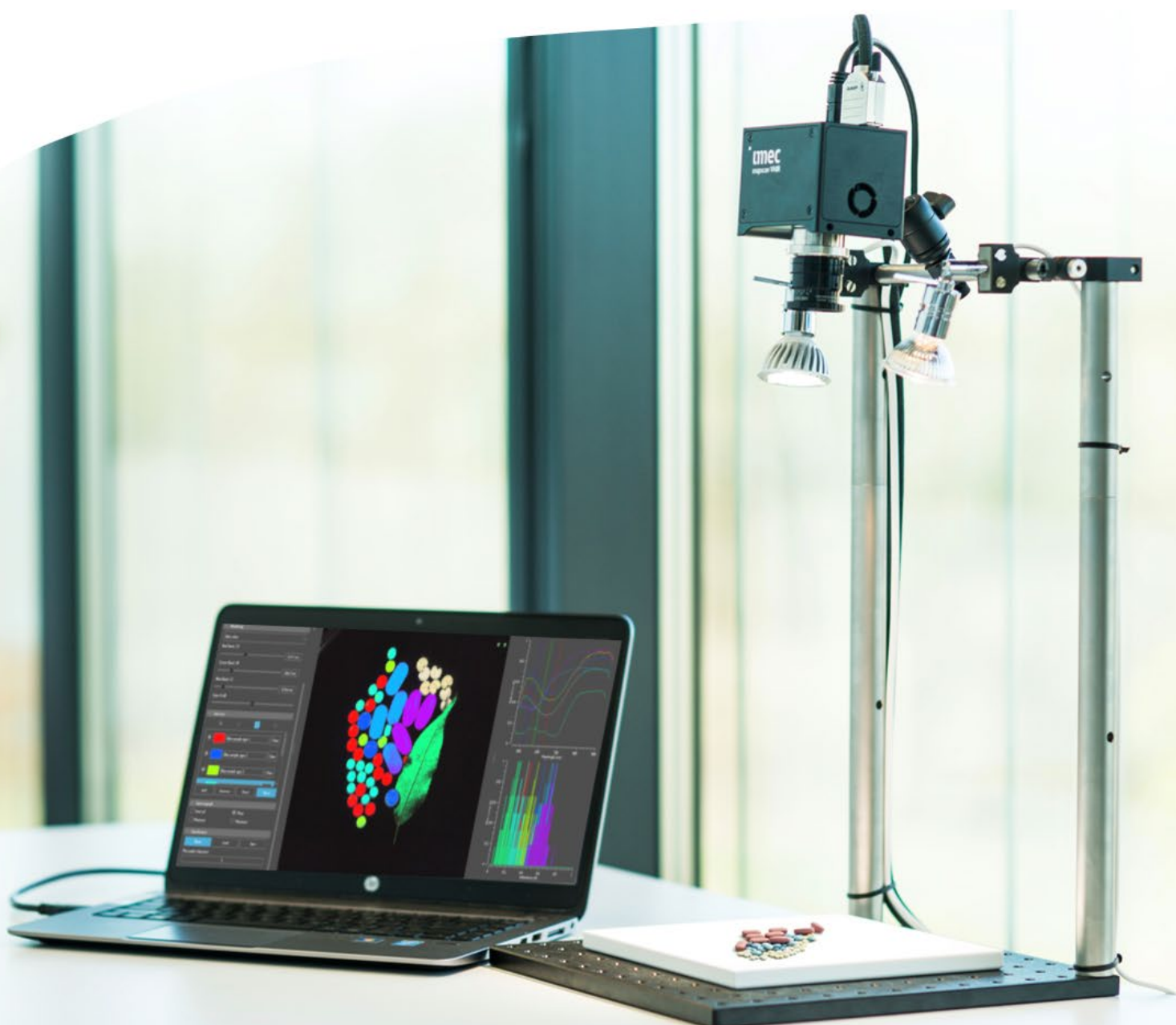




SNAPSCAN

HYPERSPECTRAL IMAGING CAMERA

SYSTEM USER MANUAL



snapscan VNIR range Hyperspectral Imaging Camera System User Manual

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Contents

I. Introduction	7
I.1 snapscan HSI sensor features	9
I.1.1 High resolution and fast sensor with 150+ spectral filters between 470-900nm	9
I.1.2 Integrated cut-off filters	9
I.1.3 Stepped filter layout (VNIR version)	10
I.1.4 Stepped filter layout (NIR version)	11
I.1.5 Narrow band spectral filters	12
I.2 snapscan camera unit features	13
I.2.1 Sensors and on-board electronics are housed in sealed dustproof chamber	13
I.2.2 Onboard cooling maintains operating temperature between 35°C to 45°C	13
I.2.3 Integrated software controlled mechanical shutter	14
I.2.4 Flexibility to select specific spectral range using inter-changeable filters	14
I.2.5 High resolution (spatial and spectral) data acquisition while keeping both the object and the camera stationary	15
I.2.6 Multiple mounting options	15
I.3 snapscan software features	16
I.3.1 Extensive data acquisition customization features	16
I.3.2 Built-in white balancing	16
I.3.3 Multiple file format options for data export options	16
I.3.4 Integrated classifier	17
I.3.5 Support for 3 rd party HSI analysis software	17
I.3.6 Multiple data visualization options	17
I.3.7 Support for multiple languages	17
I.4 snapscan API features	17
2. Working principle	20
2.1 Linescan hyperspectral camera systems	20
2.1.1 Imec hyperspectral linescan vs Traditional hyperspectral linescan	20
2.1.2 Imec hyperspectral linescan vs snapscan	20
2.1.3 Imec hyperspectral camera selection guide	22
2.2 Imec snapscan hyperspectral camera	23
2.2.1 Image acquisition	23
2.2.2 Integrated translation platform	23
2.2.3 Acquisition modes	24
2.2.4 Acquisition features for higher data quality	24
2.2.5 Image post processing	28
2.3 Illumination	30
3. Evaluation System Assembly Manual	34
3.1 Assembly steps	34
3.1.1 Step 1 - Unpack and crosscheck the contents	35
3.1.2 Step 2 - Assemble the base plate	40
3.1.3 Step 3 - Assemble the camera holder posts and tripod mount	41
3.1.4 Step 4 - Assemble the lamp holder posts and mount the lamps	46
3.1.5 Step 5 - Mount the snapscan camera	51



3.1.6	Step 6 - Connect the lamps to the power supply	56
3.1.7	Step 7 - Connect the camera to the controller and PC	58
3.2	Demo setup	65
3.3	Troubleshooting	66
4.	Hardware manual	70
4.1	Mechanical specifications	70
4.1.1	External controller dimensions	70
4.1.2	Camera dimensions	71
4.1.3	Flange focal distance	72
4.1.4	Camera mounting options	72
4.1.5	Filter cassette dimensions	74
4.2	Electrical specifications for snapscan controller's GPIO interface	75
4.3	Operating conditions	75
4.4	Storage conditions	76
4.5	Maintenance tips	76
4.5.1	Preventive maintenance	76
4.5.2	Regular maintenance	76
4.5.3	Corrective maintenance	76
5.	Software Installation Manual	79
5.1	System requirements for the PC	79
5.2	Software installation	80
5.2.1	perClass Mira installation	81
5.3	Software configuration	82
5.4	Troubleshooting	84
6.	Software User Manual	88
6.1	General	88
6.2	Cube acquisition mode	89
6.2.1	Connect step	89
6.2.2	Configure step	90
6.2.3	Acquire step	95
6.3	Cube display mode	107
6.3.1	View step	111
6.3.2	Export step	126
6.4	Tutorial	129
6.4.1	Basic configuration	129
6.4.2	Tuning focus, aperture and acquisition parameters	130
6.4.3	Typical acquisition scenarios and recommended parameter settings	131
6.5	Support for 3 rd party software	133
6.5.1	perClass Mira	133
6.6	Troubleshooting	134
7.	Applications	138



7.1	Microscopy	138
7.2	Fundus imaging	138
7.3	Skin/ wound imaging	139
7.4	Outdoor imaging	140
7.5	Art & antiquities conservation	140
7.6	Mineralogy	141
7.7	Pharmaceuticals	141
7.8	Food quality grading and sorting	142
8.	Appendix – Glossary and Shortcuts	145
8.1	Glossary	145
9.	Appendix - Software changelog	146
9.1	snapscan v1.2.0	146
9.2	snapscan v1.1.2	146





Chapter I

Introduction

I. Introduction

Congratulations on your purchase of imec's snapscan evaluation system. Imec's snapscan system is a major breakthrough for hyperspectral imaging application research. Within as little as a few hundred's of milliseconds, high quality hypercube data-sets can be created with unmatched signal-to-noise ratio and spatial and spectral resolution. The snapscan demo-kit enables application research of the highest quality, while still being user-friendly. It integrates all key components required: the spectral image sensor, camera, optics, piezo scanning, active cooling system, lighting, tripod mounts, and snapscan software (an advanced hyperspectral imaging software developed by the imec team).

The key benefits of Imec's snapscan hyperspectral imaging system are:

- Snapshot acquisition made easy and user-friendly with integrated ultrasonic scanning mechanism directly inside the camera to reach sub-second acquisition times
- Highest spatial (up to 7Mpx) & spectral (150+bands) resolutions possible for snapshot-based hyperspectral imaging in a compact, lightweight and mass-manufacturable design
- Highest SNR ever reached with imec on-chip filter technology thanks to active cooling and advanced software features for cube reconstruction and spectral correction



The contents of the snapscan evaluation system are shown in Table I and the product specifications are shown in Table 2.



Table 1 Contents of the snapscan evaluation system

snapscan camera system	- snapscan camera with integrated sensor - controller box - Schneider Kreuznach lens - USB3.0 cable, custom 16 pin cable and power supply - case for storage
Components for illumination setup	- mounting setup with vibration dampening - halogen lighting solution with diffusers - tunable stabilized DC power supply
Targets for calibration	- reflectance tile 95%, 200 x 200 mm - color checkerboard card

Table 2 Product specifications of the snapscan system

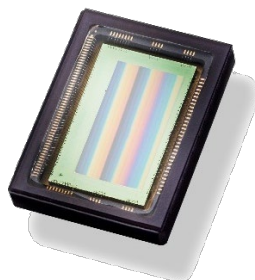
Spatial resolution	up to 3650 x 2048 pixels (7Mpx RAW per band)
Spectral resolution	100+ bands (NIR version), 150+ bands (VNIR version)
Spectral range	600-970nm (NIR version), 470-900nm (VNIR version)
FWHM	~10-15nm (collimated)
Acquisition speed	~200ms – 20 seconds, depending on acquisition parameters, lighting and object (without including pre- and post-processing time)
SNR	>100-200, flat SNR over spectral range
Software scanning modes	Software TDI (x5-8 stages max) Multi-exposure HDR (high dynamic range) Digital binning (2x2, 3x3, 4x4) Spectral Region of Interest (1 to 8 regions maximum) Spatial Region of Interest (2048 x custom scanning length)
Dynamic range	8/10 bit
Optics	Schneider Kreuznach Apo-Xenoplan lens, f2.0, C-mount Focal length options: 20/24/35/50 mm lenses
Smile & keystone	Software corrected
Interface	USB3.0 + GPIO + I/O for triggering
Cooling	Passive & active cooling (fan based + TEC)
Cooling range (sensor)	35 - 45°C
Temperature	10 - 40°C (operation), 5 - 50°C (transport)
Mechanical	Integrated mechanical shutter for automatic dark counts, Tripod mount (1/4"-20) + side mounting M5 holes
Dimensions (WxDxH)	10x7x7 cm (camera), 13x10x4 cm (external controller)
Dimensions (integrated rejection filter)	Diameter - 25.4mm, Maximum thickness - 3.44mm
Weight	580g (camera without optics), 400g (external controller)
Input voltage	24V DC 2.7A (external controller)



This manual will help you get started and guide you through system assembly, software installation and the usage of software and hardware. We begin by giving you a quick overview of salient features of the snapscan image sensor, camera system and software.

1.1 snapscan HSI sensor features

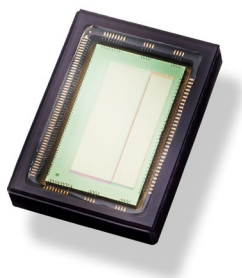
1.1.1 High resolution and fast sensor with 150+ spectral filters between 470-900nm



snapscan camera integrates linescan HSI sensor based on CMOSIS CMV2000¹ image sensor. The key specifications of this HSI sensor are shown in the table below.

Spatial resolution – sensor	1088 (H) x 2048 (V) pixels
Spectral range	470-900nm (600-970nm for NIR version)
Spectral resolution	150+ bands (100+ bands for NIR version)
Spatial resolution per band	up to 3650 (H) x 2048 (V) pixels (up to 7Mpx RAW per band)
Sensor frame rate	up to 340 fps (full sensor frame)
Bit depth	8/10 bit
FWHM	~10-15nm (collimated)

1.1.2 Integrated cut-off filters

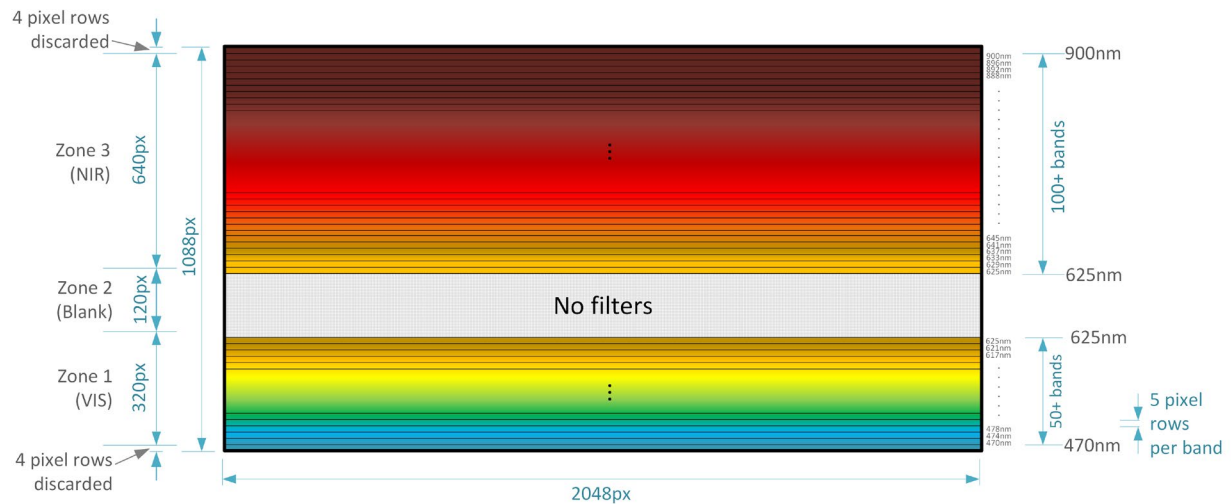


The cut-off filters are integrated on the sensor directly which simplifies the usage of the camera.

¹ <https://ams.com/cmv2000>



1.1.3 Stepped filter layout (VNIR version)



The pixel array of the VNIR HSI sensor is divided into following 3 zones:

Zone 1 (VIS)	Pixels with spectral filters between 470-625nm
Zone 2 (Blank)	Pixels in this zone do not have any filters. This zone is provided to allow tolerance in the alignment of cut-off filters for the VIS and NIR zones. Pixels in this zone are discarded in the final hyperspectral data cube reconstruction.
Zone 3 (NIR)	Pixels with spectral filters between 625-900nm

Physically there are more than 150 spectral bands on the HSI sensor. However, due to manufacturing variations, several spectral bands on the lower and upper ends of the zones can be unusable. Thus, we guarantee at least 150 usable spectral bands between 470-900nm. There can be few extra spectral bands available which can vary across the HSI sensors.

i Central wavelengths (CWL) indicated in the figure above are for illustration purpose only. The actual CWL of spectral bands are determined based on individual sensor calibration. This information is provided in the sensor calibration file provided with the camera.

Specifications for a spectral band in the VIS and NIR zones are as follows:

Spatial resolution	5(H) × 2048(W) pixels
Layout	Filters are arranged adjacent to each other in increasing order of their central wavelength

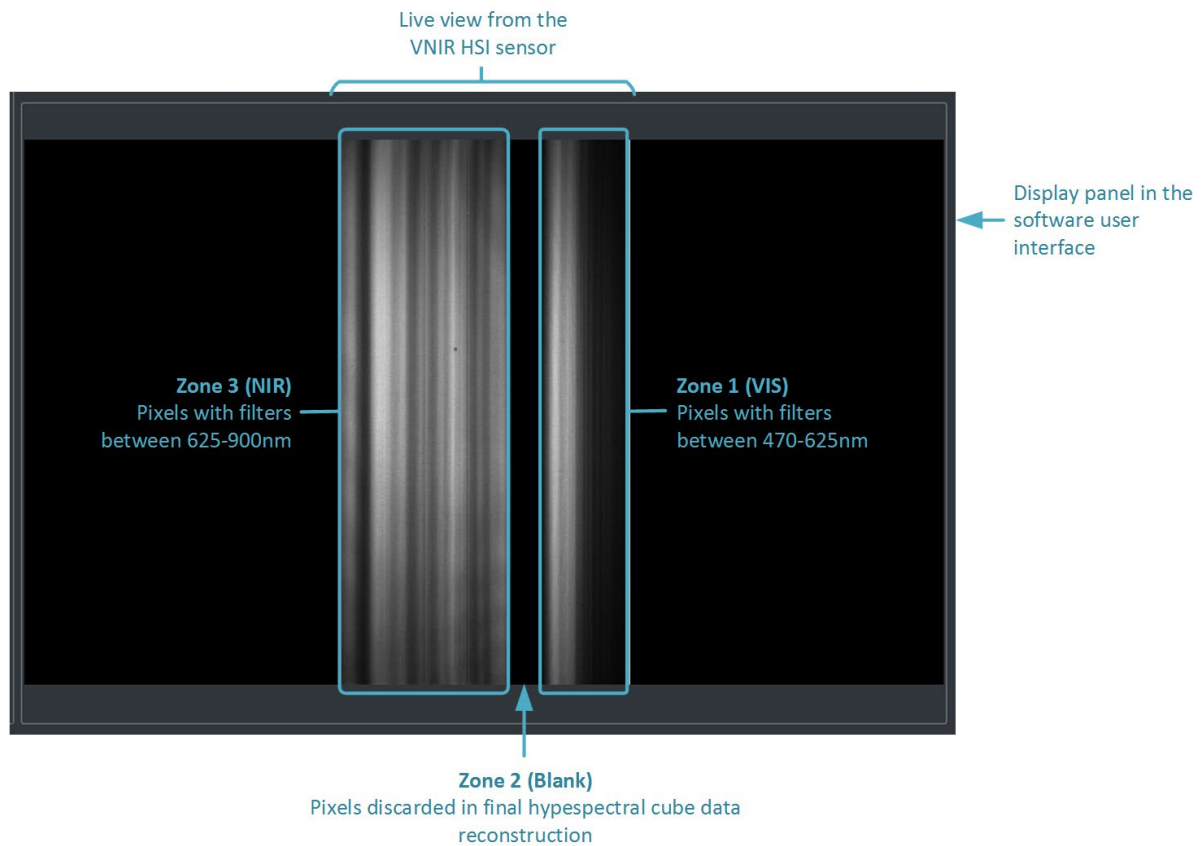
Thus, each spectral band is 5 pixel-rows high. We refer to it as the **“stepped” filter design** which provides the flexibility to select the step size (in terms of pixel rows) for the translation of the HSI sensor inside the camera body (see Section 1.2).

- Step sizes between 1 and 5 (height of a spectral band) can be selected
- Larger step sizes enable faster image acquisition whereas smaller step sizes can be used to improve the data quality.

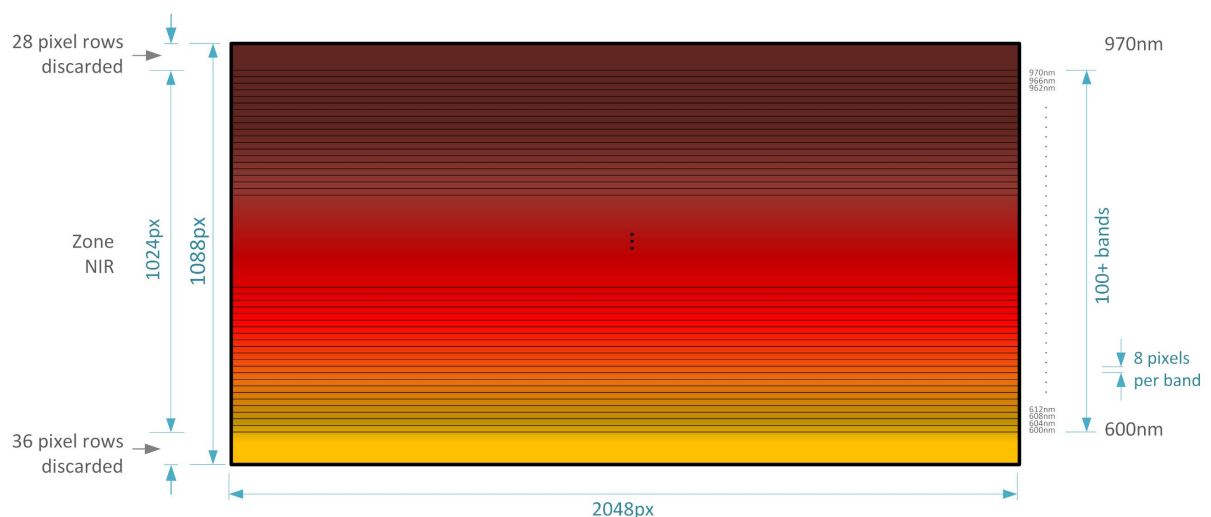
i See Section 2.2.4 “Acquisition features for higher data quality” for explanation on features such as cross talk removal by pixel row skipping and software time delay integration



The live view from the VNIR HSI sensor is shown in the figure below. The three zones can be seen in the live view.



1.1.4 Stepped filter layout (NIR version)



The pixel array of the NIR HSI has only one zone, i.e. the NIR zone having pixels with spectral filters between 600-970nm. Physically there are more than 100 spectral bands on the HSI sensor. However, due to manufacturing variations, several spectral bands on the upper end of the spectral range can be unusable. Thus, we guarantee at least 100 usable spectral bands



between 600-970nm. There can be few extra spectral bands available which can vary across the HSI sensors.

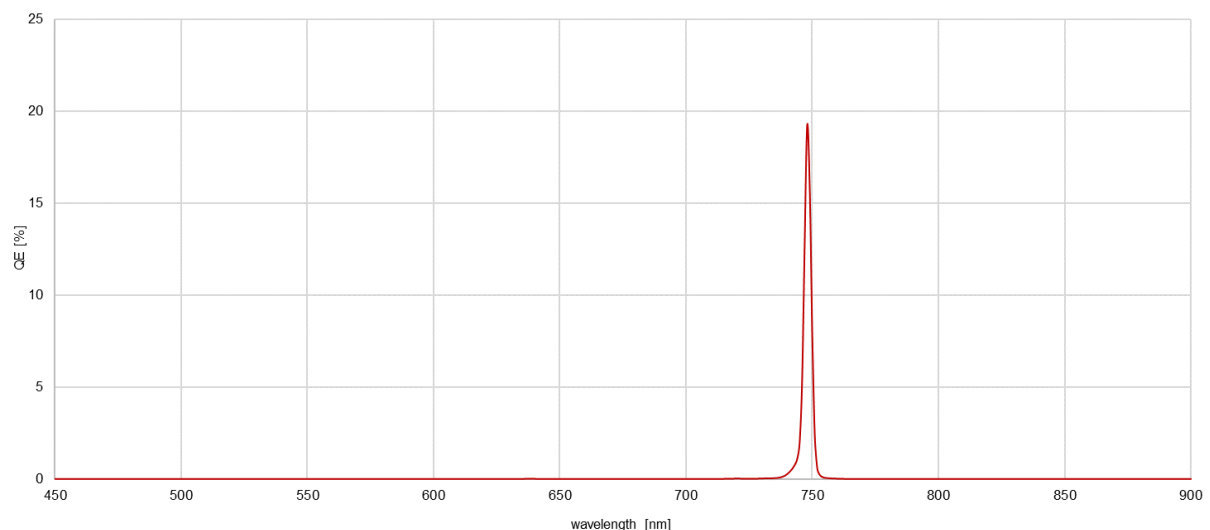
i Central wavelengths (CWL) indicated in the figure above are for illustration purpose only. The actual CWL of spectral bands are determined based on individual sensor calibration. This information is provided in the sensor calibration file provided with the camera.

Specifications for a spectral band are as follows:

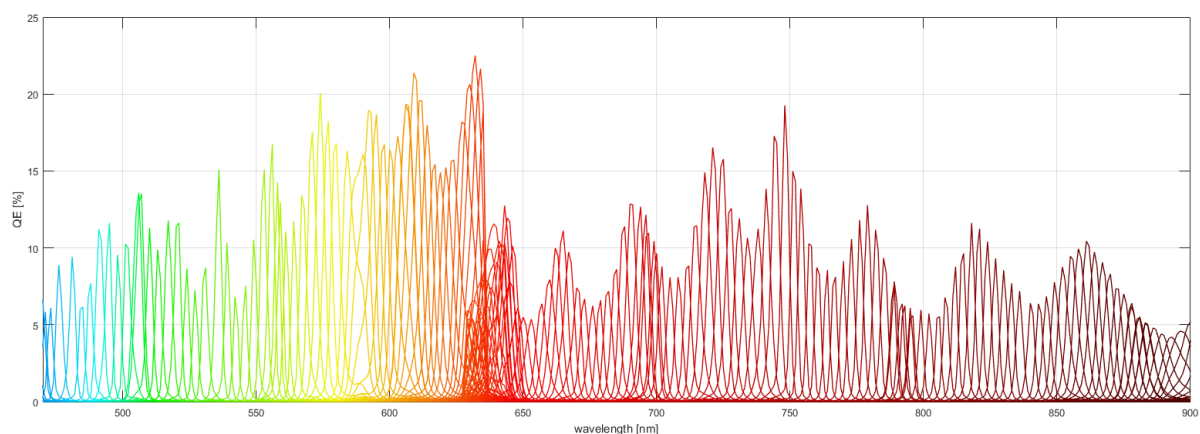
Spatial resolution	8(H) × 2048(V) pixels
Layout	Filters are arranged adjacent to each other in increasing order of their central wavelength

This sensor also uses the **“stepped” filter design** as discussed earlier for the VNIR HSI sensor.

1.1.5 Narrow band spectral filters



Each of the 150+ spectral filter is a narrow band filter with FWHM between 2-10nm. The figure above shows the spectral response of a filter with central wavelength at 748nm and FWHM of 4.9nm. The figure below shows spectral response for all the filters.



I.2 snapscan camera unit features

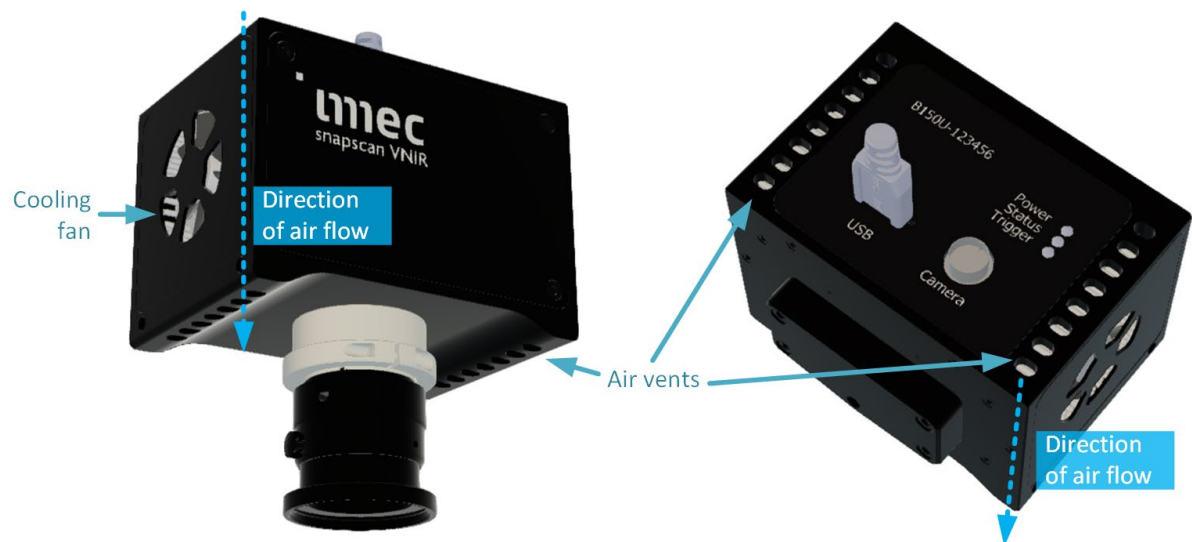
I.2.1 Sensors and on-board electronics are housed in sealed dustproof chamber



The image sensor and all the on-board electronics in the snapscan camera is housed in a sealed chamber making it dustproof. The air through the air vents on the left and right sides of the camera body does not enter the chamber.

i Currently not IP rated. Camera internals are sealed from exterior when lens is mounted.

I.2.2 Onboard cooling maintains operating temperature between 35°C to 45°C

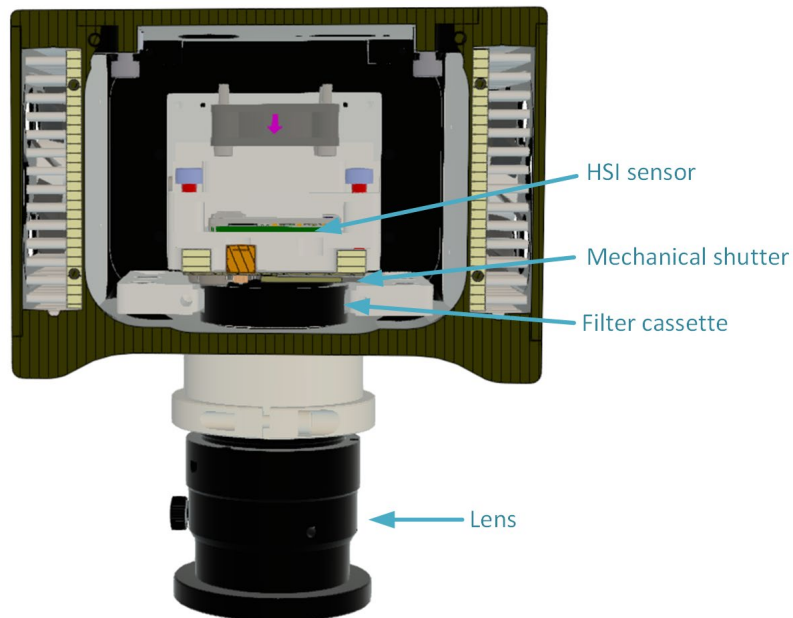


snapscan integrates 3 cooling fans, 3 heat sinks and a thermoelectric cooler (TEC). There is a set of cooling fan and a heat sink on both the left and the right sides of the camera. The third cooling fan and the heat sink, and the TEC is directly behind the HSI sensor inside the chamber housing the HSI sensor, integrated translation stage and on-board electronics.



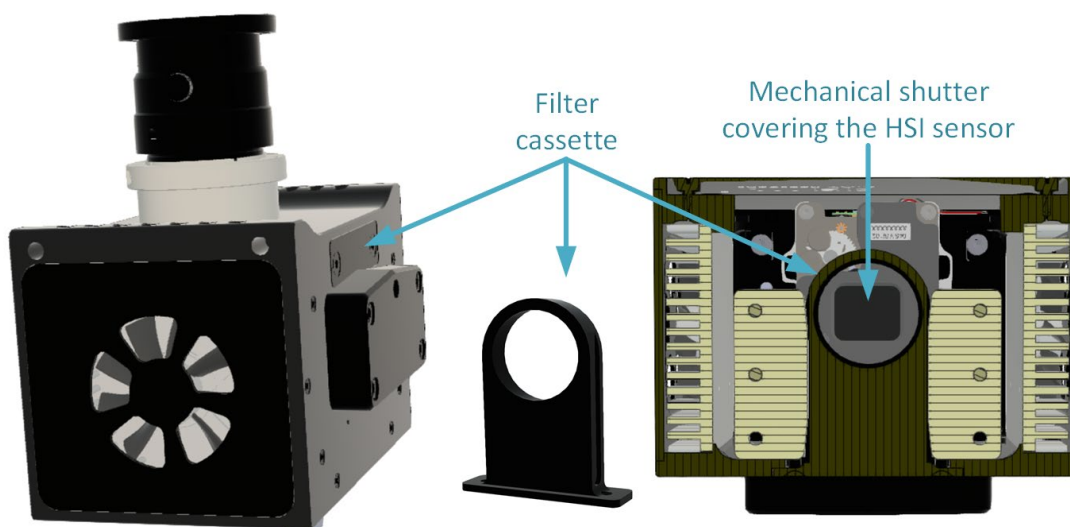
The TEC, heat sink and the cooling fan helps in cooling the HSI sensor board and evacuate the heat from the camera chamber. In future, software control of TEC will be enabled which will help in better local cooling of the hotspots of the HSI sensor board. The heat sinks and the cooling fans on the sides help in evacuating the heat from the camera body by generating an air flow as shown in the figure below.

1.2.3 Integrated software controlled mechanical shutter



snapscan integrates a software controlled mechanical shutter which is placed in front of the HSI sensor. The shutter is closed to obtain dark images to automatically calculate the dark counts in the software during image acquisition.

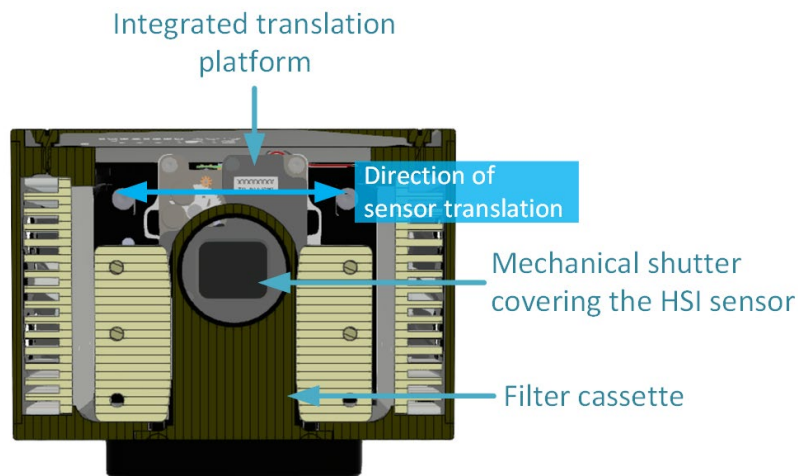
1.2.4 Flexibility to select specific spectral range using inter-changeable filters



snapscan has a built-in filter cassette. Users can select specific spectral ranges by inserting suitable filters in this cassette. The filter is placed between the lens and the image sensor when the cassette is inserted into the camera body.

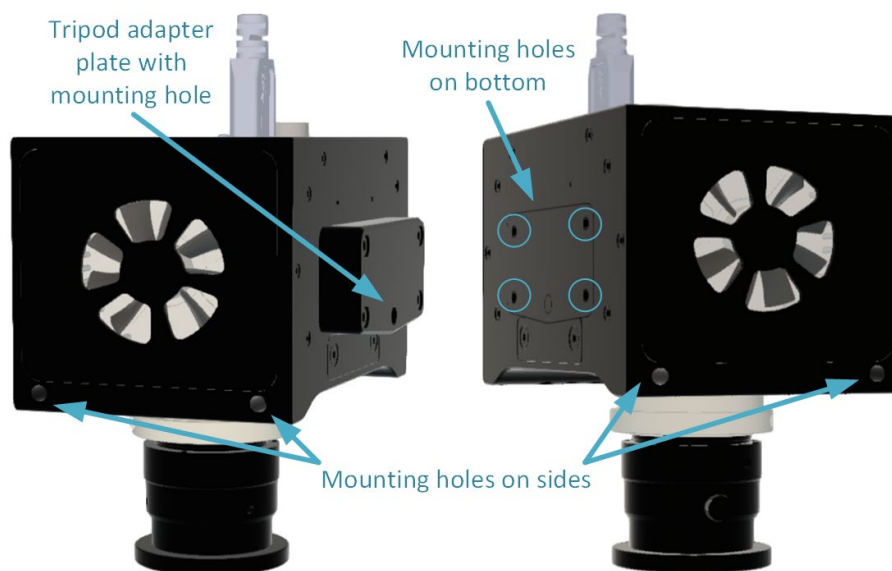


1.2.5 High resolution (spatial and spectral) data acquisition while keeping both the object and the camera stationary



snapscan integrates a linescan hyperspectral image sensor which enables acquisition of high resolution (spatial and spectral) data. This sensor is mounted on a translation platform which is integrated inside the camera body. As a result, the camera and the object can remain stationary, as the sensor translates internally during the data acquisition.

1.2.6 Multiple mounting options



snapscan camera provides multiple options for mounting the camera in a setup:

- Tripod adapter plate with mounting hole (the adapter plate is affixed by default but can be removed)
- Mounting holes on the bottom (need to remove the tripod adapter plate to expose them)
- Mounting holes on the sides



1.3 snapscan software features

The snapscan software enables acquisition and display of hyperspectral image data. The software offers user the flexibility to configure a wide range of acquisition parameters to tailor the data acquisition as per their needs and help them acquire good quality data. It also provides several useful visualization tools and a built-in classifier to quickly visualize and analyze the acquired data. The software also offers integration with 3rd party hyperspectral analysis software, such as [perClass Mira](#), for more advanced analysis. It also allows the acquired data to be exported to standard ENVI format so that users can use their own analysis flow on the acquired data.

1.3.1 Extensive data acquisition customization features

snapscan software provides a wide range of parameters to configure the snapscan system and customize the data acquisition.

Parameters	Description
Bit Depth	The sensor bit depth can be set to 8 or 10.
Cube dimensions	The number of rows and columns in the output data can be specified so that the size of the output file and data acquisition throughput can be customized.
Spatial binning	Pixels within a NxN neighborhood are merged by averaging. snapscan software allows following binning options - 1x1, 2x2, 3x3 up to 20x20.
Spectral bands selection	By default, data is acquired for all the spectral bands supported by the HSI sensor. Users can select up to 8 sets of bands to selectively skip the remaining bands while acquiring the data.
Analog gain	The analog gain of the HSI sensor can be set between 1-2.4dB to increase its sensitivity.
Selectively discard pixels	Pixel row at the edge of every spectral band can be discarded. This helps in reducing the impact of crosstalk across the spectral bands.
Software TDI	Time Delay Integration (TDI) can be enabled during data acquisition to achieve higher throughput and/or higher data quality. snapscan allows user to configure the number of TDI stages.
Multiple passes	Each frame can be acquired up to 100 times and averaged across the multiple passes to improve the image quality.
High Dynamic Range	Each frame can be acquired in HDR mode using up to 100 exposure bracketing.
Multiple file output modes	Output data can be assembled in a cube and stored in a single file, or the acquired frames are stored in separate files.

1.3.2 Built-in white balancing

snapscan software can carry out white-balancing as a post-processing step on the acquired hyperspectral data. Users are required to scan the object and a white reference target. snapscan automatically acquires the dark reference image using the built-in mechanical shutter and can carry out the white balancing.

1.3.3 Multiple file format options for data export options

The snapscan software enables user to export the acquired hyperspectral data in the following file formats – ENVI, PNG, PGM and TIFF.



In cases of PNG, PGM and TIFF file formats, each spectral band is saved as a separate image file. In each case, detailed metadata of the acquisition parameters is saved along with the exported file.

I.3.4 Integrated classifier

The snapscan software allows user to quickly analyze the acquired data using the integrated Spectral Angle Mapper based classifier.

I.3.5 Support for 3rd party HSI analysis software

The snapscan software currently provides user to obtain 14-day trial license for industry leading HSI analysis software [perClass MIRA](#).

I.3.6 Multiple data visualization options

The snapscan software provides following options for visualization of the acquired data

- Individual frame corresponding to a specific spectral band can be viewed
- Frames for all the spectral bands can be quickly stepped through and viewed
- A false color RGB image can be rendered and the users can adjust the bands selected for red, green and blue color channels. The software also provides “Color Match” feature which automatically renders a true color RGB image using information from multiple bands for the red, green and blue color channels.
- Spectral profile of one or more selected regions on the acquired data can be viewed using the integrated Spectrograph toolbox. The toolbox can be customized to display mean, minimum and maximum spectra for each selection.

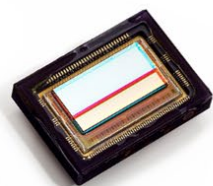
I.3.7 Support for multiple languages

The snapscan software currently supports English, Chinese and Japanese. More languages can be supported in future based on customer requests.

I.4 snapscan API features

snapscan APIs are available in C for data acquisition and visualization as supported in the snapscan GUI software. Please contact HSI Support for further details regarding the APIs.







