévenir les conséquences néfastes potentielles pour l'environnement et la santé humaine. Leur recyclage responsable favorise la réutilisation durable des ressources matérielles.

3 PRODUCT INFORMATION

Production facility address:
Invisible-Light Labs GmbH
Taubstummengasse 11
1040 Vienna
Austria

3.1 EMILIE™ nanoelectromechanical infrared analyzer

EMILIE™ is designed to seamlessly integrate into the sample compartment of your FTIR spectrometer, utilizing the spectrometer's light to characterize analytes by nanoelectromechanical photothermal spectroscopy under high-vacuum conditions.[1]

Sample collection and sensing of analytes is performed exclusively using original and disposable EMILIE™ nanoelectromechanical sampling and sensing chip. EMILIE™ is provided as a bundle, including a frequency tracking and resonance-actuation device called PHILL™. The resonance parameters are user-controlled through the proprietary user interface called PHILLharmonics. Spectral analysis is performed using the spectrometer's software, as EMILIE™ is recognized as an external detector by the spectrometer.

3.2 Environmental storage, transport, and operation conditions

Environmental conditions for safe and compliant storage, transport, and operation are specified in Table 5. Users must ensure that the equipment is installed and operated within these environmental limits to maintain safety and compliance with relevant standards. Additional information can be found on the data sheets for EMILIE™ and PHILL™ at invisible-light-labs.com/resources.

CAUTION

Dry Clean Environment Use Only
EMILIE™ and PHILL™ are intended for use exclusively in dry, controlled indoor environments such as laboratories or cleanrooms. Operation in wet or outdoor environments is not permitted. Moisture can cause corrosion, short circuits, and other malfunctions in electronic devices. Using in a wet or humid environment could lead to reduced performance, damage, and failure, and potentially lead to safety .Use EMILIE™ and PHILL™ in a dry clean environments only to avoid moisture-related risks, such as short circuits, component damage, and electric shock.

- Use in dry environments only. Avoid contact with water or other fluids.

[1] A suitable turbo-drag pump is required. As of the date of this manual, the HiPace® 10 Neo pump from Pfeiffer Vacuum GmbH is recommended and can be purchased with EMILIE™ upon request.

ATTENTION

Utilisation en environnement propre et sec uniquement

EMILIE™ et PHILL™ sont destinés à être utilisés exclusivement dans des environnements intérieurs secs et contrôlés, tels que des laboratoires ou des salles blanches. Leur utilisation en milieu humide ou extérieur est interdite. L'utilisation dans un environnement humide ou mouillé peut entraîner une baisse de performance, des dommages, des pannes et potentiellement des risques pour la sécurité. Utilisez EMILIE™ et PHILL™ dans un endroit sec pour éviter les risques liés à l'humidité, tels que les courts-circuits, les dommages aux composants, et les électrocutions.

- Utilisez uniquement dans un environnement sec. Évitez tout contact avec l'eau ou d'autres liquides.

Table 5: Environmental conditions for storage, transport, and operation of EMILIE™ and PHILL™

Environmental conditions	
Operating temperature	5 °C to 35 °C
Relative humidity	$\leq$ 80% RH, non-condensing
Altitude	Up to 2000 m above sea level
Pollution degree	2 (IEC 61010-1)
Wet location rating	Indoor use only; clean and dry environment

ⓘ EMILIE™ and PHILL™ are intended to be operated in basic electromagnetic environments.

NOTICE

Danger of damage to property

To ensure the proper function and integrity of the product, transport, store, and operate the products only within their permissible temperature and vacuum limits as specified.

AVIS

Risque de dommages matériels

Pour garantir le bon fonctionnement et l'intégrité du produit, transportez, stockez et utilisez les produits uniquement dans les limites de température et de vide autorisées, comme spécifié.

3.3 Device specifications

Tables 6 and 7 list EMILIE™ and PHILL™ specifications.

Table 6: EMILIE™ general specifications

EMILIE™ nanoelectromechanical infrared analyzer	
Weight	7.4 kg
Dimensions (LxWxH)	22×14×28 cm
Disposable sensing element	EMILIE™ nanoelectromechanical sampling and sensing chip Photothermal sensing Disposable, non-reusable
Chip temperature control range [2]	Active temperature control: 5 °C - 80 °C
Vacuum chamber[3]	Material: Aluminum 3.2315, AlMgSi1 Pressure range 5×10^{-6} to 10^{-3} mbar
Purge box	Material: Anodized aluminum 3.2315, AlMgSi1 Purge gas pressure: max. 2 bar Sustained flow: max. 200 liter/hour Purge gas: dry and clean air or nitrogen (oil-free and dust-free)
Electrical connections	Connection to PHILL™ via Sub-D 15 cable, Power supplied through PHILL™

Table 7: PHILL™ general and electrical specifications

PHILL™ general specifications	
Weight	1.1 kg
Dimensions (L×W×H)	23×17×6 cm
Enclosure material	Aluminum 3.3206, AlMgSi0.5 powder-coated, seals: TPE
PHILL™ electrical specifications	
Rated input voltage	100–240 VAC ±10%
Power rating	6.25 W, max. 20 W
Output voltage	5 V DC (SELV), supplied by a certified isolated power supply providing reinforced insulation (2× MOPP) according to IEC 60601-1, IEC 61558-1/2-16, or IEC/EN 62368-1
Host connection	Micro-USB 2.0 (480 MBit/s), Ethernet (10/100/1000 MBit/s)

[2] The minimum temperature achievable by the Peltier element is dependent on the ambient temperature. At 35 °C ambient temperature, a minimum temperature of 5 °C can be achieved by the Peltier element reliably

[3] EMILIE™ has only been tested within the specified operation pressure range.

DANGER

Danger of death from electrocution

PHILL™ is powered via an external 5 V DC power supply (minimum 4 A) and must not be connected directly to mains voltage. The EMILIE™ module receives power and control signals exclusively through the Sub-D cable connection to the PHILL™ unit and is not directly powered from the mains. The power supply provided with PHILL™ is safety-approved with 2x MOPP defined in IEC 60601-1. Unspecified and unapproved power supplies or an incorrect voltage may damage the device, prevent proper operation, cause serious injury or even death.

- Only use the power supply provided with the unit or supplied by Invisible-Light Labs GmbH specifically for this unit.
- Do not use in wet or humid environments.
- Ensure the AC adapter is connected to the correct mains voltage as indicated on the rating label.

DANGER

Danger de mort en cas d'électrocution

PHILL™ est alimenté par une alimentation externe de 5 V CC (minimum 4 A) et ne doit pas être connecté directement au secteur. Le module EMILIE reçoit les signaux d'alimentation et de commande exclusivement via le câble Sub-D de connexion à l'unité PHILL et n'est pas directement alimenté par le secteur. Les blocs d'alimentation électrique non spécifiés et non approuvés ou une tension incorrecte peuvent endommager l'appareil, empêcher son bon fonctionnement, entraîner de graves blessures, voire la mort.

- Utilisez uniquement le bloc d'alimentation fourni avec l'appareil ou fourni par Invisible-Light Labs GmbH spécifiquement pour cet appareil.
- Ne pas utiliser dans des environnements humides ou mouillés.
- Il est impératif de vérifier que l'adaptateur secteur est connecté à la tension secteur correcte, comme indiqué sur l'étiquette signalétique de l'appareil.

3.4 Instrument compatibility & requirements

This manual outlines the operation of EMILIE™ in conjunction with a spectrometer. EMILIE™ is compatible with the following spectrometer models:

- Bruker VERTEX 70 and 70v
- Bruker VERTEX 80 and 80v
- Bruker INVENIO R
- Bruker INVENIO X

To operate EMILIE™ in conjunction with the above-listed Bruker spectrometers, the following configuration is required:

- ASM external Analog-Box for connecting up to two external detectors to the VERTEX and INVENIO series spectrometers (Bruker part number E550/A).

> ⓘ The internal jumper of the input channel located inside the ASM external Analog-Box needs to be set to DC (the default is AC) - see section 4.2.4 for instructions on how to proceed.

- Installed Step/Slow Scan option for stepwise and slow scanning (Bruker part number S510).
- Vacuum pump system capable of achieving a pressure of < 10^{-3} mbar within the EMILIE™ chamber. The HiPace® 10 Neo pump from Pfeiffer Vacuum GmbH is recommended.

3.5 Product overview

EMILIE™ consists of the following parts (see Figure 6):

1. Vacuum chamber with the lid on top for access, the chip holder and the contact bridge
2. Kinetic mirror mount for focus adjustment
3. Flange for vacuum pump (DIN KF25)
4. Optical port with adjustable flange for sealing
5. Purge box with internal optics
6. SubD 15 Pin connector to connect to PHILL™
7. Bottom plate compatible with the Bruker sample compartment
8. Back panel of PHILL™ frequency tracking electronics
9. Front panel of PHILL™ frequency tracking electronics

3.6 EMILIE™ nanoelectromechanical sampling and sensing chip

The EMILIE™ nanoelectromechanical sampling and sensing chip is the key element for the NEMS-FTIR spectroscopy. These disposable chips feature a perforated nanoelectromechanical membrane and gold electrodes for signal transduction.

A schematic illustration highlighting the main features of the EMILIE™ chip is shown in Figure 7. It features:

1. A thin nanoelectromechanical membrane which has a perforated area of 600 µm in diameter, perforations with a 6 µm diameter, and a 3 µm pitch from the edge of one perforation to the next.
2. A pair of gold electrodes. One pair is for driving the resonator, and the other is for its readout.
3. Each chip has its unique number within its batch.

Figure 6: Top: Schematic illustration of EMILIE™'s front (left) and backside (right) highlighting the (1) Vacuum chamber, (2) Kinematic mirror mount, (3) KF25 vacuum flange, (4) Optical port, (5) Purge box with internal optics, (6) Sub-D 15 Pin connector, and (7) Bruker FTIR Quick-Lock plate. Bottom: Schematic illustration of PHILL™'s (8) back panel and (9) front panel.

For details on how to handle the EMILIE™ chip and tips on how to deposit analytes on the EMILIE™ nanoelectromechanical sampling and sensing chip for analysis, refer to the ”Sample collection & handling guide” that can be found on invisible-light-labs.com/resources .

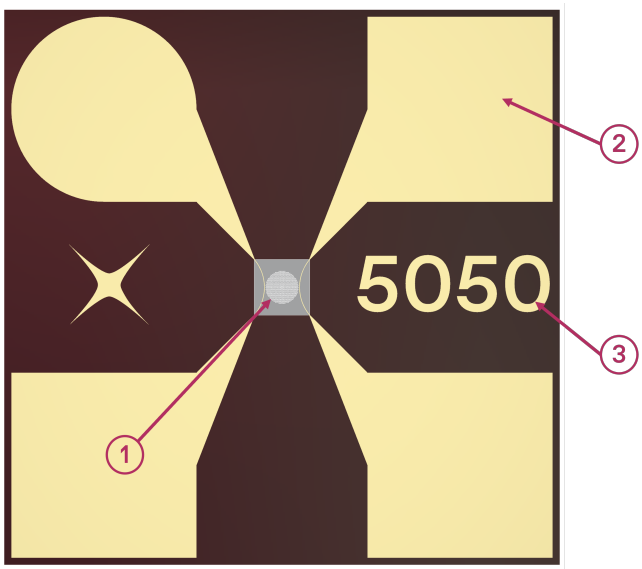


Figure 7: Illustration of the EMILIE™ nanoelectromechanical sampling and sensing chip highlighting its main components; (1) Thin nanoelectromechanical membrane, (2) gold electrodes, (3) individual chip number.

3.7 EMILIE™ LIGHT chip

The EMILIE™ Light chip features a specialized linear absorbing material to record the FTIR background spectrum of the light source. The FTIR spectrum of the light source is essential for the post-processing of the NEMS-FTIR data (see 5.2.8).

3.8 EMILIE™ VALIDATION chip

The EMILIE™ Validation chip is pre-loaded with 10 ng polystyrene beads, as shown in Figure 8. These chips can be used to verify the performance of EMILIE™ (see 5.2.8).

3.9 Product label

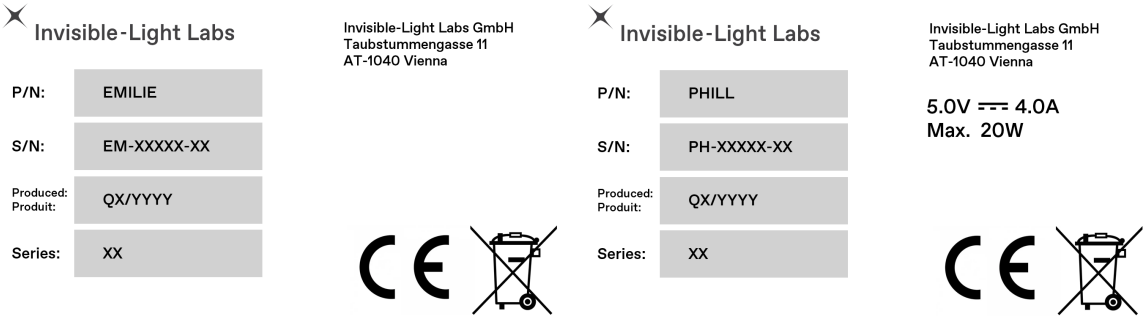


Figure 9: Product label of EMILIE™ and PHILL™ , located on the backside of each device.

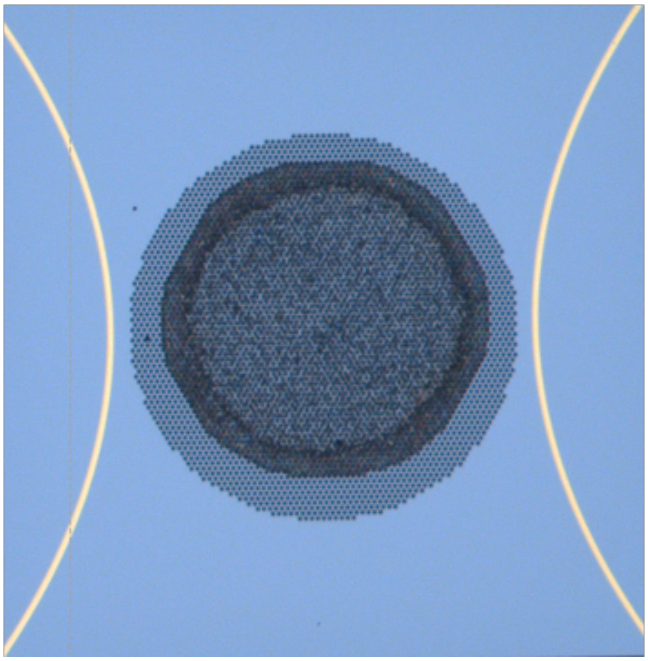


Figure 8: Micrograph of the perforated area of an EMILIE™ Validation chip loaded with 10 ng of polystyrene beads.

The product labels for EMILIE™ and PHILL™ are illustrated schematically in Figure 9) and can be found on the backside of each device. The label includes the device series and production date. Each EMILIE™ and PHILL™ has its own unique serial number (S/N). The company's address can also be found on the label. The product label of PHILL™ also includes further information on the power supply.

4 UNPACKING AND INSTALLATION

NOTICE

The packaging and products should be examined carefully before installation. Carefully inspect the packaging for any signs of damage caused during transport. Packaging damage may indicate potential damage to the product. If any damage is detected, do not operate the device. Instead, contact Invisible-Light Labs immediately for assistance.

AVIS

L'emballage et les produits doivent être examinés attentivement avant l'installation. Inspectez soigneusement l'emballage pour détecter tout signe de dommage causé pendant le transport. Des dommages à l'emballage peuvent indiquer un dommage potentiel au produit. Si vous constatez un dommage, n'utilisez pas l'appareil. Contactez immédiatement Invisible-Light Labs pour obtenir de l'aide.

WARNING

Danger of serious injury due to falling parts

Falling objects during transport can cause a risk of injury to limbs.

- Take particular care and pay attention when transporting products.
- Do not stack Invisible-Light Labs GmbH products or products from other manufacturers due to the risk of falling over.
- Wear appropriate protective equipment, e.g. safety shoes.
- The lid of EMILIE™'s vacuum chamber is not attached to the body of the chamber. Transport EMILIE™ upright to avoid damage or injury caused by a falling vacuum chamber lid. When changing samples, always place the lid on a firm stable surface to avoid damage or injury.

AVERTISSEMENT

Danger de blessures graves en cas de chute d'objets

La chute d'objets peut entraîner des blessures sur les membres, voire même des fractures osseuses.

- Soyez particulièrement vigilant lors du transport manuel du produit.
- Ne pas empiler le produit.
- Portez un équipement de protection, tel que des chaussures de sécurité.
- Le couvercle de la chambre à vide d'EMILIE™ n'est pas fixé au corps de la chambre. Transportez EMILIE™ en position verticale pour éviter tout dommage ou blessure causé par la chute du couvercle de la chambre à vide. Lors du changement d'échantillon, placez toujours le couvercle sur une surface stable et ferme pour éviter tout dommage ou blessure.

Figure 10: (Left) Packaged EMILIE™ and (right) unpacked items.

4.1 Unpacking and inspection

- Carefully remove the items from the packaging.
- Ensure that the following components are present as shown in Figure 10. The box contains:
  - EMILIE™ nanoelectromechanical infrared analyzer
  - PHILL™ actuating and tracking electronics
  - sub-D 15 pin male to female cable
  - 5V DC power supply,
  - USB cable,
  - EMILIE™ Light Chips,
  - EMILIE™ Validation Chip
  - Indium foil replacement kit
  - Carbon Fiber reinforced precision plastic tweezers
- Examine the unpacked items for any visible signs of damage, such as dents, cracks, or scratches. In case of visible signs of damage, immediately consult the support via info@invisible-light-labs.com .
- Inspect the power supply and cables for any frayed wires or visible defects.

4.2 Installation

NOTICE

Risk of contamination and/or reduced performance

To ensure optimal performance and minimize contamination, follow these basic handling and maintenance instructions for EMILIE™ and it's accessories:

- Wear clean gloves during installation and operation to avoid contamination and reduced performance.
- Only use lint-free tissue and 2-isopropyl alcohol (isopropanol) and clean pressurized air with a low flow rate to clean the inside of the chamber. Avoid canned air dusters or compressed air from a system that may contain oil residues, as they may introduce contaminants in the vacuum chamber.
- Follow the instructions in the "Sample collection & handling guide" that can be found on invisible-light-labs.com/resources for optimal handling of the EMILIE™ chip .
- Great care should be taken to avoid touching the spectrometer windows within the sample compartment while inserting EMILIE™ to avoid damage and fingerprints.

AVIS

Risque de contamination et de performances réduites

Pour garantir une performance optimale et minimiser les risques de contamination, suivez les instructions suivantes pour la manipulation et l'entretien d'EMILIE™ et de ses accessoires:

- Portez des gants propres lors de l'installation et de l'utilisation d'EMILIE™ afin d'éviter toute contamination ou réduction de performance.
- Pour nettoyer l'intérieur de la chambre, utilisez uniquement un chiffon non pelucheux, de l'alcool 2-isopropylique (isopropanol) et de l'air comprimé propre à faible débit. Évitez les bombes aérosols ou l'air comprimé provenant d'un système susceptible de contenir des résidus d'huile, car ils pourraient introduire des contaminants dans la chambre à vide.
- Suivez les instructions du guide «Sample collection & handling guide» disponible sur invisible-light-labs.com/resources pour une manipulation optimale de la puce "EMILIE™ chip ".
- Il faut faire très attention à ne pas toucher les fenêtres du spectromètre dans le compartiment à échantillons lors de l'insertion d'EMILIE™ pour éviter les dommages et les empreintes digitales.

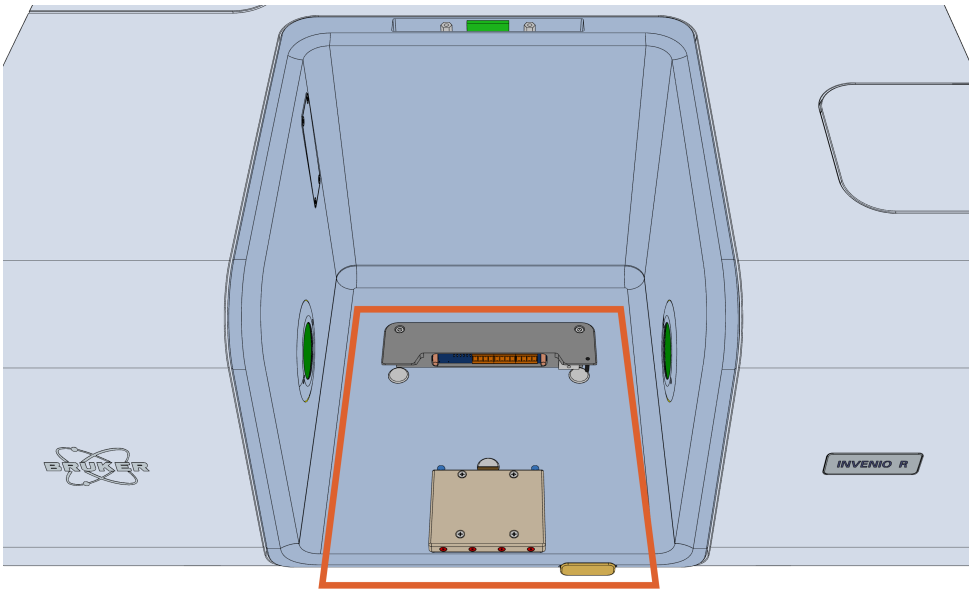


Figure 11: Closeup of the Bruker Invenio R sample compartment highlighting the contact strip (electronic connectors for AAR and CAN bus); it is the counterpart to the contact strip at the QuickLock-baseplate of EMILIE™ and the QuickLock locking mechanism and release lever.

NOTICE

When installing or operating EMILIE™ and PHILL™ , ensure that the equipment is positioned in such a way that access to the disconnecting device (e.g., power plug or external power supply) is not obstructed.
The disconnecting device must remain easily operable by the user at all times, without the need to move, lift, or disassemble any part of the equipment or surrounding setup.
This is required to ensure safe disconnection from power in case of emergency, maintenance, or malfunction.

AVIS

Lors de l'installation ou de l'utilisation de EMILIE™ et PHILL™ , assurez-vous que l'équipement est positionné de manière à ce que l'accès au dispositif de déconnexion (par exemple, une prise d'alimentation ou une alimentation externe) ne soit pas obstrué.
Le dispositif de déconnexion doit rester facilement accessible à tout moment par l'utilisateur, sans qu'il soit nécessaire de déplacer, de soulever ou de démonter une quelconque partie de l'équipement ou de l'installation environnante.
Cela est nécessaire pour garantir une déconnexion sécurisée de l'alimentation en cas d'urgence, de maintenance ou de dysfonctionnement.

4.2.1 Installing EMILIE™ in the sample compartment of a Bruker spectrometer

EMILIE™ is equipped with a QuickLock-baseplate allowing quick and exact positioning within the sample compartment of Bruker Vertex and Invenio FTIR spectrometers as shown in Figure 11. Follow the instructions below to insert EMILIE™ in your spectrometer's sample compartment.

Vertex models:

1. Before getting started, detach and completely remove the lid of the sample compartment of your spectrometer. For more information on removing the sample compartment lid, refer to the manual for your specific spectrometer device.
2. Push the base-plate trigger on the bottom of the sample compartment and remove any sample holder that may be present in the compartment.
3. Optional: The optical window located on the right side of the spectrometer sample compartment may be removed. Removing this window allows an additional 10% light throughput to EMILIE™ with a corresponding increase in sensitivity. For more information on removing this window, refer to the manual for your specific spectrometer device.
4. Lift EMILIE™ by holding it by the orange purge box and place it into the sample compartment with the contact strip of the EMILIE™ QuickLock baseplate facing to the contact strip of the QuickLock mechanism in the sample compartment (see Figure 11). While inserting EMILIE™ in the QuickLock mechanism of the sample compartment, tilt the accessory QuickLock baseplate front edge slightly upwards.
5. While pressing the QuickLock release lever, press the front edge of the EMILIE™ QuickLock baseplate downwards until it snaps into the QuickLock mechanism.
6. As soon as the EMILIE™ QuickLock baseplate locks in place, the electronic connections are established. This is indicated by a beep.
7. Turn to extend the flange to the right until it gently touches the port of the FTIR (see Figure 12).

Invenio models:

1. Before getting started, detach and completely remove the lid of the sample compartment of your spectrometer. For more information on removing the sample compartment lid, refer to the manual for your specific spectrometer device.
2. Push the base-plate button underneath of the sample compartment and remove any sample holder that may be present in the compartment.
3. Optional: The optical window located on the right side of the spectrometer sample compartment may be removed. Removing this window allows an additional 10% light throughput to EMILIE™ with a corresponding increase in sensitivity. For more information on removing this window, refer to the manual for your specific spectrometer device.
4. Unlock the QuickLock mechanism by pushing the gray button on the bottom right below the sample compartment
5. Lift EMILIE™ by holding it by the orange purge box and place it into the sample compartment with the contact strip of the EMILIE™ QuickLock baseplate facing to the contact strip of the QuickLock mechanism in the sample compartment (see Figure 11). While inserting EMILIE™ in the QuickLock mechanism of the sample compartment, tilt the accessory QuickLock baseplate front edge slightly upwards.

