MMS - Spectral Sensors

An *Extended* Introduction

Content

- Task
- Design and Basics
- Parts
- Features
- Overview of Current Modules
- Driving Electronics
- Forecast

Task

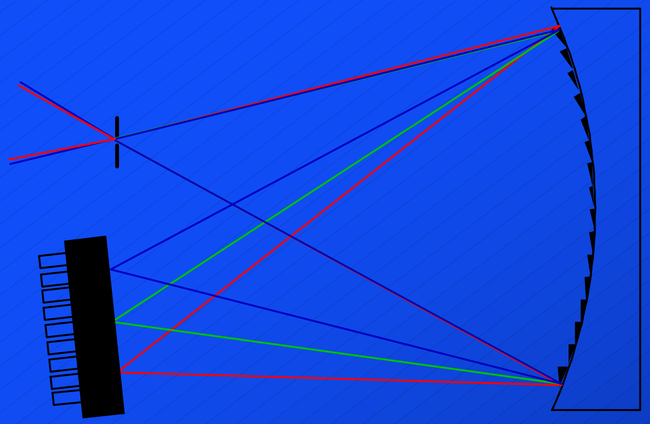
- Fast and reliable collection of complete spectra
  obtainable by
- Simultaneous Spectrometers

Solution

- Reliable and compact design
- ⇒
- Transformation of a classical spectrometer
  into a
  Spectral Sensor

Principal Layout

- Optical Input
- Imaging grating
- Photo diode array

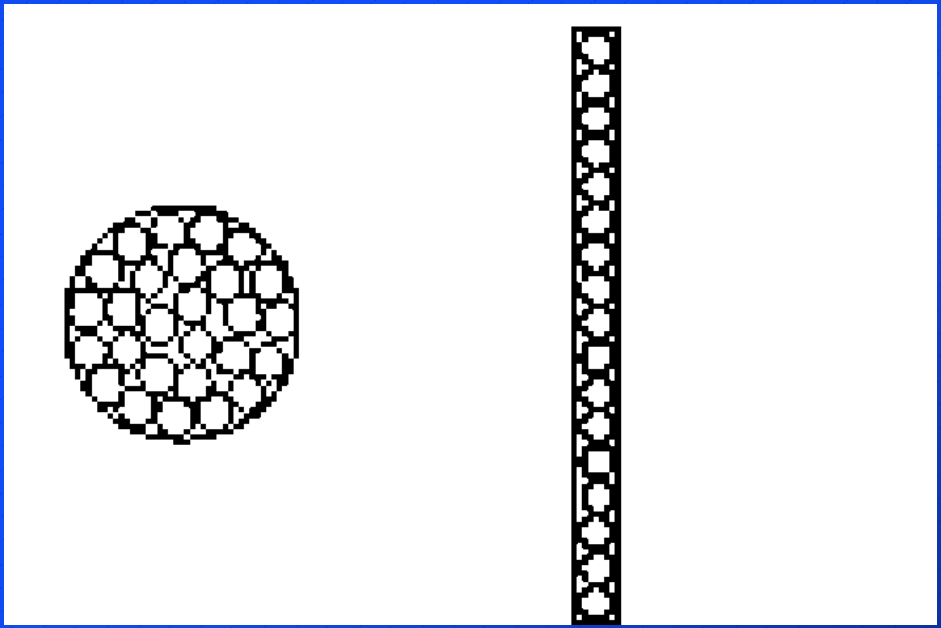


Design Goals

- Reliable, permanently alligned
  - No movable parts
- Fast - Simultaneous read-out
- Sensitive - Optimized light throughput
- Compact

Optical Input

- Fiber cross-section converter
- SMA connector
- NA = 0.22
- ∅ = 0.5mm



Optical Input 2

- Width b_{Slit}
- Height h_{Slit}

- $3 \times b_{Pixel} \approx b_{Slit}$
  $= \varnothing_{Fiber}$
- $h_{Pixel} = h_{Slit}$
  $= N_{Fiber} \times \varnothing_{Fiber}$