Chapter 2

Working Principle

2. Working principle

We begin by explaining the working principle of the snapscan camera system. We explain the differences in the working of traditional linescan, imec's linescan and imec's snapscan hyperspectral camera systems. We then discuss the working and features of snapscan camera system in further details.

2.1 Linescan hyperspectral camera systems

Linescan camera systems require a relative translational movement between the object and the camera. In traditional linescan hyperspectral camera systems, this is typically realized by moving either the object relatively to the camera or the camera relatively to the object. For example, in industrial inspection and sorting applications the object is moved on a conveyor belt, whereas in remote sensing applications, the camera is flown with a drone or satellite to scan the earth surface.

2.1.1 Imec hyperspectral linescan vs Traditional hyperspectral linescan

Traditional hyperspectral linescan camera

- Acquires the hyperspectral image of an object line by line
 - Captures immediately the complete spectral information for each point in the spatial line
-  *Light incident on the camera from each scanline is dispersed into different wavelengths using an optical system and projected on to an image sensor that records intensity at different wavelengths.*

Imec hyperspectral linescan camera

- Acquires the hyperspectral image of an object frame by frame
 - Captures the complete spectral information for a point across multiple frames
-  *The camera's lens projects an entire area image on the imec hyperspectral linescan sensor. Different filters are deposited on the sensor, stretching over the full width of the sensor and varying along the sensor's height. The light is thus filtered depending on the row position of the image on the sensor, yielding images as shown in Figure 1. This greatly simplifies the system's optical system and on top makes focusing and setting exposure times easier.*

2.1.2 Imec hyperspectral linescan vs snapscan

In imec's snapscan system, both the object and the camera remain stationary. The image sensor inside the camera and behind the lens, moves linearly to scan the projection of the object on the image circle while both the object and the camera are kept still.

The difference between imec's hyperspectral linescan and snapscan is illustrated in Figure 1 and Figure 2. These illustrations assume a hypothetical linescan sensor with three spectral bands.



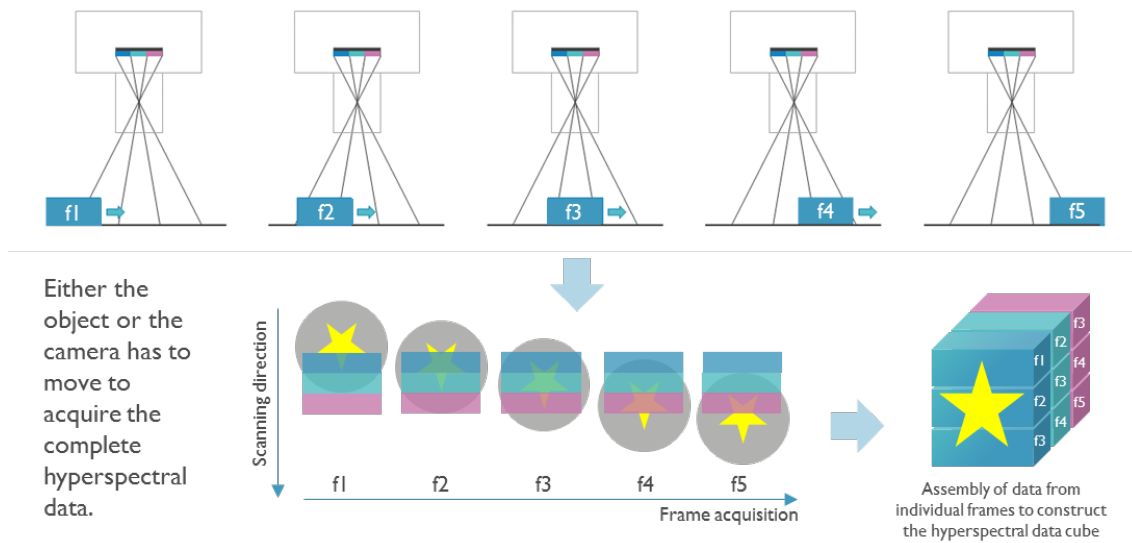


Figure 1 Working principle for imec hyperspectral linescan sensors

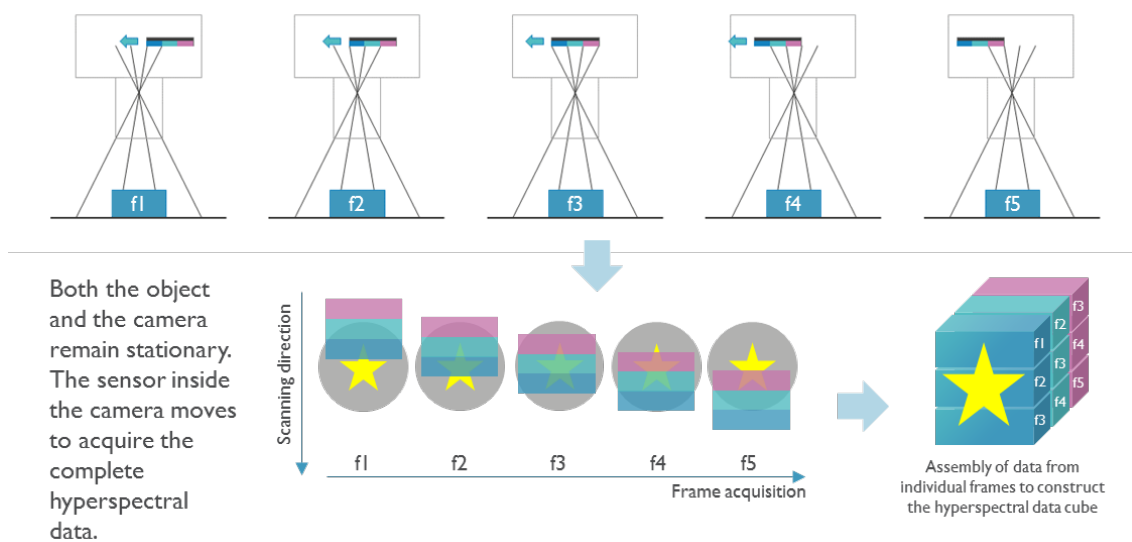
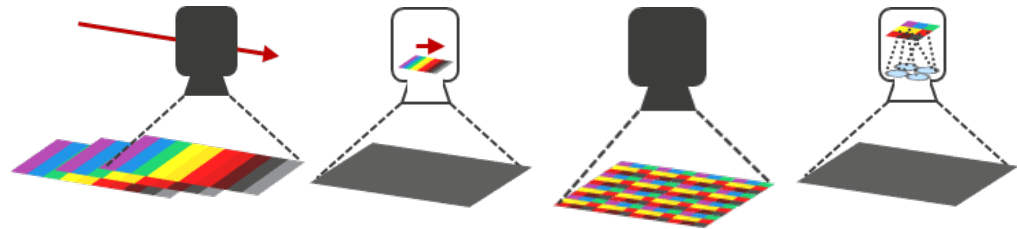


Figure 2 Working principle of imec hyperspectral snapscan camera



2.1.3 Imec hyperspectral camera selection guide

Imec has multiple camera offerings based on different sensor types (linescan, mosaic and tiled). The table below provides a high-level comparison of the different camera offerings based on the current state of our technology and offerings.



	Linescan	snapscan	Snapshot Mosaic	Snapshot Tiled
Acquisition speed	-	+	+++	+++
Video-rate	---	-	+++	+++
Maximum spatial resolution	++	+++	+	-
Spatial quality	+++	+++	+	-
Spectral resolution	+++	+++	+	+
Spectral range	+++	+++	-	++
Spectral quality	++	+++	-	++
SNR	++	+++	+	-
Key advantages	High spectral and spatial resolution	Highest quality cubes being 'snapshot', no 3D topography issue	True snapshot at video-rate	True snapshot with high quality spectra
Key limitations	Need scanning movement, issues with 3D topographies	Video-rate not in reach	Software corrections needed for cross talk	Spatial vignetting, duplicator alignment challenges
Key applications	Remote sensing (UAV, airborne, satellite), food sorting, machine vision	R&D, microscopy, medical skin & wounds healing, agriculture robotics	Industrial sorting & food quality grading, medical endoscopy, UAV inspection	Medical surgery, security surveillance

Visit our website or contact us for further details on our offerings and latest technology developments: <https://www.imec-int.com/en/hyperspectral-imaging>



2.2 Imec snapscan hyperspectral camera

2.2.1 Image acquisition

It has been mentioned in Section 2.1.2 that the snapscan camera system acquires the hyperspectral image by the movement of the sensor inside the camera body. Figure 3 illustrates the process of image acquisition. In this figure, we assume a hypothetical sensor with 3 spectral bands. The object to be imaged is the yellow star and the lens of the camera system projects the image circle (indicated in gray). The sensor moves across the image circle and acquires 5 frames in total such that the complete star is acquired for all the spectral bands. The sensor moves from top to bottom in steps equal to the height of one filter on the sensor. These frames are assembled to form a hyperspectral image cube. The frame assembly takes into account the filters layout on the sensor and the motion during the scan. Each band image is composed of parts of multiple images, acquired at different positions.

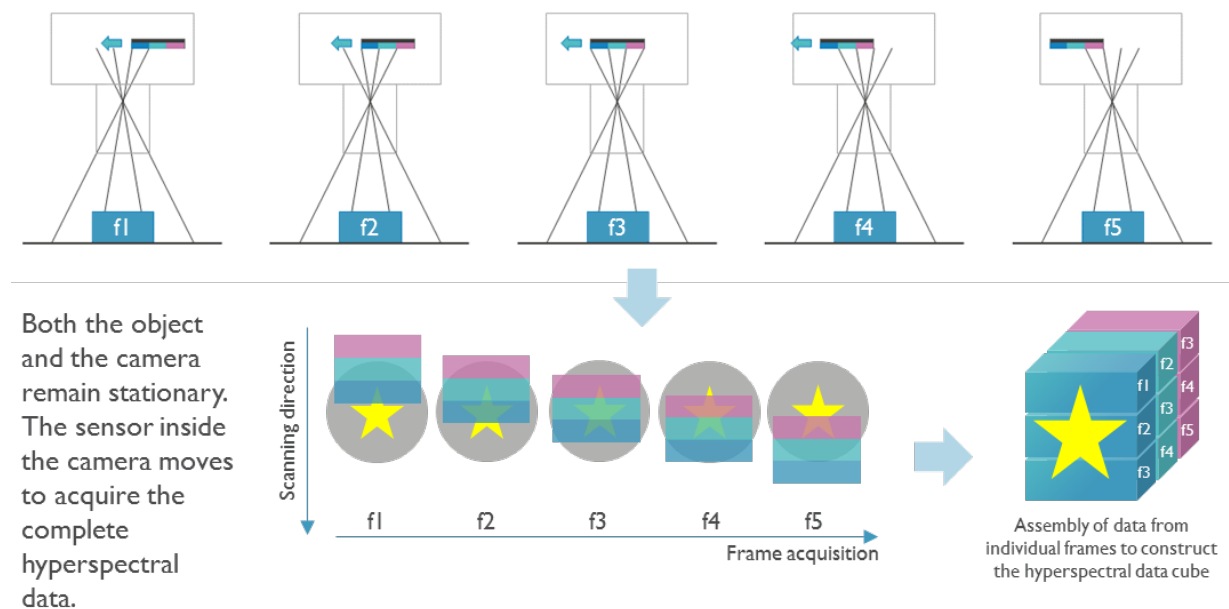


Figure 3 Working principle of image acquisition using the snapscan camera system

2.2.2 Integrated translation platform

In typical linescan setups the quality of the acquisition largely depends on (1) the alignment of the direction of motion to the camera and (2) on the synchronization between the movement and sensor readout speed. The snapscan system integrates both the sensor and the translation platform, making the system behave as a snapshot camera.

Integrating a miniaturized translation platform with the camera enables higher degree of accuracy for motion direction and control.

1. The alignment of the **direction of motion** to the sensor orientation is carried out and fixed in factory to sub-pixel accuracy.



2. The **precise motion** control enables the synchronization between the sensor translation and image acquisition to be controlled to sub-pixel precision, either by software or hardware feedback loop.

Typically, the synchronization of the motion to the sensor readout is done such that the object's projection on the sensor shifts one band between any two images.

The precise motion control in the snapscan system also enables more advanced acquisition modes, which can significantly increase the signal-to-noise ratio in the acquired data (please see Section 2.2.4.4).

2.2.3 Acquisition modes

The snapscan camera can operate in either continuous or stop motion acquisition modes. The software automatically selects the mode depending on the selected acquisition parameters.

1. **Continuous mode** - Sensor movement and sensor exposure happen simultaneously.

The translation platform's internal encoder is used to trigger the sensor at the correct position. The movement is fluent and there is no delay in acceleration and deceleration before taking an image. The movement speed is limited by the sensor's exposure time and the maximum allowable motion blur or distance moved during one exposure time.

2. **Stop motion mode** - Sensor movement and sensor exposure are alternated.

The sensor is repeatedly stopped at a selected step size to acquire the image and then move to next position. This completely avoids motion blur and allows taking multiple images at a given position, enabling for instance high dynamic range (HDR) algorithms. Evidently this acquisition mode is slower than the continuous mode. The total duration of the acquisition depends on the travel distance, the step size and the number of images times their exposure time acquired in each position.

2.2.4 Acquisition features for higher data quality

The snapscan camera provides a number of configurable parameters which can help in improving the quality of the acquired image data. These parameters are discussed further in this section.

2.2.4.1 Pixel binning

Pixel binning is a well-known concept in imaging where information from adjacent pixels are combined and reported out as a single pixel. The snapscan camera system can be configured to implement a $N \times N$ binning where $N = 1, 2, 3 \dots 20$ (default is 1).

2.2.4.2 Cross talk removal by pixel row skipping

The precise control of the integrated sensor translation platform allows the sensor to be moved in step sizes between one pixel row and height of one spectral band (typically 5 pixel rows). Hence, it is possible to skip collecting data from the pixel rows at the interfaces of two



spectral bands. Skipping the interface rows avoids recording cross-talk between different bands and hence improve the system's spectral response.

In Figure 4, we assume that the sensor has 3 spectral bands and each spectral band has 5-pixel rows. The shaded pixels are at the interface of two spectral bands and hence susceptible to cross talk. We show illustration for 4 cases having different step sizes while scanning the object. Let us further consider three points (X, Y and Z) on the object.

In case of point X, let us discuss the data collection for the different step sizes:

- 5 rows – Data for all the 3 bands are collected from interface pixels only. Thus, all the acquired data may have been affected by cross talk.
- 4 rows – Data for all the 3 bands are collected from non-interface pixels. Thus, the data is least susceptible to cross talk.
- 3 rows – Data for all the 3 bands can be collected both from interface and non-interface pixels across different frames. To minimize the susceptibility to cross talk, the interface pixels can be ignored.
- 2 rows – Same as above.

If we consider all the three points (X, Y and Z) then we see that step sizes of 2 and 3 ensures that data can be collected from non-interface pixels for all the three bands, thus ensuring a higher data quality.



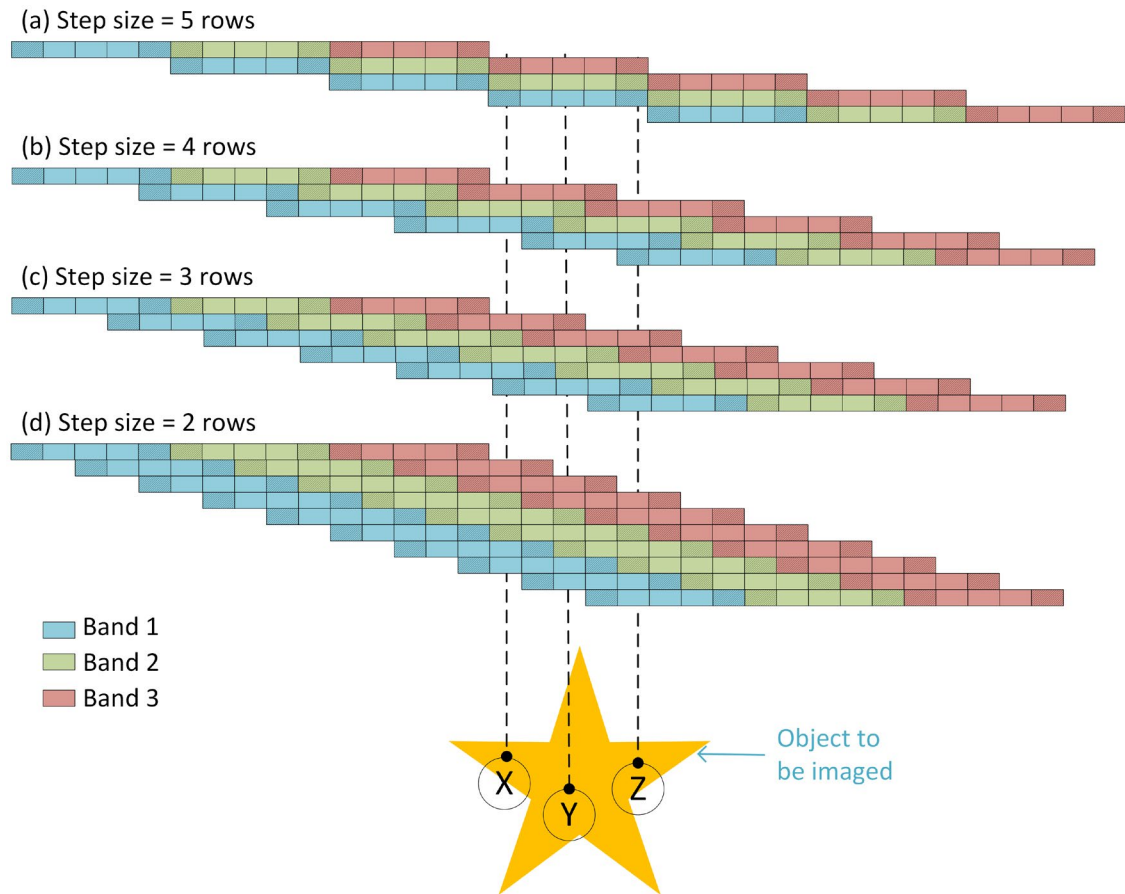


Figure 4 Illustration for pixel row skipping to remove cross talk

2.2.4.3 Software Time Delay Integration (softTDI)

Time delay integration (TDI) is a known concept in imaging where multiple frames (shifted in time and position) of the same object (with relative motion between the object and the camera) are acquired and information is combined across these frames (in hardware) to achieve high throughput and/or high quality imaging in low light conditions.

TDI is typically implemented in hardware. However, the snapscan camera enables TDI in software and provides flexibility to configure the step size at which multiple frames are acquired. The precise control of the integrated sensor translation platform allows the sensor to be moved in step sizes between one pixel row and height of one spectral band (typically 5 pixel rows).

To enable softTDI, the sensor needs to be translated at step sizes smaller than the height of one spectral band. This allows capturing images of an object such that multiple pixels across multiple frames will capture data for the same spectral band.

Figure 5 shows an illustration, where we assume that the sensor has 3 spectral bands and each spectral band has 5 pixel rows. Thus, the sensor can be translated at step sizes between 1 and 5 pixel rows. We consider 3 different step sizes in our illustration and discuss below the impact on softTDI:



- 5 rows (height of spectral band): Allows no softTDI
- 2 rows: Each point in the object is imaged at least in 2 frames for the same spectral band. SoftTDI can be implemented by averaging data collected from pixels across the 2 frames.
- 1 row: Each point in the object is imaged at least in 5 frames for the same spectral band. SoftTDI can be implemented, as discussed above.

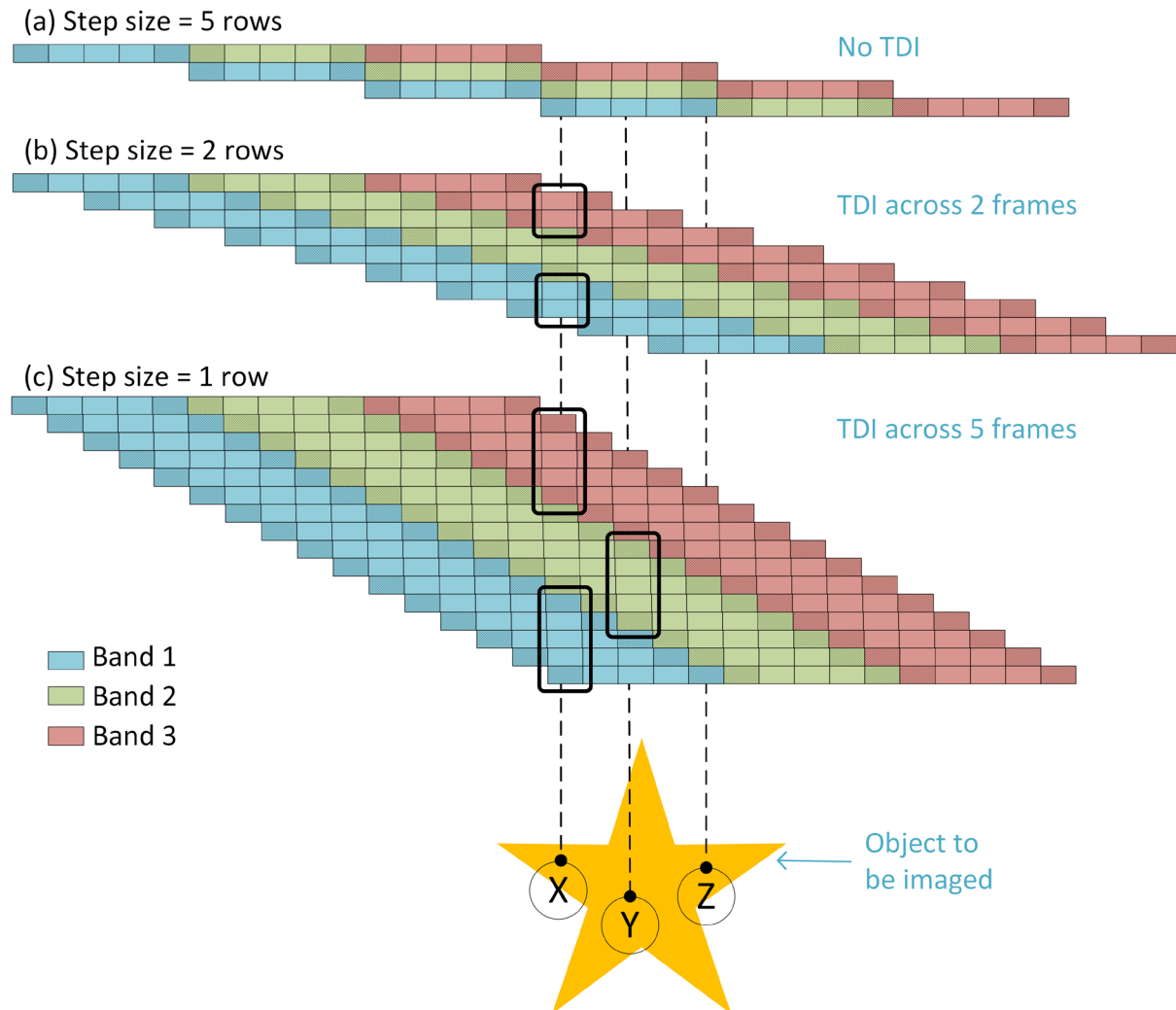


Figure 5: Illustration for software time delay integration

2.2.4.4 Spectral bands/ Regions of Interest selection

By default, the snapscan camera system acquires data for all the spectral bands supported in the integrated sensor. However, the snapscan provides the feature of band selection which allows the user to specify one or more spectral ranges that are of interest for the acquisition. The acquired data will then only contain the bands corresponding to the selected spectral ranges. Bands that fall outside the selected regions will not be acquired.



Each selected spectral range is referred to as **Spectral Region of Interest (SROI)**. The snapscan camera system allows up to 8 SROIs (default is 2).

The band selection is done directly on the sensor. As a result, the amount of readout data from the sensor can be reduced. This leads to following benefits:

- Less data is transferred from the sensor. It allows higher framerates and hence shorter acquisition times.
- Size of output data and the file is reduced. It reduces the amounts of data to be processed and stored, easing the requirements of the PC used for the acquisition and improving processing times.

2.2.4.5 High Dynamic Range (HDR) imaging

Section 2.2.3 discussed the two acquisition modes supported by the snapscan camera system – continuous and stop-motion modes. In the stop-motion mode, the sensor is repeatedly stopped at a selected step size to acquire the image and then move to next position. This allows the possibility of acquiring multiple frames at different integration times at each position. These frames can be combined using HDR technique to improve the overall dynamic range of the camera system. snapscan camera system allows user to enable/disable HDR and configure related parameters in the stop-motion acquisition mode.

2.2.4.6 Multi-pass acquisition

The snapscan camera system ensures that image acquisitions are repeatable because of the high accuracy of the motion control of the integrated translation platform. This allows further increasing the signal to noise ratio (SNR) of the acquired image data by averaging across data acquired in multiple acquisitions across multiple passes.

2.2.5 Image post processing

The key purpose of a spectral imaging system is to measure the true surface reflectance (or true material absorbance in case of measurements in transmittance mode) of the object to be imaged. However, the image acquisition is subjected to interference and non-idealities of the imaging systems and its components, and the imaging environment. White balancing needs to be applied on the acquired data to obtain true reflectance/ absorbance where all the system related effects are normalized:

2.2.5.1 White balancing

White balancing, also referred to as reflectance calculation, is the process of extracting the reflectance signal from the captured radiance of an object. The purpose is to remove the influence of the following on the hyperspectral representation of an object.

- the light source emission spectrum
- spatial non-uniformities in the illumination
- the impact of the medium through which the light travels
- vignetting of the lens system
- the spectral deformation caused by the lens system



- and small differences between the system model and reality
- sensor characteristics (QE, ...)

White balancing also enables the comparison of spectral responses across measurements and with available databases.

The white balancing is done by placing a white diffuse reflectance target in the scene. In principle any reflectance target with known spectrum can be used. In practice it is simpler to use a reflectance target with an as flat as possible reflectance spectrum and scaling up the measurement to 100% by dividing the measurement by the reflectance value. For example, the reflectance target delivered with the snapscan system has a flat diffuse reflectance spectrum of 95%.

The following formula illustrates the calculation of the reflectance, using one white reference image and two dark reference images

$$\text{object}_{\text{reflectance}} = \frac{\text{object}_{\text{radiance}} - \text{dark ref}(\text{tint}_{\text{object}})}{\text{white ref} - \text{dark ref}(\text{tint}_{\text{white ref}})} \times \frac{\text{tint}_{\text{white ref}}}{\text{tint}_{\text{object}}}$$

where

- $\text{object}_{\text{radiance}}$ is the radiance of the object of interest
- white ref is the radiance of a white reflectance tile
- dark ref ($\text{tint}_{\text{object}}$) is a dark reference image taken with the integration time of the object of interest
- dark ref ($\text{tint}_{\text{white ref}}$) is a dark reference image taken with the integration time of the white reflectance tile
- $\text{tint}_{\text{white ref}}$ is the integration time used to capture the white reference image
- $\text{tint}_{\text{object}}$ is the integration time used to capture the object image

The object, white and dark reference images are the raw output from the sensor, resulting in a set of four 2D arrays. The above-mentioned formula should be applied on the digital numbers of the corresponding pixel locations of the four images.

Reflectance vs transmittance mode imaging

There are two key differences between the two modes of imaging:

- **Placement of object, light source and camera system**
 - Reflectance mode - the light source and the camera system are on the same side of the object,
 - Transmittance mode - the object is placed in between the light source and the camera system.
- **White reference measurement**
 - Reflectance mode – carried out using a reflectance tile with known spectrum
 - Transmittance mode – carried out by using a measurement in absence of the object and without using any reference object. Note that when the object is



placed on a transparent substrate, the substrate must be kept in place when doing the white reference measurement.

2.3 Illumination

Illumination is a critical factor in hyperspectral imaging. Different sources of illumination have different intensity levels at different wavelengths, as shown in Figure 6. The choice of illumination will significantly impact the overall spectral response of the imaging system. Figure 7 shows the spectral response of different spectral bands in the HSI sensor. These responses have been obtained under ideal lab condition illumination. Figure 8 illustrates the impact of three different illumination sources (halogen, LED and sunlight). It can be seen that the spectral response of the illumination source influences the overall spectral response of the HSI sensor. Thus, it is important to take into account the spectral property of illumination used in the system based on application requirements.

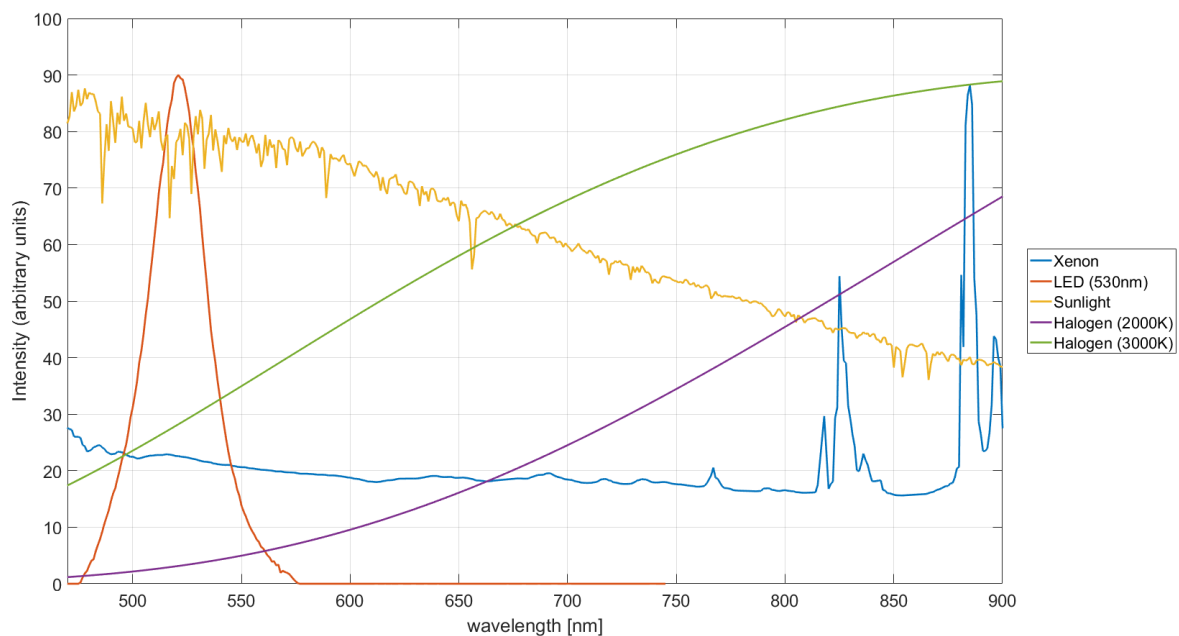


Figure 6 Spectral content of different light sources



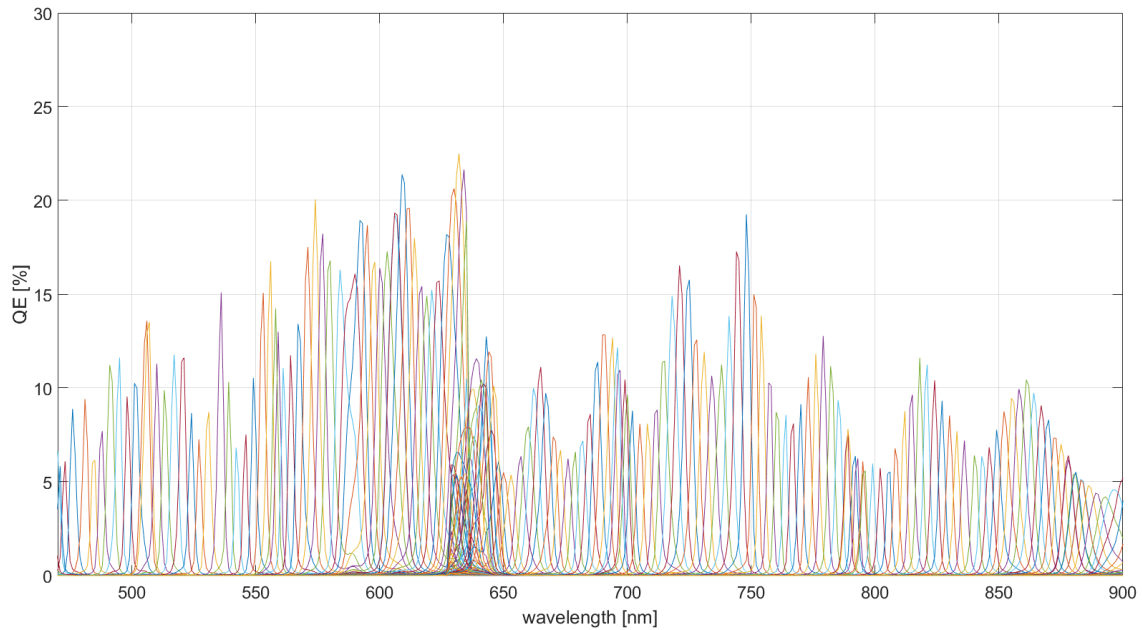


Figure 7 Responses of different spectral bands of the HSI sensor obtained under ideal illumination conditions

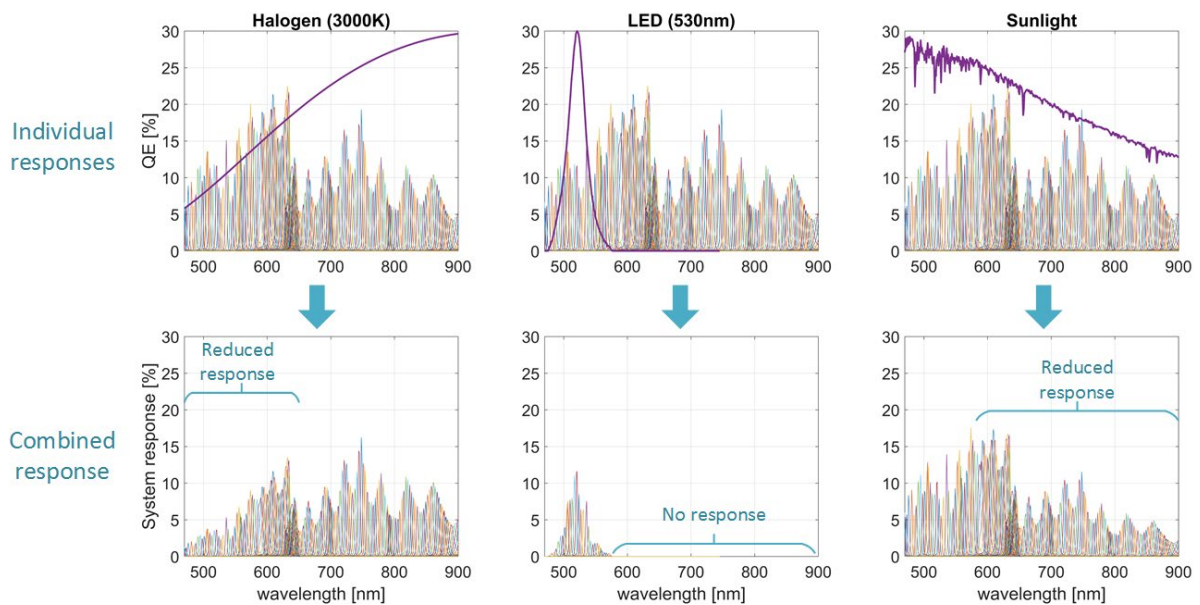


Figure 8 Illustration of impact of different illumination sources on overall spectral response of the system

- ❶ The evaluation kit includes halogen lamps as a standard configuration. It can be seen from Figure 8 that halogen based illumination has lower SNR in the blue color range. Thus, if your application requires higher SNR in the blue color range then we recommend you to contact Imec HSI support to help you with illumination customizations.
- ❶ We are currently qualifying multi LED based illumination solution which gives the user the ability to tune the spectral content of the illumination specific to application needs. Please contact imec HSI support for further information.







Chapter 3

Evaluation System Assembly Manual

3. Evaluation System Assembly Manual

This chapter will guide you through the assembly of the snapscan evaluation system. It provides an overview of all components in the snapscan evaluation system and instructions to assemble the snapscan evaluation system (as shown in Figure 9).



Figure 9 Final setup of the snapscan evaluation system

3.1 Assembly steps

Follow the steps below to assemble the evaluation system:

- Step 1** - Unpack the packages (black explorer case and cardboard box) and cross check the contents of the kit received with the list of components provided in the manual
- Step 2** - Assemble the base plate
- Step 3** - Assemble the camera holder post and mount the tripod head
- Step 4** - Assemble the lamp holder posts and mount the lamps
- Step 5** - Mount the snapscan camera
- Step 6** - Connect the lamps to the power supply
- Step 7** - Connect the camera to controller and PC



The above steps are discussed in detail further in this chapter. The interconnection between the different components is shown in Figure 10.

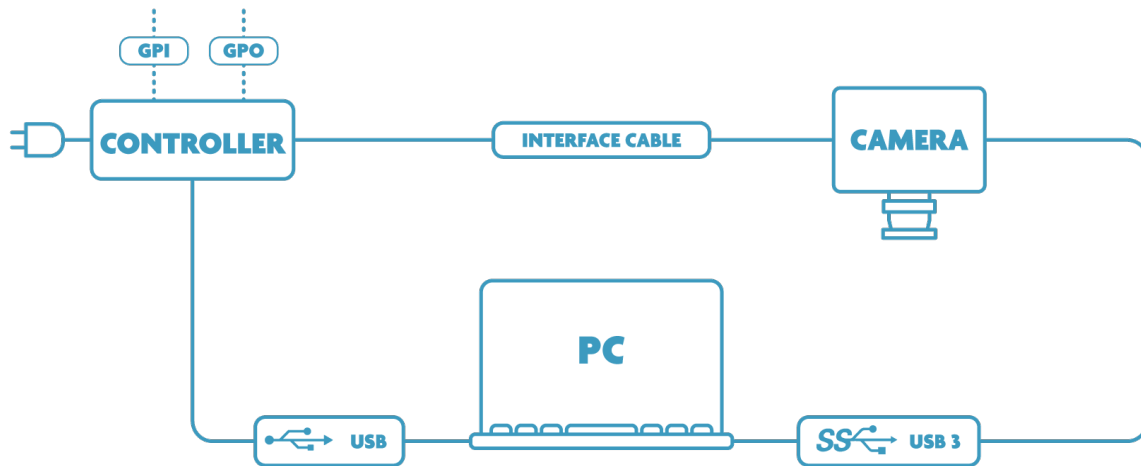


Figure 10 Interconnection between different components in the final setup

3.1.1 Step 1 - Unpack and crosscheck the contents

Step 1.1 Unpack and crosscheck the contents

The snapscan evaluation system is delivered in two main packages (as shown in Figure 11):

- Box 1 containing (see Figure 13 for contents)
 - snapscan camera with integrated sensor
 - controller box
 - Schneider Kreuznach lens
 - USB3.0 cable, custom 16 pin cable and power supply
- Box 2 containing (see Figure 13 for contents)
 - Components to build a setup with illumination
 - mounting setup with vibration dampening
 - halogen lighting solution with diffusers
 - tunable stabilized DC power supply
 - Reflectance targets for calibration
 - reflectance tile 95%, 200 x 200 mm
 - color checkerboard card

 *The color checkerboard (item 23) and reflectance standard (item 24) are optical materials. Do not touch their surface in any way and store in dark conditions.*

Table 3 provides a list of all the components and the quantity for each component included in the evaluation system.





Figure 11: Main packages delivered with the snapscan evaluation system. Box 1 (left) contains the snapscan system and cables and Box 2 (right) contains all evaluation system parts.



Figure 12 Contents of the Box 1





Figure 13 Contents of the Box 2

- i** Actual contents of the two boxes may vary depending on the options selected by you in the snapscan hyperspectral camera selection form during order placement.



Table 3: List of components and quantities in the snapscan evaluation system

Ref. No	Components	Quantity	Packaged
01	snapscan camera body	1	Box 1
02	snapscan controller	1	Box 1
03	Schneider-Kreuznach lens	1	Box 1
04	USB 3.0 cable 3m	1	Box 1
05	snapscan 16-pin cable	1	Box 1
06	USB 2.0 cable	1	Box 1
07	snapscan controller adapter	1	Box 1
08	snapscan controller adapter power cable	1	Box 1
09	Base breadboard 300x300	1	Box 2
10	Feet Ø27mm, female M6	4	Box 2
11	Hex cap screw M6, 16mm, black	4	Box 2
12	Threaded studs M6 black	2	Box 2
13	Post 300x12.7mm	5	Box 2
14	Post 150x12.7mm	2	Box 2
15	Right angle post clamp	4	Box 2
16	Post end clamp 0.5"	1	Box 2
17	Tripod ball head with 3/8" to 1/4" adapter	1	Box 2
18	Tunable stabilized DC power supply	1	Box 2
19	Tunable stabilized DC power supply power cable	1	Box 2
20	Halogen lamp 20W GU5.3 cool-fit	4	Box 2
21	Diffuser (Thorlabs DG20-120)	4	Box 2
22	Assembled lamp holder, wire, post end clamp and banana plug connectors	4	Box 2
23	Color checkerboard card	1	Box 2
24	Reflectance standard 95% 200x200mm	1	Box 2
25	Allen key 3mm	1	Box 2
26	Scanning background ²	1	Box 2

i Actual contents of the two boxes may vary depending on the options selected by you in the snapscan hyperspectral camera selection form during order placement.

