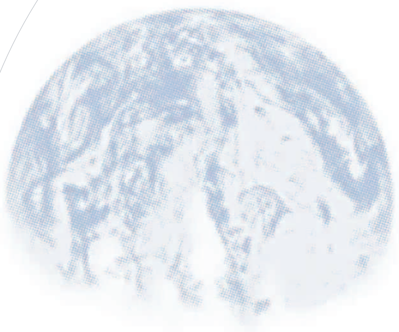
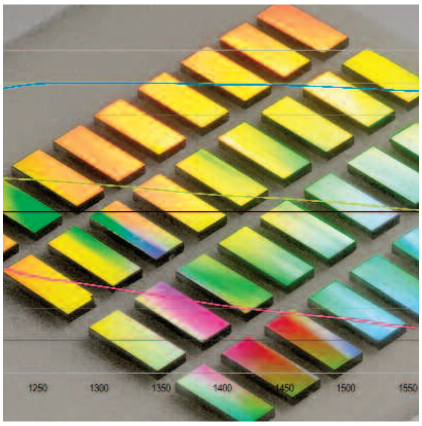


OEM Division

general spectrometer information

for OEM applications

Gratings and



HORIBA JOBIN YVON

Commitment to quality

HORIBA Jobin Yvon offers complete customer service, including expert technical advice for optimizing system configurations to meet customers’ needs.

HORIBA Jobin Yvon is ISO 9001:2000 certified, and our well-staffed departments are committed to customer satisfaction and product quality.

Introduction

As a pioneer and world leader in the field of diffraction gratings, HORIBA Jobin Yvon continues to develop advanced manufacturing processes for industrial and scientific applications.

Founded in 1819, HORIBA Jobin Yvon has defined the leading edge of optics for spectroscopy for over 180 years. Our leadership in optics has been demonstrated by the continuing development of both ruled and holographic grating technology, including the invention of aberration-corrected holographic gratings and ion-etched blazed holographic gratings.

HORIBA Jobin Yvon is a specialist in spectrometers, illumination systems and detectors. Our daily business is the development of spectrometer systems for industrial applications.

Our high volume replicated gratings and optical modules are used in many instruments such as spectrophotometers, bioanalysers, colorimeters, etc.

HORIBA Jobin Yvon's gratings for scientific applications can be found in our scientific diffraction grating catalog.

Contact your HJY representative for assistance with choosing the right grating for your application.

Visit our website: www.jobinyvon.com

Spectrometers for OEM applications

The market growth of miniature and compact spectrometers has been a significant development in recent years, and more particularly in OEM applications.

Miniaturization, robustness, cost reductions, and improvements in the performance of array detectors have allowed the use of these sensors in many industrial applications.

These spectrometers that operate from the UV to the near infrared range of the spectrum are used in many applications such as:

- o Color measurement
- o Analytical chemistry
- o Biomedical
- o Fluorescence
- o Raman
- o Elemental analysis

With more than 20 years of OEM experience in the spectroscopy market, HORIBA Jobin Yvon has taken a strong position worldwide. Our spectrometers and diffraction gratings have been selected by OEM customers because they offer higher optical performance, such as superior signal to noise ratio, high throughput, aberration correction, and robust single optic design.

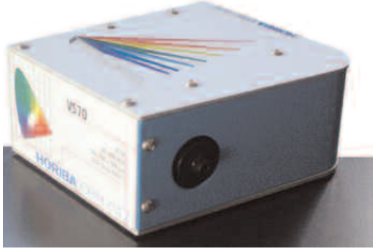
The first part of this document will help you to deal with important criteria for the choice of spectrometers. The second part introduces existing OEM proof of concept systems to help customers to validate specifications.

Then, we present a broad selection of modular components, such as miniature and compact spectrographs, detectors, electronic drivers, light sources, etc..

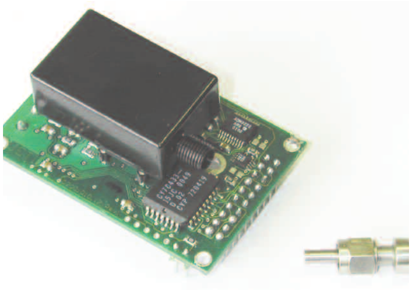
These components can be used for prototype purposes and final products.

In the last section, we offer some basic definitions related to spectrometers.

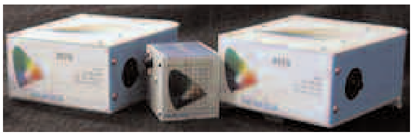
H10-34



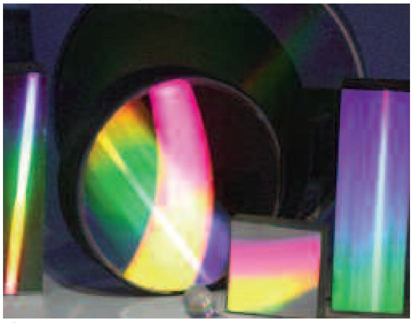
VS70



CP20



VS70 and spectro-cube

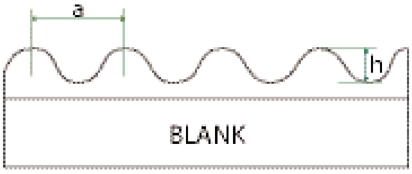


Concave gratings

Performance criteria for the choice of compact spectrometers

The performance of spectrometers is judged by three criteria:
○ System resolution
○ Throughput
○ System limit of detection

These criteria are effected by the grating efficiency, system light collection capability, system stray light and design aberrations. Each of these design criteria is described hereafter.

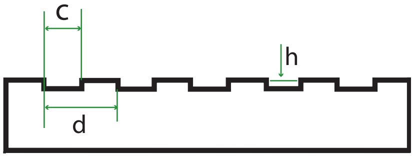


a = groove spacing
h = modulation depth

Figure 1: sinusoidal groove profile

Grating efficiency:

Holographic gratings are available with three different groove profiles. Each of these profiles has different efficiency advantages. Figures 1, 2, and 3 show the sinusoidal, laminar and triangular groove profile, respectively.

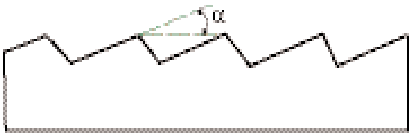


c/d = groove width to groove spacing ratio
h = groove depth

Figure 2: laminar groove profile

The maximum theoretical average efficiency (of unpolarized light) of the sinusoidal grating profile is around 35%.

Laminar and triangular groove profiles are produced with an ion etching process that shapes the groove profile.

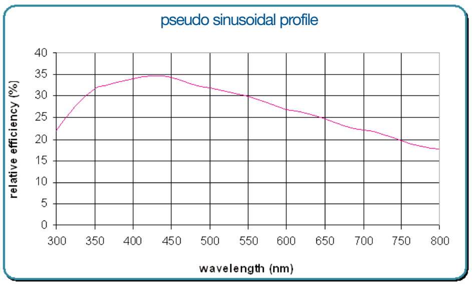


α = blaze angle

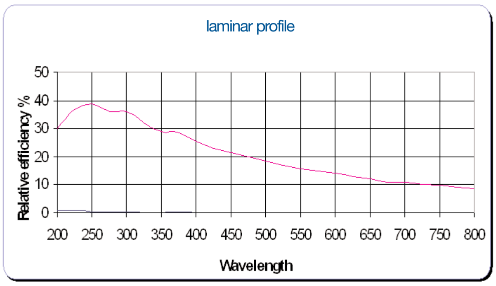
Figure 3: triangular groove profile

The laminar profile grating improves the efficiency, but the main advantage of this profile is the reduction in second order efficiency. The second order is reduced to as low as 0.4%.

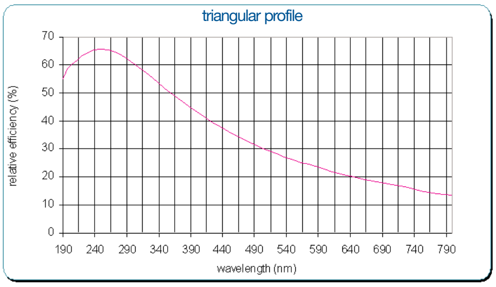
The triangular groove profile has efficiency profiles similar to ruled gratings. Peak efficiencies of 50% to 70% are possible.



Holographic sinusoidal efficiency



Holographic laminar efficiency



Holographic triangular efficiency

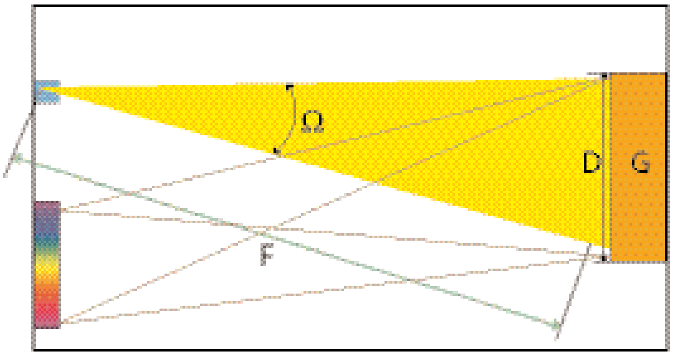
System light collection capability

Concave aberration corrected grating instruments are defined by the grating. Concave gratings are described by their arm lengths and included angle. The grating is the sole optical element in this design. The system light collection is determined by the f-number (f/#) of the grating. The f-number is the ratio of the grating focal length divided by the grating diameter (clear aperture). A lower f/# indicates a greater ability to gather light.

Aberration correction allows higher light collection compared with standard commercial spectrometer designs.

Concave grating spectrometer designs with f-numbers of f/2 and faster (toward f/1.5) are common. By comparison, most retail instruments from competition use plane grating designs and operate at f-numbers between f/3 and f/10.

Aberration correction allows a spectrometer to operate at low f-number because of the reduction in the effects of aberrations. Low f-number designs, possible with concave gratings, offer the advantage of increased light collection capability over plane grating designs. Light collection capability comparisons of instruments can be done by taking the ratio of the squares of the design f-numbers. To compare the collection ability of a f/5 plane grating design instrument and a f/2 concave grating design, calculate the ratio of 5^2 to 2^2, or 25 to 4.



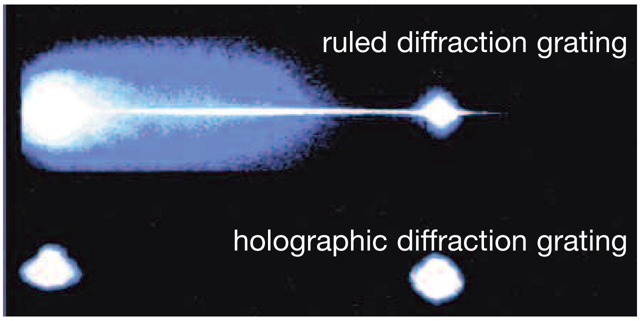
F: grating focal length - D: grating diameter

The light collection of f/2 concave grating design is more than six times greater than the equivalent f/5 design. The system collection efficiency is optimized with concave gratings while providing a simple, cost-effective design. Additional mirrors and mirror mounts are not necessary in these designs, making them more robust and intrinsically providing a better signal to noise ratio.

System stray light

The process of manufacturing holographic gratings has many advantages compared with ruled gratings for stray light rejection.

First, it provides a better periodicity of the grooves that can not be achieved with a ruled grating. Additionally, it makes the grating surface smoother than ruled gratings. Surface roughness is a significant source of grating generated stray light (see picture below). It is important to remember that everything scatters light.



All gratings exhibit some amount of scattered light. The inherently lower scatter of holographic gratings improves the system performance.

Concave grating designs have two additional design advantages, with respect to system stray light, over most commercial plane grating designs. First, grating scatter in Czerny Turner and Fastie Ebert designs is collected and focused, by the focusing mirror, toward the exit port. In concave grating designs the grating does not focus its own scattered light into the focal plane. Secondly, rediffracted light is minimized.

Rediffracted light is light that is diffracted by the grating and redirected back to the grating a second time (unintentionally of course).

When other concave optics (collimating and focusing mirrors) are used in an instrument design it is more likely that light may be rediffracted. Careful design effort is necessary to prevent rediffracted light.

Concave gratings are immune from this problem when working at f-numbers greater than f/2 with low groove density (< 600 gr/mm) gratings.

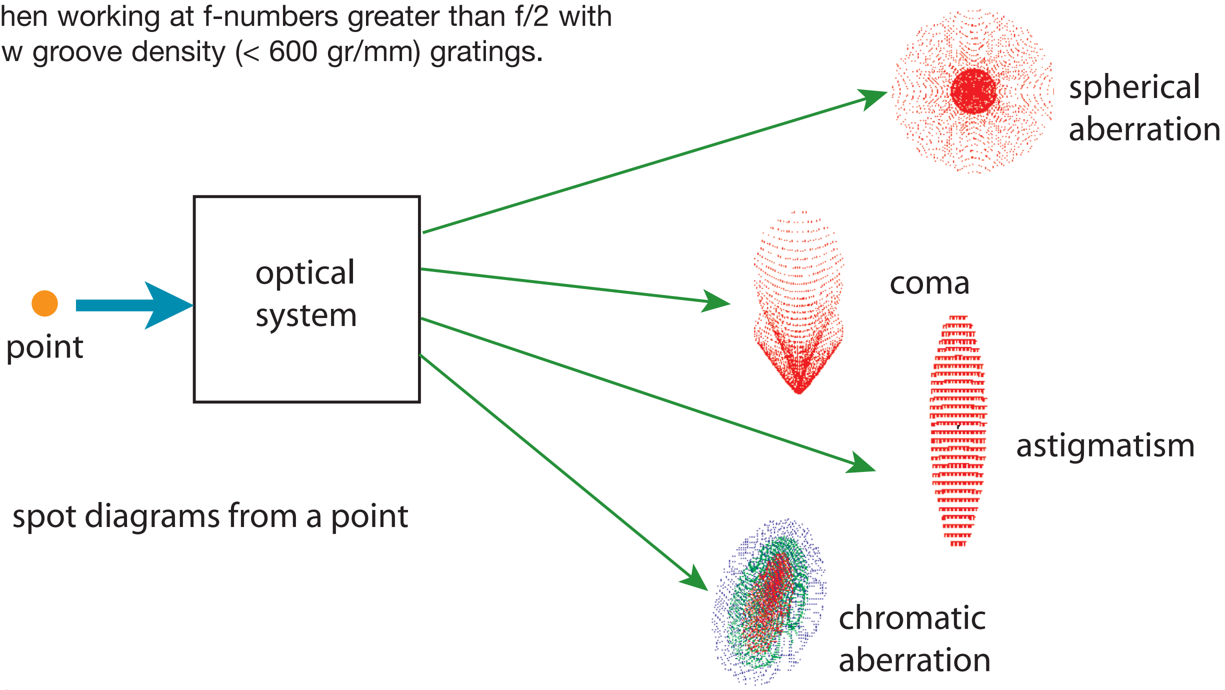
Aberration correction

Aberration correction is the most important benefit of concave aberration corrected holographic gratings.

To understand the benefit of aberration correction it is important to understand the main aberrations in spectrometer designs and their impact on system results.

