

OtO Photonics

SmartEngine (SE) Series

Product sheet



Description

SmartEngine series Czerny-Turner cavity spectrometers can be specified with a wide choice of CMOS and CCD linear sensors including Ultraviolet and Near Infrared enhanced, fast exposure, back-thinned and high pixel count options.

An extremely wide range of standard gratings allows system integrators to specify the wavelength range and fine tune peak efficiency whilst the choice of slit widths means the compromise between resolution and sensitivity can be optimized.

SmartEngine's compact and rigid package provides a stable measurement platform offering excellent thermal and humidity cycling performance together with minimum variation of resolution and wavelength shift due to shock and vibration.

PC communication and power interface with the SE series is via USB with an additional 6 I/Os for external connections.

SmartEngine's 32-bit RISC controller can be addressed via OTO's "SpectraSmart" fully-featured spectral measurement software which includes a full Windows SDK and other example code



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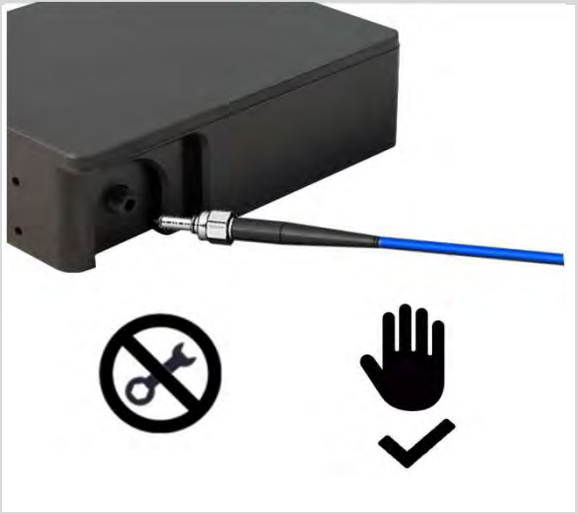
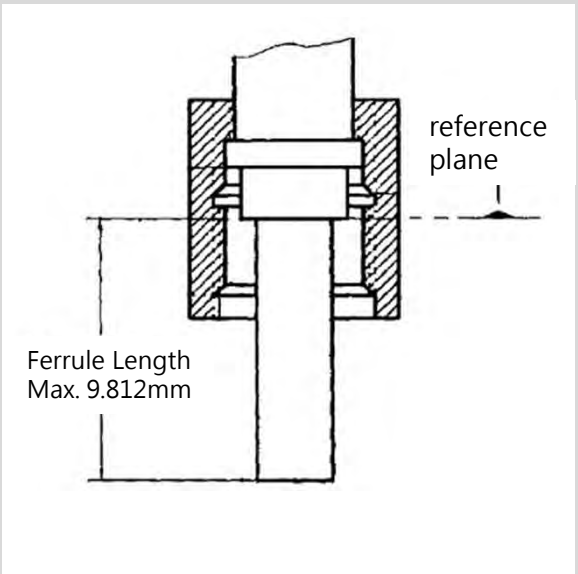
SE Series-307 Rev.1
www.otophotonics.com

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Attention

Picture	Description
	<p>To prevent over-tightening and <u>damaging the slit</u> of the spectrometer please ONLY hand tighten the SMA905 connector.</p> <p>Do not use any tool to tighten the optical fiber and SMA905 connector.</p> <p>If stable long-term operation is required we recommend application of adhesive to the connector after hand tightening.</p>
	<p>The design of the optical interface is based on <u>IEC 874-2:1993</u>. To prevent damage to the slit in the spectrometer, the ferrule length of SMA905 connector must shorter than 9.812mm.</p>

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Overview

► 1.1 Lineup of SE Series

Model	Spectral Response Range (nm)					SNR ^{*1}	Dynamic Range ^{*2}	Stray Light	A/D	Thermal Stability
	DUVN	FUV	FUVN	VNIR	NIR1					
	200 1025	180 850	180 1100	350 1020	790 1010					
SE2020	√	√	√	√	√	250	≥1630	0.2%	16 bits	<0.04 nm/°C
SE2030	√	√	√	√	√	350	≥3000 ≥3000	0.2%		
SE2040	√ ^{*3}			√		200	≥1820	0.2%		
SE2050/2052				√	√	500	≥3200	0.45%		
SE2070	√			√	√	400	≥1600	0.2%		
SE2080	√			√	√	350	≥2000	0.2%		
SE2090		√	√	√		500	≥4600	0.45%		
SE2120	√	√	√	√	√	430	4500 (>3500, 2.5MHz)	0.2%		

*1 : Single acquisition

*2 : 65535/Dark Noise(upper limit)

*3 : For SE2040, 275nm plus options only

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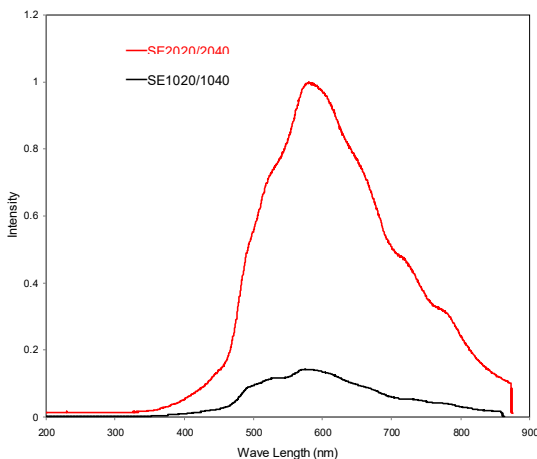
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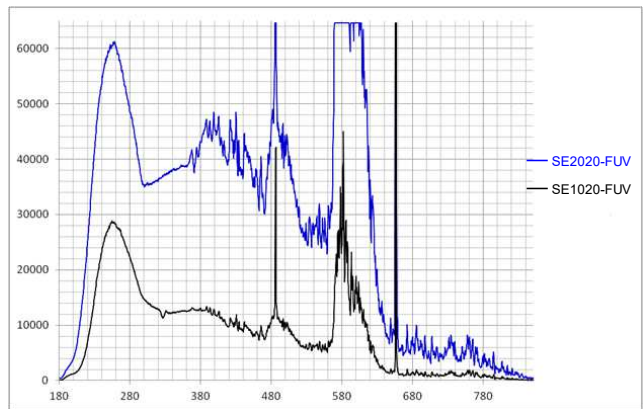
- SE2xxx series has new optical design provides higher sensitivity performance.
- SE2020 with a composite phosphor coating (Lumogen E) on CCD, that improves the sensitivity of CCD in blue-visible and ultraviolet, as well as eliminating the oscillation phenomenon caused by thin-film interference on CCD.

► 1.2 Efficiency Output Comparison

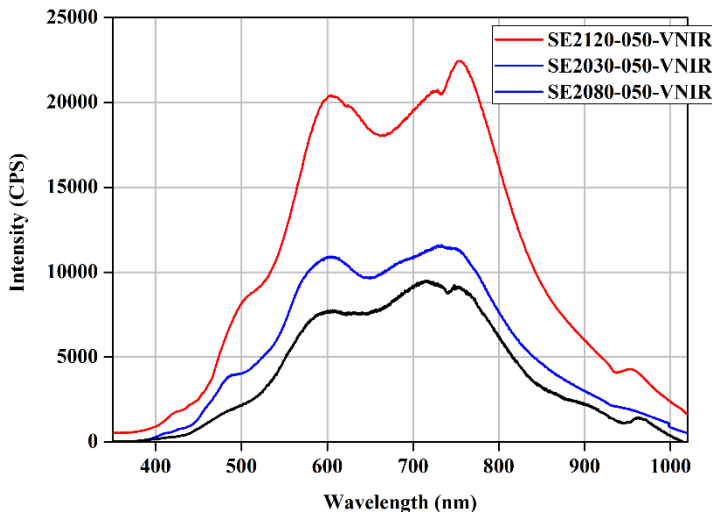
SE1020/1040 and SE2020/2040 Comparison Plot



SE1020 and SE2020 Comparison Plot



- New optical design spectrometer of SE2020 shows 7.5 times efficiency toward standard type spectrometer. (@570nm as shown on the upper left chart)
- SE2020 shows 3 times sensitivity enhancement toward SE1020 on UV range. (Upper right chart)



	SE2120	SE2030	SE2080
Pixel number	1024	2048	4096
Pixel Size (W x H, um)	28x200	14x200	7x200

- The Spec. indicate that the SE2120 has fewer pixels compared to the SE2030, but each individual pixel's area is twice that of the SE2030. As a result, the SE2120 has nearly double the photosensitivity efficiency of the SE2030.

