AMBER Consortium

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OCA Observatoire de la Côte d'Azur
LAOG Laboratoire d'Astrophysique Observatoire de Grenoble
MPIfR Max Planck Institute für Radioastronomie
OAA Osservatorio Astrofisica di Arcetri

VERY LARGE TELESCOPE

AMBER
Spectrograph
Lower Level Specifications

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Change record

Issue	Date	Section/Page affected	Reason/ Initiation/Remarks
1.0	06/03/2000	All	First issue
2.0	02/11/2000	Chapter 3	Specification on the number and the sizes of the slits of the INW
		Chapter 4	Specification on the number and the shapes of the pupil masks
		Chapter 6	Only three dispersion elements are necessary
		All	All reference about the interface between SPG and the other sub-systems are described in the “AMBER interface control document”

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1 INTRODUCTION

1.1 PURPOSE

This document defines the specifications for the spectrograph.

1.2 APPLICABLE DOCUMENTS

[1] VLT-ICD-ESO-15000-1826 Interface Control Document between VLTI and its Instruments

[2] VLT-ICD-ESO-15000-1918 Functional Description of the VLTI

1.3 REFERENCE DOCUMENTS

[3] VLT-PLA-AMB-15830-0001 AMBER Product tree

[4] VLT-TRE-AMB-15830-0001 AMBER Instrument Analysis Report

[5] VLT-SPE-AMB-15830-0004 AMBER Instrument Conceptual Design

[6] VLT-TRE-AMB-15830-20000-0001 AMBER Spectrograph Design Report

[7] VLT-ICD-AMB-15830-0001 AMBER Interface Control Document

1.4 ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this document:

AMBER	Astronomical Multi-Beam Recombiner
ANS	Anamorphosis System
DET	Detector module
OPM	Optics and Mechanics module
OSI	OPM-SPE Interface module
SPE	Spectrograph module
TBD	To Be Defined
TBC	To be confirmed
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer

2 GENERAL OVERVIEW

2.1 GENERAL FUNCTIONS

The general functions of the spectrograph are the following :
- spectral dispersion
- thermal flux reduction
- photometry calibration
- beams focalization

2.2 GENERAL SPECIFICATIONS

2.2.1 Spectral coverage

- J Band : $\lambda_0 \approx 1.25$ µm $\Delta\lambda \approx 0.3$ µm
- H Band : $\lambda_0 \approx 1.65$ µm $\Delta\lambda \approx 0.35$ µm
- K Band : $\lambda_0 \approx 2.2$ µm $\Delta\lambda \approx 0.4$ µm
- Total coverage ≈ 1.1 / 2.4 µm

2.2.2 Spectral resolution

- No dispersion
- R ≈ 35
- R ≈ 1000
- R ≈ 10000

These spectral resolutions are given for observations in the K Band.

2.2.3 Cryostat specification

Cryostat Specification	
Temperature	< 77°K
Cooling	Liquid Nitrogen
Autonomy	16 h (minimum) / 24 h (goal)

2.3 GENERAL INTERFACE

2.3.1 Beam configuration at the spectrograph entrance

The beam configuration at the spectrograph entrance is given in the "AMBER Interface Control Document" [7]

2.3.2 Detector size

The camera is a 512 x 512 HAWAII array. The pixel size (p) is 18.5 µm x 18.5 µm.

2.4 SPECTROGRAPH GENERAL SCHEMA AND MODULES FUNCTIONS

Figure 1 shows a conceptual design of the spectrograph which contains six functional units :

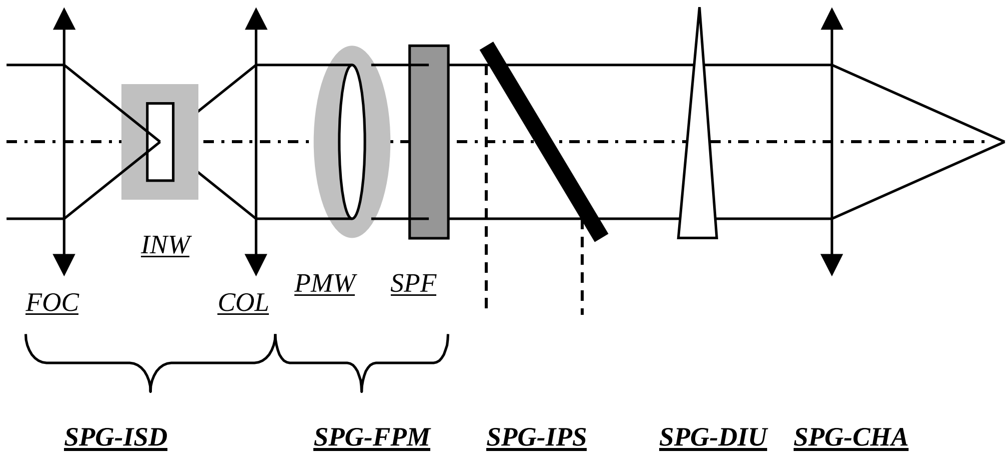


Figure 1 : conceptual design of the spectrograph of AMBER

The cooling system
Acronym : AMB-SPG-CSY
Composition :
- Cryostat (CRY)
- CCT (Cryostat ConTrol)

