ZEISS Spectrometer Modules
Compendium of products, electronic components and software solutions
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Wavelength ranges

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CGS Family
MCS FLEX Family
PGS Family

Software

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Definitions and explanations

The moment you discover that your expectations have been exceeded.
This is the moment we work for.

// SPECTROMETER MODULES
MADE BY ZEISS

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Introduction

Your application is our motivation

A traditional spectrometer and/or a traditional monochromator consists of a dispersive medium, an entrance and an exit slit and imaging elements which generate a parallel beam path. To capture a spectrum, a detector behind the exit slit must capture the light sequentially while the dispersive element or the exit slit is moved. This sort of mechanical movement requires time and is prone to interference. However, short measuring times and insensitivity to external influences are quite advantageous for many applications – especially in industry. That is why ZEISS began developing the diode array spectrometers at the end of the 1970s. In place of the exit slit, these spectrometers have a diode array and, through this replacement, capture a complete spectrum simultaneously in a fraction of a second, making moving components unnecessary. The design of the spectrometer module family from ZEISS is based on reducing the optical-mechanical design and the number of components to the physical minimum while using the greatest possible number of identical components for different versions.

In the last few years, ZEISS has developed a large number of diverse spectrometer modules for very different applications and requirements. All of these modules offer a key benefit: all spectrometer parts are permanently affixed to each other. This ensures a very high degree of insensitivity to mechanical vibrations and thus a high level of reliability. Moreover, the entire design is maintenance-free, i.e. recalibration is not necessary. The foundation for the high quality of the spectrometer is the technological know-how at ZEISS for mathematical designs, structuring (grating manufacture and replication), coatings and material processing. Ultimately the joining technology is decisive for ensuring a high degree of insensitivity to influences such as vibrations and, especially, temperature fluctuations.

The following spectrometer module families have been developed at ZEISS:

- MMS Monolithic Miniature Spectrometer
- CGS Compact Grating Spectrometer
- MCS FLEX Multi-Channel Spectrometer
- PGS Plane Grating Spectrometer

At ZEISS, the complete solution is consistently aligned with the customer’s application. Not only is the corresponding module family available for every measuring job, but the electronics, interface and processing software are always optimally configured. Furthermore, this approach ensures that the customer enjoys a consistently high level of performance and quality for all system components.
**Introduction**

**Wavelength ranges**

- **MMS Family**
  - MMS 1
  - MMS UV
  - MMS UV-VIS I
  - MMS UV-VIS II

- **CGS Family**
  - CGS UV-NIR CCD
  - CGS UV-NIR PDA

- **MCS FLEX Family**
  - MCS FLEX CCD
  - MCS FLEX PDA

- **PGS Family**
  - PGS NIR 1.7-256
  - PGS NIR 1.7-256 UC
  - PGS NIR 1.7-512
  - PGS NIR 2.0-256
  - PGS NIR 2.2-256

**Areas of application**

**Definitions and explanations**

Click on the respective wavelength range to reach the technical data of the corresponding product.
The extremely compact design is significant for the spectrometers in the MMS family. Small sizes are available because high repeatability — rather than a high resolving power — is necessary for many applications.

Optical components in the MMS family

- Imaging grating
- A fiber cross-section converter as an optical entrance
- Diode array as an opto-electronic output port

These elements are arranged around and attached to a central body. Depending on the version, the central body is designed as either a glass body or a titanium hollow body. The two components important for the interfaces — the cross-section converter and the detector — are retained.

Central body

On the MMS 1, the central body is a glass body resembling a lens. The imaging grating is replicated directly on this glass body so that it cannot be moved and is optimally protected against dust and gases. An optically denser medium also enables the use of smaller gratings because of the larger aperture, reducing aberrations.

On the UV-sensitive modules, the large glass body has been replaced by a hollow body for reasons of transmission. The grating and detector are affixed to this hollow body. The overall stability is not impaired by the tube design; the temperature-dependent drift of the wavelength has even been reduced.

Gratings

The gratings for the MMS family are holographically blazed flat-field gratings for optimized effectiveness. At ZEISS, these gratings are manufactured using the threshold value method and achieve significantly higher effectiveness (for unpolarized light) than sinusoidal gratings. In addition to the dispersive function, the grating must image the entrance slit on the detector array. Via the groove density and curved grooves, comma errors are corrected and the focal curve is evened out (flat field) so that it is optimally adjusted for the flat detector structure. Spectra of over 6 mm long are achieved — even with the small focal length available. Thus the same grating design can be used for the VIS- and the UV-VIS versions. The original grating has an efficiency maximum of approx. 220 nm. The efficiency curve is offset by the factor of the refractive index on the VIS module due to the greater optical thickness.

Cross-section converter

A fiber bundle cross-section converter further optimizes the light intensity. The linear arrangement of individual fibers creates the entrance slit (slit height h determined by the number of individual fibers; the slit width w determined by the core diameter). This is adjusted to the pixel size of the diode array used and to the dispersion properties of the flat-field grating, enabling light intensities to reach the theoretical limit. The cross-section converter is an integral part of the spectrometer design and therefore cannot simply be changed. There is, however, the possibility of changing the length of the fiber and the design of the entrance. It must also be noted that quartz fibers, such as those used on older MMS UV modules (VIS), create so-called solarization centers when irradiated with deep UV light under 220 nm. This means: the transmission of the fibers is reduced when irradiated with high-energy light. This effect occurs more strongly and more often the shorter the wavelength (higher photon energy), the shorter the intensity and the longer the brightness time. The transmission can also be limited above 220 nm up to 250 nm. This solarization effect can only be partially reversed but can be corrected via frequent reference measurements. For measurements below 225 nm, it is possible to equip the MMS module with solarization-stable fibers. Using a WG 225 filter with 3 mm thickness is an absolute must with standard modules.

Detector

MMS

In the MMS family, the silicon diode array S3104-2560 from Hamamatsu is integrated. Only the MMS 1 NIR enhanced uses the Hamamatsu type S8381-2560. By using a shorter special housing, the split-off angle is very small, enabling an efficient grating design. This and the 6 mm spectrum length must be considered when switching to another detector. The diode array is coated directly with a dielectric edge filter to suppress the second order.