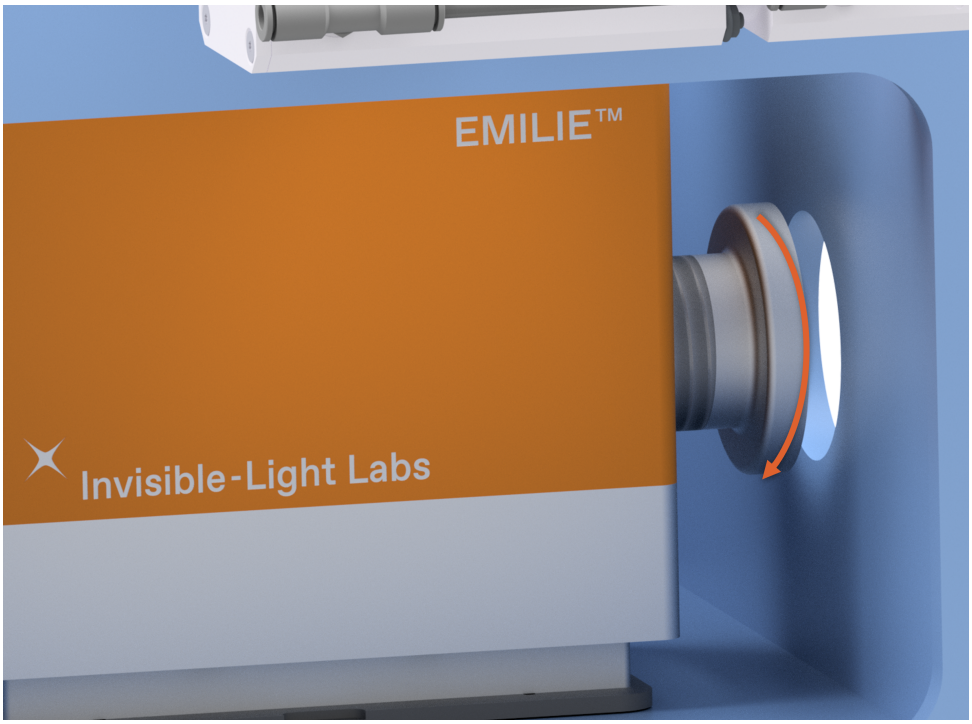


Figure 12: The flange tube needs to be screwed out until it gently touches the FTIR port

6. Press the front edge of the EMILIE™ QuickLock baseplate downwards until it snaps into the QuickLock mechanism.

7. As soon as the EMILIE™ QuickLock baseplate locks in place, the electronic connections are established. This is indicated by a beep.

8. Lock the QuickLock mechanism by pushing the button back in.

9. Turn to extend the flange the right until it gently touches the port of the FTIR (see Figure 12).

WARNING

Ensure EMILIE™ is firmly clipped into the sample compartment of the FTIR

Potential risk of permanent product damage due to mechanical stress:

- Do not leave EMILIE™ unsecured or improperly installed, as this may lead to it falling, potentially causing damage to the enclosure, malfunction, or injury. Ensure the device is fully clipped into place, and follow your spectrometer's manual for the proper clipping procedure.
- Do not subject EMILIE™ to excessive force or weight as this may result in enclosure damage, malfunction or injury.

AVERTISSEMENT

Assurez-vous qu'EMILIE™ est fermement verouillé dans le compartiment principal du spectrometre IR-FT

Risque potentiel de dommages permanents au produit en raison de contraintes mécaniques :

- Ne laissez pas EMILIE™ non fixé ou mal installé, car cela pourrait entraîner sa chute et l'endommager, provoquer un dysfonctionnement, ou des blessures. Assurez-vous que l'appareil est bien fixé et suivez le manuel de votre spectromètre pour la procédure de fixation appropriée.
- Ne soumettez pas EMILIE™ à une force ou un poids excessif, car cela pourrait l'endommager, provoquer un dysfonctionnement ou des blessures.

4.2.2 Purging EMILIE™

DANGER

Risk of asphyxiation due to lack of oxygen

EMILIE™ can be purged with clean dry air or nitrogen. The EMILIE™ purge box is not sealed. Using nitrogen for purging EMILIE™ can lead to oxygen depletion. Non-observance of applicable safety standards and guidelines for the use of nitrogen purging systems may lead to asphyxiation.

- High nitrogen gas concentrations in an enclosed area can cause asphyxiation! Only use nitrogen purge gas in well-ventilated areas and ensure that an adequate oxygen concentration in the air is maintained at all times.
- Consult the FTIR manufacturer manual for further information on the appropriate purge supply, maximum pressure, and flow rate for your specific device.
- Never exceed a pressure of 2 bar or a maximum flow of 200 liter/hour when purging EMILIE™ .

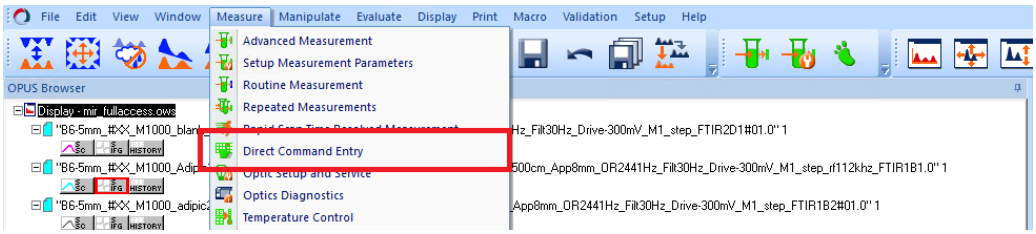


Figure 13: Direct command entry function for activating of the purge gas-flow in the box (captured in OPUS Version 7.8)

DANGER

Risque d'asphyxie par manque d'oxygène

EMILIE™ peut être purgée à l'air sec et propre ou à l'azote. Le boîtier d' EMILIE™ n'est pas étanche. L'utilisation d'azote pour la purge d'EMILIE™ peut entraîner une perte d'oxygène. Le non-respect des normes de sécurité et des directives applicables à l'utilisation des systèmes de purge à l'azote peut entraîner une asphyxie.

- Des concentrations élevées d'azote gazeux dans un espace clos peuvent provoquer une asphyxie! Utilisez le gaz de purge d'azote uniquement dans des zones bien ventilées et assurez-vous qu'une concentration adéquate en oxygène est maintenue en permanence.
- Consultez le manuel du fabricant de votre spectromètre IR-TF pour plus d'informations sur l'alimentation de purge, la pression maximale et le débit appropriés à votre appareil.
- Ne dépassez jamais une pression de 2 bars ni un débit maximal de 200 litres/heure lors de la purge d'EMILIE™ .

The purge gas-flow of the built-in diffuser located inside the purge box can be controlled via the OPUS software of your Bruker spectrometer. In OPUS, the "Direct command entry" function (see Figure 13) allows the execution of custom commands. The command for activating the purge gas-flow is "pvv=49". Follow the following steps to purge EMILIE™ :

1. Navigate to "measure".
2. Select "direct command entry" and type "pvv=49".
3. Press "send".

Consult the manual of your FTIR spectrometer for more information on the execution of direct commands.

4.2.3 Connecting EMILIE™ to a vacuum system

For operation, EMILIE™ requires a vacuum system. Invisible-Light Labs GmbH recommends the operation of EMILIE™ with a HiPace® 10 Neo from Pfeiffer Vacuum GmbH . For a detailed installation of the HiPace® 10 Neo , the user is advised to use the manual provided by Pfeiffer Vacuum GmbH in conjunction with the following setup instructions.

Alternative vacuum pump system installation: If an alternative pump system is installed, carefully

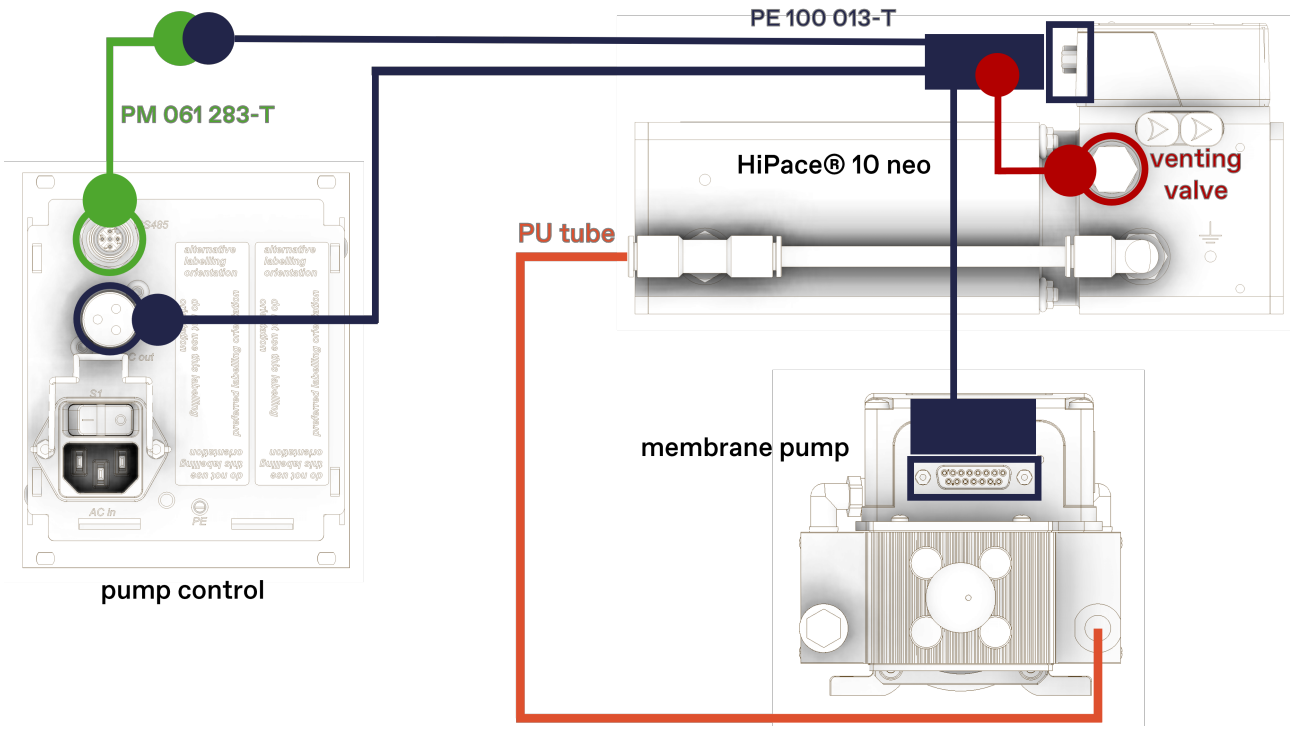


Figure 14: Schematic of the HiPace® 10 Neo pumping system setup and connections

unscrew the KF25 blind flange of the vacuum port on EMILIE™. Clean the O-ring and the surface around the port using lint-free wipes and isopropyl alcohol. Connect a vacuum-compatible KF25 adapter or tube to the alternative vacuum pump system to the vacuum port of EMILIE™. Take note that the vacuum within the vacuum chamber must reach at least 10^{-3} mbar for optimal operation. EMILIE™ is verified at 10^{-5} mbar.

HiPace® 10 Neo system installation: The following equipment is necessary for setting up the HiPace® 10 Neo vacuum pump to EMILIE™ :

- 10 mm and 13 mm wrench
- No. 4 Allen key
- isopropyl alcohol
- lint-free wipes

Follow these steps to set up the HiPace® 10 Neo pumping system according to the schematic shown in Figure 14:

1. Set up the pump controller called ”OmniControl 200” and connect it to the power supply.
2. Unbox the membrane pump ”MVP 010-3” and mount the quick connector adapter to the pump input on the right (see Figure 14) and mount the filter to the output to the left. Place the pump (ideally on the floor to reduce vibration) and plug in the connection cable ”PE 100 013-T” as shown in Figure 14.
3. Unpack the HiPace® 10 Neo and place it on a clean surface (for example on lint-free wipes).
4. Remove the protection lid on the KF40 flange opening of the HiPace® 10 Neo using the No. 4 Allen key.

5. Remove the centering ring of the KF40 O-ring and replace it with the centering splinter shield if available. Place the assembled O-ring back on the KF40 pump flange.

6. Mount the KF40-to-KF25-reducer to the flange on the pump as shown in Figure 15. Ensure the screws are tightened evenly until hand-tight. Do not apply excessive force.

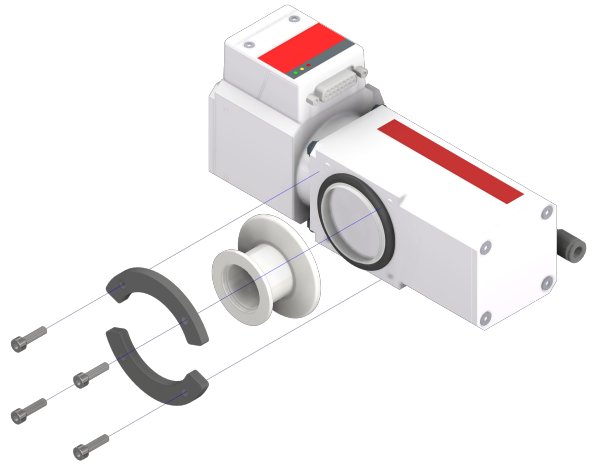


Figure 15: Mounting of the KF40-to-KF25-reducer to the HiPace® 10 Neo pump. Make sure the screws are tightened evenly and use only hand-tightening.

7. Remove the KF25 blind flange blocking the EMILIE™ vacuum port and wipe it as well as the O-ring with lint-free wipes and isopropyl alcohol .

   Cover the KF25 blind flange with the provided plastic cap (used to cover the KF25 flange of the reducer) and store it in a dust-free environment.

8. Mount the HiPace® 10 Neo with the KF40-to-KF25-reducer to the KF25 flange opening on EMILIE™ with four wall clamps, make sure the screws are tightened evenly and only hand-tight! The HiPace® 10 Neo can be mounted in any direction.

   ⓘ It is recommended to have help from a colleague to hold the pump in place while screwing the wall clamps and tightening them evenly!

9. Unscrew the closure of the venting opening of the HiPace® 10 Neo . Cover it with a plastic cap and store it in a dust-free environment.

10. Use a 13 mm wrench to mount the automatic venting valve to the venting opening until it's hand-tight. Do not apply excessive force (see, Figure 18).

11. Connect the HiPace® 10 Neo to the pump control using the connection cable "PE 100 013-T"

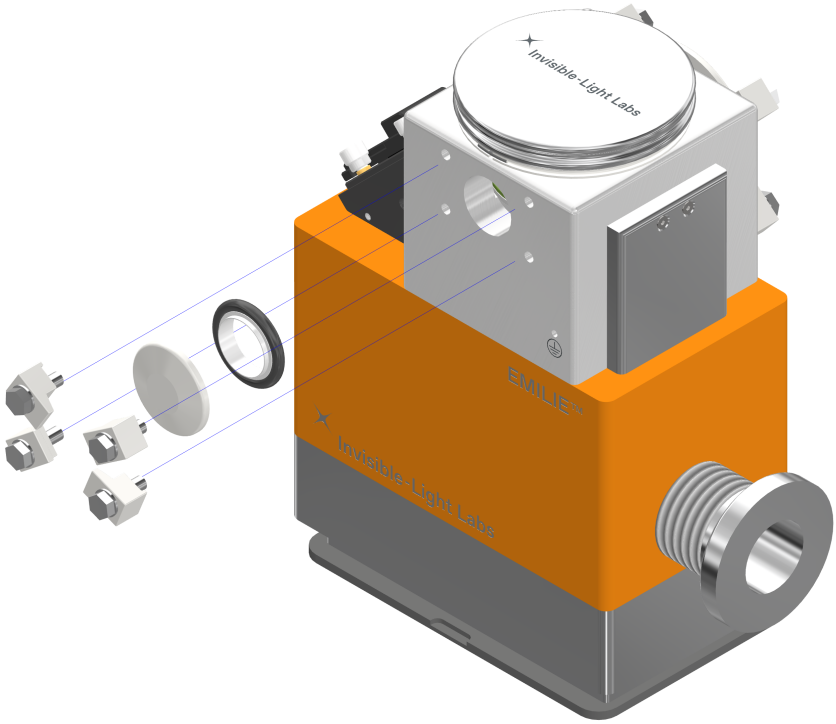


Figure 16: Removal of the KF25 blind flange covering the vacuum opening of EMILIE™.

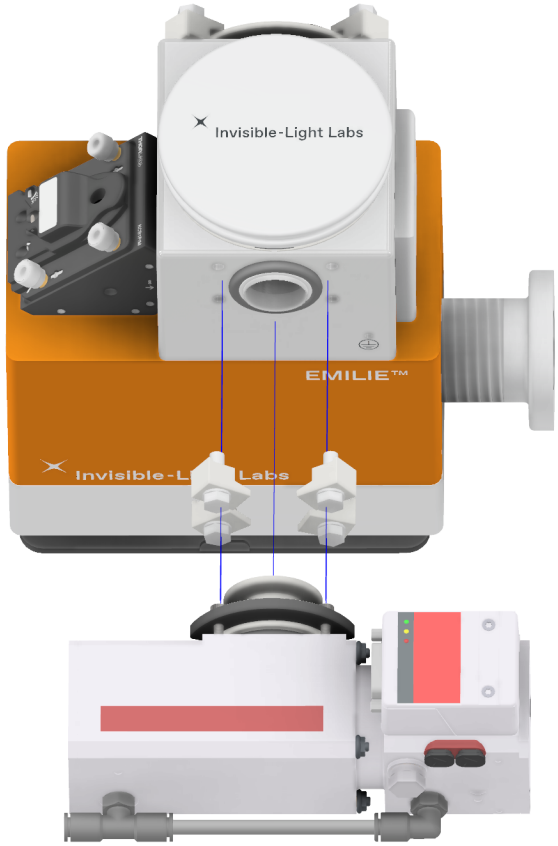


Figure 17: Mounting of the pump with the reducer to the KF25 flange on EMILIE™. Make sure all four screws of the wall clamps are tightened evenly.

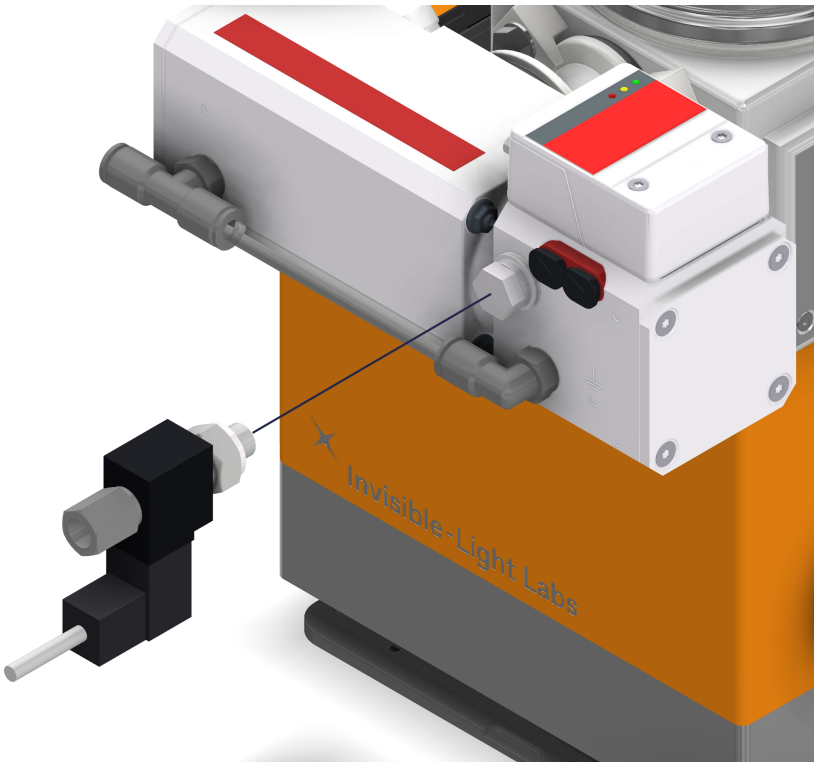


Figure 18: Mounting the automatic venting valve to the HiPace® 10 Neo by removing the closure of the venting opening and attaching the venting valve hand-tight using a 17 mm wrench

(already connected to the membrane pump) and connect the automatic venting valve cable to the socket ”b1” on the connection cable ”PE 100 013-T” as shown in Figure 14).

12. Plug in the interface cable ”PM 061 283-T” on one side to the connection cable ”PE 100 013-T” and on the other side to the pump control.

13. Remove the plug by pushing the quick-connector (see Figure 19 on how to handle a quick-connector) and store the plug in a dust-free environment.

14. Connect the PU tubing to the HiPace® 10 Neo pump and the membrane pump by pushing the tube in each of the quick-connectors and shortening the tube if necessary.

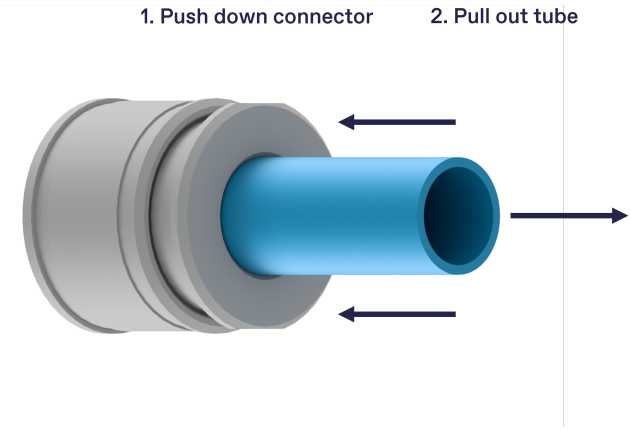


Figure 19: Disconnecting tubes/plugs from quick-connectors

Follow the following instructions to control the HiPace® 10 Neo pump:

1. Switch on the pump control (toggle the switch on the back pane of the pump control above the power plug).
2. Push the button ”data views” on the pump control start screen (Figure 20).

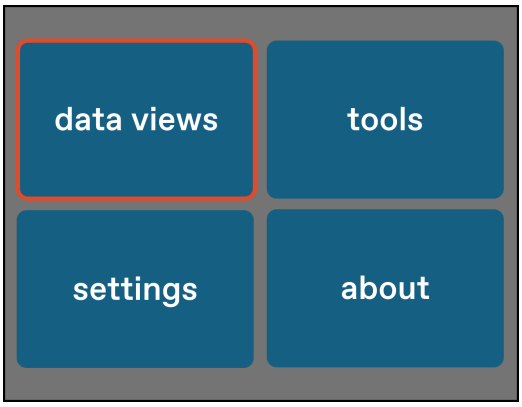


Figure 20: Pump control start screen

3. Press the gear symbol on the ”turbo pump” data view (Figure 21).

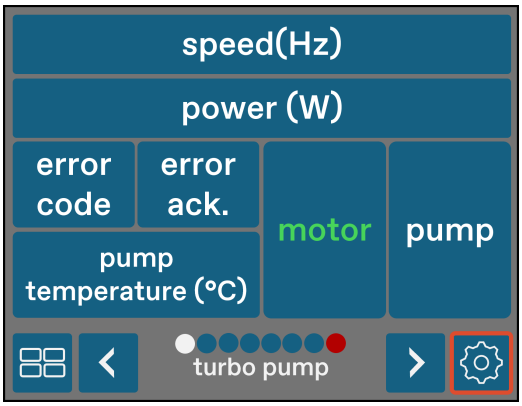


Figure 21: Initial data view of pump control

4. Press the button labeled ”application templates” (Figure 22).

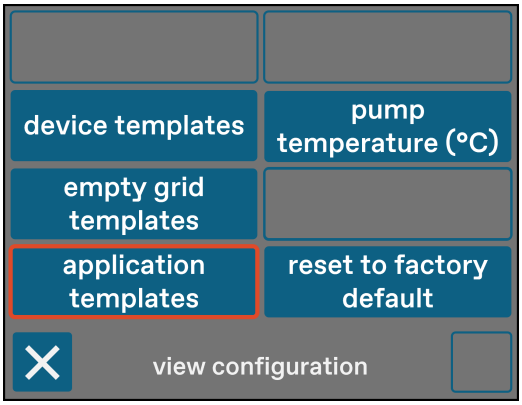


Figure 22: View configuration of pump control

5. Choose the application labeled ”TMP @ 1 + BKP @ 2” (TMP: turbo molecular pump, BKP: backing pump) and accept the change (Figures 23 & 24).

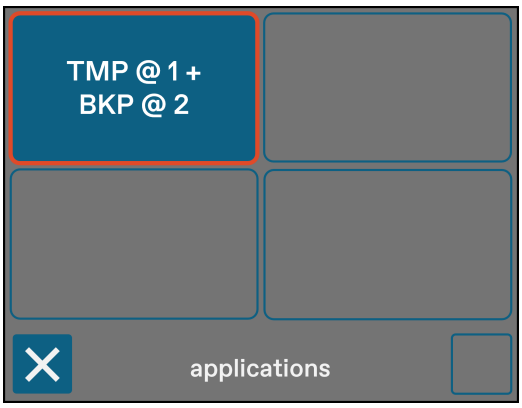


Figure 23: Application selection for pump control screen

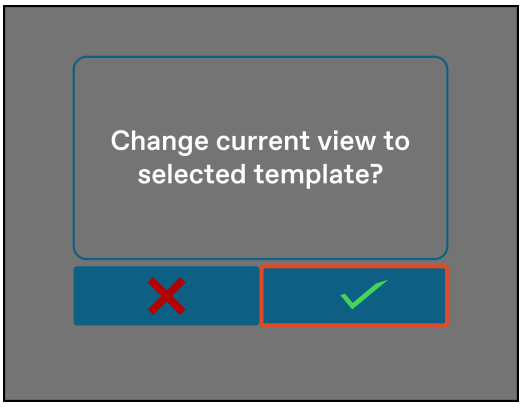


Figure 24: View configuration verification screen

6. A new screen will pop up called ”view 0” (Figure 25), where the top half is for controlling the membrane pump (backing pump) and the bottom half is for controlling the HiPace® 10 Neo (turbo molecular pump). The HiPace® 10 Neo pumping setup is now ready for use.