Functions :
- Spectrograph optics cooling
- Thermal flux reduction

The imaging and stopping device
Acronym : AMB-SPG-ISD
Composition :
- Focalization mirror (FOC)
- Input wheel with cold stop and diaphragm (INW)
- Collimator (COL)

Functions :
- Calibration (Dark) thanks to the obturation position
- Thermal flux reduction thanks to the cold stop position
- Technical operation thanks to the wide diaphragm position

The filters and pupils masks module
Acronym : AMB-SPG-FPM
Composition :
- A pupils masks motorized wheel (PMW)
- A fixed spectral filter (SPF)

Functions :
- Thermal flux reduction

The interferometric photometric splitter
Acronym : AMB-SPE-IPS
Composition :
- Beam splitter (BES)
- Photometric Deflection Device (PDD)

Functions :
- Photometric calibration
- Images positions on the detector

The dispersion unit
Acronym : AMB-SPE-DIU
Composition :
- Grating high resolution (GHR)
- Grating low resolution (LHR)
- Prism (PRI)
- Motorized wheel (WHE)

Functions :
- Spectral dispersion
- Spectral selection
- Spectral modulation

The chamber
Acronym : AMB-SPE-CHA
Composition :
- First conic mirror (FCM)
- Second conic mirror (SCM)
- Flat mirror (FMR)

Functions :
- Beam focalization

3 IMAGING AND STOPPING DEVICE MODULE

3.1 INTRODUCTION

The two sources of noise are the detector read-out noise and the photon noise due to the thermal background which comes from the blackbody emission from the fiber heads. The following figures [4] show that the thermal noise can be greater than the RON especially for long time exposures and for H-Band and K-Band observations. It means that a cold stop is necessary to reduce the thermal noise.

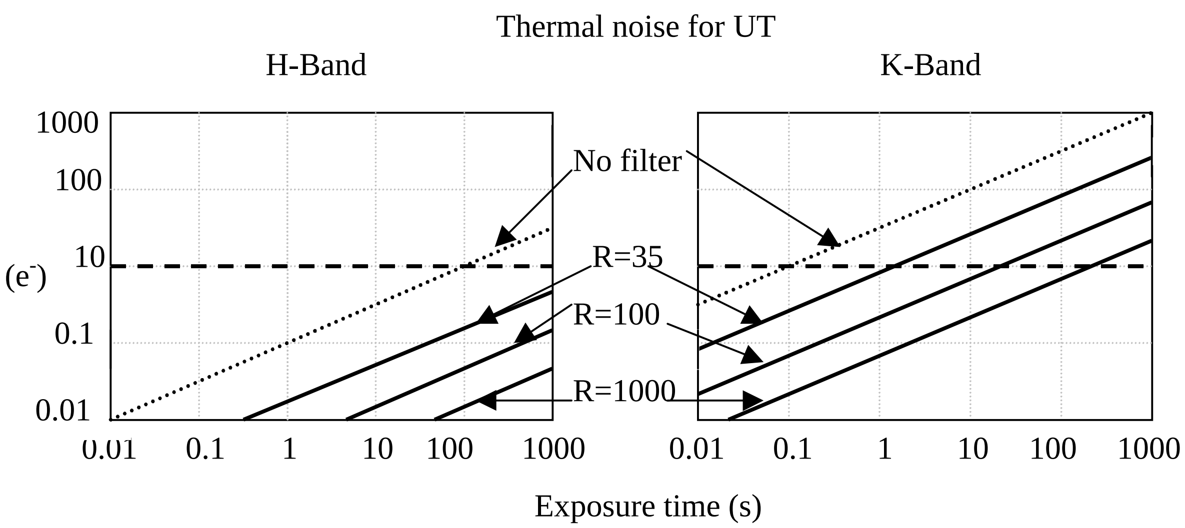


Figure 2 : Thermal noise per spectral channel for UT in K-Band and H-Band without image cold stop (dotted line) and with image cold stop for different dispersion (solid line). The read-out noise is shown by a dashed line.

