Steering Committee
of the VLTI enhancement tri-partite agreement

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AMBER

The near infrared / red VLTI focal instrument

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with the contribution of the authors of the AMBER memos:

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and all the members of the AMBER consortium

Contents

Chapter 1

Introduction and summary

The months since the July 97 ISAC meeting have been basically dedicated to the organisation of the AMBER consortium. The instrumental concept itself has not evolved much: each beam is corrected by an AO module, cleaned by polarisation and may be refraction and dispersion correctors before beeing spatialy filtered in order tp isolate a single mode. After one fraction of each beam has been separated for photometric calibration, the beams are recombined in a multiaxial way. The interferograms, spectrally dispersed or not, are then spatially sampled by an array detector. The data is stored for off line processing although a real time processor permits a partial data analysis to tell exactly what is the quality of the recorded information. The primary target is the K band but the extension to H_α is planned as soon as two ATs will be available. The possibility to use other near infrared bands is beeing explored. This information is briefly reminded in chapter 2.

Negociations between the Institutes have allowed to define the management of the project presented in chapter 3. One of the difficulties AMBER has to face is that an important fraction of the involved engineers are not fully avalaible immediately because the teams in the two main Institutes in Grenoble and in Nice are still busy with the NAOS and the PFSU ESO contracts. This is particularly true for the key Project Manager and System Engineer. It is one of the reasons why the date now aimed for first AMBER observations with the UTs is April 2001 instead of the original October 2000. The lack of availability of this key participants is expected to improve rapidly.

We have also created a set of working groups, each one in charge of one of AMBER's subsystems or of one general problem such as the Interferometric and the Science Groups. The Interferometric Group (IGR) has recetly started to assist the Project Scientist in defining the instrument technical specifications. It has deepened the analysis of the several possible observing modes offered even by the simplest implemeantation of AMBER. This is summarised in paragraph 5.2 but a much more detailed description can be found in the AMBER memo AMB-IGR-002[1]. The Interferometric Group and the Science Group (SGR: paragraph 5.1) will collaborate in order to select the priority modes, their specifications and performances before next May.

Six out of the eight technical working groups have started working. Three types of solutions are available for the detectors in three different institutes and will be combined in the development of the AMBER detector after some decisive lab tests by next spring (see paragraph 5.5). The optomechanical design (see 5.3) is waiting inputs from the system analysis but the preliminary design of the spectrograph is already started at Arcetri (see 5.4). The data processing group, called OSM for "Observing Support Module" has started collecting and developing simulation programs to help the IGR and the SGR in making their choices and the Instrument Control (ICM) group is currently starting to select the AMBER control architecture.

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[1] available on the AMBER web pages (http://www-laog.obs.ujf-grenoble.fr/amber/) together with numerous other documents

One particularly critical item are the Adaptive Optics Modules (AOM). The AMBER AO modules are based on a development started for GI2T by A. Blazit with the help of ONERA already two years ago. Nevertheless, as it is explained in some detail in paragraph 5.6 it seams quite difficult to completely develop, integrate, calibrate and test two AO modules with the kind of reliability needed for Paranal before the middle of the year 2000, which corresponds to scientific observations no earlier than the end of the 2000-2001 winter. This is the second, even more decisive reason, for a shift of the first AMBER observations with the UTs to April 2001.

The global timetable of the project leading to this date is summarized in chapter 6 and finally chapter 7 gives elements to evaluate the AMBER budget. The final and very detailed budgets and timetable will produced for the Project Definition Revue we plan to have in the very beginning of November 1998.

Chapter 2

Basic specifications and science drivers

The science drivers for the instrument will be an important subset of the science drivers for the VLTI [1, 4], selected in consideration of the wavelength coverage, field of view, imaging capabilities and fringe tracking options.