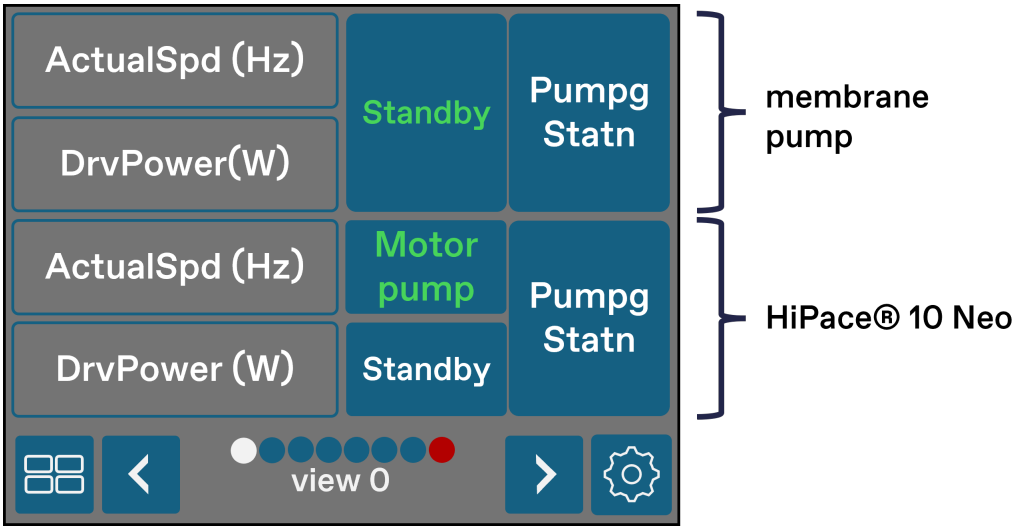


Figure 25: ”view 0” screen for operating the membrane pump (top) and the HiPace® 10 Neo (bottom)

To prevent contamination, it is recommended to leave the EMILIE™ vacuum chamber under vacuum at all times. Invisible-Light Labs GmbH further suggests evacuating the EMILIE™ vacuum chamber for 1h prior to the first measurement to remove volatile compounds and residual humidity.

In case extra grounding is needed, both EMILIE™ and the HiPace® 10 Neo have a threading on their housing. Figure 26 shows the location of the threading. EMILIE™ : M3, HiPace® 10 Neo : M4

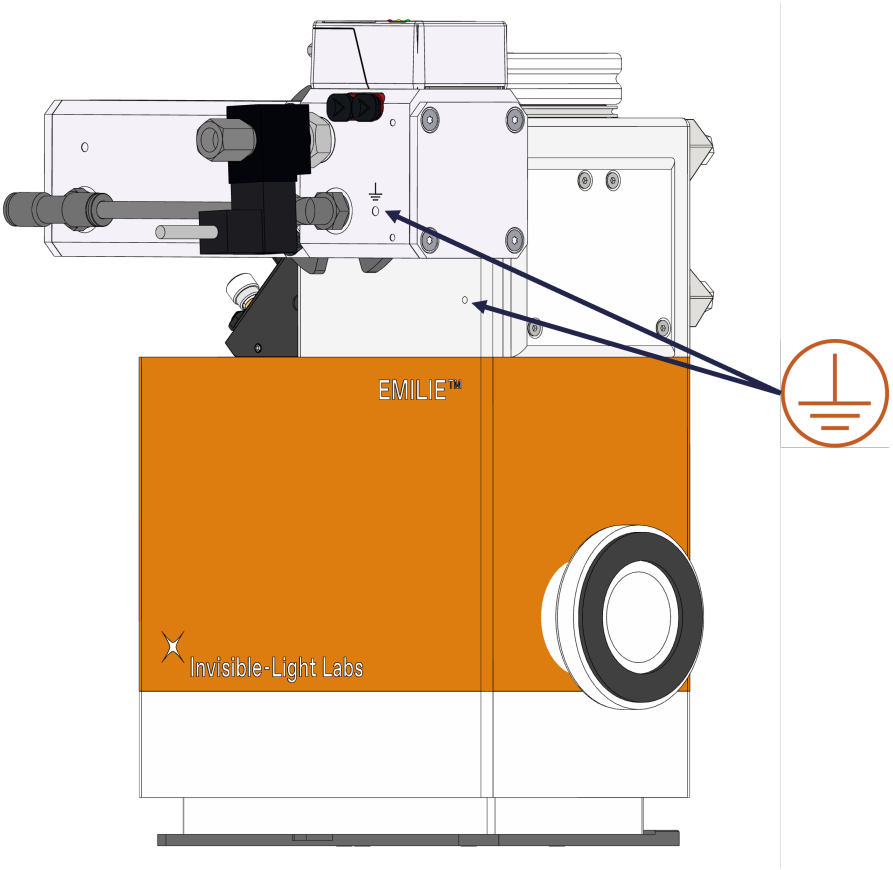


Figure 26: Extra grounding locations on the exterior of EMILIE™ and the HiPace® 10 Neo

4.2.4 Connecting EMILIE™ , PHILL™ and the FTIR spectrometer

Before connecting the devices for the first time, the coupling settings of the ASM external Analog-Box should be verified and corrected if necessary. This is done via the pin positions on the PCB inside the ASM external Analog-Box . There are two main versions of the ASM external Analog-Box PCB:

DANGER

Danger of death from electrocution

The ASM external Analog-Box is powered via the FTIR. Opening the ASM external Analog-Box during operation can cause electrocution or irreversible damage to the equipment.

- Ensure the ASM external Analog-Box is disconnected from the FTIR before opening and changing the jumper or dip siwtches.

DANGER

Risque mortel d'électrocution

Le ASM external Analog-Box est alimenté via le FTIR. L'ouverture du ASM external Analog-Box pendant le fonctionnement peut provoquer une électrocution ou des dommages irréversibles à l'équipement.

- Assurez-vous que le ASM external Analog-Box est déconnecté du FTIR avant d'ouvrir et de changer les cavaliers ou les interrupteurs DIP.

Version 1: The channel of the ASM external Analog-Box that connected to EMILIE™ must be set to DC. Open the ASM external Analog-Box by removing the four screws on top of the ASM external Analog-Box housing. Locate the jumpers "JR" and "JL" on the ASM external Analog-Box PCB. They are located next to the big connector cable as depicted in Figure 27. The channel connected to EMILIE™ needs to be set to "DC" as shown in Figure 27. The jumper shunt can be moved by carefully lifting it from its current position and then pushing it in place on top of the middle pin and the pin marked "DC". Make sure the two pins are securely connected and can be seen through the jumper shunt.

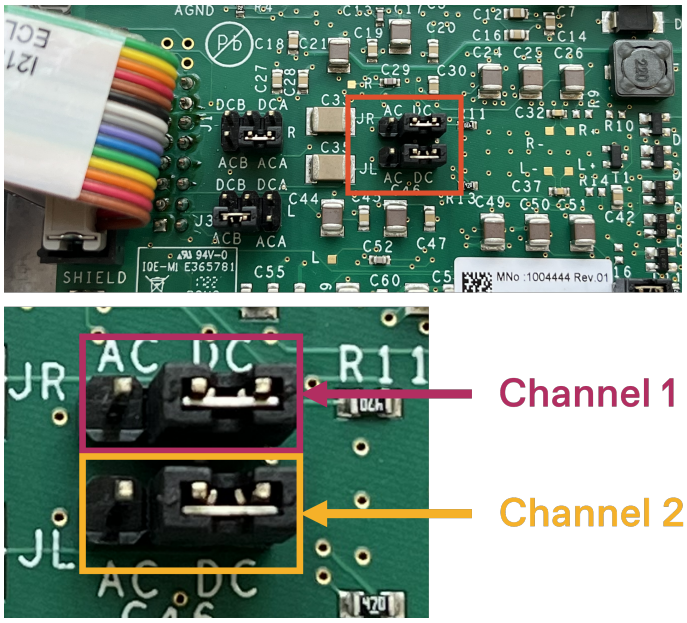


Figure 27: Version 1 of the ASM external Analog-Box : The jumpers labeled "JR" and "JL" in the ASM external Analog-Box must be set to DC for both channel 1 and 2

Version 2: The newer ASM external Analog-Box design is equipped with four toggle switches on the bottom side of the PCB. Carefully unplug the PCB and remove the screws connecting it to the housing. The toggle switch has four positions (see Figure 28). For one channel to be set to DC both switches need to be set to ”ON”. The factory settings of a newly purchased ASM external Analog-Box from Bruker set Channel 1 to AC and Channel 2 for DC. An ASM external Analog-Box purchased to use for EMILIE™ should have both channels set to DC.

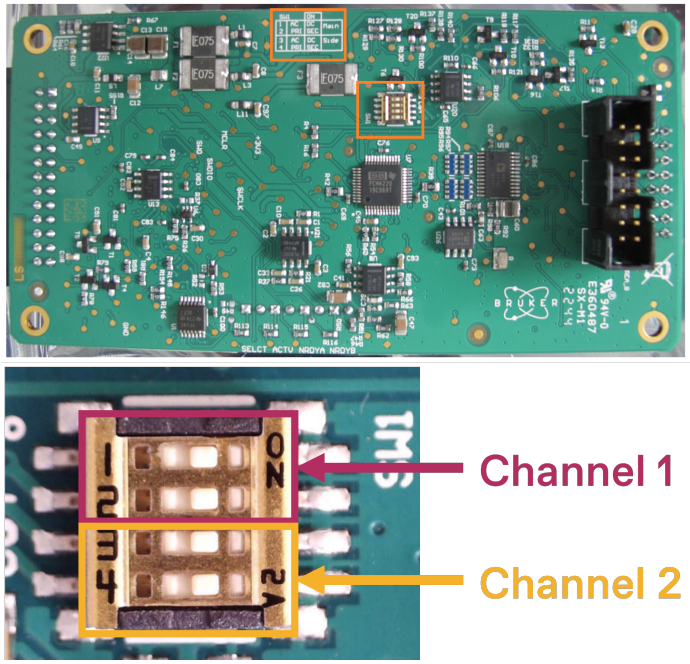


Figure 28: Version 2 of the ASM external Analog-Box with toggle switches: channels need to be set to ”ON” for DC operation

Once the ASM external Analog-Box jumper is set up to the appropriate position, follow these steps to connect EMILIE™ to PHILL™ . No extra tools are necessary for this task.

1. Plug the sub-D cable into PHILL™ and fix it via the screws.

2. Connect the power supply at the backside of PHILL™ .

3. Connect the PHILL™ ”Frequency Output” port to the ASM external Analog-Box of the FTIR spectrometer using the cable that is supplied by Bruker (see Figure 29). Take note of the selected channel on the ASM external Analog-Box .

4. Connect the ASM external Analog-Box to the FTIR spectrometer. Restart the FTIR spectrometer for automatic recognition of the ASM external Analog-Box .

5. Plug the sub-D cable into EMILIE™ and fix it via the screws as shown in Figure 29.

6. Turn on PHILL™ via the switch on the backside, a green LED lights up on the front panel once it is powered on.

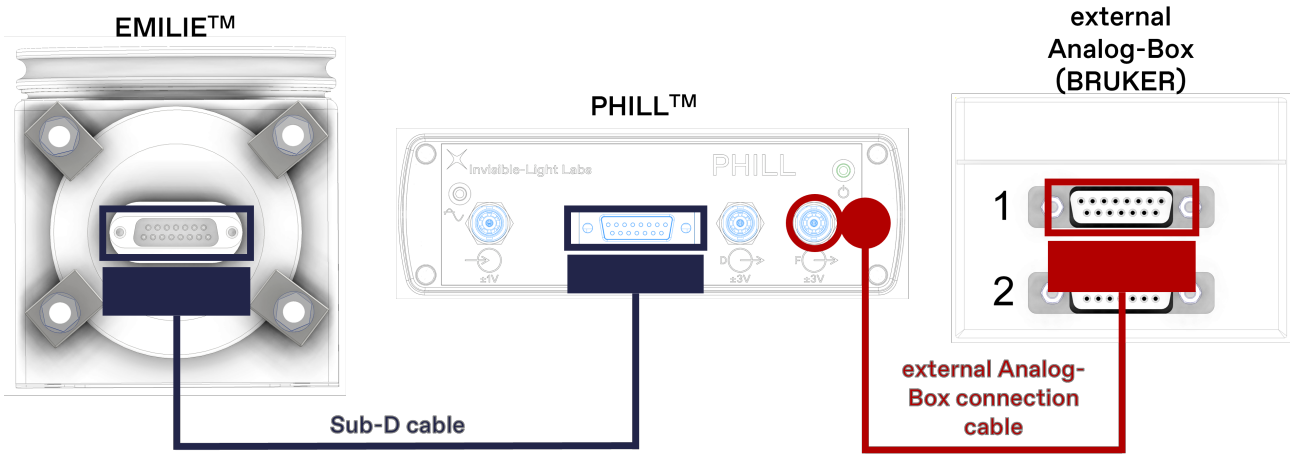


Figure 29: Electrical connection between EMILIE™, PHILL™, and the Bruker ASM external Analog-Box.

4.2.5 Setting up PHILL™

To perform a measurement, an EMILIE™ chip has to be driven at its resonant frequency. The frequency changes of the EMILIE™ chip are tracked and processed by PHILL™ for the FTIR spectrometer. The PHILLharmonics software for controlling PHILL™ consists of a server running in the background (visible in the taskbar) and a web client user interface (UI) accessible through the browser. This section deals with setting up PHILL™ for operation. The PHILLharmonics software is explained in more detail in Section 5.3. For detailed information on the connectors and electrical specifications of PHILL™, see Appendix 9.1.

Connecting PHILL™ to a PC:

1. Connect PHILL™ to the wall outlet using the provided power adapter. Insert the adapter's connector into the "Supply" port on PHILL™. Use the provided micro USB cable to connect PHILL™ to a PC via the micro USB 2.0 "port 1" (see Figure 30).

Figure 30: Back panel of PHILL™ highlighting the power switch, micro USB 2.0 port "1", and DC power supply port.

Alternatively, you can use an Ethernet port instead of USB. In that case, you need to set up a static IP address. In Windows, go to "Network & internet" → "Ethernet" and make sure you have the following settings:

IP assignment: Manual
IPv4 address: 192.168.1.12

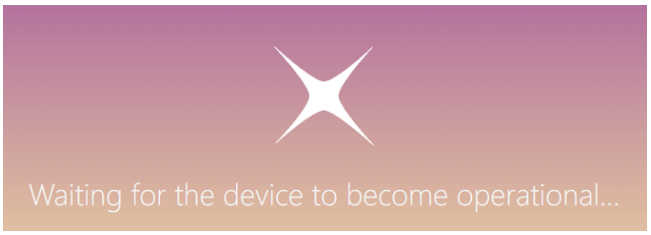


Figure 31: The PHILLharmonics loading screen

IPv4 mask: 255.255.255.0

2. Download and install the latest version of the PHILLharmonics software from invisible-light-labs.com/resources .

> ⓘ The password to download PHILLharmonics from invisible-light-labs.com/resources is ”ILLegends”.

3. Turn on PHILL™ using the switch on the back panel (see Figure 30).

4. Start the PHILLharmonics software. The default web browser automatically opens the UI. If the UI does not automatically open, manually navigate to at `http://localhost:8888/` via the address bar of the browser.

> ⓘ The recommended web browser for use with the PHILLharmonics software is ”Google Chrome”.

5. The loading screen pops up as shown in Figure 31 and will remain until device setup is ready. The setup process may take up to 1 minute each time PHILL™ is powered on.

> ⓘ When running the PHILLharmonics software for the first time, Windows may show a prompt asking for permission and to allow firewall access. Click ”Allow All”. Some PCs might also display a warning about trusting software from an unknown source. Confirm by selecting ”Run Anyway”.

6. Once setup is complete, the PHILLharmonics software interface appears, as shown in Figure 32.

> ⓘ When the UI is closed, the server keeps running in the background. To completely shut down the software, locate the PHILLharmonics icon in the taskbar, right-click, and select ”Quit.” In order for parameter changes to be saved, first close the UI before shutting down the server via the taskbar.

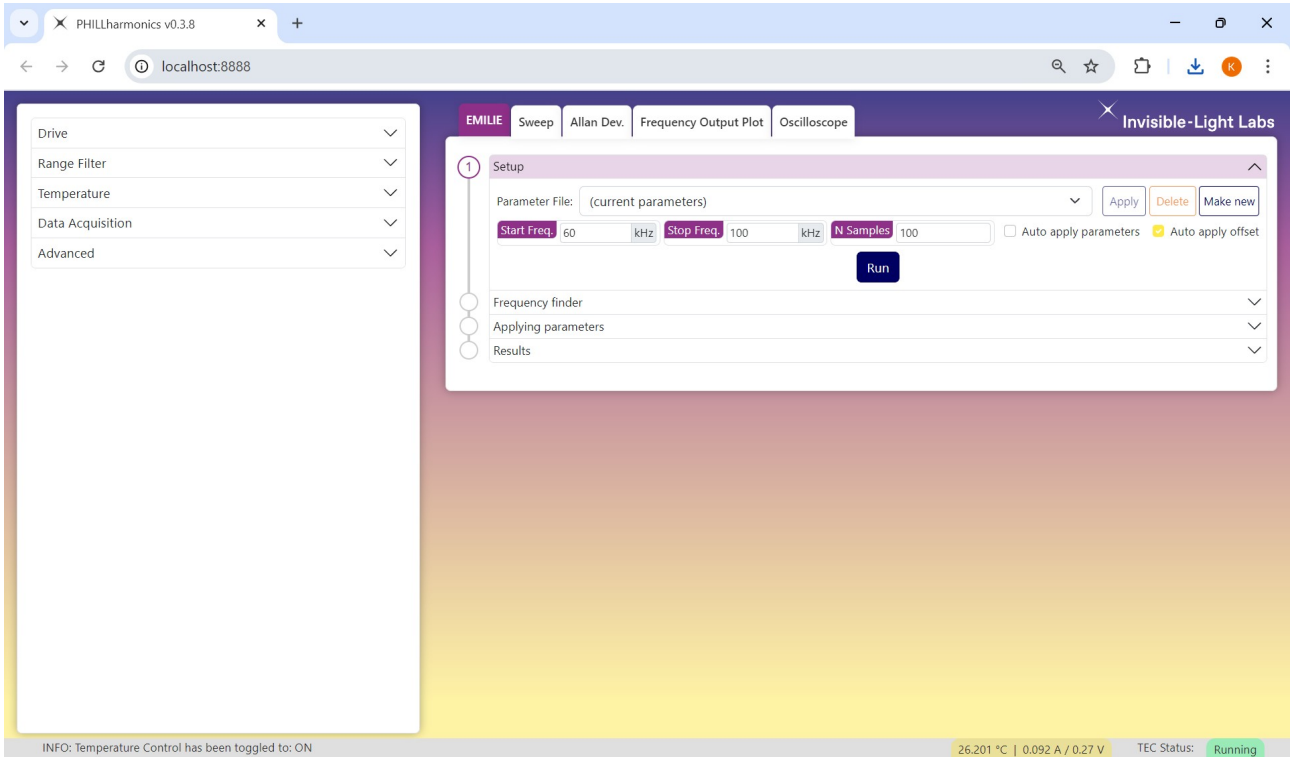


Figure 32: The PHILLharmonics user interface following successful connection

5 OPERATION

5.1 Vacuum chamber and contact bridge

The vacuum chamber (see Figure 33) hosts electronics and contact pads (1), a sample holder for the EMILIE™ chip (2), guiding rods for the contact bridge (3), and a connection test button (4). When the contact bridge is in place, pressing the connection test button tests if the EMILIE™ chip has been correctly connected and is intact. A green LED lights up if the test is positive. The sample holder is connected to a thermoelectric element (TEC) to enable temperature stabilization and control (for detailed operation of the TEC, see Section 5.3.4).

ⓘ Users are strongly encouraged to wear clean gloves and work in a dust-free environment when handling and placing EMILIE™ chips inside the EMILIE™ vacuum chamber to avoid contamination. To avoid contamination of the vacuum components, keep the lid closed at all times, even when no vacuum is applied.

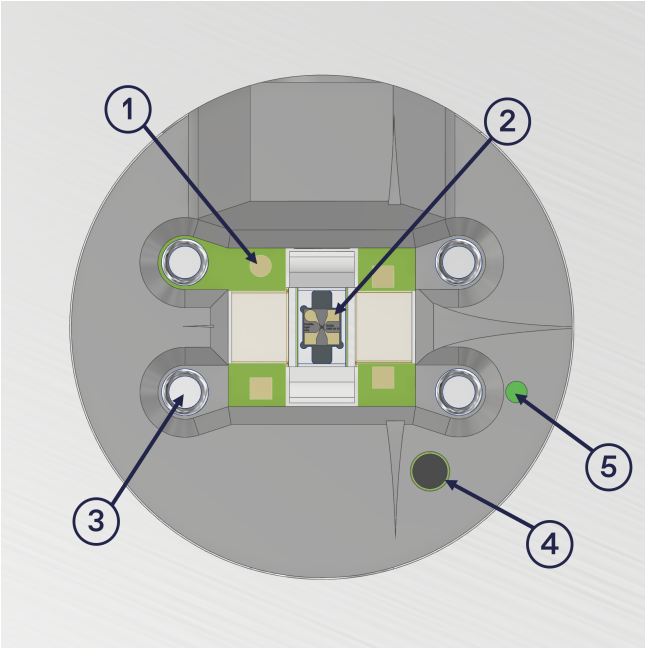


Figure 33: Internal components of EMILIE™: (1) Contact pads, (2) sample holder with EMILIE™ chip, (3) guiding rods for the contact bridge, (4) connection test button, and (5) connection test LED

1. Contact Pads: The contact pads establish the electrical connection of the EMILIE™ chip to the amplifier and readout electronics of PHILL™. The connection is established via the contact bridge (see Figure 34 for right placement.)

2. Chip holder: The chip holder located at the center of the vacuum chamber features an indentation to hold the EMILIE™ chip in place (see Figure 35). The chip holder surface is covered with an indium foil to provide optimal thermal conductance to the chip.

NOTICE

Danger of damage to indium foil

The pins of the contact bridge can puncture the thin indium foil on the surface of the sample holder. Damage to the indium foil can lead to temperature instabilities. To protect the indium foil, a chip must always be present inside the chamber before inserting the contact bridge. This protects the indium foil from direct contact with the pins of the contact bridge. Your EMILIE™ system is delivered with a dummy chip to protect the foil. Any used chip can be used as a dummy chip.

In case the indium foil is dislodged or damaged, use the replacement foil provided with your EMILIE™ system and follow the instructions, available in the maintenance Section 8.1 of this manual, on how to replace the foil.

AVIS

Risque d'endommager la feuille d'indium
Les broches de contact électrique du pont de contact peuvent perforer la fine feuille d'indium à la surface du porte-échantillon. Un endommagement de la feuille d'indium peut entraîner des instabilités thermiques.
Pour protéger la feuille d'indium, une puce doit toujours être présente dans la chambre avant l'insertion du pont. Cela protège la feuille d'indium du contact direct avec les broches du pont de contact. Votre système EMILIE™ est livré avec une puce factice pour protéger la feuille. Toute puce usagée peut servir de puce factice.
Si la feuille d'indium est délogée ou endommagée, utilisez une des feuilles de remplacement fournies avec votre système EMILIE™ et suivez les instructions de remplacement disponibles dans la section Maintenance de ce manuel.

3. Sliding rods: The sliding rods provide guidance for the easy and precise placement of the contact bridge in the measurement position. While exchanging EMILIE™ chips , the contact bridge should be placed in its parking position inside the lid as shown in Figure 34.

NOTICE

- The sliding rods can loosen over time, especially with frequent use. Fasten each rod one by one until hand-tight.
- Do not use excessive force, it could potentially damage the PCB underneath.

AVIS

- Les tiges coulissantes peuvent se desserrer avec le temps et une utilisation fréquente. Resserrez chaque tige à la main.
- Ne forcez pas trop, cela pourrait endommager le circuit imprimé situé en dessous.

4. Connection test button : Located near the contact bridge , when pushed, this button triggers visual feedback on the electrical connection between the EMILIE™ chip and the readout electronics. If the green light does not light up while the connection test button is pressed, the contact bridge might not be properly placed, or the EMILIE™ chip might be broken. Additional troubleshooting information can be found in Section 7.3.2.

5. Connection test LED: The connection test LED signals whether the chip is correctly connected and intact when the connection test button is pushed.

ⓘ The vacuum chamber lid should be placed on a stable and clean surface and should not be moved while the contact bridge is in its parking position on the inner surface of the lid.