² Not shown in Figure 13



Step 1.2 Identify the camera unit

Each camera unit is assigned a unique serial number, as shown in Figure 14. The description of the serial number is given in Table 4.



Figure 14 Serial number for camera units

Table 4 Description of the serial number

Label	Description	Values
①	Model identifier	A: model A B: model B X: model X
②	Sensor Identifier	I00: Hyperspectral NIR sensor (600-1000nm) I50: Hyperspectral VNRI sensor (470-920nm)
③	Translation stage identifier	Q: Q-motion stage U: Ultrasonic stage
④	Device number	4 digit serial number starting from 0001



3.1.2 Step 2 - Assemble the base plate

Required items (Figure 15a)

Ref. No	Components	Quantity	Packaged
09	Base breadboard 300x300	1	Box 2
10	Feet Ø27mm, female M6	4	Box 2
11	Hex cap screw M6, 16mm, black	4	Box 2

Procedure:

Attach the 4 feet to the breadboard, through the holes, offset from the array. The screw should sink completely in the hole, creating a flat surface. Tighten well.

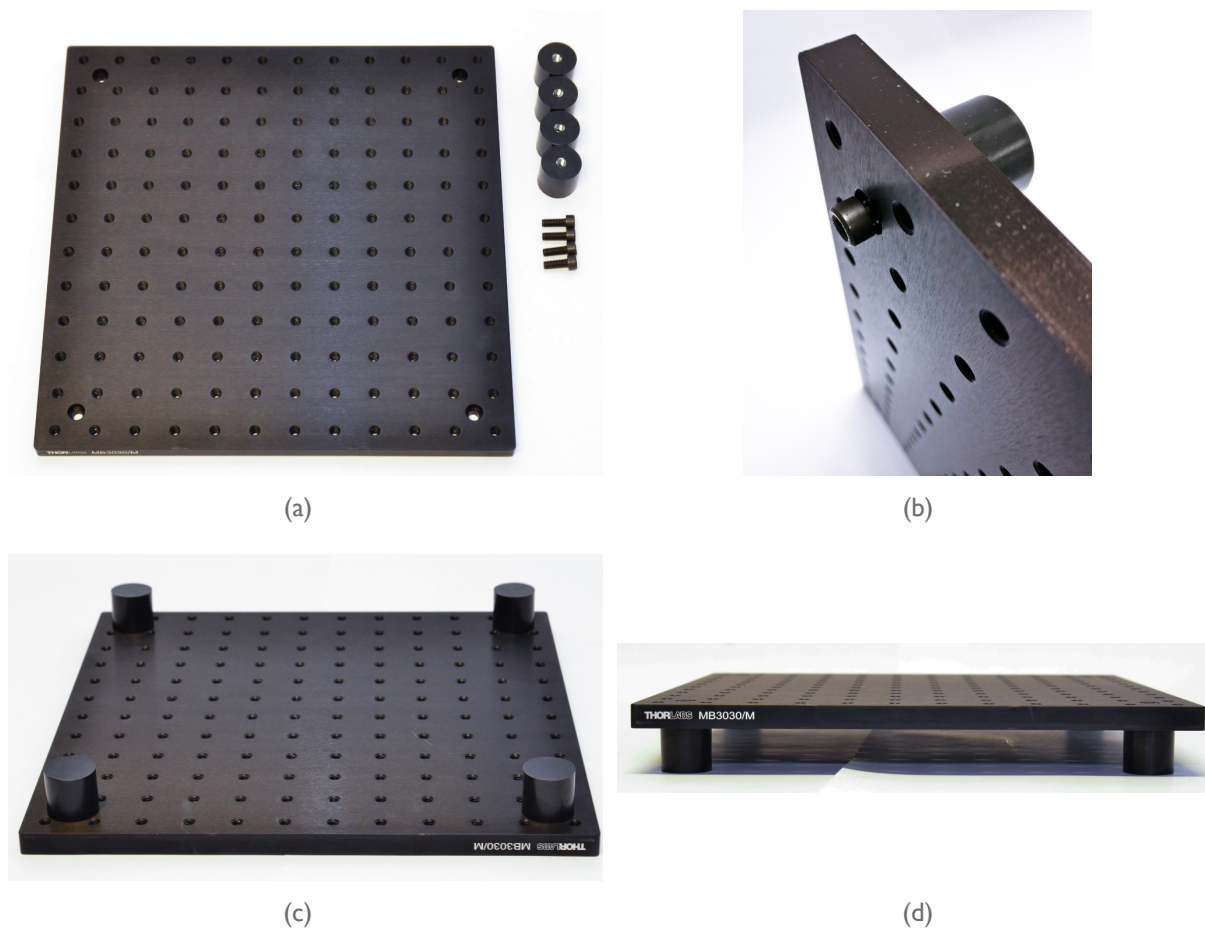


Figure 15: Assembly of the base plate (Step 2)



3.1.3 Step 3 - Assemble the camera holder posts and tripod mount

Required items

Ref. No	Components	Quantity	Packaged
17	Tripod ball head with 3/8" to 1/4" adapter	1	Box 2
13	Post 300x12.7mm	3	Box 2
14	Post 150x12.7mm	2	Box 2
12	Threaded studs M6 black	2	Box 2
15	Right angle post clamp	4	Box 2
16	Post end clamp 0.5"	1	Box 2

Procedure

Follow the steps below to assemble the camera holder posts and tripod mount, as shown in Figure 16.

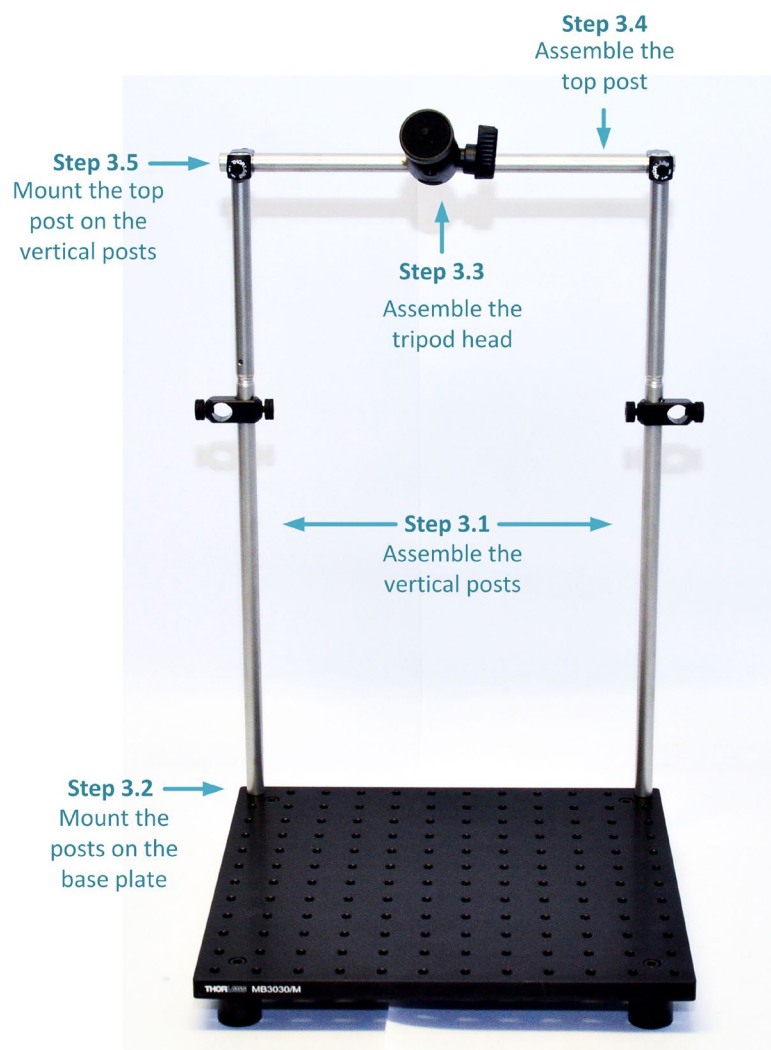


Figure 16 Mounting camera on the assembled on the base plate (Step 3)



Step 3.1 Assemble the vertical camera holder posts (Figure 17)

- Insert and screw the black threaded stud, with its conical end, in the bottom end of the long post.
- Unscrew the stainless-steel setscrew from the top of the long post (these are not required for this build, use an Allen key size 2 if necessary). Screw the top of short post onto the top of the long post, connecting them with a stainless-steel setscrew.
- Slide the right angle post clamp on to the assembled post and screw it.
- Follow steps a-c to prepare two posts.

 *The position of right angle post clamp can be changed later to adjust the height of the lamps with respect to the base plate.*

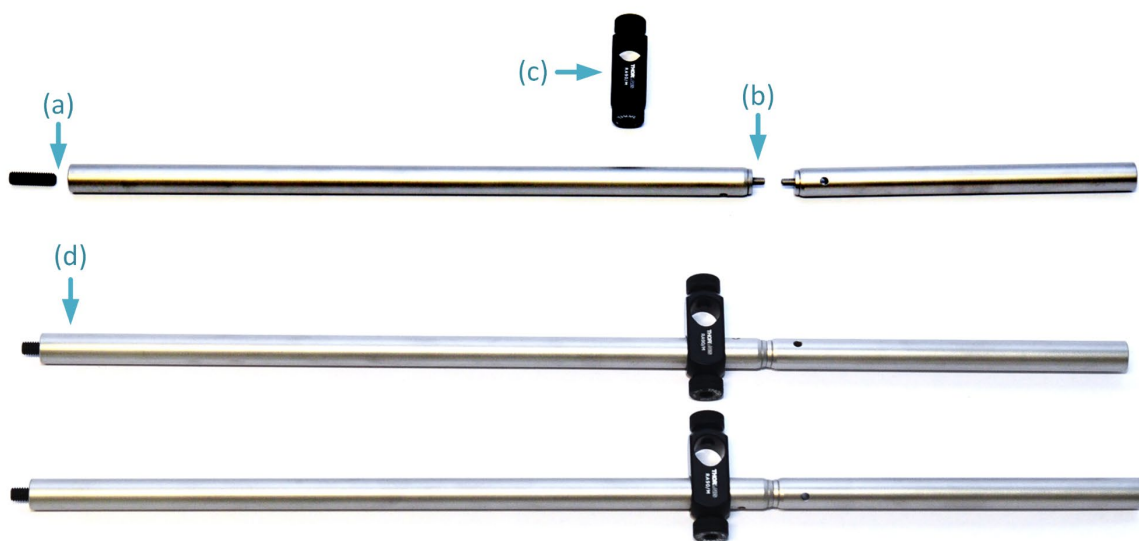
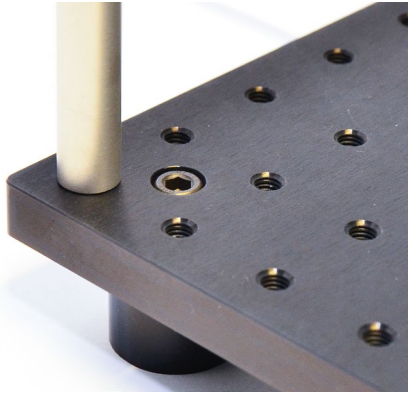


Figure 17 Assembly of the vertical camera holder posts (Step 3.1)

Step 3.2 Mount the camera holder posts on the base plate (Figure 18)

- Mount the post on the base plate such that the end of the post with the black threaded stud is screwed in to the base plate. Use the first hole in the corner as shown in Figure 18a.
- Mount the two posts in opposite corners along the same edge of the base plate, as shown in Figure 18b.





(a)



(b)

Figure 18 Mounting of the vertical camera holder posts on the base plate (Step 3.2)

Step 3.3 Assemble the tripod head (Figure 19)

- a. Unscrew the stainless-steel ring from the top of the tripod ball head (adapter), revealing the black thread on top.
- b. Screw this stainless-steel adapter piece into the bottom hole.
- c. Screw the post end clamp into the bottom hole of the tripod ball head.





Figure 19 Assembly of tripod mount (Step 3.3)

Step 3.4 Assemble the top road with tripod head (Figure 20)

- UnscREW the stainless-steel setscrew from the top of the post (these are not required for this build, use an Allen key size 2 if necessary).
- Slide the ball head assembly onto the long post and screw it in the middle of the post.
- Slide the 2x right angle post clamps onto both ends and tighten the screw.

⚠ Ensure that the screw is properly tighten once the camera is mounted to avoid the tripod head changing orientation under camera's weight.



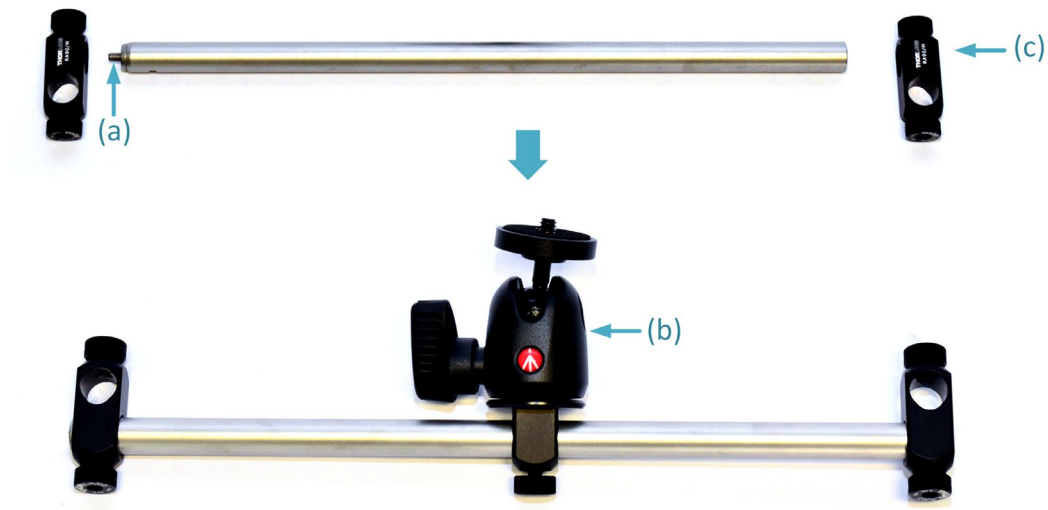


Figure 20 Assembly of the top post for camera mount (Step 3.4)

Step 3.5 Mount the top post on the vertical posts (Figure 21)

- a. Slide the assembled top post (from Step 3.4) on to the vertical posts and fix them on the top edge, as shown in Figure 21.

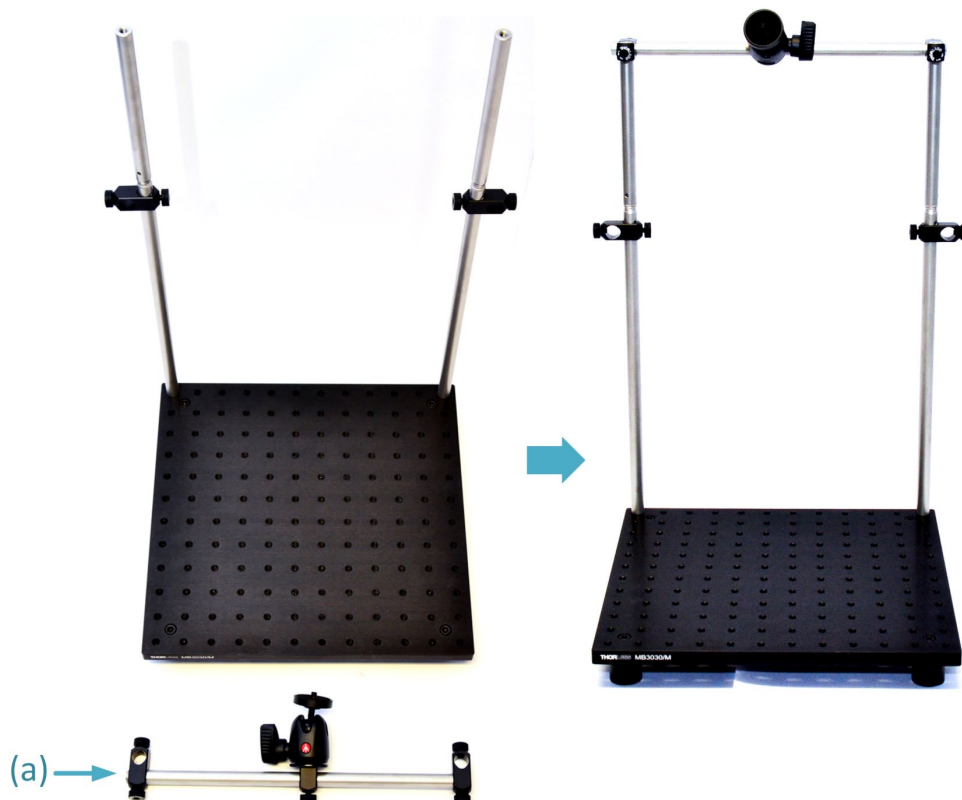


Figure 21 Assembly of top post with tripod head on the vertical posts (Step 3.5)



3.1.4 Step 4 - Assemble the lamp holder posts and mount the lamps

Required items

Ref. No	Components	Quantity	Packaged
22	Assembled lamp holder, wire, post end clamp and banana plug connectors	4	Box 2
13	Post 300x12.7mm	2	Box 2
20	Halogen lamp 20W GU5.3 cool-fit	4	Box 2
21	Diffuser (Thorlabs DG20-120)	4	Box 2

Procedure

Follow the steps below to assemble the lamps and mount them on to the setup, as shown in Figure 22.

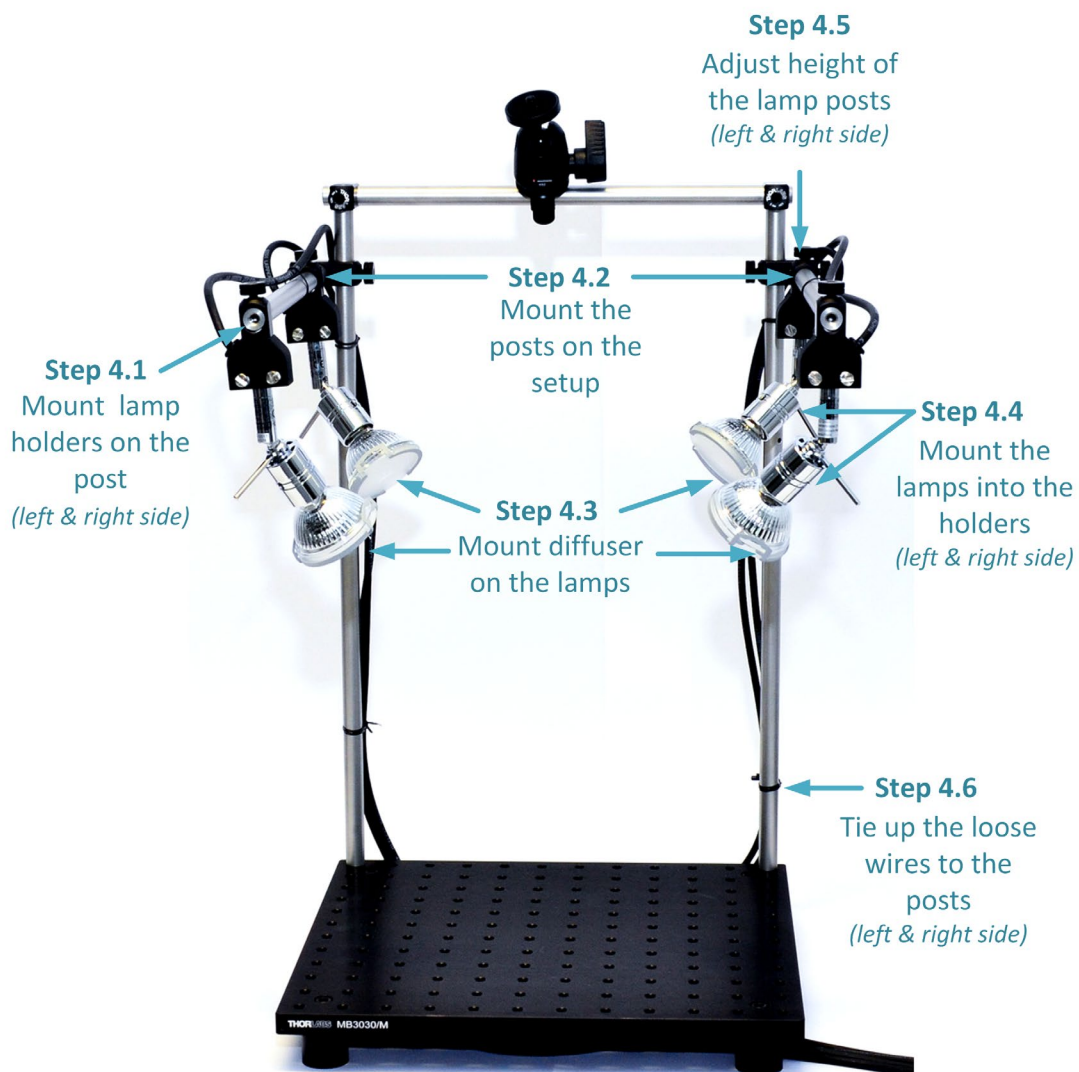


Figure 22 Assembly of lamp holder posts and mounting of lamps (Step 4)



Step 4.1 Mount the lamp holders on the post (Figure 23)

- Unscrew the stainless-steel setscrew from the top of the post (these are not required for this build, use an Allen key size 2 if necessary).
- Slide two lamp holders on the post and fix them by tightening the screw on the post end clamp, as shown in Figure 23. Repeat this step to assemble the remaining two lamp holders on the second post.

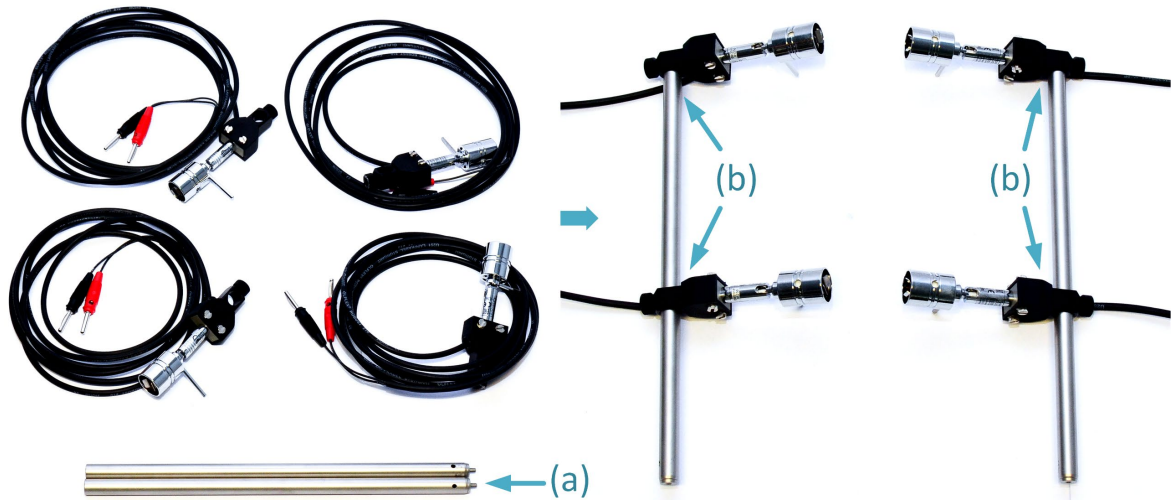


Figure 23 Assembly of lamp holders on the posts (Step 4.1)

Step 4.2 Mount the posts on to the setup (Figure 24)

- Slide the assembled post (from Step 4.1) into the right-angle post clamp fixed on the vertical post. Repeat this step for other assembled post.

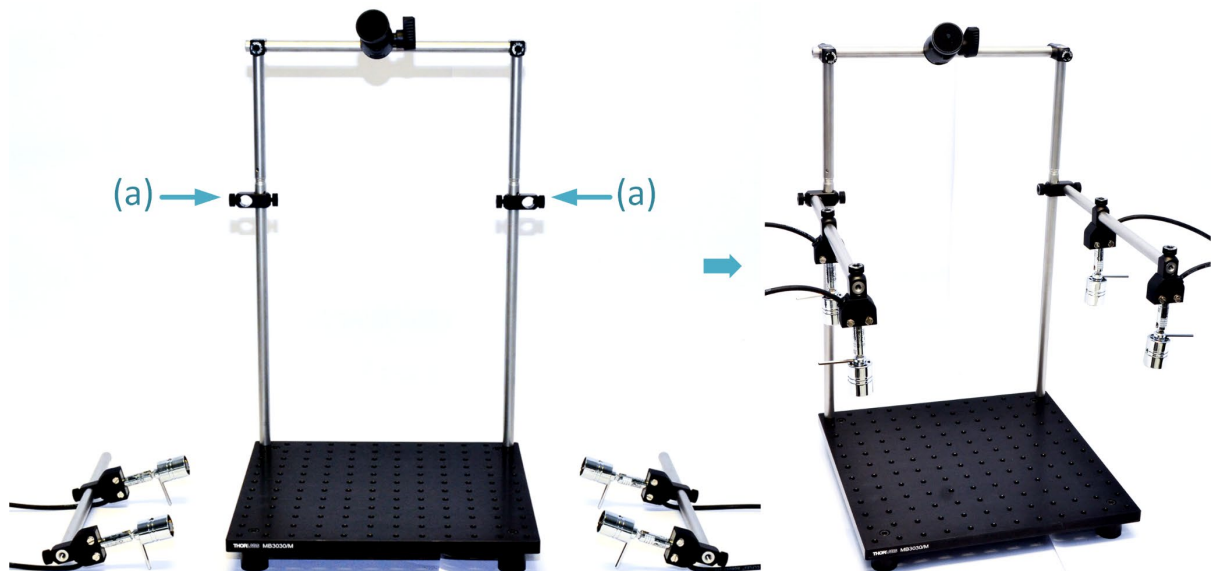


Figure 24 Mounting of lamp holders on to the setup (Step 4.2)



Step 4.3 Mount diffusers on the lamps

- a. Unpack the diffuser and the lamps, as shown in Figure 25.

i Depending on your application, using different types of lamps and/or light shaping filters can improve the SNR of the acquired data. It is strongly recommended to experiment with different types of lamps to tune the total system response. Refer to the manual *Hyperspectral Sensors* for more information.



Figure 25 Unpacking of diffuser and lamp (Step 4.3a)

- b. Press and bend inwards the clips on the diffuser, as shown in Figure 26. This is needed for good fit of the diffuser on the lamps.



Figure 26 Bending the clips of diffuser for mounting on the lamps (Step 4.3b)

- c. Press the diffuser on to the lamp such that the top edge of the lamp gets locked in to the clip of the diffuser, as shown in Figure 27.

⚠ Ensure that there is gap between the diffuser and the lamp

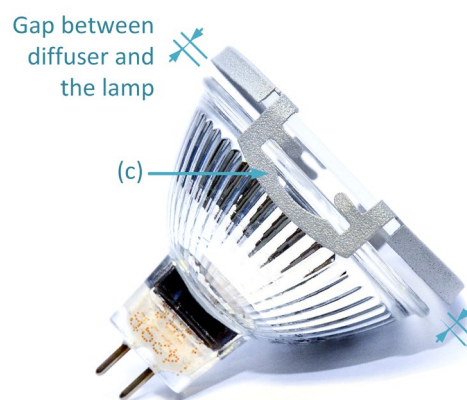


Figure 27 Mounting diffuser on the lamp (Step 4.3c)



- d. Follow steps a-c to prepare a set of 4 lamps, as shown in Figure 28.



Figure 28 Set of 4 lamps with diffuser mounted on them (Step 4.3d)

Step 4.4 Mount the lamps into the holders (Figure 29)

- a. Align the pins of the lamp to the holes in the socket and push the lamp into the holder. Repeat this step for all the four lamps.

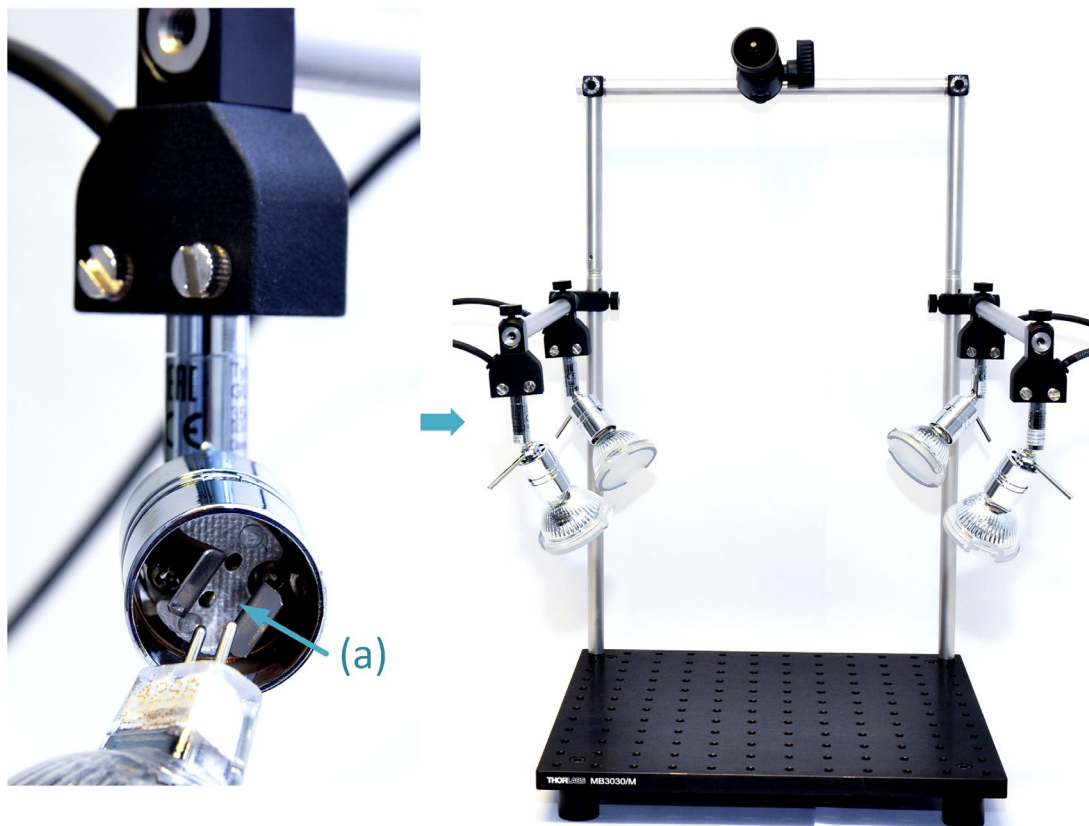


Figure 29 Mounting the lamps into the holders (Step 4.4)



Step 4.5 Adjust the height of the lamp posts (Figure 30)

- a. The height of the lamps can be adjusted by moving the lamp holding posts up and down along the vertical posts (as indicated by red arrow in Figure 30)

 The recommended height is shown in Figure 30. You can choose a suitable height depending on your application needs.

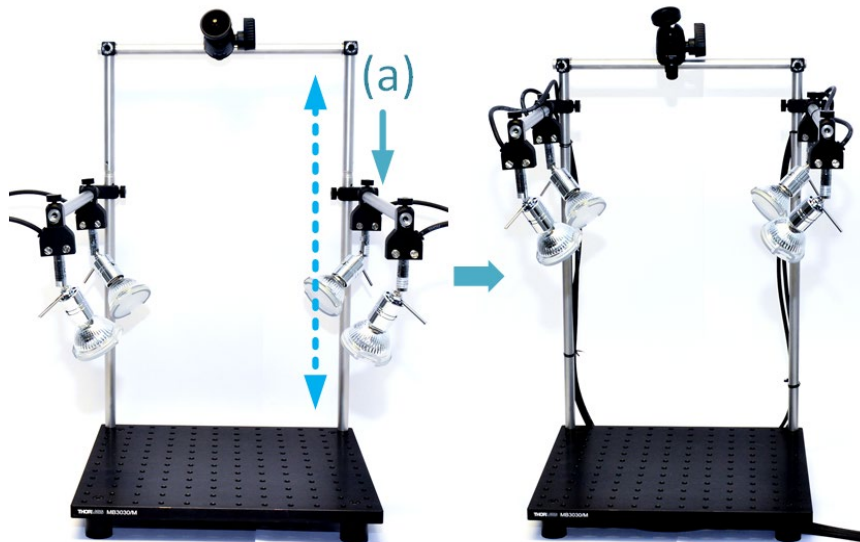


Figure 30 Adjust height of lamps depending on application needs (Step 4.5)

Step 4.6 Tie up the loose wires to the post (Figure 31)

- a. We recommend users to tie up the loose wires to the mounting posts, as shown by the blue arrows in Figure 31.



Figure 31 Tying up the loose wires to the mounting posts (Step 4.6)



3.1.5 Step 5 - Mount the snapscan camera

Required items

Ref. No	Components	Quantity	Packaged
01	snapscan camera	1	Box 1
03	Schneider-Kreuznach lens	1	Box 1

Procedure

Follow the steps below to mount the snapscan camera on to the setup, as shown in Figure 32.

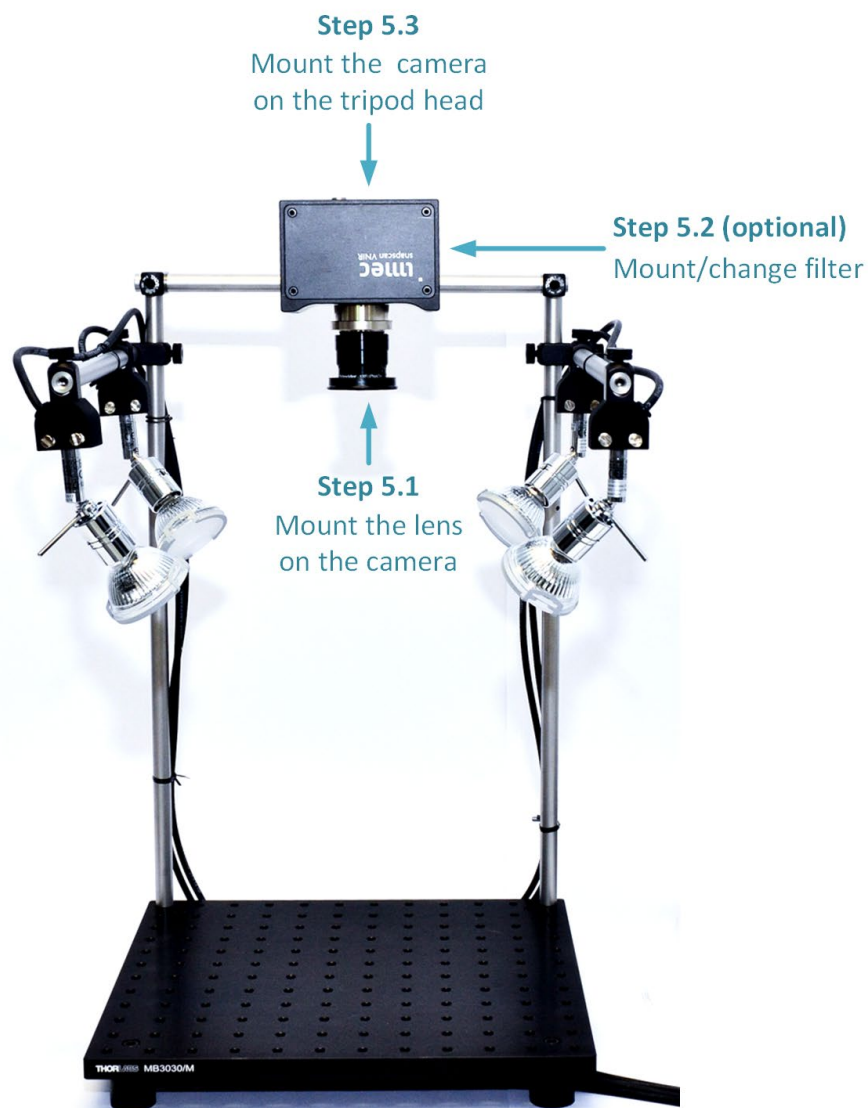


Figure 32 Mounting the snapscan camera on to the setup (Step 5)



Step 5.1 Mount the lens on the snapscan camera (Figure 33, Figure 34)

- Place the snapscan camera on a horizontal flat surface and remove the body cap of the camera
- Remove the rear cap of the lens
- Insert the rear of the lens into the c-mount of the camera and turn it clockwise to secure the lens on the camera body.

- It is recommended to leave the front cap on the lens until the system is fully assembled.*
- Do not forget to remove the front cap of the lens when using the system.*
- It is strongly recommended to put back the front cap on the lens when the system is not in use.*



Figure 33 Mounting lens on the snapscan camera (Step 5.1)

- Unlock the screw, turn the aperture ring to set the lens aperture and lock the screw.
- Unlock the locking ring with a hex key. Rotate the lens in or out until the correct focus is achieved. It is important to make sure that the lens remains fixed in the C-mount and only the lens body is rotated. Lock the locking ring with a hex key.

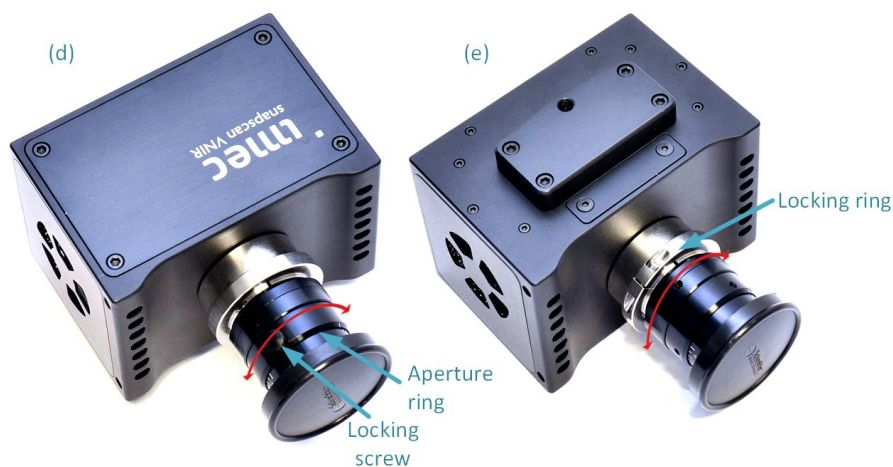


Figure 34 Focusing and setting the aperture of the lens



Step 5.2 Mount/change filter (Figure 35, Figure 36)

- a. Remove the tripod adapter plate if it is attached to the bottom of the camera. Unscrew the 4 screws in position **1** (Figure 35), with a 2.5mm alloy key. The adapter plate can now be removed. Place it aside, together with the 4 screws.
- b. Remove the two screws in position **2** (Figure 35), with a 2.5mm alloy key, which are holding the filter cassette in place. Place the screws aside. The filter cassette is now loose inside the camera and can slide out.
- c. Carefully tilt the camera, bottom plate facing down, so the filter cassette slides out. If the cassette does not slide out by itself, it might help to place a small screwdriver in one of the holes and use it as a lever.
- d. Wear gloves. Place the cassette, with the black aperture side, down onto a stable surface. The bottom side is the side that was closest to the sensor, the top side was closest to the lens. Use the spanner wrench to carefully unscrew the retaining ring, as indicated on Figure 36.

Push the filter out, with your finger, through the bottom of the filter cassette. Please store the filter safely for the time being. For instance, in some grease free paper, in a bubble shield bag.

- e. Place the new filter into the cassette, make sure you only touch it on the sides. Now place the upper retaining ring back in place and use the spanner wrench to tighten it (finger tight is sufficient).

Place the filter cassette in the upright position, as shown in Figure 36. Check if the black aperture insert is still in the correct position: the inside top and bottom of the aperture should create horizontal line. If this is not the case, you can slightly rotate the retaining ring, on the aperture's side. Tighten the ring on the filter's side afterwards, to ensure that the filter stays well in place. If you gently shake the filter holder, you should hear no noise.

- f. Slide the filter cassette back into the camera, this is only possible in one orientation, do not apply force if it appears to get stuck. There is no force required to slide the cassette in place. Place and tighten the 2 screws in position **2**.
- g. If applicable, place back the tripod adapter plate and tighten the 4 screws in position **1**. This completes the procedure.