3.2 SPECIFICATIONS

The imaging and stopping device is composed by two off-axis parabolic mirrors (the focalization mirror and the collimator) with a focal length equal to 700 mm [6]. The chamber focal length is 350 mm (see chapter 7), so the size of the image at the focal plane of this mirrors is two times larger than at the detector level.

A motorized wheel is inserted at the focal plan of these mirrors.
This wheel contains 5 positions :

- Position 1 : a single mode cold stop slit
- Position 2 : a multi mode narrow slit
- Position 3 : a multi mode large slit
- Position 4 : a wide diaphragm
- Position 5 : an obscuration position

The size and the accuracy of positioning of each positions of this input wheel are summarized in the following table :

Position			single mode cold stop slit	multi mode narrow slit	multi mode large slit	wide diaphragm	obscuration position
Size	Width A	(in equivalent detector pixel unit)	2	4	16	>512	>512
		(in µm or mm)	74 µm	148 µm	592 µm	>19 mm	>19 mm
	Length B	(in equivalent detector pixel unit)	118	118	118	118	>512
		(in µm or mm)	4366 µm	4366 µm	4366 µm	4366 µm	>19 mm
Size Accuracy		ΔA (in µm)	5				
		ΔB (in µm)	10				
Positioning Accuracy		δA (in µm)	10				
		δB (in µm)	100				
		Focus (in µm)	300				
		Orientation (in °)	0.25				

Table 1 : Size and accuracy of positioning of each positions of the input wheel of the spectrograph

4 FILTERS AND PUPILS MASKS MODULE

4.1 INTRODUCTION

The main function of the filter and the pupils masks is to reduce the background noise due to the thermal emission of the warm optics outside the cryostat. Some other filters placed before the spectrograph cryostat allow also to avoid the superposition of the spectral orders in the case of a spectral dispersion with a grating.

4.2 SPECIFICATIONS

The specification for the spectral filter is to eliminate the wavelengths higher than 2.4 µm

The pupils masks wheel at the pupil plan of the spectrograph must be motorized to select 8 positions :

Position	Pupils masks
Position 1	3T K Spatial Filter
Position 2	3T KHJ Spatial Filter
Position 3	2T K Spatial Filter
Position 4	2T KHJ Spatial Filter
Position 5	3T Wide Field
Position 6	2T Wide Field
Position 7	Technical position
Position 8	Free position

Table 2 : Pupils masks corresponding to the height positions of the PMW

Pupils masks shapes for each position

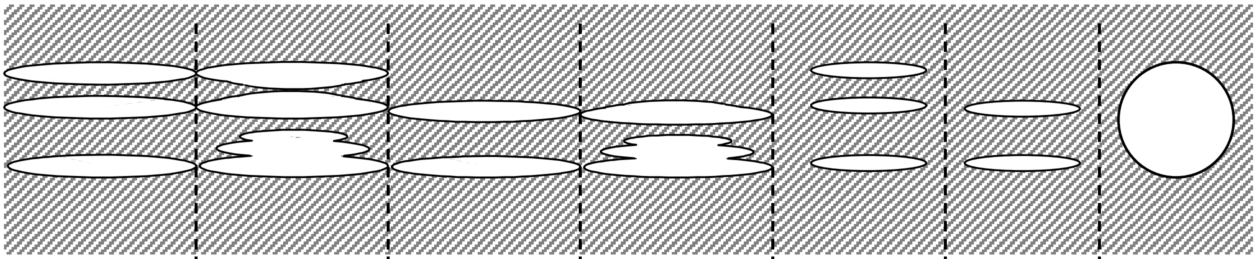
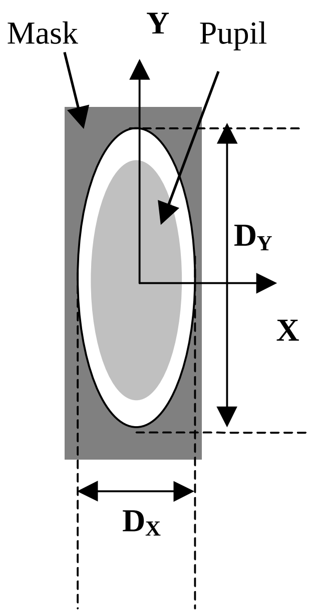


Figure 3 : Pupils masks shapes corresponding to seven positions of the PMW

Pupils masks dimensions

In order to relax the accuracy of reproducibility of the wheel, the masks are oversized by a factor 1.05. It generates an increase of the thermal noise leading to a loss of 0.06 magnitude in the K Band.