The following modules are available:

<table>
<thead>
<tr>
<th>Module</th>
<th>Spectral range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMS 1</td>
<td>310 – 1100</td>
</tr>
<tr>
<td>MMS UV-VIS</td>
<td>190 – 795 or 250 – 785</td>
</tr>
<tr>
<td>MMS UV</td>
<td>195 – 390</td>
</tr>
</tbody>
</table>
## MMS 1
### Technical Data

**Optical entrance**
- Input: round
- Output: linear
- Fiber bundle consists of 30 quartz glass fibers with a 70 µm core diameter, designed as a cross-section converter
- Diameter: 0.5 mm
- NA = 0.22 (homogeneous illumination of the acceptance angle)
- Mounted in an SMA connector
- 70 µm x 2500 µm (entrance slit)

**Grating**
- Flat field, 366 l/mm (in the center)

**Diode array**
- Manufacturer: Hamamatsu
- Type: S 3904-256Q in special housing
- Number of pixels: 256

### Specifications

**Spectral range**
- 310 nm – 1100 nm
- Specifications for the range:
  - 360 nm – 900 nm (UV-VIS enhanced)
  - 400 nm – 1000 nm (NIR enhanced)

**Wavelength accuracy**
- 0.3 nm

**Temperature drift**
- ≤ 0.001 nm/K

**Spectral pixel distance**
- ΔλPixel = 3 nm

**Resolution**
- ΔλFWHM = 10 nm

**Sensitivity**
- ≈ 10³ Vs / J

**Stray light**
- ≤ 0.8 % with halogen lamp (UV-VIS enhanced)
- ≤ 0.2 % with halogen lamp (NIR enhanced)

**Dimensions**
- With housing
- Cross-section converter (outer length)
- 70 x 50 x 40 mm³
- Standard: 240 mm, available up to 1 m

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## MMS UV-VIS I / UV-VIS II
### Technical Data

**Optical entrance**
- Input: round
- Output: linear
- Fiber bundle consists of 30 quartz glass fibers with a 70 µm core diameter, designed as a cross-section converter
- Diameter: 0.5 mm
- NA = 0.22 (homogeneous illumination of the acceptance angle)
- Mounted in an SMA connector
- 70 µm x 2500 µm (entrance slit)

**Grating**
- Flat field, 366 l/mm (in the center), blazed for approx. 220 nm

**Diode array**
- Manufacturer: Hamamatsu
- Type: S 3904-256Q in special housing
- Number of pixels: 256

### Specifications

**Spectral range**
- UV-VIS I
  - 190 nm – 720 nm
  - Specifications for the 220 nm – 720 nm range
- UV-VIS II
  - 250 nm – 780 nm
  - Specifications for the 250 nm – 780 nm range

**Wavelength accuracy**
- 0.5 nm

**Temperature drift**
- ≤ 0.006 nm/K

**Spectral pixel distance**
- ΔλPixel = 7 nm

**Resolution**
- ΔλFWHM = 7 nm

**Sensitivity**
- ≈ 10³ Vs / J

**Stray light**
- ≤ 0.3 % with deuterium lamp
- Transmission at 310 nm with NaNO₂ solution (50 g/l)

**Dimensions**
- With housing
- Cross-section converter (outer length)
- 67 x 60 x 40 mm³
- Standard: 240 mm, available up to 1 m

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### Table: MMS 1

<table>
<thead>
<tr>
<th>Order number</th>
<th>Name</th>
<th>Wavelength range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>224000-9001-000</td>
<td>MMS 1 UV-VIS enh.</td>
<td>310 – 1100 nm</td>
<td>PDA with 256 pixels, 240 mm external fiber length</td>
</tr>
<tr>
<td>224000-9001-001</td>
<td>MMS 1 UV-VIS enh.</td>
<td>310 – 1100 nm</td>
<td>PDA with 256 pixels, 180 mm external fiber length</td>
</tr>
<tr>
<td>000000-1233-038</td>
<td>MMS 1 NIR enh.</td>
<td>310 – 1100 nm</td>
<td>S8381 PDA with 256 pixels, 240 mm external fiber length</td>
</tr>
</tbody>
</table>

### Table: MMS UV-VIS I / UV-VIS II

<table>
<thead>
<tr>
<th>Order number</th>
<th>Name</th>
<th>Wavelength range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>224000-9001-000</td>
<td>MMS UV-VIS I</td>
<td>190 – 720 nm</td>
<td>PDA with 256 pixels, 240 mm external fiber length</td>
</tr>
<tr>
<td>000000-1410-176</td>
<td>MMS UV-VIS I</td>
<td>190 – 720 nm</td>
<td>PDA with 256 pixels, 240 mm external fiber length, low solarization</td>
</tr>
<tr>
<td>000000-1090-197</td>
<td>MMS UV-VIS II</td>
<td>250 – 785 nm</td>
<td>PDA with 256 pixels, 240 mm external fiber length</td>
</tr>
</tbody>
</table>
MMS UV

Technical Data

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical entrance</td>
<td>Fiber bundle consists of approx. 15 quartz glass fibers with a 70 µm core diameter, designed as a cross-section converter Diameter: 0.4 mm f/α = 0.22 (homogeneous illumination of the acceptance angle) Mounted in an SMA connector 70 µm x 1250 µm (entrance slit)</td>
</tr>
<tr>
<td>Grating</td>
<td>Flat-field, 1084 l/mm (in the center), blazed for approx. 220 nm</td>
</tr>
<tr>
<td>Diode array</td>
<td>Manufacturer: Hamamatsu Type: S 3904-256N in special housing Number of pixels: 256</td>
</tr>
<tr>
<td>Spectral range</td>
<td>195 nm – 390 nm Specifications for the 220 nm – 390 nm range</td>
</tr>
<tr>
<td>Wavelength accuracy</td>
<td>0.2 nm</td>
</tr>
<tr>
<td>Temperature drift</td>
<td>≤ 0.005 nm/K</td>
</tr>
<tr>
<td>Spectral pixel distance</td>
<td>Δλ_pixel = 0.8 nm</td>
</tr>
<tr>
<td>Resolution</td>
<td>Δλ_FWHM = 3 nm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>≈ 10^6 V/W</td>
</tr>
<tr>
<td>Stray light</td>
<td>≤ 0.3 % deuterium lamp Transmission at 240 nm with NaI solution (10 g/l)</td>
</tr>
<tr>
<td>Dimensions</td>
<td>With housing Cross-section converter (outer length) 70 x 60 x 40 mm³ Standard: 240 mm, available up to 1 m</td>
</tr>
</tbody>
</table>
**USB / ethernet configuration**

USB and ethernet electronics are available for the standard PC interfaces. The USB based electronics are powered externally through an additional power supply (self-powered USB device). The PC is connected via a standard USB cable. We recommend a hi-speed USB port (USB 2.0 or 3.0). All electronic circuit boards are designed to be integrated into a customer’s housing. The user must provide external ±12 VDC and +5 VDC supply voltages.
The CGS UV-NIR spectrometers are a class unto themselves. They are extremely compact and robust and are available with a PDA or CCD detector upon request. These spectrometers enable users to measure with maximum quality and optimal spectral efficiency.