The wavelength coverage will be limited initially to the near infrared (1 to 2.5 um) with an initial priority to the K band, although extension to the red part of the visible spectrum is planned as soon as two ATs will be available. The field of view will vary from the size of an Airy disk (i.e., 60 mas at 2 µm for the UTs, or 250 mas for the ATs) to about 2" in the so-called "wide-field" mode. Although in the beginning only three baselines will be available simultaneously (number of Coudé trains in the ESO Phase-A/B Project [2]), the imaging instrument will be the only instrument for the VLTI to offer closure phase and thus, in principle, imaging capabilities. Such imaging will be more effective for simple sources, while objects with a complicated structure will require many telescope relocations and will be time consuming. Finally, the (initial?) absence of phase referencing in a second beam will limit in practice fringe tracking to the science object itself. Limiting magnitudes will depend strongly on the bandpass of the selected filter and the color of the source, and on the AT/UT combination. Broadly speaking, one can think of a limiting magnitudeK=10 for the ATs, and K=13 for the UTs [6]. However, note that several modes of operation are foreseen, including the so-called blind tracking which will allow to push the limiting magnitude somehow.

With these constraints in mind, we identify the following as some of the main science drivers for the instrument:

- Exoplanets (detecting hot massive "Jupiters", i.e. such as 51 Peg)
- Star forming regions (disks and jets around young stellar objects)
- Circumstellar matter (circumstellar matter around AGB stars)
- AGN dust tori (probing the central engine by reprocessed radiation)
- Binaries (main sequence and giant stars, brown dwarfs, etc.)
- Stellar structure (limb-darkening, spots, rotation, etc.)

The actual scientific drivers for each of these issues have been described already in other documents, and we think that it is not necessary to present here a lengthy description of each of these topics. The interested reader can find relevant information for instance in [1, 2, 3, 4, 5, 6, 7]. More to the point of the present document, we summarize in Table 1 the requirements that each of the topics above imposes in the design of the instrument and the performance that it must achieve. We also have marked in the last two columns whether each field of research will constitute or not a primary science driver also for the other two instruments currently proposed for the VLTI, namely the astrometric instrument and the 10 µm instrument.

The values in the table should be interpreted as minimum requirements needed to carry out useful research in that field.

Table 1: Scientific requirements for the imaging instrument

Topic	Visib. Accur.	Limit. K Magn.	Wave-length Cover.	Spectr. Resol.	Polaris. useful	Wide Field useful	3 beams useful	easy for MIDI	easy for PRIMA
Exoplanets	10^{-4}	5	K	50	N	N	N	Y	Y
Star Forming Regions	10^{-2}	7	JHK +lines	1000	Y	Y	Y	N	Y
Circumstellar matter	10^{-2}	4	JHK +lines	1000	Y	Y	Y	N	Y
AGN dust tori	10^{-2}	11	K	50	Y	Y	Y	N	Y
Binaries	10^{-3}	4	K	50	N	Y	N	Y	N
Stellar Structure	10^{-4}	1	lines	10000	N	N	Y	N	N

Even with its more primitive modes, AMBER will be able to observe hundreds of young stellar objects with the UTs. Resolving the dust tori of the brighter AGNs will be within the limiting performances of early versions of the instrument. With a medium spectral resolution, one might even expect resolving the broad line region in the hydrogen lines by comparing the phase of the fringes in the two line wings. We have preselected this two programs as the main astrophysical targets with the UTs. This choice will be refined by the AMBER Science Group described in paragraph 5.1.

The imaging and spectroscopic instrument contains a number of mandatory optical elements:

- adaptive optics
- fringe tracker (provided by the ESO FSU)
- cooled spectrograph
- 3-way beam combiner
- spatial filtering and photometric calibration
- polarization control with a Babinet prism
- near-infrared detector, and later, visible detector

However it is possible to start useful operation with only:

- 2-way beam combiner
- no fringe tracker
- very low spectral resolution

and we will do it this way if this can solve delay problems. But the design is made to allow us to go to the full potential of AMBER as soon as possible.

These optical elements are required by the scientific drivers listed above. For example, spatial filtering and photometric calibration ensure visibility calibration better than 0.1% as needed for massive exoplanet study. However such an optical scheme would be inefficient with D/r0 > 6 and that is why adaptive optics is highly recommended. Fringe tracking is also highly useful when one wants to get high spectral resolution from interferometric data. Finally the aim of this instrument is to get images at very high angular resolution which requires phase closure measurements.

We have identified 3 instrument modes for the different scientific targets:

High flux sensitivity

It will be dedicated to the study of relatively complex spatial structures with a visibility accuracy of about 1%. Recombination of several beams is desirable in order to increase the (u; v) coverage. This mode should also allow us to push the performance of the instrument in sensitivity.