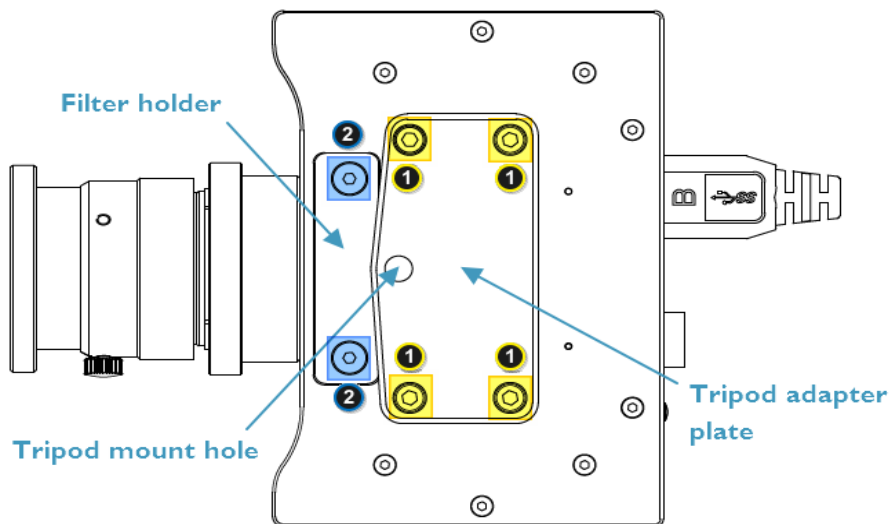


Figure 35 bottom view of the snapscan VNIR camera

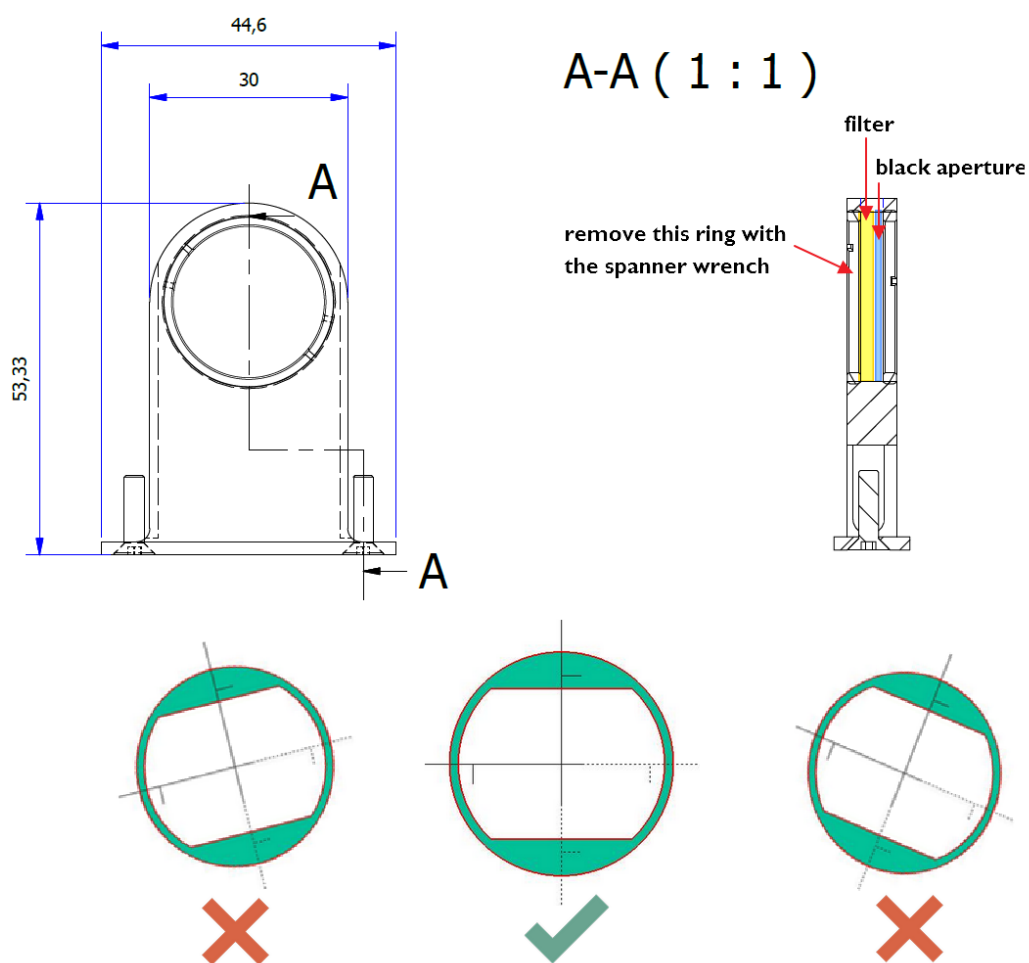


Figure 36 Filter cassette schematics, with position of the filter indicated. The bottom section of the figure shows the correct position of the black aperture.



Step 5.3 Mount the snapscan camera on the tripod head (Figure 37)

- The tripod adapter plate on the bottom of the snapscan camera provides a threaded hole to which the tripod head can be affixed. Align the hole on the camera to the screw on the tripod head.
- Rotate the tripod screw to tighten the screw to affix the camera to the tripod head. You may use the lock/unlock level on the tripod head to adjust the position of the ball head.
- Unlock the post clamp screw to adjust the tripod head on the mounting post such that the camera body is parallel to the base plate and lock it again. Make sure to tighten the screw properly to avoid tripod head rotating down due to camera's weight.

⚠ You will require imperial allen key size 3/16" for the post clamp screw

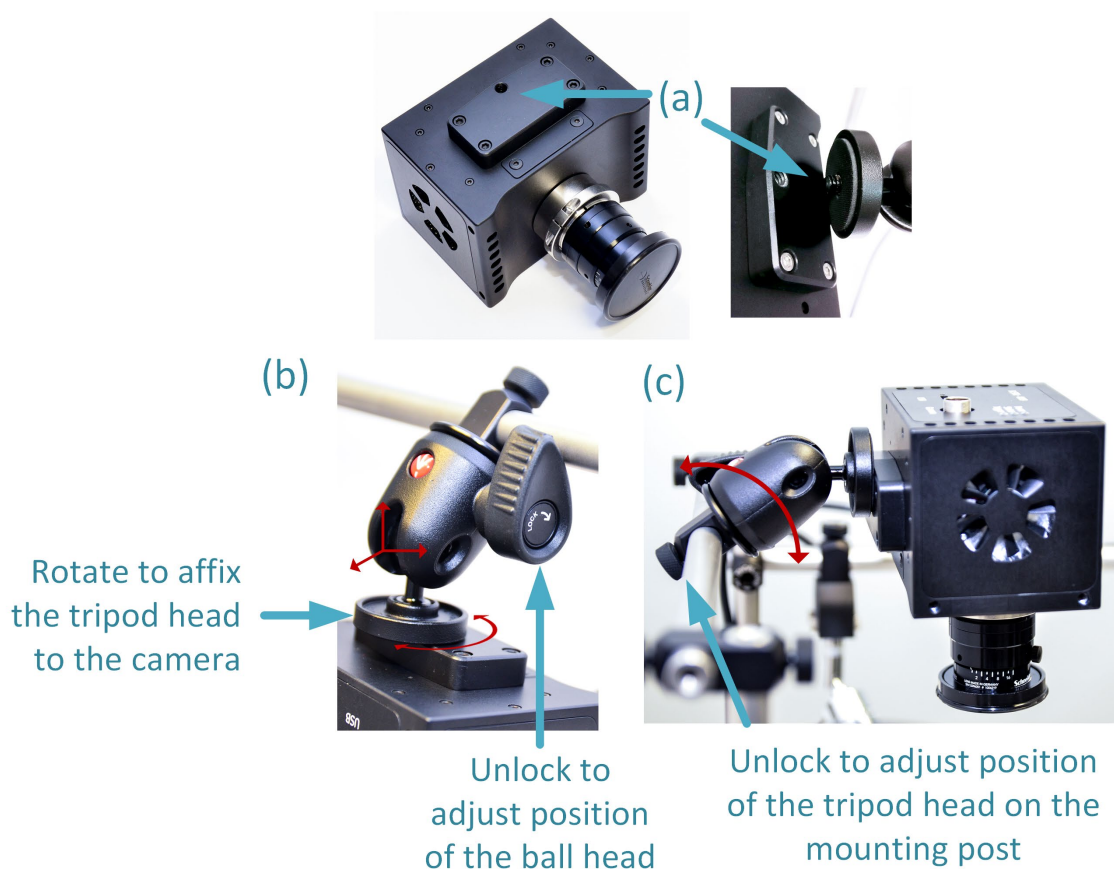


Figure 37 Mounting of snapscan camera on to the tripod head (Step 5.2)



3.1.6 Step 6 - Connect the lamps to the power supply

Required items

Serial No	Components	Quantity	Packaged
18	Tunable stabilized DC power supply	1	Box 2
19	Tunable stabilized DC power supply power cable	1	Box 2

Procedure

Follow the steps below to connect the lamps to the power supply and test, as shown in Figure 38.

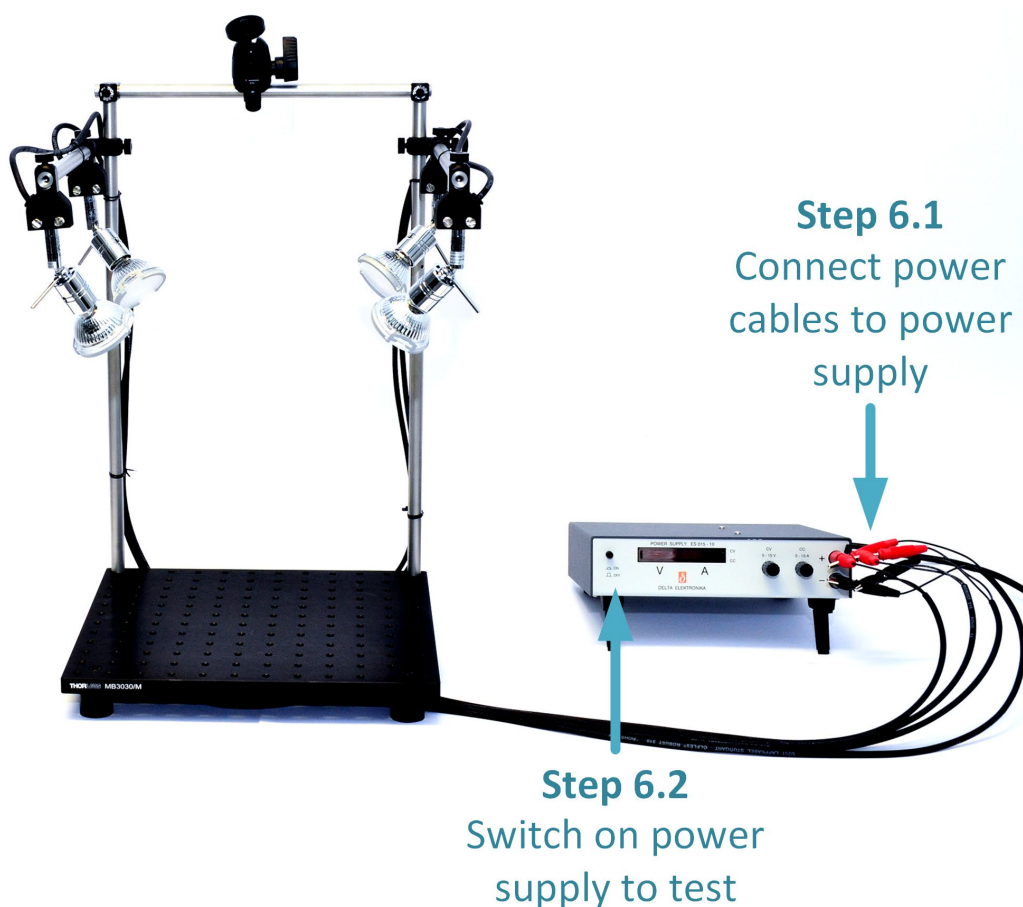


Figure 38 Connecting lamps to power supply and testing (Step 6)

Step 6.1 Connect power cables to power supply (Figure 39)

- Connect the 4 pairs of red and black connectors corresponding to the 4 lamps to the output of the power supply, as shown in the Figure 39.





Figure 39 Connecting lamps to the power supply (Step 6.1)

Step 6.2 Test the connection (Figure 40)

- Switch on the power supply and set the output voltage at 12V.
- If all the connections have been correctly done, all 4 lamps should illuminate.

i You can switch off the power supply once the test is done.

i While using the system for acquiring data, the lamps need to be switched on for at least 15 minutes to allow them to warm up and stabilize.



(a)



(b)

Figure 40 Test the power connection for the lamps (Step 6.2)



3.1.7 Step 7 - Connect the camera to the controller and PC

Required items

Serial No	Components	Quantity	Packaged
02	snapscan controller	1	Box 1
07	snapscan controller adapter	1	Box 1
08	snapscan controller adapter power cable	1	Box 1
05	snapscan 16-pin cable	1	Box 1
04	USB 3.0 cable (3m)	1	Box 1
06	USB 2.0 cable	1	Box 1

Procedure

Follow the steps below to connect the snapscan camera to the controller and the PC, as shown in Figure 4I.

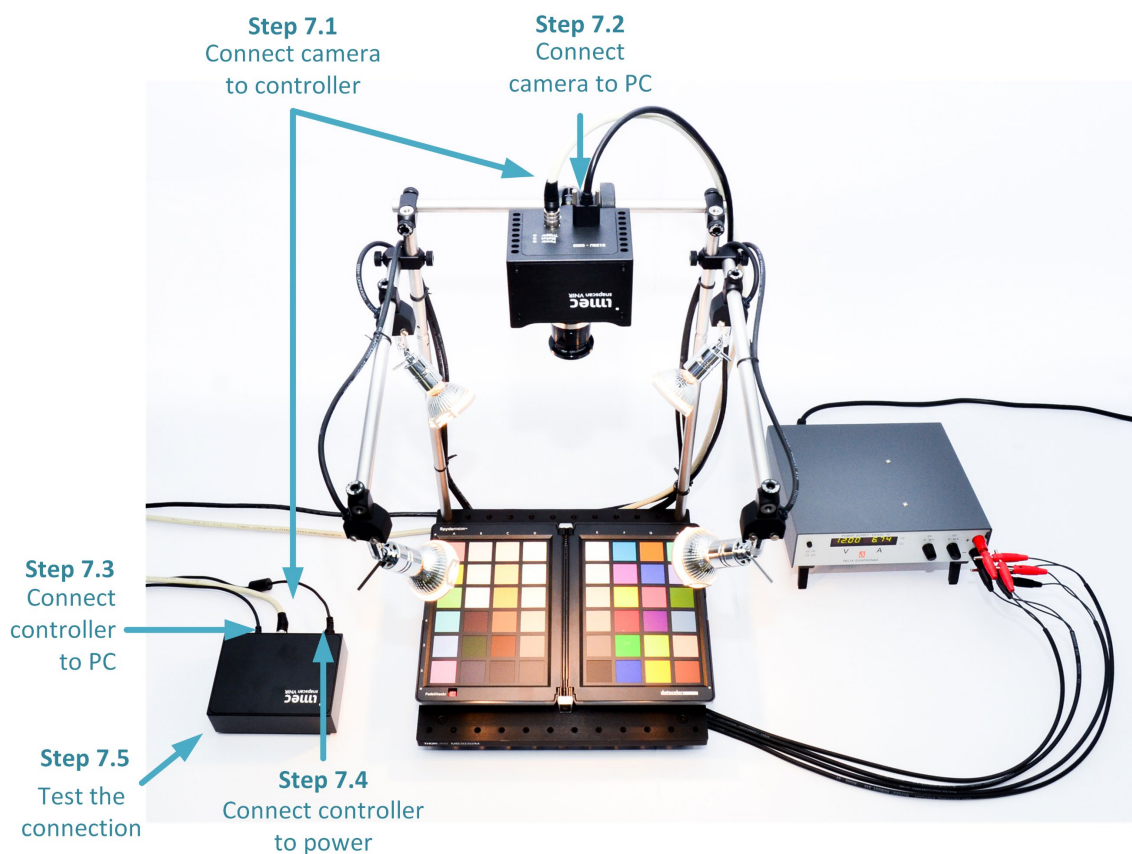


Figure 4I Connecting camera to controller and PC (Step 7)



Step 7.1 Connect camera to controller

- a. The 16 pin scapscan cable has male and female connectors on the two ends. Connect the female side to the camera, as shown in Figure 42.



Figure 42 Connecting the 16pin scapscan cable to the camera (Step 7.1a)

- b. Align the notch in the connector of the cable to the notch in the connector of the camera (as shown in Figure 43) and push the cable in place.

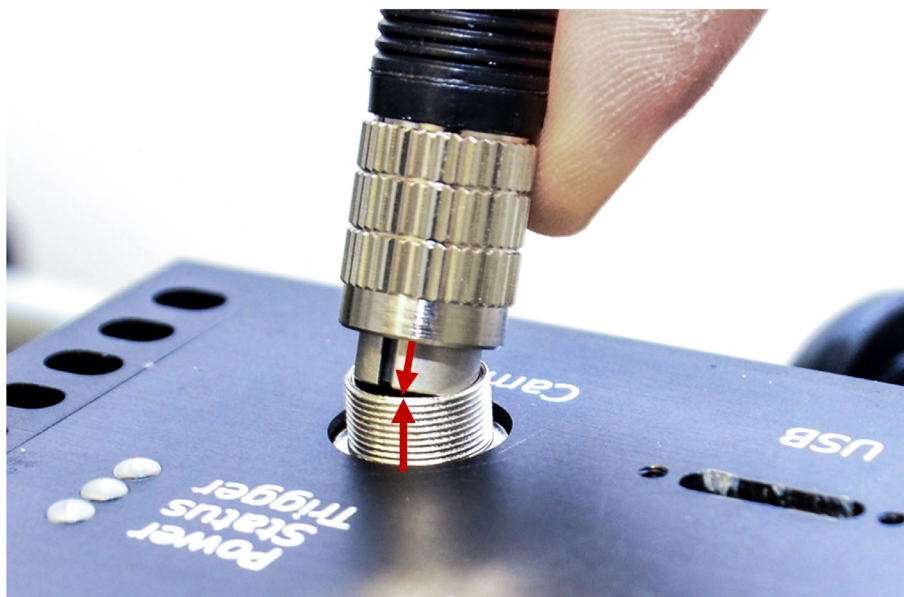


Figure 43 Align the notch on the cable connector to the notch in the camera connector (Step 7.1b)



- c. Lock the connector by turning the threaded ring, as shown in Figure 44.



Figure 44 Locking the snapscan controller cable in the camera's connector (Step 7.1c)

- d. Align the notch in the connector of the cable to the notch in the connector of the controller, as shown in Figure 45.



Figure 45 Align the notch on the cable connector to the notch in the controller connector (Step 7.1d)



- e. Push the cable connector into the controller connector and lock the connector by turning the threaded ring, as shown in Figure 46.



Figure 46 Connecting the snapscan 16 pin cable to the snapscan controller (Step 7.1e)

Step 7.2 Connect the snapscan camera to PC (Figure 47)

- a. USB 3.0 cable is used to connect the spanscan camera to the PC. The USB 3.0A connector is the PC side and USB 3.0 micro-B connector is the camera side. Align the USB 3.0 micro-B connector to the port on the back of the snapscan camera, as shown in Figure 47a.
- b. Push the USB 3.0 micro-B connector into the camera's USB port (Figure 47b)
- c. Lock the USB connector by turning the threaded rings (Figure 47c)



Figure 47 Connecting snapscan camera to the PC (Step 7.2)



Step 7.3 Connect the snapscan controller to PC (Figure 48)

- a. USB 2.0 cable is used to connect the snapscan controller to the PC. The USB 2.0 connector is the PC side and USB 2.0 mini-B connector is the controller side. Align the USB 2.0 mini-B connector to the port on the back of the snapscan controller (as shown in Figure 48), and push it into the port.



Figure 48 Connecting the snapscan controller to the PC (Step 7.3)

Step 7.4 Connect the power adapter to the snapscan controller

- a. Assemble the power adapter by affixing the power cable into the adapter, as shown in Figure 49.



Figure 49 Assembling the power adapter for the snapscan controller (Step 7.4a)



- b. Connect the barrel connector to the power input port on the backside of the snapscan controller, as shown in Figure 50.



Figure 50 Connecting power adapter to the snapscan controller (Step 7.4b)

Step 7.5 Test the connection

- a. Verify that all the connections are complete, as shown in Figure 51.

Connections for
snapscan
camera



Connections for
snapscan
controller



Figure 51 All the connections for the snapscan camera and controller (Step 7.5a)



- b. The connections between the snapscan camera, the snapscan controller and the PC should be as shown in Figure 52.

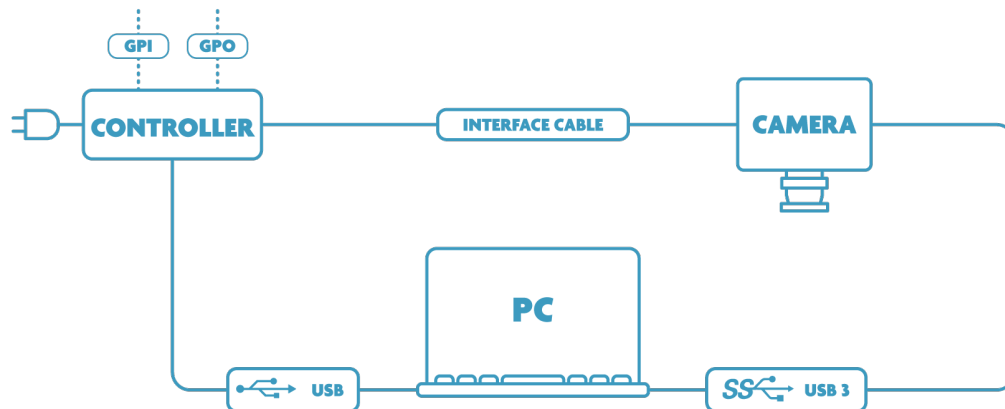


Figure 52 Connections between snapscan camera, snapscan controller and PC (Step 7.5b)

- c. Power the system by switching on the controller using the “Power” button on its rear panel (see Figure 51). If all the connections are setup correctly then the fans and the lights of the camera unit will switch on.



3.2 Demo setup

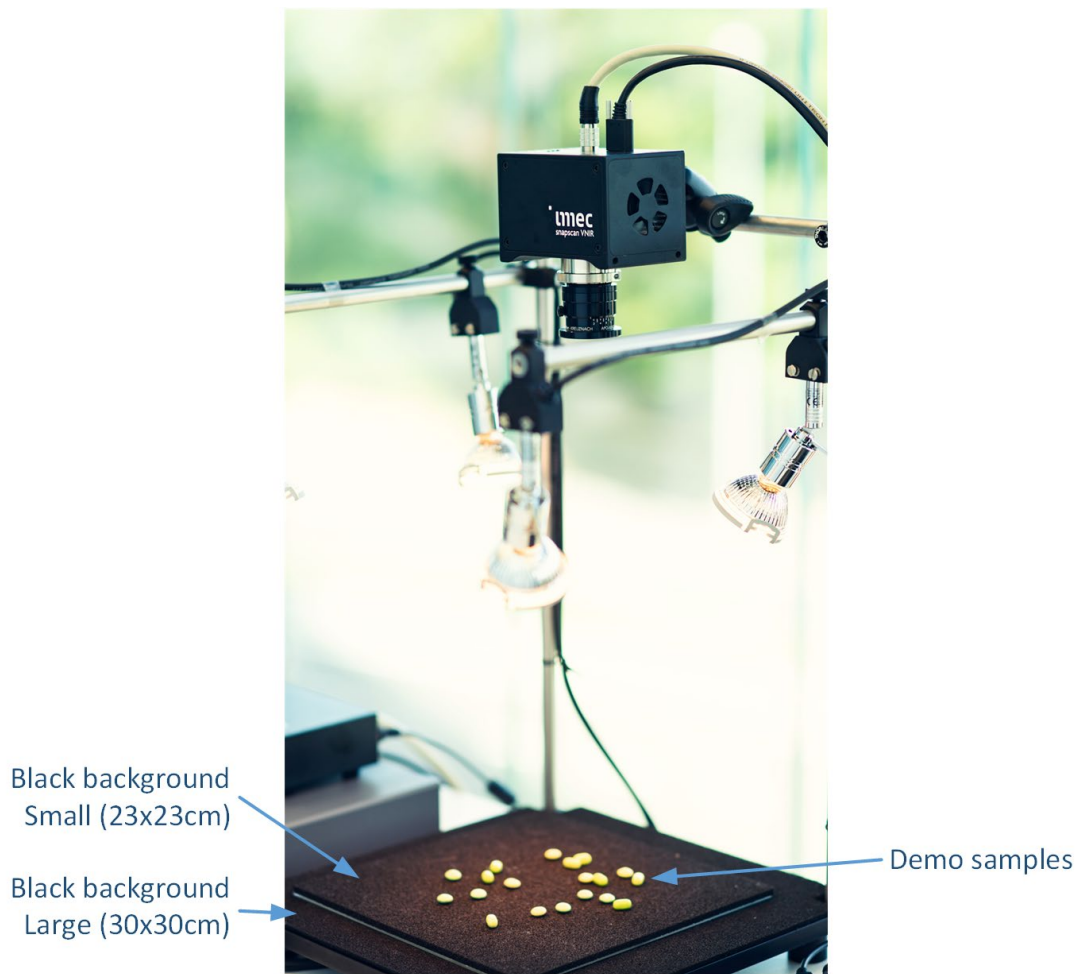


Figure 53 Demo kit included in the snapscan evaluation system

The evaluation system comes with a demo kit consisting of

- **Black backgrounds** – Two sizes are included (23x23cm and 30x30cm). These backgrounds can be kept on the base plate and the objects to be scanned can be placed over them, as shown in Figure 53.

These backgrounds are made of spectrally black material which have no spectral response in the spectral range of the snapscan camera. Hence, using these backgrounds make it easier to remove the background from the acquired hyperspectral data during analysis.

- **Demo samples** – A box of pills are included which can be used for initial scanning and demo purposes.



3.3 Troubleshooting

The lamps do not work

Carry out following checks:

Check 1: Is power supply working? If not, then check if-

- power cord is plugged in
- power supply is turned on

Check 2: Are the lamps properly inserted in the sockets? If not, then press the lamps deeper into the sockets. (see step 4.4)

Check 3: If the cables attached to the lamp holders are connected to the power supply in the correct way (see step 6.1)

Check 4: If the voltage and current is set correctly (see Step 6.2)

The controller does not work

Check if the red power LED of the controller is lit or not. If not, then check if

- the power supply is plugged in
- the controller is turned on

The camera does not work

Check if the power and status LED on the back of the camera are lit or not. If not, then check the following:

- USB3.0 cable is connected to the camera and a PC
- custom 16-pin cable is connected to the camera and the controller
- controller is connected to a PC via the USB2.0 cable
- USB ports of the PC are functioning properly
- controller is turned on

The diffuser is attached loosely to the halogen lamp

Remove the diffuser and holder from the lamp, press the holder's handles further inward to ensure a better fit and clip back on the lamp.

When handling the camera body it sounds like something is loose inside the camera

Check if the filters in the filter cassette are locked in place.



The camera makes a clicking sound after it is connected and during scanning

This is normal. The camera shutter will cycle after connection and before starting a scan. During a scan the translation stage is moved internally, which can also lead to audible clicking.

Contact imec HSI support if the problem persists or for any other problems:

Email: hsisupport@imec.be

Website: <http://hsisupport.imec.be>







Chapter 4

Hardware Manual

4. Hardware manual

4.1 Mechanical specifications

4.1.1 External controller dimensions

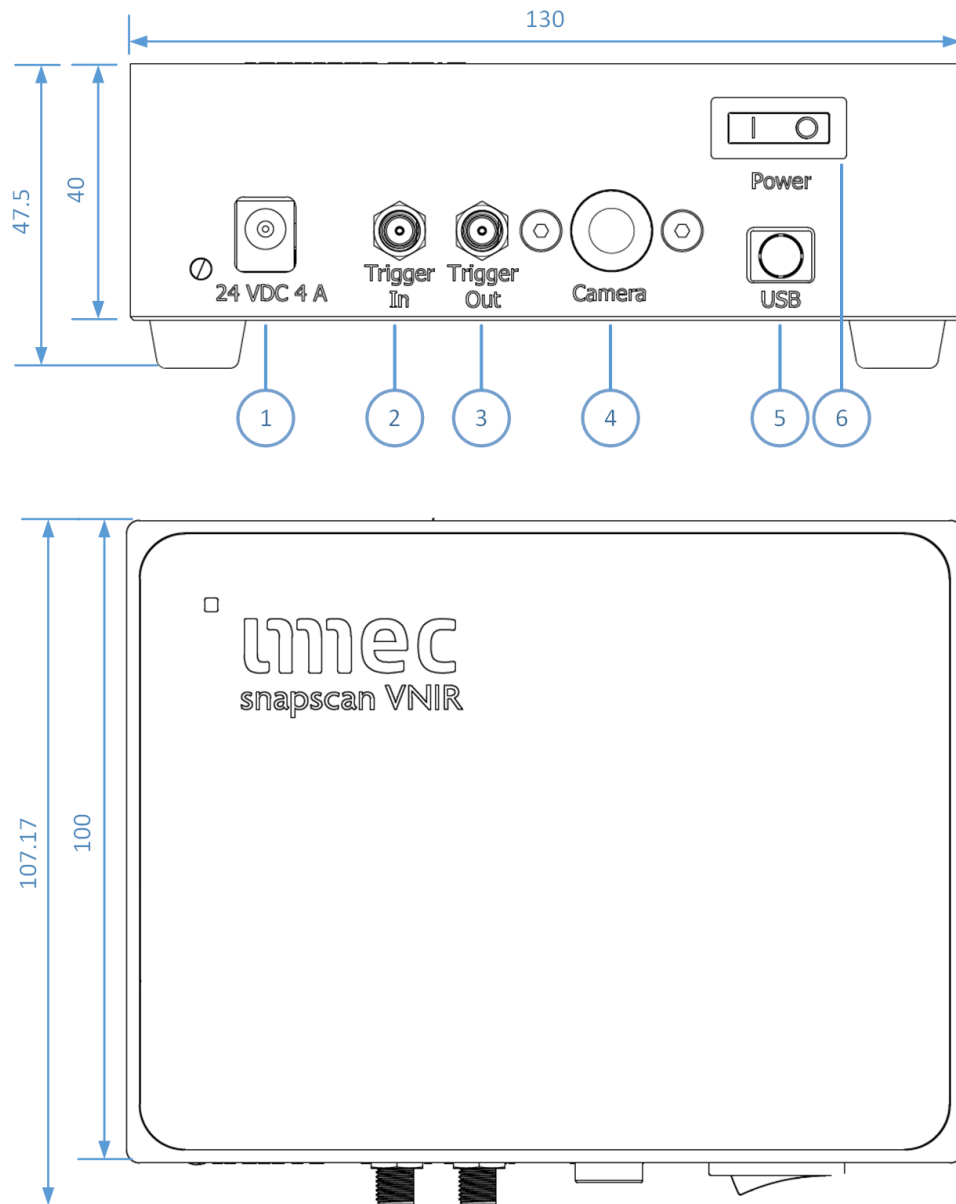


Figure 54: External dimensions of the snapscan controller and I/O in the back panel
(all dimensions are in millimeter)

1	24 VDC 2.7A power input	4	Camera port (16-pin Hirose female)
2	Trigger In (female SMA)	5	USB 2 interface (Mini-B)
3	Trigger Out (female SMA)	6	Power switch



4.1.2 Camera dimensions

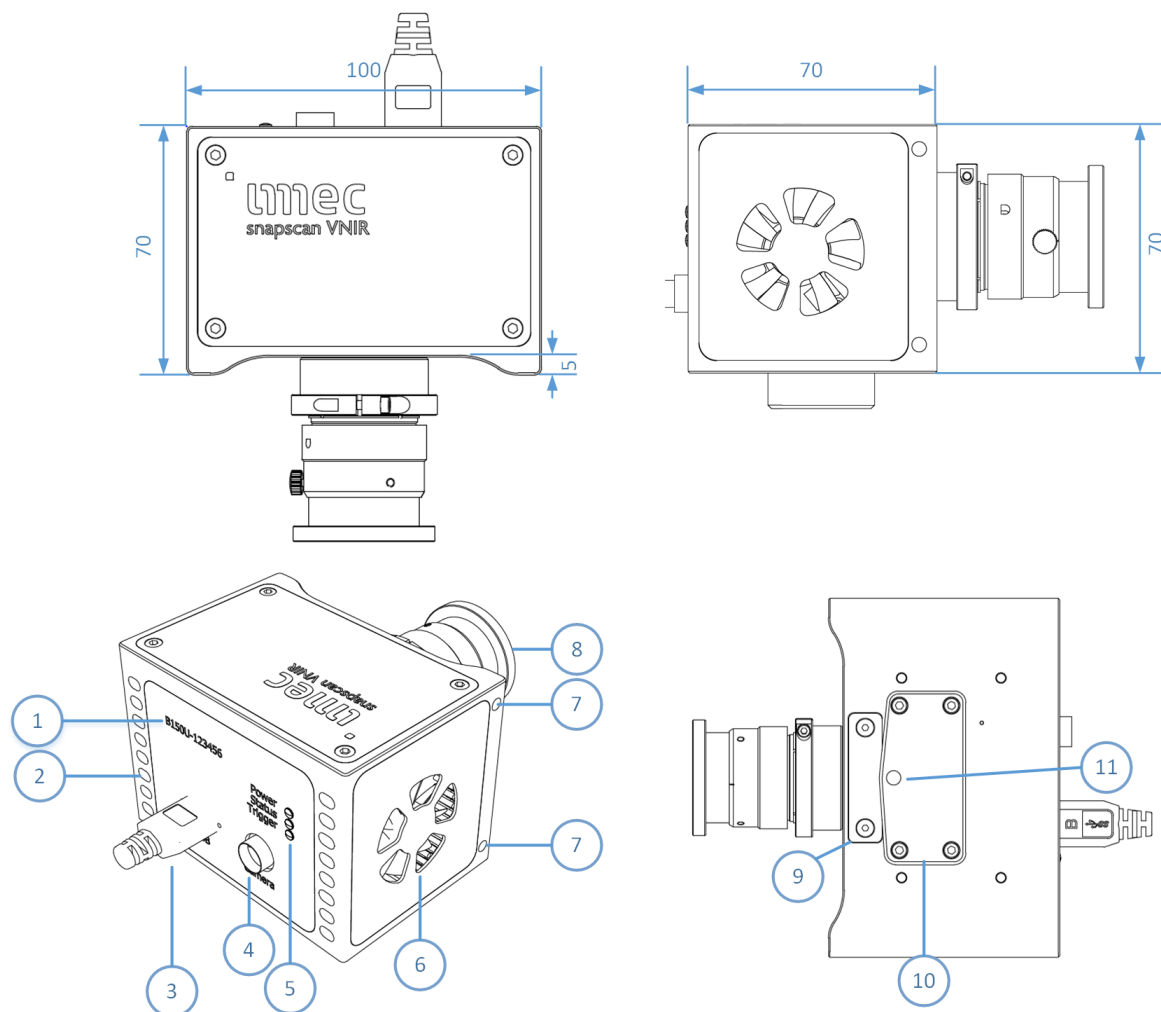


Figure 55 External dimensions of the camera body (all dimensions are in millimeter)

1	Camera serial number	7	Mounting holes
2	Air vents	8	Lens
3	USB 3 connector	9	Filter cassette
4	Camera port (16-pin Hirose female)	10	Tripod adapter plate
5	Indicator LEDs	11	Tripod mounting hole
6	Cooling fan		



4.1.3 Flange focal distance

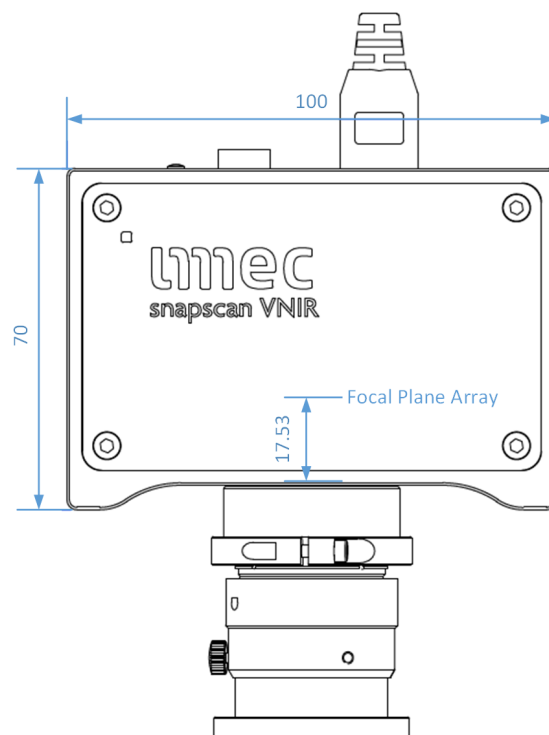


Figure 56 Flange focal distance, i.e. distance between the image sensor and the lens mount (all dimensions are in millimeter)

4.1.4 Camera mounting options

4.1.4.1 Tripod adapter plate

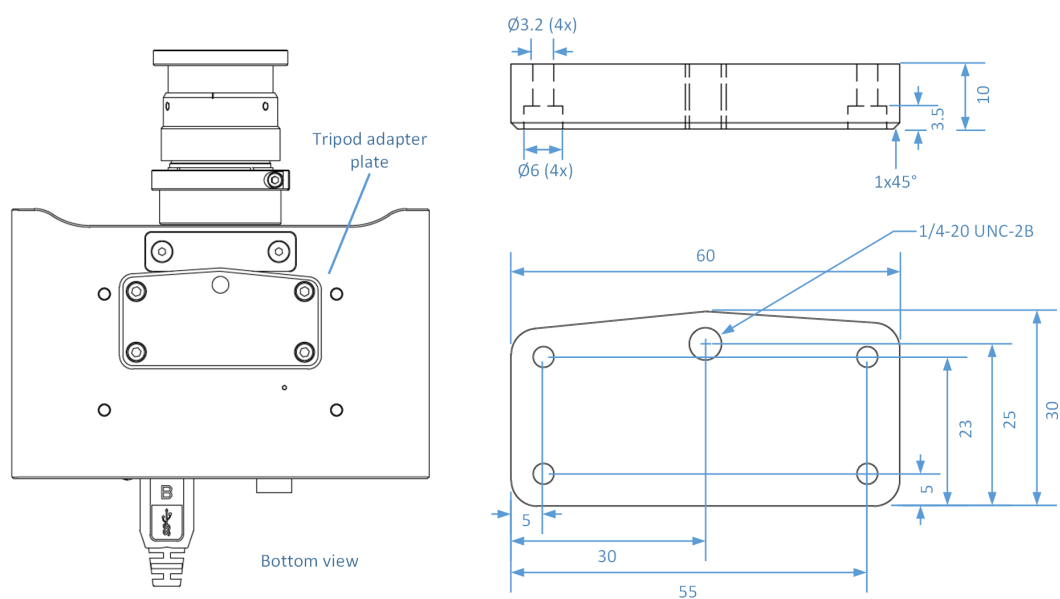


Figure 57: Top and side views of the tripod adapter plate along with its dimensions (all dimensions are in millimeter)



4.1.4.2 Mounting holes on the bottom of the camera

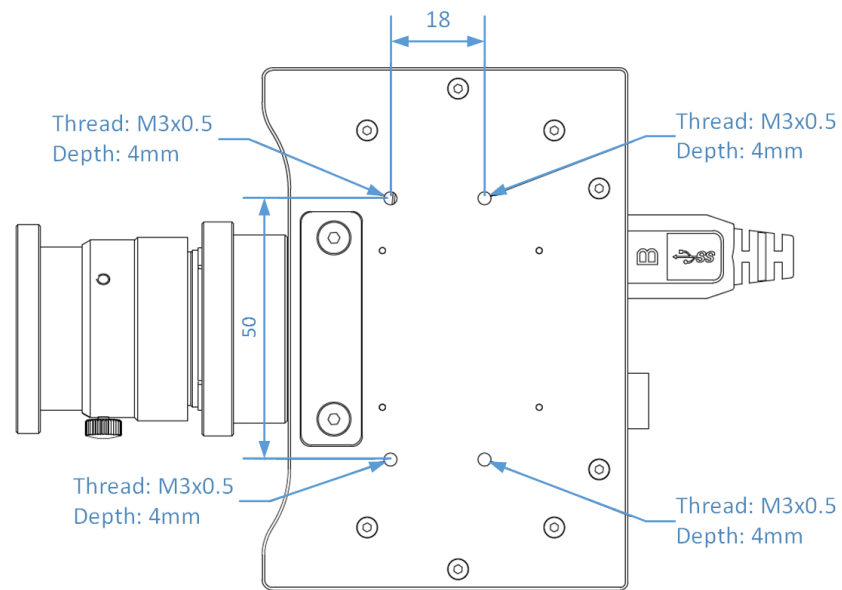


Figure 58 Bottom view of the snapscan camera showing the 4 mounting holes (all dimensions are in millimeter)

⚠ The mounting screws should not go deeper than 4mm in the holes. It can damage the internals of the camera.