- Effective Area A_{eff}
- $A_{eff} = b_{Slit} \times h_{Slit}$

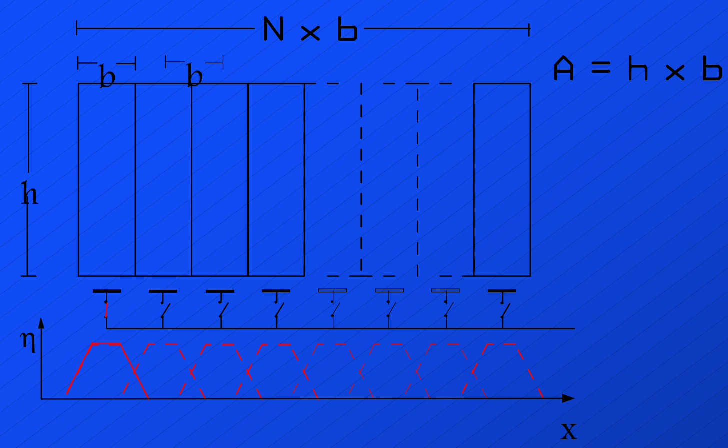
  - 1:1 Imaging

Imaging Grating

- Holographic recording
- Flat-field design
- Imaging corrected
- Blazed = efficiency optimized
- $D/f = (2x)\ NA_{Fiber}$

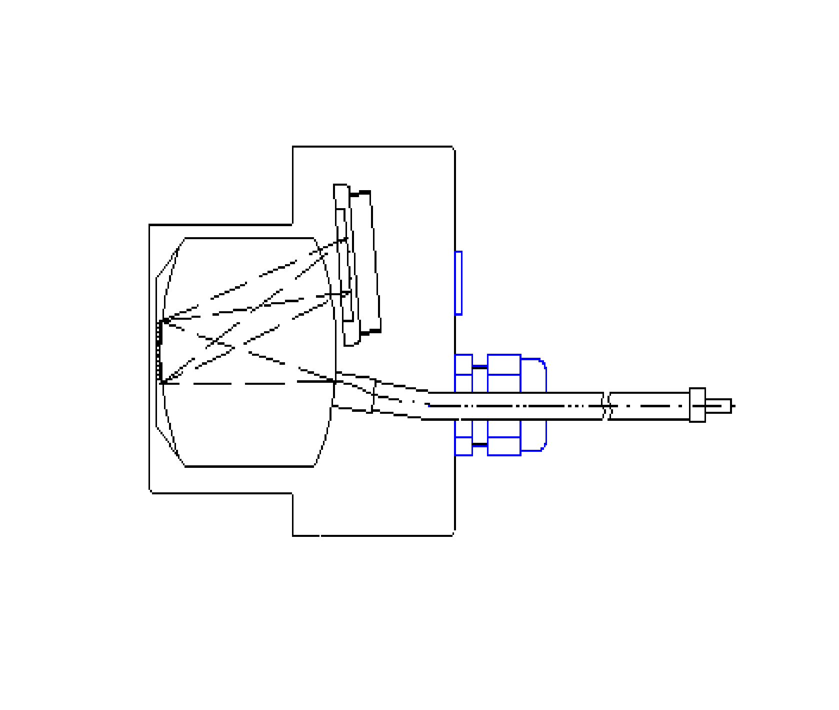
Si Photo Diode Array

- Large pixel area
- 100% fill factor
- Pitch: 25µm
- Height: 2500µm
- Number of Pixel:
  128 ... 1024
- UV-grad*
  - * NIR enh. quality possible



