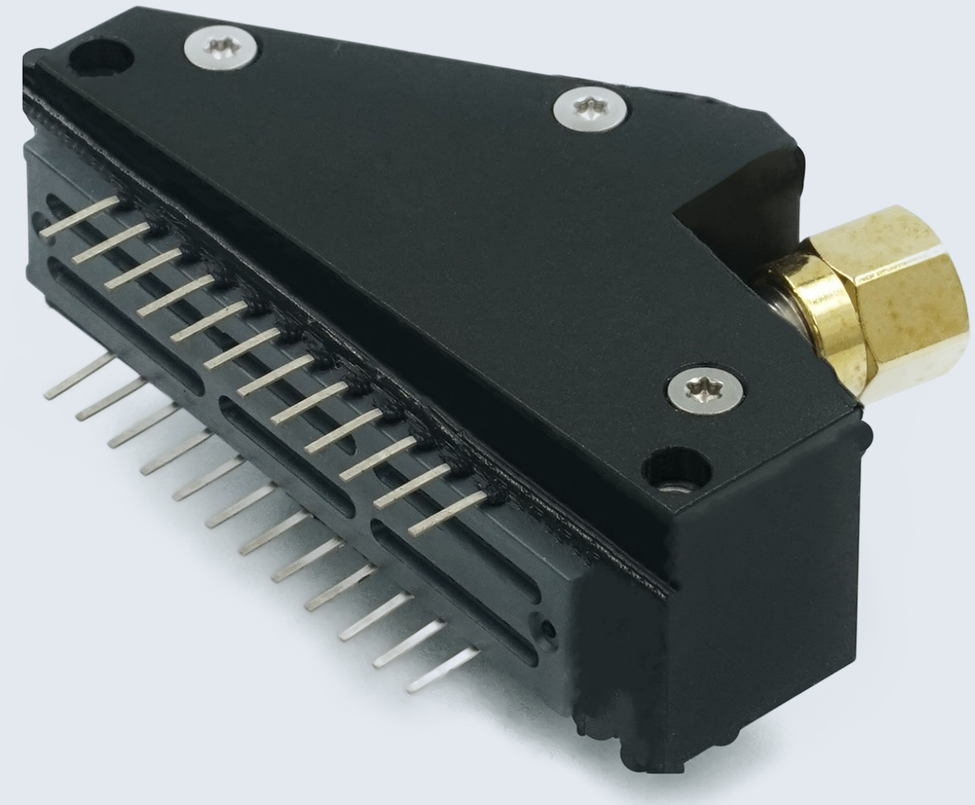
FREEDOM
Compact and Versatile OEM Spectrometers from Ibsen Photonics

Ibsen photonics



FREEDOM Platform – Versatile UV-VIS-NIR OEM Spectroscopy

The FREEDOM platform is Ibsen Photonics' most versatile spectrometers platform, which enables measurements in a wavelength range of 190 nm deep UV to the near-infrared region at 1100 nm, depending on the chosen model. Models can be supplied with three different detector options as standard and slit width is configurable at the time of purchase to best balance optical resolution and throughput to suit the end application. Packaged in a robust, compact, and athermal spectrometer body, with a 0.16 numerical aperture, the spectrometer can be optimized for use in different applications. The spectrometer can be supplied with electronics for either a standard USB interface, SPI communication useful in most hardware integrations, or without any accompanying electronics, allowing full control of the electronics design interface.

Key Specifications of the FREEDOM Platform

- Wavelength ranges:
  190-435, 360-830 or 475-1100 nm
- Configurable input slit widths
- Able to be used with either SMA fibre or Free space coupling
- Resolution from 0.7 nm (190-435), 1.3 nm (360-830) and 1.7 nm (475-1100)
- High NA of 0.16 (f-number 3.1)
- Highly efficient transmission grating designs (Peak DE up to 85%)
- Three different detector types to choose from
- Optional accompanying control electronics

Layout and Design

The FREEDOM family of spectrometers are all based on Ibsen Photonics' MGM platform utilizing high reflectivity coated collimating and focus mirrors, in combination with Ibsen Photonics transmission grating. The nature of the athermal design enables very low temperature induced wavelength shift of < 0.02 nm/°C.

Flexibility

The flexible nature of the mechanical design allows for several different input options that can be configured at the time of order.

With the choice of three different wavelength ranges, three different detector types, and five standard slit widths, a total of 45 configurations for the FREEDOM spectrometer family is offered as standard, thereby ensuring that no matter the application, the optimum solution can be found.

All FREEDOM spectrometers accept either a standard SMA905 input fiber or free space coupling via a focus lens as the input.