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■ Main Features

▶ 2.1 Feature

- Wavelength range: from 180 to 1100 nm
- Optical resolution: from 0.2 to 10.5nm, depending on the combination of various slits and gratings.
- A variety of sensor can be chosen for specific application:
 - High sensitivity 2048-pixel CCD array sensor
 - Back-thinned high SNR and high sensitivity 2048-pixel CCD array sensor
 - High speed 1024 or 2048 or 4096 pixel CMOS sensor
 - High pixel-resolution 3648-pixel CCD sensor array
- Modular configuration with various grating, sensor, and slit options
- Integration times from 0.2 ms to 65 seconds, depending on sensors
- 16 bit, 15MHz A/D Converter
- USB 2.0 @ 480 Mbps (High speed)
- 8-pin connector for interfacing to external
 - 6 user programmable digital I/O
- Plug-n-play interface for PC application
- Extremely precise continuous multiple exposures, providing up to 5,000 spectra buffering
- CCD clock rate can be adjusted to meet the demand of wavelength repeatability or processing speed.
- Flash ROM storage for
 - Wavelength Calibration Coefficients
 - Linearity Correction Coefficients
 - Intensity Calibration Coefficients
- The position of slit is able to change to the left side of spectrometer (SE2052) , provide the flexibility of integration with OEM product.

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2.2 Specification

SPEC	Content							
	SE 2020	SE 2030	SE 2040	SE 2050	SE 2070	SE 2080	SE 2090	SE2120
CCD	UV -Enhance, Front -illuminate CCD	Fast-Exposure CMOS	Front -illuminate CCD	NIR - Enhance, Back -thinned CCD	High Pixel Resolution CCD	Fast -Exposure CMOS	Fast -Exposure, Back -thinned CCD	Fast -Exposure CMOS
Dark Noise (Upper limit)	50	22* ¹ 28* ²	36	20	40	50	14	19
Dynamic Range (minimum.)* ³	≥1630	≥3000* ¹ ≥2300* ²	≥1820	≥3200	≥1600	≥2000	≥4600	≥3500
SNR* ⁴	250	350	200	500	400	350	500	430
Parameters of Optical System	f/# : 5, NA :0.1, Focal Length(R1-R2) :60-60 (It is recommended that the Incident NA should larger than the NA of spectrometer.)							
Spectro-meter	SE series; Czerny-Turner Optical Structure 2nd & 3rd order rejection							
Dimension	Type I version: 110(L) x 86(W) x 32.4(H) mm Type II version: 110(L) x 86(W) x 35.4(H) mm SE Plus version: 110(L) x 86(W) x 53.9(H) mm; Plus version is only for SE2030P-FUV2 & NIR1, SE2050P-NIR1, SE2060P-FUV2; FUV2:180-500nm, NIR1:790-1010nm)							
Grating	15 grating options ; spectral range from UV to NIR							
Wave-length	From 180 to 1100 nm with a variety of wavelength range							
Slit Size	10, 25, 50, 100, 200,300 um							
Integration Time	0.2ms ~ 65sec, depending on sensors							
Wavelength Repeatability	+/- 0.05 nm Continuous 100 measurements (Hg-Ar Light Source)							

*1 : Sensor clock rate 2,5MHz *2 : Sensor clock rate 10 MHz

*3 : 65535/Dark Noise(upper limit)*4 : Single acquisition

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SPEC		Content
Wavelength accuracy		± 0.3 nm (Testing environment is based on SE1020-050-VNIR's parameter, and accuracy may be up to ± 1.0 nm according to different environment such as severe temperature change and long-time vibration. OtO can offer free software for WL calibration if customer needed.)
Resolution(FWHM)		From 0.2 nm to 10.5 nm, depending on different modular configuration
Thermal Stability		<0.04nm/°C
Environmental Conditions	Storage	-30°C to +70°C
	Operation	0°C to +50°C
	Humidity	0% - 90% non-condensing
Interfaces		USB 2.0 @ 480 Mbps (High speed)
Input Fiber Connector		SMA905: $\Phi 3.18 \pm 0.005$ mm
		SMA905: $\Phi 3.20 \pm 0.01$ mm
Recommend Tightening Torque		0.3 Nm (Mating Part : 5mm thick, Flatness 0.1mm, Aluminum sheet)
Power		Power requirement (VBUS): 300mA at +5 VDC Supply voltage: 4.75-5.25 Power-up time : < 4s Maximum USB input power Vcc : +5.25VDC Maximum I/O signal voltage : +5.5VDC

- Customized design for your various special requirements including higher resolution, specific wavelength range, higher SNR, special gratings or sensors not in the list, specific software or hardware design, or special exposure modes, is welcome and will be elaborately built and tested by our R&D team.