4.1.4.3 Mounting holes on the sides of the camera

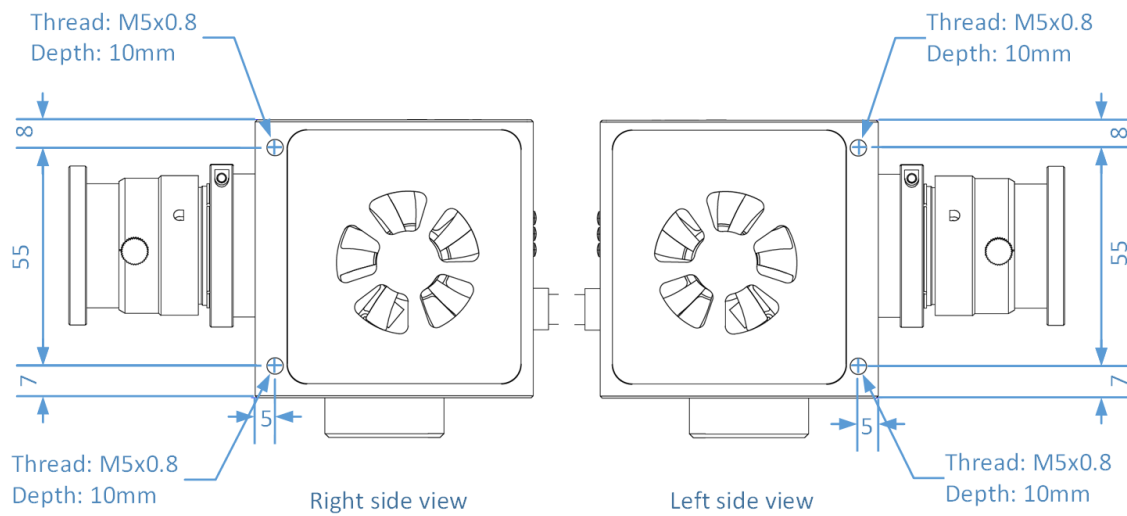


Figure 59: Side views of the snapscan camera along with dimensions and the available mounting holes (all dimensions are in millimeter)

4.1.5 Filter cassette dimensions

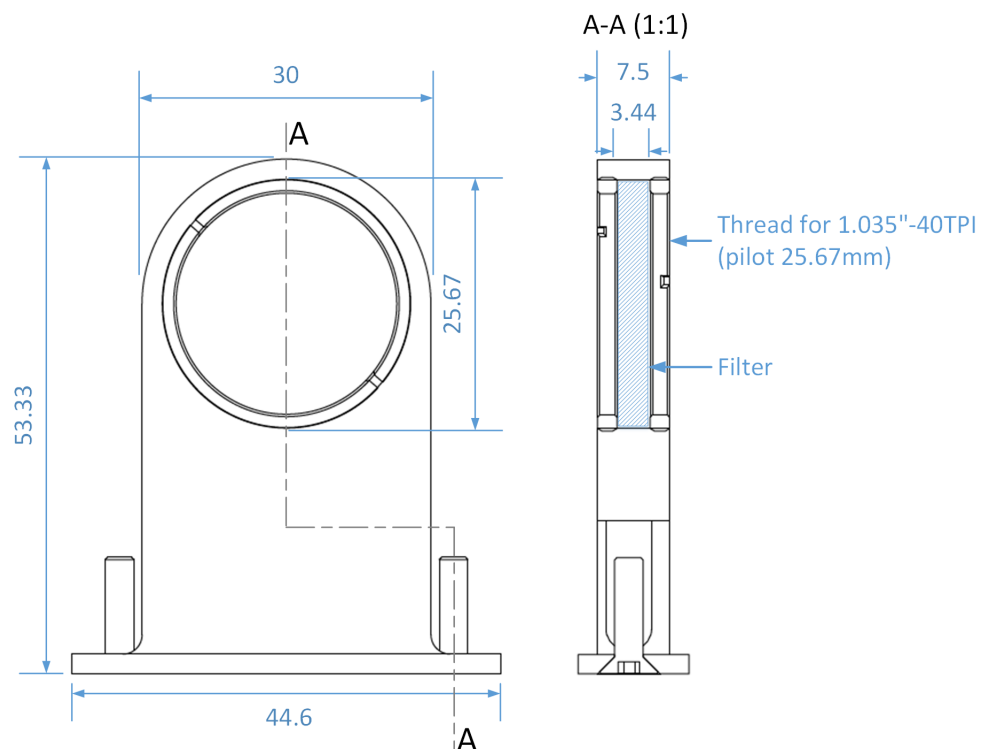


Figure 60: Front and side views of the filter holder along with its dimensions (all dimensions are in millimeter). The optical filter will be placed between two retaining rings, as indicated. The filter diameter is 25.4mm and maximum thickness is 3.44mm.



4.2 Electrical specifications for snapscan controller's GPIO interface

Table 5 Overview of output parameters for the controller

Output parameters	Values
Frequency	Synchronized with camera frame acquisition
Output pulse	50 ns in continuous scanning mode 10 ms in discontinuous scanning mode
Max output frequency	1700 Hz
Voltage levels	0-5 V TTL
Opto-coupled	Yes
Fuse	No
Max. current	10 mA
Logic	Pull down
Visual indication	Trigger LED flashes red

Table 6 Overview of input parameters for the controller

Input parameters	Values
Function	Can be used to start the acquisition
Minimum duration of input pulse	50 ms
Voltage levels	0-5 V TTL
Opto-coupled	Yes
Fuse	No
Max. current	10 mA
Logic	Pull down

 *High voltage 71V DC. When removing the interface cable between controller and camera, actuators inside the camera can stay charged for several hours. Temperature changes can also induce charges on the internal actuators.*

4.3 Operating conditions

- The snapscan system is intended to be used in a lab environment.
- Always ensure that the camera is connected and mounted correctly before operation.
- Never operate the camera without lens or without filter cassette.
- Only use the power supply and cables provided with the system.
- Respect the electrical specification when connecting to the GPIO ports.



4.4 Storage conditions

The snapscan system is delivered in a ruggedized plastic case. The camera should be stored in this case when not in use. Please ensure that you always place the camera, lens, controller box and its main cables back in this case for safe storage. Use the provided lens, C-mount and connector caps when storing the system.

 Please note that, while this plastic storage case is highly resistant to vibrations, impact due to falls, high and low temperatures, the camera and the components are not. Subjecting the camera unit or any of the included components to excessive vibrations, impact due to falls or extreme temperature outside the specified ranges might cause a damage even when they are inside the storage case.

4.5 Maintenance tips

4.5.1 Preventive maintenance

- Do not use the camera when the filter cassette or lens is removed
- Do not leave the camera lens mount uncovered after the lens is removed. Immediately cover it with the provided C-mount cap.
- When removing the filter cassette, take following steps to avoid the dust from entering the system
 - Cover the filter cassette slit
 - Rest the camera with the filter cassette slit facing down
- Take special care not to damage the connectors
- Secure the USB connector on camera by tightening the screws
- Protect the camera system from water and excess humidity
- Protect the camera system from vibrations, while in operation and during storage
- Do not touch the filters, sensor and shutter.
- Always use the camera with the controller it was delivered with. Using a different controller may irreversibly damage the camera.

4.5.2 Regular maintenance

- Clean the lens input port on a regular basis with a clean micro tissue.
- Remove dust from fans with a camera dust blower.
 - Do not use a vacuum cleaner or apply air forcefully.

4.5.3 Corrective maintenance

- Contact imec HSI support for case specific support.
- Specialty maintenance at imec is available upon request.
- In case of particle contamination in the optical system:
 - Sensor cleaning should not be performed by the user.
 - Clean the lens output port with a clean cotton swab.
 - Clean filter in the filter cassette with a clean cotton swab.

 Opening the camera or controller voids the warranty. Special precautions have been taken to make this noticeable.







Chapter 5

Software Installation Manual

5. Software Installation Manual

This chapter will guide you through software installation and configuration.

5.1 System requirements for the PC

For successful operation of the software it is required that the computer conforms at least to the minimum system requirements as given in Table 7 and has a compatible USB3.0 adapter as specified in Table 8. It is highly recommended to reserve the use of the computer to the snapscan system.

 *Do not connect the snapscan system to the PC until after the installation.*

 *On computers with Windows 7 it's recommended to install dedicated USB3.0 drivers for your hardware instead of using the default generic drivers. Check your computer vendor's support site to download these drivers.*

Table 7: Minimum and recommended system requirements for the PC

Parameters	Minimum configuration	Recommended configuration
Operating System	Microsoft Windows 7, 64 bits	
Processor	Intel i5	Intel i7
Hard disk type	Solid State Drive (SSD)	
Free hard disk space	10GB	Usage dependent
RAM	16 GB	32 GB
USB for camera	1x USB 3.0	
USB for controller	1x USB 2.0	

Table 8: List of compatible driver version for different USB3.0 adapters

Adapter type	Compatible driver version
Fresco Logic FL1100	3.5.24.0
Renesas D720202	3.0.12.0
Intel QM77, Z77, Z87, Z97	Latest
Intel Broadwell	Latest
ASMedia AS1042	Not compatible
Etron EJ168A	Not compatible
Via Labs VL800-Q8	Not compatible



5.2 Software installation

Follow the steps below to install the software:

- Download the latest version “*snapscan - Software installer*” from the imec hyperspectral support site: <http://hsisupport.imec.be>. The filename of the downloaded installer is *snapscan_installer_<version>.exe*
- Double click the installer to start the installation wizard
- Follow the steps as guided by the installation wizard
- The following software components are included in the installer -

Software components	Description	Disk space required
Imec snapscan acquisition	Mandatory. Required to control the snapscan system.	288.2 MB
Imec HSI studio	Optional. Can be used to view the data acquired with the snapscan acquisition software (data is in ENVI format).  <i>Currently, there is no separate documentation available. We refer users to Chapter 6 (Software user manual) of this manual.</i>	0.2 MB
perClass Mira	Optional. perClass Mira is a spectral imaging software from perClass BV. perClass Mira can be used for viewing and analyzing the acquired hyperspectral image data. A 14 day limited functionality demo license is included with snapscan software.  <i>Documentation and user manual can be found online at http://doc.perclass.com/perClass_Mira/Introduction.html</i>	2.3 GB

- If needed, the wizard will start the installers of the third-party software/drivers that is required to communicate with the snapscan hardware. Follow the instructions to complete the installation or update.

Driver type	Description	Disk space required
FTDI	Interface snapscan controller with PC	500 MB
PI	Internal stage control	
Ximea	Camera control	
MSVC redistributable	Run-time components for snapscan software	



5.2.1 perClass Mira installation

Following are the system requirements for perClass Mira

Parameters	Minimum configuration
Operating System	Microsoft Windows 7 (or higher), 64 bits
RAM ²	8 GB
GPU	NVIDIA GPU supporting CUDA 9.0 library (needs to be installed separately)
GPU memory	4GB

 Please refer to perClass' website for the latest system requirements - http://doc.perclass.com/perClass_Mira/Systemrequirements.html

Follow the steps below to install and activate perClass Mira:

- perClass Mira can be installed with an installer bundled in IMEC software
- 14-day limited functionality demo license is provided with the snapscan purchase. Follow the steps shown here to activate the license (http://doc.perclass.com/perClass_Mira/Firststart.html)

-  Once a demo is activated, scanned images can be loaded in perClass Mira
 - classification solution can be created
 - decisions on more images can be tested from within perClass Mira
 - the solution can be exported in a file, loaded in IMEC software and applied to new images
-  perClass offers a 1-hour remote training using TeamViewer to help users to get started
-  Demo does not allow saving project files or exporting data. Please contact perClass for licensing options for full functionalities



5.3 Software configuration

Follow the steps below to configure the software and complete the installation:

- Ensure that the system is connected, as shown in Figure 61.

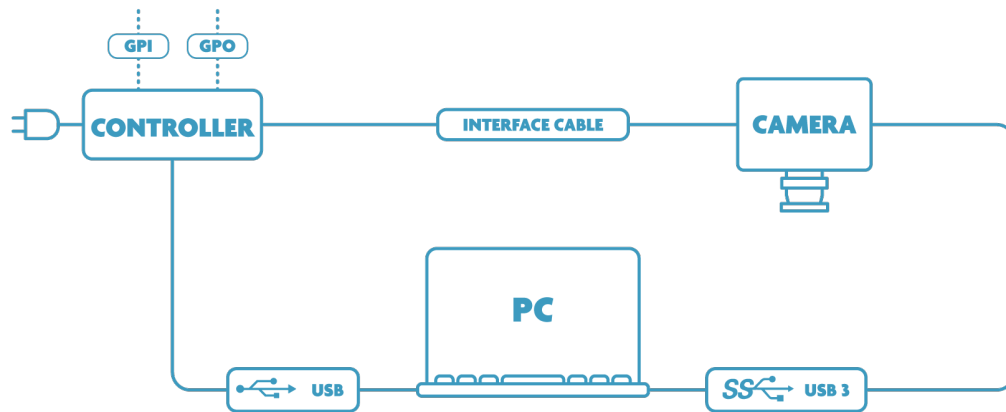


Figure 61: Connection diagram showing the connections between all components of the snapscan system.

- Configure the software by selecting the “System information file” that has been delivered with the camera unit. The software will prompt to select this file when it is launched after the installation, as shown in Figure 62.

Each camera unit comes with two unique files – system information file and sensor calibration file. Both the files should be kept together in the same folder. It is advised not to modify these files to ensure proper functioning of the camera unit and the controller.

The system information file identifies the system and its different components. This information is used by the acquisition software to connect to the system and to correctly produce spectral measurements.

The sensor calibration file contains the full calibration report for the hyperspectral image sensor integrated in the camera unit.



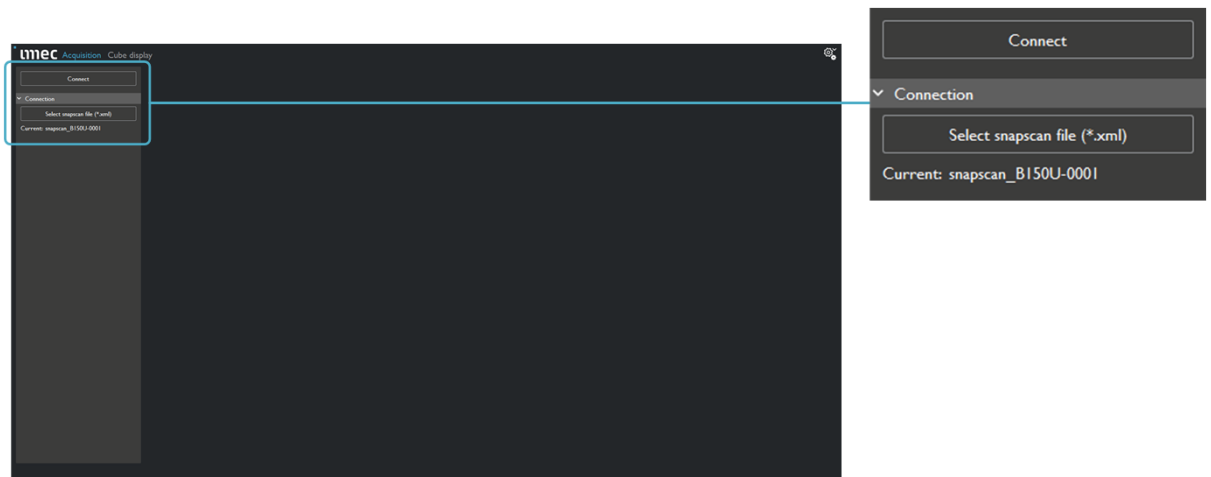


Figure 62 Configure system information file specific to the camera unit

-  Refer to the troubleshooting section in case of problems.
-  Contact HSI support if the problems persist.



5.4 Troubleshooting

The installation process didn't complete successfully

Locate the installation directory and verify if it exists and contains a shortcut to launch the software. If not, then launch the installer and run through the wizard again. Contact support in case of repeated failure.

The PC cannot find the correct drivers for the hardware

Make sure to first install the snapscan acquisition software. During installation all required device drivers will be installed on the PC.

The software cannot connect to the snapscan camera

Check 1: Correct system file is loaded and try connecting again.

Check 2: snapscan system is connected correctly to the computer:

- (Re-)Connect the snapscan camera's USB cable to a USB3.0 port.
- Try connecting the software again.
- Try with a shorter cable

Check 3: snapscan camera is detected in the device manager.

- Verify that the computer's USB ports are powered. This might not be the case when working on battery or in a power optimization mode.
- Try using a different USB3.0 port.
- Ensure that you are using the USB3.0 cable supplied with the system.

Check 4: There are no unknown devices in the device manager. If there are unknown devices:

- Disconnect the snapscan system by removing all connections to the computer.
- Open the directory resources\installers in the installation directory.
- Run the installer (XIMEA_API_Installer_Beta.exe) with at least the "Drivers" option checked and make sure it completes successfully.
- Connect the snapscan system. The operating system should now detect the device and install the correct driver.
- Try connecting again.

Check 5: USB3.0 drivers for the machine are installed correctly.

The default Windows 7 USB3.0 drivers might not be suited, especially on laptops. Navigate to the support site of your computer to download and install the dedicated USB3.0 drivers for your computer.



The software cannot connect to the snapscan controller

Check 1: The correct system file is loaded and try connecting again.

Check 2: Power cycle the snapscan controller and try connecting again.

Check 3: snapscan controller is connected correctly to the computer:

- (Re-)Connect the snapscan controller's USB cable to any USB port.
- Try connecting the software again.

Check 4: All devices are detected in the device manager. If either of the USB 2.0 hub, USB serial converter or PI controller are not detected then check the following -

- Controller is connected to mains power and is switched on.
- Computer's USB ports are powered. This might not be the case when working on battery or in a power optimization mode.
- Try using a different USB port.

Check 5: There are no unknown devices in the device manager. If there are:

- Disconnect the snapscan system by removing all connections to the computer.
- Open the directory resources\installers in the installation directory.
- Run the installers for the USB serial converter (CDM21226_Setup.exe) and PI USB driver (PI_USB_Driver_Setup_64Bit.exe) individually and make sure they complete successfully.
- Connect the snapscan system. The operating system should now detect the device and install the correct driver.
- Try connecting again.

Check 6: When working on a laptop, the laptop's USB port may not provide sufficient power. In this case,

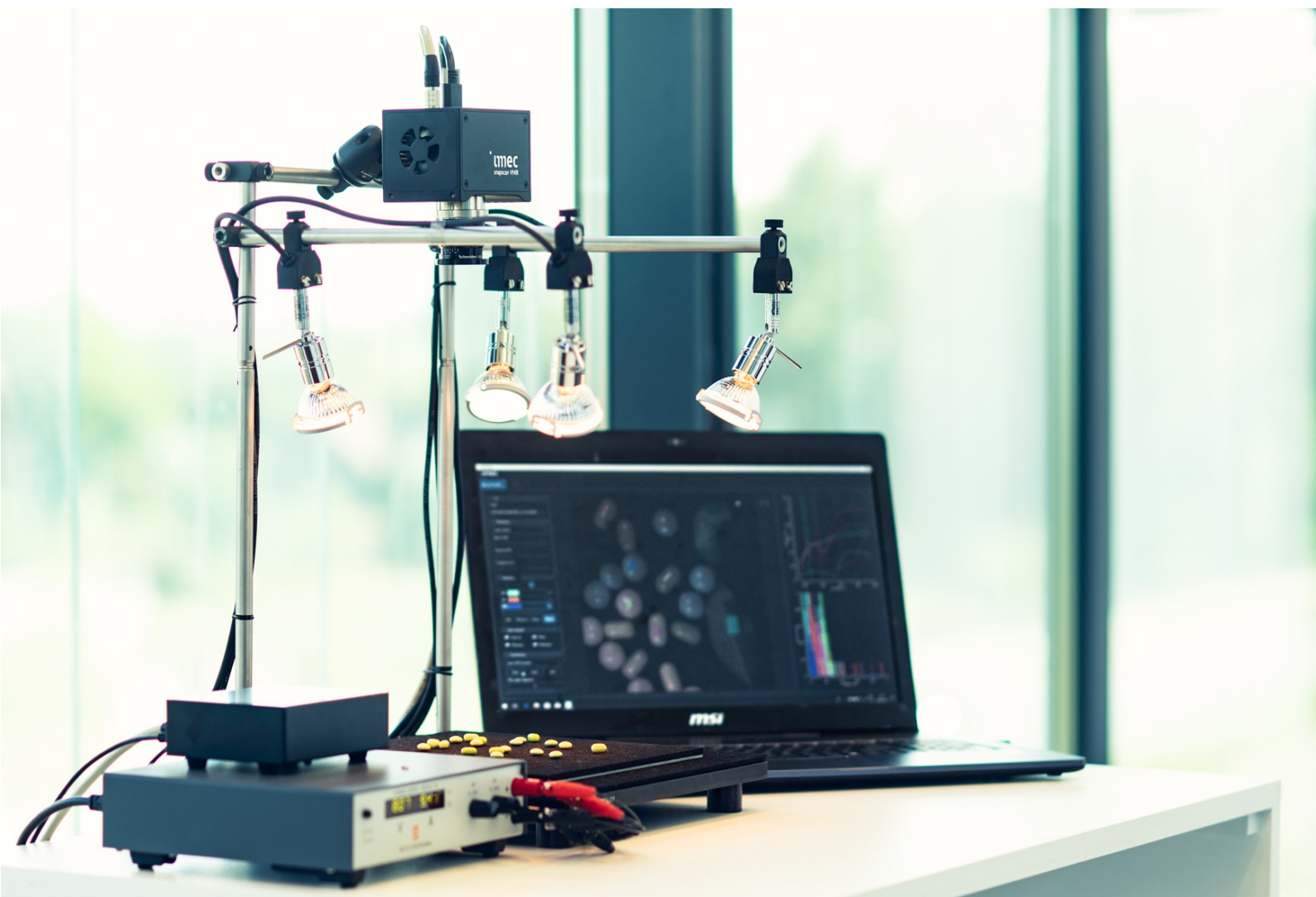
- Try connecting the controller through an external USB hub.
- Put the laptop in a docking station and try using a docking station's USB port.
- Try using a shorter USB cable with micro USB connector.

Contact imec HSI support if the problem persists or for any other problems:

Email: hsisupport@imec.be

Website: <http://hsisupport.imec.be>







Chapter 6

Software User Manual

6. Software User Manual

This chapter explains how the snapscan software can be used to configure the snapscan system, acquire hyperspectral data cubes and finally view and export the data.

First, an overview is given of the workflow and user interface layout, after which each view is explained in more detail.

6.1 General

snapscan software provides the following two key functionalities:

1. Cube acquisition (see Section 6.2)
2. Cube display (see Section 6.3)

Figure 63 shows the different elements in the user interface of the software:

- **Mode selection panel** – Provides separate tabs to select cube acquisition or cube display mode.
- **Control & configuration panel** – This panel is specific to the selected mode. It provides control and configuration options to the user.
- **Display panel** – This panel is also specific to the selected mode. In acquisition mode, the panel displays live view from the sensor, whereas in cube display mode it shows a previously acquired cube as selected by the user.
- **Status panel** – Provides camera related information. For example, sensor temperature.

 *Cube acquisition tab is selected by default when the software starts.*

Figure 64 shows the typical workflow that a user must follow while using the software. Details of each step in the workflow are provided in the upcoming sections.



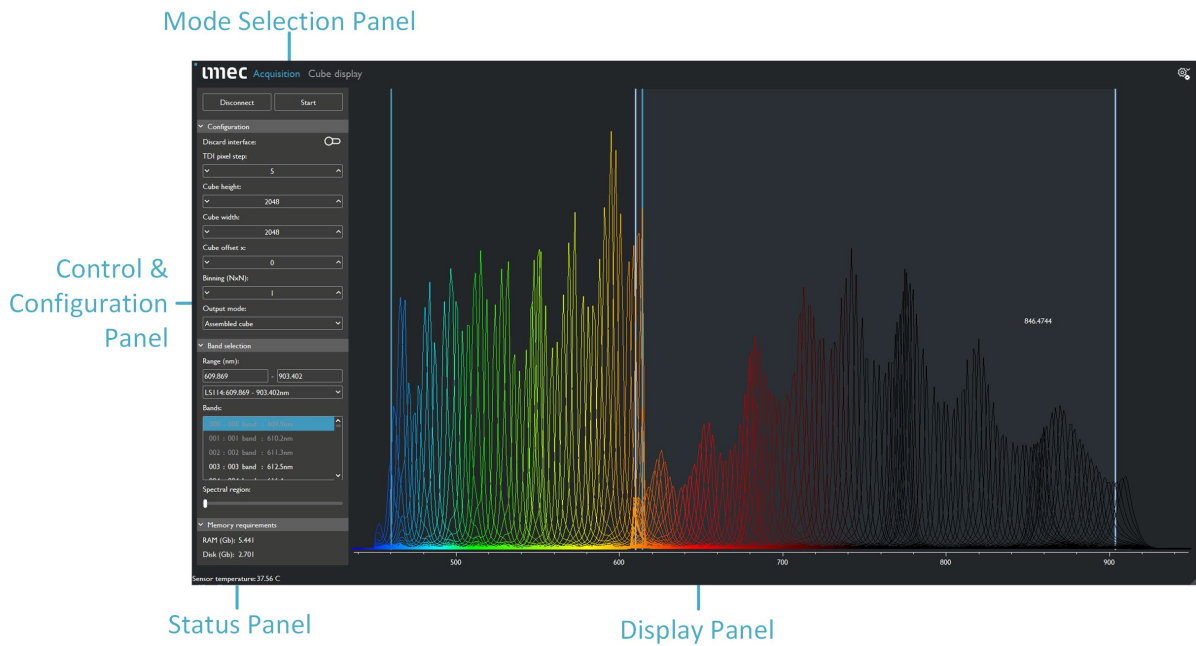


Figure 63: Annotation of the main elements in the snapscan software's user interface

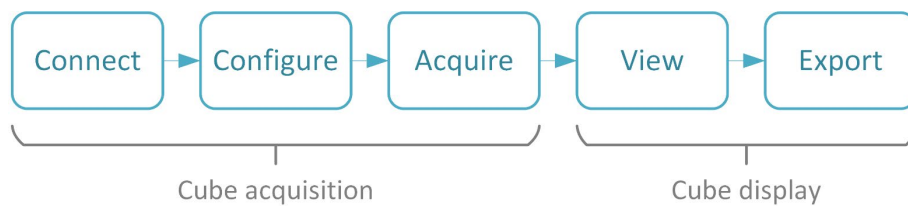


Figure 64: Illustration of the workflow of the snapscan software. This workflow guides the user from connecting to the snapscan system to exporting hyperspectral data.

6.2 Cube acquisition mode

Cube is acquired from the snapscan camera by following the first three steps in the workflow shown in Figure 64.

Connect step – select your snapscan system and establish connection

Configure step – configure the acquisition properties

Acquire step – control the system and acquire data

Each of these steps are discussed in detail in the upcoming sections.

6.2.1 Connect step

Follow the steps below to connect to the snapscan camera system:

Step 1 - Click the “Select SnapScan file” button to load the system configuration file specific to your snapscan camera unit.



This file contains information on how to connect to the hardware as well as which sensor calibration file to use to interpret the data. When the file is loaded, the name of the file is shown and the connect button becomes available.

i The software keeps track of the last used snapscan system file. When restarting the software, reconnecting is possible without having to select the system file again.

Step 2 - Click the “Connect” button

This will establish a connection to the snapscan system, initialize the hardware and switch the user interface to the configuration step. If needed, refer to Section 5.4 for troubleshooting instructions.

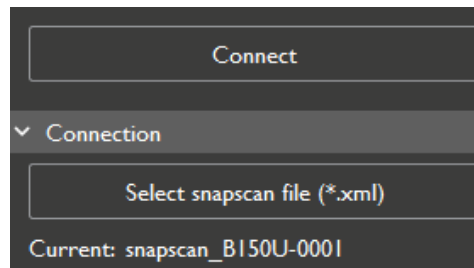


Figure 65: Controls available to connect to the snapscan system.

6.2.2 Configure step

Follow the steps below to configure the snapscan camera system for the cube acquisition:

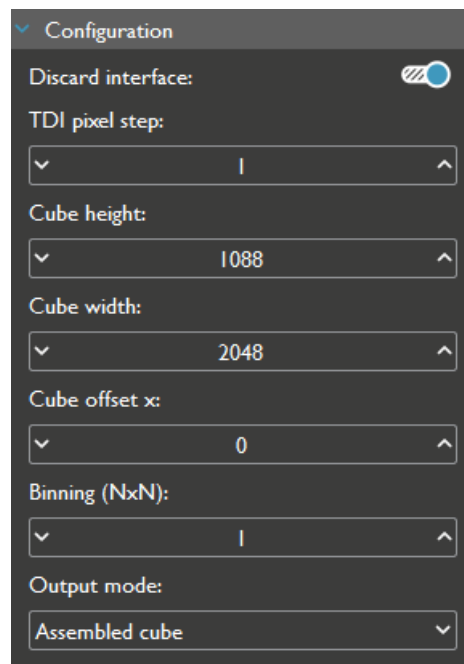
- Step 1 -** Set the camera parameters by following the instructions in Section 6.2.2.1
- Step 2 -** Select the spectral bands by following the instructions in Section 6.2.2.2
- Step 3 -** Click the Start button to switch to acquisition interface (discussed in details in Section 6.2.3)

6.2.2.1 Configuration parameters

The configuration parameters available are shown in Figure 66 and their description is provided in Table 9. These parameters determine the memory requirements, output data size, quality, and maximum acquisition speed.

i An estimation of the memory requirements and data size is displayed below the settings and are updated when the user changes a configuration parameter.





The image shows a configuration panel with a dark background and light text. At the top is a section header 'Configuration' with a small blue checkmark icon to its left. Below this are several settings:

- 'Discard interface:' followed by a toggle switch that is currently turned on (blue circle with a white dot).
- 'TDL pixel step:' followed by a dropdown menu showing the value '1'.
- 'Cube height:' followed by a dropdown menu showing the value '1088'.
- 'Cube width:' followed by a dropdown menu showing the value '2048'.
- 'Cube offset x:' followed by a dropdown menu showing the value '0'.
- 'Binning (NxN):' followed by a dropdown menu showing the value '1'.
- 'Output mode:' followed by a dropdown menu showing the value 'Assembled cube'.

Each dropdown menu has a small downward arrow on the left and an upward arrow on the right.

Figure 66: Controls available to configure the snapscan output data. The output data properties define the memory requirements, output data size, quality, and maximum acquisition speed.



Table 9: Overview of the parameters available to configure the snapscan system.

Parameters	Values	Description
Discard interface pixels	ON / OFF Default: OFF	ON: Pixel rows at the edges of spectral bands are ignored. This will reduce the crosstalk between the spectral bands. OFF: All the pixels rows of a spectral bands are used.
TDI pixel step	1 to 5 (number of pixel rows per spectral band) Default: 5	Sets the travel range between two consecutive images. <i>Tip:</i> Smaller values avoid band to band crosstalk, enable software TDI, reduce noise, increase number of frames needed, increase acquisition duration.
Cube height	1 to 3600 (number of pixel rows in the sensor) Default: 1088	Sets the number of rows in the output data. <i>Tip:</i> Higher values will increase the vertical spatial resolution but it will also increase the required memory and the size of output file.
Cube width	1 to 2048 (number of pixel columns in the sensor) Default: 2048	Sets the number of columns in the output data. <i>Tip:</i> Higher values will increase the horizontal spatial resolution but it will also increase the required memory and the size of output file.
Cube offset x	0 to 2048 (number of pixel columns in the sensor) Default: 0	Sets the offset from top edge in live view in case the selected cube width is lower than 2048. <i>Tip:</i> Use cube height, width and offset to acquire selected region in the field of view.
Binning (NxN)	1 to N (2, 3, ... ,20) Default: 1	Pixels within a NxN neighborhood are merged by averaging. <i>Tip:</i> Binning increases the SNR but decreases the spatial resolution and the size of output file.
Output mode	Assembled cube / Frame stack	Assembled cube: The acquired frames are assembled in a cube and stored in a single file. Frame stack: The acquired frames are stored in separate files. The number of files generated is equal to number of bands.

6.2.2.2 Spectral bands selection

In Section 2.2.4.4, we have introduced the principle and benefits of band selections. In this section, we will guide you on how to select bands using graphical visualization and configuration panel.

The default band selection is configured during the in-factory system calibration, which selects all the bands in the full spectral range of the camera. In case of VNIR version, the default number of SROI is 2 which corresponds to the separate VIS and NIR filter zones on the sensor (see Section 1.1.3 for details about the VNIR filter layout). In case of NIR version, the default number of SROI is 1 which corresponds to the single NIR filter zone on the sensor (see Section 1.1.4 for details about the NIR filter layout).



Band selection can be carried out using the graphical visualization in the Display panel where the spectral response of all the bands are shown. The selected bands can be edited either using the graphical visualization or using the Control & Configuration panel.

- i When using band selection, the software will automatically compute a correction matrix to compute the true spectral signal from the selected bands.
- i The actual index of the band on the sensor is stored in the band's name when exporting the data without correction.

Using graphical visualization

Follow the steps below to add, remove and modify SROIs:

Add	Left click on the plot to add a SROI. A faint blue overlay, bordered by two blue lines (handles), indicates the added SROI. The response of all selected bands is shown in the color corresponding to the wavelength.
Remove	Right click on a SROI to remove it
Modify	Hold and drag the left or right handles on the overlay to include or exclude additional bands.
Reset	Left click and drag over the full spectral range displayed

Figure 67 shows an example of band selection with two SROIs.

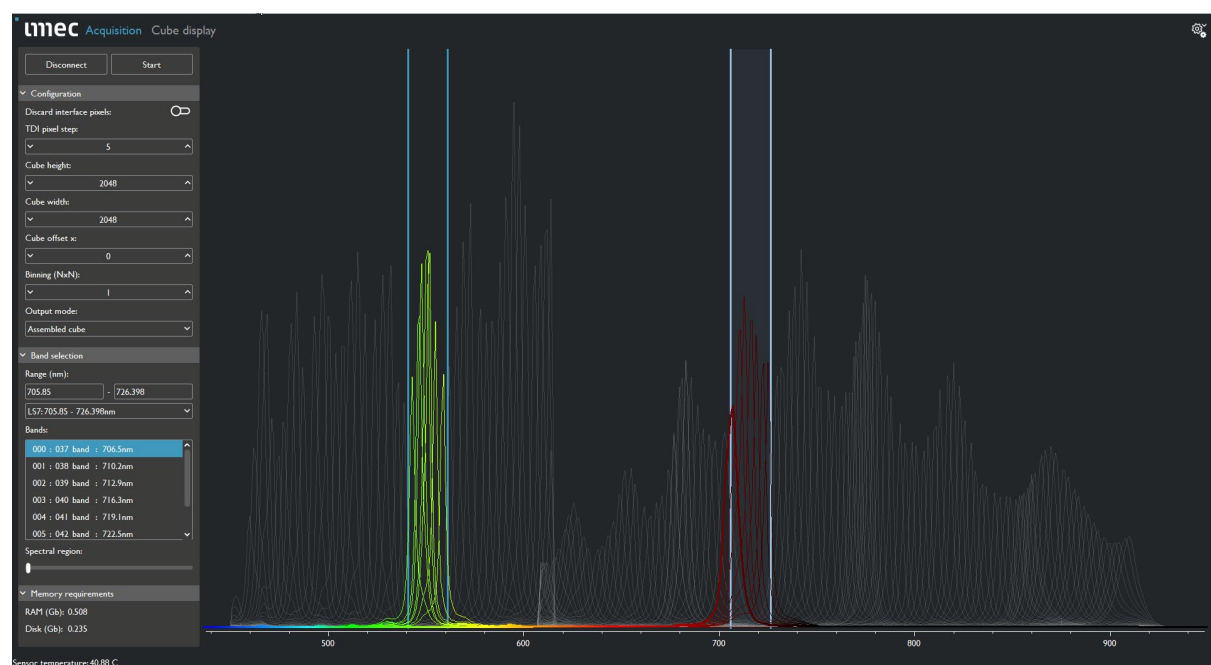


Figure 67: Example of a band selection with two spectral regions of interest. The user can interact with the visualization to modify the band selection. By default, after connection, the full sensor is read out.



Using configuration panel

The band selection can also be modified using the configuration panel, as shown in Figure 66. The lower part of the panel provides controls for band selection, as shown in Figure 68. These controls are described in Table 10.

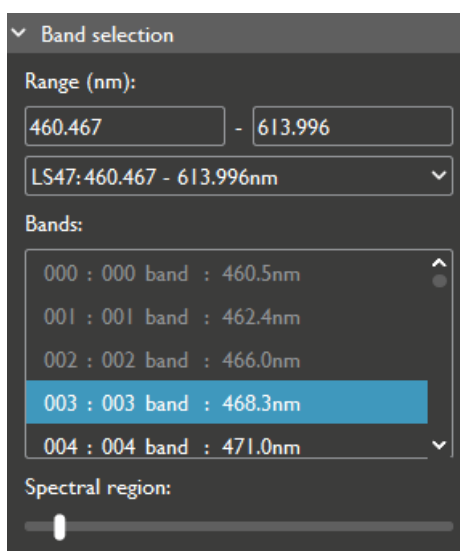


Figure 68. Band selection tool is complementary to the right side and can be used to fine-tune the range or highlight a given band by clicking on it or moving the slider.

Table 10 Description of controls for band selection in the configuration panel

Range (nm)	The central wavelength of the first and last spectral band in the selected SROI is displayed here. The spectral range of the selected SROI can be edited by changing the beginning and the end wavelengths. All the SROIs selected using the graphical visualization are listed in the pulldown menu and it can be used to select a specific SROI.
Bands	Displays the list of bands in the selected SROI. Specific band can be highlighted by clicking it in the band list or using the slider below. <i>Tip:</i> Some bands on the sensor have been disabled during the in-factory system calibration to optimize the system's spectral response. When these bands fall in a spectral region they are greyed out in the region's band list. The band data will be recorded in the data, but will not be used for spectral correction.
Spectral region	The slider can be used to scroll through the bands displayed for the selected SROI.



6.2.3 Acquire step

The user interface for the acquisition mode is shown in Figure 69, where

1. The Control & Configuration panel can be used to set the image acquisition parameters, such as integration time, gain and scanning mode.
2. The Display panel shows the live view from the snapscan camera.
 - The live view provides a sight on the scene as seen by the snapscan camera. The outer border is displaying the maximum possible size while the inner one indicates the region that will be scanned as specified in the configure step.
 - When a preview image has been captured it is displayed as a background of the view.
 - An overlay is masking the unselected bands of the sensor.
 - In the top-right corner, controls are provided to rotate/flip the view. Saturated pixels are shown in red.

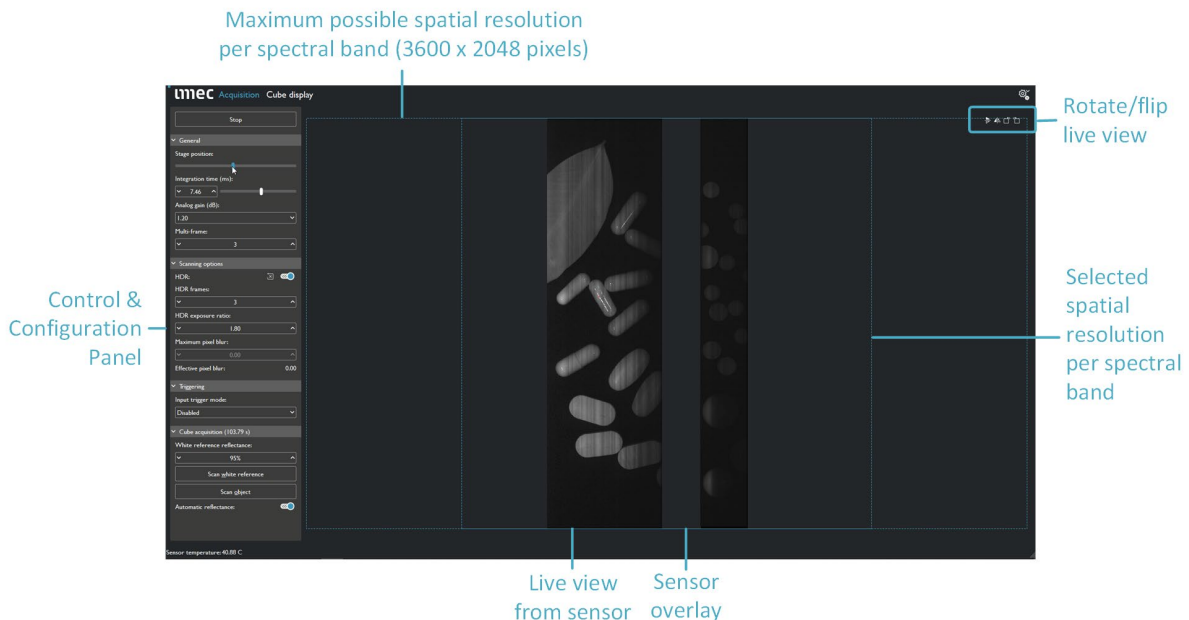


Figure 69: User interface and live view display for the acquisition mode after the camera has been connected and configured with default SROI settings, i.e. all spectral bands are selected.