Optical components can create errors in an image even if they are made of the best materials and have no defects. These aberrations can be grouped into several different categories: spherical aberration, coma, astigmatism, and field curvature.

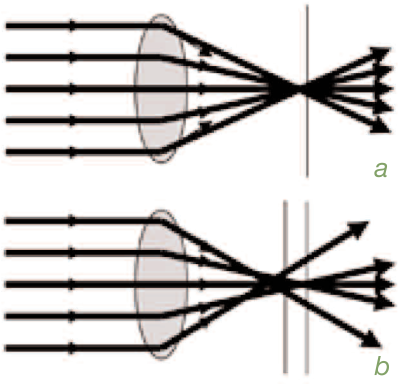
The effects of coma, spherical aberration, astigmatism and field curvature can cause degradation of the system's performance. Some description is necessary for how these aberrations relate to the exit focal plane of a spectrometer.



spot diagrams from a point

Spherical aberration (SA)

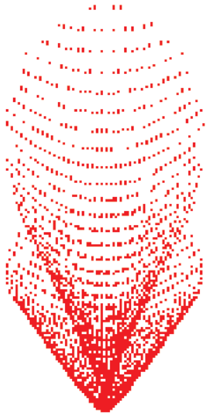
Spherical aberrations result from the fact that the focal points of light rays far from the optic axis of a spherical lens or mirror are different from the focal points of rays of the same wavelength passing near the center.



Optical system without (a) and with (b) spherical aberrations. Spherical aberration is caused by different focal points for rays far from the center and others closer to it (b).

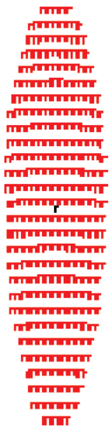
A spherical mirror does not precisely focus a point to a point. As light rays move further away from the center axis of a mirror, the focal point moves closer to the mirror. A zone of confusion is created in the image plane because of the changing focal point with distance from center axis. This "zone" of confusion prevents the ability to obtain a sharp focused image. SA is difficult to eliminate without the use of aspheric optics.

The result of SA is loss of resolution. Imaging performance degrades causing crosstalk from adjacent wavelengths. In aberration corrected designs the concave grating is designed to correct SA.



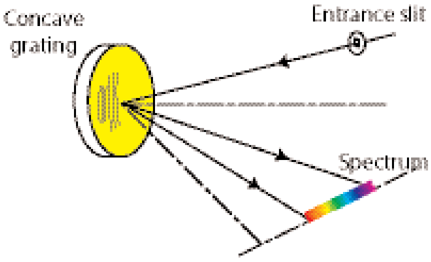
Coma is an aberration resulting from using off axis optics. Coma causes an unsymmetrical spectral line broadening. This broadening leads to resolution losses and stray light. On a detector array, the impact is pixel to pixel crosstalk and loss of resolution.
Coma can be corrected in some instruments, at one wavelength, by adjusting the optical geometry.

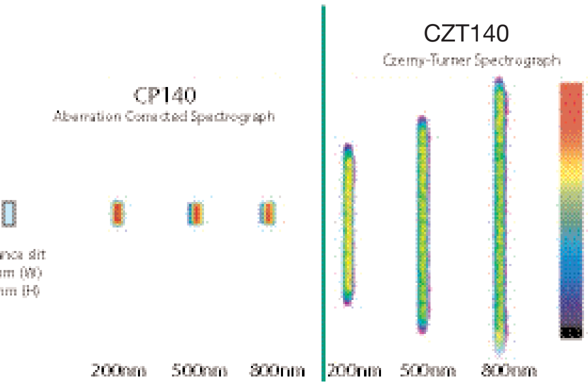
Coma can be corrected at many wavelengths in the concave aberration corrected grating design.

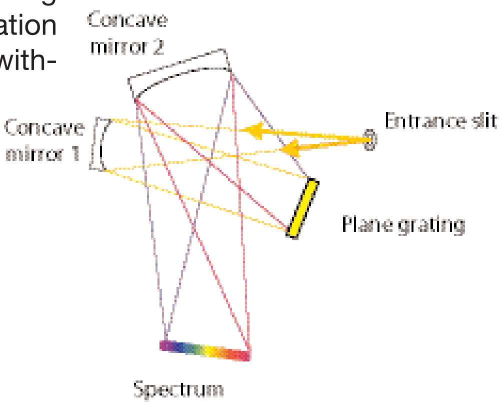


Astigmatism (AST) is another aberration resulting from the use of off axis optics. Point sources "grow" in height as the longitudinal astigmatism increases. Longitudinal astigmatism is the result of the tangential and sagittal components focusing in different planes. Astigmatism effects can lead to a 400 micron input fiber (at the input slit position) "growing" to 2 millimeters high at the output focal plane. When using a 0.5 millimeter high array, and the exit focal plane image is 2 millimeters, 75% of the output signal is not measured. This effect leads to loss of system throughput and the limit of detection.

To illustrate the possibilities of concave aberration corrected grating designs, the figure below shows the performance of a concave aberration corrected grating design compared with that of Czerny-Turner design without astigmatism correction.







Here, spot diagrams for an f/2 CP140 aberration corrected spectrograph are compared to those from an equivalent focal length Czerny-Turner spectrograph ("CZT140", f=140 mm) at f/4.

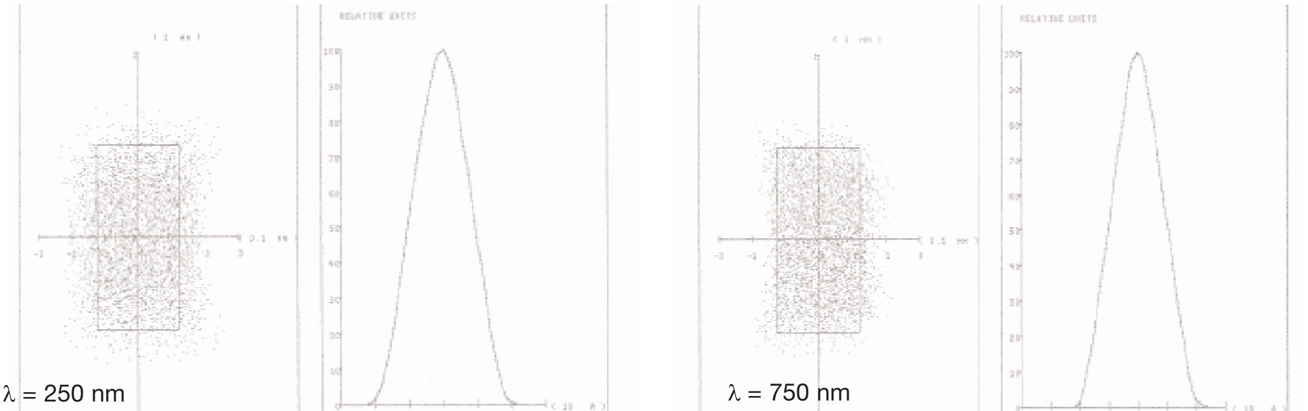
The input slit size in both instruments was set to 0.20 mm (W)x0.5 mm (H). The CP140 optimally images at all wavelengths, whereas the CZT140 produces a very tall image. As the wavelength increases, the degree of astigmatism in the Czerny-Turner design also increases, resulting in a decrease of flux density due to the increasing image height.

The fast f/2 CP140 has a much higher light gathering capacity compared to the CZT140 at f/4.

Thus the effective flux density of signal from the aberration corrected CP140 is almost 40 times higher than that from the equivalent Czerny-Turner instrument.

H1034 scanning spectrometer spot diagrams

SPOT DIAGRAM INSTRUMENTAL PROFILE SPOT DIAGRAM INSTRUMENTAL PROFILE



λ = 250 nm
bandpass (FWHM) = 2 nm
*TH = 93.1 P.C.
dispersion = 6.2 nm/mm

λ = 750 nm
bandpass (FWHM) = 2 nm
TH = 95.5 P.C.
dispersion = 7.2 nm/mm

This figure shows spot diagrams of the H1034, 100 millimeter focal length, scanning spectrometer. This instrument uses a 1200 grooves per millimeter concave aberration corrected f/3 grating. The 250 nanometer to 750 nanometer wavelength range is very well corrected for coma, SA, AST and field curvature.

*TH : rate of the useful ligth limited by the height of the exit slit (or pixel).

Field curvature (FC) is the shape of the image plane (usually called the Petzval Field). The shape of the field determines the shape of images at the exit. Field curvature can cause calibration errors for off-axis sources and pixel to pixel crosstalk on arrays. Calibration errors and increased blur of off-axis inputs are considered stray light. Aberration corrected gratings can change the shape of the exit focal plane field. Aberration corrected gratings are often called “flat field” gratings. This feature prevents image degradation for off axis images. Designs without this correction often suffer from spatial and spectral resolution losses for off axis inputs.

Aberration conclusion review

Coma, SA, and FC contribute to near end stray light (light from adjacent wavelengths). Light that does not properly strike the detector decreases the system performance.

The signal to noise ratio suffers because of low throughput per pixel and increased pixel to pixel crosstalk.

Putting the advantages of efficiency, system light collection capability, system stray light advantages and aberration correction together provides a clear view of the advantages of the holographic concave aberration corrected grating designs. The performance advantages of aberration corrected concave gratings, together with the simple, compact and robust design optimize system performance

Technology pushing instrument design

In the past three decades detector technology has progressed from film to phototubes to photodiode arrays to charge coupled devices (CCDs). The use of small diameter optical fibers (with high numerical apertures) coupled with new detector technology has made improving imaging performance of existing instruments much more important.

Good off axis performance has become necessary as applications using fiber arrays and tall CCD arrays are used together in applications. It is in this area that aberration corrected holographic grating designs have made the biggest impact. Aberrations such as coma, spherical aberration, astigmatism and field curvature make point to point imaging a difficult challenge.
Commercially available instruments are designed as all-purpose instruments. They must adapt to applications that work well in the UV through the far infrared in scanning and image modes. For dedicated industrial applications, a more specific design can lead to an instrument that outperforms the all-purpose, one size fits all, instrument design.

For those users with dedicated, repetitive applications (as with most OEM grating customers), spectrometers with concave gratings are the obvious choice. Another advantage of aberration correction gratings well worth mentioning is the ability to correct for aberrations in other parts of the optical system.

Other system aberrations (e.g., aberrations from lenses, mirrors or sample-related problems) can be corrected with an appropriate grating design. The concave aberration corrected grating design can incorporate the required corrections for system coma, spherical aberration, astigmatism and field curvature.
This system design approach can improve resolution and spatial imaging. Design success will often depend on achieving the optimal coupling of all system components.

Aberration corrected holographic grating designs are used in many industrial systems to optimize throughput while reducing noise.

State of the art OEM solutions

Existing proof of concept systems

Modular spectroscopy components

Existing proof of concept systems

This new line of modules is an example of how HORIBA Jobin Yvon can supply spectroscopy solutions which are suitable for a wide range of applications.

These modules are exclusively available to help OEM customers quickly define important performance parameters, after which a fully customized spectroscopy solution can be achieved. They have been specially developed with the main goal of significantly reducing OEM's development time.

OEM customers can take advantage of our spectroscopic experience and become our next industrial partner for their next project.

These rugged and compact modules, designed around a family of aberration corrected holographic concave gratings which maximize optical performance and minimize the stray light, feature a high efficiency level, the largest aperture in their class, and a large choice of spectral ranges.
Available with a choice of linear array detectors, these modules can be equipped either with linear CCD detectors for high sensitivity or with a photodiode array, ensuring a wide dynamic range and a high signal to noise ratio when coupled with a 16 bit A/D converter. These fully packaged systems are built around the modular components described in the next section.

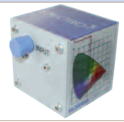
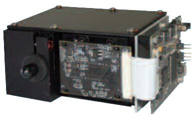
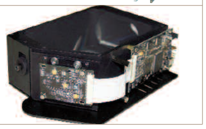
The following table outlines the proof of concept systems and their constituent spectrographs:

Applications

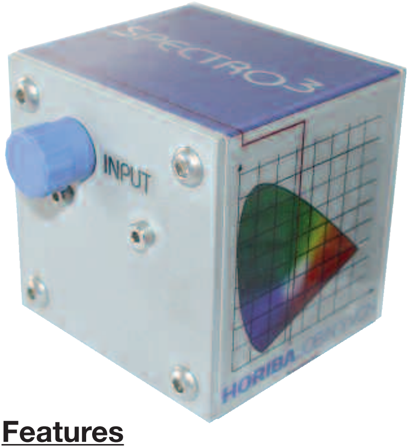
- Colorimetry
- Life science
- Analytical chemistry
- Process monitoring
- and many others

Three modules are currently available:

- Spectro-cube
- VS70-M
- VS140-M

Proof of concept systems		See page	Constituent Spectrographs	See page	
SPECTRO-CUBE		14	CP20 (Miniature spectrograph)	20	
VS70-M		15	VS70 (Compact spectrograph)	22	
VS140-M		17	VS140 (Compact spectrograph)	22	

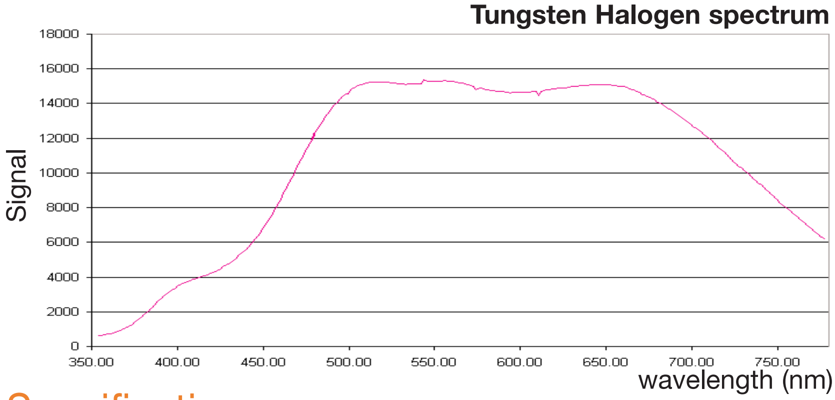
SPECTRO-CUBE



Designed around the miniature CP20 spectrograph, the spectro-cube is a plug & play module that can be customized for a variety of OEM applications such as color measurement, life science, process monitoring, etc.

The spectro-cube is available in 2 versions:

- spectro-cube-T
- spectro-cube-H


Tungsten Halogen spectrum

Features

- Compact, for hand-held instruments
- Low stray light
- Superb imaging properties
- Reliable
- Robust

Specifications

	SPECTRO-CUBE-T	SPECTRO-CUBE-H
optical		
optical bench design	CP20	
wavelegth range	350-900 nm	380-760 nm
aperture (f/#)	2.7	
average dispersion*	65 nm/mm	
stray light	< 0.1% at 415 nm with RG630	
entrance aperture	50, 100, 250 µm wide slits or fiber	
fiber optic connector	SMA 905	
wavelength accuracy	< 0.5 nm (with a mathematical fit)	< 0.5 nm (with a mathematical fit)
wavelength reproducibility	< 0.1 nm	< 0.1 nm
electronic		
detector	CMOS linear sensor array (TAOS)	CMOS linear PDA (HAM...)
number of pixels	128 pixels	128 or 256 pixels
pixel width	55.5 µm	25 or 50 µm
pixel height	63.5 µm	500 µm
signal to noise	300:1 (at full signal)	2500:1 (at full dynamic)
A/D resolution	14 bit	
computer interfaces	USB	
operating systems	Windows 98/ME/2000/XP	
physical		
dimensions (mm)	50x50x50 mm	
power supply	USB powered	

*For example : the optical resolution with a slit or fiber of 50 µm width is around 5 nm

VS70-M

The VS70-M is a plug and play evaluation module that is exclusively available to help OEM customers quickly define important performance parameters, after which a fully customized spectroscopy solution can be achieved.