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■ Structure

▶ 3.1 Mechanical Diagram

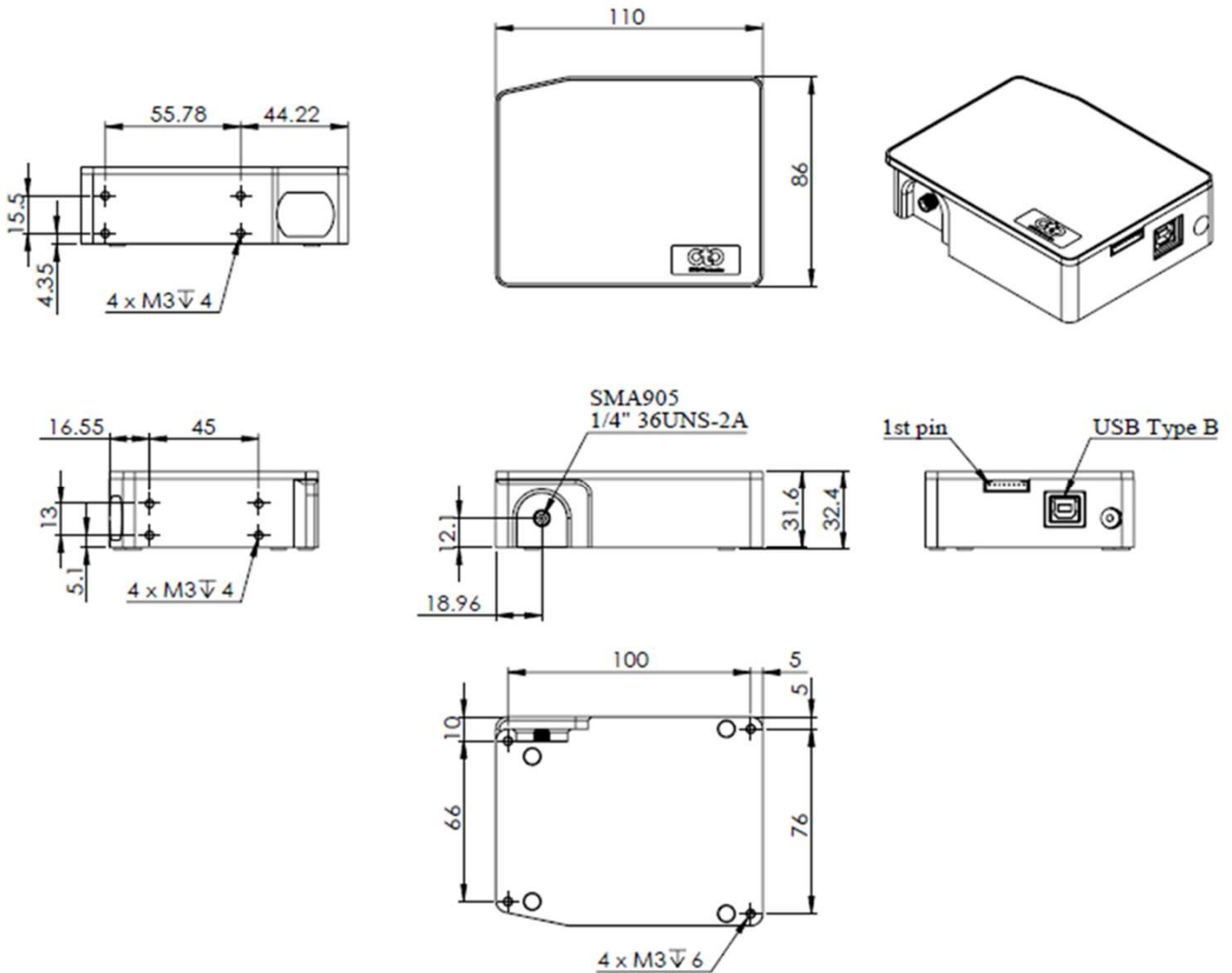


Fig. 1: SE Series outer dimensions (Type I)

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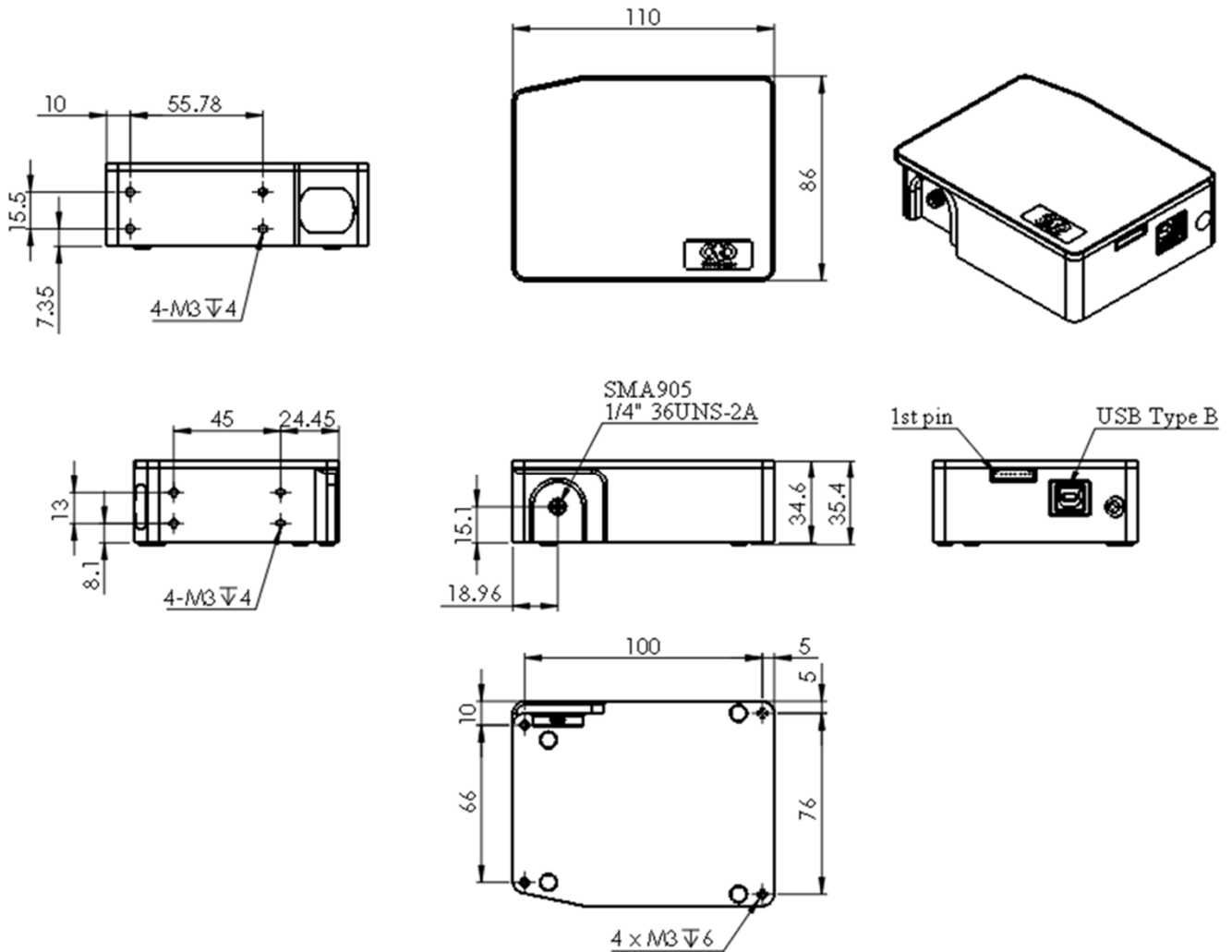


Fig. 2: SE Series outer dimensions (Type II)