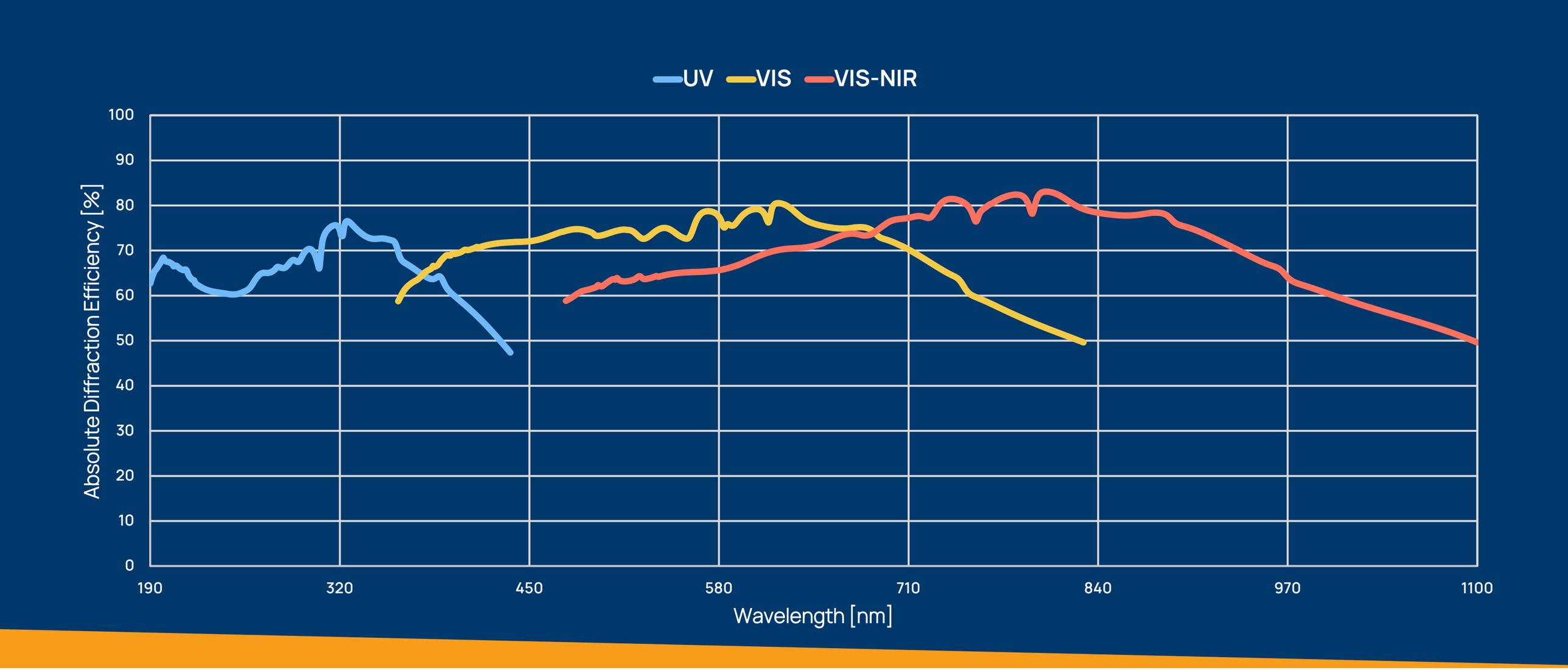
The three standard detector options allow for choices that either prioritize cost-effectiveness, flat spectral response, or low read-out noise. Ibsen can also build customized spectrometers to suit specific requirements.

If the solution you are looking for is not suited for the standard products we offer, reach out to our sales team to discuss the optimal solution for your spectrometer project.

Technical Specifications

		FREEDOM UV	FREEDOM VIS	FREEDOM VIS-NIR
Spectral range		190-435 nm	360-830 nm	475-1100 nm
Wavelength accuracy		≤ 0.24 nm	≤ 0.24 nm	≤ 0.24 nm
Resolution*	Slit width 12.5 µm 35 µm 50 µm 70 µm 125 µm	 0.7 nm 1.3 nm 1.9 nm 2.7 nm 4.9 nm	 1.3 nm 2.5 nm 3.6 nm 5.1 nm 8.8 nm	 1.7 nm 3.8 nm 5.3 nm 7.5 nm 12.5 nm
Slit height		250 µm	250 µm	250 µm
Numerical aperture		0.16	0.16	0.16
Stray light	Monochromatic input	< 0.03 % (at ± 10 x FWHM from peak)	< 0.03 % (at ± 10 x FWHM from peak)	< 0.03 % (at ± 10 x FWHM from peak)
Detector				
101	CMOS	Hamamatsu S11639N-01 2048 x 1 pixels (1000 used pixels) 14 x 200 µm pixel size SNR 380:1 Dynamic range 2150:1	Hamamatsu S11639N-01 2048 x 1 pixels (1000 used pixels) 14 x 200 µm pixel size SNR 380:1 Dynamic range 2150:1	Hamamatsu S11639N-01 2048 x 1 pixels (1000 used pixels) 14 x 200 µm pixel size SNR 380:1 Dynamic range 2150:1
305	BT-CCD	Hamamatsu S10420-1006 1024 x 64 pixels 14 x 14 µm pixel size SNR 542:1 Dynamic range 4800:1	Hamamatsu S10420-1006 1024 x 64 pixels 14 x 14 µm pixel size SNR 542:1 Dynamic range 4800:1	Hamamatsu S10420-1006 1024 x 64 pixels 14 x 14 µm pixel size SNR 542:1 Dynamic range 4800:1
380	BT-CCD	Hamamatsu S11156-2048-02 2048 x 1 pixels (1000 used pixels) 14 x 1000 µm pixel size SNR 350:1 Dynamic range 3000:1	Hamamatsu S11156-2048-02 2048 x 1 pixels (1000 used pixels) 14 x 1000 µm pixel size SNR 350:1 Dynamic range 3000:1	Hamamatsu S11156-2048-02 2048 x 1 pixels (1000 used pixels) 14 x 1000 µm pixel size SNR 350:1 Dynamic range 3000:1
Interface		SPI or USB 2.0	SPI or USB 2.0	SPI or USB 2.0
Temperature induced drift		< 0.02 nm/ °C	< 0.02 nm/ °C	< 0.02 nm/ °C
Operating temperature range	Non-condensing	0 °C to +50 °C	0 °C to +50 °C	0 °C to +50 °C
Storage temperature range	Non-condensing	-40 °C to +65 °C	-40 °C to +65 °C	-40 °C to +65 °C
Dimensions	Excluding electronics	25 x 48 x 16 mm	25 x 48 x 16 mm	25 x 48 x 16 mm
Weight	Excluding electronics	35 grams	35 grams	35 grams