Designed around the versatile VS70 spectrograph, this high performance module can be used for a variety of OEM applications:

- Colorimetry
- Analytical chemistry
- Life science
- Process monitoring
- and many others

The VS70-M is aligned, wavelength calibrated and tested at the factory in accordance with your requirements, ensuring consistently high performance.

Connect the VS70-M to your USB interface and take data immediately.

The VS70-M is currently available in two versions:

- **VS70-M-CCD**
- **VS70-M-PDA**

VS70-M-CCD

This version is suggested for applications when sensitivity is needed. It is based on a VS70 equipped with a linear CCD array.

VS70-M-PDA

For applications where high dynamic range is a premium, the VS70-M-PDA is preferable. It is based on a VS70 equipped with a linear PDA.

Features

- **Plug and play module**
  Just plug the USB connection to the 16 bit electronic driver and start your measurements
- **Integrated spectroscopy module**
  Ready for integration into OEM instruments
- **UV to NIR range**
  One grating to cover 190-1050 nm
- **High optical performance**
  High thoughput (f/2 optic)
  Resolution < 2 nm
  Stray light < 10^{-3}
- **High sensitivity and dynamic range**
  CCD and PDA detectors ensure high sensitivity and high dynamic range
- **Internally stored wavelength calibration coefficients**
  Calibration done at factory
- **Compact size**
  Easy to integrate in a variety of instruments
- **Flexibility and robustness**
  Safe and simple optical design; custom OEM design possible
- **SMA fiber optic interface**
  Standard SMA interface simplifies compatibility

Specifications

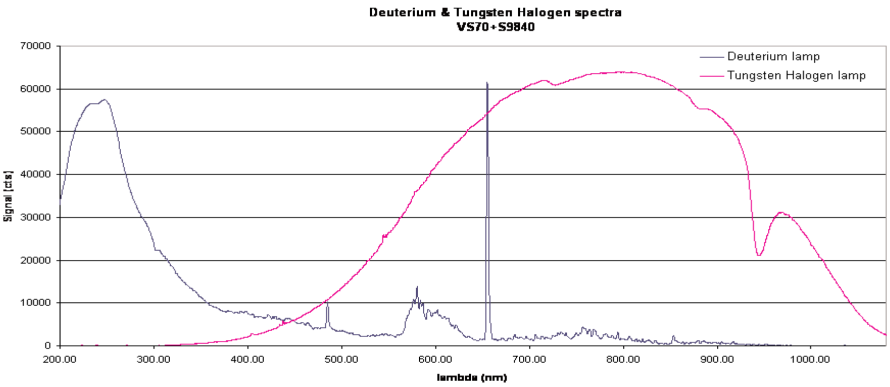
	VS70-M-CCD-BT	VS70-M-CCD	VS70-M-PDA/C	VS70-M-PDA/N
optical				
optical bench design	VS70			
wavelength ranges	from 190-1050**			
aperture (f/#)	2			
average dispersions*	17 nm/mm; 23 nm/mm; 33 nm/mm			
entrance aperture	50,100,250 µm wide slits or fiber			
fiber optic connector	SMA 905			
order sorting filter	yes			
wavelength accuracy	< 0.5 nm (with a mathematical fit)			
wavelength reproducibility	< 0.1 nm			
electronic				
detector	back thinned CCD array S9840 (Ham.)	linear CCD array TCD 1304 (Tosh.)	CMOS PDA S83xx (Ham.)	NMOS PDA S39xx (Ham.)
number of pixels	2048 pixels	3648 pixels	512 or 1024 pixels	
pixel width	14 µm	8 µm	25 or 50 µm	
pixel height	200 µm		500 or 2500 µm height	
signal to noise***	1000:1	300:1	3500:1	6000:1
A/D resolution	16 bit			
computer Interfaces	USB/RS232			
operating systems	Windows 98/ME/2000/XP			
physical				
dimensions	90x110x49 mm			
weight	500 g			

* depending on the grating. For example: with an average dispersion grating of 17 nm/mm, the optical resolution with a slit or fiber of 50 µm width is around 1 nm

** depending on the grating and on the position of the array

*** at full signal

This module comes with Windows-based software which includes basic functions like dark subtraction, reference, absorbance, etc. as well as an Excel link. In addition a set of DLLs or software development kit (SDK) is available to help customers develop their own application software.



These two spectra have been measured with different integration times

Software Features

- real time
  %T, AU, spectral -+/,log
- real-time data smoothing
- real-time data transfer to Excel
- automated acquisition with time
- stamped file names
- external triggering
- polynomial fit wavelength linearization
- user notes with automated acquisition parameters insertion

VS140-M

The VS140-M is a plug and play evaluation system that is available to help OEM customers during proof of concept phase, to define important performance parameters, after which a fully customized spectroscopy solution can be achieved.

Designed around the versatile VS140 spectrograph, this high performance module can be customized for a variety of OEM applications:

- o Colorimetry
- o Analytical chemistry
- o Life science
- o Process monitoring
- o and many others

The VS140-M is aligned, wavelength calibrated and tested at the factory in accordance with your requirements, ensuring consistently high performance.
Connect the VS140-M to your USB interface and take data immediately.

The VS140-M is currently available in three versions:

- o **VS140-M-CCD**
- o **VS140-M-PDA**
- o **VS140-M-INGAAS**

VS140-M-CCD
This version is suggested for applications where sensitivity is needed. It is based on a VS140 equipped with a linear CCD array.

VS140-M-PDA
For applications where high dynamic range is a premium, the VS140-M-PDA is preferable. It is based on a VS140 equipped with a linear PDA.

VS140-M-INGAAS
For applications in the NIR range, the VS140-M-INGAAS is obvious choice. It is based on a VS140 equipped with a InGaAs linear array detector.

Features

o **Plug and play module**
Just plug the USB connection to the 16 bit electronic driver and start your measurements

o **Integrated spectroscopy module**
Ready for integration into OEM instruments

o **UV to NIR range**
Large selection of gratings to cover from 190 to 2500 nm

o **High optical performance**
High thoughput (f/#2 optic)
Resolution ≤ 1 nm
Stray light < 10^{-3}

o **High sensitivity and dynamic range**
CCD and PDA detectors ensure high sensitivity and high dynamic range

o **Internally stored wavelength calibration coefficients**
Calibration done at factory

o **Compact size**
Easy to integrate in a variety of instruments

o **Flexibility and robustness**
Safe and simple optical design; Custom OEM design possible

o **SMA fiber optic interface**
Standard SMA interface simplifies compatibility

Specifications

	VS140-M-CCD-BT	VS140-M-PDA	VS140-M-PDA	VS140-M-INGAAS
optical				
optical bench design	VS140			
wavelength ranges	from 190-1050 nm**			from 800-1700 nm**
aperture (f/#)	2.4			
average dispersions	17 nm/mm; 24 nm/mm; 30 nm/mm			70 nm/mm
entrance aperture	25, 50, 100, 250 µm wide slits or fiber			
fiber optic connector	SMA 905			
order sorting filter	yes	yes	yes	no
wavelength accuracy	< 0.5 nm (with a mathematical fit)			
wavelength reproducibility	< 0.1 nm			
electronic				
detector	back thinned CCD array S9840	CMOS S83xx linear photodiode array	NMOS S39xx linear photodiode array	INGAAS linear photodiode array
number of pixels	14 lines of 2048 pixels	512 or 1024 pixels	512 or 1024 pixels	256 pixels
pixel width	14 µm	25 or 50 µm	25 or 50 µm	25 or 50 µm
pixel height	200 µm	500 or 2500 µm height	500 or 2500 µm height	500 or 2500 µm height
signal to noise***	1000:1	3500:1	6000:1	6000:1
A/D resolution	16 bit			
computer Interfaces	USB/RS232			
operating systems	Windows 98/ME/2000/XP			
physical				
dimensions	120x150x110 mm			
weight	900 g			

* depending on the grating. For example: with an average dispersion grating of 17 nm/mm, the optical resolution with a slit or fiber of 50 µm width is around 1 nm

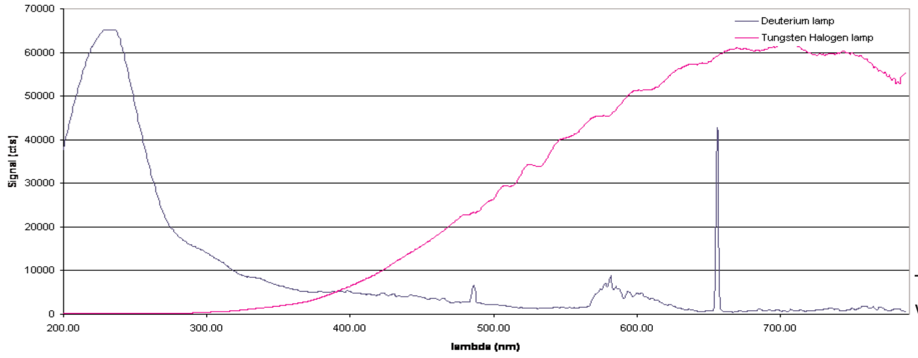
** depending on the grating and on the position of the array

*** at full signal

This module comes with Windows based software which includes basic functions like dark subtraction, reference, absorbance, etc. as well as an Excel link. In addition a set of DLLs drivers or a software development kit (SDK) is available to help customers develop their own application software.

Software Features

- real time
  %T, AU, spectral -+/,math log
- real-time data smoothing
- real-time data transfer to Excel
- automated acquisition with time
- stamped file names
- external triggering
- polynomial fit wavelength linearization
- user notes with automated acquisition parameters insertion



These two spectra have been measured with different integration times

Modular spectroscopy components

a starting point for rapid prototypes

HORIBA Jobin Yvon's miniature & compact spectrographs can be customized for most major spectroscopy applications of Original Equipment Manufacturers (OEMs).

Available from ultraviolet to infrared, these spectrographs are compact with focal lengths ranging from 20 mm to 140 mm.
These versatile spectrographs use aberration corrected high efficiency concave holographic gratings.

HORIBA Jobin Yvon manufactures a wide variety of high performance diffraction gratings for these spectrographs configured for spectral regions from 190 to 2500 nm.

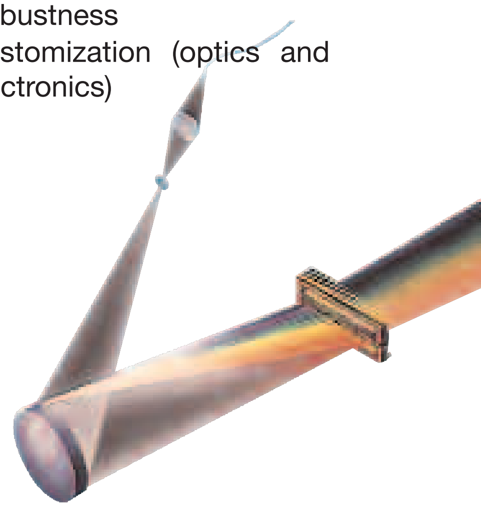
The optical spectrometer design consists of a fixed input slit with fiber adapter, an aberration corrected concave grating and a linear or 2-D array with electronics. The whole set is assembled into a rugged and compact housing.

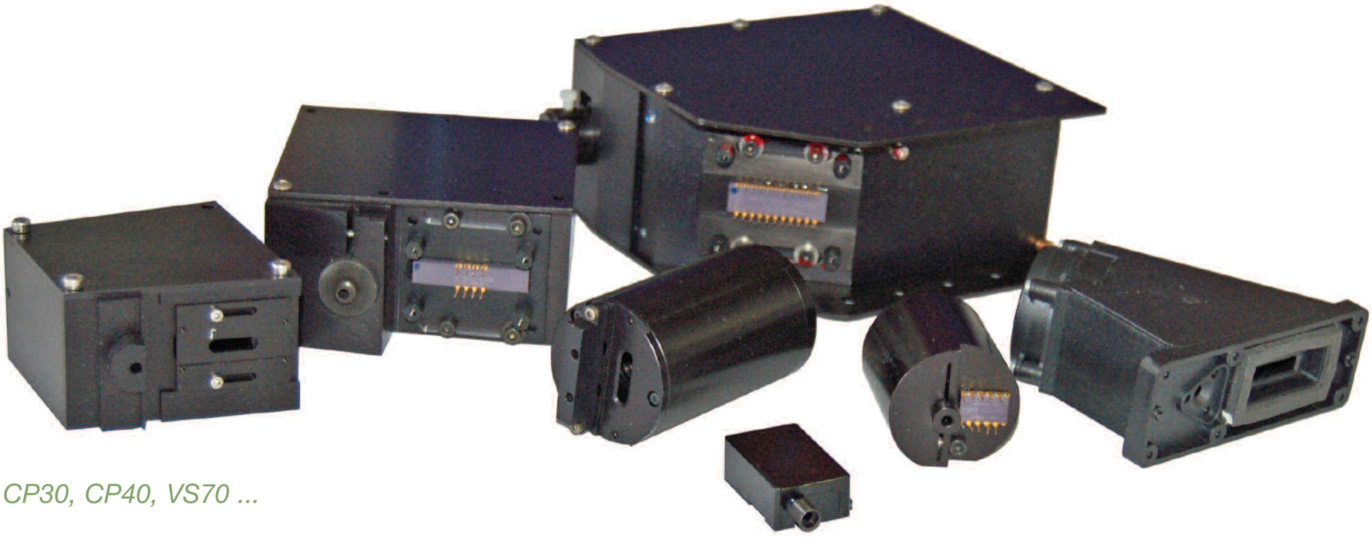
The design is optimized to produce well focused spectra over a long flat focal plane making it ideal for photodiode arrays, linear CCDs or 2 dimensional CCDs.

Applications include color monitoring, food inspection, petrochemical analysis, clinical chemistry, radiometry, chromatography detection, plasma monitoring, pollution detection, etc.

Benefits

- ○ Compactness
- ○ Versatility
- ○ Reliability
- ○ Performance
- ○ Robustness
- ○ Customization (optics and electronics)





CP20, CP30, CP40, VS70 ...

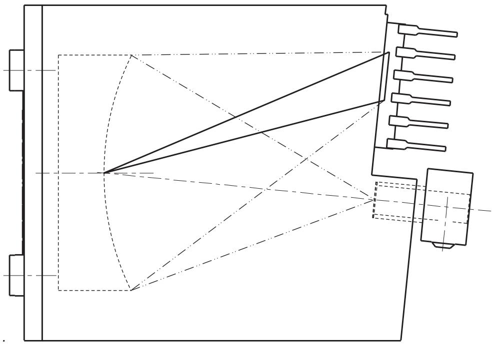
For evaluation purpose, plug & play demonstration systems including detectors, electronics and software are available (see section on proof of concept systems).