The contact bridge connects the EMILIE™ chip to the preamplifier inside the vacuum chamber. It features two magnets and eight spring-loaded pins at the base. Four of these pins, positioned in the center, establish connections with the contact pads of the chip, while the remaining four

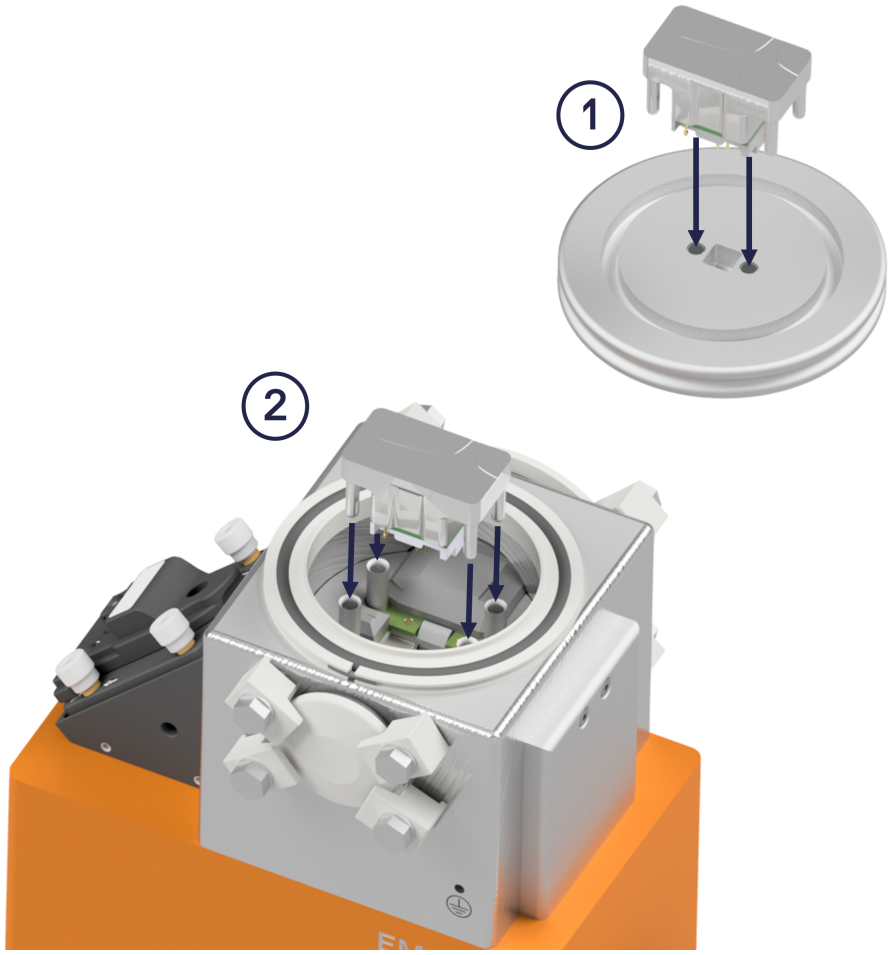


Figure 34: Illustration of appropriate placement of the contact bridge from (1) the parking position on the inner surface of the vacuum chamber lid to (2) the measurement position on the sample holder.

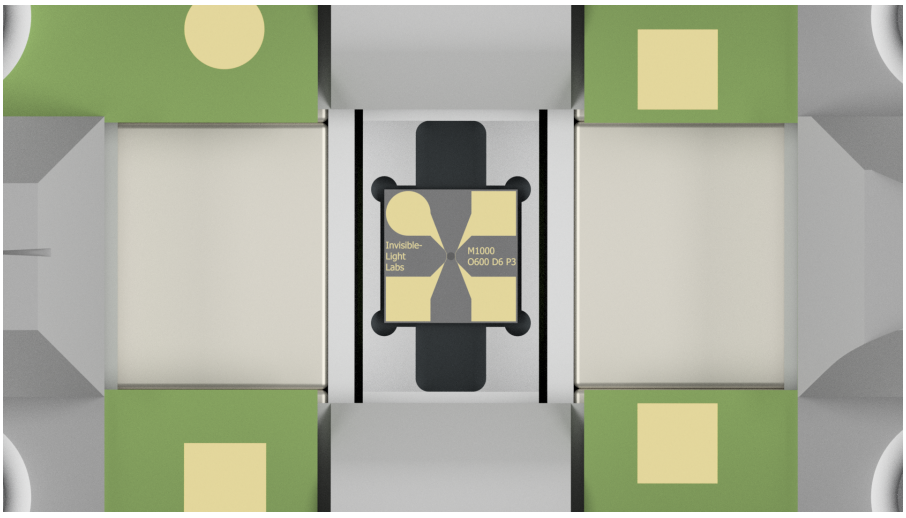


Figure 35: Correct placement of the EMILIE™ chip in the chip holder with the round gold electrode on the chip pointing towards the gold pad featured on the PCB.

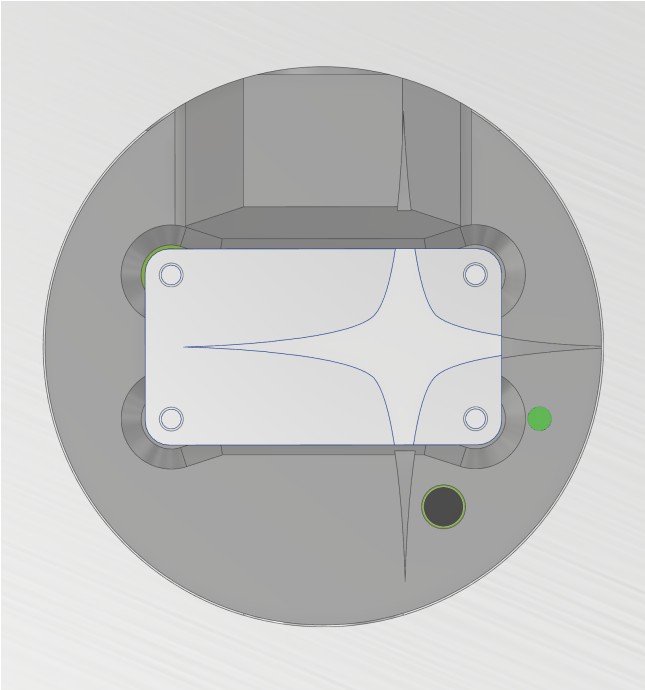


Figure 36: The engraved mark on the contact bridge aligns and forms a star with the internal cover of the vacuum chamber.

connect to the internal electronics. Figure 34 shows the appropriate placement of the contact bridge . The correct placement can be seen by the overlapping visual marks (see Figure 36).

CAUTION

Risk of puncturing the skin

The four spring-loaded pins of the contact bridge contacting the chip are pointy and sharp and could puncture your gloves or fingertips.

- Do not leave the contact bridge exposed in areas where it may be accidentally touched, struck, or leaned on.
- Exercise caution when handling the contact bridge.

ATTENTION

Risque de perforation de la peau

Les quatre broches à ressort du conducteur qui servent de contact avec la puce sont pointues et acérées. Elles pourraient perforer vos gants ou le bout de vos doigts.

- Ne laissez pas le pont de contact exposé dans des zones où il pourrait être accidentellement touché, heurté ou appuyé.
- Soyez prudent lorsque vous manipulez le pont de contact.

ⓘ If the bridge is in the wrong orientation, a slight repulsion force from the magnets inside the chamber can be felt when inserting the contact bridge . In this case rotate the contact bridge by 180 degrees.

5.2 Standard measurement procedure

This section details the necessary steps to acquire a NEMS-FTIR spectrum of an EMILIE™ chip . Before starting with the operation of the system, ensure that all the installation instructions from Section 4.2 have been followed.

5.2.1 Loading of an EMILIE™ chip

For replacing or loading a new EMILIE™ chip in the chip holder :

1. Switch off the vacuum pump system and wait until the automated venting procedure is finished (see Section 5.2.2).
2. Remove the lid of the EMILIE™ vacuum chamber and place it with the inside face pointing upwards on a stable and clean surface (place, for example, lint-free tissue or lint-free wipes on the surface before depositing the vacuum chamber lid).
3. Remove the contact bridge and place it in the parking position on the inner surface of the vacuum chamber lid (see Figure 34).
4. To remove a chip from the sample holder, grab it with tweezers on the top and bottom edges, where there is no labeling, and store the dummy chip in a clean container.

ⓘ For detailed instructions on proper chip handling to prevent damage or contamination, please refer to the Sample collection & handling guide.

5. Load the desired chip by placing it in the chip holder such that the round gold electrode pad on the chip aligns with the round gold pad featured on the PCB next to the sliding rods as displayed in Figure 35.
6. Place the contact bridge in position using the guidance rods until it is being pulled in by the magnets (see Figure 34). The star marking on top of the bridge aligns with the markings inside the chamber. If inserted incorrectly, the magnets repel the bridge, indicating that it needs to be rotated 180 degrees. Gently push the contact bridge from the top to ensure a good fit.
7. Press the connection test button near the contact bridge (see Figure 35) to verify that the electrical connection is established as indicated by the green light. If the LED does not light up when the connection test button is pressed, the contact bridge may not be properly placed, the EMILIE™ chip might be broken, or it may be placed in the wrong orientation. Remove the contact bridge, check for the integrity and correct orientation of the chip (see

Figure 35) and place the contact bridge back in the measurement position. Additional troubleshooting information can be found in Section 7.3.2.

8. For the analysis of potentially semi-volatile compounds, the chip holder can be cooled by the TEC before starting the pump and evacuating the chamber (see 5.3.4.

WARNING

Risk of burn injury on hot surfaces

EMILIE™ contains a Peltier element capable of regulating surface temperatures up to 80°C.

- Do not touch the chip or its holder with your fingers before, during, or after operation to prevent burn injuries.
- Use tweezers when handling the chip.
- Wear personal protective equipment if necessary.

WARNING

Risque de brûlure sur les surfaces chaudes

EMILIE™ contient un élément Peltier capable de réguler les températures de surface jusqu'à 80°C.

- Ne touchez pas la puce ou son support avec vos doigts avant, pendant ou après l'opération pour éviter les brûlures.
- Utilisez des pincettes de précision pour manipuler la puce.
- Portez si nécessaire des équipements de protection individuelle.

5.2.2 Operating the vacuum pump

After successfully loading the EMILIE™ chip to the chip holder inside EMILIE™ , the vacuum pump can be started. Ensure that the lid of EMILIE™ is placed securely. The start process described below only applies for the HiPace® 10 Neo pump. For different pumping systems, check the technical requirements in the attached datasheet and consult the manual of your specific device.

Powering up the pumping system:

1. Go to page "speed + vent" on the pump control and verify that the button "venting" is gray. If it is green, press it (see Figure 37).

2. Go to "View 0" of the pump control and press the upper "PumpgStatn" button labeled (1) in Figure 38 to start the membrane pump.

3. After >5 sec passed, press the lower "PumpgStatn" button labeled (2), which powers up the turbo pump. Watch the speed and the drive power displayed to the left on the display. At full speed, the pump should reach 1500 Hz, and the drive power should drop to <10 W after the max. speed has been reached, if not, please consult Section 7.10.

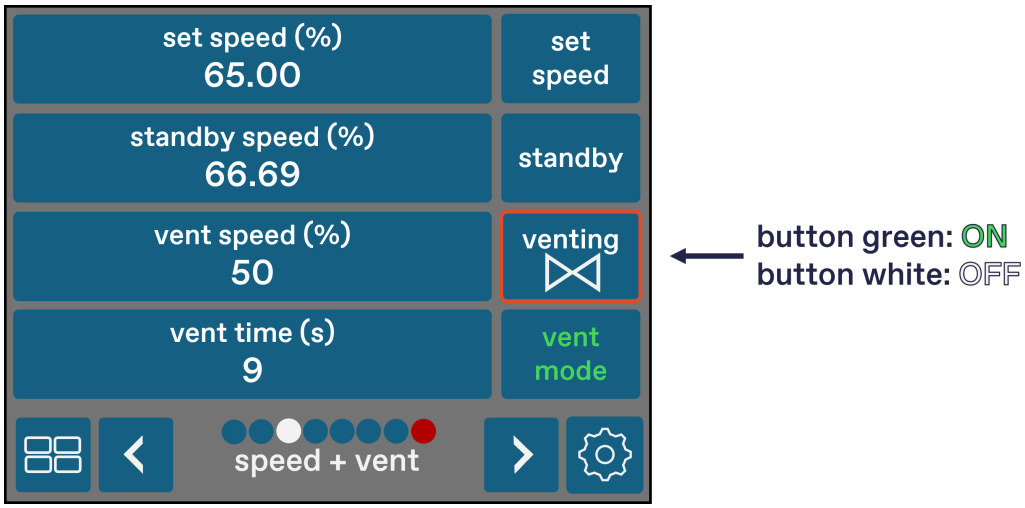


Figure 37: Check and disable "venting" of the pump on page 3 of the pump controller.

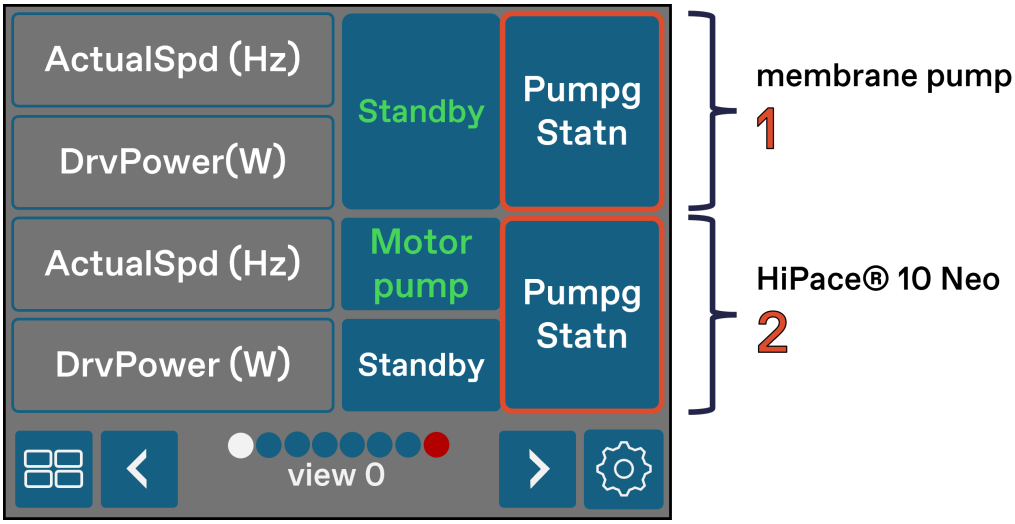


Figure 38: Pump control panel (Pfeiffer Vacuum GmbH) for enabling the membrane and turbo pump system.

NOTICE

Risk of reducing the lifetime of the pump Increased drive power (> 10 W) indicates a leak and will reduce the lifetime of the pump.

- The pump drive power must remain below 10 W at a speed of 1500 Hz.
- Consult Section 7 for further info on troubleshooting the system.

AVIS

Risque de réduction de la durée de vie de la pompe Une puissance d'entraînement accrue (> 10 W) indique une fuite et peut réduire la durée de vie de la pompe.

- La puissance d'entraînement de la pompe doit rester inférieure à 10 W à une vitesse de 1500 Hz.
- Consultez la section 7 pour plus d'informations sur le dépannage du système.

Venting the system:

To change or remove the chip, the chamber needs to be vented. The HiPace® 10 Neo package is equipped with an automatic venting valve, making it fast and easy to vent the system.

1. Stop the turbo pump by pressing the button marked (2) on ”View 0” in Figure 38, the button will turn from green to white.

2. Go to the screen ”speed + vent” on the pump control panel and press the button named ”venting”, it will turn from white to green.

3. Once the chamber is vented, the ”ActualSpd” on ”View 0” will show 0 Hz and the pump will be silent. The lid from the EMILIE™ vacuum chamber can now be removed.

WARNING

Risk of injury

- Do not attempt to remove the vacuum chamber lid during operation.
- Follow the instructions ”Venting the system” in Section 5.2.2 for venting the vacuum chamber prior to removing the lid.

ATTENTION

Risque de blessure

- N’essayez pas de retirer le couvercle de la chambre à vide pendant l’évacuation.
- Suivez les instructions «Purge du système» dans la section 5.2.2 pour purger la chambre à vide avant de retirer le couvercle.

5.2.3 Setting up measurement parameters in PHILLharmonics

ⓘ PHILLharmonics may stop or freeze when the PC it is connected to goes into power save mode or gets locked. If this happens, restart PHILLharmonics and, if necessary, restart PHILL™ .

Once PHILL™ is successfully connected to the PC as described in Section 4.2.5, it is necessary to configure the measurement parameters. This section is a brief step-by-step guide on how to find and apply the optimal measurement parameters in the PHILLharmonics software using the ”EMILIE tab”. For more details on the PHILLharmonics software, refer to Section 5.3.

Invisible-Light Labs GmbH provides dedicated presets for every EMILIE™ chip batch. The presets accommodate different measurement scenarios, taking into account the approximate mass load on the chip and planned measurement temperature. For example, ”(ILLabs) AL-W01-25C-10ng” represents a provided preset from Invisible-Light Labs GmbH for a chip from the batch ”AL-W01”, operating at 25 °C and for an approximate mass load of 10 ng.

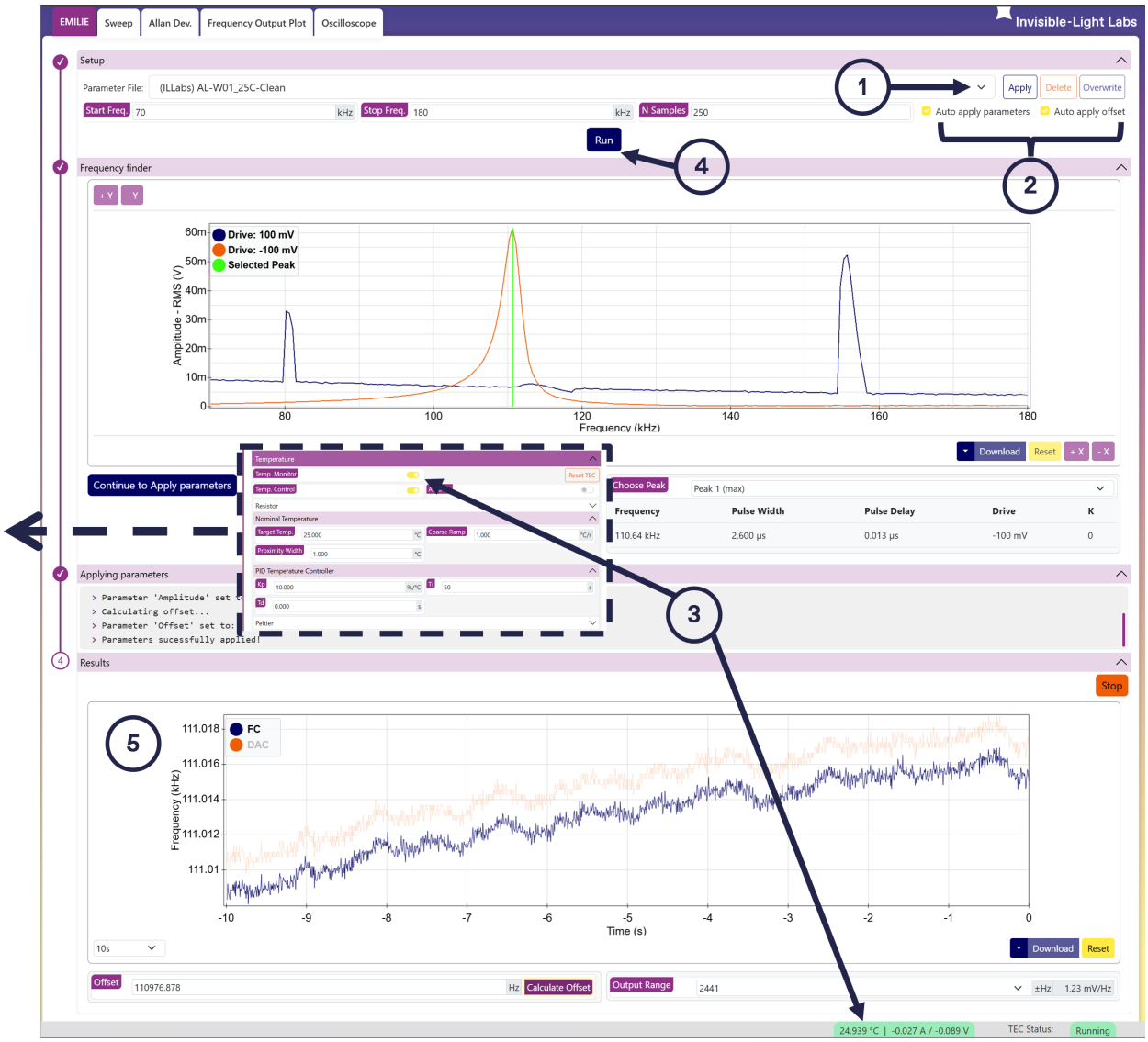


Figure 39: The ”EMILIE” tab in the PHILLharmonics UI with all steps expanded. When ”Auto apply parameters” is checked, all steps will automatically collapse upon completion for a clearer overview.

To find the optimal measurement parameters, use the following steps (see Figure 39):

1. Select the desired preset from the drop down menu in the setup step, identified by the chip batch name, operation temperature, and approximate loading, and click the ”Apply” button.

2. Ensure that ”Auto apply parameters” and ”Auto apply offset” checkboxes are checked.

3. After applying the preset, make sure the temperature control and temperature monitor are turned on in the left pane under ”Temperature” and that the target temperature corresponds to the preset file. The current chip temperature is shown in the monitor located at the bottom right corner of the UI. Wait until the target temperature is reached and the temperature field becomes green, indicating that the temperature is stable. For more details on temperature controller, refer to Section 5.3.4.

4. Click ”Run” to start the frequency finder. The software will sweep through the given frequency range and search for the resonance modes of the chip. If ”Auto apply parameters” is

selected, the software applies the optimal parameters and locks on the mode with the highest amplitude automatically. If you want to choose the resonance peak manually, refer to Section 5.3.

5. After selecting and applying the parameters, the ”Results” step will appear and display a graph with the locked frequency (FC) and converted output voltage (DAC) of the EMILIE™ chip .

> ⓘ Locking a resonance frequency: The meaning of ”locking” a frequency is that PHILL™ tracks the changes of the specific resonance frequency that was selected in the ”Frequency finder” step. Once the parameters there are applied, changes to this frequency are shown in the ”Results” step. If changes to this original resonance frequency due to temperature, pressure or light intensity are too large to follow, the frequency shown in the ”Results” step will no longer match the selected frequency in the ”Frequency finder”. In this case, PHILL™ is no longer tracking the intended frequency, so start the process of the ”EMILIE” tab from the beginning.

6. The RMS (Root Mean Square) value shown below the graph indicates the amplitude of the input signal. A green indicator (100–500 mV) signifies an optimal signal range, and frequency tracking is considered sufficient for starting the measurement (see Figure 41). If the RMS value falls below 100 mV, the input signal is too weak, and the indicator turns orange. In this case, increase the drive amplitude until the RMS exceeds 100 mV and the indicator turns green. If the RMS value exceeds 500 mV, the input signal is too strong, and the indicator turns red (see Figure 40). Reduce the drive amplitude until the RMS falls below 500 mV and the indicator returns to green.

7. If the input signal exceeds the threshold of PHILL™ , an “Input overflow” warning appears above the plot, and the red LED on the front panel of PHILL™ illuminates. To resolve this, lower the drive amplitude using the control in the left pane of the UI until the LED turns off.

8. If ”Output Overrange” warning appears above the frequency plot (Figure 40), increase the ”Output Range” in the drop-down menu located below the ”Results” graph, and press ”Calculate Offset”.

9. If no warnings are present, PHILL™ has locked onto the resonance frequency of the chip and you can continue to the next measurement step. Figure 41 shows the ”Results” step in the case where everything is properly set and no warnings are present.

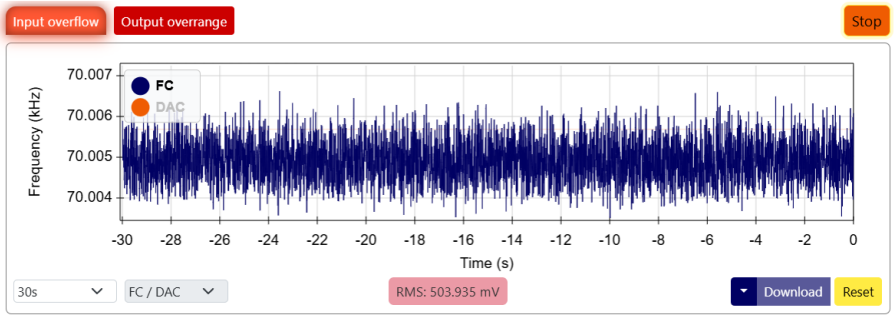


Figure 40: Screenshot of the ”Results” step with ”Input overflow” and ”Output Overrange” warnings triggered

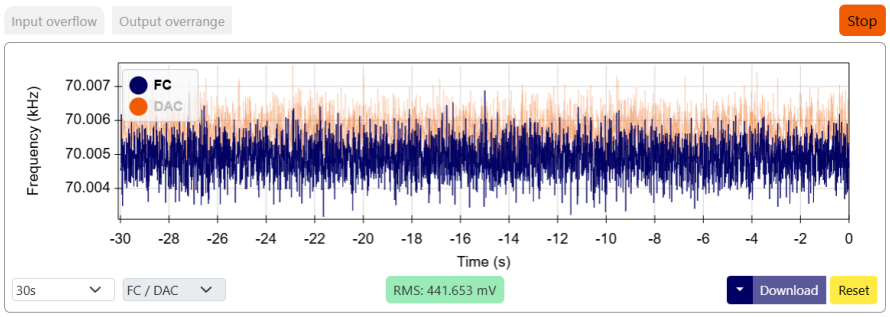


Figure 41: Screenshot of the ”Results” step with no warnings

A low-frequency output range (below ± 1220 Hz) can result in clipping of the analog output, indicated by the ”Output Overrange” warning. In case the warning appears during the measurement, the measurement is compromised and has to be restarted. Increase the ”Output Range”, press ”Calculate Offset”, and start the measurement again.