*Typical values with the Hamamatsu S11639 detector



Transmission Gratings

The FREEDOM spectrometer platform utilizes three different grating designs for either the UV, VIS, or VIS-NIR region. All gratings provide a high symmetrical diffraction efficiency, as evident by the absolute diffraction efficiency graph displayed above. A noteworthy specification is that all listed diffraction efficiencies are absolute values, that account for any absorbance by the material or unwanted reflections from the grating's surface.

Additionally, the grating itself, ensures great wavelength stability due to the inherent self-corrective nature of transmission gratings, compensating for misalignment, shock, or vibrations that the spectrometer may experience. The designs also provide very low polarization dependence as an added benefit.

Every grating used in the FREEDOM spectrometer platform is a master grating, fabricated at Ibsen Photonics' clean-room facility in Denmark.

Spectrometer Input Coupling

Ibsen Photonics' FREEDOM spectrometer line-up, is equipped with a standard SMA905 fiber adapter and numerical aperture 0.16 input. This allows for the use of either standard fiber coupling via SMA, or free-space coupling using focusing optics.

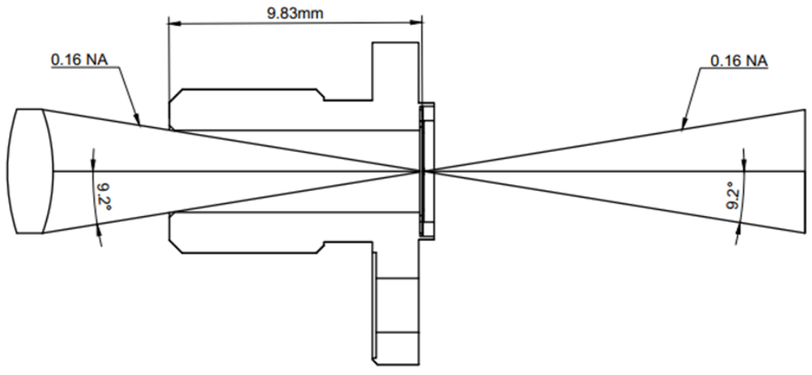
Slit options are configurable at the time of purchase with standard options and the corresponding resolutions are listed in the table below. Customized slit dimensions are available upon request.

	Slit width [µm]	12.5	35	50	70	125
FREEDOM UV	Typical Maximum	0.7 nm 0.9 nm	1.3 nm 1.5 nm	1.9 nm 2.1 nm	2.7 nm 2.9 nm	4.7 nm 5.2 nm
FREEDOM VIS	Typical Maximum	1.3 nm 1.5 nm	2.5 nm 2.8 nm	3.6 nm 4.0 nm	5.1 nm 5.5 nm	8.8 nm 9.8 nm
FREEDOM VIS-NIR	Typical Maximum	1.7 nm 2.3 nm	3.8 nm 4.2 nm	5.3 nm 5.8 nm	7.2 nm 8.0 nm	12.5 nm 14 nm

To ensure maximization throughput of the spectrometer, it is required to fully illuminate the full slit and numerical aperture homogenously. Over-illumination of the spectrometer's 0.16 numerical aperture, such as using a 0.22 numerical aperture fiber, is perfectly valid and handled by internal apertures as part of the spectrometer's optical design.

Free Space Coupling

The illustration below displays a cross-section of the input SMA adapter used in a free space coupling setup, with the lens illuminating the slit. The physical dimensions of the adapter can accept a maximum numerical aperture of 0.16, which allows for filling out the entire numerical aperture of the FREEDOM spectrometer. It is important to use a lens or other focusing optics to ensure proper and even illumination of the spectrometer's numerical aperture.