Figure 4 : Pupil masks dimension. The size of the mask is 1.05 time greater than the pupil.



Size in (mm)	D_X	D_Y
K Band	2.7	42
H Band	2.05	32
J Band	1.6	25

Table 3 : Pupil mask dimensions for the spatial filter mode in different spectral bands.

Size in (mm)	D_X	D_Y
Wide Field	1.3	20
Tech pos.	22	22

Table 4 : Pupil mask dimensions for the wide field mode and the technical mode

<u>Pupils masks localization</u>

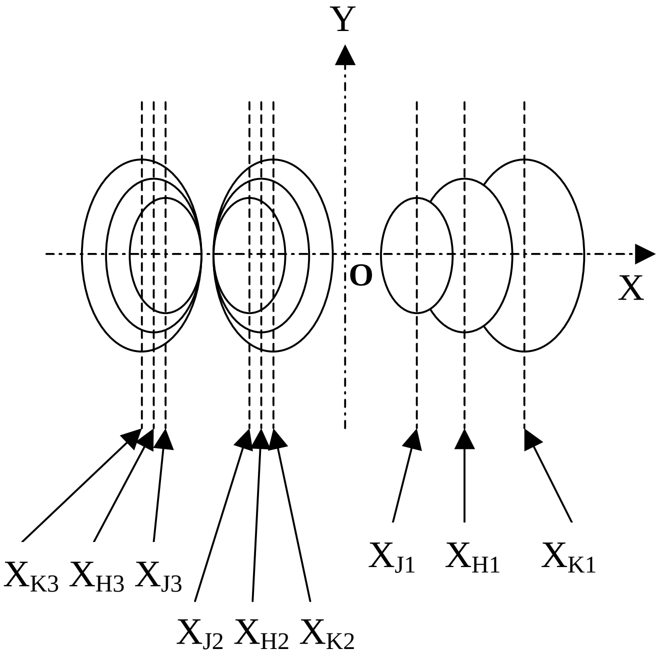


Figure 5 : Positions of the centers of each pupil for the spatial filter mode. The reference origin O represents the middle of the furthest spatial filter beams in K band.

	X_{K1}	X_{H1}	X_{J1}	X_{K2}	X_{H2}	X_{J2}	X_{J3}	X_{H3}	X_{K3}
Distance in (mm)	5	2.917	1.458	-1.667	-2.083	-2.375	-4.292	-4.583	-5

Table 5 : Position of the center of each pupil mask to the reference origin (middle of the 2 furthest beams in K band) for the spatial filter mode

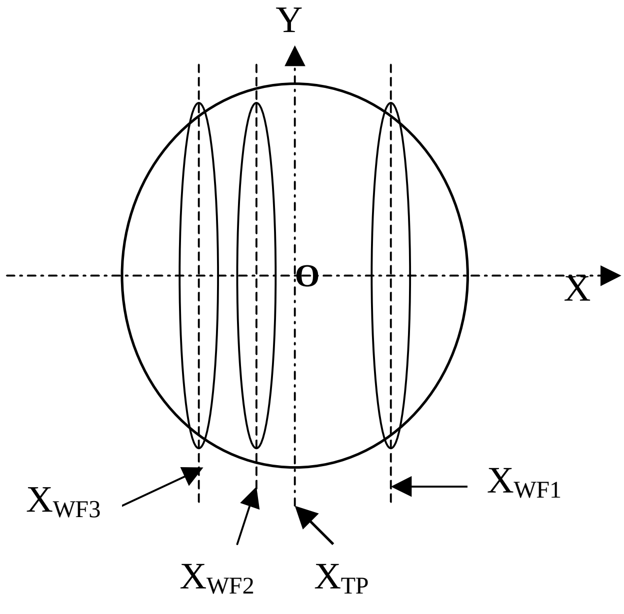


Figure 6 : Positions of the centers of each pupil for the spatial filter mode. The reference origin O represents the middle of the furthest spatial filter beams in K band.

	X_{WF1}	X_{WF2}	X_{WF3}	X_{TP}
Distance in (mm)	5	-1.667	-5	0

Table 6 : Position of the center of each pupil mask to the Reference origin for the wide field and technical modes

Accuracy of positioning of the pupils masks wheel

In order to optimize the flux (to avoid beam obstruction), the accuracy of positioning the wheel is :

	ΔY	ΔX
Accuracy of positioning	+/- 500 µm	+/-30 µm

Table 7 : Accuracy of positioning of the filters and pupils masks wheel

5 PHOTOMETRIC-INTERFEROMETRIC DEVICE MODULE

5.1 INTRODUCTION

In spatial filtering mode, it is necessary to monitor the photometric fluctuations of each beam to reach a good visibility accuracy.