**Optical components in the CGS family**
- Imaging grating
- Optical entrance
- CCD or PDA as an opto-electronic exit port

The CGS comprises an imaging grating, an optical entrance and an uncooled CCD receiver array or a silicon photodiode array (PDA). The CCD receiver array has an electric shutter function which requires minimal integration times and consequently enables high sensitivity. The PDA requires an extremely low noise, ensuring a high signal-to-noise ratio — even in low lighting conditions. The core of the spectrometers is a blazed flat-field grating for light dispersion and imaging. The overall configuration results in a spectral pixel distance of 0.4 nm/pixel with a CCD detector and 0.7 nm/pixel with the PDA detector. A spectral resolution smaller than 3 nm is achieved in accordance with the Rayleigh criterion. The optical entrance is an optical slit on the module side (available in different widths) and an SMA connector on the customer side. All optical components are mounted in a housing made of aluminium.

The spectrometer modules are compact and thermally stable, making them ideal for industrial applications. Their excellent thermal stability and a very low amount of stray light ensure reliable measuring results — even in rough environments. The CGS spectrometer modules extend the MMS and MCS spectrometer module product families.

The new CGS spectrometer combines the benefits of the MMS and MCS spectrometers:
- High resolution
- High sensitivity
- Very good signal-to-noise ratio
- High dynamic range
- Small size

**Areas of application**
The areas of application for these spectrometers are diverse because of their flexible design. They can be classified in accordance with measurement principles, areas of application or the materials to be analyzed.

Yet their most important advantage is their compactness and insensitivity to external influences so that the modules can be installed in very close proximity to production. An option for on-line inspection is available for most of the applications mentioned below.

**The following modules are available:**

<table>
<thead>
<tr>
<th>Module</th>
<th>Spectral range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGS UV-NIR CCD</td>
<td>190 – 1015</td>
</tr>
<tr>
<td>CGS UV-NIR PDA</td>
<td>190 – 935</td>
</tr>
</tbody>
</table>

Email
www.zeiss.com
**CGS UV-NIR CCD**

**Technical Data**

<table>
<thead>
<tr>
<th>Order number</th>
<th>Name</th>
<th>Wavelength range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000-1794-791</td>
<td>CGS UV-NIR CCD</td>
<td>190 – 1015 nm</td>
<td>Back-thinned CCD, 2048 pixels</td>
</tr>
</tbody>
</table>

**Optical entrance**

SMA connector

50 µm optical slit (can be varied upon request)

NA = 0.22 (homogeneous illumination of the acceptance angle)

600 µm mono-fiber interface recommended for customer

**Grating**

Flat field

534nm (in the center), blazed for approx. 230 nm

**Spectral range**

190 nm – 1015 nm

**Resolution (FWHM) with 50 µm slit**

UV-VIS < 2.2 nm

NIR < 2.5 nm

**Streay light (ASTM 387-04)**

3 AU at 240 nm with deuterium lamp (absorption $A_{10}$ of NaI)

**Integration time (dependent on on-site electronics)**

min. 30 µs

**Sensor**

Hamamatsu S11156, back-thinned CCD, 2048 pixels

Detector height: 1 mm

Pixel pitch: 14 µm

**Housing size L x W x H**

78 x 30 x 75 mm³

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**CGS UV-NIR PDA**

**Technical Data**

<table>
<thead>
<tr>
<th>Order number</th>
<th>Name</th>
<th>Wavelength range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>000000-2034-897</td>
<td>CGS UV-NIR PDA</td>
<td>190 – 935 nm</td>
<td>Hamamatsu S3903, 1024 pixels</td>
</tr>
</tbody>
</table>

**Optical entrance**

SMA connector

40 µm optical slit (can be varied upon request)

NA = 0.22 (homogeneous illumination of the acceptance angle)

600 µm mono-fiber interface recommended for customer

**Grating**

Flat field

534nm (in the center), blazed for approx. 230 nm

**Spectral range**

190 nm – 935 nm

**Resolution (FWHM) with 50 µm slit**

UV-VIS < 2.0 nm

NIR < 2.0 nm

**Streay light (ASTM 387-04)**

3 AU at 240 nm with deuterium lamp (absorption $A_{10}$ of NaI)

**Integration time (dependent on on-site electronics)**

min. 500 µs

**Sensor**

Hamamatsu S3903, 1024 pixels

**Housing size L x W x H**

78 x 30 x 75 mm³
**Configuration: an overview**

<table>
<thead>
<tr>
<th>CGS UV-NIR PDA with preamplifier DZA-S3901-4 1M/03</th>
<th>CGS UV-NIR PDA with USB interface electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>DZA-S3901-4 1M/03</td>
<td>DGA-USB11/1MOS-1 with USB interface electronics</td>
</tr>
<tr>
<td>FEE-1M/NMOS-1EMB</td>
<td>USB, ethernet</td>
</tr>
<tr>
<td>16 bit / 1 MHz</td>
<td></td>
</tr>
</tbody>
</table>

**USB / ethernet configuration**

USB and ethernet electronics are available for the standard PC interfaces. The interface electronics (USB and/or ethernet) are powered externally via a power supply unit (self powered). USB-based electronics are connected with the PC via a standard USB cable. A hi-speed USB port (USB 2.0 or 3.0) is required for this configuration.

Ethernet based configurations are connected to networks via a standard ethernet cable (patch cable) or directly to PCs or laptops via a cross-over ethernet cable. All electronic circuit boards are designed to be integrated into a customer’s housing. The user must provide the external +5 VDC supply voltage.
USB / ethernet configuration

USB and ethernet electronics are available for the standard PC interfaces. The interface electronics (USB and/or ethernet) are powered externally via a power supply unit (self-powered). USB-based electronics are connected with the PC via a standard USB cable. A hi-speed USB port (USB 2.0 or 3.0) is required for this configuration.

Ethernet-based configurations are connected to networks via a standard ethernet cable (patch cable) or directly to PCs or laptops via a cross-over ethernet cable. All electronic circuit boards are designed to be integrated into a customer’s housing. The user must provide the external +5 VDC supply voltage.
The spectrometers in the MCS FLEX family feature a good resolving power in addition to their high repeatability. All optical components are firmly affixed via a central body, ensuring a robust design.