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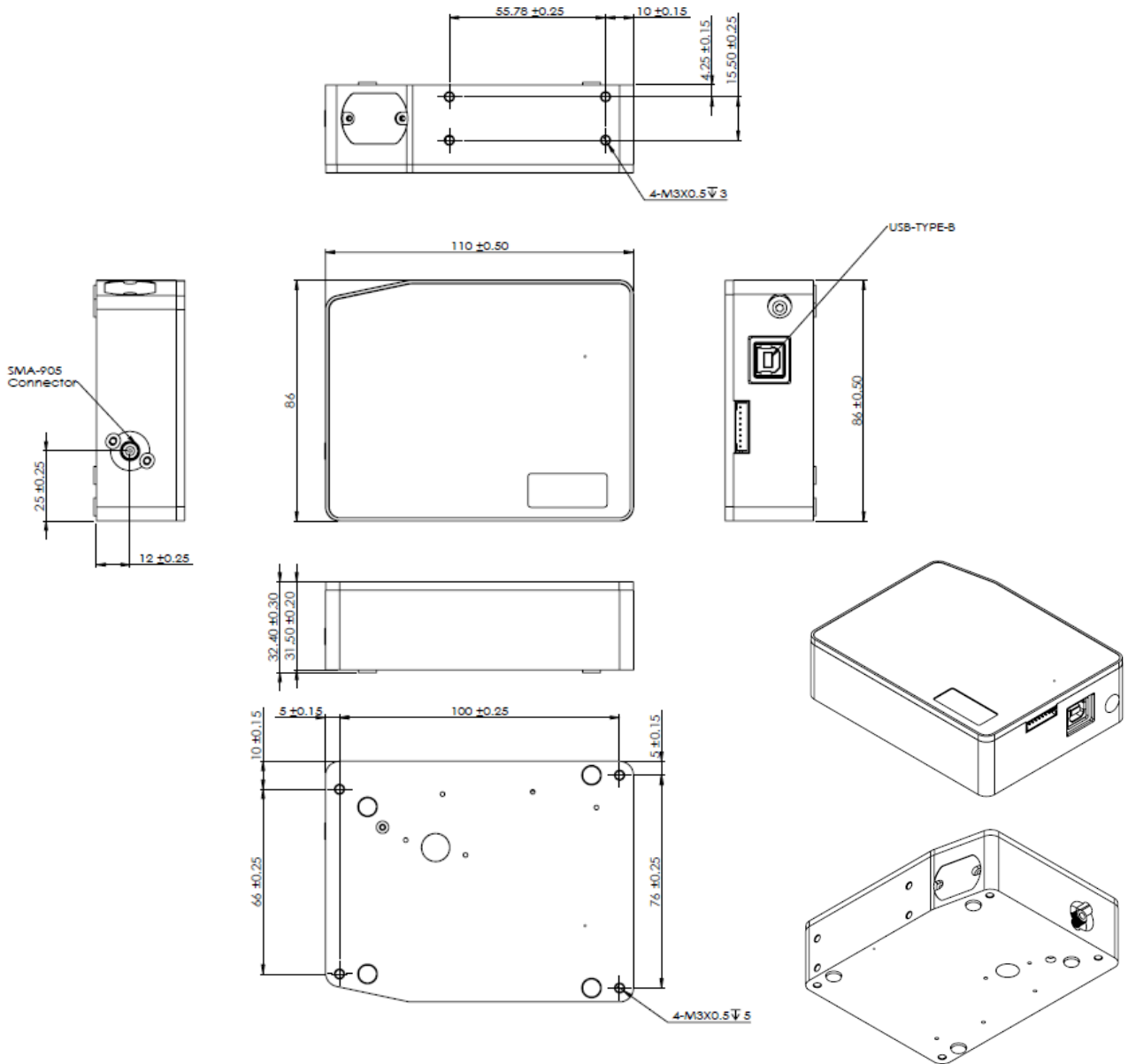
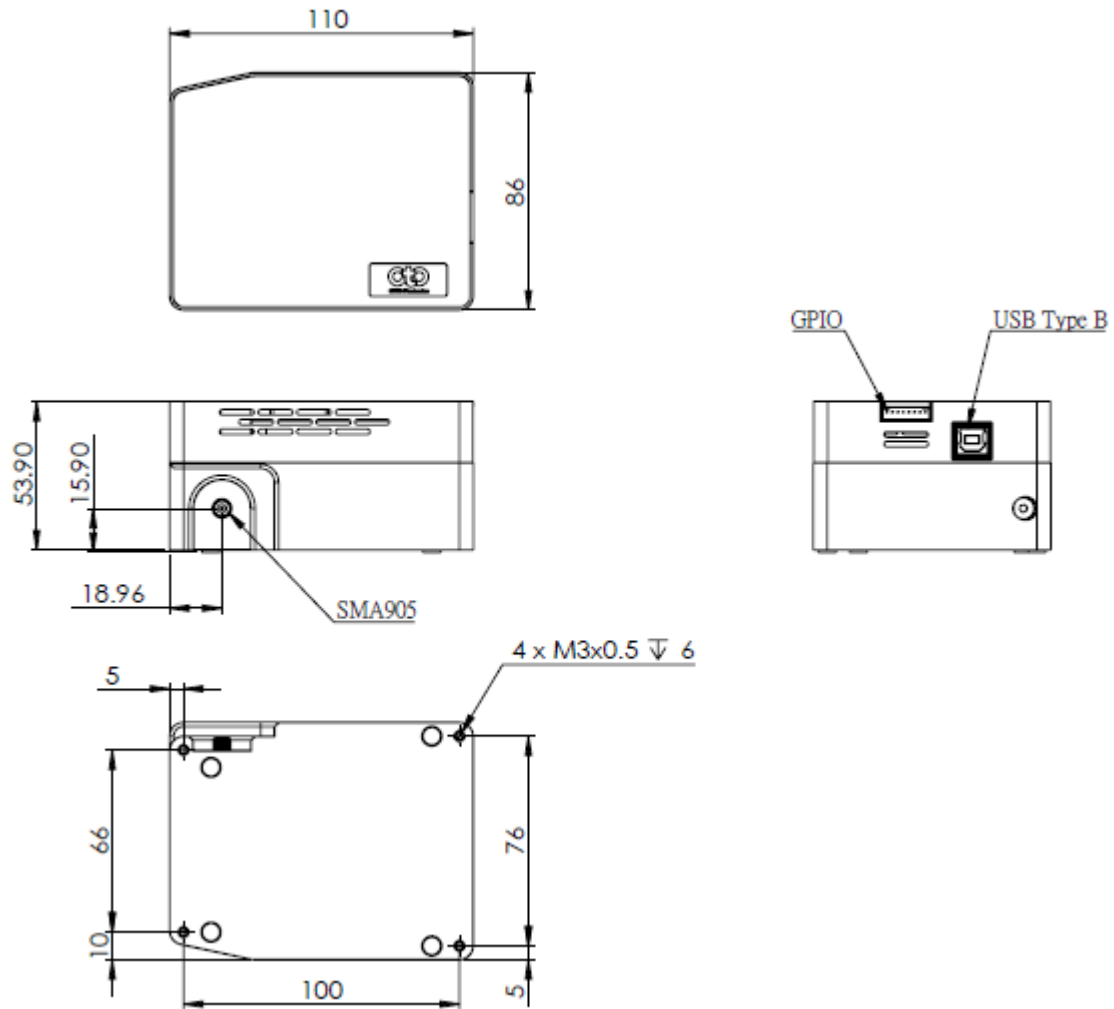


Fig. 3: SE2052 outer dimensions (slit on the left side)

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**Fig. 4: SE Plus version outer dimensions
(only for SE2030P, SE2050P, SE2060P AND Wavelength
Range of FUV2, FUVN2, NIR1, NIR4)**

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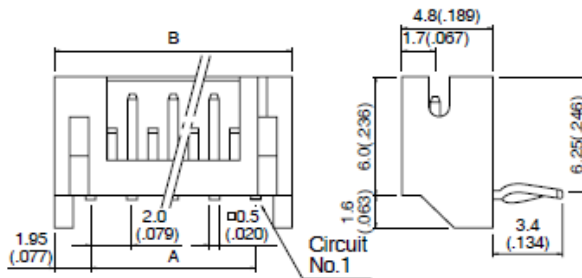
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► 3.2 Electrical Pinout

The following listed is the pin description for the SE Series Extension Connectors. The Back Extension Port is a 8 pin 2.0mm connector.

Side entry type



Cir- cuits	Model No.		Dimensions mm(in.)		Q'ty / box	
	Top entry type	Side entry type	A	B	Top entry type	Side entry type
8	B 8B-PH-K-S	S 8B-PH-K-S	14.0(.551)	17.9(.705)	500	250

Fig. 5 : Back Extension Port 2.0 mm 8 pin drawing

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Back Extension Port Pin# Description Alt Function

*All I/Os are TTL-Level input/output

Pin No.	Direction	Pin Name	Function Description
1	Power	5V Input/Output	When connecting to PC USB port, this pin is also connected to VBUS. This pin can provide around 0.1A power for external device.
2	Output	TX	UART TX. TX is the output from the RISC controller.
3	Input	RX	UART RX. RX is the input for the RISC controller.
4	Output	GPIO0	General Purpose Output 0.
5	Output	GPIO1	General Purpose Output 1.
6	Output	LS_ON	Light Source Turn ON.
7	Input	Trigger_IN	External Trigger Input Signal.
8	GND	GND	GND

● Pin orientation

Looking at Front of SE Series connector side, from left to right are Back Extension Port and PC USB.