High Precision Visibility

It is foreseen for high dynamic range study of relatively simple objects, like multiple systems or massive hot Jupiters around stars. The goal is to have the most accurate calibration procedure as possible.

High Spectral Resolution

The high spectral resolution is recommended for the study of stellar lines. The spectral resolution is em- phasized even if the accuracies in visibilities or the sensitivity performance are not extreme.

The reader must refer to the memo AMB-IGR-002 in order to get an update and more details on the instrument modes.

Bibliography

[1] ISAC report, 1996, A new start for the VLTI, The ESO Messenger, 83

[2] Implementation Plan of ESO VLTI, Issue 2.0 Draft, 9 janvier 1997, ed. O. von der Lüehe.

[3] Update of the Agreement on the enhancement of the Very Large Telescope Interferometer with a third auxiliary telescope and delay line from December 18, 1992, autumn 1996, between ESO, CNRS and MPG.

[4] VLT report 59b, 1989, The VLT Interferometer Implementation Plan, ESO/VLT Interferometry Panel, ed. J.M. Beckers

[5] VLT report 65, 1992, Coherent combined instrumentation for the VLT Interferometer, ESO/VLT Interferometry Panel, ed. J.M. Mariotti

[6] Coudé du Foresto V., Malbet F., Mékarnia D., Petrov R., Reynaud F., Tallon M. 1997, PNHRAA report, "Preliminary study of the near-infrared/red instrumentation of VLTI and GI2T" (AMB-REP-001 on the AMBER web pages: http://www-laog.obs.ujf-grenoble.fr/amber/)

[7] Malbet F., Perrin G, Petrov R., Richichi A., Schöller M. 1997, "AMBER -- The imaging and spectroscopic VLTI focal instrument", Preliminary study for the ESO Interferometry Science Advisory Committee (ISAC) (AMB-REP-002 on the AMBER web pages: http://www-laog.obs.ujf-grenoble.fr/amber/)

In order to raise the spirits of the participants to the AMBER consortium and of their sponsors the following page shows a first result obtained on a protoplanetary disk by long baseline interferometry in the K band. With the existing small aperture interferometers, this kind of observations can be obtained on very few sources. With the UTs the number of astronomical candidates will be of several hundreds.

Protoplanetary disk resolved at the 2-AU scale by infrared long-baseline interferometry

The figure below shows the first detection of fringes on a young stellar object with the Palomar Testbed Interferometer. The observations are in good agreement with predictions given by Malbet & Bertout (1995). This observation demonstrates the first steps in the knowledge of star forming regions at the 1-AU scale which will be enhanced with the AMBER instrument on VLTI. Many observations of that type at other spatial frequencies will allow us to retrieve image of protoplanetary disks with unpreceded resolution.