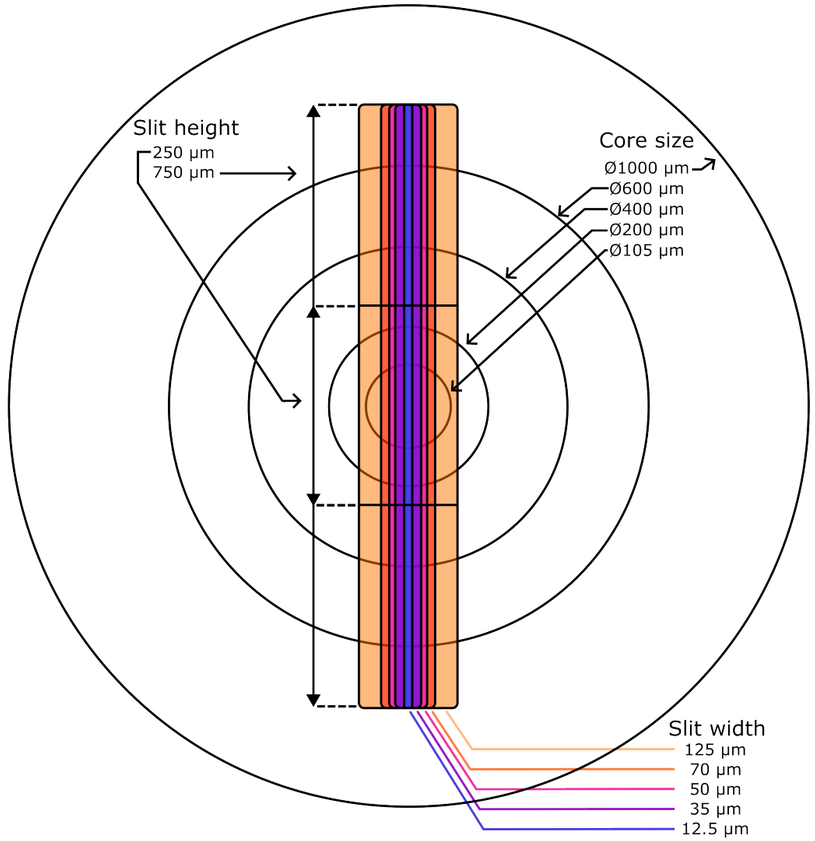


Optical Fiber Coupling

Optical fiber coupling is most often used for its convenience with regard to lack of alignment and ease of setup process.

For best signal strength, the diameter of the optical fiber core should be chosen such that the entire slit is illuminated evenly. The standard slit height of FREEDOM spectrometers is 250 µm, and the optical fiber core size should be larger than this to ensure the best performance.

The common size available would be 400 µm or 600 µm diameter core. The below illustration shows the different optical fiber sizes concerning the series of standard slit sizes, offered for the FREEDOM spectrometer platform.



Detectors

The FREEDOM spectrometer platform supports three different types of detectors as standard, to cater to whichever requirements a particular application might have. These different detectors are referred to via the last three numbers of the spectrometer product name, namely 101, 305, or 380.

101 - Hamamatsu S11639N-01

Hamamatsu S11639N-01 detector provides a well-rounded performance in a cost-effective package, making it the most popular choice.

This detector has a 2048 x 1 pixels layout, with 14 x 200 µm tall pixels, that allows for better coupling with the spectrometer slit's dimensions.

The quantum efficiency remains high, even down into the deep UV spectral region, while a high conversion factor and shallow well depth make this particular detector especially sensitive. Combined with fast exposure times of down to 10.8 µs, robust nature, and simple CMOS readout logic, it makes it the detector of choice for most applications.

305 - Hamamatsu S10420-1006

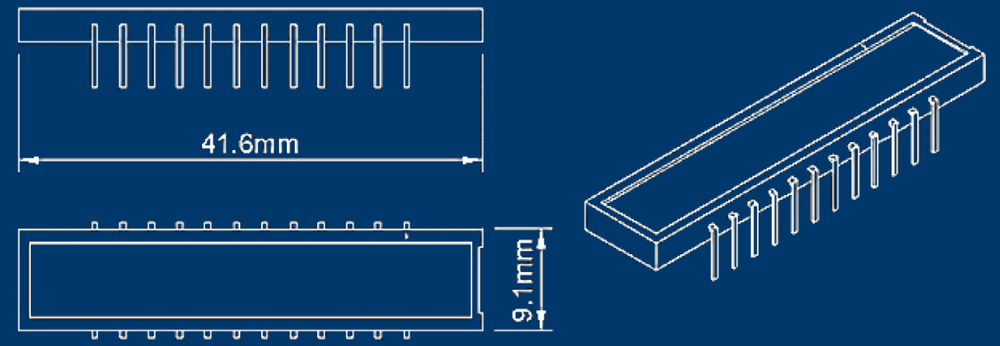
This Hamamatsu S10420-1006 detector is optimized towards low read-out noise, making it the detector of choice when working with applications where either signal strength is low or the signal-to-noise ratio is the primary concern. The back-thinned CCD provides an excellent and smooth quantum efficiency throughout its entire spectral range while being optimized to exhibit a significantly reduced etalon effect compared to most back-thinned CCDs.