To monitor the analog output signal going to the FTIR, click on the ”DAC” label in the graph legend in the ”Results” step. The ”FC” label represents the measured resonance frequency in kHz (see Figure 40, 41), while the ”DAC” graph represents the converted signal in Volts.

5.2.4 OPUS configurations for NEMS-FTIR measurements

EMILIE™ and PHILL™ are now ready for operation with the spectrometer. The final step is to perform the measurement via the Bruker OPUS software. This guide is based on OPUS 8.7 and outlines the necessary configuration steps for optimal performance.

Due to the long thermal response time of $\tau = 25$ ms of the EMILIE™ chip , EMILIE™ is only compatible with the step scan acquisition mode. To configure and perform a measurement, follow these steps:

- Open the OPUS software and confirm that the FTIR system is functioning correctly, as indicated by the green light in the bottom-right corner of the interface.

Table 8: Recommended operation settings for EMILIE™ with a Bruker spectrometer.

Basic FTIR operation settings	
Acquisition mode	Step Scan
Stabilization delay	25 ms
Coadditions	> 10
Presetting file	”EMILIE-Standard-StepScan-Res4cm-5MIN-SQ.XPM” (online)

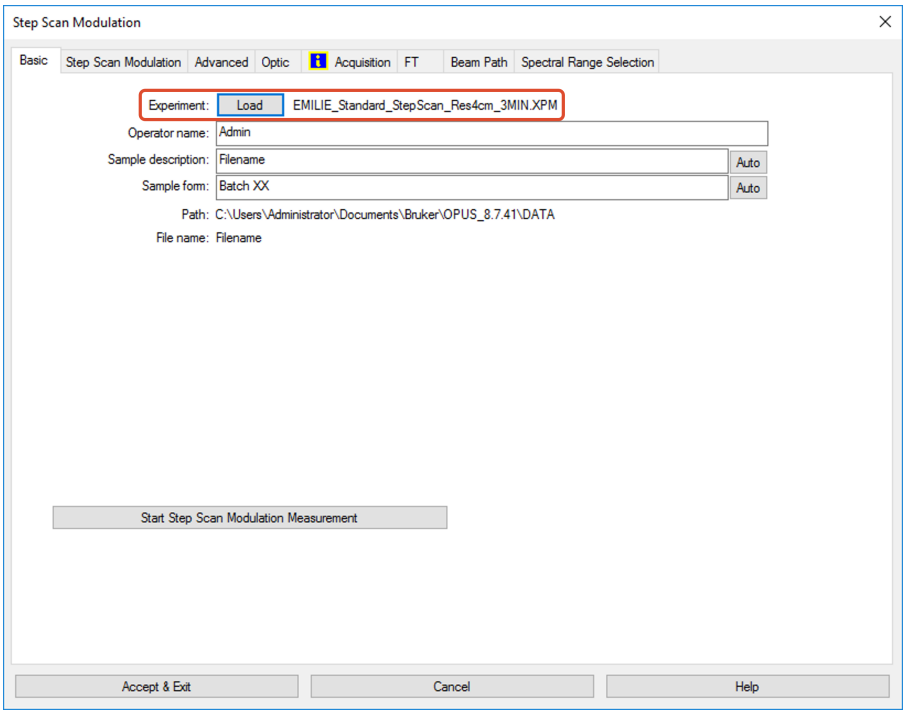


Figure 42: OPUS Step Scan Modulation window. Experiments (Settings) can be loaded with the button ”Load”.

- For launching a measurement, use the basic operation settings in Table 8.
- Open the settings for ”Step Scan” in the ”Measure” tab, by clicking on the Icon with the small green foot.  .
- To expedite a rapid analysis, move to the ”Advanced” tab and load one of the ”EMILIE-Standard-StepScan-Res4cm-5MIN-SQ.XPM” settings files provided online at invisible-light-labs.com/resources. The settings files indicate the wavenumber resolution, approximate measurement time, and quality of the spectrum (LQ/SQ/HQ = Low/Standard/High Quality). Note that the ”FILTER” settings can only be applied when the appropriate optical filter ”F321-LWP” is installed, and the spectral range is limited to below $4000\,\mathrm{cm}^{-1}$.
- The default step scan for EMILIE™ is set to a spectral range of $4000\,\mathrm{cm}^{-1}$ to $400\,\mathrm{cm}^{-1}$ with a spectral resolution of $4\,\mathrm{cm}^{-1}$, a stabilization delay of $30\,\mathrm{ms}$ for each step (matching the average thermal response time of the chip) and > 10 coadditions (optimized for Bruker Vertex70). Ensure in the ”Optics” tab, as displayed in Figure 43, that under ”Detector setting” the external input is selected (typically ”Classic Style Ch1”), and the ”Sample signal gain” is set to ”X1”. With these settings, a regular step scan with EMILIE™ takes about 5 minutes. In-

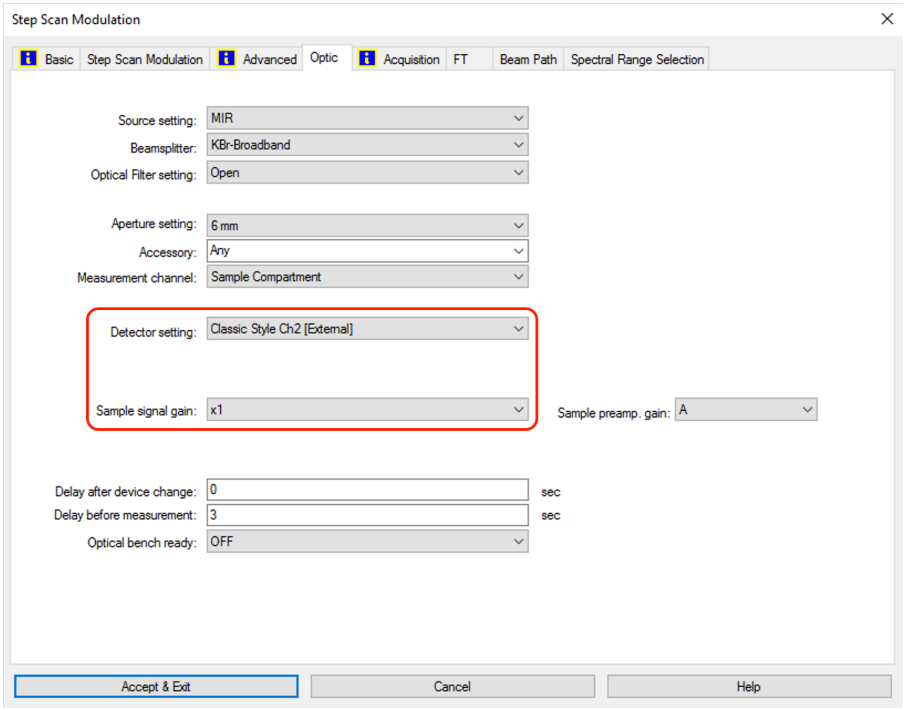


Figure 43: OPUS Step Scan Modulation window. The ”Detector setting” changes the channel for the input of the FTIR. To avoid malfunction or an error in OPUS, the ”Sample signal gain” needs to be set to X1.

creasing the spectral resolution, stabilization delay, or number of coadditions increases the acquisition time. To take full advantage of the sensitivity, a stabilization delay of at least 25 milliseconds is recommended.

- To ensure the correct signal input channel for EMILIE™, move to the ”Optics” tab and select the proper external input channel in the ”Detector setting” dropdown menu. This corresponds to the channel that PHILL™ is connected to on the external Analog-Box (see Figure 29).

- The ”Advanced” tab allows specification of the measurement name, spectral resolution, and range.

- Once configuration is complete, start the step scan spectrum acquisition by switching to the ”Basic” tab and pressing ”Start Step Scan Modulation Measurement”.

- After the step scan is completed, ensure that the analog output of PHILL™ does not indicate an ”Output Overrange” flag (see Figure 40. If the ”Output Overrange” flag was triggered, increase the ”Output Range” in the text box below the results step, click the ”Calculate Offset” button, and then restart the step scan. For more information, refer to the previous Section 5.2.3.

Figure 44: Illustration of the adjustment screws on the side of the kinetic mirror mount that align the optical focus to the center of the EMILIE™ nanoelectromechanical sampling and sensing chip .

Depending on the settings of the FTIR before starting a measurement, the IR beam is not initially set to the sample compartment, but rather to another port or a different aperture. This is automatically adjusted when starting a step scan using the EMILIE™ settings as described above. Any changes in the light path or the light intensity by selecting a different aperture leads to a change in the resonance frequency. Therefore, it is necessary to re-adjust the resonance frequency in the PHILL™ software by pressing ”Run” in the EMILIE tab.

For a detailed explanation of all system parameters and configurations for the spectra acquisition, consult the OPUS software manual through the OPUS menu ”Help”.

5.2.5 Optical alignment procedure

The optical path is aligned with the center of the chip during installation. However, due to slight variations when placing the chip in the vacuum chamber, the center of the chip might shift slightly from measurement to measurement. To compensate for this, the focus can be adjusted via the kinetic mirror, mounted to the side of EMILIE™ (see Figure 44). To realign the focus, follow these steps:

- Load an EMILIE™ chip in the vacuum chamber following the steps outlined in Section 5.2.1.
- Find and adjust the resonance frequency of the chip following the steps outlined in Section 4.2.5.

- Monitor the frequency output in the ”Results” step of the EMILIE tab.
- Begin by gently turning the bottom-right knob of the kinetic mirror mount (see Figure 44) clockwise and counterclockwise. While doing so, monitor the frequency on the PHILLharmonics software’s frequency plot. Continue adjusting the knob until the resonance frequency reaches a minimum value; a better focus corresponds to a lower resonance frequency.
- After finding the optimal position of the bottom-right knob, gently move first the top right and then the top left knob of the kinetic mirror mount following the same procedure.
- Once the optimal position, corresponding to the lowest possible frequency, has been found - repeat the entire procedure with slight adjustments, starting again from the bottom right knob to verify that the focus is properly set.

ⓘ If the beam was far out of focus, the PHILLharmonics software may lose the tracking of the frequency during optical alignment due to the large frequency change. In that case, re-run the EMILIE tab as described in Section 5.2.3.

5.2.6 Far infrared measurements

The EMILIE™ infrared analyzer is equipped with a diamond window to provide an optimal measurement window over the entire visible-to-far infrared spectrum. The transmittance of the built-in diamond window over the entire near-IR to FIR range is shown in Figure 45.

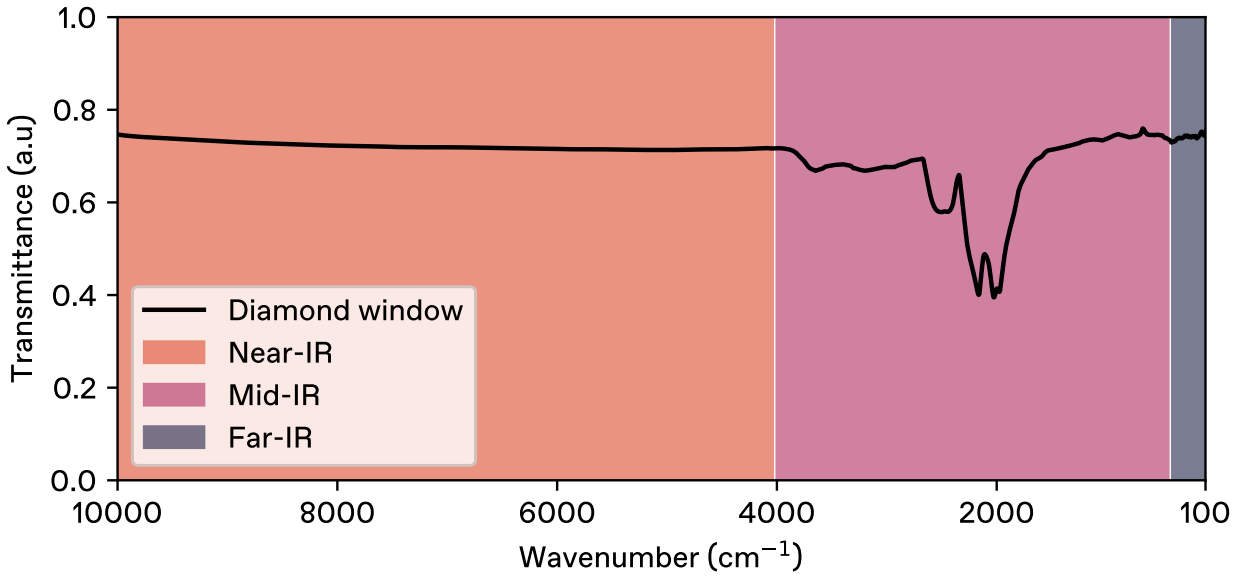


Figure 45: Transmittance of EMILIE™ ’s built-in wedged diamond window providing high throughput from the near-IR to FIR spectral region.

The measurement range of EMILIE™ is limited by the optical elements of the spectrometer system, such as the beamsplitter and the light source available. In order to perform measurements in the FIR, ensure that:

- An FIR-appropriate FTIR beamsplitter is installed in the FTIR device. To exchange the beam splitter in your spectrometer, follow the instructions given by the FTIR manufacturer.
- When using a Bruker FTIR spectrometer, the dedicated OPUS setting file for FIR measurements is used. It can be found online at invisible-light-labs.com/resources .
- The optical alignment must be adjusted after exchanging the beam splitter, as described in Section 5.2.5.

When operating EMILIE™ with a Bruker spectrometer, ensure OPUS is set to the continuous acquisition mode before exchanging the beam splitter. This can be achieved by opening the default measurement tab (”Advanced Data Collection”), loading a default measurement setting and recording a spectrum.

5.2.7 Acquisition of a background spectrum

The background spectrum is recorded in the absence of analyte using an EMILIE™ LIGHT chip (see Section 3.7). Compared to a sampled or blank EMILIE™ chip , the EMILIE™ LIGHT chip has a linear and strong response to the entire infrared spectrum and is recommended to be measured with the dedicated pre-settings. The following steps are required to obtain a background spectrum:

1. Load an EMILIE™ LIGHT chip into the sample compartment of EMILIE™ following the steps in Section 5.2.1, and start the vacuum pump.
2. Configure the spectrometer by loading the pre-setting ”EMILIE-LIGHT-Background-StepScan-Res4cm-Fullrange.XPM” in OPUS and press ”Start a Step Scan” to apply the parameters. Abort the running step scan once the parameters are set.
3. Configure PHILL™ by loading the pre-settings ”ILLabs-LIGHT-L-Pt-XXXXX” in PHILLharmonics and press ”Apply”. The number ”XXXXX” in the pre-setting should match the batch number written on the slip of the EMILIE™ LIGHT chip bag.
4. Once the frequency of the EMILIE™ LIGHT chip is successfully tracked, check the optical alignment of EMILIE™ (see Section 5.2.5 for more details).
5. Acquire the spectrum by pressing ”Start a Step Scan” in OPUS. Figure 46 shows a NEMS-FTIR background spectrum of a Bruker Vertex 70 globar with a KBr Broadband beamsplitter.

Note: The output range of PHILLharmonics software might be insufficient to cover the large frequency changes of the EMILIE™ LIGHT chip , causing a warning ”Output Overrange”. This can be solved by reducing the size of the aperture in the optics settings of the spectrometer.

5.2.8 Data processing steps & OPUS Macro

The following data processing steps are required to obtain a blank-corrected NEMS-FTIR sample spectrum in absorption units. For Bruker FTIR users, these steps can be performed automatically using the dedicated OPUS macro ”EMILIE-Dataprocessing-Macro-V4.mtx”, available for down-

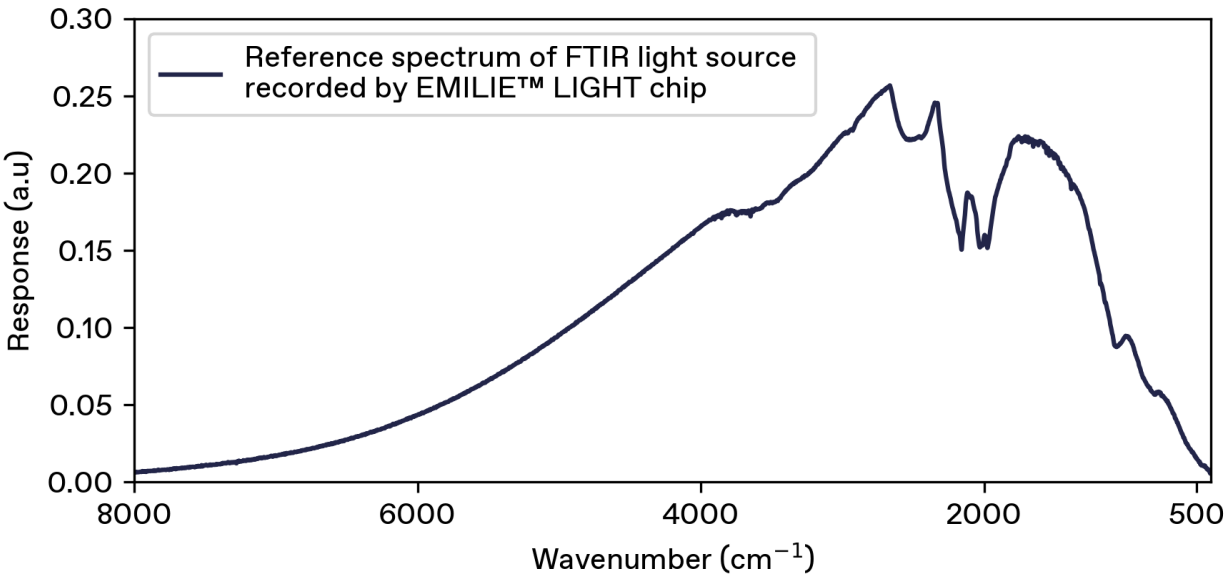


Figure 46: Example of a NEMS-FTIR background spectrum recorded with an EMILIE™ LIGHT chip in a Vertex 70 using a KBr Broadband beamsplitter.

load at invisible-light-labs.com/resources . A demonstration of the macro's application is provided at the end of this section.

Overview of data processing steps:

1. Record a background NEMS-FTIR spectrum of the light source with an EMILIE™ LIGHT chip .
2. Record a NEMS-FTIR spectrum of the sampled chip & divide it by the background spectrum recorded with the EMILIE™ LIGHT chip from step 1 to obtain the sample spectrum.
3. Record a NEMS-FTIR spectrum of a blank chip & divide it by the background spectrum recorded with the EMILIE™ LIGHT chip from step 1 to obtain the blank spectrum.
4. Normalize the sample spectrum from step 2 to the EMILIE™ chip 's silicon nitride peak at 835 cm^{-1} to obtain the normalized sample spectrum.
5. Normalize the blank spectrum from step 3 to the EMILIE™ chip 's silicon nitride peak at 835 cm^{-1} to obtain the normalized blank spectrum.
6. Subtract the normalized blank spectrum (step 5) from the normalized sample spectrum (step 4) to obtain the final, blank-corrected, NEMS-FTIR spectrum of the sample.

The following section provides a detailed description of the suggested data processing workflow. It outlines the steps from the raw signal to the final absorbance spectrum of the sample, using an EMILIE™ VALIDATION chip loaded with 10 ng of polystyrene as an example.

1. Record a background NEMS-FTIR spectrum of the light source with an EMILIE™ LIGHT chip .
   The background spectrum is recorded in the absence of analyte using an EMILIE™ LIGHT chip and can be obtained by following the instructions in Section 5.2.7. Figure 46 shows a NEMS-FTIR background spectrum of a Bruker Vertex 70 globar with a KBr Broadband beamsplitter.

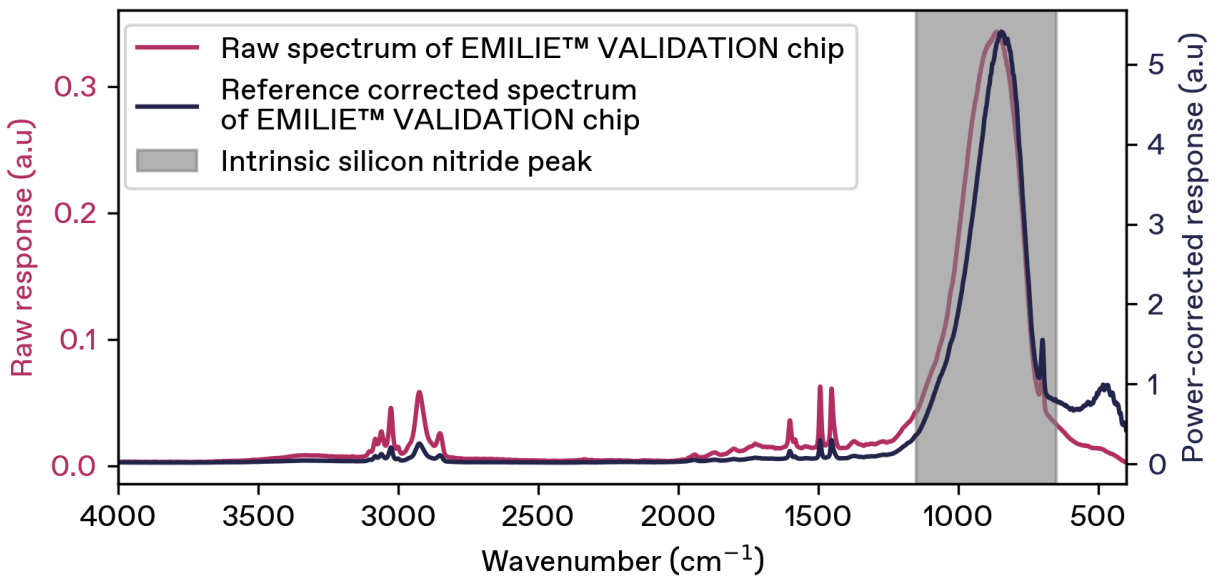


Figure 47: Example of a NEMS-FTIR spectrum of an EMILIE™ VALIDATION chip before and after correction with the background spectrum. The gray region highlights the silicon nitride peak of the EMILIE™ chip, which is used as an internal standard for normalization.

2. Recording a NEMS-FTIR spectrum of the sample.
   The sample spectrum is recorded with an EMILIE™ chip on which the analyte of interest was deposited using one of the methods described in the Sample collection & handling guide. Figure 47 shows as an example the NEMS-FTIR spectrum of an EMILIE™ VALIDATION chip before, and after, dividing by the background spectrum recorded it step 1.

3. Recording the NEMS-FTIR spectrum of a blank.
   A blank spectrum can be recorded to remove spectral interferences from concomitant species. The blank chip should be sampled with everything in the sample (for example the sample solvent) except for the analyte.

4. Signal normalization.
   To account for different output ranges in PHILLharmonics (see Section 5.3.7), we recommend using the silicon nitride peak of the EMILIE™ chip material as an internal standard for normalization of the spectral data. This broad vibrational mode is typically situated between 1000 cm^{-1} and 700 cm^{-1} with a maximum at 835 cm^{-1}. It is highlighted in grey in Figure 48.

5. Blank correction.
   After background correction and normalization, the NEMS-FTIR spectrum of the blank can be subtracted from the NEMS-FTIR spectrum of the sample to obtain the final blank corrected sample spectrum. Figure 50 shows the post-processed NEMS-FTIR spectrum of an EMILIE™ VALIDATION chip after subtraction of a blank spectrum.