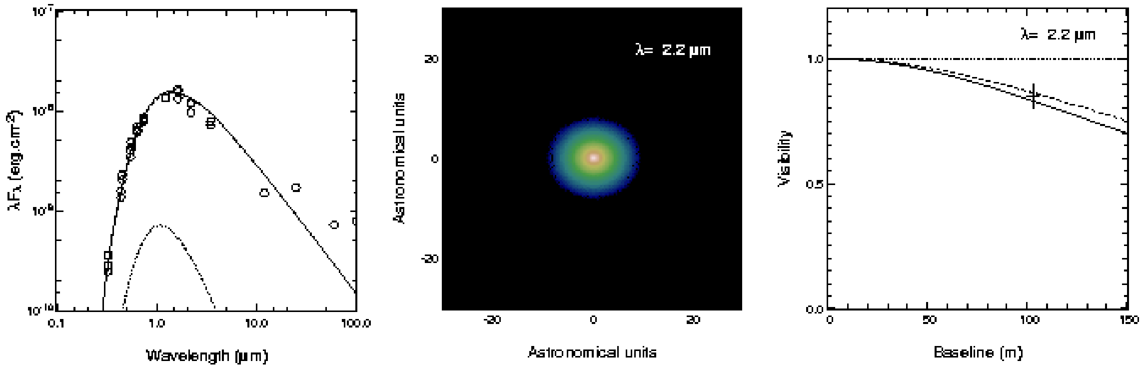


Figure: Left panel displays the spectral energy distribution of the accretion disk model (dashed line), the star (dotted line) and the whole system (solid line). An interstellar extinction law with AV = 1 mag is applied. The circles represents FU Ori photometry measured by Allen (1973), Glass & Penston (1974), Kenyon et al. (1988) and IRAS. Middle panel displays the synthetic image of the accretion disk at 2.2um . Right panel displays the visibility curves of the accretion disk model for the x and y directions (respectively solid and dashed lines). The result of PTI observation of FU Ori is placed on the figure with its error bars (Malbet et al. 1998).

Chapter 3

General description of AMBER

The general description of AMBER has not changed much from the presentation to ISAC in July. The reader would usefully refer to the July AMBER report (ref [7]) and to the collection of viewgraphs then distributed by ESO. An update about the instrument observing modes, has they are beeing analysed by the AMBER interferometric group (see 5.2) can be found in the AMBER memo AMB-IGR-002. This two and other documents are in the AMBER web pages at

http://www-laog.obs.ujf-grenoble.fr/amber/

3.1 Functional analysis

The main function of AMBER is to measure the spatio-temporal coherence of the observed source. To perform this one needs the following secondary functions:

F01: To adapt the input beam size

F02: To calibrate the instrumental aberrations of the degree of coherence

F03: To correct the wavefront

F04: To analyze the wavefront

F05: To compensate the effect of atmospheric refraction and dispersion

F06: To control the polarization state

F07: To compensate the residual OPD

F08: To analyze the residual OPD

F09: To put the beam in single mode

F10: To scan the OPD in a coherence length

F11: To measure the photometric signal from each beam

F12: To interferometrically combine the beams

F13: To spectrally disperse the signal

F14: To measure the interferometric signal

F15: To estimate the signal coherence from the stored data

F16: To store the information

3.2 Possible Instrument Layout

From this functional analysis, we have defined the different modules needed to get scientific information:

- Beam size adapter
- Adaptive optics
- Fringe tracker
- Beam quality module (polarization, spatial filtering, calibrations, atmospheric refraction compenser...)
- OPD scanner
- Photometric/interferometric separator
- Beam combiner (3-way)
- Spectrograph
- Detector
- Acquisition and archive system
- Data reduction module

The solutions for some parts are already defined (AO, beam combiner, spectrograph, detector,...) and others are under study (polarization, spatial filtering, OPD scanner,...). The reader is invited to read the AMB-REP-002 report for more details and the chapter on the different working group reports.

3.3 Instrument subsystems

We have divided the project in 8 subsystems:

- **OPM: optomechanics**
  It consists in all optical, mechanical and electrical elements on the optical table (beam size adapter, beam quality control, OPD scanner, FSU interface, AO mechanical supports, beam combiner,...) as well as the local control of them.

- **SPE: spectrograph**
  It consists in the spectrograph with the gratings and the various optical elements, filters and the dewar.

- **DET: detector**
  It consists in the detector chip, the read-out electronic, the acquisition and archiving system.

- **AOM: adaptive optics module**
  It consists in the set of active optical elements (deformable mirror, wavefront sensor, real-time computer,...) as well as the control of them (servo-loop)

- **ICM: instrument control module**
  This module is the main operator of the instrument. It controls each module with a high level language and make them work together and manages the communications with the VLTI. A sequencer allow to run different sequences for observing, calibrating or aligning.

- **OSM: observing support module**
  This module is purely software-oriented. It supports the user in preparing the observations and in reducing and calibrating the data. Part of the software will be used by the real-time computer (RTP) to monitor the quality of the observations. The OSM is also in charge of developing a simulation tool to help the conception of the instrument.

- **RTP: real time processing**
  The real time processor (or monitor) runs a small, fixed part of the software defined in the OSM in real time simultaneously with the data acquisition. It is intended to have permanently a reliable estimate of the quality of the data which is beeing recorded. In some cases, to be defined in the System Definition Phase, informations might be send from the RTP to the ICM.