Miniature spectrographs - the CP family

The family of miniature spectrographs CPXX has been developed for OEM applications. Each fits into a small, hand-held, portable instrument, or can take the place of larger spectrographs when space is at a premium.

These spectrographs include an aberration corrected concave holographic grating, an optical slit, an SMA connector, a choice of linear arrays and a USB electronic driver as an option.

The optical input is based on an SMA connector with an integrated slit. Different models of slits are offered depending on the resolution requirement. The basic model is supplied with a slit of 100 µm width and 500 µm height.



Features

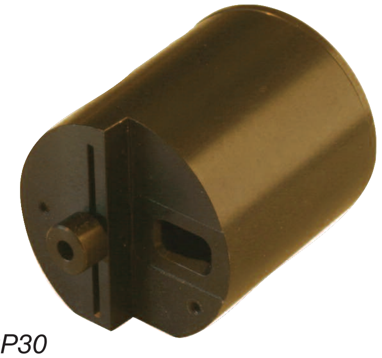
- Compact, for hand-held instruments
- Low stray light
- Superb imaging properties
- Reliable
- Robust

Applications

- Color measurement
- Spectrophotometry
- Process monitoring
- Life science
- Etc.

	CP20	CP30	CP40
optical design	flat field		
focal length (nm)	20	30	40
wavelength range (nm)	380-760		
average dispersions (nm/mm)	65	60	60
aperture (f/#)	2.7	1.5	1.5
entrance slit (µm)	50/100/250 wide slits or fiber		
fiber optic connector	SMA 905		
spectrum length (mm)	5.8	5.8	6.4
physical dimensions (mm)	22x35x14	37x51x35	55x59x52

CP20 with PDA detector



CP30

CP40

Slits and optional CMOS or NMOS detectors for the CP spectrograph family

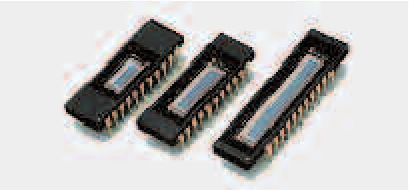
entrance slit

Entrance slits

Different models of slits are offered depending on the resolution required by the application. The standard slits come in widths from 50 to 500 µm.

Detectors

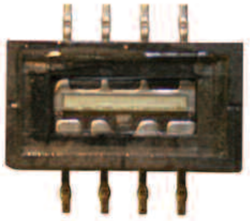
The design of these spectrographs allows the use of a large choice of linear arrays as well as custom arrays for specific applications. The standard models are:



CMOS and NMOS Photodiode arrays

CMOS or NMOS Photodiode arrays (PDAs)

- CMOS PDA
  S8377/ S8378-XXX
  128 or 256 pixels with 25 or 50 µm pixel width and 500 µm height
- NMOS PDA
  S3903/S3904 – XXX
  128 or 256 pixels with 25 or 50 µm pixel width and 500 or 2500 µm height



TAOS CMOS TSLW-1401R series

CMOS low cost linear sensor arrays

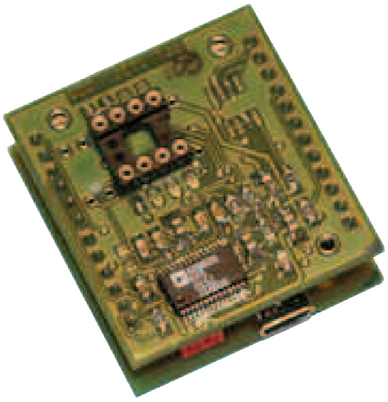
TSLW-1401R from TAOS

The TSL1401R linear sensor array consists of a 128 × 1 array of photodiodes. The pixels measure 63.5 µm (H) by 55.5 µm (W) with 63.5 µm center-to-center spacing and 8 µm spacing between pixels. Operation is simplified by internal control logic that requires only a serial-input (SI) signal and a clock.

Optional Electronics for CP Spectrographs

High performance and compact electronic boards are available and feature:

- 14 or 16 bit analog digital converter
- M16C624 controller with 256K internal flash
- trigger output
- a selection of interfaces: USB / Serial / Parallel..... (TTL level)
- power supply +5V (for RS232 interface)



USB SDC Board

Compact spectrographs - the VS family

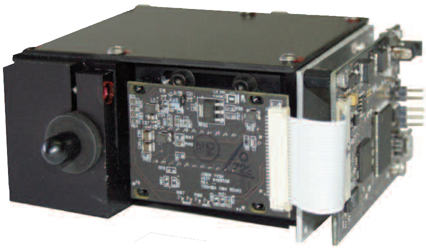
This new OEM spectrograph family consists of a compact Versatile Spectrograph coupled with a multi-channel array detector and integrated electronics.

These versatile spectrographs are configurable, high performance spectrographs that can be customized for a variety of OEM applications.

They have been specially designed to easily adapt to a large variety of detectors and electronic drivers.

The optical design has been optimized to minimize stray light and maximize optical throughput.

These spectrographs are based on a high performance aberration corrected concave grating fitted with a custom variable order-sorting filter to eliminate higher orders.



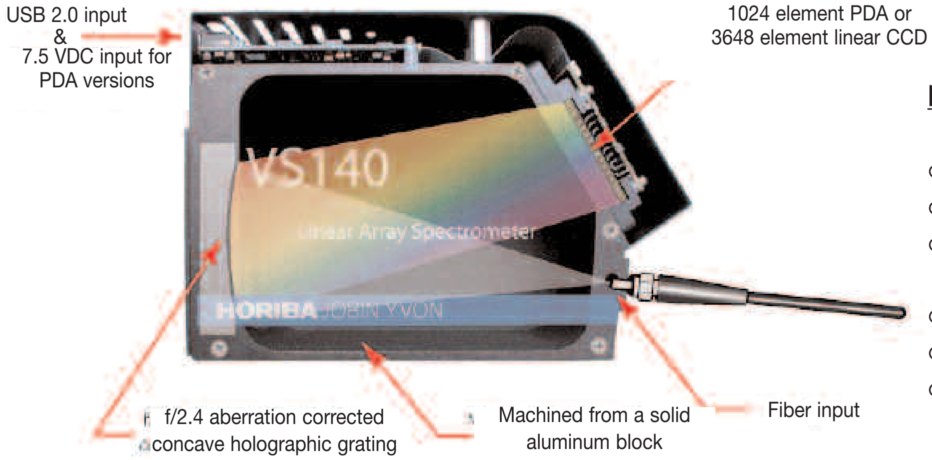
Compact spectrograph with integrated electronics

Applications

- Color measurement
- Spectrophotometry
- Process monitoring
- Life science
- Etc.

Features

- High optical performance
- Versatility
- Custom OEM design solutions
- Compact size
- Robust
- Stability



Specifications

	VS70	VS140
optical geometry	flat field	
focal length (mm)	70	140
spectral range (nm)	from 190 to 1050*	from 190 to 2500*
aperture (f/#)	2	2.4
average dispersions** (nm/mm)	17 - 23 - 33	17 - 24 - 30 - 70
stray light: (at 340 nm with deuterium lamp)	< 0.1%	< 0.1%
dispersion	grating dependent	
wavelength accuracy (with a mathematical fit) (nm)	< 0.5	
wavelength reproducibility (nm)	< 0.1	
physical dimensions (mm)	90x100x49	120x150x110

* depending on the grating and on the position and the type of the array detector used
** depending on the grating

Input:

VS entrance fiber SMA adapter and integrated slit.

The VS spectrographs can accept light directly through either a fixed slit or a through an SMA fiber connector including an integrated slit. Different slit sizes can be offered depending on the resolution required by the application and the type of the detector.

The standard slits come in widths from 50 to 500 µm

Output:

HJY Order sorting filters

In conjunction with our aberration corrected concave grating, we have developed integrated HORIBA Jobin Yvon order sorting filters.

This specialized order sorting filters permit the instrument to work from 200 to 900 nm and eliminates the issues related to higher orders without degrading the optical performance of the instrument.

Order sorting filters.

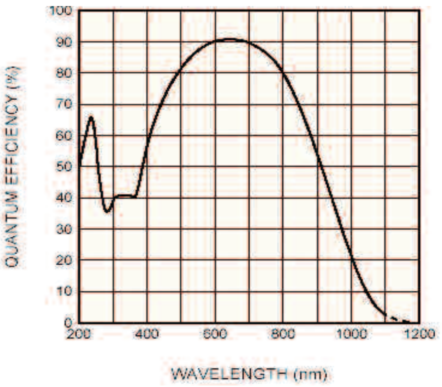
Detectors:

The VS spectrographs are designed for a selection of linear arrays, or for custom arrays for specific applications.

1. CCD image sensors

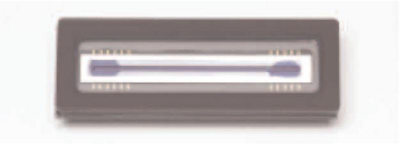
a. back-thinned CCD S9840

The S9840 is a back-thinned linear CCD. It features high quantum efficiency in the UV region, low readout noise, low dark signal and wide dynamic range.



*S9840 spectral response (without window)**

The array measures 28.672 (H) × 0.196 (W) mm and is comprised of 2048 x 14 pixels measuring 14 x 14 µm. Each 14 pixel column is binned to create an effective pixel size of 14 x 196 µm



Back thinned CCD image sensor S9840

**Courtesy of Hamamatsu*

b. Toshiba CCD TCD1304

The TCD1304DG is a high-sensitivity 3648 element linear image sensor.

It features 3648 pixels (8 microns wide and 200 microns high) and has an electronic shutter function.
A special UV coating process can be applied to the array in order to increase sensitivity below 350 nm.

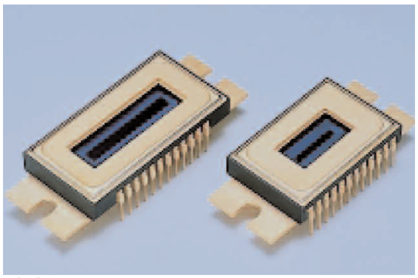
Toshiba detector

c. back-thinned CCD S7030/31

The S7031 is a back-thinned type CCD image sensor. It features high quantum efficiency in the UV region, high dynamic range and low readout noise.
It is also available with a thermoelectric cooler for detection of low-level light and good stability in scientific and industrial applications.

An uncooled version, the S7030 is also available.
It has a pixel size of 24 × 24 µm and is available in image areas from 12.288 (H) x 1.392 (W) mm (512 x 58 pixels) up to 24.576 (H) × 6 (W) mm (1024 × 250 pixels).

This detector is available with the VS140 spectrograph only (physical size issues).



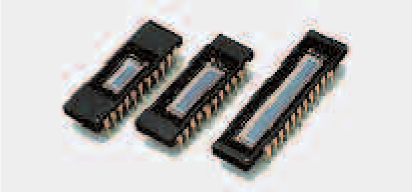
CCD area image sensor
S7030/S7031 series

2. PDA: NMOS & CMOS technology

For applications requiring high dynamic range measurements, a PDA is a superior solution.

The VS140 is available with the following PDAs:

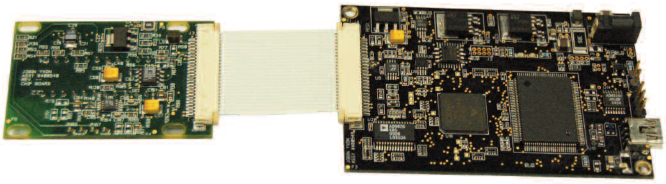
- CMOS PDA
  S8377/ S8378-XXX
  512 or 1024 pixels with 25 or 50 µm pixel width and 500 µm height
- NMOS PDA
  S3903/S3904 – XXX
  512 or 1024 pixels with 25 or 50 µm pixel width and 500 or 2500 µm height



CMOS and NMOS Photodiode arrays

Tall and high end chips such as the E2V Open Poly and back-thinned units are also available for integration in custom spectrometer designs, and can allow multiple spectra simultaneous monotoring, or full vertical binning in case of weak signal and tal entrance fiber slit.

Drive Electronics:



Line scan board

These detectors are driven with high performance electronics which feature:

- high dynamic range with 16-bit pixel resolution
- a 32 bit processor at MCU 30 Mhz
- flash memory for data storage of digitized pixel information
- a Field Programmable Gate Array (FPGA) providing control logic for data transfers, exposure control and CCD readout (optimal)
- integration time from 5 ms to 65.535 ms
- user selectable computer interface for communication with host computer and data transfer operations to host memory: Universal Serial Bus (USB) link operating at 3 Mbyte/sec; RS-232 link providing selectable baud rates from 9600 to 38.4 Kbits/sec
- operating systems: Windows 98/ME/2000/XP

Options

- Different slit sizes
- Removable SMA connector
- CCD or PDA detectors
- Electronic drivers USB, RS232, etc.

VSXX-B (version with detector and order sorting filter)

The basic version of the VS spectrograph includes an aberration-corrected concave holographic grating, an optical slit, an SMA connector, a detector and an HJY order sorting filter.

These components are in an optimized housing designed to maximize the optical performance of the grating.

There are no optical adjustments and tests; simply connect the electronic driver to the detector to make precision measurements.

VS70

VSXX-E (version with electronic driver)

In addition to the components of the basic version, this version includes a high performance electronic driver.

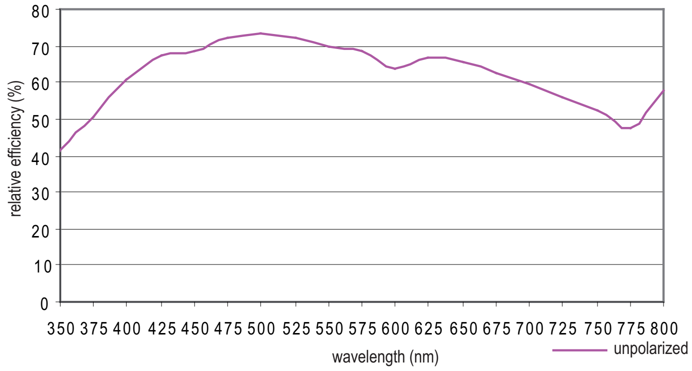
Customers simply connect to the VSxx via the USB or RS232 interface.