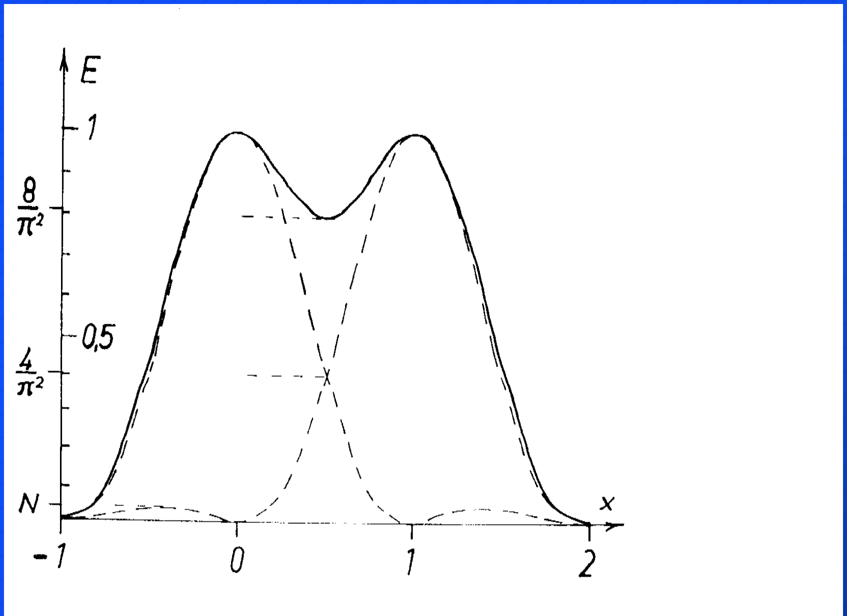
Spectrometer

- All parts glued together
- Integrated preamplifier
- Standard interfaces



Spectral Resolution

- Rayleigh Criterion
- FWHM
- Bandwidth
- Sub-Pixel Resolution
- Reproducibility



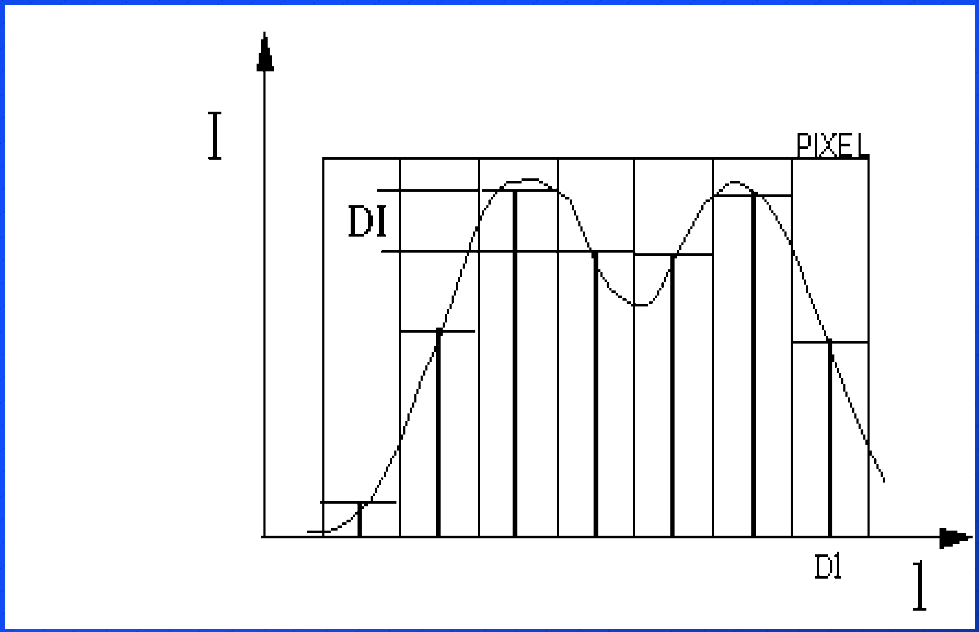
Spectral Resolution DAS

- Rayleigh Criterion
- FWHM ≈ Bandwidth
- Sub-Pixel Res.
- Reproducibility / Read-Out Accuracy

- $\Delta\lambda_{Rayl.} \approx 3 \times \Delta\lambda_{Pixel}$
- $\Delta\lambda_{FWHM} \approx 0.9 \times \Delta\lambda_{Rayleigh}$
- $\Delta\lambda_{SPR} \approx 0.1 \times \Delta\lambda_{Pixel}$
- $\Delta\lambda_{abs}$,(ΔI)