- **INT: integration and tests**
  This module which is not yet active is in charge of all optomechanical elements needed to align and to calibrate the instrument. It will be in charge of the system integration and tests. It will develop the simulation tools started by the OSM in an end-to-end simulation used to test the software, simulate the observation and estimate the performances and therefore the feasability of the astrophysical programs.

Chapter 4

Project organization

4.1 Participating Institutes and Members of the AMBER consortium

The table 4.1 shows the list of the members of the AMBER consortium and indicates their home Institutes. The management tasks and the memberships to working groups are indicated. Two main French Institutes will be in charge with the realisation of AMBER:

- Observatoire de la Côte d'Azur (OCA)
- Laboratoire d'Astrophysique de l'Observatoire de Grenoble (LAOG)

with the help of the:

- Osservatorio Astrofisici di Arcetri (OAA) near Florence, Italy

and the

- Max Planck Institute fur Radioastronomie (MPIfR) in Bonn, Germany.

The other Institutes will provide expert scientists or engineers but should not build or integrate hardware. They are:

- Office National d'Etudes et de Recherches Aérospatiale (ONERA), France,
- U.M.R. 6525 "Astrophysique" de l'Université de Nice - Sophia Antipolis, France
- Centre de Recherche Astronomique de Lyon (CRAL), France

Table 4.1. Members of the AMBER consortium

Names in **bold** refer to permanent staff while the Ph.D. students and post-doctoral researchers are designed in *italic*. Sci = Scientist, Eng = Engineer, Tec = Technician, Stu = Ph.D. student.

Laboratoire d'Astrophysique de l'Observatoire de Grenoble

NAME	***STATUS***	***FUNCTION***	% time 97-98	% time 98-99	% time 99-00
MALBET	Sci	Project Scientist	70	80	80
LECOARER	Eng	physics, Coordinator ICM	50	70	80
KERN	Eng	after mid 98 possible Project Manager	20	50	80
RABOU	Eng	optics, OPM	10	10	10
PETMEZAKIS	Eng	electronics, DET	75	75	75
FEAUTRIER	Eng	electronics, Coordinator DET	25	25	50
CHARTON	Eng	electronics, ICM	10	10	50
BEREZNE	Eng	computer science, ICM	0	10	50
MAGNARD	Tec	mechanics	10	20	50
DUVERT	Sci	OSM	25	40	40
MOUILLET	Sci	OSM	25	25	50
FORVEILLE	Sci	IGR Coordinator OSM	30	40	50
HENRI	Sci	SGR	10	10	10
PERRAUT	post-doc	OPM	50		
MONIN	Sci	DET, SGR	25	40	50

Observatoire de la Côte d'Azur

			% time 1998	% time 1999	% time 2000
ANTONELLI	Eng	electronics, Coordinator OPM	80	90	90
BLAZIT	Sci	AOM	80*	70*	
BRESSON	Tec	optics, OPM	50	50	50
DUGUE	Eng	real time processing, ICM	40	90	90
GLENTZLIN	Eng	mechanics, OPM	60	80	
KAMM	Tec	electronics, OPM, ICM	80	90	90
MARS	Eng	computer science, OPM, AOM	50	90	90
MENARDI	Eng	optics, System Engineer	60	90	90
PETROV	Sci	Principal Investigator	80	80	80
REBATTU	Eng	mechanics, OPM	80	90	90
SCHNEIDER	Tec	mechanics, OPM	50	50	50
CRUZALEBES	Sci	IGR, OSM	70	70	70
LOPEZ	Sci	SGR	40*	40*	40*
MOURARD	Sci	IGR	20	20	20
STEE	Sci	SGR	50	50	50
VERINAUD	Stu	AOM	70*	70*	70*
BERIO	Stu	OSM	20	20	

Université de Nice - Sophia Antipolis (U.M.R. 6525)

ARISTIDI	Sci	OSM	30	40	40
PETROV	Sci	Principal Investigator	80	80	80

Observatoire Astronomique d'Arcetri

BAFFA	Eng	electronics, DET	~ 40	~ 40	~ 40
COMORETTO	Eng	elctronics, DET	~ 40	~ 40	~ 40
GENNARI	Eng	optics, SPE	~ 40	~ 40	~ 40
LISI	Eng	Chief Engineer in Arcetri, SPE, DET	~ 40	~ 40	~ 40
RICHICHI	Sci	Chairman SGR	~ 50	~ 50	~ 50
CARBILLET	post-doc	OSM, AOM	~ 30	~ 30	
RAGLAND	post-doc	OSM	~ 50	~ 50	

Centre de Recherches Astrophysiques de Lyon

TALLON-BOSC	Sci	IGR	20	20	20
THIEBAUT	Sci	OSM	20	30	40

O.N.E.R.A.