Figure 70: User interface and live view for the acquisition mode after the camera has been connected and configured with specific bands selected. The semi-transparent colored overlay indicates bands that fall outside of the band selection.

Follow the steps below to configure the acquisition parameters and acquire images from the snapscan camera

- Step 1** - Set the image acquisition parameters by following instructions in Section 6.2.3.1.
- Step 2** - Acquire reference data for white balancing and image data for the object under scanning by following instructions in Section 0.
- Step 3** - Go to “*Cube Display*” tab for viewing the acquired data and for further processing or click “*Disconnect*” button to go back to configuration mode.

Figure 71 shows the different elements available in the Control & Configuration panel.



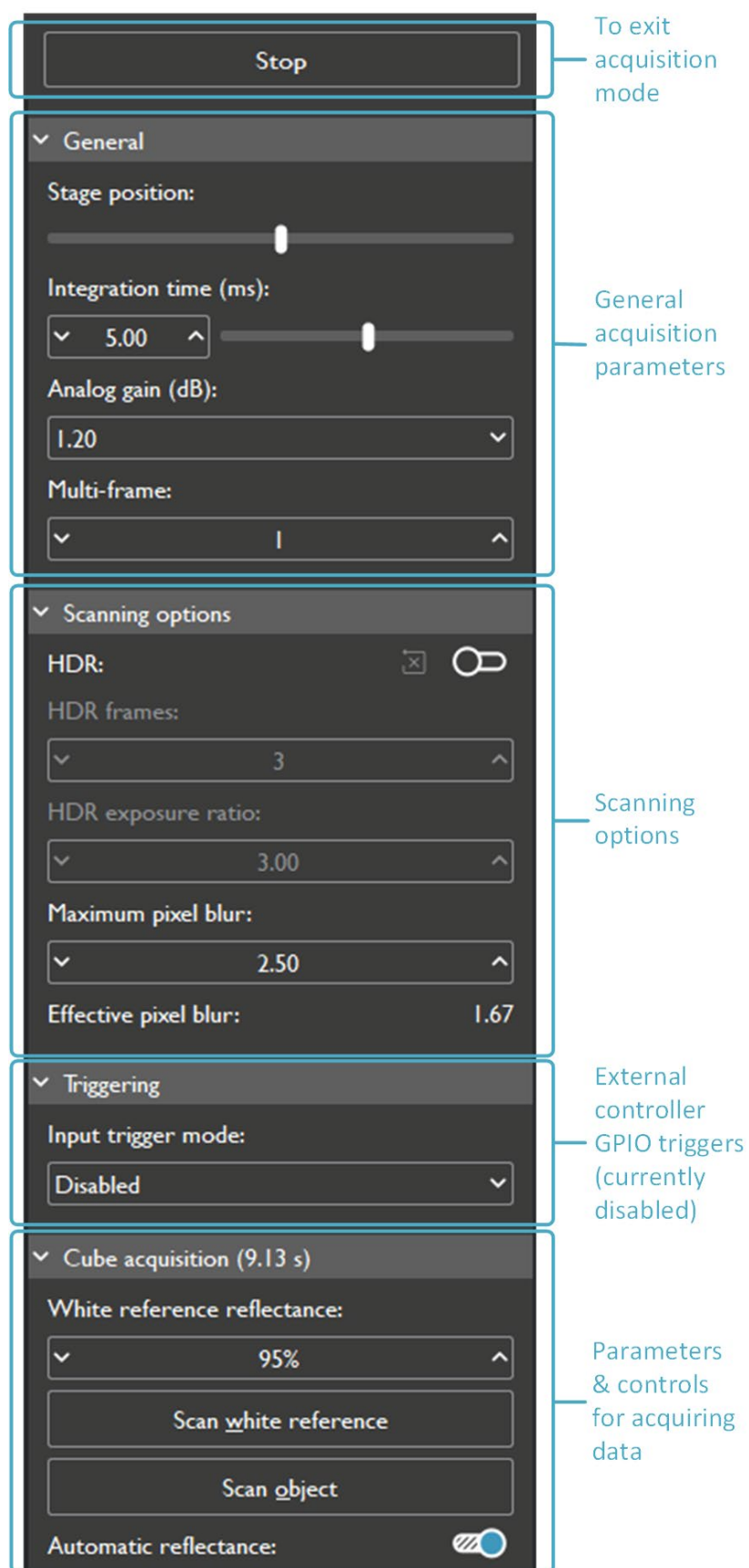


Figure 71 Control and configuration panel in the acquisition mode



6.2.3.1 Image acquisition parameters

There are the following categories of image acquisition parameters:

- General
- High Dynamic Range (HDR) control
- Pixel blur control
- External triggering control

 *Modifying the cube size and TDI settings requires returning to the configuration mode by stopping the acquisition. This is done by clicking the stop button.*

General acquisition parameters

The general acquisition parameters, as shown in Figure 72, let the user set the integration time and analog gain for the acquisition as well as the number of times a single frame should be acquired and averaged. An overview of these parameters is given in Table I I.

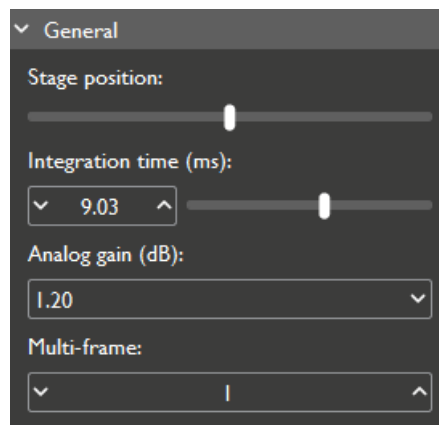


Figure 72: The general acquisition parameters allow setting integration time, gain, scanning mode.

Table I I: Overview of the general parameters available to configure the acquisition with the snapscan system.

Parameter	Values	Description
Stage position	N.A	Drag the slider left or right to move the sensor live view across the field-of-view of the camera.
Integration time	0.5 – 50ms	Set the time period during which photons are collected by the sensor to capture a single frame. <i>Tip:</i> Lower values enable faster acquisition but may decrease the SNR.
Analog gain	1 – 3.2dB Default: 1.2	Set the sensor analog gain. <i>Tip:</i> Higher gain allows shorter integration times, but increases photon shot noise.
Multi-frame	1 – 100 Default: 1	Sets how many times the measurement must be repeated. The final scan is an average of the repeated measurements. Higher values increase SNR at the cost of scanning time.



Tips for obtaining sensor's maximal dynamic range

- The integration time and gain settings are the primary tools to maximize the use of the sensor's dynamic range.
- The dynamic range is maximized by choosing the parameters such that a slight increase of either the integration time or analog gain results in saturated pixels.
 - ❶ *The impact of selected parameters can be verified by looking at the live view from sensor. The entire field of view can be verified by translating the sensor in the camera body by using the Stage position slider.*
 - ❶ *Double clicking the Stage position slider will center the sensor.*
- A higher gain allows using shorter integration times and hence increases the scanning speed. The drawback of a higher gain setting is that this amplifies the photon shot noise.
- A reasonable tradeoff is found with a gain between 1 and 3.2db and integration time below 15ms.

High Dynamic Range (HDR) control parameters

HDR scanning increases the dynamic range of the captured data by selecting optimal integration time for frame acquisition of each spectral band.

Why HDR is needed?

There is variation in sensitivity of different spectral bands due to the variation of sensitivity of the underlying CMOS image sensor and variation in the intensity of illumination across different wavelengths (as shown in Figure 8 and Figure 73). Thus, selecting a single integration time for all spectral bands will under-expose spectral bands with lower sensitivity as the integration time should be set such that the most sensitive spectral band does not saturate. It can be seen in the left-hand side sensor live view in Figure 73 that spectral bands on the right-half of the sensor are under-exposed as compared to the spectral bands on the left half of the sensor.

The exposure can be balanced across all spectral bands by enabling HDR, as seen in the right-hand side live view in Figure 73.

Figure 74 shows an example of image acquired using different integration times for different spectral bands when HDR is enabled. It can be seen that higher integration times were used for spectral bands between 470-680nm (physically located on the right half of the sensor live view in Figure 73) as compared to spectral bands between 680-900nm (physically located on the left half of the sensor live view in Figure 73).



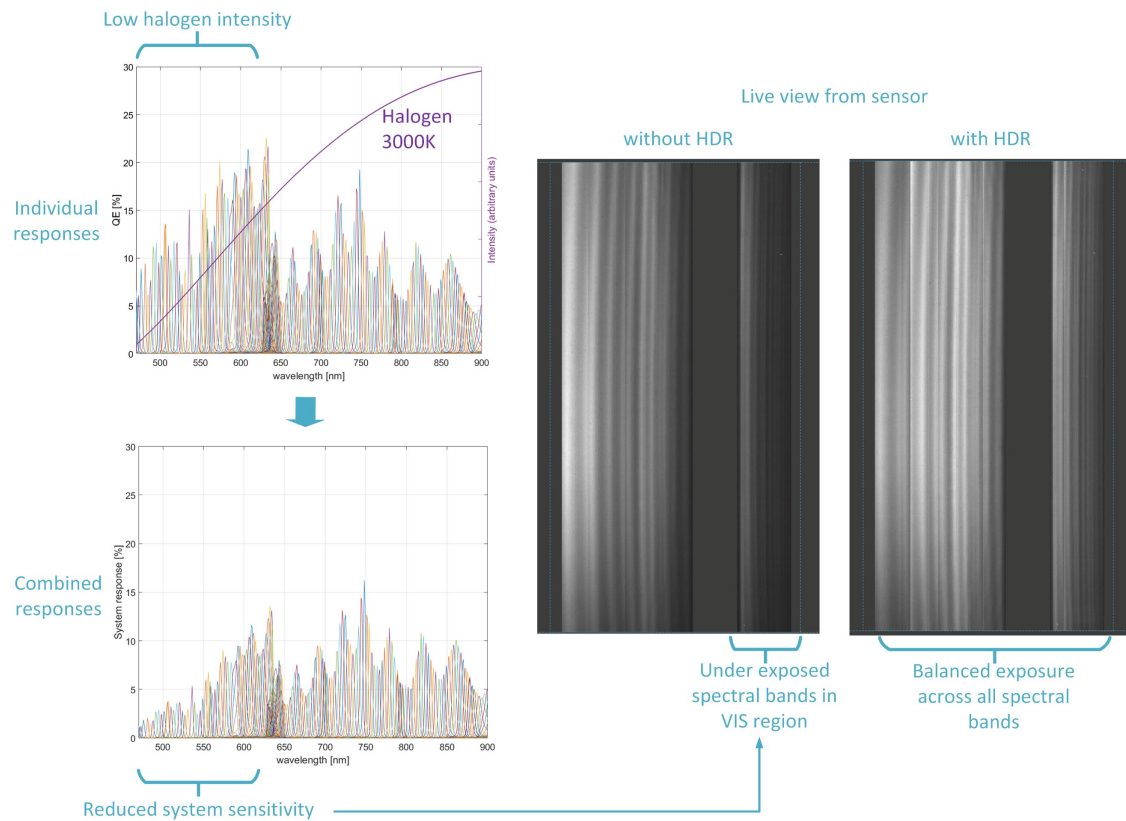


Figure 73 Illustration for the need of HDR to have balanced exposure across all spectral bands. The system response is a product of sensor QE and the spectral response of the illumination. Due to lower intensity of halogen in the VIS spectral range, the overall system sensitivity is reduced, resulting in underexposed spectral bands in VIS spectral range.

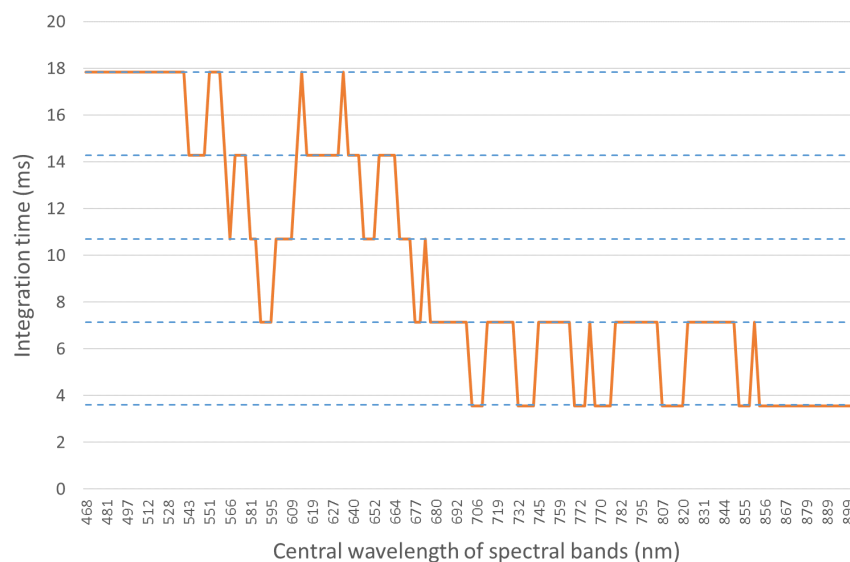


Figure 74 Integration times selected for different spectral bands when HDR is enabled. In this case, the system acquired images for different spectral bands using 5 different integration times. Setting used: HDR frames = 5, HDR exposure ratio = 5, integration time = 3.7ms (see Section 0 for explanation of these terms)



What is the effect of HDR?

Enabling HDR results in improved SNR of the acquired images, as shown in Figure 75. The figure illustrates the same scene acquired with and without HDR. In case of image acquired without HDR, the spread in spectral responses across the pixels in the selected region (shown as red block on the left-hand side of the image) is higher than in the case with HDR. This shows that the SNR of the image can be improved by using HDR. However, enabling HDR will increase the overall time required to acquire the image. Thus, there is a trade-off in quality versus time and the user should taking this into consideration will configuring the acquisition parameters.

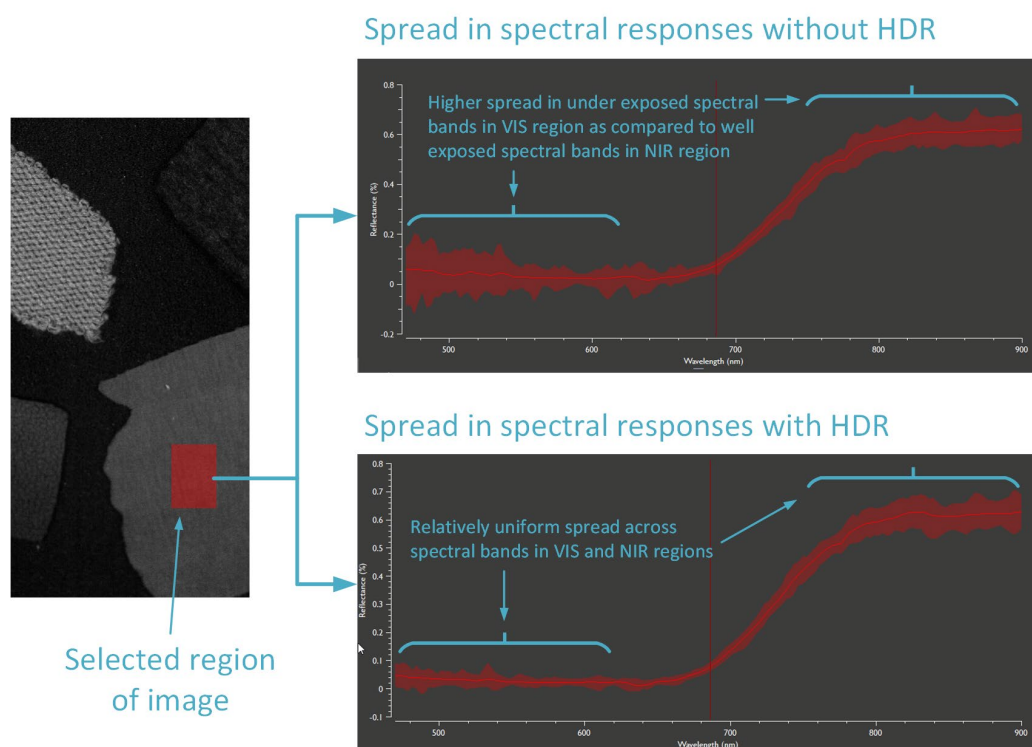


Figure 75 Illustration of reduction in spread in spectral responses with HDR, i.e. improving the SNR of the acquired image.

How to configure HDR in snapscan?

The HDR scanning parameters provided in snapscan software are shown in Figure 76 and Table 12.

Follow the steps below to configure HDR:

- Step 1 -** Place the white tile below the camera such that it covers the entire field of view of the camera.
 *Always use the white tile as it has a uniform surface.*
- Step 2 -** Enable HDR by clicking on the slider button.
- Step 3 -** Set integration time and analog gain under general acquisition parameters.



Step 4 - Set the number of “HDR frames”. This parameter sets the number of different integration times that will be used for acquiring HDR frames. The software will automatically compute these different integration times (see next step).

For example, if “HDR frames” is set to 3, then the software will calculate 3 different integration times and will acquire all the HDR frames using one of these integration times.

Tip: Larger values yield flatter SNR over the spectral range at the cost of acquisition speed.

Step 5 - Set the “HDR exposure ratio”. This parameter sets the maximum integration time that will be used.

For example, if “Integration time” (under general acquisition parameters) is set to 10ms, “HDR frames” is set to 3 and “HDR exposure ratio” is set to 5 then the software will compute three different integration time as shown below.

Minimum integration time	10ms (=integration time set under general acquisition parameters)
Maximum integration time	50ms (=Minimum integration time x HDR exposure ratio)
Intermediate integration time	30ms (= average of minimum and maximum integration times) In case, of more than 3 HDR frames, the intermediate integration times are selected at equal intervals between minimum and maximum integration times.

Tip: Larger values increase the final dynamic range at the cost of acquisition speed.

Step 6 - Verify the effect of HDR by dragging the stage across the field of view of the camera to ensure that

- there is no saturation in any spectral band(s) for the spatial region to be acquired
- the spectral band(s) are optimally exposed as expected

Step 7 - Click  to recompute the HDR, i.e. the software will compute the integration time for the HDR frames based on the current scene and the above settings.

Tip: Always recompute HDR after changing any parameters under HDR and/or general acquisition when HDR is enabled.

Step 8 - If needed, repeat above steps and verify again.

 *The live view shows the effect of the HDR computation without normalization by integration time. The data is automatically normalized when processed into a hyperspectral data cube.*



- ⚠ The internal HDR settings must be computed either with the white reference in view or with a diffuser in front of the lens.
- i Using different internal HDR settings for the object and white reference acquisition may further increase the SNR of your recording.

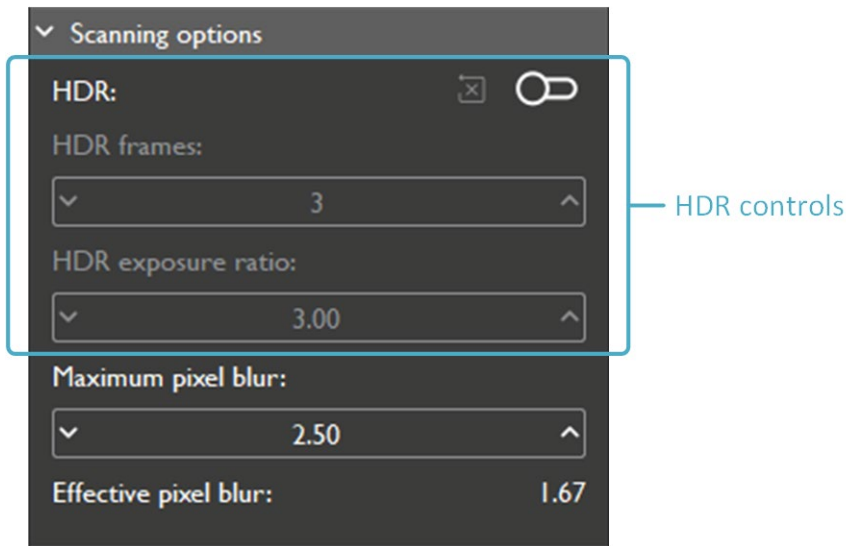


Figure 76: Scanning options available in the stop motion scanning mode. HDR can be enabled and configured by setting the number of frames and the multiplier limiting the maximum integration time used as compared to the integration time set in the general settings.

Table 12: Overview of the parameters available for HDR controls

Parameter	Range	Description
HDR	On / Off Default: Off	Enables / disables the HDR mode. HDR increases the SNR of bands with low signal at the cost of acquisition speed.
	N.A.	Triggers computation of the integration time for the HDR frames based on the current scene.
HDR frames	2 – 100 Default: 3	The number of different integration times used to compute one HDR frame. Larger values yield flatter SNR over the spectral range at the cost of acquisition speed.
HDR exposure Ratio	1 – 100 Default: 3	Factor multiplied to the general integration time defining the maximum integration time used for HDR. Larger values increase the final dynamic range at the cost of acquisition speed.

Pixel blur control parameters

Pixel blur refers to the distance travelled by the sensor while sensor exposure is in progress. The traveled distance is measured in terms of pixels. The snapscan camera can operate in one of the following two modes:



1. Continuous: Data is acquired in-motion. The frame acquisition is synchronized to the motion by a hardware signal. The motion during the acquisition causes motion-blur in the data which can be controlled using the pixel blur control parameter.
2. Stop motion: Data is acquired in standstill. The sensor is moved by the pixel step (defined in the configuration view) and brought to standstill before acquiring the next frame. Hence, the pixel blur control parameter is not applicable in this mode.

The snapcan will always operate in stop motion when HDR is enabled. Hence, skip this setting if you have enabled HDR. Otherwise, follow the steps below to configure pixel blur control parameter (see Figure 77 and Table 13):

- Step 1 -** Check the “Effective pixel blur” value. This value is automatically calculated by the software based on the achievable frame rate, TDI steps and selected integration time. The achievable frame rate is displayed in the Configuration panel and is dependent on the bit-depth and number of spectral regions-of-interest (SROI).
- Step 2 -** Estimate the required resolution in terms of minimum number of pixels required to cover the targeted feature size. Count the number of pixels covering the feature size in the live view of the sensor.
- Step 3 -** Verify if the “Effective pixel blur” value is acceptable or not based on the table below.

Feature size (in pixels) [as seen in sensor live view]	Recommended maximum pixel blur
≥ 7	≤ 5
6	≤ 4
5	≤ 3
4	≤ 2
3	≤ 1
2	0

- Step 4 -** If the “Effective pixel blur” value is higher than the recommended maximum allowable pixel blur, set “Maximum pixel blur” parameter to a value lower or equal to the recommended value.
- Step 5 -** If the system does not accept the specified value then change the configuration and acquisition parameters mentioned in Step 1. If the “Effective pixel blur” is still higher than the recommended value and it is not acceptable then you may have to change the optics and/or working distance such that the targeted feature size (in terms of pixels) and as seen in sensor live view increases.



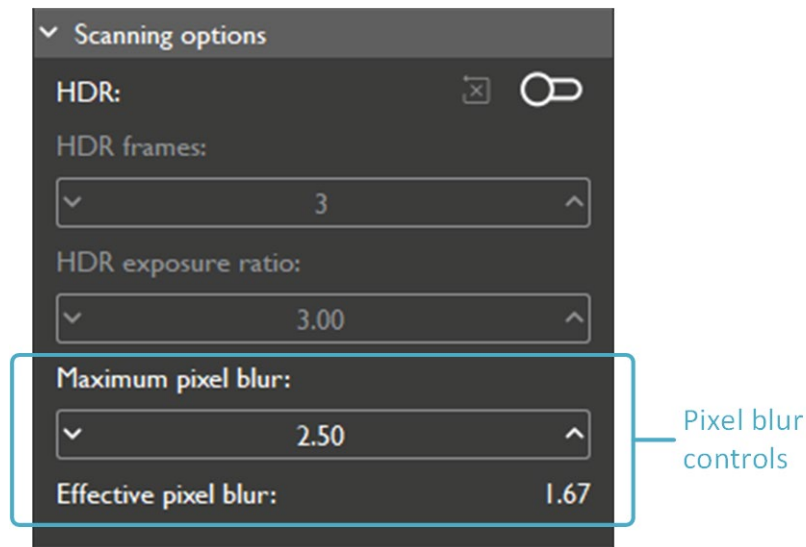


Figure 77: Scanning options available in the continuous scanning mode. Motion blur is controlled by limiting the distance traveled during the exposure time.

Table 13: Overview of the parameters available to configure the pixel blur controls

Parameter	Range	Description
Effective pixel blur	0 - 5	Distance traveled by sensor (in terms of pixels) during the exposure time. Tip: Smaller values indicate lower blurring and hence sharper images.
Maximum pixel blur	0 - 5	Threshold specified by user on the pixel blur.

External triggering control parameters

The snapscan hardware is equipped with two triggering ports: in and out. Output can be used to control additional hardware synchronously to frame acquisition (e.g. a punctual illumination). By default, the sensor's read out is handled by the software. If need be, the user can use an external triggering system: the camera will then acquire frames when told to.

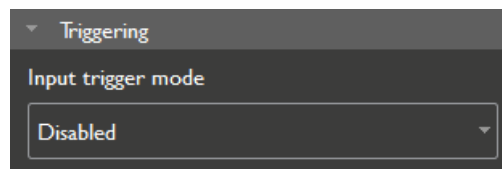


Figure 78. Triggering system selection. When disabled, the software is let in charge of the control.



6.2.3.2 Acquiring data

The actual data acquisition typically consists of two acquisitions:

1. A scan of the object
2. A scan of a white reference (used in the software to normalize or white balance the object data into raw reflectance or raw transmittance)

-  *These acquisitions can be done in any order.*
-  *Multiple object scans can be acquired with the same white reference. The software temporarily stores internally the white reference after it is acquired. This temporary copy is maintained until the user exits acquisition mode by clicking “Stop” (see Figure 71) or a new white reference is acquired.*

Figure 79 shows the controls for acquiring the data. The estimated time required for an acquisition is displayed above the controls.

-  *Scans are always stored in memory until exported. Creating a new object or white reference scan replaces in memory the previously acquired object or reference scan respectively.*

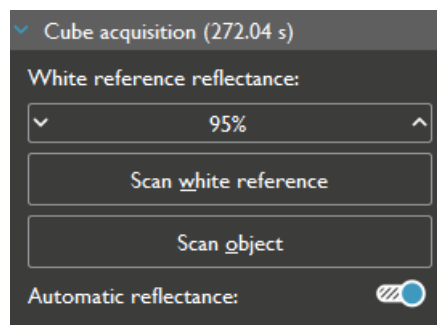


Figure 79: Cube acquisition controls. An estimate of the acquisition time given the current parameters is displayed on top of the section.

Acquiring white reference image

Follow the steps below to acquire white reference scan:

- Step 1 -** Place a white reference under the camera.
- Step 2 -** Set “White reference reflectance” parameter. The default value is 95%. If you are using the white reference target provided with the snapscan system, then leave this value at 95%. In case you are using a different white reference target then set this value accordingly.
- Step 3 -** Ensure that the spatial resolution of the white reference image is same as that of the object image.
- Step 4 -** Set the acquisition parameters (general, default and HDR) as needed. Ensure that there is no over or under exposure for any of the spectral band(s) and parts of the scene.



Step 5 - Click “Scan white reference”.

- i. The system will start acquiring the image and wait until it is over.
- ii. The snapscan camera has an integrated software-controlled mechanical shutter (see Section 1.2.3). The software will automatically acquire the dark reference image by closing the shutter.

Acquiring object image

Follow the steps below to acquire object scan:

Step 1 - Place the object under the camera.

Step 2 - Ensure that the spatial resolution of the object image is same as that of the white reference image.

Step 3 - Set the acquisition parameters (general, default and HDR) as needed. Ensure that there is no over or under exposure for any of the spectral band(s) and parts of the scene.

Step 4 - Click “Scan object”.

- i. The system will start acquiring the image and wait until it is over.
- ii. snapscan has an integrated software-controlled mechanical shutter (see Section 1.2.3). The software will automatically acquire the dark reference image by closing the shutter.

Step 5 - If “Automatic reflectance” is enabled (default setting) and both object and white reference images are available, then the software will automatically carry out the reflectance correction (see Section 2.2.5) and prompt the user to go to “Cube display” mode.

6.3 Cube display mode

The acquired cube is visualized, analyzed and saved by following the last two steps in the workflow shown in Figure 80 (see Section 6.2 for the first three steps).

View step – process, visualize and analyze the acquired data

Export step – export to save the acquired data and reference data

Each of these steps are discussed in detail in the upcoming sections.



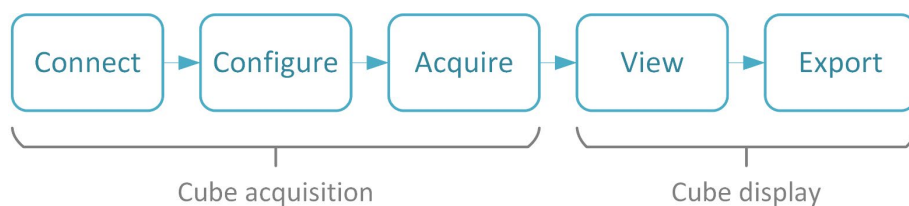


Figure 80: Illustration of the workflow of the snapscan software. This workflow guides the user from connecting to the snapscan system to exporting hyperspectral data.

The user interface for the cube display mode is shown in Figure 81, where

- Control & Analysis panel can be used select, export and render the acquired images. This panel also provides controls to display spectral information of selected regions on the image as well as carry out classification.
- Image Display panel shows the rendered image. This panel can also display the classified image.
- Data Visualization panel can be used to view the metadata of the acquired cube, spectral and pixel responses of regions selected in the control & analysis panel, as well as ground truth and class image for classification.

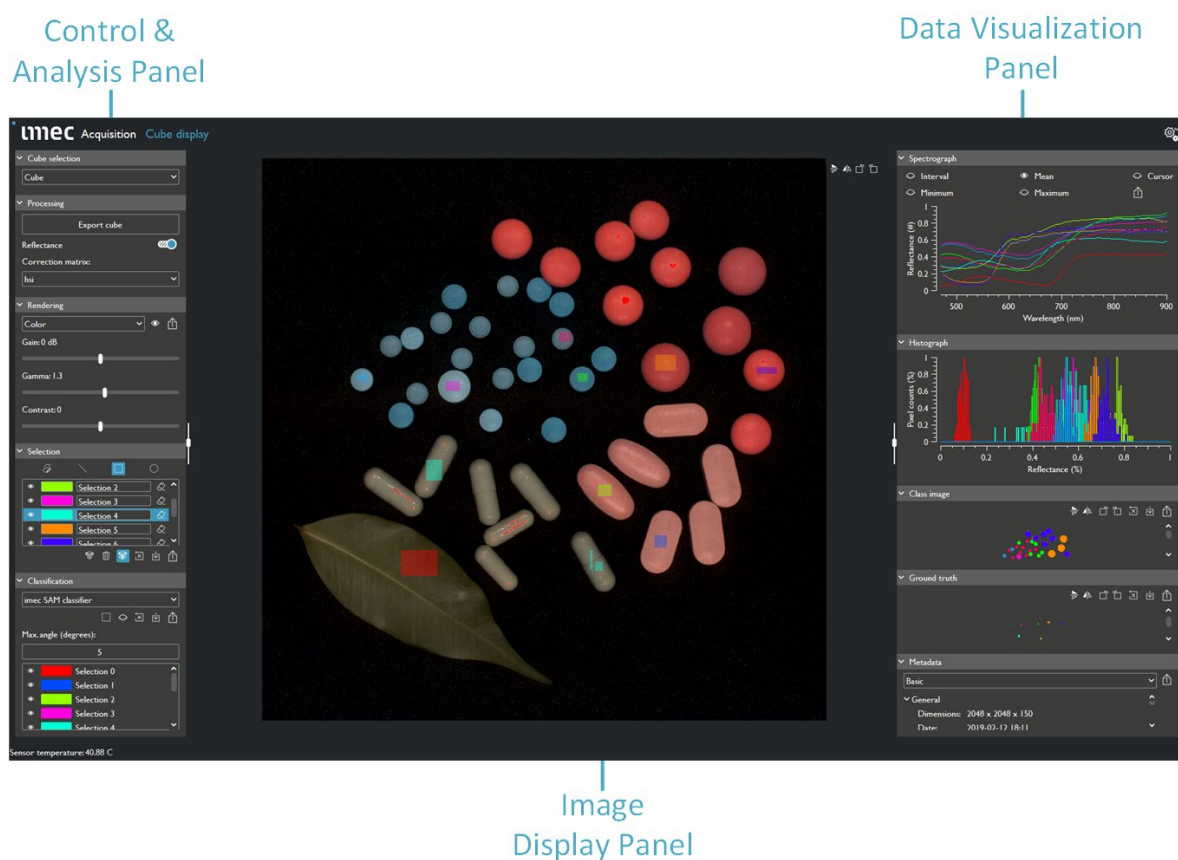


Figure 81: GUI of the Cube display mode



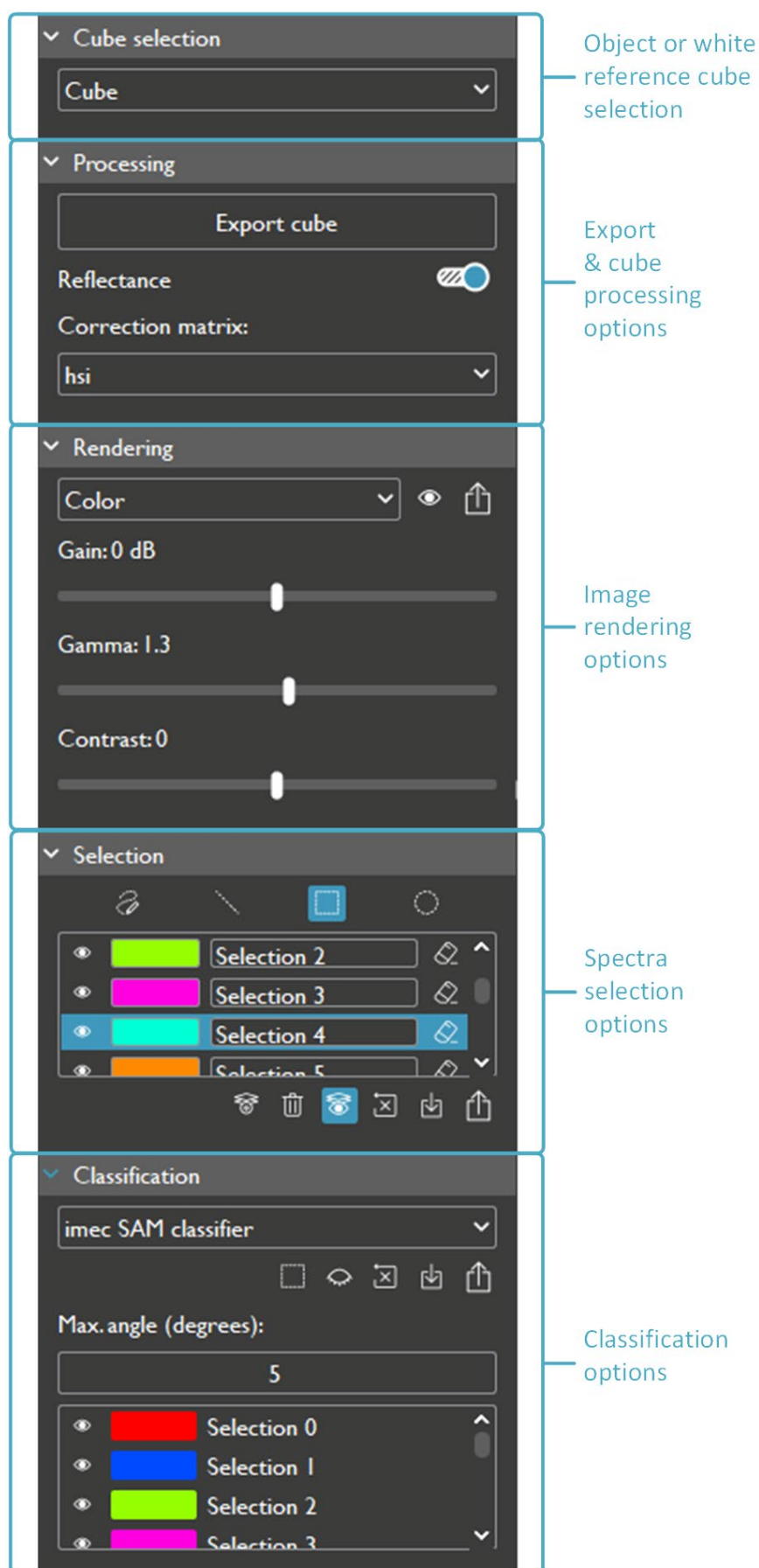


Figure 82 View of the “Control & Analysis Panel” (see Figure 81)



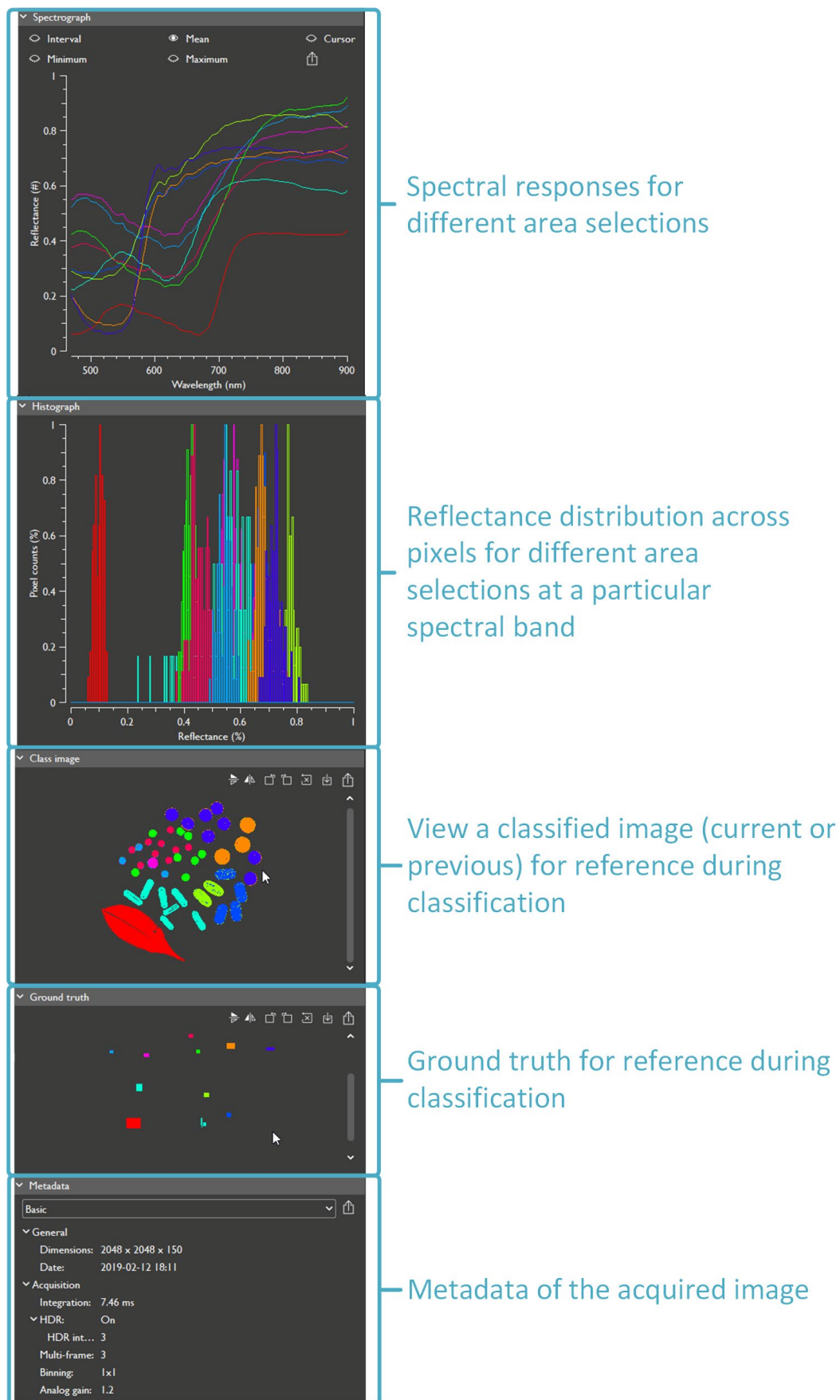


Figure 83 View of the "Data visualization" panel (see Figure 81)



6.3.1 View step

Follow the steps below to view the acquired cube –

- Step 1 -** Select the object or the white reference cube using the “Cube selection” control. The object cube will be selected and displayed by default after switching to cube display mode.