In order to simplify the interface between OPM and SPG (only one beams triplet at the entrance of the spectrograph) the separation between photometry and interferometry channels is inserted into the spectrograph cryostat, just before the grating.

5.2 SPECIFICATIONS

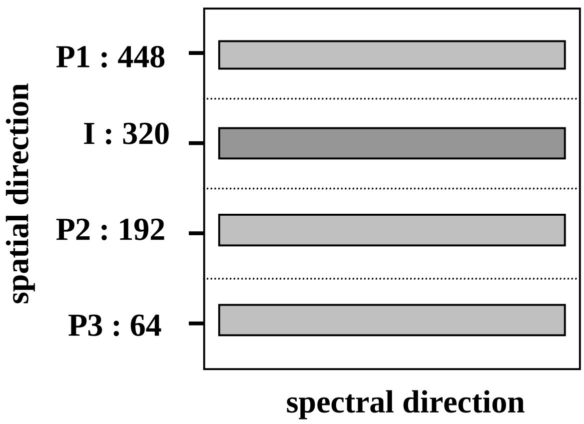
Flux ration between the interferometric and photometric beams

A computation has been made to evaluate the best ratio between the photometric and interferometric channels [4]. 35% of flux for the photometric channel and 65% for the interferometric channel is a good trade-off.

Positions and accuracy of positions of each image on the detector

The four positions of each image on the detector are the following :

Figure 7 : Positions of the three photometric images and the interferometric image on the detector.



	Position of the image center (in pixel)	Accuracy of positioning (in pixel)	
		Spatial direction	Spectral direction
Photometric image 1	448	3	3
Interferometric image	320	3	3
Photometric image 2	192	3	3
Photometric image 3	64	3	3

Table 8 : Position and accuracy of position of the images on the detector

6 DISPERSION UNIT MODULE

6.1 INTRODUCTION

The general function of this module is to disperse the fringes. Additionally for the differential mode observations, it will be interesting to be able to shift the images on the detector in the spectral direction. This spectral modulation allows to obtain a measurement of the derivative of the fringe phase variation free of instrumental defects and to be only affected by photon and detector noise.

6.2 SPECIFICATIONS

Spectral resolution

- Low resolution, R ≈ 35, spectral sampling ≈ $\lambda_0/\delta\lambda$ ≈ 70 ($\delta\lambda$ analyzed by one pixel)
- Medium resolution, R ≈ 1000, spectral sampling ≈ $\lambda_0/\delta\lambda$ ≈ 2000 ($\delta\lambda$ analyzed by one pixel)
- High resolution, R ≈ 10000, spectral sampling ≈ $\lambda_0/\delta\lambda$ ≈ 20000 ($\delta\lambda$ analyzed by one pixel)

These spectral resolutions are given for observations in the K Band.

Accuracy of positioning of the grating wheel

The gratings and prism support must be motorized to be able to select the spectral resolution. The specification of the angular accuracy of these support is about 10 pixels on the detector, but if an accuracy less than 1 pixel is possible it could allow to perform the spectral modulation and to simplify the observation procedures (no spectral calibration and no modification of detector reading zone after each spectral set-up change).

7 CHAMBER MODULE

7.1 INTRODUCTION

In order to implement the ABCD algorithm for the data reduction, it is necessary to sample the fringes produced by the more distant beams (152 mm of separation for the K Band) on 4 pixels.

7.2 SPECIFICATIONS

To sample the fringes on 4 pixels, the chamber focal length must be at least :

$$f = 4p / a\ (\lambda_0/B_{MAX})$$

where p is the detector pixel size (18.5 mm), a the anamorphosys factor (15.6), λ_0 the wavelength (for example 2.2 microns for the K band), and B_{MAX} the maximal value of the beams separation (for example 152 mm for the K band). It should be noted that the ration λ_0/B_{MAX} is the same for each spectral band.

$$\Rightarrow f \approx 336 \text{ mm}$$

If the chamber focal length equals to 350 mm, the consequence on the sampling is the following :

	J Band			H Band			K Band		
Wavelength (µm)	1.1	1.25	1.4	1.5	1.65	1.8	2	2.2	2.4
Number of pixels per fringe	≈3.6	≈4.1	≈4.6	≈3.8	≈4.2	≈4.5	≈3.8	≈4.2	≈4.5

Table 10 : Number of pixels per fringe produced by the furthest beams for different wavelengths if the chamber focal length equals to 350 mm.

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