CASSAING	Eng	IGR, AOM			
MADEC	Eng	Coordinator AOM			
SORRENTE	Eng	AOM			
RABAUD	Eng	AOM			

Max Planck Institute fur Radioastronomie à Bonn

HOFMANN	Sci	IGR, OSM, Co Investigator	50	50	50
BECKMANN	Eng	Chief Engineer in Bonn, DET, OSM, RTP	20	20	20
GENG	Eng	electronics, DET, RTP	60*	60*	60*
HEIDEN	Eng	electronics, DET, RTP	25*	25*	25*
SOLSCHEID		mechanics and electronics, DET, RTP	25*	25*	25*
GEORGES		OSM, RTP	25	25	25
DORNSEIFER	Stu	OSM, RTP	25	25	25
NUSSBAUN		OSM, RTP	50	50	50
DRESS		OSM, RTP	25	25	25

From miscellaneous Institutes

NAME	*INSTITUTE*	*FUNCTION*
COUDE DU FORESTO	Paris-Meudon Observatory	IGR
MAYOR (TBC)	Geneva Observatory	SGR
REYNAUD	IRCOM	IGR
WINTERS (TBC)	Berlin	SGR

VON DER LUEHE (TBC)	Freiburg	SGR

(*) Work common to AMBER and other projects

4.2 General organization

Principal Investigator: Romain Petrov (UNSA/OCA)

The PI is responsible for the project. He negociates with the participating institutes and sponsoring organizations. He defines the project strategy, supervises the compromise between the needs expressed by the Science Group and the possibilities defined by the Instrument Definition Group. He arbitrates problems which could not be solved at other levels.

Project Scientist: Fabien Malbet (LAOG)

The PS translates the scientific goals in instrument specifications. He defines the instrument concept with the help of the Interferometric Group he chairs. He supervises the interfaces between the subsystems. He arbitrates conflicts between technical (or cost) limitations and instrument specifications.

Chairman of the Science Group: Andrea Richichi (OAA)

The CSG coordinates the work of the Science Group who is in charge with refining the scientific objectives and preparing the astrophysical interpretation of the observations.

Co-Investigators: Karl-Heinz Hofmann (MPIfR).

A Co-investigator represents an important geographic pole of the consortium and is associated to key decisions as a member of the direction committee. Petrov (Nice), Malbet (Grenoble) and Richichi (Arcetri) are also co-investigators.

Project Manager:

The PM is in charge with the budget, the timetable and the evaluation of the final performances of the instrument. He arbitrate technical problems which could not be solved in the subsystems or at interface level by the SE.

Pierre Kern (LAOG)

has been idendified as being quite probably the best fitted for this function. However he has important responsabilities in the NAOS project. The LAOG is presently discussing with the NAOS consortium solutions which would allow Pierre Kern to take progressively in charge the management of the AMBER project after the NAOS Final Design Revue (2nd trimester 98). The timetable in chapter 6 assumes that the Final Concept Revue in July 98 is prepared without Pierre Kern (but for limited consultations), who then gets progressively involved in AMBER until the Preliminary Design Revue in November 98 when he starts behaving fully as the AMBER PM. In the system definition phase, the PM tasks will be shared by R. Petrov and F. Malbet. Other consortium members are able to be PM (Antonelli and Menardi at OCA, Lisi at OAA for example) but they are loaded with other important AMBER tasks. At the end of January 98 we will know if Pierre Kern can be PM at a reasonable date. If he cannot, an other solution and the reorganization it implies will be proposed.

System Engineer: Serge Menardi (OCA)

The SE defines the interfaces between the subsystems and therefore the specific subsystem functions and specifications. He helps the PS in selecting the instrument concept by evaluating, with the help of the subsystem coordinators, the feasability and difficulties of the proposed solutions. He is charge with the instrument integration and tests.