VS140

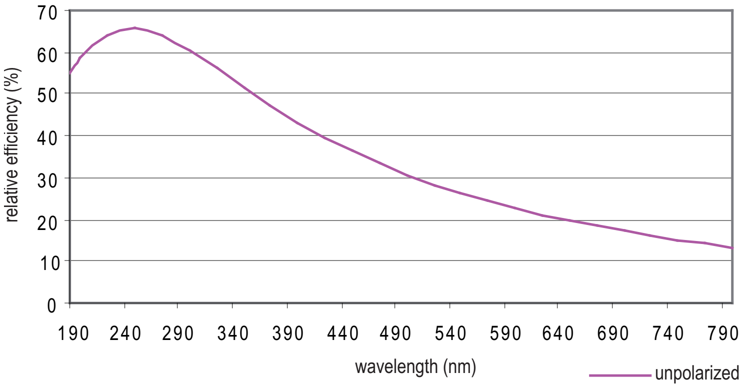
VS70 and VS140 gratings

225	Spectral range (nm)	Optimized at (nm)	Number of grooves (l/mm)	Blazed	Average dispersion (nm/mm)	Spectral length (mm)
VS70 Gratings	190-800	250	477	N	25	25,4
	190-1050	250	365	N	30	28,6
	190-1050	250 & 500	365	Double	30	28,6
	330-750	350	582	N	16	25,4
	350-800	500	582	B	16	25,4
	350-1050	500	365	N	30	25,4
	650-1020	675	365	N	30	12,7

VS70 grating blazed at 500 nm



VS140 grating blazed at 250 nm



	Spectral range (nm)	Optimized at (nm)	Number of grooves (l/mm)	Blazed	Average dispersion (nm/mm)	Spectral length (mm)
VS140 Gratings	190-800	250	285	Y	24,2	25,2
	350-1030	350	285	Y	24,2	28,6
	190-625	250	405	Y	17	25,6
	380-780	450	405	Y	16,7	24
	400-1100	500	230	N	30	23,3
	700-1060	800	230	N	29	12,3
	800-1700	900	97	N	71	12,7
	1100-2500	1200	120	N	56,6	24,7

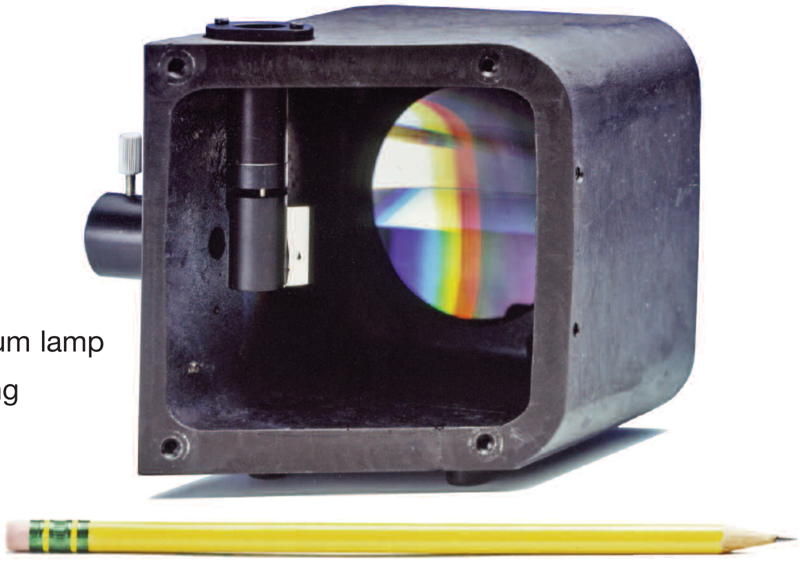
Imaging compact spectrographs

This imaging spectrograph offers the OEM customer a sturdy, low-cost, f/2, modular instrument, with unsurpassed spatial resolution. High-efficiency, ion-etched, holographic gratings make the CP140 the perfect spectrograph for use with multiple fiber inputs, linear arrays, and CCD type detectors. Selected gratings cover specific spectral regions from 190 nm to 2500 nm.

The CP140

The grating element has four functions:

- Collimation
- Dispersion
- Correction
- Focusing



Specifications:

- Flat field grating (aberration corrected)
- Focal length: 140 mm
- Spectral range*: from 190 to 2500 nm
- Aperture: f/2
- Stray light: < 0.1 % at 340 nm with Deuterium lamp
- Average dispersion: depending of the grating
- Wavelength accuracy: < 0.5 nm (with a mathematical fit)
- Repeatability: < 0.1 nm
- Dimensions: 120x150x110 mm

* depending on the grating and on the position and the type of the array detector used

Models and gratings available

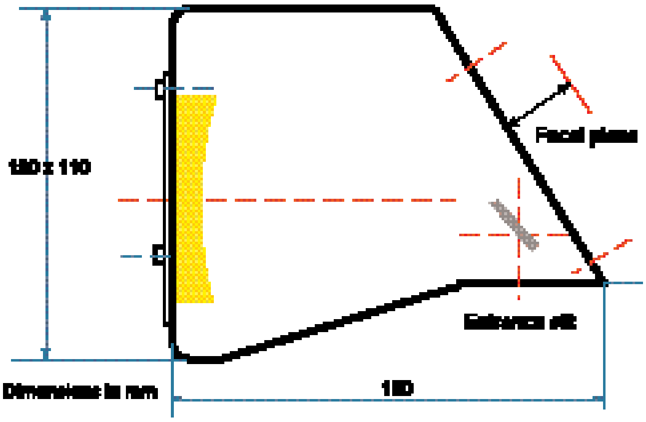
model number	grooves (l/mm)	wavelength range (nm)**	length of spectrum (mm)	average dispersion (nm/mm)
CP 140 - 103	285	190-800, B 250	25.2	24.2
CP 140 - 104	285	250-850, B 350	24.7	24.3
CP 140 - 202	140	190-800	12.2	50
CP 140 - 1602	405	285-715, B 350	25.6	16.8
CP 140 - 1603	405	190-410, B 250	12.8	17.2
CP 140 - 1604	405	190-625, B 250	25.6	17
CP 140 - 1605	405	380-780, B 450	24	16.7
CP 140 - 1821	230	700-1700	34.9	28.6
CP 140 - 1824	230	400-1100	23.3	30
CP 140 - 1825	230	380-780	13.2	30.3
CP 140 - 2021	120	1100-2500	24.7	56.6
CP 140 - 202L	140	190-800	12.2	50
CP 140 - 2951	97	800-1700	12.7	70.9
CP 140 - 3301	150	400-800	8.8	45.5

Options:

Entrance slit:

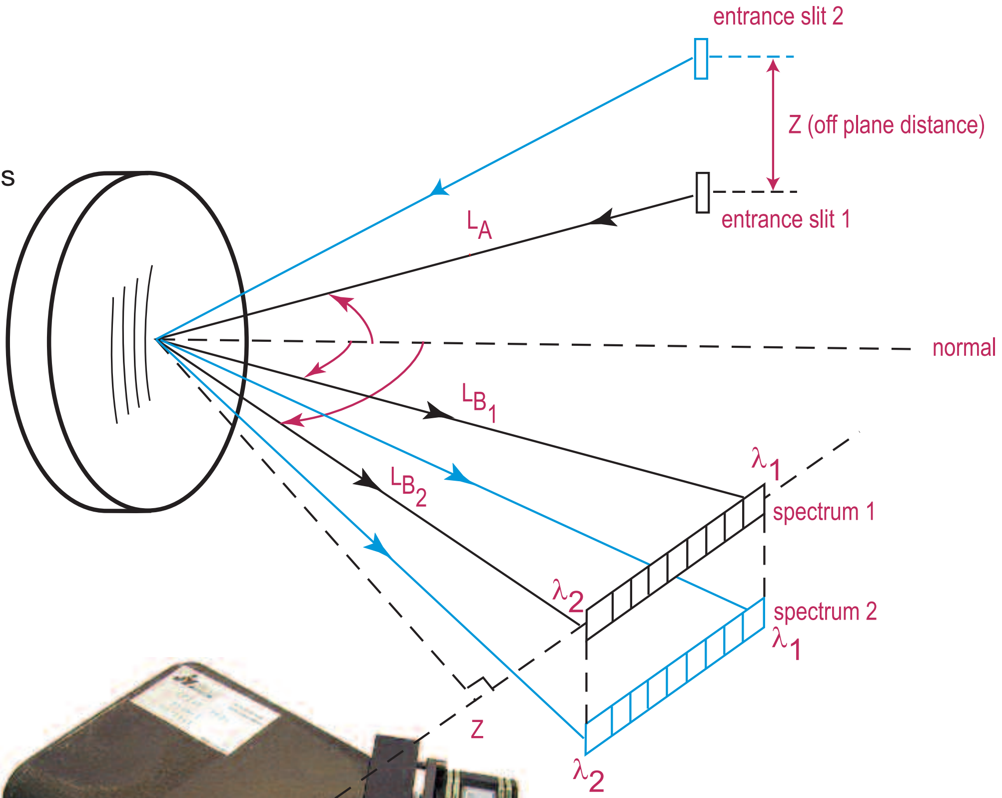
The CP140 is available with the following entrance slit options:

- SMA Connector
- Fiber Holder (up to 10 mm diameter)
- Fixed Entrance Slit
  - Width from 0.025 mm to 1 mm
  - Height: 4 or 2.5 mm

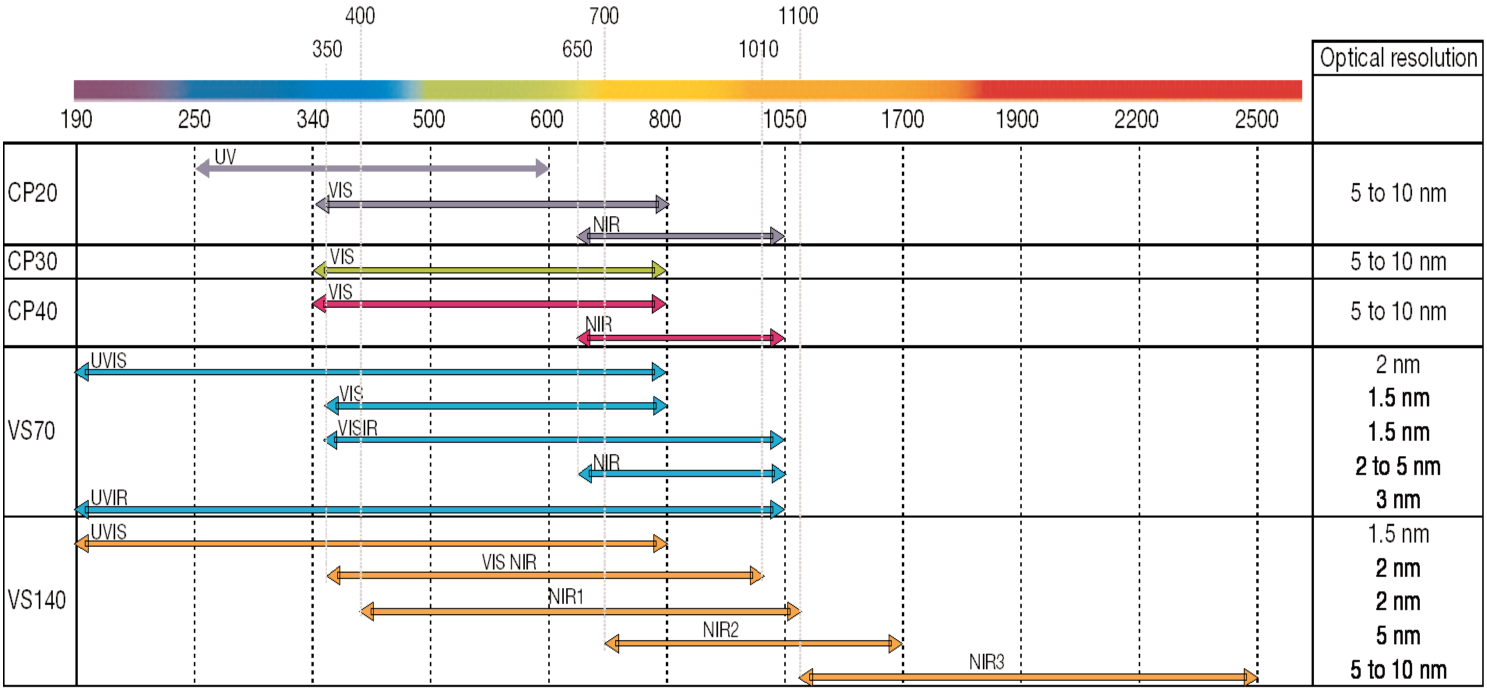


Benefits:

- Compact
- Superb imaging properties
- Reliable
- Robust
- Low cost
- OEM product



Spectrometer comparaison chart



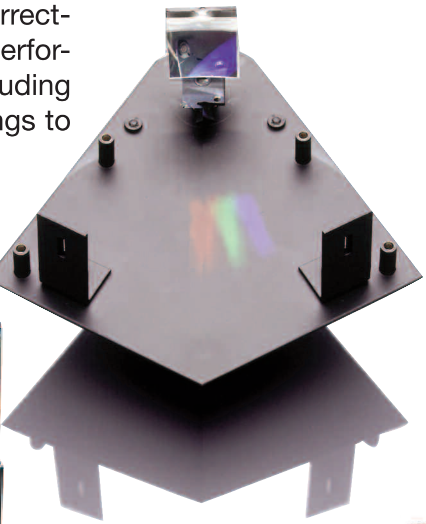
		CP20	CP30	CP40	VS70	VS140
CMOS	•S837X	**V**	**V**	**V**	**V**	**V**
	•Taos TSLW 1401	**V**	**V**	**V**	**V**	
	•ELIS 1024	**V**	**V**	**V**	**V**	
NMOS	•S838X series	**V**	**V**	**V**	**V**	**V**
	•S390X series	**V**	**V**	**V**	**V**	**V**
CCD	•Toshiba 1304DG				**V**	**V**
	•Sony ILX511				**V**	**V**
Back Thinned CCD	•S9840				**V**	**V**
	•S7031 (cooled)					**V**
	•S10141(cooled)					**V**
InGaAs	•G920X					**V**
	•SU256					**V**
Photodiode	•S4111				**V**	**V**

V	compatible

Compact scanning monochromators

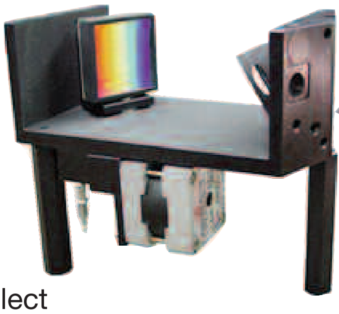
A complete range of compact monochromators has been developed for use as components for OEM spectroscopy applications.

Available from ultraviolet to infrared, these rugged and compact monochromators, designed around a family of aberration corrected holographic concave gratings which maximize optical performance and minimize stray light, feature high throughput including the best aperture in their class and a large selection of gratings to match spectral range requirements.



Applications

- Fluorescence
- Spectrophotometry
- Environmental testing
- Clinical chemistry
- Process monitoring



HORIBA Jobin Yvon manufactures a wide variety of high performance diffraction gratings and provides select gratings covering spectral regions from 190 to 2500 nm.

The optical monochromator design consists of 2 fixed slits (entrance and exit), an aberration corrected concave grating, and a scanning drive mechanism all assembled into a rugged and optimized housing.

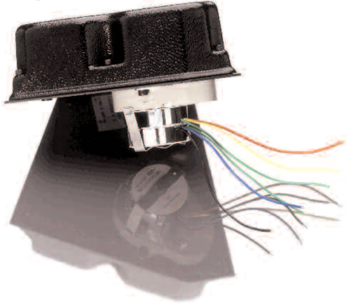
Different scanning drive models are available: a sine drive mechanism or a direct drive system. These mechanisms are used to rotate the grating either manually or via a stepping motor.