**Optical components in the MCS FLEX family**
- Imaging, aberration-corrected grating
- Fiber cross-section converter or slit as an optical entrance
- Diode array and/or a cooled back-thinned CCD as the optoelectronic exit port

In the MCS FLEX family, the different design of the central body determines the system’s application. The cross-section converter and detector are used in all the different versions.

**Central body**
The central body of the MCS FLEX spectrometers consists of a special aluminum alloy to ensure thermal stability (expansion coefficient $a \approx 13 \times 10^{-6}$). The aberration-corrected grating, the cross-section converter (or the mechanical slit) as an optical port and the detector are connected via the central body, ensuring excellent stability and reliability. The hollow body means the MCS FLEX can be used for the complete spectrum of the UV-NIR.

**Gratings**
The gratings for the MCS FLEX family are also holographically blazed flat-field gratings for optimized effectiveness. Maximum grating efficiency has been optimized for different wavelength ranges through additional ion beam etching. Even spectra over a length of 25 nm are achieved through the aberration correction of the gratings. The grating surface is dimensioned in such a way that light from the fiber can be imaged with $NA = 0.22$.

**Cross-section converter**
A fiber bundle cross-section converter further optimizes the light intensity. The linear arrangement of individual fibers forms the entrance slit (slit height is determined by the number of individual fibers, the slit width $w$ is determined by the core diameter). The slit is adjusted to the pixel size of the diode array used and to the imaging dispersion properties of the flat-field grating, enabling light intensities to reach the theoretical limit. The cross-section converter is an integral part of the spectrometer design and therefore cannot simply be altered. There is, however, the possibility of changing the length of the fiber and the entrance design. Please note that quartz fibers, such as those used on older MCS FLEX UV modules (VIS), create so-called solarization centers when irradiated with deep UV light under 220 nm. This means that the transmission of the fibers is reduced when irradiated with high-energy light. This effect is stronger and occurs more often, the shorter the wavelength (higher photon energy), the greater the intensity and the longer the exposure time. The transmission can also be limited above 220 nm up to 250 nm. This solarization effect can only be partially reversed but can be corrected via frequent reference measurements. For measurements below 225 nm, it is possible to equip the MCS FLEX modules with solarization stabilized fibers. Using a WG 225 filter with 3 mm thickness is an absolute must with standard modules.
MCS FLEX PDA
Technical Data

Optical entrance
Cross-section converter

Cross-section converter
Diameter: 0.5 mm
NA = 0.22 (consistent illumination of the acceptance angle)
Mounted in an SMA connector

Grating
Flat field

Grating

Diode array
Manufacturer: Hamamatsu
Type: S 3904-1024Q
Number of pixels: 1024

Diode array
Manufacturer: Hamamatsu
Type: S 7031-1006
Number of pixels: 1044 x 64

Spectral range
190 – 1015 nm

Wavelength accuracy
≤ 0.5 nm

Temperature drift
≤ 0.009 nm/K

Spectral pixel distance
ΔλPixel ≈ 0.8 nm

Resolution
ΔλFWHM ≈ 3 – 4 nm

Stray light
≤ 0.1 % at 340 nm with deuterium lamp
(Transmission of NaNO₂ solution, 50 g/l, 1cm)

Housing size L x W x H
160.3 x 62 x 122.2 mm

Order number Name Wavelength range Description
000000-1459-276 MCS FLEX UV-NIR 190 – 1015 nm PDA with 1024 pixels

MCS FLEX CCD
Technical Data

Optical entrance
Cross-section converter

Cross-section converter
Diameter: 0.5 mm
NA = 0.22 (consistent illumination of the acceptance angle)
Mounted in an SMA connector

Grating
Flat field

Grating

Diode array
Manufacturer: Hamamatsu
Type: S 7031-1006
Number of pixels: 1044 x 64

Diode array
Manufacturer: Hamamatsu
Type: S 3904-1024Q
Number of pixels: 1024

Spectral range
190 – 1015 nm

Wavelength accuracy
≤ 0.5 nm

Temperature drift
≤ 0.009 nm/K

Spectral pixel distance
ΔλPixel ≈ 0.8 nm

Resolution
ΔλFWHM ≈ 3 – 4 nm

Stray light
≤ 0.1 % at 340 nm with deuterium lamp
(Transmission of NaNO₂ solution, 50 g/l, 1cm)

Housing size L x W x H
160.3 x 62 x 122.2 mm

Order number Name Wavelength range Description
000000-1423-352 MCS FLEX CCD UV-NIR 190 – 980 nm With Hamamatsu CCD detector S7031 with 1024 (1044) x 64 pixels, short cross-section converter

000000-1761-535 MCS FLEX CCD UV-NIR 190 – 980 nm With Hamamatsu CCD detector S7031 with 1024 (1044) x 64 pixels, long cross-section converter

000000-1459-276 MCS FLEX UV-NIR 190 – 1015 nm PDA with 1024 pixels

000000-1423-352 MCS FLEX CCD UV-NIR 190 – 980 nm With Hamamatsu CCD detector S7031 with 1024 (1044) x 64 pixels, short cross-section converter

000000-1761-535 MCS FLEX CCD UV-NIR 190 – 980 nm With Hamamatsu CCD detector S7031 with 1024 (1044) x 64 pixels, long cross-section converter

190 - 1015 nm

190 - 980 nm

190 - 1015 nm

190 - 980 nm

190 - 980 nm

190 - 980 nm

190 - 980 nm

190 - 980 nm

190 - 980 nm

190 - 980 nm

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190 - 980 nm

190 - 980 nm
**Introduction**

**Wavelength ranges**

**MMS Family**

**CGS Family**

**MCS FLEX Family**

**Technical Data**

**On-site electronics**

**PGS Family**

**Software**

**Areas of application**

**Definitions and explanations**

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**Configuration: an overview**

MCS FLEX PDA

<table>
<thead>
<tr>
<th>DZA-S3901-4</th>
<th>FEE-1M/MDGS-D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB/ethernet</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DZA-S3901-4</th>
<th>FEE-1M/MDGS-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB/ethernet</td>
<td></td>
</tr>
</tbody>
</table>

**USB / ethernet configuration**

USB and ethernet electronics are available for the standard PC interfaces. The USB-based electronics are powered externally through an additional power supply (a self-powered USB device). The PC is connected via a standard USB cable. We recommend a hi-speed USB 2.0 port (compatible with a standard USB 1.1).