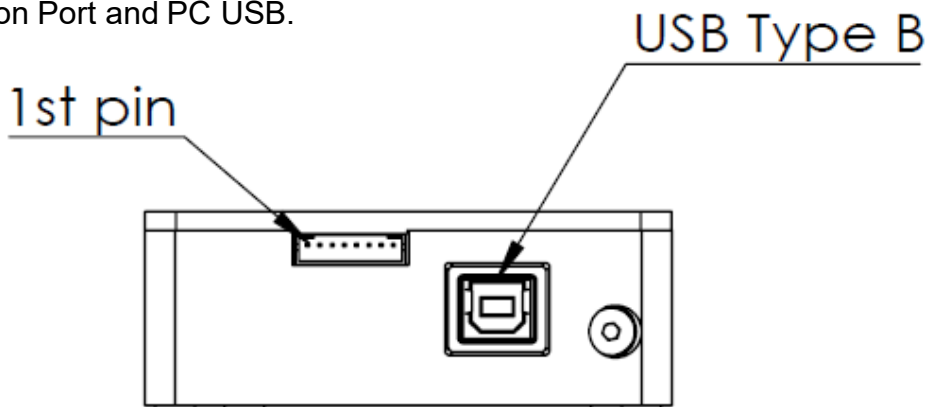


Fig. 6 : SE Series the front-view of connector mechanical graph

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► 3.3 CCD Overview

● CCD DETECTOR

ILX511B/ILX554B is a rectangular reduction type CCD linear image sensor designed for optical measuring equipment use. A built-in timing generator and clock-drivers ensure single 5V power supply for use.

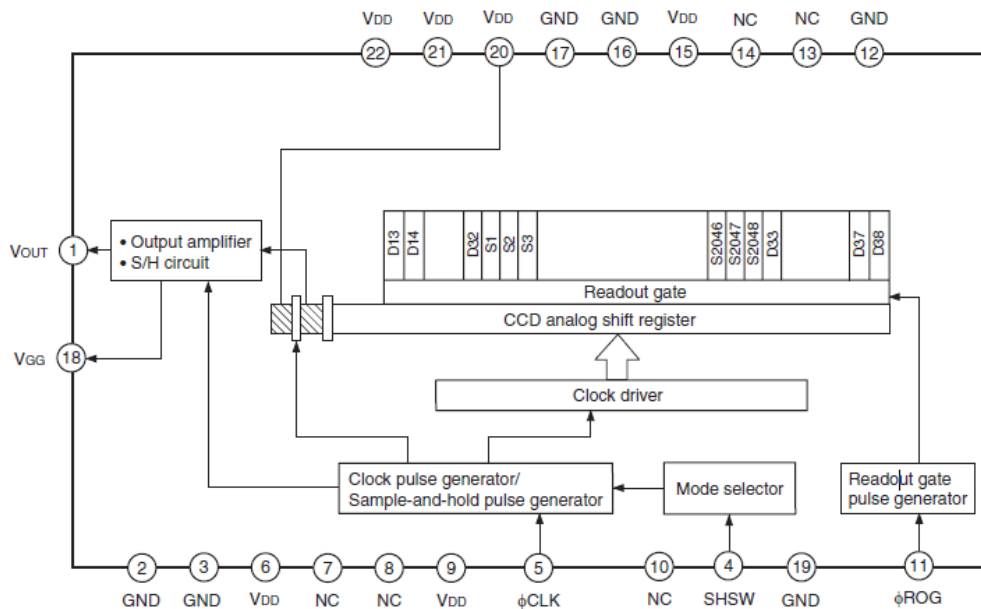


Fig. 7: ILX511B CCD Block Diagram

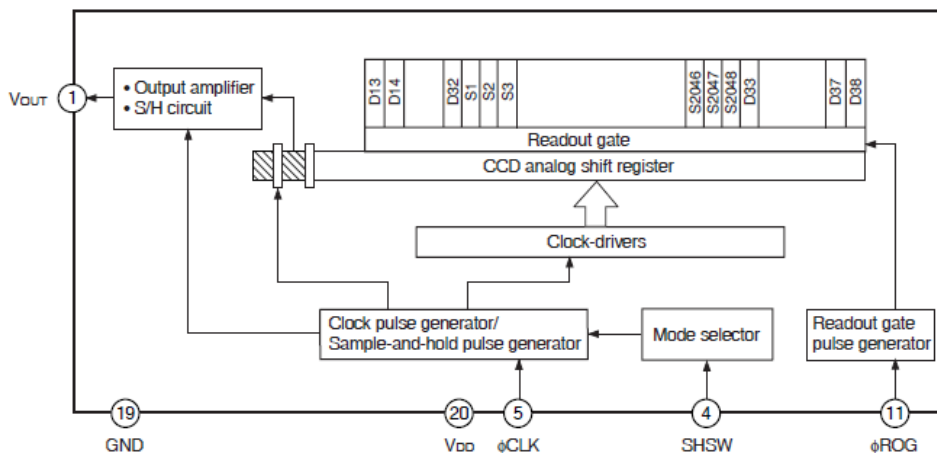


Fig. 8: ILX554B CCD Block Diagram

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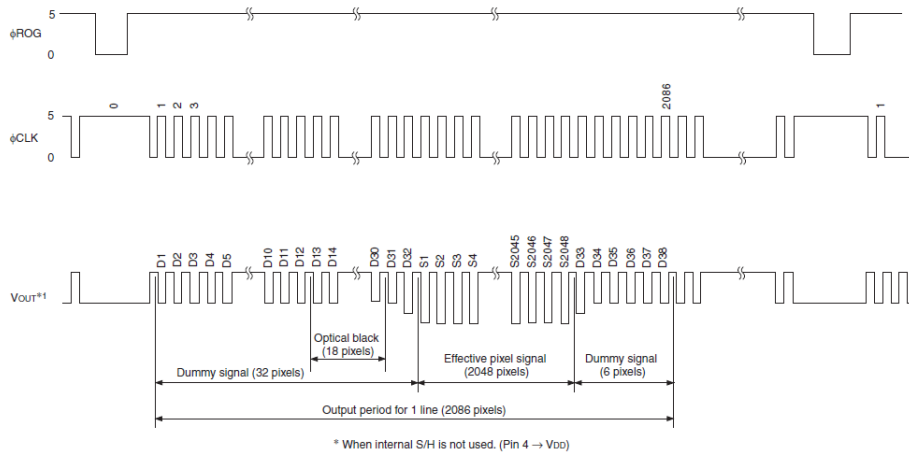


Fig.9: CCD SH operation timing waveform

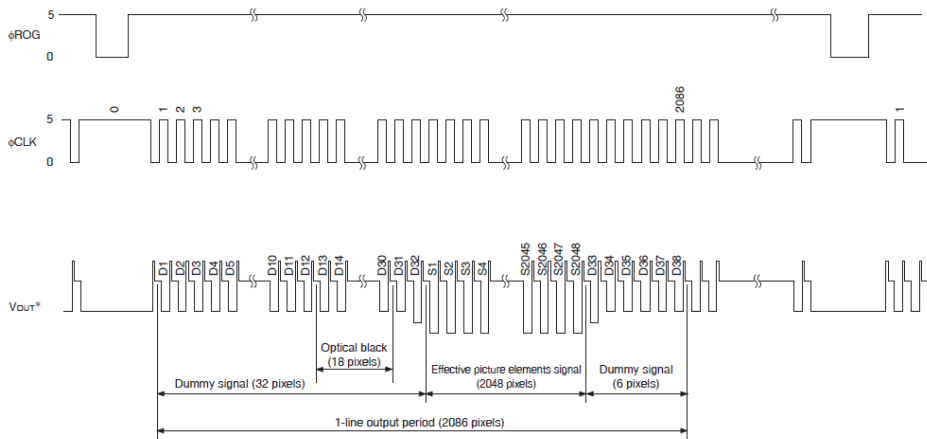


Fig.10: CCD CDS operation timing waveform

There are two operation modes in this Sony CCD. One is sample & hold mode, another is the CDS mode. The above timing chart is running without the sample/hold mode. There is one reset level during each clock cycle. SE Series is operated under this mode. The corresponding AFE (Analog Front End) device needs to be run at CDS mode. (Correlated Double Sample)

The CCD operation sequence is exposed-transferred-readout. We need to perform the integration time first, then, read the Vout in the next cycle. The operation is like pipeline. The Vout signal shows in the top waveform actually is the exposed result in the previous cycle. The output signal is almost proportion to the integration time. When the light power or integration time is long enough to fully charge the pixel, the CCD output will be saturated. Per the characteristic of this CCD sensor, like ILX554B CCD, the over-saturated condition will cause the signal to be reversed.