Contact us for affordable OEM electronics to drive our monochromators.

The wavelengths are sequentially focused at the exit slit.

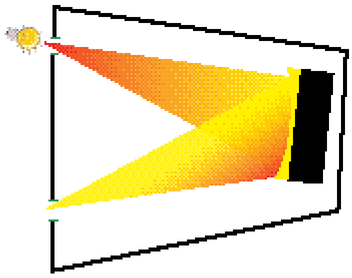
By using a concave diffraction grating, a single optical element is used to replace 3 elements in a standard spectrometer:
- the collimating element
- the dispersing element
- the focusing element

For DOUBLE monochromator designs in additive or subtractive mode, or for low cost high intensity excitation lamps, please contact us for your OEM volume requirements.



Features

- High optical performance
- Compact size
- UV to NIR range
- Low stray light
- Custom OEM design
- Reliability



A simple optical design with high f/#, aberration corrected grating and no extra mirrors brings more signal to your detector.

H10-34B OEM imaging monochromator

Building on the success of the H10-61 monochromator series, we introduced a generation of higher performance gratings in the H10-34B monochromator design.

The H10-34B is an imaging scanning monochromator with exceptional stray light rejection.

Features

- Grating: Aberration corrected concave holographic grating
- Focal length: 100 mm
- Deviation angle: 34.7°
- Aperture: f/2.8
- Dispersion: 7 nm/mm (with 1200 g/mm).

With a 100 mm focal length and f/2.8 aperture, the H10-34B monochromator is equipped with a rapid scanning direct drive system; the wavelength drive is directly coupled to a stepper motor.
This special design of the stepper/worm drive balances the speed of a stepper motor with the precision of a gear drive.

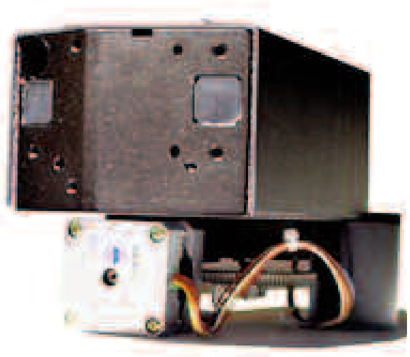
The entire spectrum can be scanned in under a second with excellent accuracy.

Several grating models are available to cover the UV range to the IR range as well as sets of fixed slits to optimize resolution and throughput.

Drop the H10-34B into your product and start collecting data! Each unit is factory pre-aligned and tested in accordance with your requirements, ensuring consistently high performance.
We cooperate with OEM volume customers for custom modification requirements and optimizations.

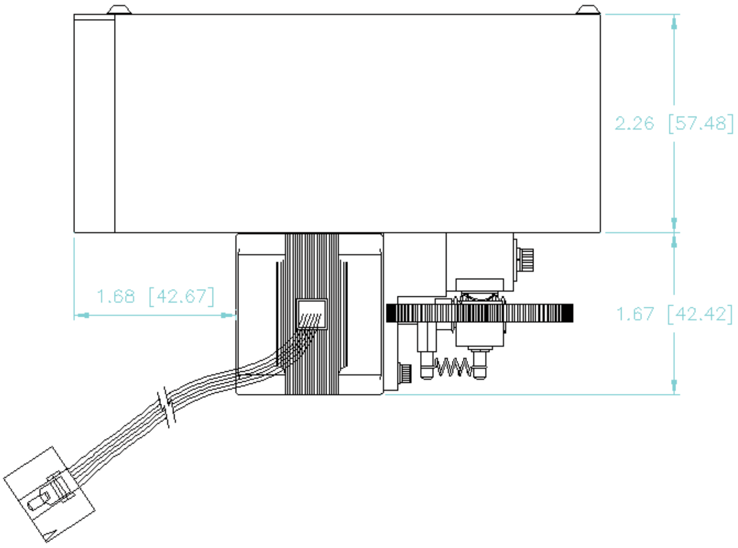
Applications

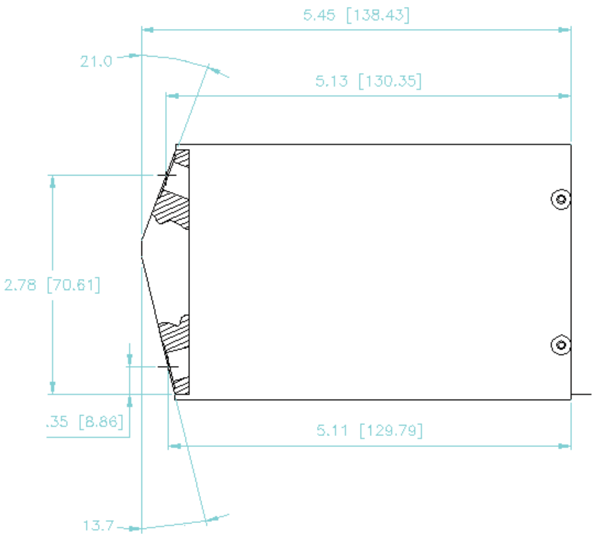
- Fluorescence
- Spectrophotometry
- Environmental testing
- Clinical chemistry
- Process monitoring



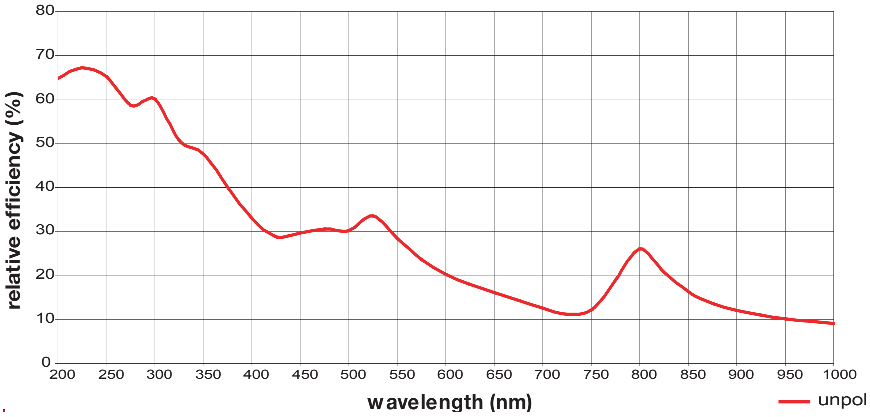
H10-34B

H10-34B





Available options:



Theoretical spectral efficiency curve of the UV model

Entrance slits

Different models of slits are offered depending on the resolution requirements.

The standard slits are:
25, 50, 100, 250, 500, 1000 µm width and 4 or 8 mm height.

Gratings

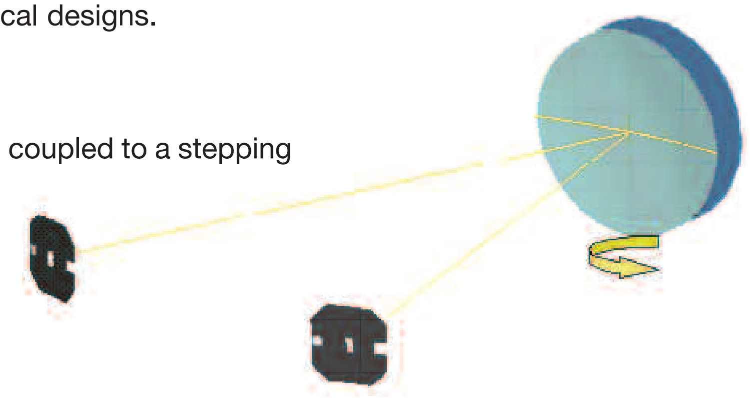
Advanced holographic designs pioneered by HORIBA Jobin Yvon achieve performance not possible with other small designs. Maximum efficiency results from an ion etched, blazed profile.

The aberration corrected concave gratings enable a simplified design with excellent imaging. This concave grating design also allows for an f/# not achievable in other typical designs.

Scanning drive mechanism

This custom designed stepper/worm drive is coupled to a stepping motor which features:

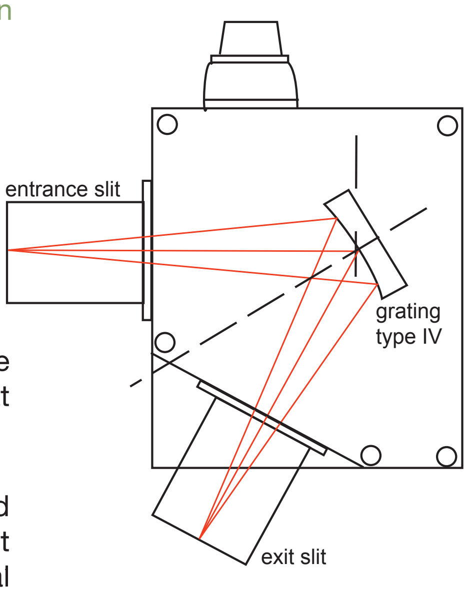
- ○ 1.8° stepper operating in half step mode
- ○ 0.01° grating rotation per step
- ○ 4 volt, 0.95 A, 2 phase
- ○ Grating rotation: 360°



ref:	H10-34 UV	H10-34 VIS	H10-34 VNIR	H10-34 NIR
spectral range (nm)	190-800	250-800	350-900	900-2500
peak efficiency	250	350	450	1600
linear dispersion (nm/mm)	7	7	7	12
wavelength accuracy (nm)	± 1	± 1	± 1	±2

H10-61 OEM monochromator

Since its introduction to OEM customers, thousands have been manufactured for a variety of spectroscopy applications.



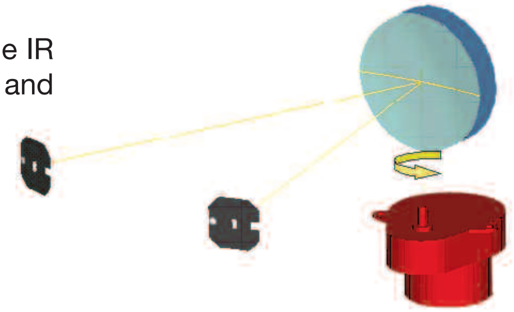
H10-61

The H10-61 is available in two versions:
- ○ H10-61 SB
- ○ H10-61 FS

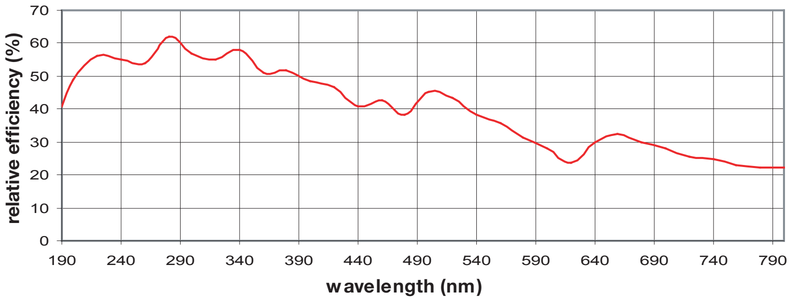
The H10-61 SB is equipped with a sine drive mechanism to rotate the grating, either manually or via a stepping motor, so that discrete wavelengths are sequentially scanned.

The new H10-61 FS has been designed with high adaptability and cost reduction in mind. It is equipped with a rapid scanning direct drive system directly coupled to a stepper motor; the spectral range can be scanned in less than 2 seconds.

Many grating models are available to cover the UV range to the IR range as well as sets of fixed slits to optimize resolution and throughput.



Rapid scanning direct drive: full scan in less than 2 seconds



Theoretical spectral efficiency curve of the UV model

	H10-61 SB	H10-61 FS
optical design	concave aberration corrected grating	concave aberration corrected grating
focal length (mm)	100	100
wavelength range (nm)	190 - 2500*	190 - 2500*
optical resolution (nm)	< 1*	< 1*
aperture (f/#)	f/3.5	f/3.9
deviation angle	61.6°	61.6°
entrance aperture	from 25 µm up to 1 mm	from 25 µm up to 1 mm
fiber optic connector	no	optional
wavelength accuracy (nm)	± 0.5**	± 1.5 with a fitting**
reproducibility (nm)	± 0.25	± 0.5
physical		
weight (kg)	2	1
dimensions (mm)	156 x 130 x 81	120 x 135 x 80

* depending on the grating
** with a 1200 l/mm grating

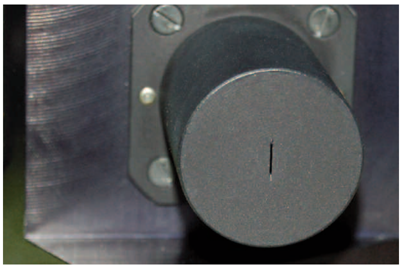
Available options:

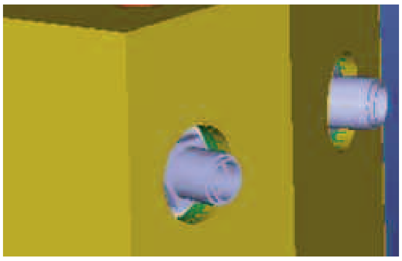
Entrance slits

Different models of slits are offered depending on the resolution requirement.

The standard slits are:
25, 50, 100, 250, 500, 1000 µm width and 4 or 8 mm height.

The H10-61 FS can accept light directly through either a fixed slit or an SMA fiber connector (optional).


H10-61 slit


H10-61 slit

Gratings

models	**H1061-UV**	**H1061-UVIS**	**H1061-VIS**	**H1061-VNIR**	**H1061-NIR**
spectral range (nm)	190-800	250-800	350-900	400-1600	800-3200
peak efficiency	250	350	450	600	1200
linear dispersion (nm/mm)	8	8	8	16	32

Scanning drive mechanism

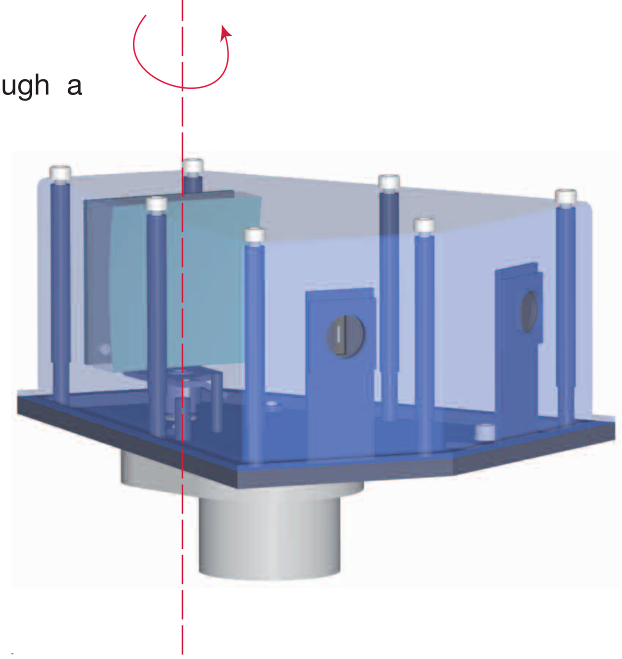
The H10-61 SB features a sine drive mechanism which rotates the grating via a lead screw/sine bar mechanism, which yields high accuracy and linearized spectra, so that discrete wavelengths are sequentially scanned.