High-speed USB communication is required to use the fast FEE-1M. All electronic circuit boards designed to be integrated into a customer’s housing. The user must provide the external +5 VDC supply source.

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**Front end electronics**

MCS FLEX PDA

<table>
<thead>
<tr>
<th>FEE-1M/MDGS-D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 bit 1 MHz</td>
</tr>
</tbody>
</table>

**On-site electronics**

16 bit 100 kHz

DZA-S3901-4 D04

DZA-S3901-4 STD

FEE-1M/NMOS-D1

FEE-1M/NMOS-1

USB/ethernet

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**Email**

www.zeiss.com
USB / ethernet configuration

USB and ethernet electronics are available for the standard PC interfaces. The USB-based electronics are powered externally through an additional power supply (a self-powered USB device). The PC is connected via a standard USB cable. We recommend a high-speed USB 2.0 port (compatible with a standard USB 1.1). All electronic circuit boards designed to be integrated into a customer’s housing. The user must provide the external +5 VDC supply voltage.
The spectrometers in the PGS family are designed to be used in NIR. InGaAs (indium gallium arsenide) is used as a detector material in this wavelength range. The special combination of an aspheric collimator lens and a focusing lens enables the use of optimized plane gratings for NIR while retaining good flat field correction of the spectral imaging. To ensure long-term stability, all optical components are firmly affixed to each other.

**Optical components in the PGS family**
- Blazed plane grating
- Aspheric lenses
- Mono-fiber with a slit as an optical entrance
- Cooled InGaAs photodiode array as an optoelectronic output

**Central body**
In the PGS family, a special aluminum alloy (expansion coefficient $\alpha \approx 13 \times 10^{-6}$) is used for the central body. This body is the carrier for the blazed grating and the aspheric collimator and focusing lens. The input fiber and the detector are firmly affixed to the central body, guaranteeing excellent stability.

**Gratings**
The gratings used in the PGS family are mechanically ruled or holographically exposed. The maximum of the efficiency is modified to the special wavelength range in NIR. With the free diameter, the grating surface is dimensioned in such a way that the light from a fiber can be imaged with a NA of up to 0.37.

**Input fiber**
The light is generally coupled via a mono quartz fiber. These fibers have a diameter of 600 µm and a NA = 0.22. There is a slit at the end of the fiber with a height of 500 µm (NIR 1.7) and/or 250 µm (NIR 2.2). The slit heights are adjusted to the pixel heights in the InGaAs arrays. A cross-section conversion of the light for creating a higher entrance slit, such as on modules with silicon detectors, is not necessary because of the lower detector height of the InGaAs arrays.

**Detector**
InGaAs detectors are used in the near infrared range. For the PGS NIR modules, arrays with InGaAs are used for the range up to 1.7 µm and modules with extended InGaAs are used for the range up to 2.2 µm. Arrays are also available with an element number of 256 or 512 (only 1.7 µm pixels). For the extended InGaAs arrays, an order-sorting filter is applied to the array, depending on the wavelength range, to suppress the 2nd diffraction order.

The following modules are available:

<table>
<thead>
<tr>
<th>Module</th>
<th>Spectral range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGS NIR 1.7-256 UC</td>
<td>960 – 1690</td>
</tr>
<tr>
<td>PGS NIR 1.7-256</td>
<td>960 – 1690</td>
</tr>
<tr>
<td>PGS NIR 1.7-512</td>
<td>960 – 1690</td>
</tr>
<tr>
<td>PGS NIR 2.0-256</td>
<td>1340 – 2000</td>
</tr>
<tr>
<td>PGS NIR 2.2-256</td>
<td>1000 – 2150</td>
</tr>
</tbody>
</table>

**Areas of application**
- NIR applications
- Material analysis
- Food industry
- Environmental monitoring
- Biochemistry

**Definitions and explanations**
- NIR: Near Infrared Range (1000 nm to 2500 nm)
- InGaAs: Indium Gallium Arsenide
- NA: Numerical Aperture
- UC: Uncooled
- C: Cooled
PGS NIR 1.7 -512
Technical Data

- **Optical entrance**: Fiber consists of Infrasil quartz glass
- **Input**: round
- **Output**: linear
- **Fiber**: 950 nm edge fiber
- **Grating**: Plane grating, 484 l/mm, blazed for approx. 1.2 µm
- **Diode array**: Manufacturer: Hamamatsu, Type: S9204, Number of pixels: 512
- **Spectral range**: 960 – 1690 nm
- **Wavelength accuracy**: ± 1 nm
- **Temperature drift (10 – 40°C)**: ≤ 0.012 nm/K
- **Spectral pixel distance**: ∆λpix ≈ 1.5 nm
- **Resolution**: ∆λres ≈ 7 nm
- **Stray light**: ≤ 0.1 % as transmission of 10 mm of water at 1405 nm (measured using a halogen lamp)
- **Weight**: approx. 590 g
- **Operating temperature**: 0 – 40°C (standard, depending on cooling electronics)
- **Minimal bending radius of fiber (for storage and transport)**: 50 mm
- **Minimal bending radius in operation (for wavelength accuracy)**: 100 mm

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PGS NIR 1.7 -256
Technical Data

- **Optical entrance**: Fiber consists of Infrasil quartz glass
- **Input**: round
- **Output**: linear
- **Fiber**: 950 nm edge fiber
- **Grating**: Plane grating, 484 l/mm, blazed for approx. 1.2 µm
- **Diode array**: Manufacturer: Hamamatsu, Type: S 9203-256, Number of pixels: 256
- **Spectral range**: 960 – 1690 nm
- **Wavelength accuracy**: ± 1 nm
- **Temperature drift (10 – 40°C)**: ≤ 0.012 nm/K
- **Spectral pixel distance**: ∆λpix ≈ 3 nm
- **Resolution**: ∆λres ≈ 8 nm
- **Stray light**: ≤ 0.1 % as transmission of 10 mm of water at 1405 nm (measured using a halogen lamp)
- **Weight**: approx. 590 g
- **Operating temperature**: 0 – 40°C (standard, depending on cooling electronics)
- **Minimal bending radius of fiber (for storage and transport)**: 50 mm
- **Minimal bending radius in operation (for wavelength accuracy)**: 100 mm
PGS NIR 2.0-256
Technical Data

Optical entrance
Fiber consists of Infrasil quartz glass
Diameter: 0.6 mm
Length 300 mm
NA = 0.22 (homogeneous illumination of the acceptance angle)
Mounted in an SMA connector
Slit width: 80 µm