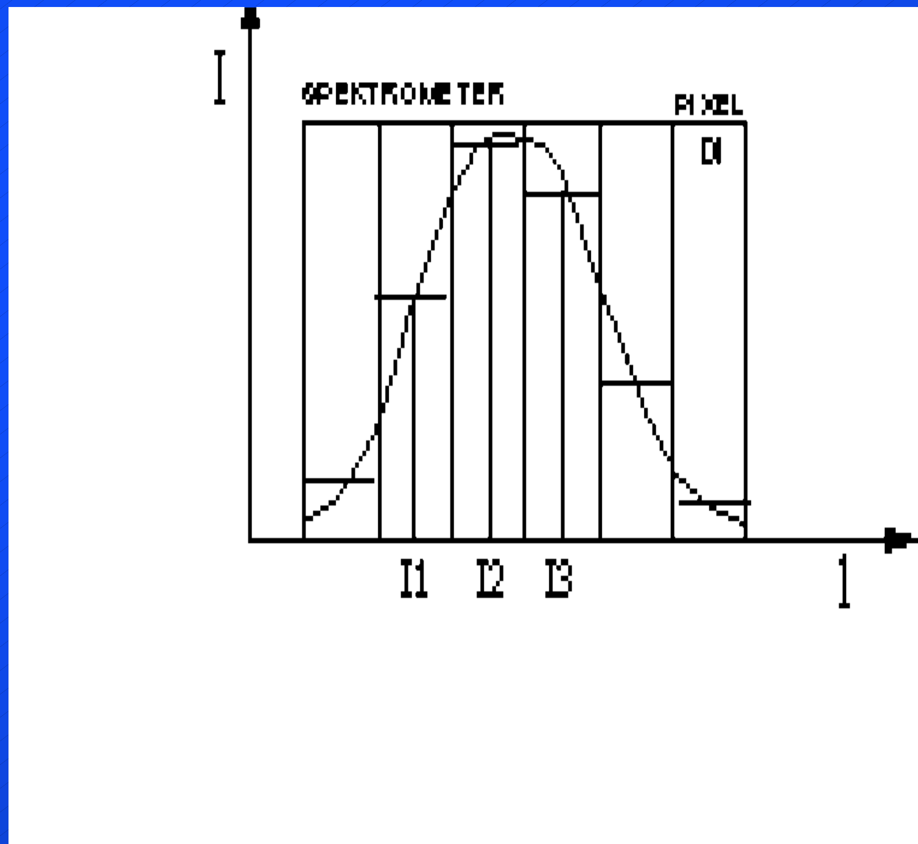
Rayleigh Criterion DAS

- $\Delta\lambda_{\text{best case}} =$
  $2 \times \Delta\lambda_{\text{Pixel}}$
- $\Delta\lambda_{\text{worst case}} =$
  $3 \times \Delta\lambda_{\text{Pixel}}$



Sub-Pixel Resolution

- Parabolic Fit: $I(\lambda) = a\,\lambda^2 + b\,\lambda + c$
  - $a = (I_3 + I_1 - 2I_2)/2\Delta\lambda^2$
  - $b = (I_3 - I_1)/2\Delta\lambda - 2a\lambda_2$
  - $c = I_2 - a\lambda_2^2 - b\,\lambda_2$
- $\lambda_{max} = -b/2a$
- Fit Procedures for Calibration



Intensity Resolution

- Dynamic Range
- Stability
  = Stand. Deviation
  = Noise
  = Sensitivity
- Dark Current
- Linearity

- Signal / Noise
- ΔI = N.E.P.
- $I_{Dark} = f(T, t_{int})$

Intensity Accuracy

- Dynamic
  - Signal / Noise
  - ADC
  - Sensitivity
  - Linearity
- False Light
  - Straylight
  - Other Orders

- S / N
- ADC ≥ S/N
- ΔI = 1 Count
- ΔL < 1%

- Grating is Source
- Blocking Filter
- Structurization

Features

- Robust
- Permantly Calibrated
- High Dynamic Range
- High Light Sensitivity
- High Reproducibility
- Low Temperature Drift

History

- End of 70th
  - Flat-Field-Grating + Dioden Arrays
- 1985 - MCS-Module
- 1993 - MMS 1
- 1995 - MMS UV-VIS
- 1996 - MMS UV
- 1997 - MMS NIR

Overview Modules

Name	#Pixels	λ_{Start}/nm	λ_{end}/nm	Resol../nm
MMS 1	256	305	1100	10
MMS UV-VIS	256	190	740	7
MMS UV	256	200	400	3
MMS NIR	128	900	1680	18
MCS UV-NIR	1024	200	1020	2,5
MCS UV-VIS	512	200	620	2,5
MCS VIS	512	360	780	2,5
MCS VIS-NIR	512	680	1100	2,5

Comparison MMS - MCS

Figure	MMS	MCS
Spectral Range	UV - NIR	UV - IR
Resoltution	Low	High
Accuracy	High	Very High
Sensitivity	High	Low
False Light	Moderate	Low
Size/Weight	Small	Medium

Driving

- Clock Rate f_{Clock}
- Integration Time = Exposure Time
- Measurement time
- Measurement Rate (Speed)

- $t_{int,min} \geq N_{Pixel}/f_{Clock}$
- $t_{int,max}$ limited by I_{Dark}
- $t_{total} = N_{cycle} \times t_{int}$
- $f_{Rate} = 1/t_{total}$

Overview Driving Electronics

Figure	CZ 12-Bit	tec5	CZ MCS
ADC	12 Bit	15 Bit	16 Bit
Noise	1 Count	2 Counts	2 Counts
$t_{int,min}$	10 (5) ms	4ms	3ms
$t_{int,max}$	0.65s	6s	5s
Interface	XT or PCMCIA	AT PC/104	AT or PCMCIA
Multiple Modules	No	4	Cascading Possible

Intensity Accuracy 2

- Signal should be high - Throughput!
- Besides hardware design "intelligent" software design should be applied
- Long-term stability is difficult to check
- Improvement by accumulation of measurements
- Don't forget light source stability!

Forecast

- MMS NIR 2.4 (extented + cooled)
- MMS MIR for Mid-IR-Range
- Low-cost modules
- MCS with higher resolution