In addition, wavelengths can easily be read in nm, through a digital counter graduated in 0.2 nm intervals.

With the H10-61 FS, we offer different models of stepper motors depending on resolution requirements.

The basic model is equipped with a 4 phase stepper motor with 12000 step/360°.


sine bar



Technical information

Before introducing the basic equations, a brief note on monochromatic light and continuous spectra must first be considered.

Monochromatic light has infinitely narrow spectral width. Good sources which approximate such light include single mode lasers and very low pressure, cooled spectral calibration lamps. These are also variously known as "line" or "discrete line" sources.
A continuous spectrum has finite spectral width, e.g. "white light". In principle all wavelengths are present, but in practice a "continuum" is almost always a segment of a spectrum. Sometimes a continuous spectral segment may be only a few parts of a nanometer wide and resemble a line spectrum.

The equations that follow are for systems in air where $n_0 = 1$. Therefore, $\lambda = \lambda_0$ = wavelength in air.

Definitions

α - angle of incidence ....degrees
β - angle of diffraction ....degrees
k - diffraction order ....integer
N - groove density ....grooves/mm
D - the included angle or deviation angle ....degrees
n_0 - refractive index
λ - wavelength in vacuum ....nanometers
λ_0 - wavelength in medium of refractive index, n_0, where $\lambda_0 = \lambda/n_0$

1 nm = 10^{-6} mm ; 1 micrometer = 10^{-3} mm ; 1 A = 10^{-7} mm

The most fundamental grating equation is given by:

$$\sin \alpha + \sin \beta = 10^{-6} kN\lambda \qquad \text{(equation 1)}$$

Monochromator configuration

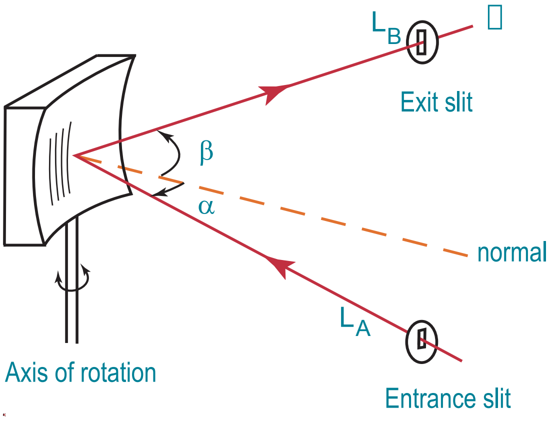
L_A = Entrance arm length
L_B = Exit arm length at λ_n
D is constant. The grating is rotating to select the wavelength going through the exit slit.

$$D = \beta - \alpha$$

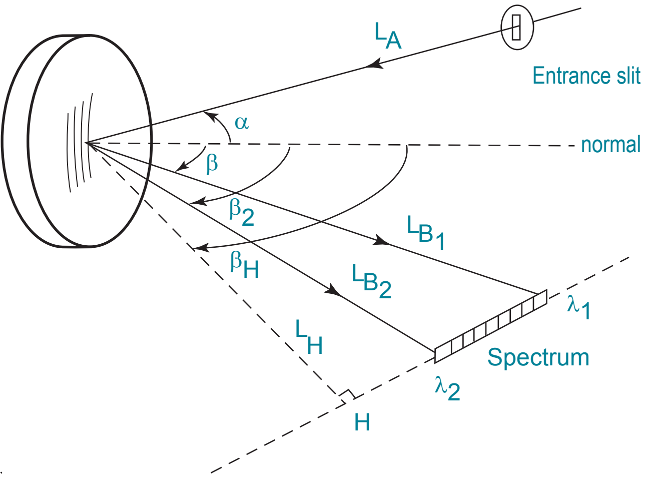
$$\beta = D/2 + \theta$$
$$\alpha = -D/2 + \theta$$

θ is the rotation angle from zero order to the wavelength λ

$$\theta = \arcsin(k \lambda N / (2 \cos(D/2)))$$



Spectrograph configuration



L_A = Entrance arm length
L_{B_λ} = Exit arm length at λ_n
β_H = Angle between the perpendicular to the spectral plane and the grating normal
L_H = Perpendicular distance from the spectral plane to grating

Angular Dispersion

$$d\beta / d\lambda = (k\, N 10^{-6}) / \cos\beta$$

$d\beta$ = angular separation between two wavelengths (radians)
$d\lambda$ = differential separation between two wavelengths (nm)

Linear Dispersion

Linear dispersion defines the extent to which a spectral interval is spread out across the focal field of a spectrometer and is expressed in nm/mm, Å/mm, cm^{-1}/mm, etc.

For example, consider two spectrometers: one instrument disperses a 0.1 nm spectral segment over 1 mm while the other takes a 10 nm spectral segment and spreads it over 1 mm.

It is easy to imagine that fine spectral detail would be more easily identified in the first instrument than the second. The second instrument demonstrates "low" dispersion compared to the "higher" dispersion of the first. Linear dispersion is associated with an instrument's ability to resolve fine spectral detail.

Linear dispersion perpendicular to the diffracted beam at a central wavelength, λ, is given by:

$$d\lambda / dx = (10^6 \cos\beta) / (k\, N\, L_{B_\lambda})$$

where L_B is the effective exit focal length in mm.

In a monochromator, L_B is the arm length from the focusing mirror to the exit slit or if the grating is concave, from the grating to the exit slit. Linear dispersion, therefore, varies directly with cos β, and inversely with the exit path length, L_B, order k, and groove density, n.

In a spectrograph, the linear dispersion for any wavelength other than that wavelength which is normal to the spectral plane will be modified by the cosine of the angle of inclination at wavelength λ.

Note that the lower the dispersion number is in wavelength unit /spectrum length unit the more dispersive is the instrument.
Note there is a linear dispersion both at the entrance and at the exit of the system.

○ Case of a monochromator:

entrance linear dispersion: $d\lambda / dx = (10^6 \cos \alpha) / (k\ N\ L_A)$

exit linear dispersion: $d\lambda / dx = (10^6 \cos \beta) / (k\ N\ L_B)$

○ Case of a spectrograph with L_H β_H:

linear dispersion: $d\lambda / dx = (10^6 \cos \beta \cos Y) / (k\ N\ L_{B_\lambda})$

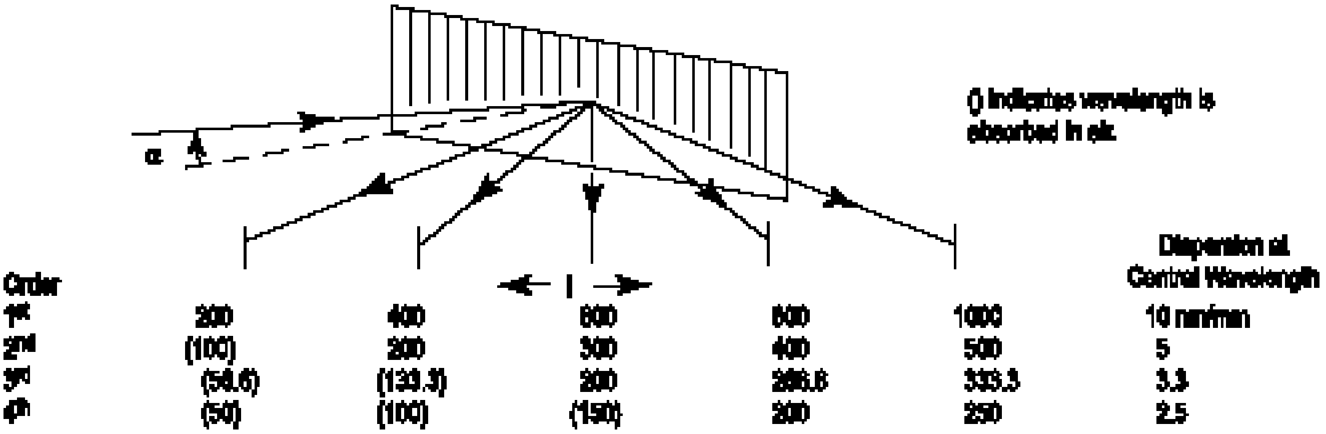
$Y = \beta_H - \beta$

linear dispersion: $d\lambda / dx = (10^6 \cos \beta \cos^2 Y) / (k\ N\ L_H)$

Wavelength and Order

The figure below shows a first order spectrum from 200 to 1000 nm spread over a focal field in a spectrograph configuration. From (equation 1) with a grating of given groove density and for a given value of alpha and beta:

$k\ \lambda$ = constant
so that if the diffraction order k is doubled, lambda is halved, etc.



() Indicates wavelength is absorbed in air.

Order						Dispersion at Central Wavelength
1st	200	400	600	800	1000	10 nm/mm
2nd	(100)	200	300	400	500	5
3rd	(66.6)	(133.3)	200	266.6	333.3	3.3
4th	(50)	(100)	(150)	200	250	2.5

Dispersion and order

If, for example, a light source emits a continuum of wavelengths from 20 nm to 1000 nm, then at the physical location of 800 nm in first order wavelengths of 400, 266.6, and 200 nm will also be present and available to the same detector. In order to monitor only light at 800 nm, filters must be used to eliminate the higher orders.

First order wavelengths between 200 and 380 nm may be monitored without filters because wavelengths below 190 nm are absorbed by air. If, however, the instrument is evacuated or N_2 purged, higher order filters would again be required.

Spectrometer throughput

Aperture ratio (f-number) and Numerical Aperture (NA)

In most areas of optics, the numerical aperture of an optical system such as an objective lens is defined by:

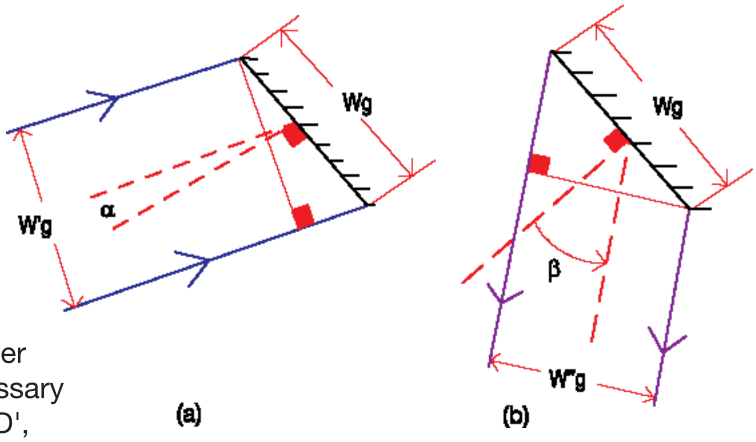
$NA = n \sin \theta$
where n is the index of refraction of the medium in which the lens is working (1.0 for air), and θ is the half-angle of the maximum cone of light that can enter or exit the lens.

Numerical aperture is a measure of the diameter of the aperture compared to the focal length. In photography, this relationship is usually expressed via the f-number, f/#, which for a thin lens imaging an object at infinity is given by:
$f/\# = 1 / (2\ NA)$

(This is only good for very low numerical aperture lenses.)
The light gathering power of an optic is rigorously characterized by numerical aperture (NA).

f/value of a Spectrometer

Because the angle of incidence, alpha, is always different in either sign or value from the angle of diffraction, beta (except under Littrow conditions), the projected size of the grating varies with the wavelength and is different depending on whether it is viewed from the entrance or exit slit. In Figures (a) and (b), the widths W' and W'' are the projections of the grating width as perceived at the entrance and exit slits, respectively.

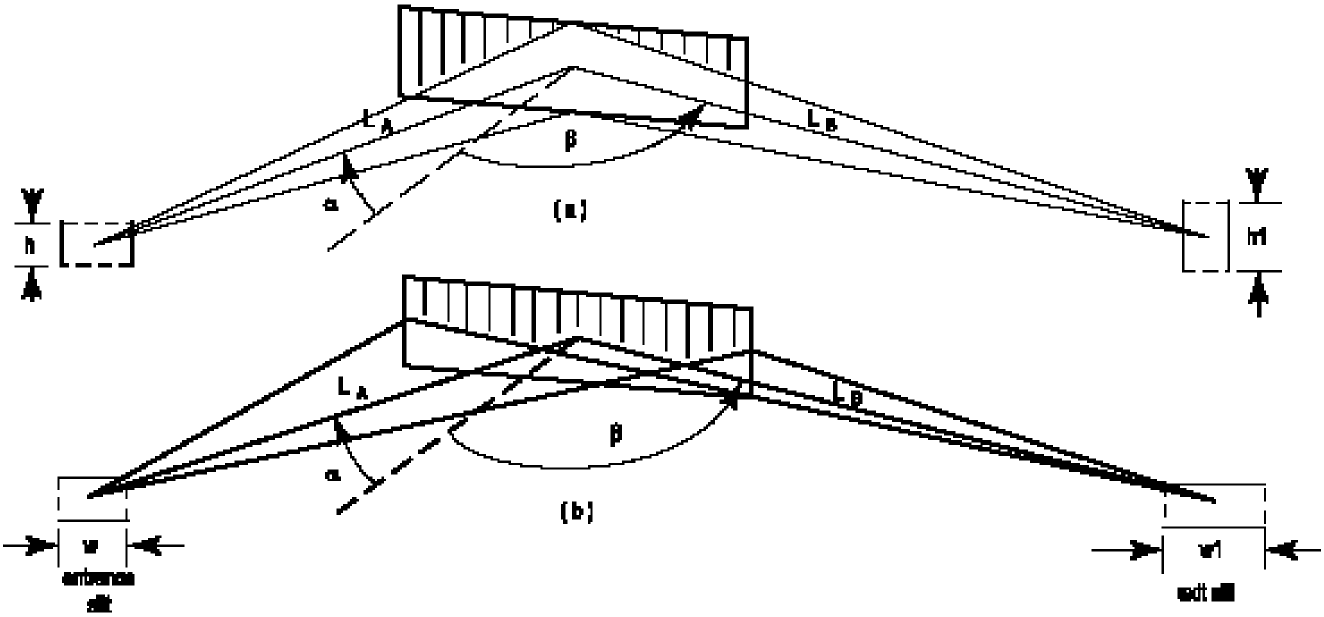


Projection of the grating width on (a) the entrance and (b) the exit

To determine the f/value of a spectrometer with a rectangular grating, it is first necessary to calculate the "equivalent diameters", D', as seen from the entrance slit, and D" as seen from the exit slit. This is achieved by calculating the diameter of the circular disk that has equal area to the projected area of the grating. The f/# is then the ratio of the arm length to this diameter.

Exit Slit Image and Anamorphism

Anamorphic optics are those optics that magnify (or demagnify) a source by different factors in the vertical and horizontal planes. An optical system which includes a grating is such a system.



(a) vertical and (b) horizontal magnification

○ Slit width magnification

In the case of a diffraction grating-based instrument, the image of the entrance slit is NOT imaged 1:1 in the exit plane (except in Littrow and perpendicular to the dispersion plane assuming $L_A = L_B$). This means that in virtually all commercial instruments the tradition of maintaining equal entrance and exit slit widths may not always be appropriate.