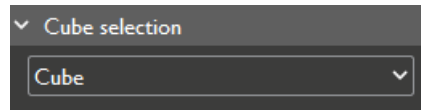


Figure 84. Cube selection. Switches between cube and white reference.

- Step 2 -** Select/ de-select the post-processing to be applied on the cube. By default, the software applies reflectance correction (when both object and white reference cubes are available) and spectral correction to the acquired cube. User can select/ de-select one or both post-processing to visualize the cube. (see Section 6.3.1.1 for details)

 *This step is applicable only to the object cube.*

- Step 3 -** Select the rendering type for visualization. The snapscan software offers three rendering types – color matching, false color and single band. (see Section 6.3.1.2 for details)
- Step 4 -** Analyze the spectral quality of the acquired image by selecting different areas on the image and plotting the spectral response for these different areas. (see Section 6.3.1.3 for details)
- Step 5 -** Carry out classification (if needed). (see Section 6.3.1.4 for details)

6.3.1.1 Processing

The snapscan software offers following post-processing options prior to visualization –

- Export cube – see Section 6.3.2.
- Reflectance – software will automatically carry out reflectance correction when both object and white reference images are available. It is possible to disable reflectance to view the irradiance cube.
- Correction matrix – software will automatically carry out spectral correction if reflectance is enabled. It is possible to disable spectral correction by selecting “None” in the pull-down menu.

Figure 85 shows the configuration parameters for the processing section.



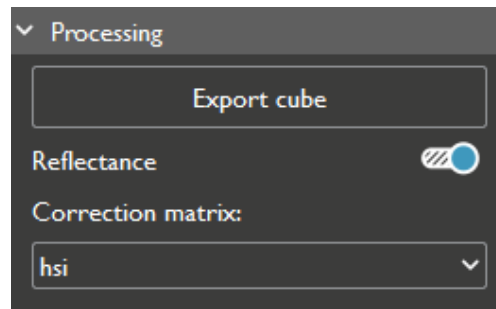


Figure 85. The processing section lets the user switch between irradiance and reflectance data and choose which correction matrix to apply to the reflectance data. The Export cube button gives access to the data export dialog.

6.3.1.2 Rendering

The snapscan software provides the following three rendering options to view the selected cube:

- Color
- Single band
- False color

The rendering type can be selected using the pull-down menu (see Figure 86) and each rendering type is discussed further in this section.

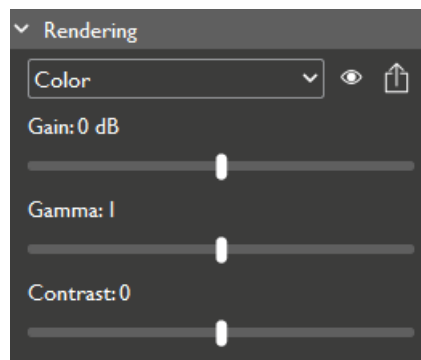


Figure 86 Rendering type selection

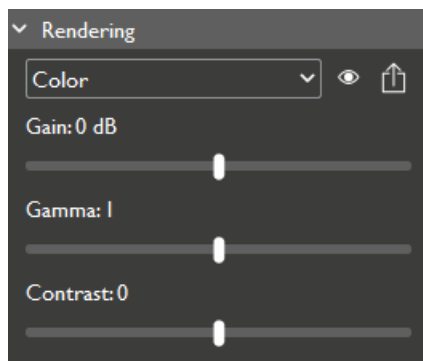
Color rendering

The color rendering generates an RGB image using three groups of spectral bands in blue, green and red regions. The software automatically selects these spectral bands to generate as good as possible, a true color rendering of the image.



Following controls are available to adjust the rendering (see Figure 87):

Parameter	Range	Description
Gain (in dB)	-40 to 40 Default: 0	Adjust brightness of the image by increasing or decreasing the gain.
Gamma	0.17 – 6 Default: 1	Adjusts both brightness and contrast of the image. Different pixels in the images are impacted differently depending on their original intensity levels.
Contrast	-128 to 128 Default: 0	Adjust the distinction between the lighter and darker areas in the image by increasing or decreasing the contrast value.



(a)



(b)

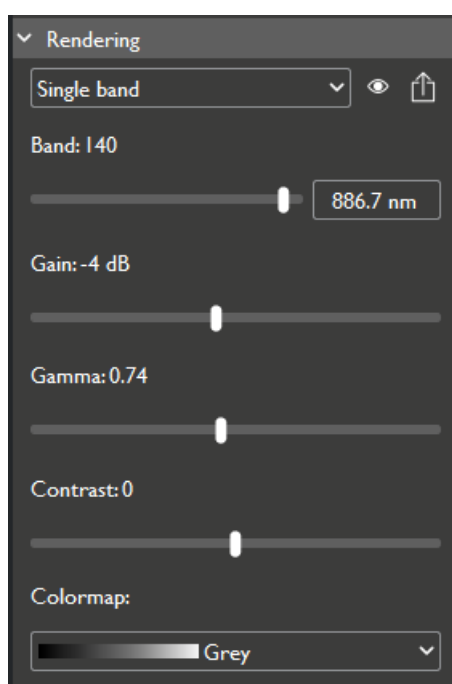
Figure 87 (a) Color rendering controls, (b) Rendered image



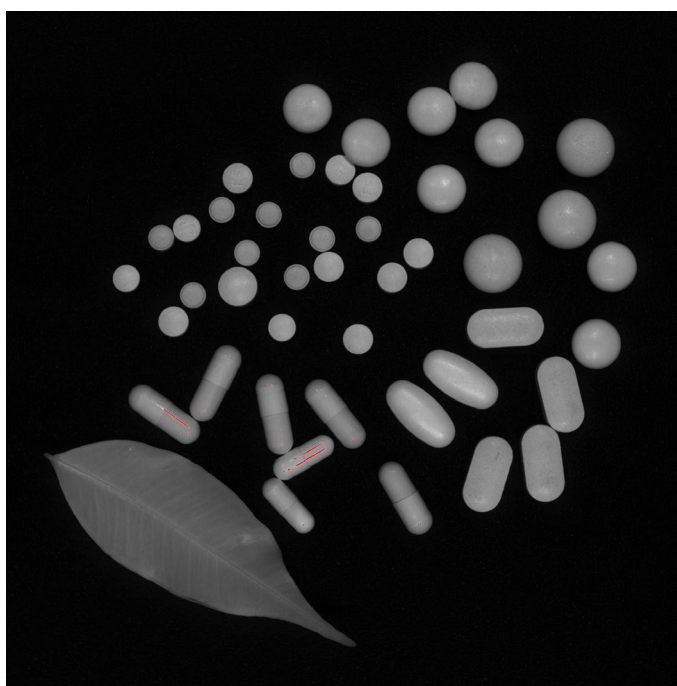
Single band rendering

The single band rendering generates an image from a single spectral band in the data cube. Following controls are available to adjust the rendering (see Figure 88):

Parameter	Range	Description
Band	0 to 150 Default: NA	Move the slider left or right to scroll through the images corresponding to different spectral bands. The bands are ordered from left to right in increasing order of their central wavelengths, i.e. moving slider to the left will select bands with decreasing central wavelengths and vice versa when slider is moved to the right.
Gain (in dB)	-40 to 40 Default: 0	Adjust brightness of the image by increasing or decreasing the gain.
Gamma	0.17 – 6 Default: 1	Adjusts both brightness and contrast of the image. Different pixels in the images are impacted differently depending on their original intensity levels.
Contrast	-128 to 128 Default: 0	Adjust the distinction between the lighter and darker areas in the image by increasing or decreasing the contrast value.
Colormap	Grey Grey inverted Inferno Viridis Default: Grey	snapscan software provides 4 different color maps. Switching between color maps helps enhancing the visualization contrast. The colormaps have been selected to maximize the contrast sensitivity to the human eye.



(a)



(b)

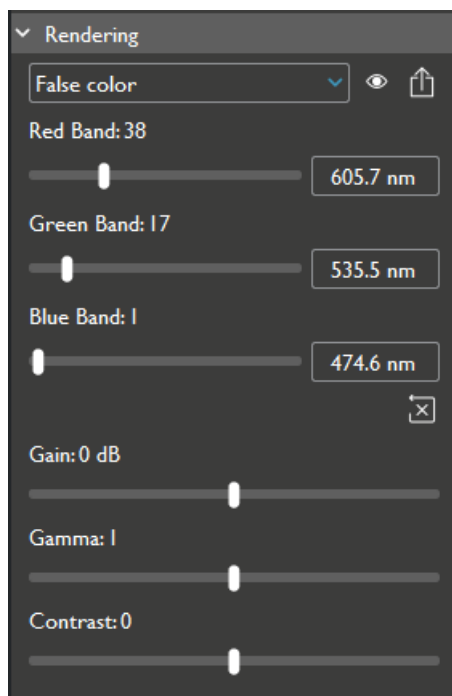
Figure 88. (a) Single band rendering controls, (b) Rendered image of spectral band with central wavelength at 747nm



False color rendering

The false color rendering generates an RGB image using three spectral bands in the data cube. The difference as compared to color rendering is that in case of false color rendering single bands are selected for each of the RGB channels whereas in case of color rendering multiple bands are selected for each of the RGB channels. Following controls are available to adjust the rendering (see Figure 89):

Parameter	Range	Description
Red/ Green/ Blue Band	0 to 150 Default: Computed by software	The snapscan software automatically selects the red, green and blue bands such that the color rendering is close as possible to the true color rendering. User can change the band selection for red, green or blue channels by moving the respective sliders.
Gain (in dB)	-40 to 40 Default: 0	Adjust brightness of the image by increasing or decreasing the gain.
Gamma	0.17 – 6 Default: 1	Adjusts both brightness and contrast of the image. Different pixels in the images are impacted differently depending on their original intensity levels.
Contrast	-128 to 128 Default: 0	Adjust the distinction between the lighter and darker areas in the image by increasing or decreasing the contrast value.



(a)



(b)

Figure 89 (a) False color rendering controls, (b) Image rendered in false color



6.3.1.3 Spectral analysis

The selection panel allows user to select specific areas on the rendered image and display the spectral response of the pixels in the selected area in the spectrograph. This helps the user to quickly analyze the spectral quality of the acquired data.

Figure 90 shows an example where a single area is selected on the image (marked in red) and the corresponding mean and interval spectra are displayed in the spectrograph.

Figure 91 shows an example where multiple areas are selected on the image (marked in different colors) and the corresponding mean and interval spectra for each area is displayed in the spectrograph.

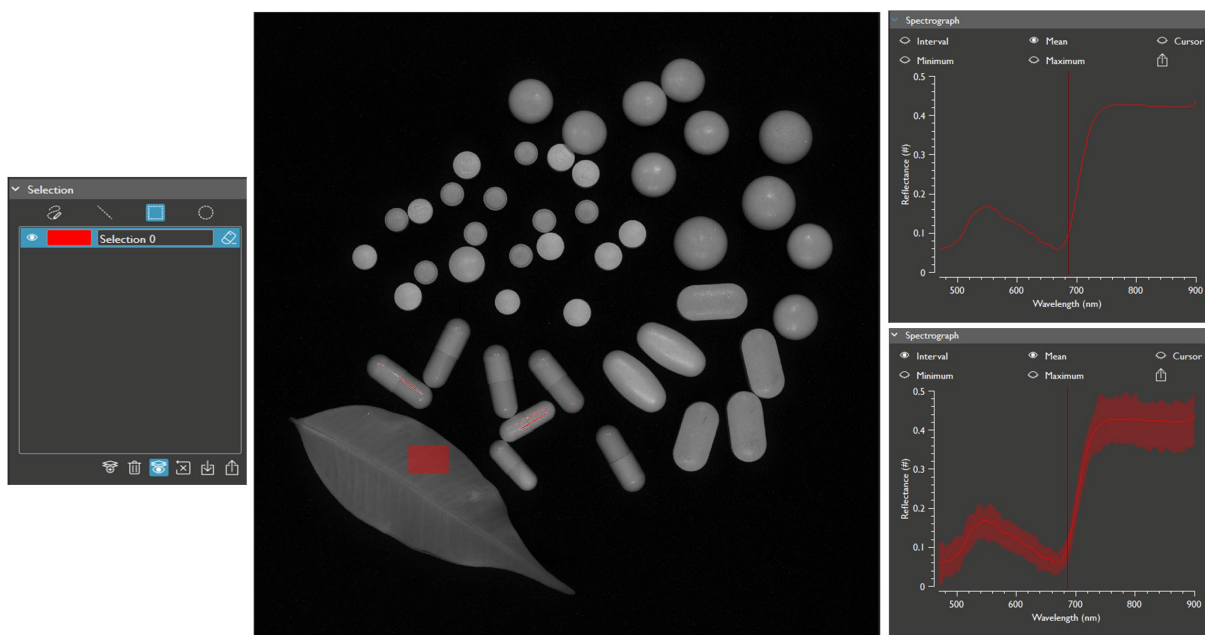


Figure 90 Illustration of the selection of single area on the rendered image and displaying in the spectrograph, the mean & interval spectra across all the pixels



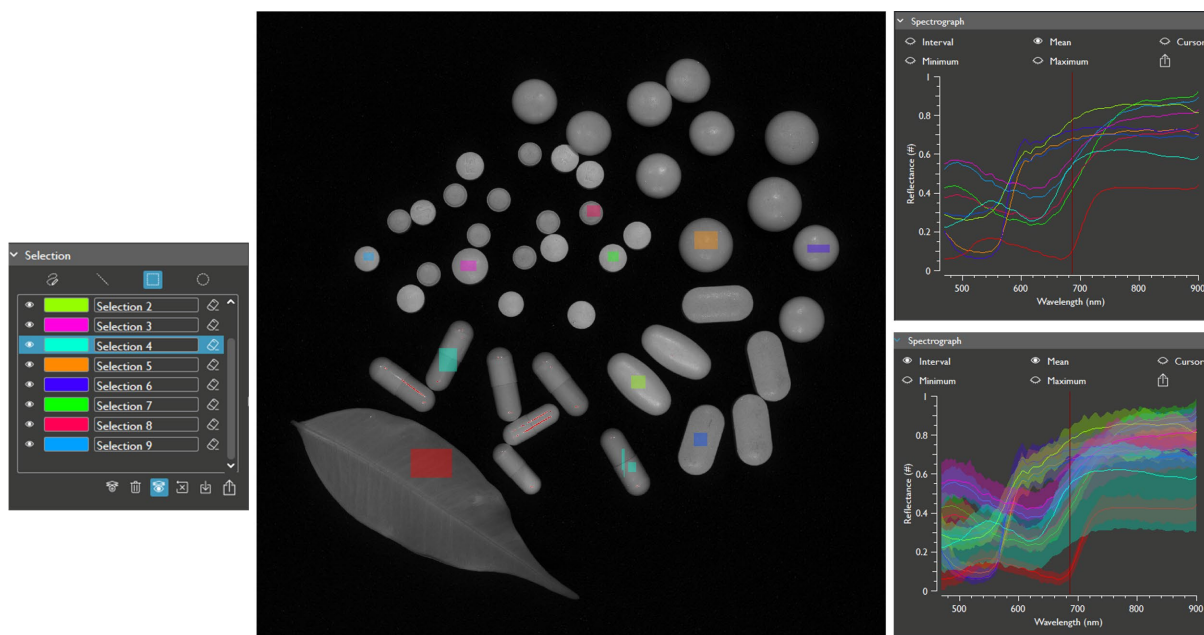


Figure 91 Illustration of the selection of multiple areas on the rendered image and displaying in the spectrograph, the mean and interval spectra across all the pixels for each of the selected area

Follow the steps below for carrying out spectral analysis:

- Step 1** - Add a new selection by clicking on the  icon. Provide a suitable name and select a suitable color for the selection (if needed).
- Step 2** - Select a suitable drawing tool  and mark the area(s) on the image to be included in this selection.
- Step 3** - Repeat steps 1 and 2 until all desired selections are created and areas for each selection are marked on the image, as shown in Figure 91.
- Step 4** - Analyze the spectral responses using the spectrograph.
- Step 5** - Edit the selections (if needed) by using the icons provided on the panel and as described in Table 14 and Table 15.
- Step 6** - If needed, export and save the selections as well as the spectrograph.

A description of different controls in the selection panel is given in Table 14 and those for spectrograph is given in Table 15.



Table 14 Description of controls in the selection panel

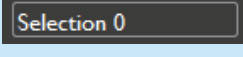
Icon	Description
	Free hand drawing tool to select regions on the image. Pixels under the drawn curve are selected.
	Straight line drawing tool to select regions on the image. Pixels under the drawn line are selected.
	Rectangle drawing tool to select regions on the image. All the pixels within the drawn rectangle are selected.
	Circle drawing tool to select regions on the image. All the pixels within the drawn circle are selected.
	Add new selection
	Delete an existing selection. First select the selection to be deleted.
	Toggle ON/OFF visibility of all selections
	Delete all selections
	Import a file with pre-saved selection(s)
	Export and save the current selection(s)
	Toggle visibility of a selection
	Software will automatically assign a color when a new selection is added. This color will be used to mark the selected area on the image as well as for plotting the spectra in the spectrograph. User can change the color by clicking on this icon and selecting a new color.
	Software will automatically assign name to each selection. User can edit the assigned name by clicking on the text box.
	Erase the areas marked on the image for a selection



Table 15 Description of controls in the spectrograph

Icon	Description
 Interval	By default, the software plots the mean spectra for a selection. Click on this icon to toggle on/off the display of spectral responses for all the pixels included in the selection(s). This will affect plots for all the selections.
 Mean	Click on this icon to toggle on/off the display of mean spectra. This will affect the plots for all the selections.
 Cursor	Click on this icon to toggle on/off the display of spectra under the cursor.
 Minimum	By default, the software plots the mean spectra for a selection. Click on this icon to toggle on/off the display of lower limit in the spread of spectra across all the pixels included in the selection(s). This will affect plots for all the selections.
 Maximum	By default, the software plots the mean spectra for a selection. Click on this icon to toggle on/off the display of upper limit in the spread of spectra across all the pixels included in the selection(s). This will affect plots for all the selections.
	Export and save the spectrograph.

Histogram

The histogram visualizes the data variability and distribution of a selection in a specific spectral band. To enable comparison of different selections the distributions are normalized to the number of pixels in a selection. A screenshot of the histogram is given in Figure 92.

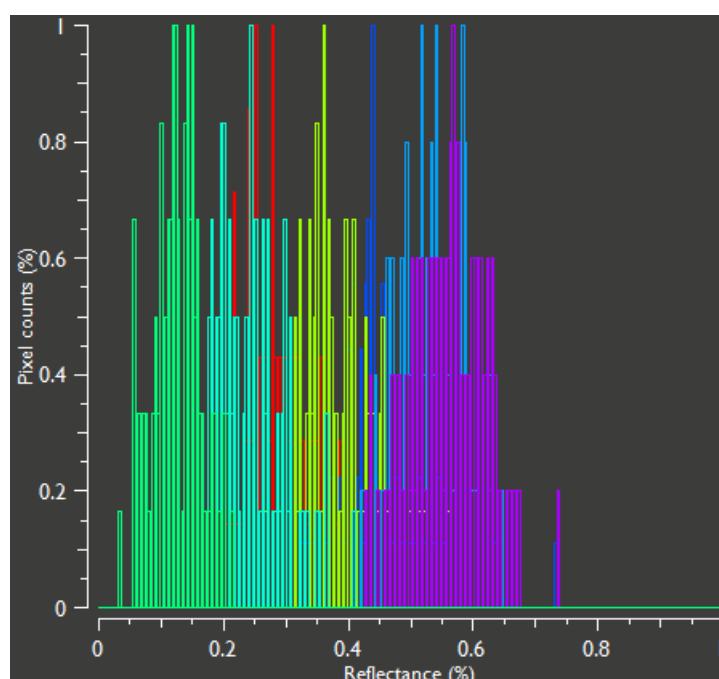


Figure 92. Distribution of three different selections in a specific spectral band.



6.3.1.4 Classification

snapscan software provides the following two options for classification:

- In-built imec Spectral Angle Mapper (SAM) classifier
- Integration with 3rd party industry leading HSI analysis software [perClass Mira](#)

Imec Spectral Angle Mapper (SAM) classifier

Follow the steps below to use SAM classifier:

Step 1 - Create the training set by creating one or more selections and marking areas per selection on the image (see Section 6.3.1.3 for instructions on how to create the selections).

Each selection will be treated as a separate class by the classifier and the spectral response of all the pixels in all the areas belonging to a selection will be treated as the set of training data for that class.

Step 2 - Select “*imec SAM classifier*” using the pull-down menu (see Figure 93).

Step 3 - If needed, adjust the classifier parameter “*Max. angle degrees*” (see Figure 93). The default value for this parameter is 5.

Step 4 - Train the classifier by clicking on  icon. This will also automatically apply the trained model on the selected cube and display the classified image (see Figure 94).

Clicking on  icon will also toggle on/off the display of classified image. When toggled off, the classified image can still be seen in the class image panel on the right hand side (see Figure 83).

All the selections used for training the classifier will also be listed in the classification panel (see Figure 93).

Step 5 - Repeat steps 1 to 4 if needed to get the desired classification results.

Step 6 - The classifier model can be exported and saved by clicking on  icon.

Step 7 - A pre-saved classifier model can be loaded and applied by clicking on  icon. Use this option to apply the same classification model on more than one images. Repeat steps 1 to 4 if needed. Export and save the edited classification model if needed.

A description of different controls in the classification panel is given in Table 16.



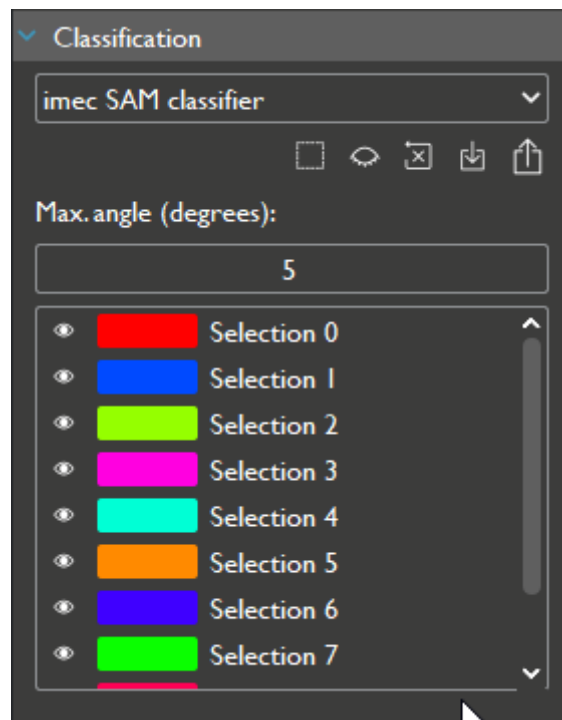


Figure 93. View of the classification panel when “imec SAM classifier” is selected

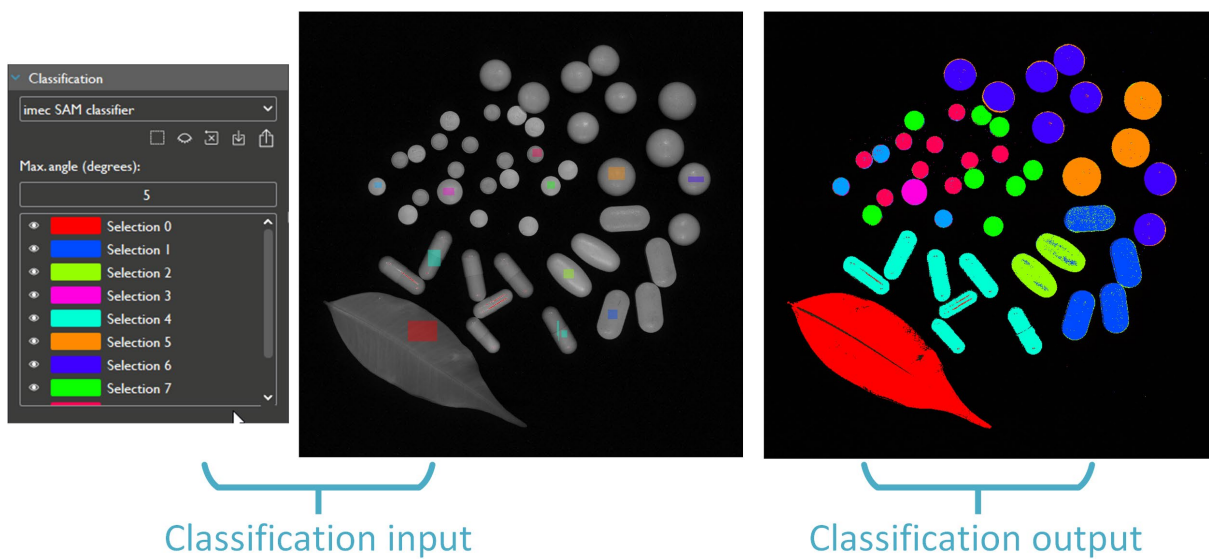
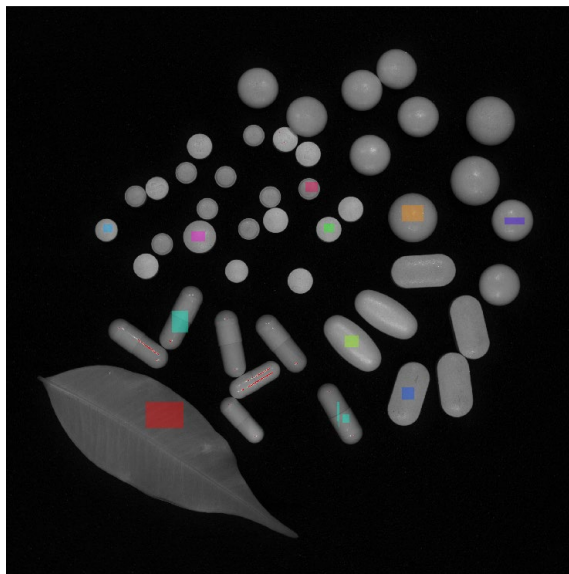


Figure 94 Illustration of the input and output of classification using imec SAM classifier

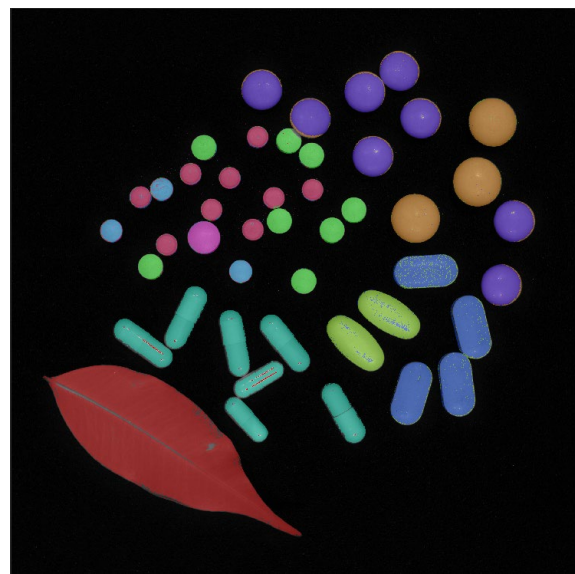


Table 16 Description of controls in the classification panel when imec SAM classifier is selected

Icon	Description
	The SAM mapper will assign different pixels to different selections while carrying out the classification. By clicking this icon, the original selection is replaced with the output of the classification, i.e. the areas classified by SAM as belonging to a particular class will be assigned to the corresponding selection. (see Figure 95)
	This icon has two functionalities - Train the classifier, apply the trained model on the selected cube and display the classified image - Once the above is done, toggle on/off the overlay of classified image over the actual image.
	Reset the classifier model. These will delete the existing classes and the trained model.
	Import a file with pre-saved classification model. Use this option to apply the same classification model on more than one images.
	Export and save the current classification model.
Max angle	Sets the tolerance on the spectral angle from a spectrum to a centroid. Value range: 0 to 180 Default value: 5
	Toggle on/off the display of classification of a class. By default, the classification for all the classes are displayed.



(a)



(b)

Figure 95 Example of impact of  “Convert to Selection” icon. (a) Original selection, (b) Updated selection after clicking on  icon.



perClass Mira classifier

[perClass Mira](#) is a spectral imaging software from perClass BV which can be used for viewing and analyzing the acquired hyperspectral image data. A 14-day limited functionality demo license is included with snapscan software.

See Section 5.2.1 for instructions on how to install and activate perClass Mira.

Follow the steps below to use perClass Mira classifier:

- Step 1** - Select “*perClass classifier*” using the pull-down menu (see Figure 96).
 - Step 2** - Click on “*perClass Mira*” button to open the perClass Mira software (see Figure 96).
 - Step 3** - A new project dialog box will open. Select “*IMEC*” as the project type and select an appropriate path to store the data (see Figure 97).
 - Step 4** - The cube will open in the perClass Mira software (see Figure 98). Please refer to http://doc.perclass.com/perClass_Mira/Introduction.html for full documentation and user manual on how to use perClass MIRA software to analyze the cube.
- You may also refer to the video on the following link to see the workflow for using perClass Mira with the snapscan software - <http://perclass.com/applications/separating-dark-textiles>.
- Step 5** - A pre-saved classifier model created in perClass Mira can be loaded and applied by clicking on  icon. Use this option to apply the same classification model on more than one images.

A description of different controls in the classification panel is given in Table 17.

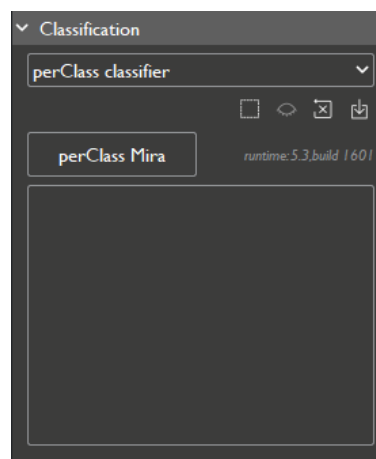


Figure 96 View of the classification panel when “*perClass classifier*” is selected



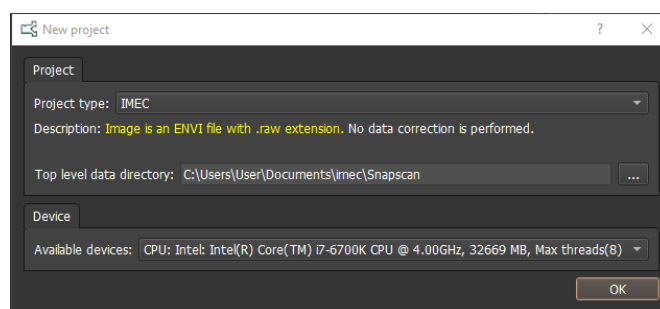


Figure 97 New project dialog box when the cube is opened in perClass Mira software. Select “IMEC” as the project type and select an appropriate path to store the data.

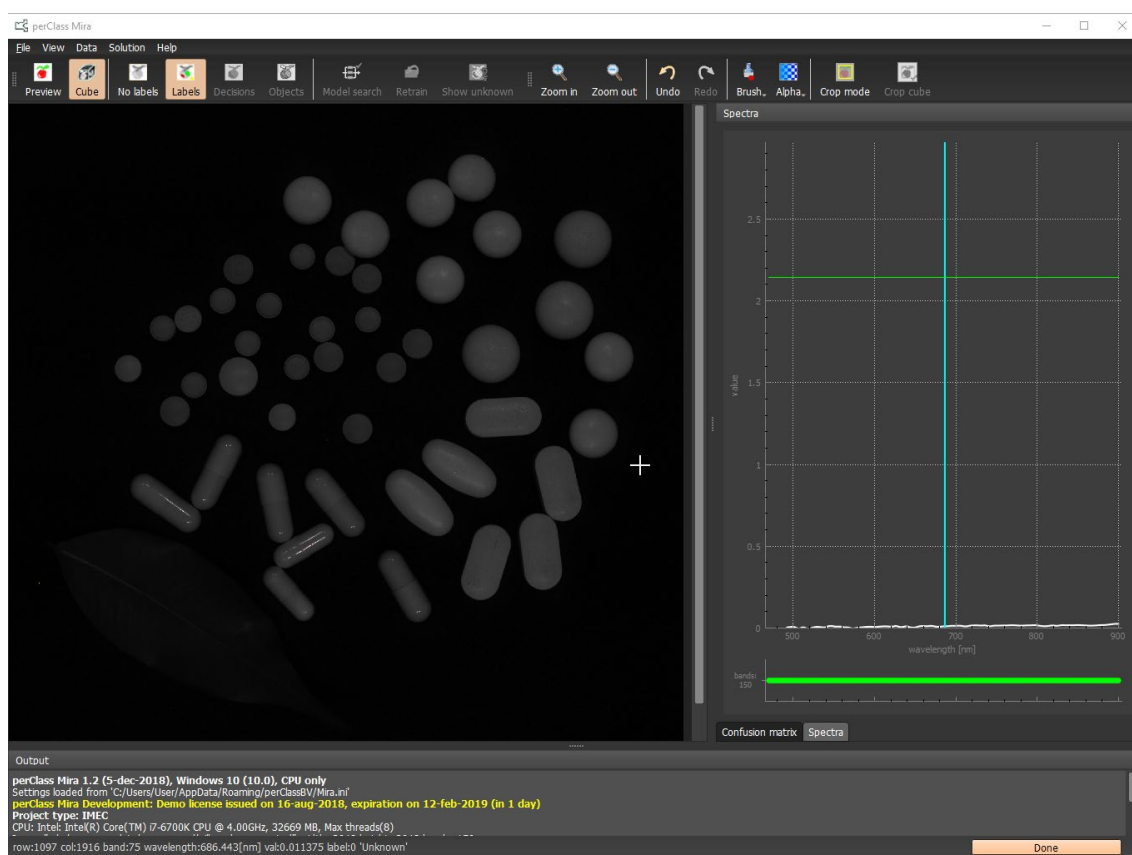


Figure 98 GUI of perClass Mira software



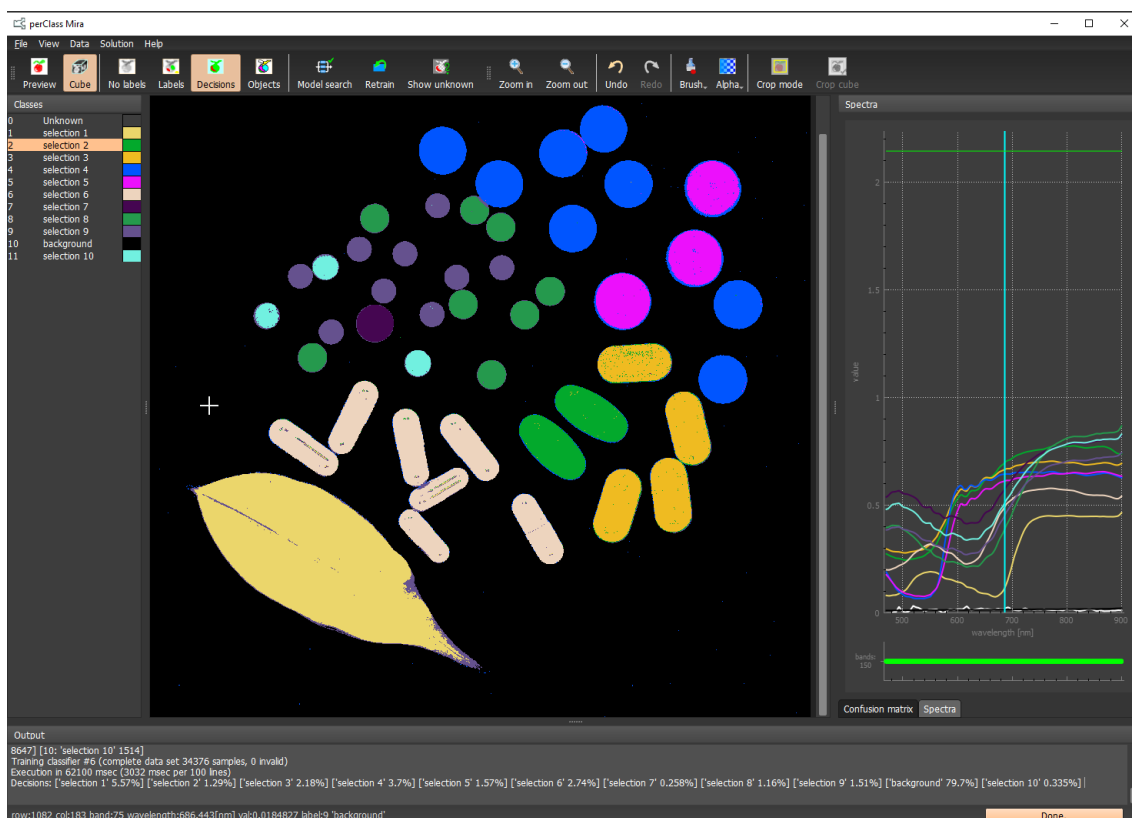


Figure 99 An example of classification carried out in perClass Mira software

Table 17 Description of controls in the classification panel when “perClass classifier” is selected

Icon	Description
	The perClass classifier will assign different pixels to different selections while carrying out the classification. By clicking this icon, the original selection is replaced with the output of the classification, i.e. the areas classified as belonging to a particular class will be assigned to the corresponding selection. (see Figure 95)
	Click on this icon to toggle on/off the overlay of classified image over the actual image. (Active only when a pre-saved classification model is imported)
	Reset the classifier model. These will delete the existing classes and the trained model.
	Import a file with pre-saved classification model. Use this option to apply the same classification model on more than one images.



6.3.2 Export step

The snapscan software enables user to export the acquired hyperspectral data in the following file formats – ENVI, PNG, PGM and TIFF.

Follow the steps below to export the acquired hyperspectral data:

Step 1 - Click “Export cube” button on the left-hand side panel (see Figure 100).

Step 2 - An “Export Setting” dialog box will open (see Figure 101). Follow the sub-steps below:

- a. Select the destination folder and provide the filename
- b. Select the file format. The snapscan software can export file in ENVI, PNG, PGM and TIFF formats.

ENVI is the default file format³ in which the hyperspectral data is exported. In cases of PNG, PGM and TIFF file formats, each spectral band is saved as a separate image file and the metadata is stored in an accompanying XML file.

An overview of the non-standard metadata stored in the ENVI file header or in the XML file is given in Table 18.

- c. Select the references to be exported along with the object cube. The snapscan software does not exports the references by default.

 *It is important to export the references if you plan to re-process the data cubes later using a different software pipeline. In this case, the irradiance data cube should also be exported (see the next step).*

 *Dark references are always exported as RAW and white references are always exported in ENVI file format.*

 *White Reference and White Dark Reference are only available if a white reference was acquired.*

 *Cube Dark Reference is only available if an object was acquired.*

- d. Select the data cubes to be exported.

- *Irradiance – raw data cube without white balancing applied (see Section 2.2.5.1)*

- *Reflectance – data cube with white balancing applied (see Section 2.2.5.1)*

- *Corrected – data cube with white balancing and spectral correction applied. The available correction matrices are listed in the dropdown menu, which is enabled if the “Corrected” option is checked.*

 *Reflectance and Corrected are only available if a white reference was acquired.*

³ See the following link for the ENVI file format specification:
<http://www.harrisgeospatial.com/docs/ENVIHeaderFiles.html>



-  The snapscan software exports only the corrected cube by default (if white reference was acquired).

Step 3 - Click “OK” to start exporting the data and close the dialog box.

-  Applying reflectance and spectral correction to the object cube requires processing of the acquired data. This operation may take up to a couple of minutes depending on the resolution of the cube and the computing power of the system.