Quality Engineer: TBD

Coordinator of the OPtomechanics Module: Pierre Antonelli (OCA)

Coordinator of the SPEctrograph module: An OAA engineer (probably Franco Lisi)

Coordinator of the DETector module: Philippe Feautrier (LAOG)

Coordinator of the Adaptive Optics Module: Pierre-Yves Madec (ONERA)

Coordinator of the Instrument Control Module: Etienne Lecoarer (LAOG)

Coordinator of the Observations Support Module: Thierry Forveille (LAOG)

Coordinator of the Real Time Processing module: A MPIfR engineer (probably Udo Beckmann)

Coordinator of the INTegration module: TBD, this working group will be set up in March

Direction Committee: For particularly critical decisions, the PI consults a direction committee formed by the co-investigators, the PS, the CSG, the PM and the SE.

Instrument Definition Group: the Interferometric Group, led by the Project Scientist, the System Engineer and the Subsystem Coordinators constitute the instrument definition group.

Chapter 5

Working groups reports

5.1 SGR: Science Group

(see AMBER Memo: AMB-SGR-001)

5.1.1 Scope of the Science Group

The Science Group (SGR) must refine the Scientific objectives of Amber, prepare the observing programs and interpret the reduced data. Amber will begin operations in a very critical phase when a small amount of guaranteed UT time will be available for interferometry (30 nights for the first two years). The proportion of this time obtained by AMBER must be dedicated to a small number of key programs with high scientific return and visibility. It is very important to optimise the use of this time and also to shorten as much as possible the delay between observations and the actual scientific interpretation.

The task of the SGR will be articulated in the main following points:

- To select the list of key programs which can best benefit from AMBER

- To define, develop and support a software package which can convert astrophysical models into parameters observable by AMBER and, vice versa, which can input the parameters obtained first by a simulation of AMBER and later by AMBER itself in the astrophysical models. The programming load will be shared with the OSM and the INT groups

- To establish a list of candidate targets for each key program and use the numerical models and simulated observations to define criteria of feasibility and the expected results for each target. The final result will be observations schedules for the guaranteed UT time and guidelines to evaluate observing programs in general.

5.1.2 Motivation and workload of the SGR

The SGR scientists will be associated to the results of AMBER as all other scientists participating in the project. In the UT phase, it is foreseen that the time accessible to AMBER will be too short to share it between all the programs of interest for the AMBER participants. The participation of the Scientists to the result of the few key programs identified for the UT phase will be insured by coauthorship of the first key papers, regardless of their specific area of expertise. Later, the scientists participating to AMBER will have priviliges for the use of the time accessible for this experiment on the UTs and on VISA.

The SGR work will have the following typical phases:

- During the first half of the System Definition Phase (i.e. until April 1998), the SGR will provide scientific input for the choice of the observing modes of AMBER and of still discussed instrumental parameters such as the wavelength coverage (only K or also H and J ?) or the possibility to have a wide field.
- Then, until the PDR (November 1998), the SGR will confront the scientific possibilities of the selected concept with the astrophysical programs and select the key programs.
- Between the PDR and the MIR (June 2000), the SGR will fully simulate the astrophysical exploitation of AMBER, select the observing schedules and interact with the OSM software development.
- Between the MIR and the scientific observations (April 2001), the SGR will update the observing programs according to the actual AMBER performances measured in the test phase.

5.1.3 Composition of the SGR

The SGR Chairman is Andrea Richichi from the OAA.
Initially the SGR should be constituted of a small number of scientist who will serve a quite significant fraction of their time under close supervision from the chairman and with tight schedules in order to meet the 2001 deadlines with a well defined list of priorities. However, as work develops, it will be necessary to expand its field, particularly to realize the full scientific goals of the AT phase, when time will be more generously avalaible and much more programs can be implemented. Then the SGR will expand to include collaborations with a larger circle of scientific contributors, at various levels of formal membership and workload.

The initial list of colleagues invited in the SGR contains:

- Mayor (exoplanets)	Geneva
- Monin (star formation)	Grenoble
- Stee (Be stars, general)	Nice
- Lopez (AGB stars, general)	Nice
- Winters (AGB stars)	Berlin
- Henri (Galaxies)	Grenoble
- Von der Luehe (Stellar structure)	Freiburg

According to their answers and to some negociations internal to AMBER and with the sponsoring institutes, a list of the initial SGR members will be finalised in the next weeks.