Filter
1350 nm edge filter

Grating
Plane grating,
484 l/mm, blazed for approx. 1.4 µm

Diode array
Manufacturer: Hamamatsu
Type: G 9206
Number of pixels: 256

Spectral range
1340 – 2000 nm

Wavelength accuracy
± 1 nm

Temperature drift (10 – 40°C)
< 0.012 nm / K

Spectral pixel distance
∆λPixel ≈ 3 nm

Resolution
∆λFWHM ≈ 8 nm

Stray light
≤ 0.1 % as transmission of 10 mm of water at 1405 nm (measured using a halogen lamp)

Weight
approx. 590 g

Operating temperature
0 – 40°C (standard, depending on cooling electronics)

Storage temperature
-40 – +70°C

Minimal bending radius of fiber
(for storage and transport)
50 mm

Minimal bending radius in operation
(for wavelength accuracy)
100 mm

Order number Name Wavelength range Description
000000-1396-757 PGS NIR 2.0-256 1340 – 2000 nm NIR spectral sensor, Peltier cooled Extended InGaAs PDA up to 2.2 µm 256 pixels, dispersion: 1.5 nm/pixel, external fiber length: 300 mm

PGS NIR 2.2-256
Technical Data

Optical entrance
Fiber consists of Infrasil quartz glass
Diameter: 0.6 mm
Length 300 mm
NA = 0.22 (homogeneous illumination of the acceptance angle), mounted in an SMA connector
Slit width: 80 µm

Filter
950 nm edge filter

Filter for 2nd order on detector
Yes

Grating
Plane grating,
300 l/mm, blazed for approx. 1.4 µm

Diode array
Manufacturer: Hamamatsu
Type: G 9206
Number of pixels: 256

Spectral range
1000 – 2150 nm

Wavelength accuracy
± 1 nm

Temperature drift (10 – 40°C)
< 0.012 nm / K

Spectral pixel distance
∆λPixel ≈ 5 nm

Resolution
∆λFWHM ≈ 16 nm

Stray light
≤ 0.1 % as transmission of 10 mm of water at 1405 nm (measured using a halogen lamp)

Weight
approx. 590 g

Operating temperature
0 – 40°C (standard, depending on cooling electronics)

Storage temperature
-40 – +70°C

Minimal bending radius of fiber
(for storage and transport)
50 mm

Minimal bending radius in operation
(for wavelength accuracy)
100 mm

Order number Name Wavelength range Description
000000-1396-757 PGS NIR 2.0-256 1340 – 2000 nm NIR spectral sensor, Peltier cooled Extended InGaAs PDA up to 2.2 µm 256 pixels, dispersion: 1.5 nm/pixel, external fiber length: 300 mm
### PGS NIR 1.7-256 UC

**Technical Data**

<table>
<thead>
<tr>
<th>Optical entrance</th>
<th>Input: round</th>
<th>F5MA 905</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output: linear</td>
<td>950 nm edge fiber</td>
</tr>
</tbody>
</table>

**Filter**

- Plane grating, 484 l/mm, Blazed for approx. 1.2 µm

**Grating**

- Plane grating, 484 l/mm, Blazed for approx. 1.2 µm

**Diode array**

- Manufacturer: Hamamatsu
- Type: G9211-01SP
- Number of pixels: 256

**Spectral range**

- 960 – 1690 nm

**Wavelength accuracy**

- ± 1 nm

**Temperature drift (10 – 40°C)**

- < 0.012 nm/K

**Spectral pixel distance**

- ∆λPixel ≈ 3 nm

**Resolution**

- ∆λFWHM ≈ 8 nm

**Stray light**

- ≤ 0.1 % as transmission of 10 mm of water at 1405 nm (measured using a halogen lamp)

**Weight**

- approx. 590 g

**Operating temperature**

- 0 – 40°C (standard, depending on cooling electronics)

**Storage temperature**

- -40 – +70°C

---

**Order number** | **Name** | **Wavelength range** | **Description**
---|---|---|---
000000-2109-070 | PGS NIR 1.7-256 UC | 960 – 1690 nm | NIR spectral sensor, uncooled Extended InGaAs PDA up to 1.7 µm 256 pixels, dispersion: 3 nm/pixel, external fiber length: 300 mm
Configuration: an overview

**PGS NIR 1.7-256 UC**

**PGS NIR 1.7-256**

**PGS NIR 1.7-512**

**PGS NIR 2.0-256**

**PGS NIR 2.2-256**

**FEE-1M/NIR-4**

USB/ethernet

**USB / ethernet configuration**

USB and ethernet electronics are available for the standard PC interfaces. The USB-based electronics are powered externally through an additional power supply in a self-powered USB device. The PC is connected via a standard USB cable. We recommend a high-speed USB 2.0 port (compatible with a standard USB 1.1).

The fast FEE-1M requires high-speed USB communication. All electronic circuit boards designed to be integrated into a customer’s housing.

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**Constraints**

- **Peltier controller**
- **Supply voltage**
- **Front and electronics**
- **Interface electronics**
- **On-site electronics**
- **Host PC connected to USB port or ethernet network**
- **Cable set: CAB-NIR 1M set**
- **Cable set: CAB-USBx IF**
- **Cable set: CAB-USBPS IF**
- **Cable set: CAB-USBx IF**
- **Cable set: CAB-USBPS IF**

---

*Not necessary for PGS NIR 1.7-256 UC*
The architecture of the software products for capturing and processing spectral data is based on a modular structure. This ensures that the software meets diverse, customer-specific specifications and enables different hardware configurations to be adjusted flexibly. For the various operating electronics units, device drivers are available for Windows 2000, XP and Vista.

The universal Aspect Plus program package featuring comprehensive functions is available along with the drivers for the PC bus interface. A programming interface for the SDACQ 32 MP function library is also offered to ensure easy integration into customer-specific applications. This interface directly supports C/C++, Visual Basic and Delphi, and a LabVIEW™ driver for programming in a LabVIEW™ environment. It is possible to program with finished menu structures for data capture by using the SDPROC32 function library for data capture, configuration and entering parameters.

The SDACQ32MP function library directly addresses these device drivers and supplies a hardware-independent collection of functions, enabling the configuration of the on-site electronics and spectral data capture.

Software Solutions
Directly in the process

Modular software package for spectral analysis
Aspect Plus

General
Aspect Plus is the complex and flexible modular spectral analytical software for MS Windows with special options available as add-ons. Spectral measurements with the spectrometers from ZEISS can be performed and evaluated using Aspect Plus. Comprehensive functions – from the measurement all the way to the formatted printout – simplify analytical evaluation.