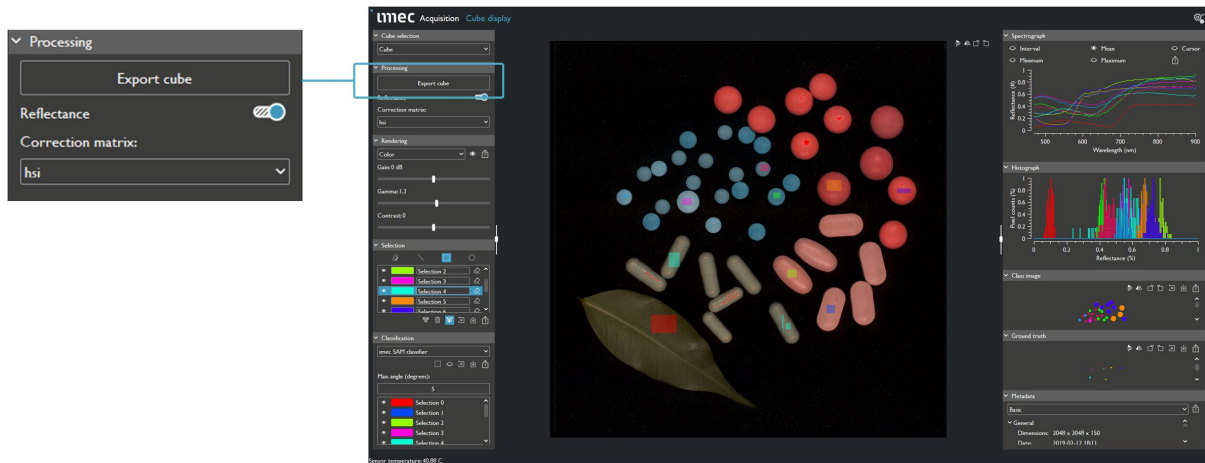


Figure 100 “Export Cube” selection button in the “Cube display” GUI.

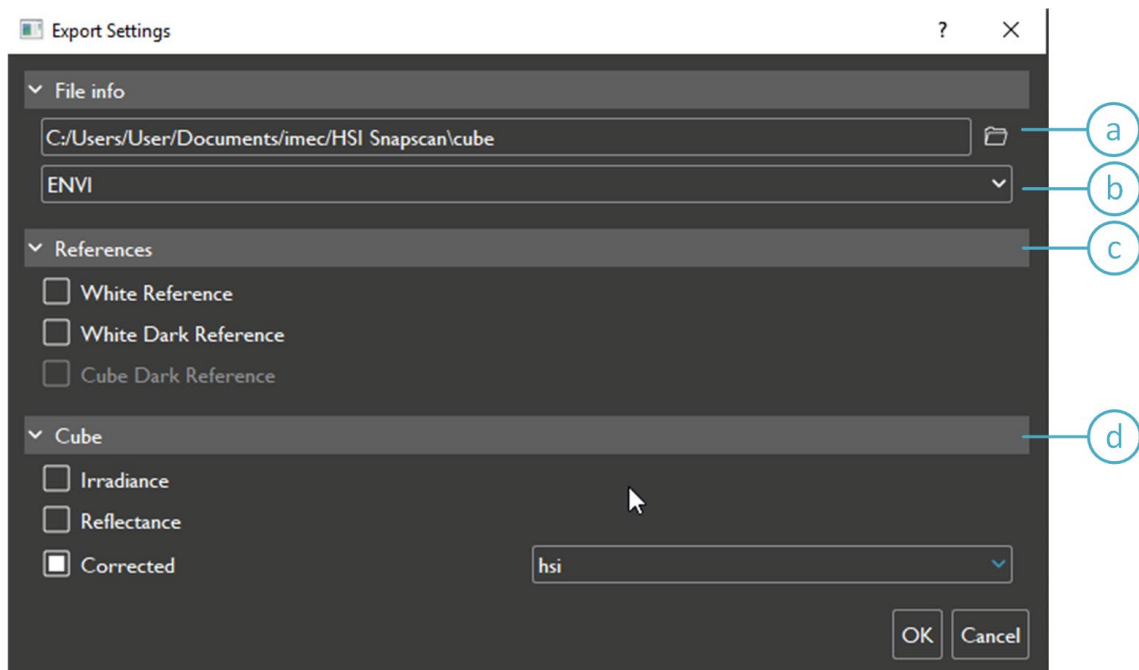


Figure 101 Screenshot of the export settings dialog box which allows the user to choose the location, name and format of the file. It also allows user to select the references and cubes to be exported.



Table 18: Overview of all metadata fields stored in the ENVI file header or XML metadata file.

Parameter	Description
Binning columns	The binning applied on the columns during the acquisition.
Binning rows	The binning applied on the rows during the acquisition.
Integration time	The integration time (in milliseconds) used to create the scan.
Analog gain	The sensor analog gain used to create the scan.
Scanning mode	The scanning mode used to create the scan.
Scanning direction	Direction of motion of the sensor during the scan. Either right to left or vice-versa.
Scanning velocity	The velocity of the sensor during the scan, in millimeters per second.
Pixel step	The step size between any two positions in number of pixels.
Pixel blur	The effective pixel blur incurred due to motion during integration.
HDR flag enabled	Flags if HDR was enabled (1) to acquire the data for the scan or not (0).
HDR flag scaling	Flags if the HDR frames are rescaled by their exposure time factor (1) or not (0). This flag is meaningless if HDR is not enabled.
Number of averaged frames	The number of frames that are averaged to acquire one frame. This value is equal to the multi-pass setting.
Number of frames	The total number of frames acquired to create the scan.
Frame positions	Vector with the position of each frame that was acquired during the scan, in millimeters.
Frame temperatures	Vector with the sensor temperature for each frame that was acquired during the scan, in degrees Celsius.
Frame timestamps	Vector with the time of acquisition of each frame that was acquired during the scan, relative to the first acquired frame, in seconds.
Output mode	Depicts if the data contains a stitched cube (Datacube) or a stack of unstitched frames (Framestack).
Max value	The maximum data value.
Saturation value	The data value marking saturation. All values in the data equal or larger than this value are considered saturated. This value is always less or equal to the maximum data value.
No data value	The value marking data points with “no value”, e.g., due to defect pixels.
Corrected data	Flags if a correction matrix was applied to the data (1) or not (0).
Reflectance data	Flags if the data has been white balanced and hence can be interpreted as reflectance percentage (1) or not (0).
Data source	The software name and version that generated the data.
Sensor bit depth	The bit-depth of the ADC on the sensor converting electrons to digital number.
Sensor id	The four-number unique sensor identifier.
Sensor pixel pitch	The size of one pixel, in millimeters.
Sensor type	The sensor’s hyperspectral filter layout type.



6.4 Tutorial

This chapter provides step by step tutorials to easily learn making good acquisitions with the snapscan system.

6.4.1 Basic configuration

This tutorial will guide the user to easily acquire, analyze and export hyperspectral data cubes.

1. Connect your snapscan system to the PC.
2. Open the snapscan software.
3. Select your snapscan system file.
4. Click “Connect”.
5. Keep the default configuration settings.
6. Click “Start”
7. Put your object in the field of view.
8. Set the lens parameters.
 - Set the aperture to F/2.8.
 - The optimal focus is found such that all spatial features appear sharp in the image.
9. Set the gain to 2.0 and tune the integration time.
 - The optimal integration time is found as the large possible value at which only very few or no pixels are saturated.
 - In case of strong light conditions lower gain values may be required to avoid saturation.
 - In case of low light conditions, first increase the integration time and gain.
10. Verify your integration time setting.
 - Moving the sensor left and right will show if the integration time is valid to capture spectral data for all spatial points. Reduce the integration time if pixels saturate when moving the sensor left and right.
11. Click “Scan object” in the “Cube acquisition” section.
12. Remove the object and put the reflectance target in the field of view.
13. Tune the integration time. Verification is not needed in case of uniform illumination.
14. Click “Scan white reference” in the “Cube acquisition” section.
15. Go to the “Cube display” tab to show the data.
16. Inspect the spatial data in the image view.
 - Scroll through the bands using the slider in the rendering group.
 - Adjust the digital gain using the slider in the rendering group.
 - Zoom and pan using the mouse.



17. Select pixels within the view.
 - Press and hold the left mouse button. Move the mouse keeping the left mouse button pressed to drag. Then release the left mouse button to complete the selection.
18. Optional: click  icon in the “Selection” panel or by using the right click context menu and select other pixels. Click  icon the “Classification” panel to show a classified image on top of the rendering.
19. Open the data export dialog by clicking “Export cube” button.
20. Select a destination folder and filename prefix.
21. Disable all options except “Corrected”. This will export the hyperspectral data reflectance data, corrected for the system model.
22. Click “Ok” to export the data.
23. The last step concluded the acquisition. The software can now be closed or go back to the “Acquisition” tab to acquire more data.

6.4.2 Tuning focus, aperture and acquisition parameters

There is an interplay between the acquisition parameters (i.e., integration time and analog gain), the lens’ aperture and the focus. Opening the lens’ aperture allows more light in the system, allowing shorter integration time and lower gain settings, but reducing the depth of field. It is also recommended to limit the aperture to a maximum opening of F/2.8 as the Fabry-Perot filters have an angular dependency. This tutorial provides guidelines to find the optimal configuration of these parameters.

1. The aperture should be set to the largest value possible yielding the required depth of field. For a given focal length and distance to the subject, the f-stop can be computed with the following tool: <http://www.dofmaster.com/dofjs.html>
 - Limit the maximum aperture opening to F/2.8.
2. Set the analog gain to 1.0 and choose an integration time such that the image is optimally exposed, while keeping the scan duration within acceptable limits.
 - The optimal integration time is found as the large possible value at which no pixels are saturated.
 - Increase the analog gain setting in case the maximum integration time is reached far below the saturation point.
 - Limit the maximum integration time to 25 ms for low gain values.
3. Focus the lens on the subject such that all features are clearly in focus.
 - On surfaces with disparity, the sharpest focus must be achieved halfway the total depth of the subject.
 - Different wavelengths have a different focal error, hence focusing for one wavelength may bring the image out of focus in different wavelengths. Optimize the focus for the wavelengths of interest for your application.



As the available parameters are all connected, there might not be an optimal solution within the constraints of the application. In this case a tradeoff must be made, or the illumination intensity must be increased.

6.4.3 Typical acquisition scenarios and recommended parameter settings

The snapscan camera system provides flexibility to optimize the acquisition parameters depending on the application requirements. In this section, we use three typical scenarios as example to show the trade-off between these scenarios and recommended parameter settings.

The three typical scenarios are:

- High speed acquisition – scenarios where acquisition time is critical. E.g. in-line sorting applications or applications where target objects can be stationary only for limited duration.
- High quality acquisition – scenarios where image quality is critical. E.g. microscopy and art restoration.
- Speed-quality balanced acquisition – scenarios where both acquisition time and image quality are equally critical and needs to be balanced. E.g. skin oximetry.

The performance trade-offs across these scenarios are shown in Figure 102 and the recommended settings for configuration and acquisition parameters are shown in Table 19. It is assumed that the spatial dimensions of the acquired cube are same in all the scenarios.

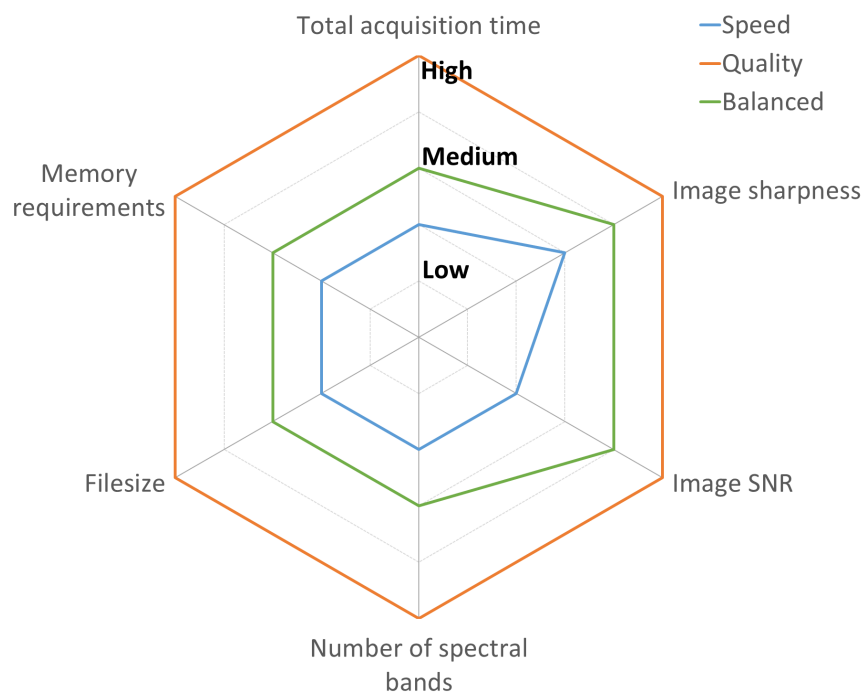
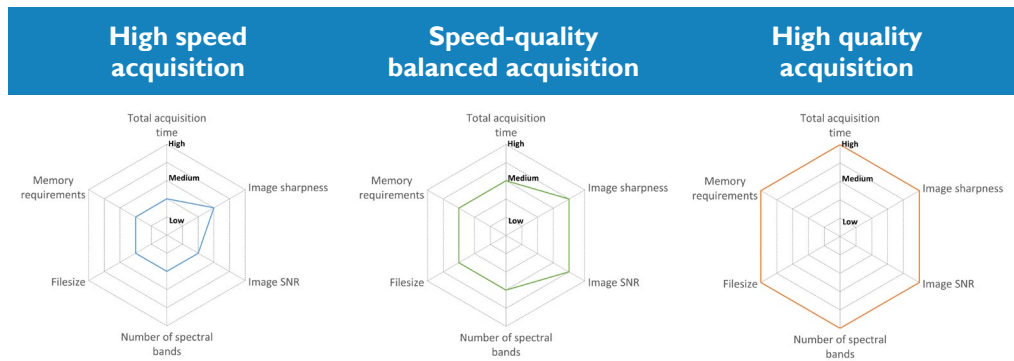


Figure 102 Performance trade-offs across the three acquisition scenarios – high speed, high quality and speed-quality balanced. It is assumed that the spatial dimensions of the acquired cube are same in all the scenarios.



Table 19 Recommended configuration and acquisition parameter settings for the three acquisition scenarios



Discard interface	NO	YES	YES
TDI pixel steps	5	3	1
Cube height	Minimum required to cover the field-of-view		
Cube width	Minimum required to cover the field-of-view		
Binning	2x2 to 4x4 (to improve SNR while trading-off some spatial resolution)	Up to 2x2 (improve SNR while minimizing loss in spatial resolution)	NO
Spectral band selection	Select minimum required spectral bands	Select almost all key spectral ranges of interest	Use all spectral bands
Integration time	Minimum possible without underexposing	Set it between minimum & maximum values based on overall acquisition time targeted	Maximum possible without saturating
Analog gain	> 1.6	1.6	Minimum possible (1.2)
Multi-frame	1	2-3	> 3
HDR	NO	YES Smaller HDR steps (2-3)	YES Larger HDR steps (4-6)



6.5 Support for 3rd party software

6.5.1 perClass Mira

perClass Mira is a spectral imaging software from perClass BV which can be used for viewing and analyzing the acquired hyperspectral image data. A 14-day limited functionality demo license is included with snapscan software.

Full documentation and user manual can be found online at http://doc.perclass.com/perClass_Mira/Introduction.html. Please refer to Section 5.2.1 for instructions on installing and activating perClass Mira.

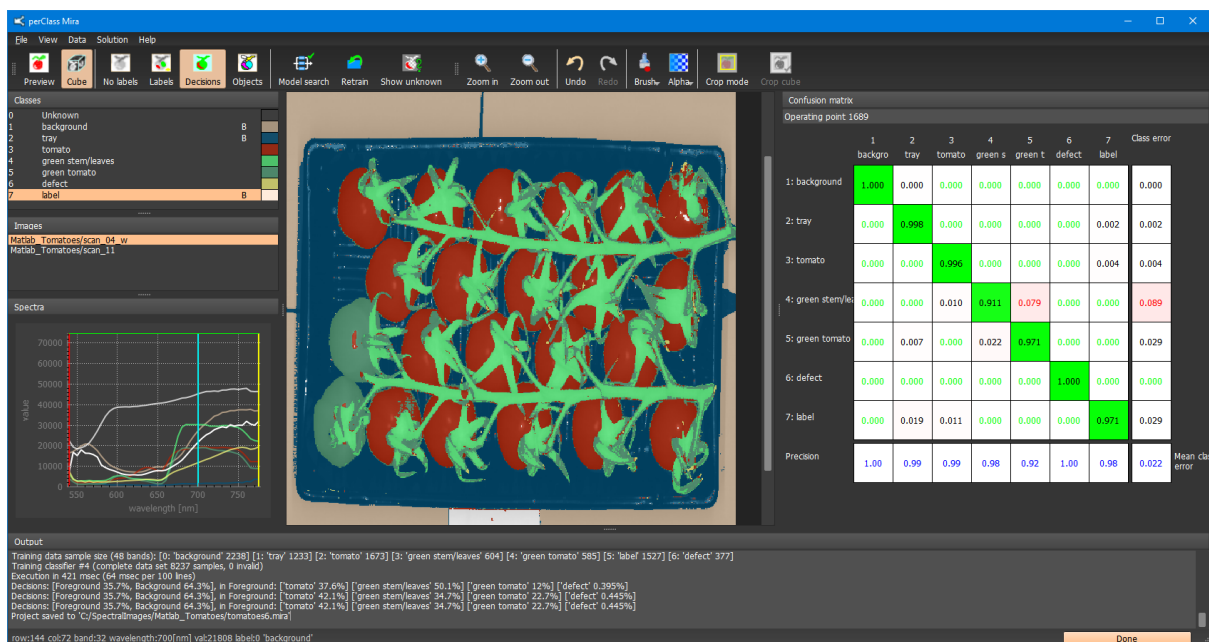


Figure 103 Screenshot of perClass Mira GUI (source: http://doc.perclass.com/perClass_Mira/Introduction.html)

6.6 Troubleshooting

There is no live image after starting the snapscan system

Check if there is enough memory available to allocate all data. If not, then stop the snapscan system and free up memory by closing other software.

-  *All required memory is allocated when starting the snapscan system. To not compromise the performance of the system, the camera driver will not work when the system is swapping memory to disk.*

Data acquisition is very slow and the software is unable to acquire cube

Check 1: Camera is plugged in a USB3.0 port.

Check 2: No other devices are connected to the same USB hub.

Check 3: When working on a mobile system, ensure it is on mains power and the system is set to high performance mode.

Check 4: The CPU not to be fully used; close other software to reduce load.

Scanning finishes with an error message of dropped frames

Switch to the stop motion scanning mode.

-  *When scanning large cubes at high speed it is possible that the system cannot process the data in time. Switching to the stop motion scanning mode will pace the acquisition to the system's processing speed.*
-  *When scanning at long exposure times and/or small pixel blur settings the stage speed is too low to guarantee a smooth and stable movement. Switching to stop motion scanning mode will yield better results.*

The camera makes a clicking sound after it is connected and during scanning

This is normal. The camera shutter will cycle after connection and before starting a scan. During a scan the translation stage is moved internally, which can also lead to audible clicking.



The software does not respond when exporting a cube

Check 1: There is sufficient disk space.

- ❗ *Exporting data can appear slow as filesize of a cube can reach up to 5.4Gb. When disks run full, the export speed may further slow down due to fragmentation of free disk space.*

Check 2: System has enough RAM available.

- *The system will swap RAM to disk in case more memory is needed than available. This is very slow and seriously affects system performance.*

Check 3: Please wait.

- *Computing spectral correction on the exported data may appear slow as it involves up to 2.6 trillion operations. Depending on the computer's processor speed and the size of the data cube, this operation may take up to one full hour.*

Contact imec HSI support if the problem persists or for any other problems:

Email: hsisupport@imec.be

Website: <http://hsisupport.imec.be>







Chapter 7

Applications

7. Applications

We provide here a few examples of applications for which our customers and partners are using the snapscan camera system. Besides these applications, snapscan can be used in a wide range of other applications such as forensics, agriculture, quality control in industrial processes, waste sorting, food & feed analysis, etc.

7.1 Microscopy

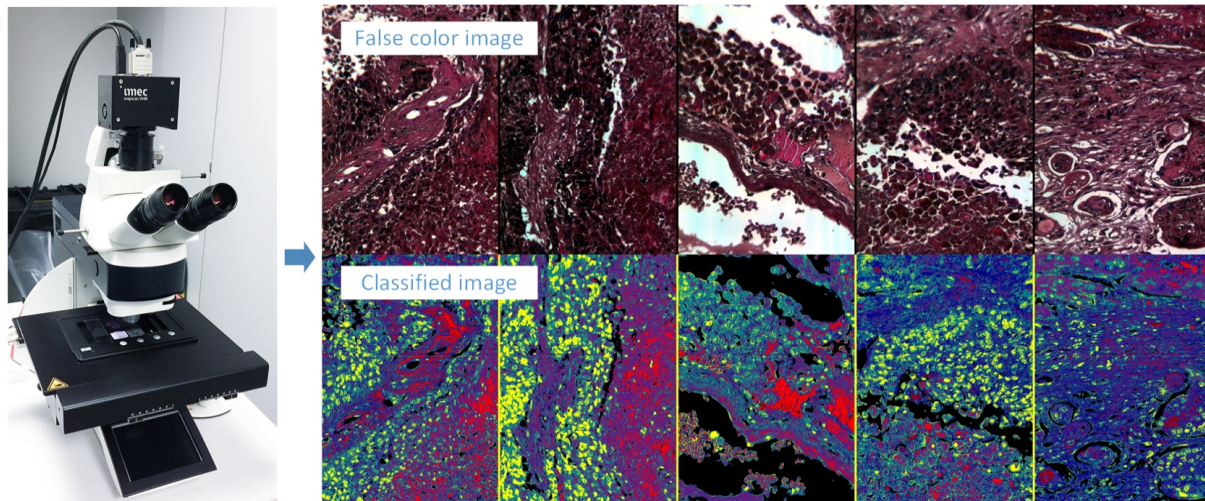


Figure 104 snapscan camera mounted on a Leica microscope and example of histopathology samples for H&E stained lung cancer (image courtesy: Hyperspectral Intelligence Inc⁴)

The snapscan camera can be mounted on microscope, as shown in Figure 104. This enables high spectral and spatial resolution hyperspectral imaging of samples examined under microscopes. Figure 104 shows an example of histopathology samples for H&E stained lung cancer for which hyperspectral images were obtained at more than 150 spectral bands and the spatial resolution for each band is 7Mpx.

snapscan makes it easy to setup hyperspectral imaging for microscopy and acquire high quality at a fast acquisition speed. Care must be taken to select the right components (illumination and optical lenses) and also to carry out system calibration and white balancing correctly. Please contact [imec HSI support](#) for further details.

7.2 Fundus imaging

The snapscan camera can also be integrated with fundus cameras. In a manner similar to microscopy, snapscan enables high spectral and spatial resolution hyperspectral imaging of retina. Please contact [imec HSI support](#) for further details.

⁴ <https://www.hyperspectral-intelligence.com/>



7.3 Skin/ wound imaging

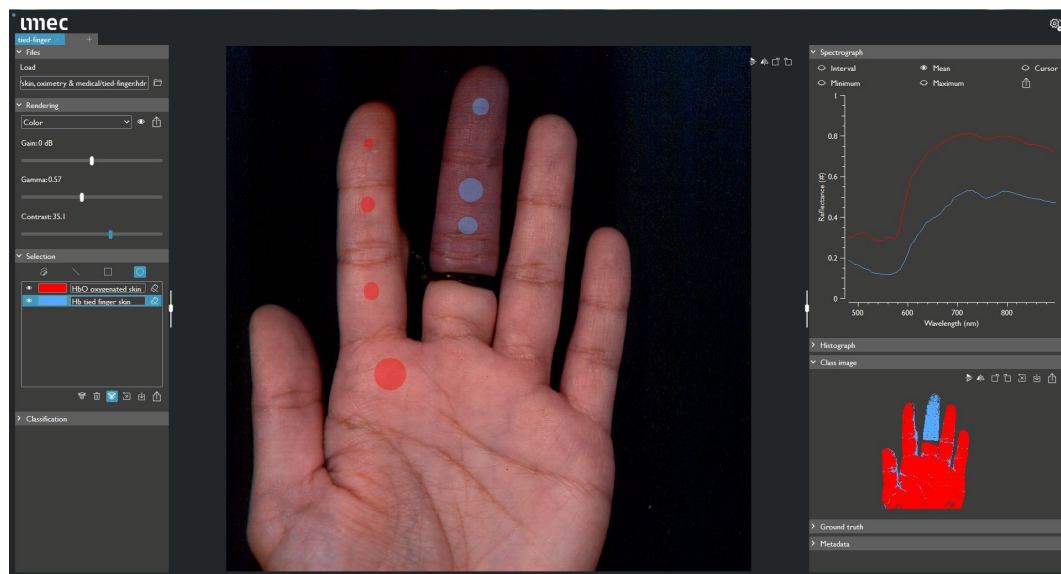


Figure 105 Example of skin oximetry. The blood flow to the upper part of the middle finger is restricted by tying the finger. The difference in oxygenation levels in the index finger and the tied finger results in differences in their respective spectral responses. This can be used to generate oxygenation maps, as shown in the classified image on the right-hand side.

The snapscan camera system can be used for health and medical applications, such as skin imaging, wound imaging, etc. The spectral range of snapscan covers several important skin/tissue biomarkers such as oxygenated/ de-oxygenated hemoglobin, hemoglobin, fat, hydration, etc. Please contact [imec HSI support](#) for further details.



7.4 Outdoor imaging

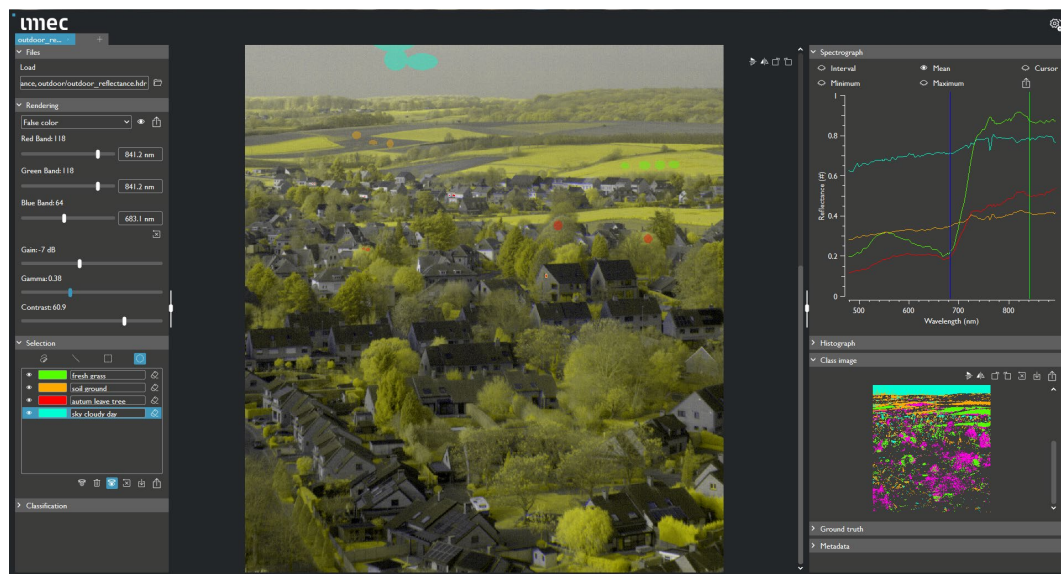


Figure 106 Example of pseudo NDVI image of an outdoor scene

The snapscan camera system can be used for outdoor imaging where natural light is used as the illumination. Care must be taken to correctly carry out system calibration and white balancing. Please contact [imec HSI support](#) for further details.

7.5 Art & antiquities conservation

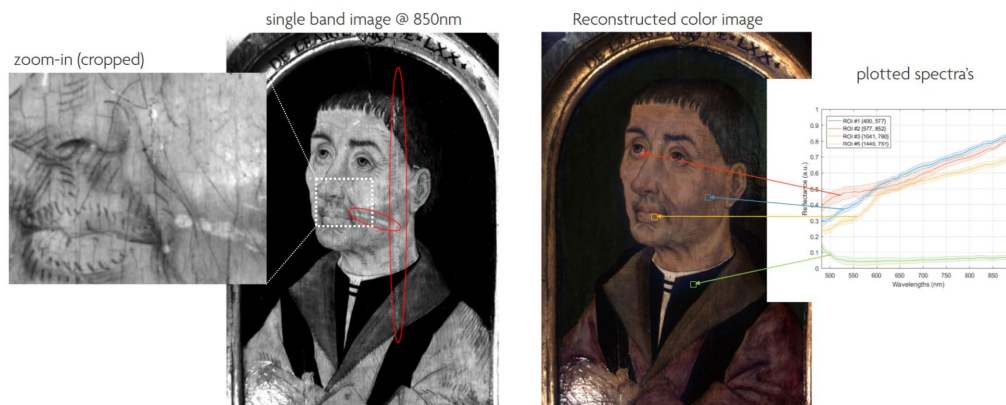


Figure 107 Digitize artwork to generate preliminary study information on exact color and pigment information's used by the original painter. Courtesy Prof. dr. Maximiliaan Martens, Dept. Art History, Musicology and Theatre Studies, Ghent University. Painting – portrait of Jean Wouters, collection of Jan Muller.

Combined VIS-NIR spectral range, high spatial and spectral resolution of the snapscan camera system allows art and antiquities conservators to extract exact color and pigment information. Please contact [imec HSI support](#) for further details.



7.6 Mineralogy

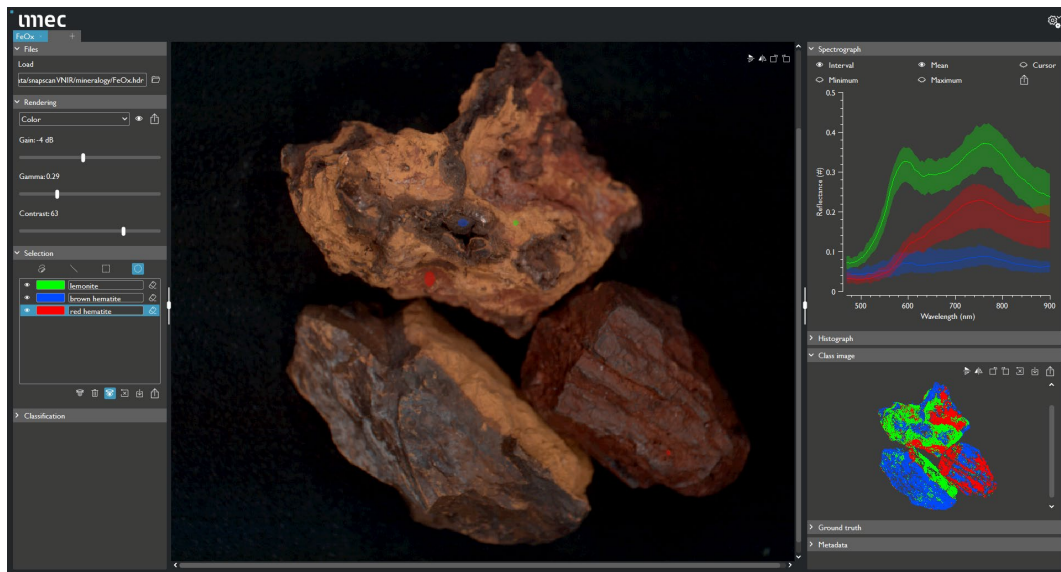


Figure 108 Spectral analysis of iron ore to determine the iron content as well as distribution for grading the ore.

Combined VIS-NIR spectral range, high spatial and spectral resolution, dust-proof and robust construction and on-board cooling of the snapscan camera system also makes it suitable for use in outdoor and dusty environments, such as ore extraction mines or ore analysis labs. Please contact [imec HSI support](#) for further details.

7.7 Pharmaceuticals

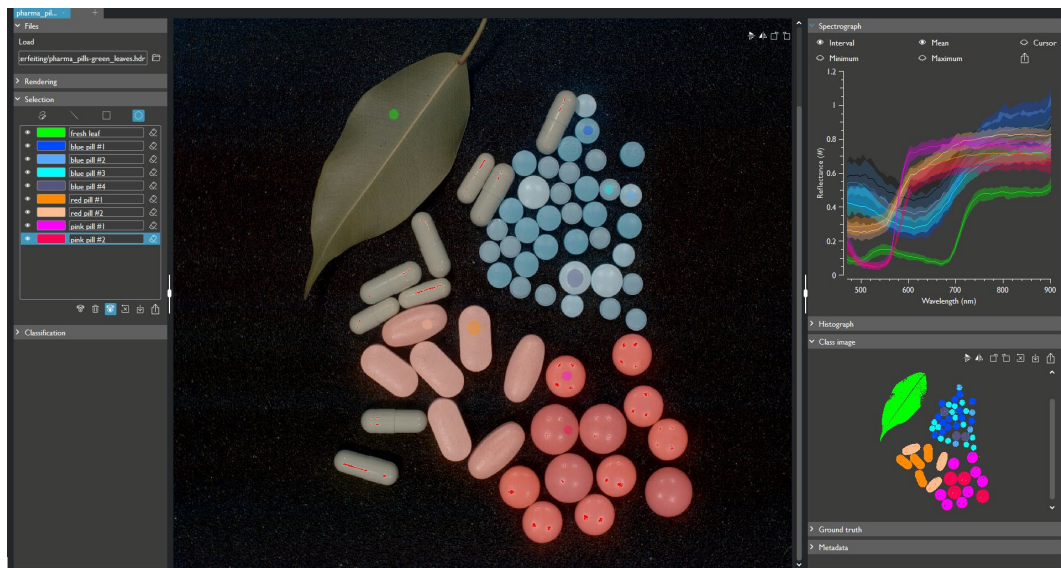


Figure 109 Example of differentiating similar looking pharmaceutical pills.

Combined VIS-NIR spectral range and ability to optimize spatial and spectral resolution along with scanning speed of the snapscan camera system enables non-destructive inspection of the pharmaceutical products for quality control, composition analysis as well as differentiating



similar looking products. Snapscan camera system can also be used to identify counterfeit drugs. Please contact [imec HSI support](#) for further details.

7.8 Food quality grading and sorting

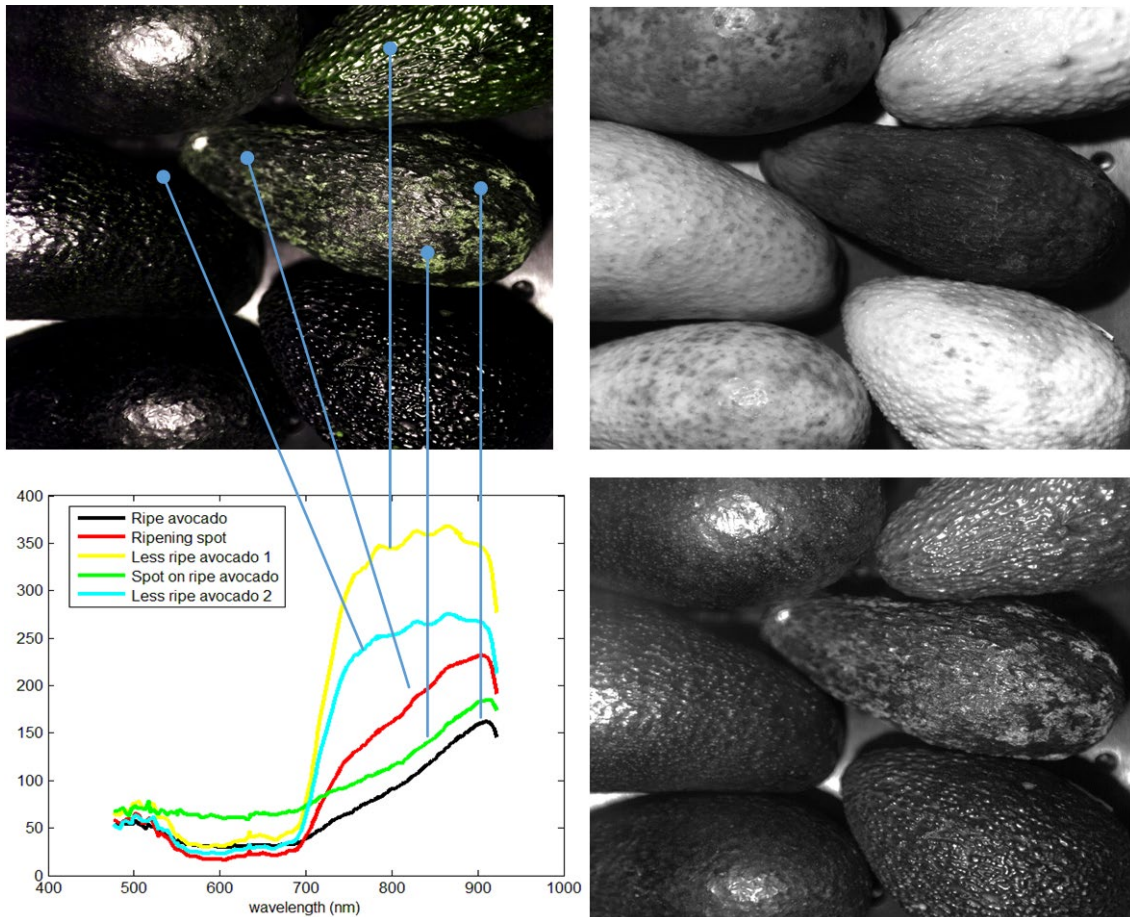


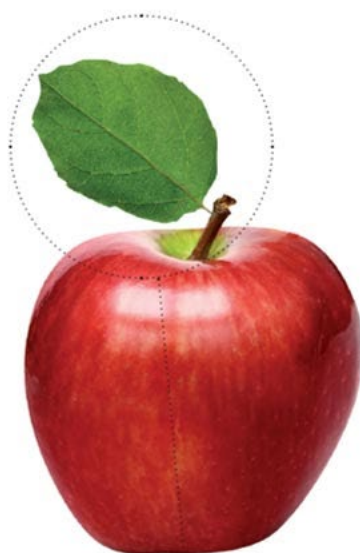
Figure I 10 Detection of ripeness of avocados

The snapscan camera system enables high spatial and spectral hyperspectral imaging for food quality grading and sorting. For example, fruit growers can use it for detection of ripeness, bruises and diseases for fruits like apples, lemons, cherries, kiwis, peaches, avocados, etc. Please contact [imec HSI support](#) for further details.

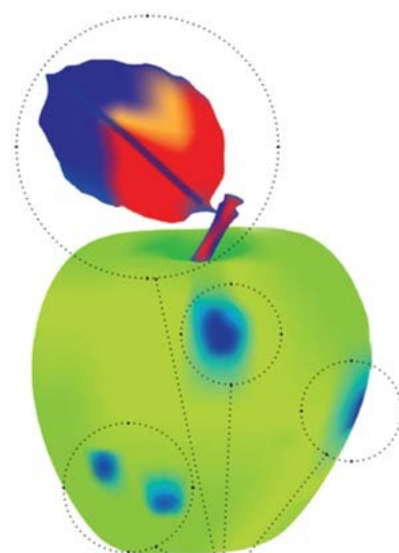




MONOCHROME IMAGING



COLOR IMAGING



CHEMICAL COLOR IMAGING



Chapter 8

Appendices

8. Appendix – Glossary and Shortcuts

8.1 Glossary

Parameter	Description
Analog gain	Gain applied when converting photons to electrons.
Cross talk	Signal in a pixel generated by electrons leaking in from neighboring pixels.
Digital gain	Gain applied when converting electrons to digital number.
Exposure / Integration time	Time during which the sensor is exposed to photons.
HDR	High Dynamic Range
SAM classifier	Spectral Angle Mapper classifier
SNR	Signal to Noise Ratio
TDI	Time Delayed Integration



9. Appendix - Software changelog

9.1 snapscan v1.2.0

- Following enhancements have been made to the user interface
 - Tooltips have been added to icons and buttons
 - New icons have been added
 - Toolbar has been extended by adding support, about and languages in the tool button
 - Support for following languages have been added – Japanese and Chinese
 - Abort and progress bar have been added in spinner dialog
- Configuration parameter “Cube Offset X” have been added which sets the offset from top edge in live view in case the selected cube width is lower than 2048.
- Stop Motion and Continuous camera modes are automatically selected by the software and is no longer a user setting
- Support for snapscan SWIR range hyperspectral camera added to the software
- Following widgets added to cube display - class image, ground truth and metadata
- Import/ export options added to different widgets in cube display mode (for example, rendering, spectrograph, selection, classification, etc.)
- Default location for file I/O is moved to Documents\imec\<AppName>
- Internal file management is moved to AppData\Roaming\imec\<AppName> for admin restricted systems

9.2 snapscan v1.1.2

- Added support for perClass Mira
- Selection model is no longer reset on loading classifier
- Class model is now separated from selection model
- Class label layer is now split into multiple layers that can be hidden/shown individually
- Background image can be hidden to focus on classes
- Gaussian smoothing on spectrums added
- Default export reworked: unchecked by default but the most processed available cube
- There is now a visual feedback when modification of a parameter is not yet taken into account. Enter or focusOut to validate entry.
- Storing to cache is now only applied when required to fasten up the visualization of irradiance.
- Color match rendering is now default





snapscan SWIR arriving Q2 2019

100+ bands, 1.1-1.7 μ m, 1200x640 px/ band



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