6. Conversion to absorbance units.
   The NEMS-FTIR response can be converted into absorbance A using a correction factor related intrinsic absorptance of the silicon nitride, the illumination and sample distribution on the membrane. For the usual case of full illumination of the membrane (using an aperture of

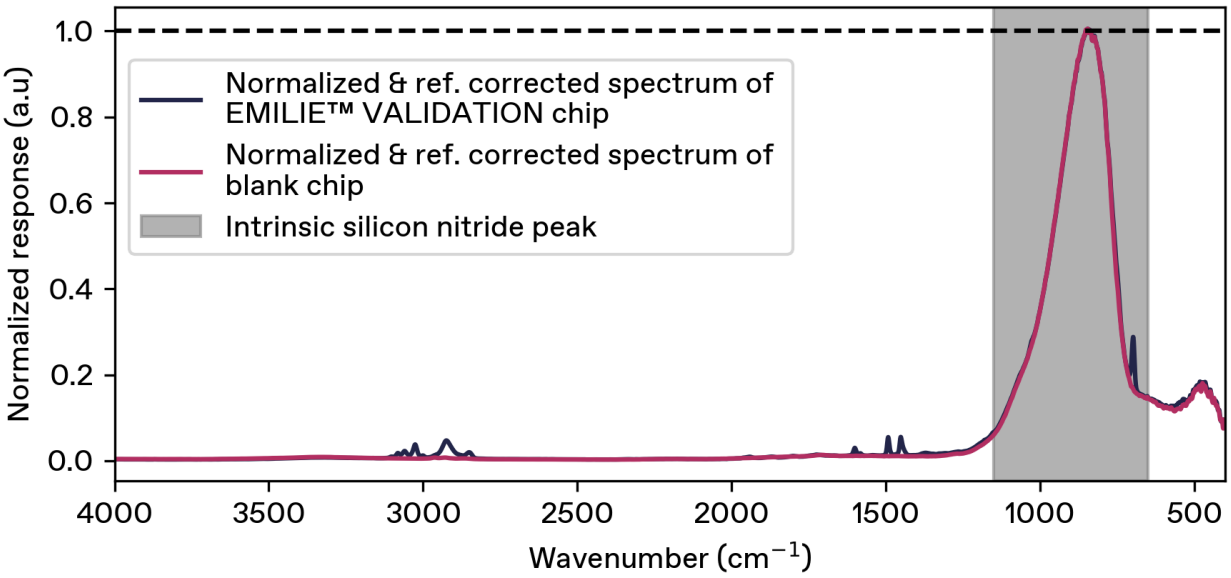


Figure 48: NEMS-FTIR response of a sampled chip and blank chip after correction with the background spectrum and normalization to the intrinsic silicon nitride absorption feature.

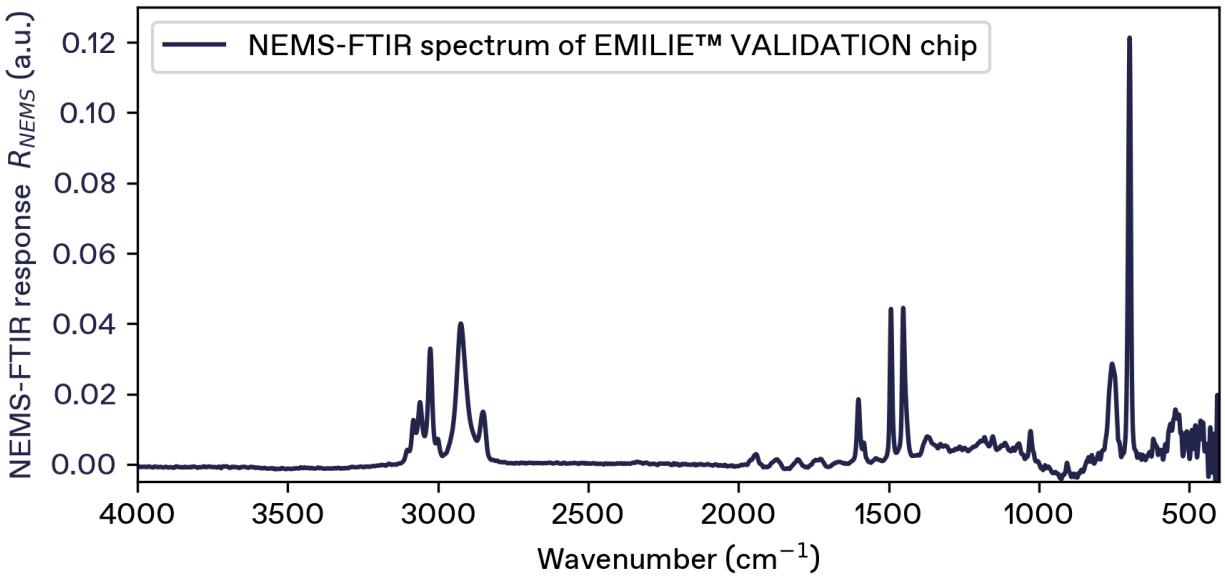


Figure 49: NEMS-FTIR spectrum of the EMILIE™ VALIDATION chip after background correction, normalization and subtraction of the blank chip spectrum.

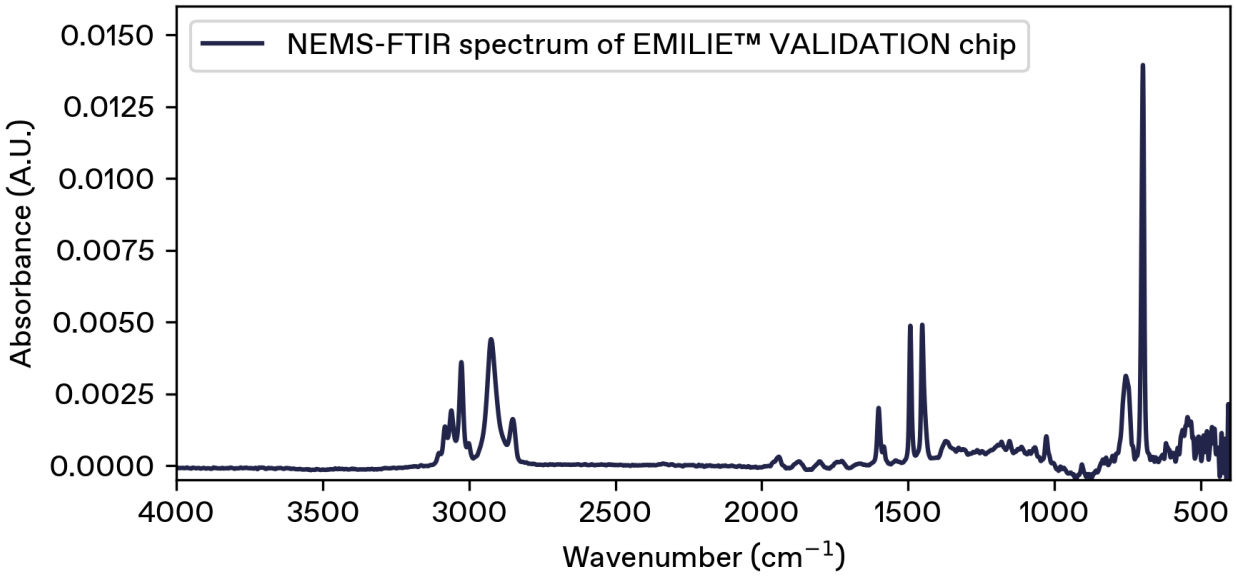


Figure 50: Final processed NEMS-FTIR spectrum converted to absorbance A. The example shows the spectrum of an EMILIE™ VALIDATION chip sampled with 10 ng polystyrene beads.

6 mm or more), and full distribution of the analyte over the perforated area, the default scaling factor is $a_{EMILIE} = 0.695$. The absorbance A of the normalized NEMS-FTIR response R_{NEMS} is obtained by scaling the spectrum and applying Beer Lambert's law: $A = -log_{10}(1 - R_{NEMS} \cdot aEMILIE)$. More information on the theory behind the data processing and scaling factor can be found in the "data processing guide for NEMS-FTIR spectroscopy", available for download at invisible-light-labs.com/resources .

For Bruker FTIR users, all post-processing steps described above can be performed in OPUS directly using the spectra calculator tool. To facilitate the data processing steps, one can use the dedicated OPUS macro "EMILIE-Dataprocessing-Macro-V4.mtx" (see Figure 51), available for download at invisible-light-labs.com/resources . The steps to process the recorded spectra with the macro are the following:

1. Run the Macro
2. Drag & drop the raw spectra to their corresponding box: background, blank and sample spectrum.
3. If needed, adjust the EMILIE default factor
4. Apply the macro by pressing "Continue"
5. Once the macro is applied, the background corrected and balnk subtracted spectrum is automatically added and safed in the same file location as the sample spectrum with an additional suffix "processsed". Further, the processed data are exported to the same file location as .csv file.

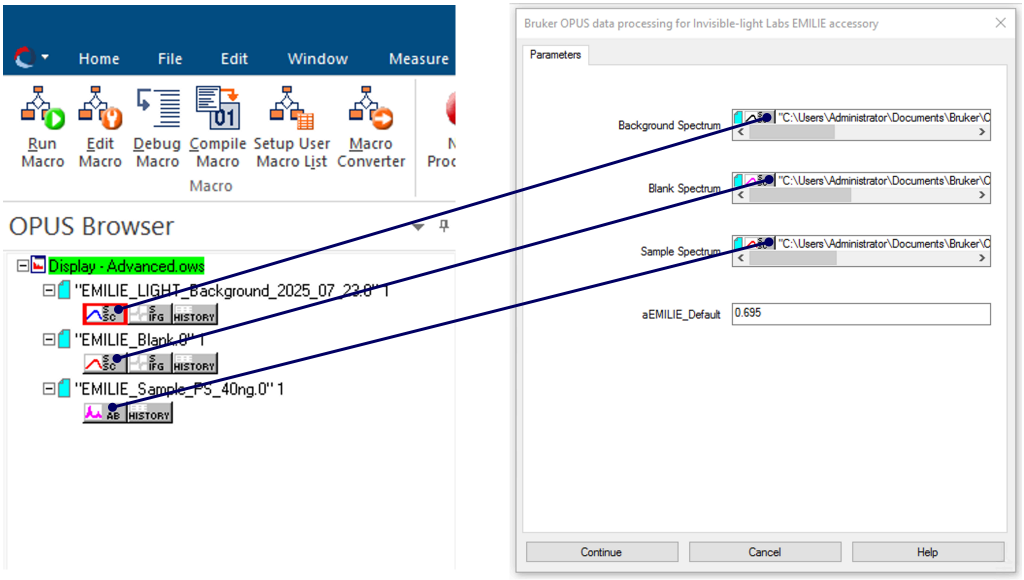


Figure 51: Application of the OPUS macro ”EMILIE-Dataprocessing-Macro-V4.mtx” for data processing of NEMS-FTIR spectra featuring background correction, blank subtraction and conversion to absorption units.

5.3 PHILLharmonics software

The PHILLharmonics software is used to control and monitor the measurement parameters of PHILL™ and EMILIE™. It provides many user-friendly automatic functions in the EMILIE™ tab which cover the most frequent use cases. The left side of the UI contains several settings widgets that can be expanded/collapsed as well as reordered (drag and drop). They provide advanced functionality for manual fine-tuning of the parameters and advanced monitoring functions for better diagnostics and troubleshooting. This section will cover most useful components of the software. To install the software and connect to PHILL™, refer to Section 4.2.5. For a quick start guide, refer to Section 5.2.3.

5.3.1 EMILIE tab

The EMILIE tab provides all the most important features for automatically finding and monitoring the resonance frequency of an EMILIE™ chip (see Figure 52). The process is streamlined into four steps:

1. Setup - allows for the selection of a preset file and other process parameters.
2. Frequency finder - sweeps the given frequency range for the resonance frequency of the chip.
3. Applying parameters - applies and displays the parameters for the chosen resonance peak.
4. Results - plots the resonance frequency in real time and allows for the frequency monitoring during the FTIR measurement.

The PHILLharmonics software comes with default preset files for different chip batches and different measurement scenarios. The presets can not be altered or deleted from the preset list and accommodate different measurement scenarios, taking into account the approximate mass load on the chip and planned measurement temperature. For example, ”(ILLabs) AL-W01-25C-10ng”

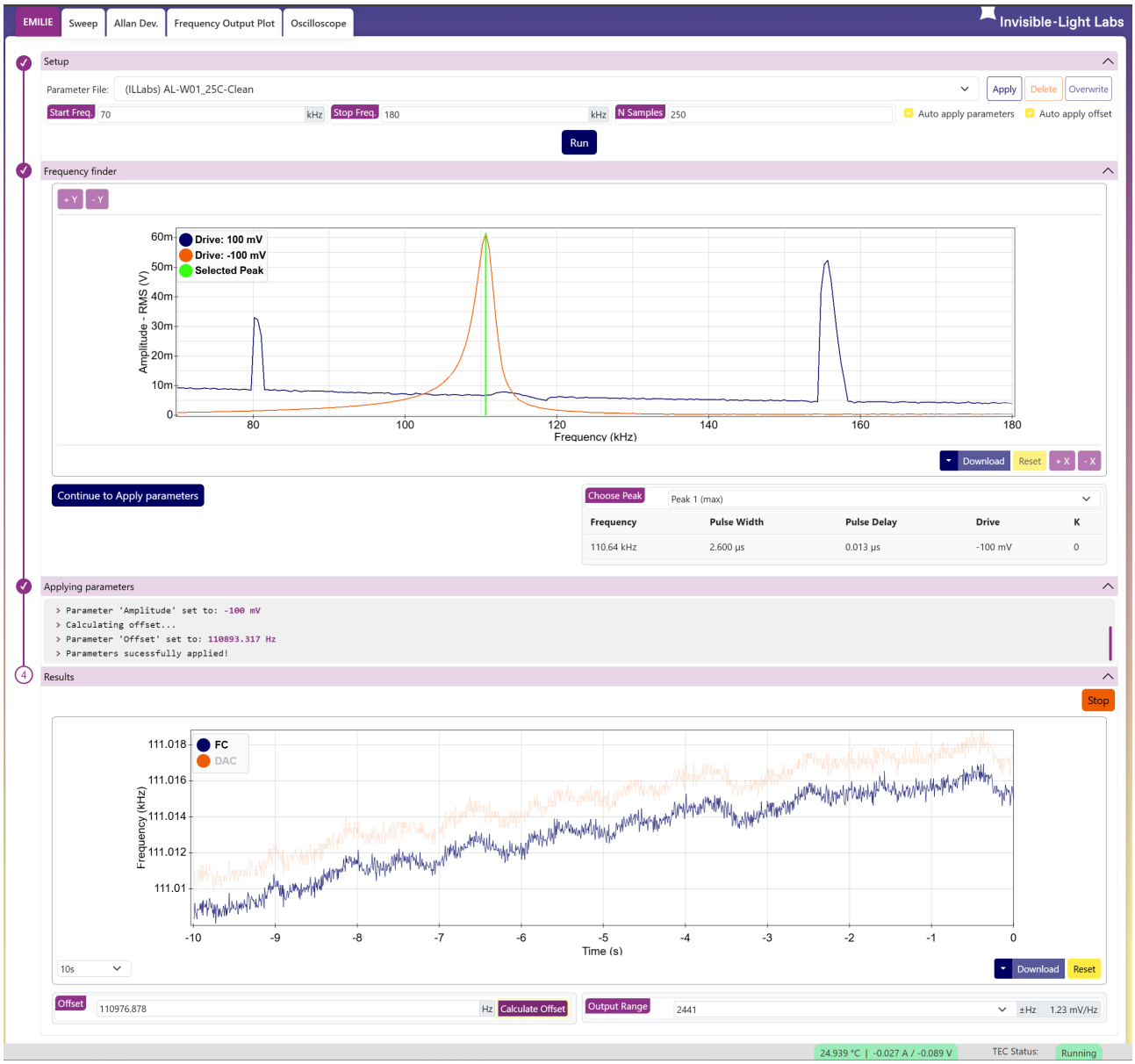


Figure 52: The EMILIE™ tab in the PHILLharmonics UI with all steps expanded.

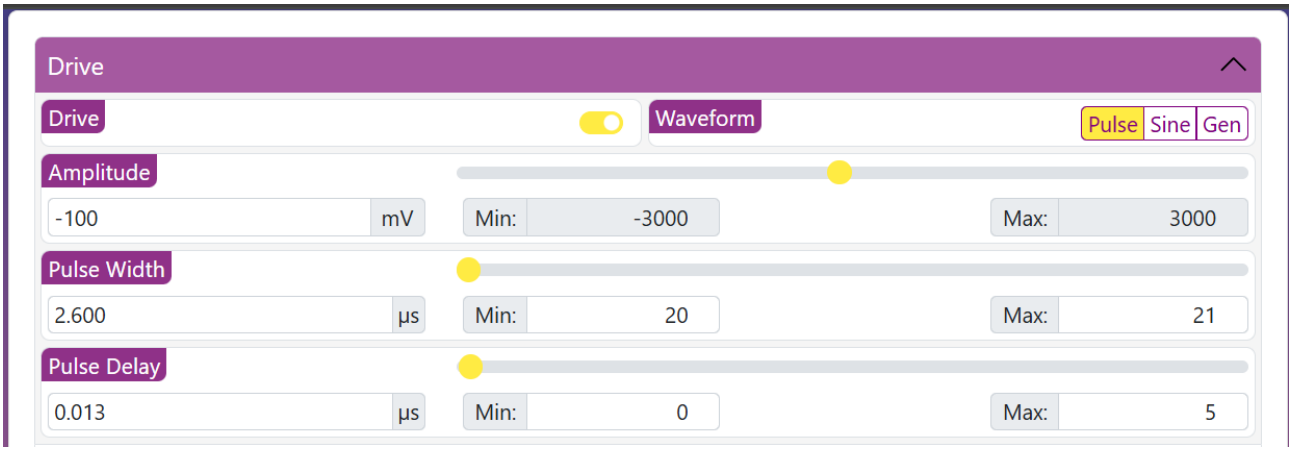


Figure 53: Drive settings in the PHILLharmonics software.

represents a provided preset from Invisible-Light Labs GmbH for a chip from the batch ”AL-W01”, operating at $25\,^{\circ}\mathrm{C}$ and for an approximate mass load of $10\,\mathrm{ng}$. The user can create their own preset file by selecting ”(current parameters)” from the drop-down menu, and pressing ”make new”. After naming the preset, it will be shown in the drop-down menu. The custom preset files can be overwritten or deleted with the two buttons on the right, respectively.

5.3.2 Drive settings

”Drive” is the first expandable widget in the left pane of the UI (see Figure 53) and enables the configuration and fine-tuning of the signal driving the EMILIE™ chip. The drive is off by default at device startup, but switches on automatically when the EMILIE tab is used.

- The first switch allows the drive to be toggled on or off manually. When switched on, the drive will take on the set amplitude value.
- Drive can have different waveforms, but for the use with EMILIE™, ”Pulse” should always be used.
- ”Amplitude” sets the maximal voltage of the drive signal. The heavier the sample load on the EMILIE™ chip, the higher the amplitude needed to achieve a stable monitoring of the chip frequency. The presets provided in the EMILIE™ tab take this into account, but sometimes additional manual adjustment of the amplitude is needed. If the red LED on the front side of PHILL™ is on (”Input overflow” warning is shown), lower the amplitude. If you are having trouble finding the resonance peaks, increase the amplitude and rerun the EMILIE™ tab.
- ”Pulse Width” adjusts the width of the driving pulses. When applying parameters automatically in the EMILIE™ tab, this value is set to one-third of the resonance period. Usually, no manual adjustment is needed.
- ”Pulse delay” is an advanced parameter that creates a phase delay of the drive pulses. It should be kept at it’s minimum value.

Sliders and input fields:
All input fields in the UI turn yellow while being edited. A new value is applied when the Enter key is pressed. If the value is changed without pressing Enter, the old value will remain applied. Sliders have Min and Max input fields controlling the range of each slider, as well as the third input field containing the current slider value. All sliders can also be moved by scrolling, typically enabling smoother fine-tuning of parameters.

5.3.3 Range filter settings

”Range filter” settings are the second expandable widget on the left pane of the UI. The range filter is the band-pass filter applied to the raw input signal from the sensor (Figure 54). The EMILIE™ tab sweeps through the given frequency range automatically, so these settings can be used for manual resonance search or for fine-tuning after the lock has been found.

- The input signal can be amplified by setting the ”Input Gain” to values higher than 1 for low amplitude input signals. Avoid clipping of the input signal, indicated by the ”Input Overrange” button in the software and red LED on the front panel of PHILL™
- The filter can be toggled on or off using the ”Bandpass” toggle button. Under operation conditions, the filter should always be on.
- Filter ”Bandwidth” can be set using a drop-down menu. The bandwidth should cover the frequency shifts during an FTIR measurement. Under typical measurement conditions, a bandwidth of 3 kHz should be sufficient. For heavily loaded chips or the EMILIE™ LIGHT chip , a higher value might be required in order to keep the frequency tracked throughout the measurement.
- The filter ”Order” should be kept at 1 at all times.
- The center ”Frequency” of the filter is the most important parameter in this section and it should be set to the resonance frequency of the EMILIE™ chip in order to filter out the unwanted noise from the signal.
- The pulse width of the drive signal should correspond to one-third of the resonance frequency. After changing the frequency, press ”Apply suggested pulse width” to apply the optimal pulse width for the current center frequency in order to achieve the lock. This is done automatically when using the EMILIE tab.

5.3.4 Temperature settings

EMILIE™ features an integrated temperature control of the EMILIE™ chip in vacuum. This can be used to cool or heat the EMILIE™ chip to enable in-situ desorption of the analyte or to separate analytes with varying volatility (For examples, see application notes online invisible-light-labs.com/resources . The presets in the EMILIE™ tab contain a fixed target temperature of 25°C to avoid condensation or desorption effects and compensate for any changes in the ambient temperature. Settings related to the temperature can be found in the ”Temperature” section on the left pane (see Figure 55). The most important settings are:

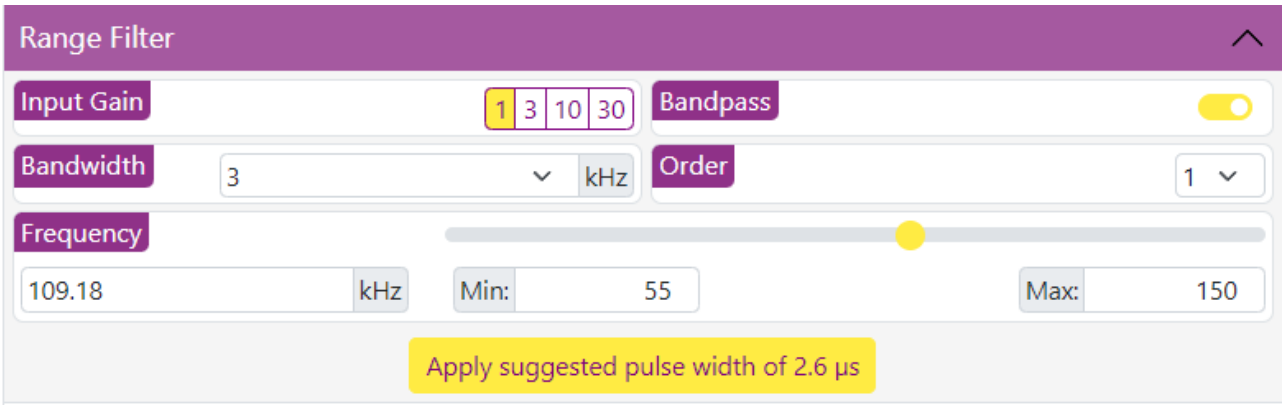


Figure 54: Range filter settings in the PHILLharmonics software.

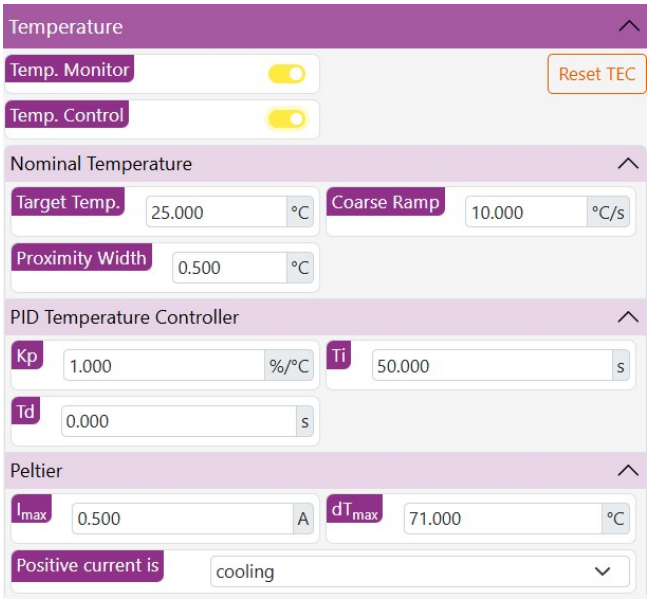


Figure 55: Temperature section of the PHILLharmonics software to adjust the temperature and the PID controller.

- ”Temp. Monitor” - toggles the monitoring of the chip temperature on or off (see Figure 56).
- ”Temp. Control” - toggles the control of the chip temperature on or off (see Figure 56).
- ”Reset TEC” - resets the TEC controller. Used when the TEC controller reaches an error state.
- ”Target Temp.” - the desired temperature that the chip should be held at. The controller tries to reach this temperature when ”Temp. Control” is on.

The TEC status and the chip temperature are displayed in the bottom right corner of the UI. The TEC can be in different states, as displayed in Figure 56 and explained below:

- Ready (blue) - ”Temp. Control” is off and the controller is ready to be turned on (Figure 56 case 1 and 2)
- Running (green) - ”Temp. Control” is on and the TEC is controlling towards the target temperature (Figure 56 case 3 and 4)
- Error (red) - The TEC encountered an error with a specific error code. The only way to get

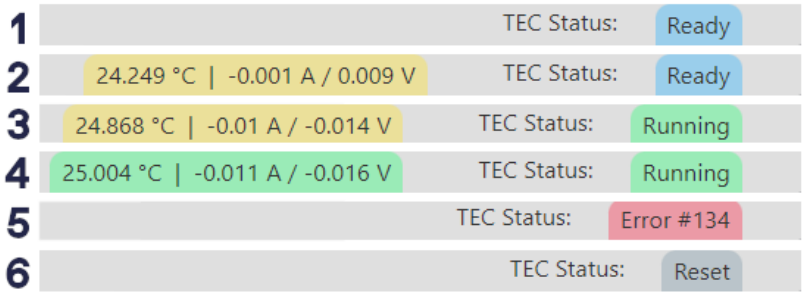


Figure 56: TEC status and Temperature displayed in the bottom right corner of the PHILLharmonics window. There are 6 possible status and temperature cases

out of the Error state is to reset the TEC by pressing ”Reset TEC” (Figure 56 case 5)

- Reset (gray) - This status is shown briefly during the reset process of the ”TEC”; if there are no errors, the controller should return to a ready state (Figure 56 case 6).