Benefits
- Available in multiple languages (English, French, German, Italian, Portuguese, Spanish), other languages to follow
- More than one spectrometer can be controlled simultaneously
- Supports calibrations (chemometric models) created using standard chemometric software such as GRAMS, UNICRAMBLE® or UCAL
- Filter function eliminating outlying spectra
- Communication via OPC for integration into production line inspection
- Use of pre-defined products or creation of user-specific products, as required
- Calculations, evaluation and integration into an upstream process environment
- Control of results via Digital I/O

<table>
<thead>
<tr>
<th>Order number</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>263259-5022-020</td>
<td>Aspect Plus</td>
<td>Windows spectrometer software</td>
</tr>
<tr>
<td>030030-1242-601</td>
<td>Aspect Plus driver for PCs and USBs</td>
<td>Aspect Plus driver for Windows 2000 and XP tec5 electronics</td>
</tr>
</tbody>
</table>

Aspect Plus software package + driver

Interface

SDACQ32MP and SDPROC32P function libraries

Instrument driver

User-specific applications

Instrument driver for LabVIEW™

User-specific applications
The areas of application for these spectrometers are diverse because of their flexible design. They can be classified in accordance with measurement principles, areas of application or the materials to be analyzed. Compactness and insensitivity to external influences are crucial so that modules can be installed in close proximity to production. An on-line control option is provided in most of the applications mentioned below.

**Measuring principles:**
1. Emission
2. Diffuse reflection
3. Reflection
4. Transmission – absorption
5. White light interference

**Emission**
A part of the light is injected into the spectrometer to determine the spectral emission of a light source. In many cases, the coupling fiber bundle only needs to be brought close to the light source because of the high light sensitivity. An achromatic converging lens can be used for optimization.

**Examples**
- Monitoring illuminations (aging)
- Determining the wavelength of LEDs or (tunable) lasers
- Luminescence, fluorescence
- Monitoring the solar spectrum, burns, discharges or plasmas
- Determining the temperature T as per Wien’s displacement law: e.g.: 3000 K <— > 966 nm

**Diffuse reflection**
The diffuse reflection (from rough surfaces) provides information on the color of the surface. In addition to the spectrometer, the light source and the placement (angle to surface normal) of the spectral sensor are important.

**Requirements**
- The wavelength accuracy is very high for the size of the module. Enabling, through a sub-pixel resolution procedure, an exact identification of the wavelength from light sources which emit a line, e.g. LEDs (calibration).
- The spectrometer modules are not suitable for analyzing emissions which contain many spectrally adjacent lines.

**Reflection**
Reflection is a special case of diffuse reflection and refers to the directionally reflected light from ‘smooth’ low-scatter surfaces.

**Requirements**
The spectrometer modules have been specially developed for color measuring technology. Their high repeatability and light intensity at a moderate spectral resolution meet the specifications exactly.

**Transmision**
Radiographic material with the thickness d provides information on the spectral dependence of the absorption constant σ (I = I₀ x e⁻α x d).

**Requirements**
- High absolute accuracy of the wavelength is also necessary to accurately determine the thickness. The maximum measurable thickness is coupled with the spectral resolving power (split of two interference maxima). The minimal thickness with the spectral range to be captured displays a least a half-period. Absolute intensity values must be known to determine even thinner layers (performing an evaluation of less than a half period).

**White light interference**
Interferences are the result of radiating white light on optically transparent interfaces because, for certain wavelengths, the optical path difference is exactly the multiple of the optical layer thicknesses n x d (λ₁, λ₂: position of the extrema; distance: one period). If the refractive index n is known, then the geometric layer thickness d can be determined. The fiber interface ensures easy coupling to microscopes or flanging onto coating systems. Inversely, if layer thickness d is known, then the dispersion n (λ) can be determined.

**Requirements**
- Performing layer thickness measurement on photo resists and dielectric layers
- Performing quality assurance in the petrochemical industry

**Examples**
- Determining the sugar and alcohol content in beverages
- Determining the concentration of liquids
- Performing the concentration of liquids
Definitions and Explanations of Terms

One of the most important criteria when selecting a spectrometer is the spectral range which the spectrometer must cover. It is usually clear what range is required. However, the two other important criteria for a spectrometer – the spectral and the intensity-related (dynamic) resolution – are not usually clearly defined.

Spectral resolution

The following four terms refer to ‘spectral’ resolution:

1. Rayleigh criterion – ΔλRayleigh (DIN standard)

2. Wavelength range

3. Peak resolution

4. Pixel dispersion – Δλpixel

A meaningful definition results from the application. A spectrometer is essentially used to perform three different jobs. These tasks may, of course, overlap:

1. Splitting two or more lines within a spectrum – analyzing compounds

2. Determining the line form – usually the half-value width or full width at half maximum – ΔλFWHM

3. Measuring a line with respect to peak wavelength and intensity at the maximum – e.g. determining emissions.

Spectral resolving power

The Rayleigh criterion is relevant for splitting spectral lines as per DIN. This shows how large the spectral distance of two lines ΔλRayleigh must be so that each line can be recognized as separate from the other. The spectral width of the individual lines Δλpixel (see above) must be significantly less than their distance. This is the only significant definition for the spectral resolving power.

2 lines with ΔλRayleigh = 1 nm are split if

Δλpixel ≥ 19 %

Spectral line width

The widening of the line via the spectrometer must be less than the spectral width of the line itself so that the width of a spectral line Δλresolution can be measured. It is important to know how the expansion of Δλresolution created by the spectrometer. This property is related to the Rayleigh criterion:

Δλresolution = ΔλRayleigh ∙ (λ²/ΔλRayleigh²)

Δλresolution = 0.8 ∙ ΔλRayleigh

Spectral features of diode array spectrometers (DAS)

Wavelength accuracy

To determine the absolute spectral position λ – with a certain accuracy Δλ – of an individual line, a spectrometer with at least this absolute wavelength accuracy Δλmin is required. This parameter depends on the position accuracy of the readout elements (pixels or slit/detector) and the stability of this position (see below) characterized by the reproducibility. In contrast, the absolute wavelength accuracy only depends indirectly on the dispersive and focal properties of the spectrometer and is not a ‘resolution’ in the traditional sense. The stability (or repeatability) of a spectral sensor depends on the mechanical stability and the temperature-determined wavelength drift. The former is completely noncritical for spectrometer modules and the drift is practically negligible.