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● CCD/SYSTEM NOISE

There are three major sources impact the Vout signal reading. One is the light source stability, the second is the electronics noise, and the other is CCD detector noise. If we don't consider the outer light source influence, we can check the dark noise performance of this system first. The dark noise we define here is the RMS of Vout signal under 1ms integration time in dark condition. So the dark noise will be only contributed by electronics readout noise and the CCD sensor.

The other major parameter to define the noise performance is the SNR. The SNR we define here is the ratio of the full signal (65535 counts) to the RMS value under the full signal condition. The higher SNR performance indicates the readout signal is more stable. It will be helpful for the low signal differentiation.

● SIGNAL AVERAGING

The software-SpectraSmart provides two options for the signal curve operations. The first one is the signal averaging. By the averaging method, we can reduce the noise impact on each pixel. Surely, more sampling points will bring the better averaging performance. But it will need more time to get one spectra. When we use the time-base type of signal averaging, the S:N increases by the square root of the number of samples. Thus, a S:N is readily 10x achieved by averaging 100 spectra.

The other curve smoothing is boxcar filter. It can average the adjacent points to show the smoother curve, but it will lower optical resolution. So if the target signal is peak type, the boxcar may not be suitable for this.

These two methods can be enabled at the same time if the measurement target is suitable for this operation. But if the user would like to check all the original data and performance, time-based average or boxcar smoothing needs to be un-checked. The default setting for these two average methods is un-checked.

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■ Internal Operation

▶ 4.1 Pixel Definition

The baseline signal is around 1,000 counts in our current system. We can provide the tool/command to manually adjust the baseline. (adjust the AFE OFFSET) The other baseline adjustment method is to enable the background removal from the software. It depends on the user how to use the baseline. Normal output signal is not obtained immediately after device switch on. Use the output signal added 22500 pulses or above to CLK clock pulse.

- The following is a description of all of the pixels

Pixel	Description
1–12	Dummy pixels
13–30	Optical black pixels
31–32	Dummy pixels
33–2080	Optical active pixels
2081–2086	Dummy pixels

▶ 4.2 Digital Inputs & Outputs

- General Purpose Inputs/Outputs (GPIO)

SE Series has 6 user programmable 3.3V digital Input/Output pins, which can be accessed at the 8-pin Extension connector. Through software, the state of these I/O pins can be defined and used for multi-purpose applications. If the user needs the special timing generation (like single pulse or PWM), SE Series provides the flexibility to implement this.

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GPIO Recommended Operating Levels:

$V_{IL}(\text{max}) = 0.8\text{V}$

$V_{IH}(\text{min}) = 2.0\text{V}$

GPIO Absolute Maximum/Minimum Ratings are as follows:

$V_{IN}(\text{min}) = -0.3\text{V}$

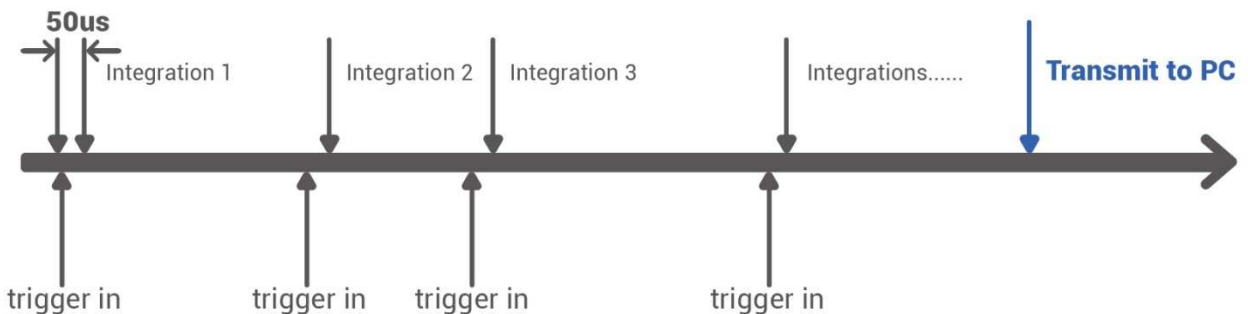
$V_{IN}(\text{max}) = 5.5\text{V}$

- **Communication and Interface**

USB 2.0

480-Mbit **U**niversal **S**erial **B**us is the standard and popular communication interface in PC. Our PC software allows connecting multiple SE Series via USB and monitors multiple SE Series spectra. The low power requirement allows operating the SE Series through the USB cable and VBUS.

- **Extremely Precise Continuous Multiple Exposures**



- ❑ Arbitrary integration times
- ❑ Spectra are stored in the huge memory on our board, providing up to 4000 spectra buffering
- ❑ After all integrations are done, the spectra are transmitted to your PC

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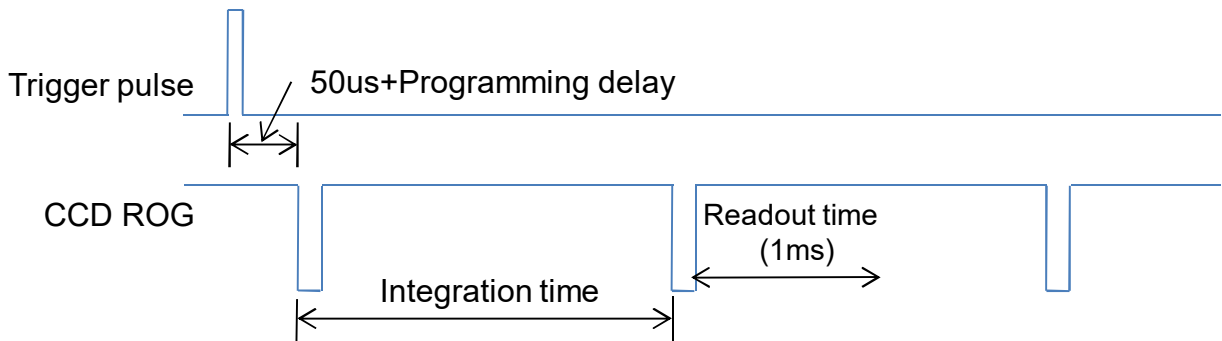
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▶ 4.3 Trigger Mode

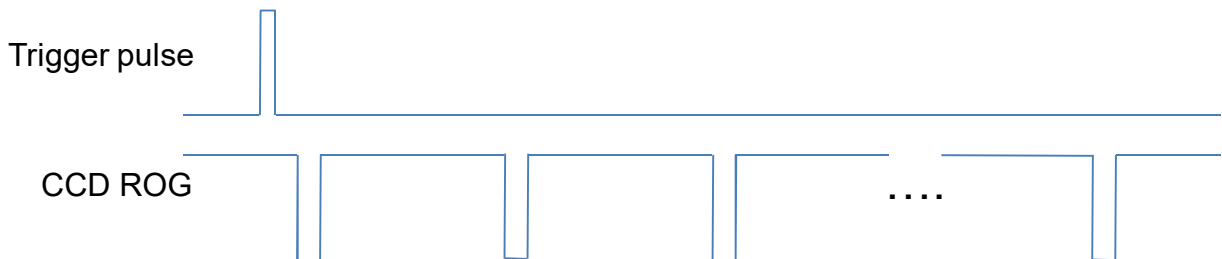
● Single Trigger Single Data

Single Trigger Single Data (integration time has been set by the command first). Spectrometer waits for single pulse to acquire one spectrum. The trigger edge can be set by rising edge or falling edge.