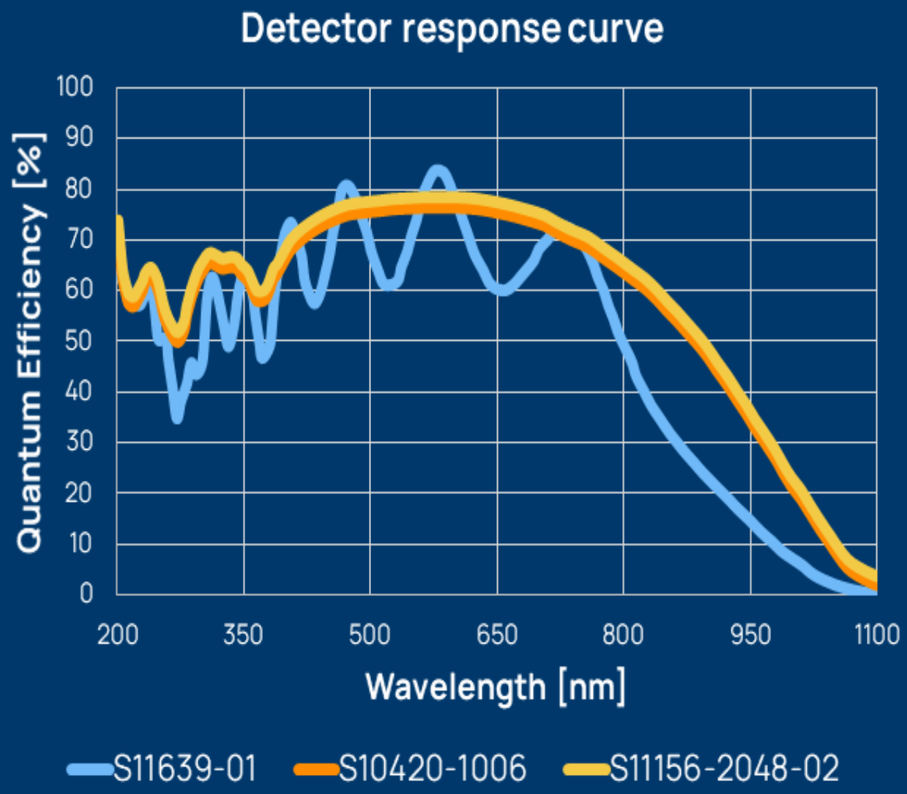
The detector has a 1024 x 64 pixels array, with square 14 x 14 µm pixels, creating an active array size of 14.336 x 0.896 mm.

380 - Hamamatsu S11156-2048-02

The Hamamatsu S11156-2048-02 is the fastest detector available as a standard detector for the FREEDOM spectrometer platform. The back-thinned CCD, has a 1D array of 2048 x 1 pixels with very tall 14 x 1000 µm pixels, allowing for more light to be captured per pixel. The detector electronics layout is comprised of a double side horizontal shift register, that allows for the tall pixels to be read impressively fast, with exposure times all the way down to 2 µs possible. This makes the S11156-2048-02 ideal for applications that require short and precise time-gating of the collected signals.

The exhibited quantum efficiency is identical to that of S10420-1006, with a smooth high level throughout the bandwidth and noticeably better performance at longer wavelengths compared to S11639N-01.





Electronics

Every FREEDOM spectrometer can be supplied with one of three different electronic configurations depending on the desired level of integration.

The spectrometer can be purchased without any accompanying electronics, giving direct access to the pins on the chosen detector. Alternatively, Ibsen Photonics can supply its Digital Image Sensor Boards (**DISB**), designed to operate the detector of choice via hardware commands over a Serial Peripheral Interface (**SPI**). The DISB electronics can also be supplied with a **DISB to USB Bridge** board, which converts the SPI connection to a standard USB 2.0 for convenient connection to a PC.

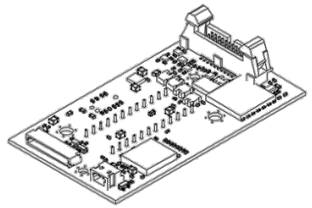
DISB electronics

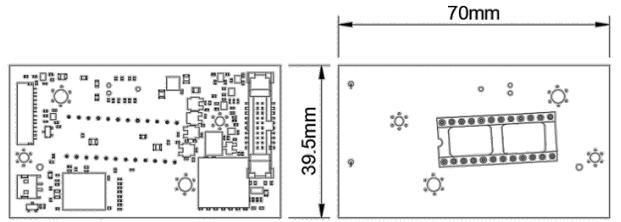
Three different DISB board options are available to accommodate the series of detectors offered as standard for the FREEDOM spectrometer platform. For S11639N-01 (101), DISB-101T can be supplied. Detector S10420-1006 (305) utilizes DISB-315 and finally, S11156-2048-02 (380) should be used with DISB-380.

All DISB platforms utilize the same SPI communication protocol, making it straightforward to move from one platform to another without having to change the hardware interface or code.