If the TEC status is ”Ready”, it is possible to monitor the chip temperature by turning the ”Temp. Monitor” on in the Temperature settings. If the chip has reached the target temperature and the value is stable, the temperature bubble is green (Figure 56 case 4), otherwise the bubble is yellow (Figure 56 case 2 and 3).

The TEC controller is a proportional–integral–derivative (PID) controller, and the PID values can be adjusted for controlling behavior (speed/precision/noise/overshoot). The PHILLharmonics software comes with default PID settings that cover most use cases, but for all other cases, the values can be adjusted in the ”PID Temperature Controller” section. The default ”Kp” value is chosen for low noise during measurements when the temperature has already been reached, but can be slow for reaching the target temperature. To achieve a large change in temperature in a short amount of time, the ”Kp” value can be temporary increased (e.g. to 50) and after the temperature has been stable for approx. 30 seconds, the ”Kp” value can be slowly decreased back to the default value. A low ”Kp” value usually comes with less temperature fluctuations, which directly influences the measurement noise.

Impact of temperature on resonance frequency:
The temperature of the EMILIE™ chip affects its resonance frequency. Therefore, it is necessary to re-adjust the resonance frequency offset in the PHILLharmonics software via ”Calculate Offset” in the ”Results” step after each temperature change to avoid any clipping of the output signal. For large temperature changes, the lock can be completely lost and the measurement parameters must be readjusted by going through the EMILIE tab from the beginning.

Condensation effects for operation below room temperature:
Setting the temperature of the chip below room temperature can lead to the condensation of contaminants from the vacuum chamber on the chip surface. This condensation causes a continuous change in the resonance frequency and the appearance of impurities in the recorded NEMS-FTIR spectra. Measurement of an empty EMILIE™ chip under the same operating conditions can help in condensation impurities identification.

5.3.5 Parameter settings

The PHILLharmonics software uses parameter files to save all settings and measurement parameters that are adjustable in the UI. This allows for experiment reproducibility by saving and loading the desired parameter files. To save the current parameters applied in the software, press ”Download Settings” in ”Parameters” menu. To load a parameter file and apply it, use the ”Choose file” button to browse for it, or just drag it and drop it into the upload box. Press ”Load Settings” to apply the settings.

5.3.6 Oscilloscope tab

The oscilloscope tab displays a real-time plot of the three signals within PHILL™ in the time domain (see Figure 57), providing a more detailed view of the resonance frequency lock. This can be helpful when the EMILIE™ chip proves difficult to lock using the EMILIE tab. It also gives a good visualization of the resonance and the self-sustaining oscillation functions. The 3 signals are:

- ”Raw” - the raw input signal coming from EMILIE™ into PHILL™ .
- ”Filtered” - the input signal after the Range filter is applied.
- ”Drive” - the pulsed output signal, used to drive the EMILIE™ chip at the resonance frequency.

As with a conventional oscilloscope, one of the signals serves as a trigger to keep the graph centered. You can choose between triggering on the raw ”Input” or on the ”Filtered” signal. We recommend using ”Filtered” for a smoother display. To toggle the display of individual signals, click on their names in the legend located in the upper-left corner of the graph. When a signal is disabled, its name will be shown in strikethrough. To zoom in or out, use the ”+X” and ”-X” buttons for the time axis (bottom right corner) and ”+Y” and ”-Y” for the amplitude (top left corner). The ”Reset” button sets the scale back so all signals are visible. To download the current oscilloscope data, use the ”Download” button.

5.3.7 Frequency output plot tab

The ”Frequency Output Plot” tab (Figure 58) is almost identical to step 4 of the EMILIE tab (”Results”), apart from the additional low-pass filter settings. The measured frequency is plotted in real-time; time scale can be changed using the drop-down menu in the lower-left corner of the plot. Both the frequency (FC) and the voltage of the analog output (DAC) are plotted at the same

Figure 57: The oscilloscope tab in PHILLharmonics with a positive drive lock.

time. By default, the FC is plotted on top of the DAC. You can change the order by clicking on the signal name in the plot legend (upper left corner).

- ”Offset” sets the new zero value for the analog output. It should be set to the resonance frequency. Clicking ”Calculate Offset” will calculate and apply the offset automatically. The offset should be readjusted before each measurement for optimal results.
- ”Output range” controls the sensitivity of the voltage compared to the frequency shifts. More loaded chips require higher ranges, otherwise output overrange can happen during the measurement, indicated by a red warning above the frequency plot.
- Low-pass filter is applied on top of the measured frequency over time for a smoother curve. This makes the analog output smoother too, which means FTIR is provided with a smoother signal. The values under 30 Hz can cut off the data from the signal, so it is recommended to keep this value at 30.

5.3.8 Sweep tab

The ”Sweep” tab (Figure 59) offers an advanced version of step 2 from the EMILIE tab (”Frequency Finder”). It sweeps through the given range of frequencies defined by ”Start Freq.” and ”Stop Freq.” fields. ”Num. of Samples” and ”Time per Increment” control the number of points between the start and stop frequency and the time between the data acquisition of the points, respectively.

In contrast to the EMILIE tab, where the sweep is performed for both positive as well as negative polarity of the drive amplitude, the Sweep tab only sweeps with the drive that is currently set under ”Drive” settings in the left pane. After sweeping with the given drive, it sweeps one more time with the drive off to measure the background noise in the frequency range. This is represented with an orange line called ”Noise Floor”. The ”Noise Floor Mean” is then used to calculate a ”K” value, representing the quality of the peak.

Figure 58: The frequency output tab with a 100 kHz resonance frequency lock.

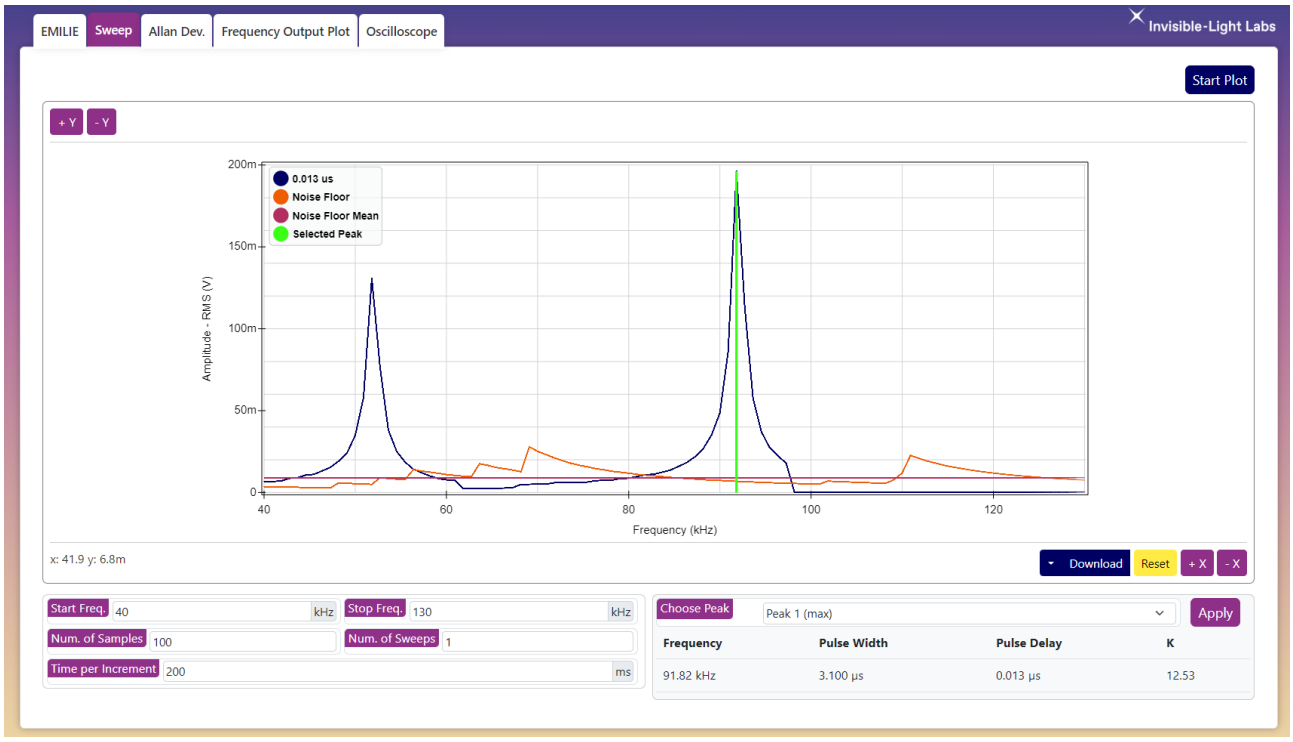


Figure 59: The sweep tab with two resonance peaks, noise floor, and a noise floor mean curve.

”Num. of Sweeps” is an advanced option that allows for sweeping with different pulse delay values. By default, 1 sweep with the minimum pulse delay of 0.013 µs is used.

After the sweep is done or is stopped by pressing ”Stop Plot”, resonance peaks are listed in the lower right corner in the drop-down menu. Apply the optimal parameters for locking on the chosen frequency.

6 UNMOUNTING AND STORAGE

To unmount and store EMILIE™ refer to Section 4.2.3 and follow these steps:

1. Stop the vacuum pump and vent the system (see Section 5.2.2). Once venting is finished remove the lid and close the venting valve.
2. Place a dummy chip inside the chamber to avoid any damage to the indium foil. Put the lid back on the chamber and secure it to the vacuum chamber with some adhesive tape without covering the warning labels on the lid itself.
3. Unplug the PU tube from the HiPace® 10 Neo .
4. Dismount the automatic venting valve by unplugging the cable and unscrewing it with a 13 mm wrench. Close the ventilation opening of the HiPace® 10 Neo with the hexagonal screw the pump was shipped with, and cover the automatic venting valve opening with the plastic cap it was shipped with. Store it in a dust-free environment, ideally in the original packaging.
5. Unplug the power plug and the PU tube of the membrane pump. Cover the open end of the PU tube or remove it completely and store the membrane pump and the tube in a dust-free environment, ideally in the original packaging.
6. Unplug all cables from the pump control, and store the pump control and the cables in a dust-free environment, ideally the original packaging.
7. Unplug the sub-D cable from EMILIE™ .
8. Unplug all cables from PHILL™ and store them in the original packaging together with the power supply, the USB, and the sub-D cable.
9. Unlock EMILIE™ from the FTIR and place it in the original packaging EMILIE™ was shipped in. The EMILIE™ original packaging was specifically designed to store EMILIE™ with the HiPace® 10 Neo still attached by simply removing the extra foam cutout.

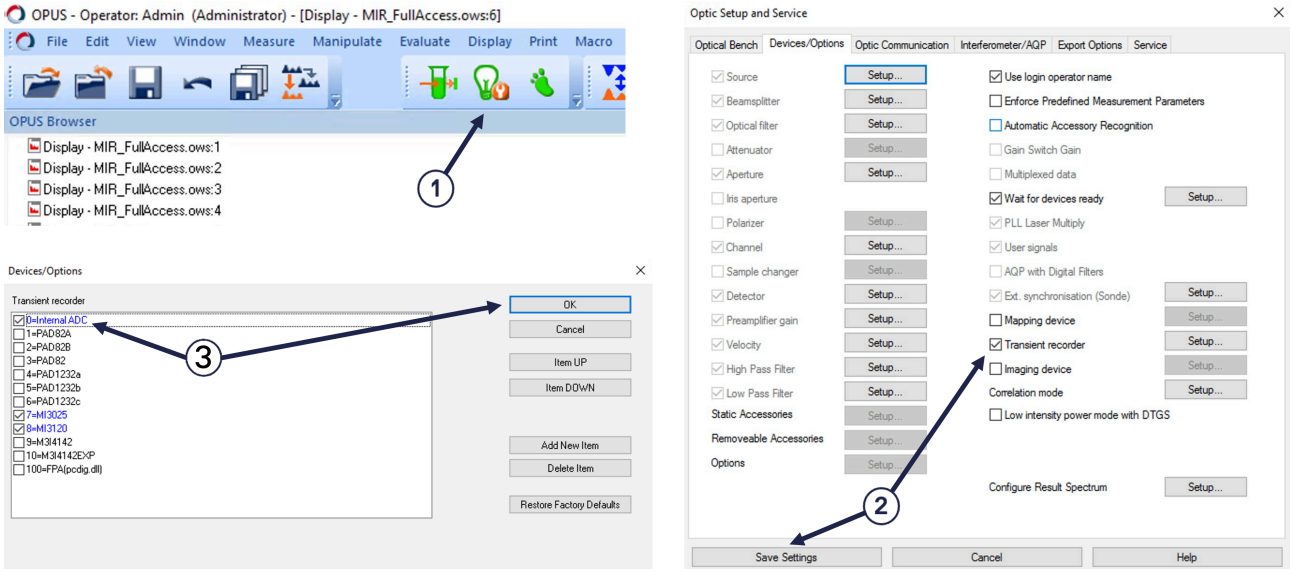


Figure 60: OPUS optics settings for activation of the internal transient recorder for step scan modulation. Step 1: Open the optics setup and service tab; step 2 open the transient recorded setup and Step 3: Ensure the box for internal ADC is checked.

7 TROUBLESHOOTING & FAQ

7.1 PHILL™ does not connect to the PC

- Verify that PHILL™ is switched on.
- Verify whether the micro-USB cable of PHILL™ is properly connected to the PC.
- Shut down the software completely by right clicking the icon in the taskbar and then selecting 'Quit'. After that, start it again.
- Restart PHILL™ by switching it off and on again, start the software again.

7.2 OPUS error "can not open transient recorder"

When operating EMILIE™ for the first time, ensure that OPUS's internal transient recorder is activated. This feature, required for step-scan modulations, is not enabled by default. To activate it, open the Optics Setup and Service tab in OPUS (see Figure 60, step 1), navigate to the Devices/Options tab (step 2), and open the Transient Recorder setup. Check the box labeled 0 = Internal ADC (step 3) and click OK. Confirm that the transient recorder is active — as shown in Figure 60 step 2, and that the checkbox remains selected. Finally, exit the menu by clicking Save Settings. The internal transient recorder is now ready for step-scan operation.

7.3 Unable to find a resonance frequency

The correct setting of the resonance frequency using PHILL™ is crucial for acquiring an IR spectrum. However, there can be several reasons why the resonance frequency can not be found:

- Wrong settings are applied or the wrong working temperature is used.

- Insufficient drive value is used.
- Resonance frequency is not located in chosen sweep range.
- Resolution (N Samples) is too small.
- Chip or sample collection issues are present.

7.3.1 Faulty connection between EMILIE™ and PHILL™

During the installation of EMILIE™ in the FTIR sample compartment, the ”15Pin SubD” cable mounting could get loose. Therefore, ensure a proper connection of the cable to EMILIE™ and PHILL™ .

7.3.2 Faulty connection of the contact bridge

The chip is intact and the connection could not be established on several chips:

- Check whether the pins are damaged or bent.
- Carefully check if the force of the spring-loaded pointy center pins and the flat outer pins is even. Make sure to wear clean gloves!

CAUTION

Risk of puncturing the skin

The four spring-loaded pins contacting the chip are pointy and sharp and could puncture your gloves or fingertips.
- Do not leave the contact bridge exposed in areas where it may be accidentally touched, struck, or leaned on.
- Exercise caution when handling the contact bridge.

ATTENTION

Risque de perforation de la peau

Les quatre broches à ressort qui servent de contact avec la puce sont pointues et acérées et pourraient perforer vos gants ou le bout de vos doigts.
- Ne laissez pas le pont de contact exposé dans des zones où il pourrait être accidentellement touché, heurté ou appuyé.
- Soyez prudent lorsque vous manipulez le pont de contact.

- Check the electrical connection of the pins with a multimeter according to the Figure 61. The pin pairs are marked by small and capital letters displayed in the same color.
- Check the tightness of the four guide pins, and re-tighten them hand-tight if necessary.
- Check for dust or dirt on the pins and the body of the contact bridge. Dust-off the contact bridge with clean and dry pressurized air. More persistent contamination can be carefully

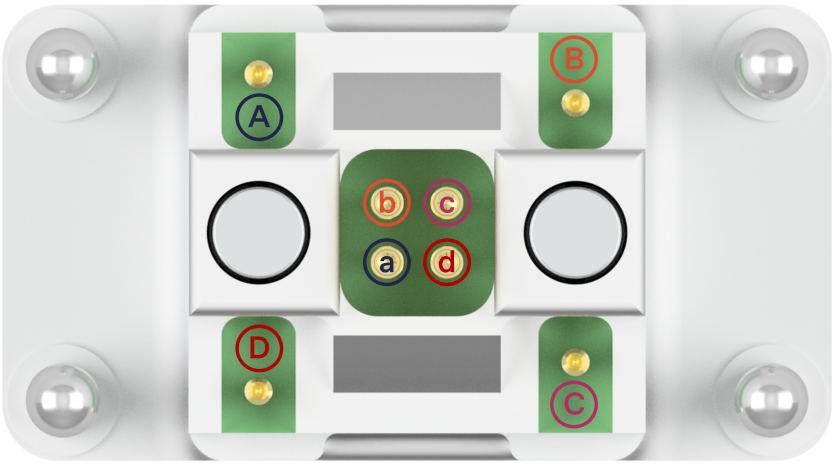


Figure 61: Electrical connection of the spring-loaded contacts on the contact bridge. The pairs are marked by color and capital and small letters.

removed with a lint-free wipes or cotton swab and isopropyl alcohol . Do not put pressure on the pins from the sides, this can bend and break them.

7.4 Identifying a broken EMILIE™ chip

The chip can not be locked and/or the connection check lamp does not light up.

- Check the orientation of the chip inside the chamber, and make sure the shape of the electrodes on the EMILIE™ chip matches the shape of the electrodes on the chip holder as shown in Figure 62.
- Check the EMILIE™ chip under a microscope and look for:
  - Big particles on or close to the membrane/electrodes.
  - Holes, other than the perforation, in the membrane.
  - Broken edges of the EMILIE™ chip or electrode pads.
  - Other abnormalities.
- Check the electrical conductivity of the electrodes on the EMILIE™ chip , Figure 63 shows the electrode pairs connected to each other. The expected resistance should be between 50 Ohm and 150 Ohm.

7.5 PHILLharmonics frozen

- Shut down the software completely by right clicking the icon in the taskbar and then selecting 'Quit'. After that, start it again.

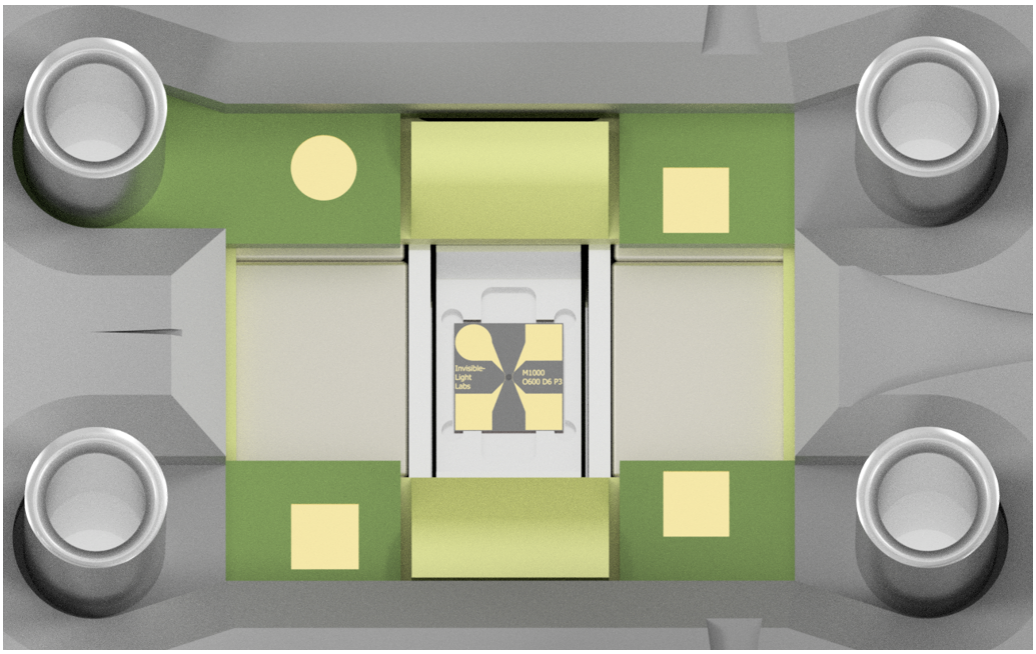


Figure 62: EMILIE™ chip orientation inside the vacuum chamber

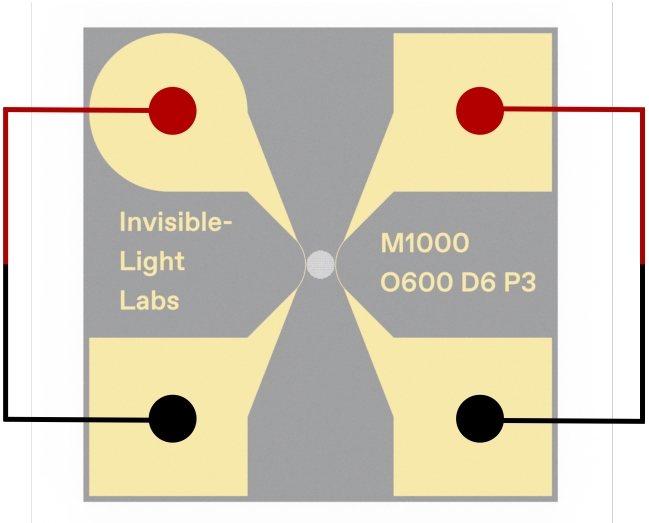


Figure 63: Placement of the multimeter pins on the electrodes of the EMILIE™ chip .

7.6 TEC error

- Clicking the reset button is advised to resolve any temporary memory issues or disruptions within the TEC such as no temperature value displayed or an error.
- If the TEC is set to incorrect parameters, it may enter an error state again after getting reset. The most commonly misconfigured parameter is 'Positive current is'. If you are unsure, set the default parameters shown in the figure 55.
- If the reset button fails to rectify the issue, it suggests a potential connection problem with the TEC unit housed within the PHILL™. device. Contact Invisible-Light Labs GmbH for support.

7.7 Unsteady frequency during analysis

- An unsteady frequency during analysis can indicate that the frequency is not adequately locked. Adjust the parameters as described in section 5.2.3.
- An unsteady frequency may also be caused by unstable temperature and pressure conditions.

7.8 The FTIR spectrum is not displayed

- Ensure that the frequency is properly locked.
- Inspect all cables and connections to rectify any issues that might be disrupting the communication between the FTIR and EMILIE™.
- Verify that the "Frequency Out" port of PHILL™ is connected to on the ASM external Analog-Box is the same that is specified in the settings of the scan. This can be found in the tab "Optics" and under "Detector Settings" of the measurement window.
- If the resonance frequency drifts strongly, this can cause an issue with the FFT of the FTIR device. Wait for the temperature to stabilize. In the case of volatile compounds, this could indicate a compound evaporating. Cool down the chip to prevent evaporation or temporarily heat the chip up to increase the desorption rate, which can stabilize the frequency faster.

7.9 Unusual noise coming from the pump

If an unusual noise is emanating from the pump, it indicates a leak within the vacuum system.

- One common cause for this issue is an improperly closed lid of the EMILIE™ chamber. Make sure the lid is tightly connected and nothing blocks the proper seal between the O-ring and the chamber
- Check whether the venting valve is closed
- Check the tubing between the HiPace® 10 Neo and membrane pump for a loose connection or damage

If the previous steps do not resolve the issue, turn off the pump via the controller and contact Invisible-Light Labs GmbH at info@invisible-light-labs.com for support.

7.10 Drive power of turbo pump does not drop below 10 W

In case the pump reaches its max. speed (1500 Hz) and the Drive Power does not drop below 10 W:

- Vent the system and check the lid and the O-ring for damage and dirt
- Clean the lid and the O-ring with clean pressured air and if necessary with lint-free wipes wetted with isopropyl alcohol
- Check the tubing between the HiPace® 10 Neo and membrane pump for a loose connection or damage
- Make sure the venting valve is closed

Should the problem still occur, please contact Invisible-Light Labs GmbH at info@invisible-light-labs.com for support.

8 MAINTENANCE AND CLEANING PROCEDURES

8.1 Indium foil replacement

This section describes the detailed workflow on how to replace the Indium foil. The Indium foil should be replaced when it is visibly damaged, scratched, or has big particles stuck to it. A lack of proper thermal connection (frequency drifts for long periods of time before stabilizing) is a hint of the need for replacement.