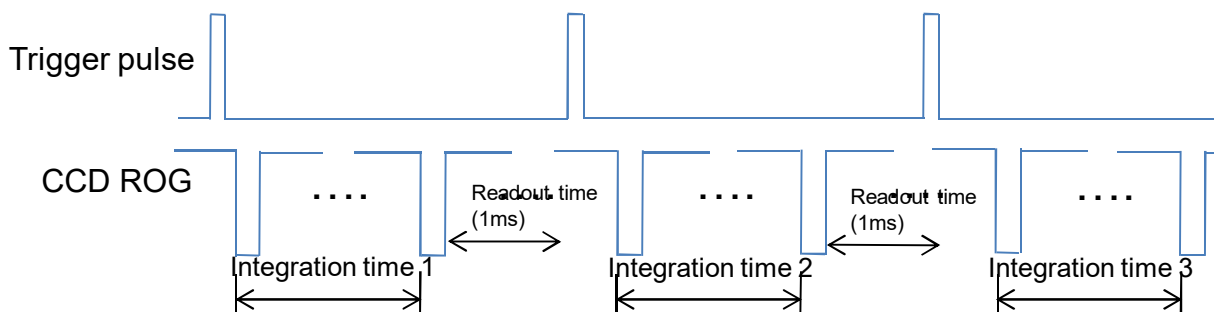
● Single Trigger Multiple Data

Single Trigger Multiple Data (integration time and frame number has been set by the command first). Based on single trigger pulse, the system will continue to capture the spectrums. The data is continuous.



● Multiple Trigger Multiple Data

Multi Trigger Multi Data (different integration times have been set by the command first). Based on pre-setting different integration times, the spectrums will be captured for each trigger pulse.



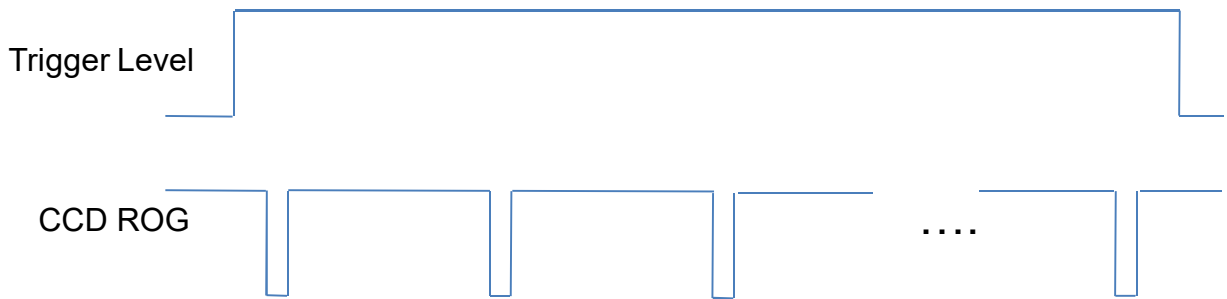
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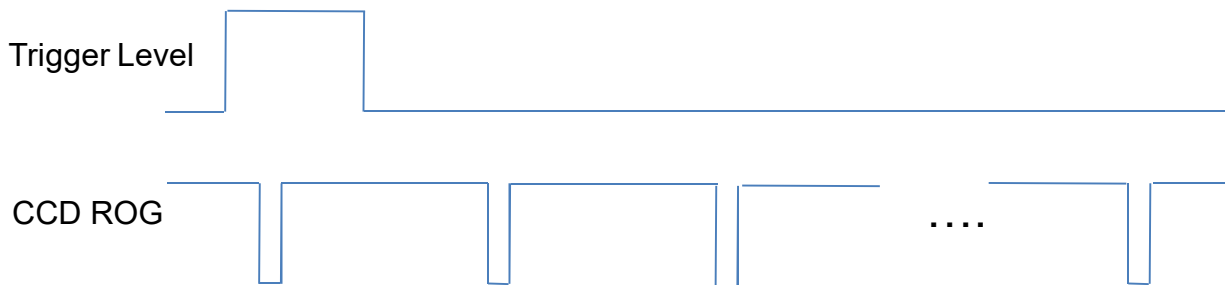
- **Software Level Trigger**

Software Level Trigger (integration time has been set by the command first, spectrometer waits for external trigger signal). When the trigger signal is high, software will continue to capture the spectrums.



- **Software Level Trigger continuous data**

Software Level Trigger continuous data(integration time has been set by the command first, spectrometer acquires data by command). When the trigger signal is high, software will continue to capture the spectrums even the trigger level is changed to low later.



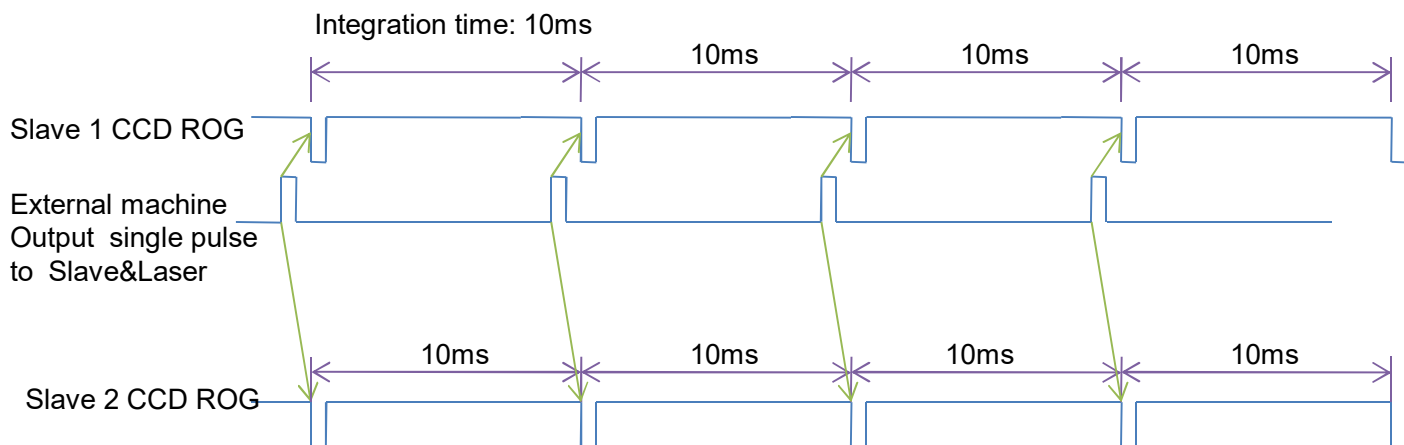
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- **External Trigger control integration time**

In multiple external trigger modes, SE series can support the integration time is controlled by the external trigger signal. Customer can request this kind of trigger mode when placing an order (currently support in SE1020/2020). If customer uses this kind of the spectrometer, the user can configure the SE spectrometer in this kind of operation mode through USB. Then send the external trigger pulse to the spectrometer. The time interval of two trigger pulses is equal to the integration time.