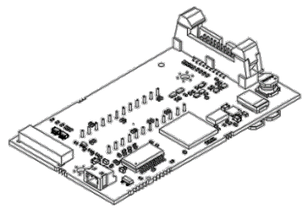
	DISB-101T	DISB-315	DISB-380
Read-out speed	600 Hz (2048 pixels)	165 Hz (1024 pixels)	600 Hz (2048 pixels)
A/D bit depth	16-bit	16-bit	16-bit
Communication interface	SPI	SPI	SPI
Software trigger	Yes	Yes	Yes
Ext. hardware trigger	Yes	Yes	Yes
Min. trigger delay	1.2 µs	2.939 ms	360 ns
Trigger jitter	10 ns	20 ns	10 ns
Time increments	200 ns	2 µs	200 ns
Exposure time	10.8 µs – 859 s	2.939 ms – 8589.9 s	2 µs – 859 s
On-Board calibration data	Yes	Yes	Yes
On-Board averaging	Yes	Yes	No
GPIO pinout	Yes	Yes	No
Programmable lamp control	Yes	Yes	No
Region of interest	Yes	Yes	No
Temperature sensor	Yes	Yes	Yes

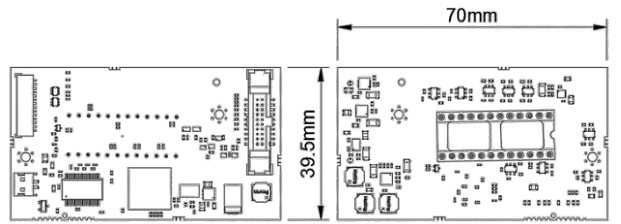
DISB - 101T



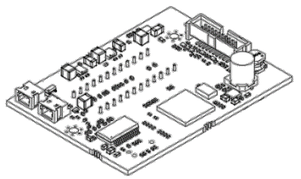


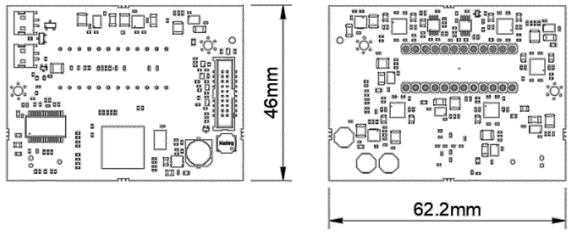
DISB - 315





DISB - 380





Software interfacing

The **DISB-to-USB bridge** board developed by Ibsen Photonics is an additional board that can be added to any spectrometer equipped with DISB electronics, to convert the DISB's SPI connection to a standard USB 2.0 connector, for convenient use via a standard PC.

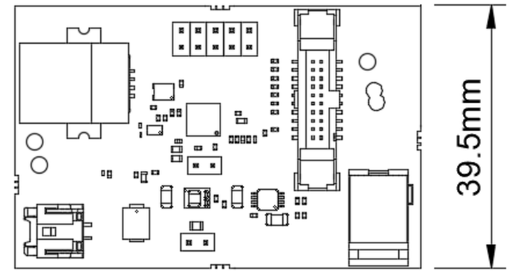
The DISB-to-USB board is based around the **FTDI FT4222H** chipset, with drivers available for Windows, Linux, or Mac. The entire USB protocol is handled in the chip with no requirement for specific complicated USB firmware programming.

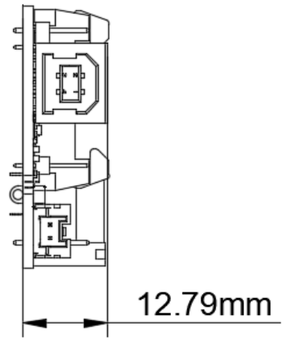
Ibsen Photonics supplies its LabVIEW-developed **Ibsen DISB-USB Evaluation software** as standard with the bridge board. This allows for the operation of the spectrometer and its features in a straightforward fashion using the Windows Operation system.

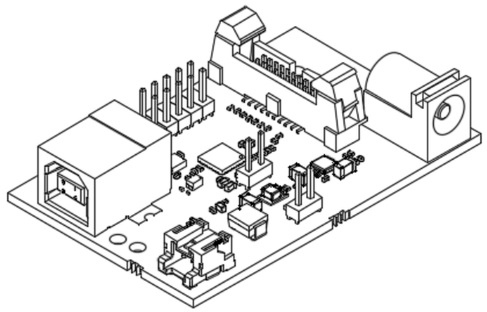
Additionally, an **SDK** is available for the Bridge board, allowing for simple, intuitive, and fast deployment of instruction sets and code via C/C++, C#, LabVIEW, Python, or MATLAB, via DLL and accompanying header files. The proprietary Ibsen command set allows for initialization, spectrum capturing, and closing of the spectrometer connection, with as little as three commands, as shown below.

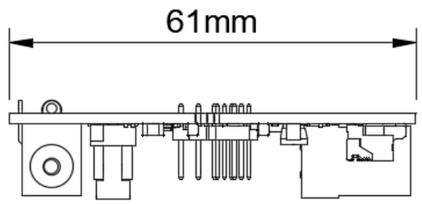
IBSEN_InitSpectrometer → **IBSEN_produceSpectra** → **IBSEN_closeDevice**

It is also possible to interface with FT4222H library files directly. Code samples using C/C++, C#, LabVIEW, and Python are available, if you need to develop your own implementation from the ground up.