1. Put on gloves, vent the system and remove the chip from the chamber.
2. Remove the old Indium foil from the chip holder and discard it according to local regulations.
3. Clean the chip holder with clean pressured air (optional) and a cotton swap dipped in isopropanol (see Figure 64 for this and all further steps).
4. Dip the tip of the toothpick in vacuum grease and make four small dots in each corner of the chip holder.
5. Take the new indium foil from the packaging with tweezers and place it in the center of the chip adapter.
6. Press the foil down with a clean and dry cotton swab.
7. Place a clean (dummy) chip in the chamber and place the bridge, this presses the Indium foil in place, the chamber is now ready to use again!

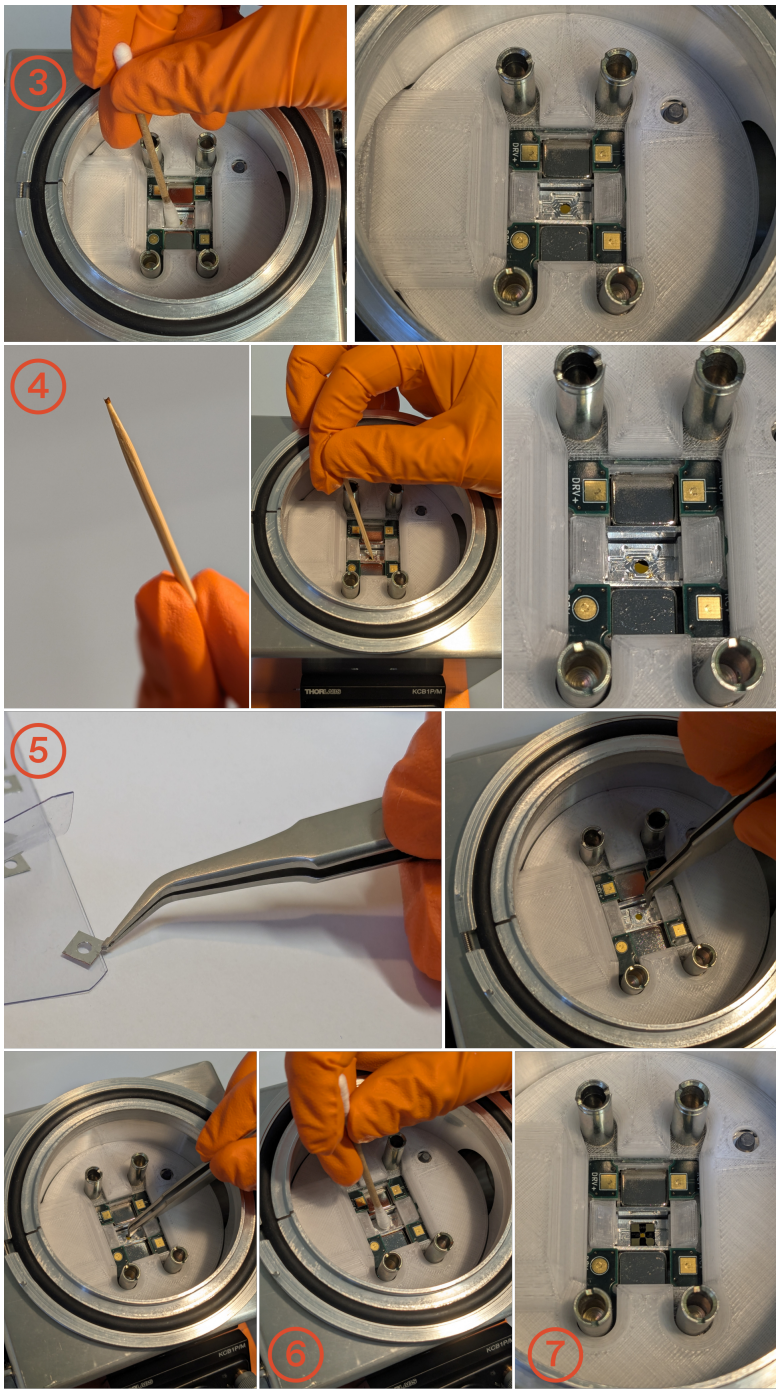


Figure 64: Visual support for the Indium foil exchange workflow.

8.2 Cleaning of vacuum chamber and its components

The vacuum chamber and all its components can be cleaned with dry and clean pressured air to get rid of loose particles. Due to the magnetic field inside the chamber, metal particles can accumulate on top of the PCB cover over time. It can be wiped with a lint-free wipes and isopropyl alcohol . Do not use other solvents!

NOTICE

Risk of damage to the electronics or their housing

Exercise care when cleaning with isopropyl alcohol to avoid damaging electronics or the housing.

- Spray isopropyl alcohol on lint-free wipes before using it to wipe over surfaces in the chamber. Do not spray isopropyl alcohol directly into the chamber!
- Use isopropyl alcohol in moderation. Do not submerge the vacuum chamber or any of its components.

AVIS

Risque de dommages aux composantes électroniques ou leur boîtier

Soyez prudent lors du nettoyage avec l'isopropyl alcohol afin d'éviter d'endommager les composantes électroniques ou leur boîtier.

- Vaporisez l'isopropyl alcohol sur une lingette non pelucheuse avant de l'utiliser pour essuyer les surfaces de la chambre à vide. Ne vaporisez pas l'isopropyl alcohol directement dans la chambre à vide!
- Utilisez l'isopropyl alcohol avec modération. N'immergez pas la chambre à vide ni aucune de ses composantes.

It should be avoided to clean the contact bridge with anything but clean and dry pressured air. Should the spring-loaded contact pins get in touch with contaminants that can not be removed with pressured air, they can be very carefully wiped cleane with a lint-free wipes and isopropyl alcohol . Do not apply pressure on the pins, especially from the side. In case the pins are bent, they will no longer properly connect the chip to the electronics and have to be replaced.

In the case of a chip breaking inside the chamber, remove the bigger pieces with tweezers. The rest can be removed with clean and dry pressured air and a lint-free wipes with isopropyl alcohol .

NOTICE

Risk of damage to the pump

Do not push debris and particles in the direction of the vacuum pump opening. This damages the pump and reduces its lifetime.

- Remove bigger pieces of debris with tweezers.
- Guide the stream of the clean and dry pressured air away from the vacuum pump flange.

AVIS

Risque d'endommager la pompe

Ne poussez pas de débris ni de particules vers l'ouverture de la pompe à vide. Cela endommagerait la pompe et réduirait sa durée de vie.

- Retirez les plus gros débris à l'aide d'une pincette de précision.
- Guidez le flux d'air comprimé propre et sec loin de la bride de la pompe à vide.

9 APPENDIX

9.1 Electrical specifications

9.1.1 Connector configuration and function

The EMILIE connector on PHILL™ is connected to the Sub-D 15-pin port on the side of EMILIE™ shown in Figure 65. The pinout of the Sub-D 15-pin connector located on the side of EMILIE™ is listed in Table 9. The pinout of the EMILIE connector on PHILL™ is shown in Table 10. The pin ”P_Drive” is internally shorted to the ”(D) Drive” BNC port and ”P_Sensor” is internally shorted to the ”Input” BNC port (see Table 11).

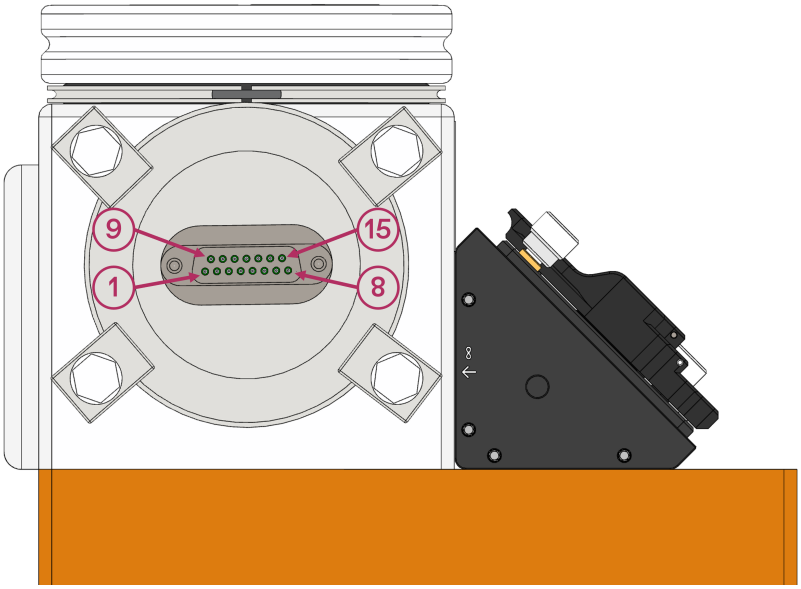


Figure 65: A Sub-D 15-pin port is located on the side of EMILIE™. The pin numbering is indicated in red. For detailed information see Table 9.

Table 9: Pinout of the Sub-D 15-pin port located on the side of EMILIE™

Pin	Name	Type	Description
8	E_TEC D-	Input	Peltier drive (–)
7	E_TEC D+	Input	Peltier drive (+)
15	E_TEC R-	Input	Thermal sensor read (–)
14	E_TEC R+	Input	Thermal sensor read (+)
3	E_V+	Input	Positive voltage supply
11	E_V-	Input	Negative voltage supply
10	E_Sensor	Output	Input signal of the sensor
9	E_Drive +	Input	Positive drive signal of the sensor
1	E_Drive -	Input	Negative drive signal of the sensor
2,4,5,6,12,13	E_GND	GND	Common ground

The interface and connectors of PHILL™ are shown in Figures 66a and 66b. The connectors and

Table 10: Pinout of the Sub-D 15-pin EMILIE connector located on the front panel of PHILL™

Pin	Name	Type	Description
1	P_TEC D-	Output	Peltier drive (–)
2	P_TEC D+	Output	Peltier drive (+)
9	P_TEC R-	Output	Thermal sensor read (–)
10	P_TEC R+	Output	Thermal sensor read (+)
6	P_V+	Output	Positive voltage supply
13	P_V-	Output	Negative voltage supply
14	P_Sensor	Input	Input signal of the sensor
15	P_Drive	Output	Drive signal of the sensor
3,4,5,7,8,11,12	P_GND	GND	Common ground

their functions are detailed in Table 11. The front panel of PHILL™ (Figure 66a) features a central connector labeled ”EMILIE” used to carry analog signals for controlling EMILIE™ . The green LED is a power indicator which allows the user to verify visually that PHILL™ is switched on. The red LED is an ”Input overflow” indicator which notifies the user visually that an analog input is too strong. More details on the ”Input Overflow” can be found in Section 5.2.3. The ”Input” and ”Drive” BNC connectors are not required when working with EMILIE™ . The back panel of PHILL™ (Figure 66b)features micro-USB and Ethernet connectors for communication as well as a power switch with power-on “I” and power-off “O” positions to switch the device between on and off states.

Figure 66: (a) Front plate of PHILL™ , (b) Back plate of PHILL™

9.1.2 Electrical characteristics

The electrical characteristics of all signals and interfaces between the PHILL™ and EMILIE™ devices are summarized in Table 12. This includes typical voltage and current ranges, signal directions, and maximum ratings under normal operating conditions. Voltages are specified with respect to the local system ground unless otherwise noted.

The drive signals for the Peltier element (TEC D±) are generated by a bipolar output stage capable of producing differential voltages up to ± 9.6 V. As such, the output is not symmetric with respect to ground, but rather delivers a floating voltage across the TEC load. Care must be taken not to reference either TEC output terminal directly to ground. To protect the thermoelectric element from overheating or damage, the effective output voltage is limited by the software to a maximum of ± 0.9 V under normal operating conditions.

Table 11 lists the insulation requirements for each connector. The external DC power input requires reinforced insulation, as it interfaces with a separately powered Class I or Class II supply certified according to IEC 60601-1, IEC 61558, or IEC/EN 62368-1. All other connectors operate within SELV voltage levels and require only basic insulation between internal circuits and accessible surfaces.

9.1.3 Former labeling of PHILL™ connectors

Figures 67a and 67b show the previous front and back plate covers of PHILL™ . The corresponding connectors can be identified by their Function in Table 11.

[5] Shorted to pin 14 (P_Sensor) of EMILIE connector and has the same ratings

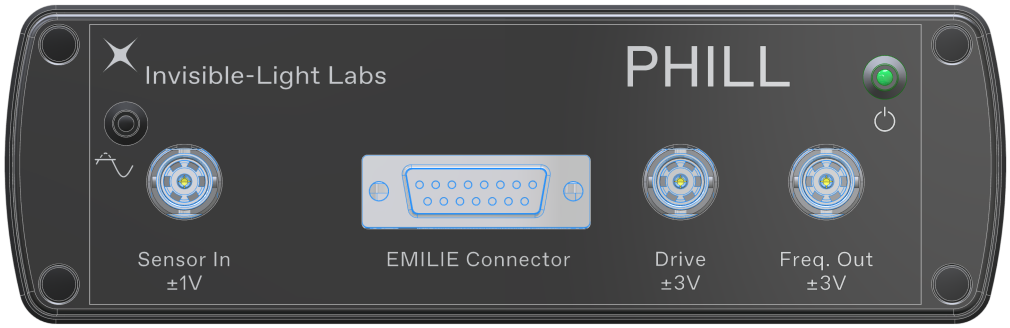
[6] Shorted to pin 15 (P_Drive) of EMILIE connector and has the same ratings

[7] **External Power Source Classification** - The device is powered by an external AC/DC wall adapter rated with 2× MOPP (Means of Patient Protection), ensuring reinforced insulation between mains and output. This provides a high degree of electrical isolation, allowing all internal circuits and accessible I/O ports to be classified as Overvoltage Category I (ovc I) per IEC 61010-1, Clause 5.4.2

[8] **Terminals Arrangement – Clause 16.2 Compliance.** The product is powered via an external SELV 5 V DC power adapter, connected through a keyed DC barrel jack, preventing incorrect polarity insertion. Immediately after the barrel jack, an overvoltage protection diode and a fuse are installed to protect downstream circuitry from overcurrent and transient overvoltage conditions. Internal connections between the DC jack and PCB are made using fixed-orientation, keyed connectors with appropriate insulation and separation. The entire 5 V section is classified as a limited energy circuit per IEC 61010-1, and the terminal layout ensures that accidental shorts or misconnections are unlikely. Terminals are fully enclosed in the housing, inaccessible to the user under normal operation, and require tools for access. The design satisfies the requirements of Clause 16.2 regarding safe arrangement and protection of terminals.

[9] **Insulation at power supply input** - The power supply input requires only basic insulation within the device, as the connected external power supply provides reinforced insulation (2× MOPP) between the mains and its output. This insulation requirement applies only when the device is operated with such a certified, isolated SELV power supply. Use with any other type of power source (e.g. open-frame or non-isolated supplies) would invalidate this insulation classification and require additional protection within the device.

(a)



(b)

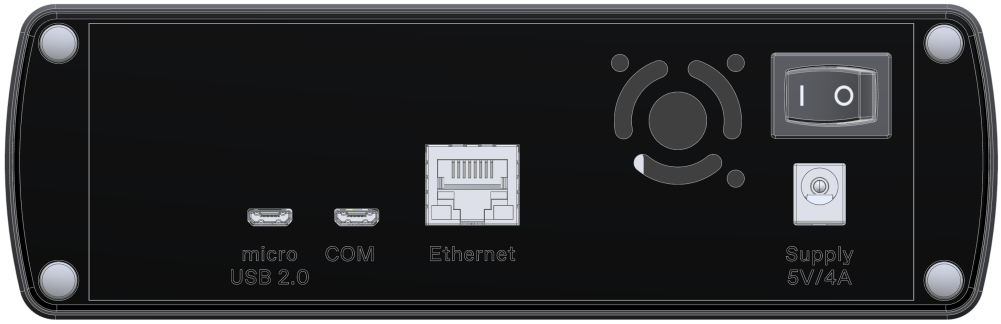


Figure 67: (a) Former front plate of PHILL™, (b) former back plate of PHILL™

9.2 Dimensional drawing of EMILIE™

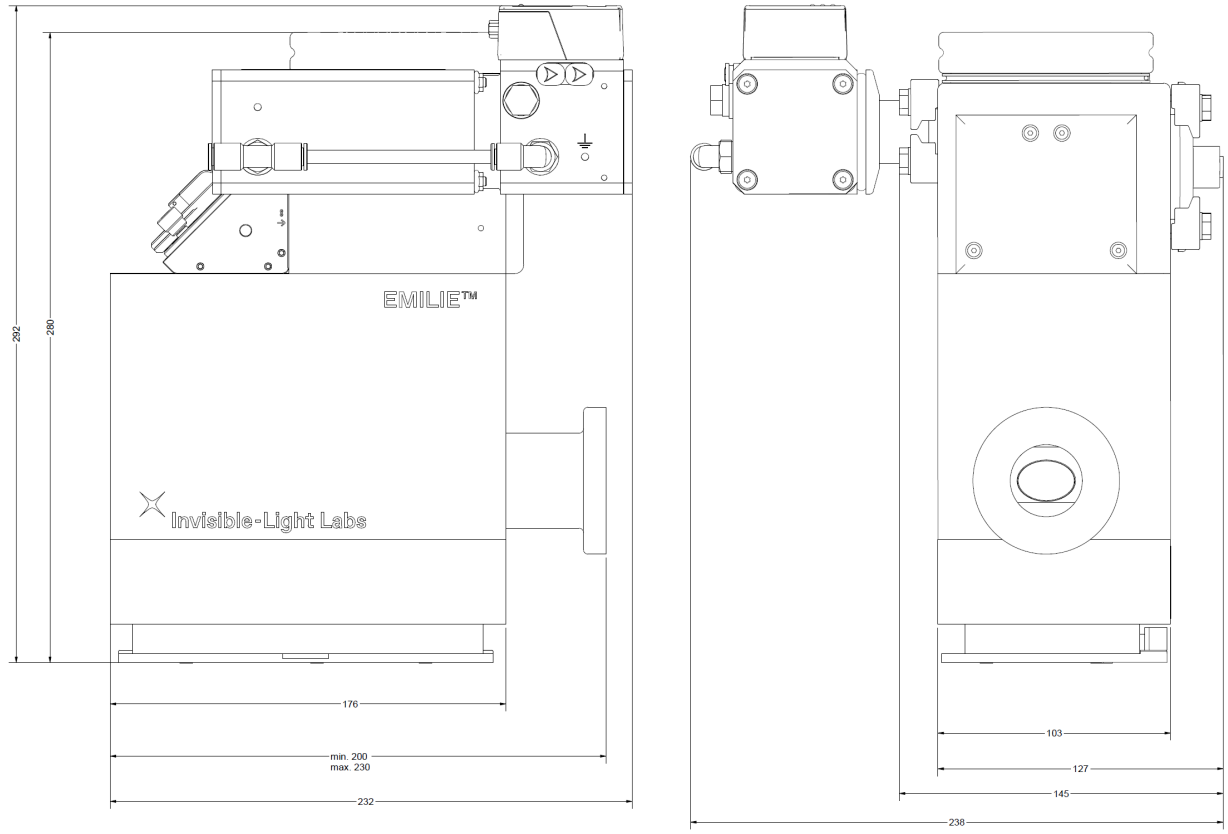


Figure 68: Dimensional drawing of EMILIE™, includes dimensions for use with and without HiPace® 10 Neo

9.3 Dimensional drawing of PHILL™

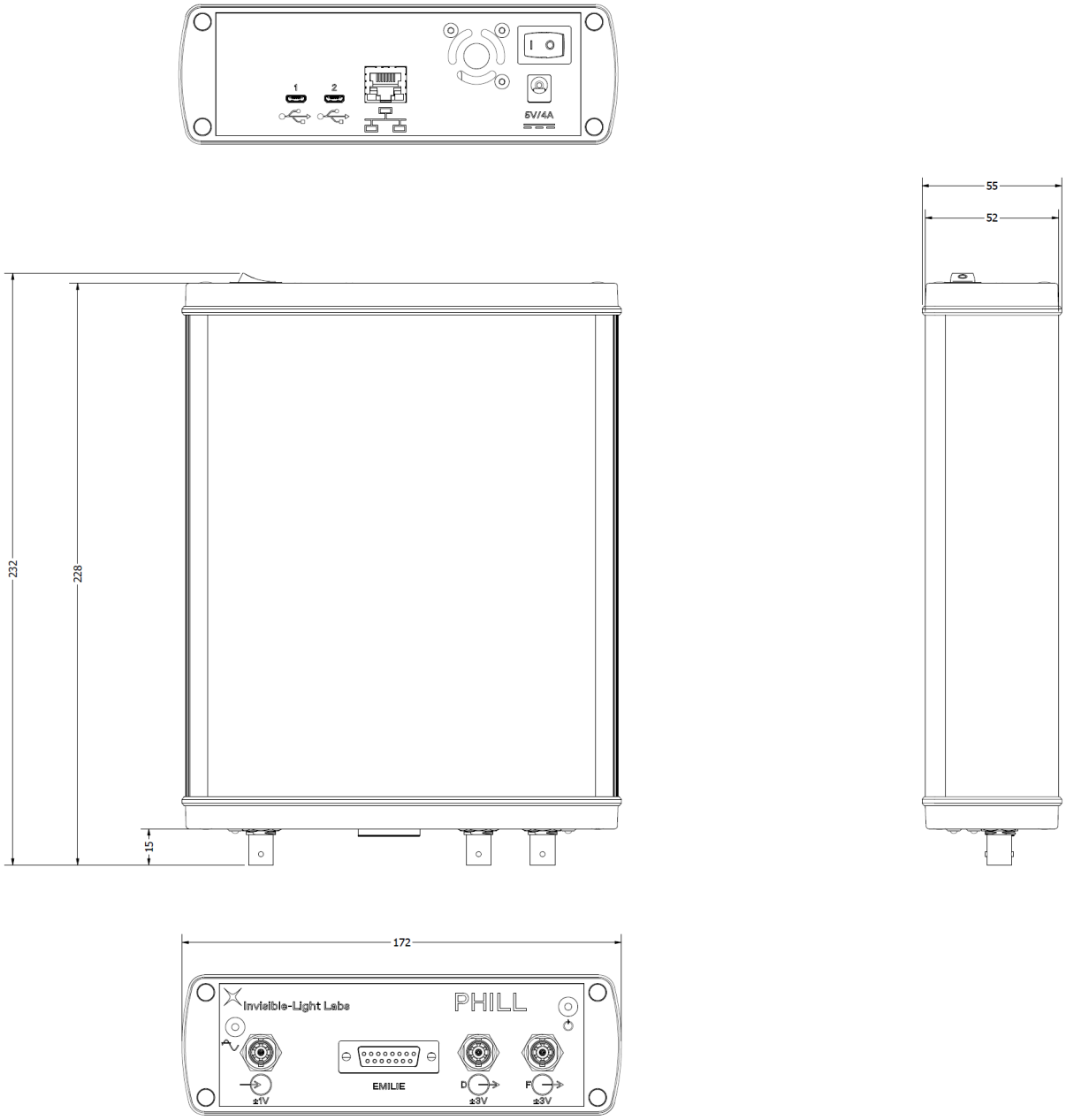


Figure 69: Dimensional drawing of PHILL™

Table 11: Overview of front and back plate connectors of PHILL™ .

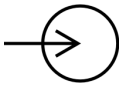
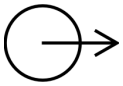
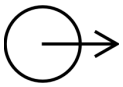
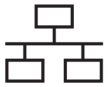
Connector (Terminal)	Symbol	Description	Function	Req. insulation, OVC[4]
Input[5]		±1V BNC connector (analog input)	Sensor input	basic, OVC I
(D) Drive[6]		±3V BNC connector (analog output)	Drive signal output	basic, OVC I
(F) Frequency		±3V BNC connector (analog output)	Frequency signal output	basic, OVC I
EMILIE	N/A	Sub-D 15-pin connector (analog input/output and power)	Connection to EMILIE	basic, OVC I
Supply[7] [8] [9]		Barrel jack (5.5/2.1 mm) connector for external 5 V / 4 A power supply	Power supply input	basic, I
Ethernet		Standard Ethernet port	Communication with PC	basic, OVC I
(1) micro USB 2.0		micro USB 2.0 connector	PC connection for measurement operation	basic, OVC I
(2) micro USB 2.0		micro USB 2.0 connector	PC connection for service purpose only	basic, OVC I

Table 12: Electrical specifications for all PHILL™ and EMILIE™ ports as described in Table 9 & 10.

Signal / Port	Direction.	V_{min}–V_{max} [V]	I_{max} [mA]
P_TEC D-	Out	0 to 9.6	1200
P_TEC D+	Out	0 to 9.6	1200
P_TEC R-	Out	0 to 5.1	-
P_TEC R+	Out	0 to 5.1	-
P_V+	Out	5.5 to 6.5	125
P_V-	Out	–6.5 to –5.5	125
P_Sensor	In	–1 to 1	—
P_Drive	Out	–3 to 3	50
P_GND	GND	0	—
E_TEC D-	In	1.9	1100
E_TEC D+	In	1.9	1100
E_TEC R-	In	0 - 0.3	0.3
E_TEC R+	In	0 - 0.3	0.3
E_V+	In	4 to 12	50
E_V-	In	–12 to –4	50
E_Sensor	Out	E_V– to E_V+	35
E_Drive +	In	0 to 3	—
E_Drive -	In	0 to 3	—
E_GND	GND	0	—
Supply	In	5 to 5.5	4000
Sensor In	In	–1 to 1	0
Drive	—	–3 to 3	50
Freq. Out	Out	–3 to 3	50