Dispersion

The specification Δλ/pixel (= Δλpixel) has nothing to do with spectral resolution. Instead, it is just the linear dispersion of a diode array spectrometer. Pixel dispersion and spectral resolution are linked via the width of the entrance slit and the imaging properties; if the entrance slit is imaged on approx. 3 pixels, the triple pixel dispersion corresponds approximately to Δλresolution.

The position of the maxima corresponds relatively exactly to the central wavelengths of the pixels displayed.

If, however, the maximum of a line is imaged onto the dividing line of two pixels (i.e., then four pixels are required to establish a clear resolution in pixel intensities. Both pixels exhibit roughly the same intensity so that a reduction to 1% is only displayed in the next pixel (i.e., in this case, the real maxima are separated by less than three pixels. However, the DAS displays a spectral distance of 3 x Δλresolution because a diode array only captures discrete values with the step size of the pixel dispersion. A total of four pixels are required for the evaluation.

Sub-pixel resolution

Determining the peak wavelength λmax (and/or peak intensity I max) requires that the spectral line to be measured be imaged onto at least three pixels. With three intensity value pairs per pixel I1, I2, I3 the following properties are of interest for measuring intensities:

• Lowest detectable light quantity or sensitivity

• Linearity

• Signal stability

• Detection range or dynamic range

• Unnarrowing

Absolute:

• Lowest detectable light quantity or sensitivity

Parabola equation

\[ f(x) = a x^2 + b x + c \]

Coefficients:

- \[ a = \frac{(I_3 + I_1 - 2 I_2)}{2 \Delta \lambda^2} \]
- \[ b = \frac{(I_1 + I_3 - 2 I_2)}{\Delta \lambda} \]
- \[ c = I_2 - a \times l_2^2 - b \times l_2 \]

Maximum at \[ \lambda_{max} = \frac{-b}{2a} \]

Intensity resolution

The following properties are of interest for measuring intensities:

Relative:

- Smallest detectable change

- Signal stability

- Detection range or dynamics

- Unnarrowing

Absolute:

- Lowest detectable light quantity or sensitivity
Accuracy

Measurements of minimal changes and stability depend directly on each other and are essentially determined by the noise with-in the electronics because most spectrometers ensure a stable ‘light path’. As well as all sizes, it is important how a value – in the strict sense of the word – is determined. For the spectrometer module specifications, e.g. a 10 ms integration time is selected and the standard deviation Δν is calculated above 20 captures. This supplies a measure for the accuracy Δν which can be used to determine an intensity value.

\[ Δν = \frac{I}{ν} = Δν \]

Dynamics and intensity changes

The dynamic is understood as the relationship between the saturation level and the noise. From 16384 steps, the slightest measurable change is thus 1/16384 of the saturation signal. The photodiode arrays do not show any deterioration in the signal-to-noise ratio. Only the dark current IDark increases with rising temperature, resulting in a reduction of the dynamic range. This is why detectors – in particular InGaAs diode arrays – are often cooled. With this in mind, it should be noted that the light quantities to be measured are also subject to fluctuations. The instability of the illumination source is often the limiting factor.

\[ ΔI = I_{\text{Noise}} = Δν \]

\[ \text{outside of the specified range is a stronger stray light} \]

Stray light

Specifying the stray light value only makes sense in conjunction with the measurement instructions. Stray light values for the spectrometer modules are determined with different light sources to determine the different spectral components in stray light and/or false light: a deuterium lamp for the UV range and a halogen lamp for the VIS-NIR range.

\[ \text{stray light is the result of the numeric aperture (NA).} \]

Stray light affects the dynamic range because the full dynamic range is no longer available due to false light. Changes in the causative radiation only break through in relation to the stray light proportion. If the stray light proportion is at 1% of the effective radiation means a change of 10⁻⁴. If the causative radiation is not used, then the proportion can be further reduced via filtering. In the example described, a blockage of 10⁻⁴ leads to a total change of 10⁻⁴. There are only small limitations to measuring minute changes because the noise is usually much stronger. The stray light proportion can be calculated out if the cause of the signal is known.

Optical interface

Interfaces must be defined mechanically and optically. The SMA plug-in connector – such as that used on all modules – is useful for industrial use in a plastic, resulting in a clear interference along with the well-defined etendue of a fiber bundle.

Diode array spectrometer optimization

In order to optimize the existing light source (fiber, lamp, imaging system), it is recommended that the corresponding etendue be determined first. The following coupling efficiency can be estimated through the comparison with the MMS etendue due. 4.4% Fresnel reflection loss (index jump at the glass fiber) must be considered.

\[ \text{coupling efficiency} \]

\[ \text{Transmission increase} \]

Assuming the beam is round, then an increase in transmission of \( \eta_{\text{MMS}} \), \( \eta_{\text{QSW}} \) is achieved by using a cross-section converter (CC) as compared to the classical slit. This can be calculated using the ratio of the light transmitted via the QSW to the light transmitted via a rectangular slit.

With the CSC, the transmitted portion through the fill factor is \( \eta_{\text{QSW}} \). The fill factor is defined as an optically effective surface \( A_{\text{eff}} \) with respect to the illuminated entire surface \( A_{\text{ill}} \). In the case of the QSW, the product of the fiber core cross-section with the diameter \( d_{\text{F}} \) and the number of fibers \( N_{\text{F}} \) at the slit, the surface from slit-width b and the slit height h. The entire surface is the circular surface with a diameter \( d_{\text{F}} \).

\[ \text{QSW etendue} \]

\[ \text{Diode array spectrometer optimization} \]

In order to select the most effective elements (blazed grating, a trapezoidal enter slit) and the dispersion, imaging properties, entrance slit, pixel size and pixel distances must be evaluated in the first approximation that with monochromatic light – more than 2 pixels are ill-illuminated for the spectral resolution. The grating imaging 1:1 in the first approximation, e.g. the entry slit should be 2 to 3 pixels wide. If more pixels are illuminated, the signal-to-noise ratio and the sensitivity become worse (1 pixel captures a bandwidth that is too narrow). If fewer than 3 pixels are illuminated, the wavelength accuracy becomes worse. That is why a selection of 70 µm individual fibers for the QSW on the MMS modules is nearly perfect for a pixel width of 25 µm. The number of fibers is the result of the pixel height divided by the external diameter of the fibers.
Introduction
Wavelength ranges
MMS Family
CGS Family
MCS FLEX Family
PGS Family
Software
Areas of application
Definitions and explanations

The moment you achieve absolute confidence.
This is the moment we work for.