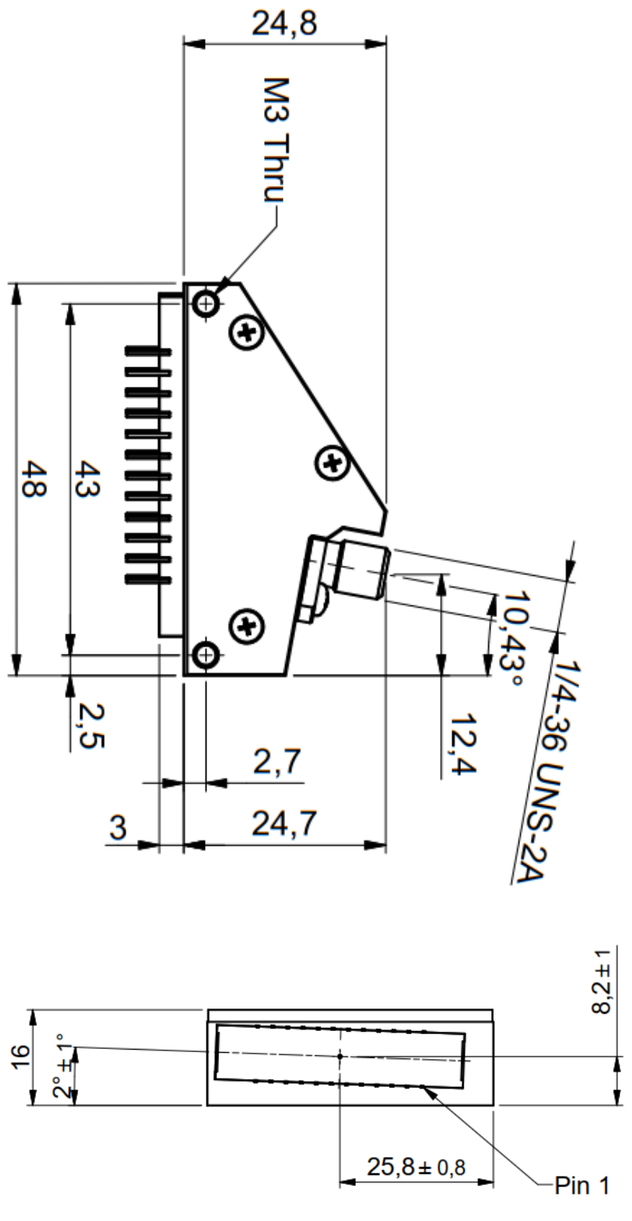




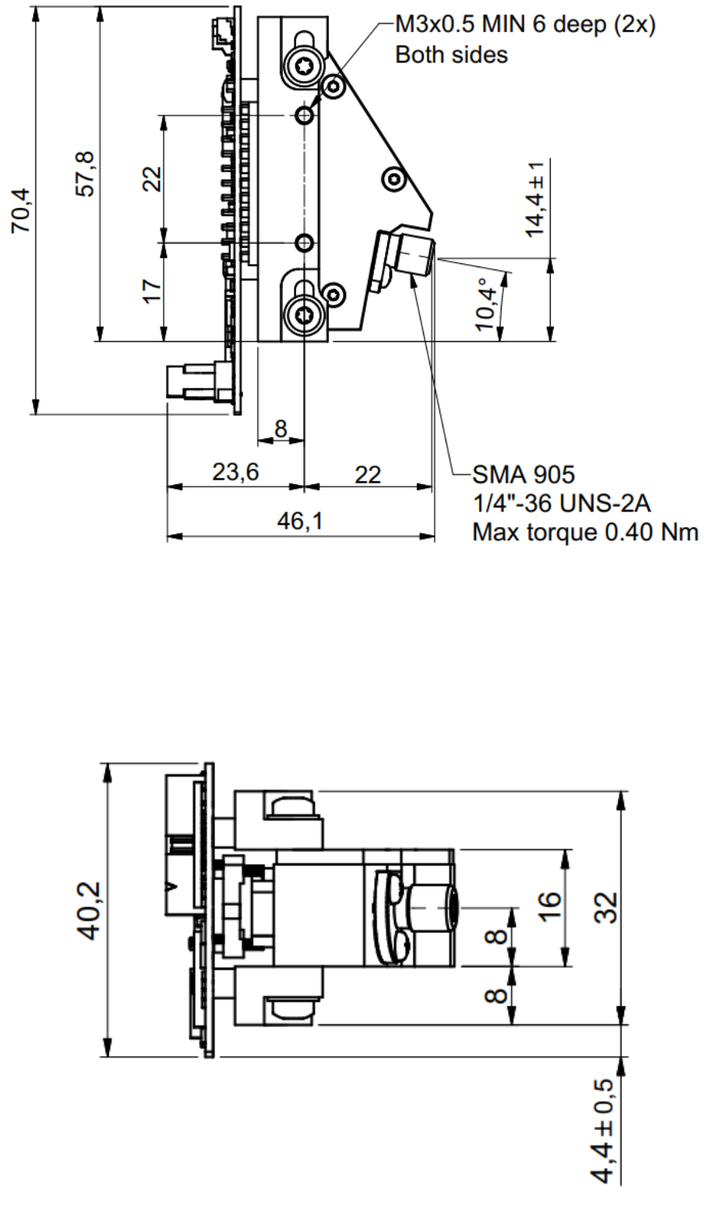


Mechanical Drawings

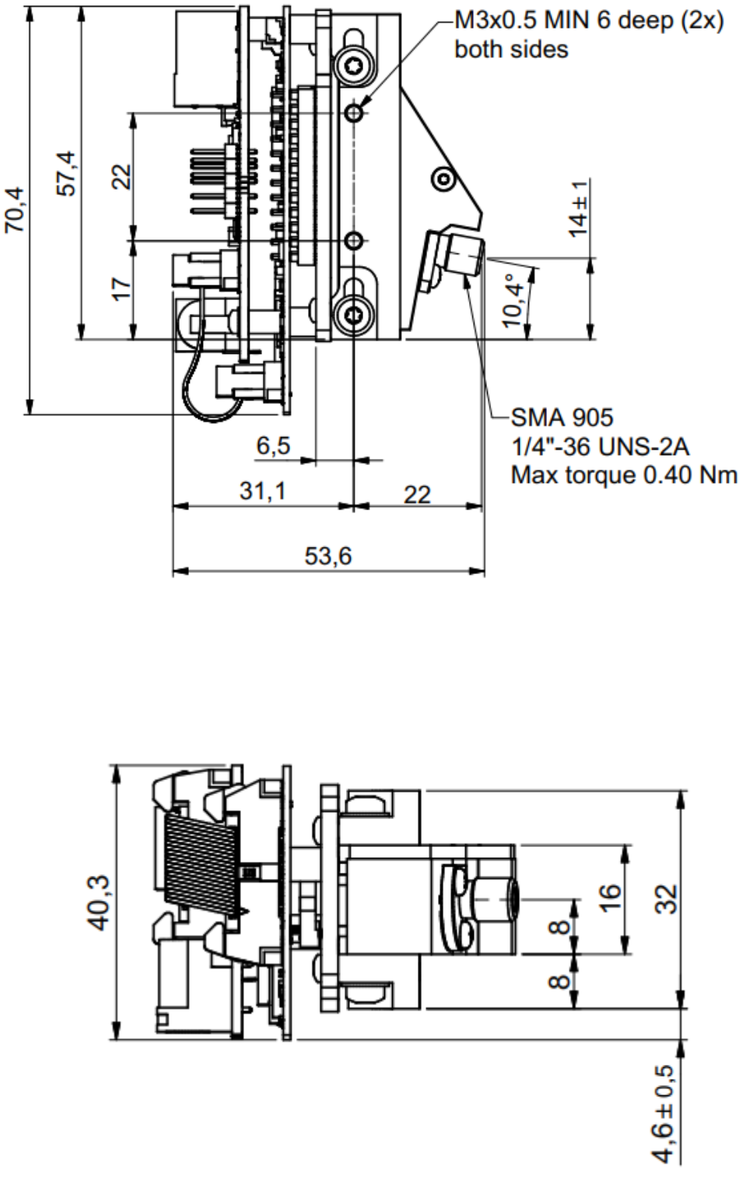
FREEDOM UV / VIS / VIS-NIR excluding DISB



FREEDOM UV / VIS / VIS-NIR including DISB-101T



FREEDOM UV / VIS / VIS-NIR including DISB-101T and DISB-USB



About Ibsen Photonics

Ibsen was founded in 1991 by Per Ibsen under the name of Ibsen Micro Structures A/S. Today 88% of Ibsen Photonics' share is majority owned by Foss A/S, a world leader in analytical solutions for the Food and Agricultural industries. Ibsen management and employees hold the remaining 12 % of the shares.

The Ibsen spirit combines the dynamic, entrepreneurial culture of a medium size company with a disciplined, operational mentality of a large corporation. With an average employee tenure of more than 10 years, Ibsen makes for a very effective organization that builds on more than 30 years of experience as a company.

Ibsen employs more than 90 people at our R&D and manufacturing facility in Denmark and has achieved a turnover of more than 180 MDKK in 2022.

Working with Ibsen Photonics

The core expertise of Ibsen Photonics lies in the opto-mechanical design, grating technology and metrology. We master the cycle from optics, grating simulation and design, through optical and semiconductor production technologies, to high volume assembly, packaging and testing. Over the years we have developed many new designs, technologies and processes - many patented.

Our customers are large to medium-sized manufacturers of advanced optical devices and instruments, into which our products are integrated. With a highly organized production process, we are able to help customers obtain smooth instrument production, low unit-to-unit variation, high level of right first time, no field returns, and a low level of rework.

Our grating production facilities are world-class, including class 10 cleanroom facilities that we designed and built in 2000/2001, in which all environmental parameters are under continuous surveillance.

Our spectrometers are produced under strict quality control in our assembly facility in Denmark. We have been granted ISO 9001, ISO 13485, ISO 14001 and ISO 45001. This confirms Ibsen's' consistent capability to produce high quality products that meet market standards and all regulatory requirements.

Contact us

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