Magnification in the dispersion direction is:

$$w' = w \frac{\cos\alpha}{\cos\beta} \frac{L_B}{L_A}$$

○ Slit height magnification

Slit height magnification is directly proportional to the ratio of the entrance and exit arm lengths.

$h' = (LB/LA)h$

In the case of a flat field spectrometer, the height magnification is changing with wavelength because L_B is changing.

Note: Geometric magnification is not an aberration!

Definitions

Etendue (G): a measure of the size of the beam that an optical system is able to accept, also called the area - solid angle product.
The term étendue comes from the French (literally meaning extent). The french expression for this property is “étendue géométrique”, meaning geometrical extent.
An optical system with an etendue G cannot accept a beam with an etendue larger than G.

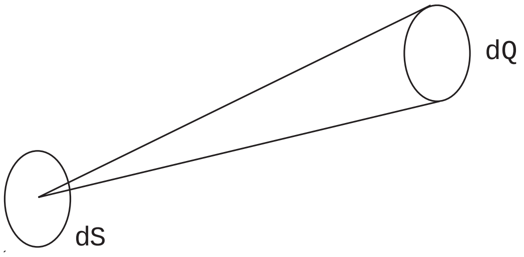
The etendue of a beam is constant when the beam shape is changed by an optical element.
The etendue is related to the Lagrange invariant and the optical invariant, which share the property of never increasing in any real optical system.

Geometric etendue (geometric extent), G, characterizes the ability of an optical system to accept light. It is a function of the area, S, of the emitting source and the solid angle, Q, into which it propagates. Etendue therefore, is a limiting function of system throughput.

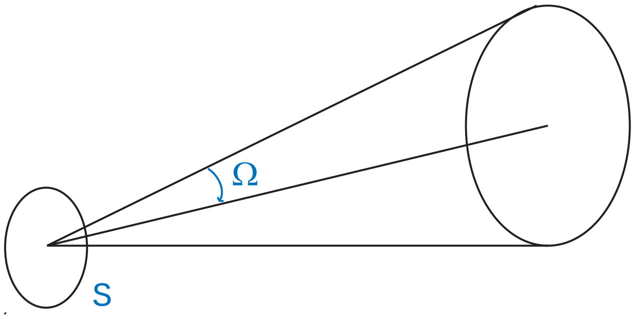
For an elementary beam

$d^2G = dS\,dQ$

and for a finite beam



$$G = \int_{\text{area of the source}} \int_{\text{solid angle of the beam}} d^2G$$



Following integration for a conical beam the axis ofwhich is normal to source of area S

$$G = \pi S \sin^2 \Omega$$

Etendue is a constant of the system and is determined by the LEAST optimized segment of the entire optical system. Geometric etendue may be viewed as the maximum beam size the instrument can accept, therefore, it is necessary to start at the light source and ensure that the instrument, including ancillary optics, collects and propagates the maximum number of photons.

Flux: flux is given by energy/time (photons/sec, or watts). Spectral Flux is energy/time/bandpass.

Intensity (I): the distribution of flux at a given wavelength (or bandpass) per solid angle (watts/steradian).

Radiance (Luminance) (B): radiance is the flux emitted per unit area per unit solid angle. B = Intensity/Surface Area of the Source (watts/steradian/cm^2).
Luminance is the “visible flux” or lumens per unit area per unit solid angle

Throughput: the flux that is available at the exit of an optical system. It is a function of the etendue (geometrical factor) and of the transmission factor of the system.

Relations between flux, etendue, luminance, throughput

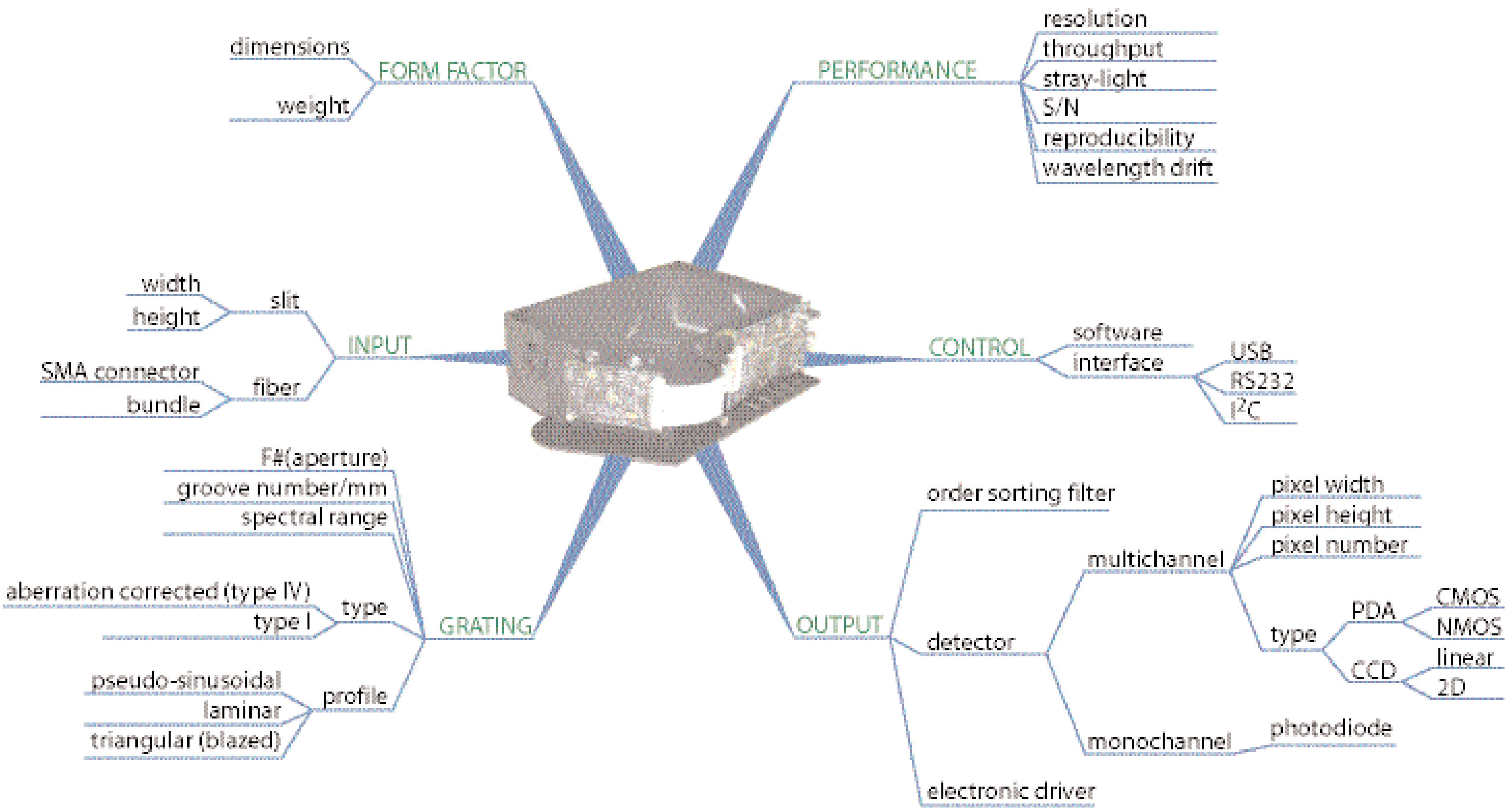
Flux = etendue x radiance

Radiance of the input light is further modified by the transmission factor of the system (reflectivity of mirrors, grating efficiency, filters, etc..)
Geometrical losses resulting for example from astigmatism, limit the real etendue of the instrument. The real etendue is equal to the etendue of the entrance beam corrected by the geometrical losses.

Stray light: in a spectrometer, light that strikes the detector other than the intended wavelength is referred to as stray light. This is generally a combination of various reflections of higher order diffracted light, zero order light and scatter from the optical parts of the spectrometer.

Resolution: the resolution of a spectrometer is defined as the smallest separation of 2 spectral lines that can be detected as separate lines. In general, this is equivalent to the FWHM of the bandpass function of the spectrometer. Additionally, the detector must be carefully selected to provide at least 3 pixels per bandwidth interval in order to adequately detect these lines, otherwise the effective resolution of the system is degraded.

Main characteristics of a spectrometer



Information request form

If you have a customer requiring an OEM spectrometer system, please fill out the following information request form.

Sales and technical information

Application field:

Customer:

Reference document (if any):

Sales potential per year:

Life time product:

Status of customer R&D project (feasibility study, started…):

Starting date:

Prototype delivery date:

Starting date of series:

Competition:

Confidentiality agreement:

Exclusivity:

Product presentation:

Description of the main requirements:

Specifications	Values	Ref./Comments
Spectrograph or monochromator		
Spectral range		
Band pass (resolution)		
Optical design		
Numerical aperture		
Grating type		
Input (slit or optical fiber)		
Slit:		
Height		
Width		
Fiber		
Output (slit or detector)		
Exit slit		
Height		
Width		
Detector reference		
Pixel height		
Pixel width		
Number of pixels		
Window: (Y/N)		
Electronics		
Size of the module		
Environmental		
Temperature working range		
Atmosphere		
Shocks, vibrations		
Electric ground		
Special requirements		

Fax form

For more information or custom grating / mirror quotations, please complete the corresponding request info on our web site: www.jobinyvon.com or send this completed form by fax.

The personal details that we use to provide or promote our products and services (for example your name and telephone number), will NOT be passed to ANY organization beyond the HORIBA Group, its Subsidiary or Associate Companies, Agents or Distributors to be used for marketing purposes.

Your Contact Details:

Last Name: ....

Title: ....

Dept: ....

State/Province: ....
Country: ....
(USA please include Zip)

Telephone: ....
Fax: ....

First Name: ....

Organization: ....

Address: ....
....
....
Postal Code: ....

E-Mail: ....

○ Please keep me informed with up-to-date information.

Your Interest

My interest is:
○ Information only
○ Possible purchase
○ I have funding
○ I am applying for funds

I intend to purchase
○ Now!
○ Within 3 months
○ Within 6 months
○ Within 12 months
○ More than 12 months

○ Salesperson please call

Please Send Product Information For:

○ Gratings & OEM

○ Diffraction Gratings
○ Pulse Compression Gratings
○ OEM Spectrometers
○ Imaging CCDs
○ Multi Channel Imaging

○ Vacuum UV

○ Monochromators & Spectrographs
○ Mirrors
○ Gratings

My Application is:

We would be interested in learning more about your application. Please give details below:
....
....

Comments

Please include any comments or further information about your requirement below:
....
....

HORIBA Jobin Yvon divisions

HORIBA Jobin Yvon: dedicated to scientific innovation in optical spectroscopy and other techniques since 1819

MOLECULAR AND MICROANALYSIS

FLUORESCENCE

Analytical and modular research spectrofluorometers for steady-state, TCSPC and frequency domain lifetime. For biotechnology to nanotechnology.

RAMAN ANALYSIS

Laboratory, research and process instruments from UV to IR. Microscope, remote probe and custom sampling options.

X-RAY FLUORESCENCE

Non-destructive EDXRF elemental analysis to less than 10 µm spot size. Micro/macro sampling, and mapped imaging. WEEE/RoHS compliance testing.

EMERGING BUSINESS

FORENSICS

Crime scene and laboratory light sources. Fingerprint and palm print identification systems. Image enhancement software.

ELLIPSOMETRY

Benchtop and in-situ spectroscopic and laser ellipsometers. Non-destructive characterisation of thin films for thickness and optical properties.

THIN FILM PROCESS CONTROL

Thin film processing and plasma diagnosis using imaging laser interferometry, optical emission spectroscopy, ellipsometry and polarimetry.

MARKETS AND INDUSTRIES

Academia

Biotechnology

Chemicals

Coatings

Environmental

Food & Beverage

Forensic Science

Geology & Exploration

Instrumentation

Life Sciences

Semiconductors

Pharmaceuticals

Petroleum

Optoelectronics

Nanotechnology

Medical

Materials Science

and product lines

HORIBA Jobin Yvon: dedicated to scientific innovation in optical spectroscopy and other techniques since 1819

MARKETS AND INDUSTRIES

Academia

Biotechnology

Chemicals

Coatings

Environmental

Food & Beverage

Forensic Science

Geology & Exploration

Instrumentation

Life Sciences

Semiconductors

Pharmaceuticals

Petroleum

Optoelectronics

Nanotechnology

Medical

Materials Science

OPTICAL COMPONENTS

OPTICAL SPECTROSCOPY

Monochromators, spectrographs, array and single-channel detectors, light sources and sample accessories.

DETECTORS

CCD and other detectors for spectroscopy and imaging applications. Contract manufacture for OEM.

OEM SPECTROMETERS AND GRATINGS

Gratings, monochromators, spectrographs including detectors, acquisition electronics and light sources for industrial applications.

CUSTOM GRATINGS AND VUV BEAMLINES

Gratings for high power lasers, space flight experiments and VUV instruments. Synchrotron VUV chambers, mirrors and beamlines.

ELEMENTAL ANALYSIS

ATOMIC EMISSION SPECTROSCOPY

ICP, spark and glow discharge optical emission spectrometers. Elemental analysers for C, S, H, N & O. Sulphur in petroleum analysis.

PARTICLE SIZE ANALYSERS

Particle characterization equipment covering the range from 3 nm to 3 mm.

COMPANY PROFILE

HORIBA Jobin Yvon is one of the world's largest manufacturers of analytical and spectroscopic systems and components and we are committed to serving our customers with superior products and technical support.

Established in 1819, Jobin Yvon is part of the HORIBA Group which employs more than 4,500 people worldwide, with annual sales in excess of $900,000,000.

HORIBA Jobin Yvon, Sofie, Dilor, Spex and IBH are some of our well known and respected brand names.

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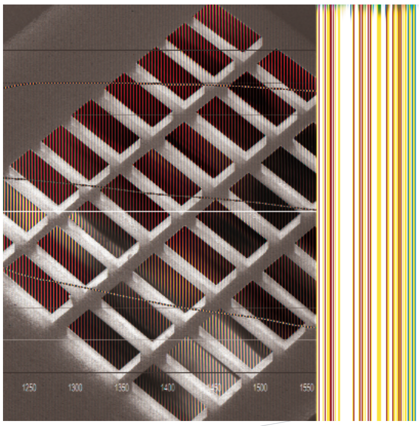

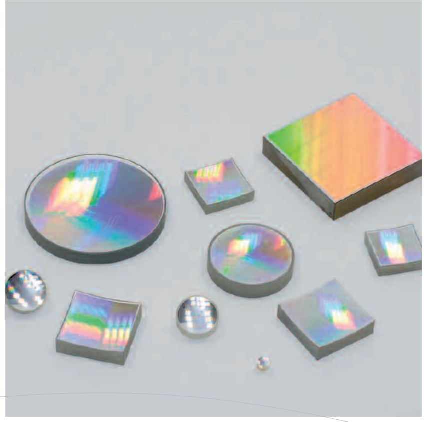

HORIBA JOBIN YVON

(All HORIBA Jobin Yvon companies were formerly known as Jobin Yvon)

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