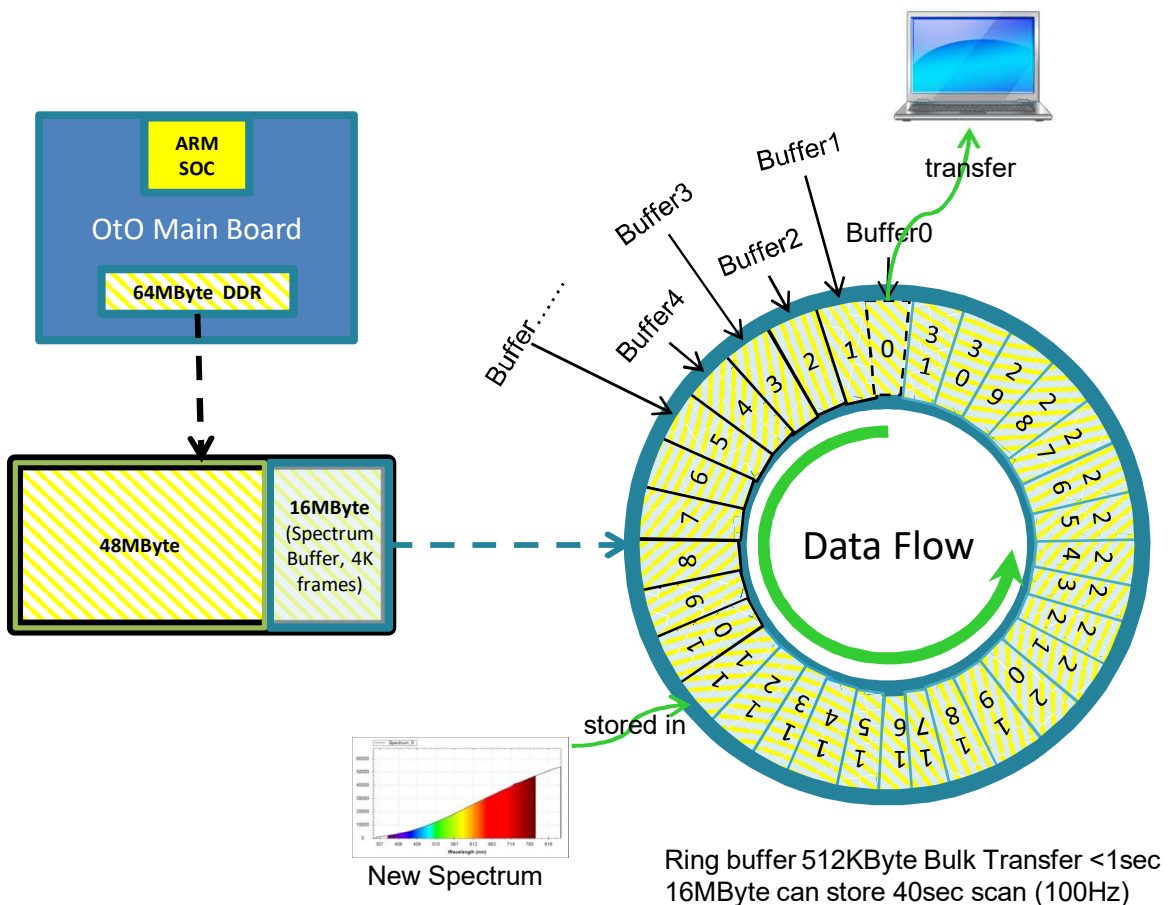
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► 4.4 Ring Buffer

SE series support the ring buffer function to record the continuous spectrum. Customer can request this kind of ring buffer function when placing an order (currently support in SE1020/2020). With this ring buffer function, user can record the continuous spectrum. For example, 10ms integration time, the PC host can receive 360K continuous spectrums in one hour. In this operation mode, the PC host can configure the length of each transfer to save the USB transfer efficiency. The ring buffer can provide the flexibility when the USB transfer is busy for a while. The fast integration time 1ms is supported in ring buffer function.



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■ USB Port Interface Communications and Control Information

▶ Overview

SE Series is a microcontroller-based Miniature Fiber Optic Spectrometer that can communicate via the Universal Serial Bus. This section contains the necessary programming information for controlling SE Series via the USB interface. This information is only pertinent to users who wish to not utilize SpectraSmart software to interface to SE Series.

● Hardware Description

SE Series utilizes a 32 bit RISC controller built in USB 2.0. Program code and data coefficients are stored in SPI Flash. The RISC controller supports 32 MByte DDR and 64 Mbits Flash.

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- **USB Info**

SE Series USB Vendor ID number is 0x0638 and the Product ID is 0x0AAC. SE Series is USB 2.0 compliance. The data exchange between host and spectrometer is via bulk streams. The detail USB information please refer USBIF @ <http://www.usb.org>.

- **INSTRUCTION SET**

Application Programming Interface

The list of the APIs is shown in the following table followed by a detailed description of each function call.

- **Open SE Series Spectrometer**

Description: To connect Windows host to SE Series

a.Function Name: UAI_SpectrometerOpen

b.Arguments:

dev: 8 SE Series spectrometers can be attached to one host at the same time. dev is the device number to specify which one will be opened.

handle: the unique Windows identifier to operate devices. Windows will return the identification number which is necessary for further operation.

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□ Query Frame Size

Description: To get the data frame size of the spectrometer.

a.Function Name: UAI_SpectromoduleGetFrameSize

b.Arguments:

device_handle: a pointer to the device information structure which is returned when device open.

size: a 16-bit unsigned integer will be returned to indicate the data length.

□ Acquire Wavelength

Description: Initiates a wavelength acquisition. SE Series will acquire a complete wavelength distribution.

a.Function Name: UAI_SpectrometerWavelengthAcquire

b.Arguments:

device_handle: a pointer to the device information structure which is returned when device open.

buffer: the storage buffer acquired data.

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□ Acquire Spectra

Description: Initiates a spectra acquisition. SE Series will acquire a complete intensity distribution which corresponds to the wavelength which is acquired by `OtO_UAI_SpectrometerWavelengthAcquire`.

a. **Function Name:** `UAI_SpectrometerDataAcquire`

b. **Arguments:**

device_handle: a pointer to the device information structure which is returned when device open.

integration_time_us: a 32-bit unsigned variable to determine the integration time of the micro-seconds.

buffer: the storage buffer acquired data.

average: the spectrum could be averaged by several continuous acquisitions to reduce the noise.

□ Query Wavelength Range

Description: To get the minimum and maximum wavelength

a. **Function Name:** `UAI_SpectromoduleGetWavelengthStart`

Function Name: `UAI_SpectromoduleGetWavelengthEnd`

b. **Arguments:**

device_handle: a pointer to the device information structure which is returned when device open.

lambda: a 32-bit floating type data which is indicate the minimum or maximum wavelength, in nm, of SE Series will be returned.

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□ Query Integration Time Range

Description: To get the minimum and maximum integration time.

a.Function Name: UAI_SpectromoduleGetMinimumIntegrationTime

Function Name: UAI_SpectromoduleGetMaximumIntegrationTime

b. Arguments:

device_handle: a pointer to the device information structure which is returned when device open

Integration Time: a 16-bit integer type data which indicates the minimum or maximum integration time of SE Series will be returned. The minimum integration time is in micro-second and the maximum integration time is in milli-second.

□ Close SE Series Spectrometer

Description: To connect Windows host to SE Series

a.Function Name: UAI_SpectrometerClose

b.Arguments:

handle: the unique Windows identifier to operate devices. Windows will detach the device and any operation is invalid after this function is executed.

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