5.2 IGR: Interferometric Group

5.2.1 Scope of the Interferometry Group

The concept proposed for Amber by the two previous working groups offers a large range of observing procedures,whose priorities must be specified by specialists. Some of them are standard modes derived from experience accumulated with FLUOR, GI2T and other interferometers. There are still other new possibilities.

The Interferometry Group (IGR) includes experimented interferometrists and instrumentalists who assists the project scientist (PS) in translating the scientific needs in instrument specifications. The group will also define the sequence of implementation of the modes, and the observing and calibration procedures. They can also help the subsystems in selecting the best solutions in some very specific technical fields.

The IGR, who is leaded by the PS, is a subset of the instrument definition group (IDG) which includes in addition the System Engineer and the Subsystem Leaders.

5.2.2. Task of the Interferometry Group

The work of the group is organized as follows:

- two-day meetings to discuss the work of the individuals and the open points
- home works that will be assigned at each meeting
- discussion via email distribution list

The tasks assigned to this group are:

- Review the fonctional analysis of the instrument before the System Definition Review (FCR) in July 1998.
- Assist the Project Scientist in analyzing the global system of the instrument
- Define the observing procedures and calibrations
- Assist the Observation support module to identify the necessary algorithms for preparing the observations and reducing the data
- Answer to specific questions asked by the PS according to their specialities, insterests and disponibilities.
- Other works not yet identified

5.2.3. Composition of the IGR and motivations

The status of the IGR will the same as the one of the Science Group (cf. document AMB-SGR-001) and the members will be fully associated to the results of the instrument.

For the composition of the group, we chose interferometrists who have experience in dif- ferent fields. For example, people from GI2T and FLUOR, but also other persons who have experience in radio-interferometry in the millimetric range, silicate-based fibers/integrated optics, atmospheric simulations. The list of appointed members is:

- Frédéric Cassaing (ONERA)
- Vincent Coudé du Foresto (DESPA)
- Pierre Cruzalèbes (OCA)
- Thierry Forveille (LAOG)
- Karl-Heinz Hofmann (MPIfR)
- Fabien Malbet (LAOG)
- Denis Mourard (OCA)
- François Reynaud (IRCOM)
- Isabelle Tallon-Bosc (CRAL)

The members of the IGR are full members of the AMBER consortium. They have the same kind of priviligied access to the instrument and its scientific results than the members of the Science Group. The exact policy about coauthorship and guaranteed time will be finalised during the first semester of 1998.

5.2.4. Status of the work

The IGR has met once on December 10 and 11, 1997. The minutes are written in memo AMB-IGR-002. The major issues addressed by the meeting were:

- Definition of the spatial filter. Should it be a pin-hole or a fiber
- What is the length of the OPD scan
- Fringe tracker issues (scintillation, OPD with the instrument)
- Photometric calibration (spectral resolution, ratio photometry /interferometry)
- Observing and acquistion modes
- Spectral coverage
- Polarization
- Atmospheric dispersion and refraction
- Need for internal metrology

Each participant has a homework to do by the end of February. A meeting at the beginning of March will allow to choose the final options in function of these individual studies.

5.3 OPM: Optomechanics

5.3.1 Scope and composition

The optomechanics subsystem contains all optical, mechanical and electrical elements on the optical table as well as the low level control of them. It includes the optical interface to the Fringe Sensor Unit. Initialy, it contained also the spectrograph, but this one has been isolated in a specific subsystem because it is possible to predefine its basic specifications quite early and the people in charge with it are mostly concentrated in Arcetri, where they have specific schedule constraints (actually they are quite avalaible immediately, which is not the case of the OCA and Grenoble people in charge of OPM, while the situation might be reversed later this year).

The working group is coordinated by Pierre Antonelli (OCA) and contains:
- Yves Bresson (OCA)
- Michel Dugué (OCA)
- Andre Glentzlin (OCA)
- Daniel Kamm (OCA)
- Serge Menardi (OCA)
- Karine Perraut (LAOG)
- Patrick Rabau (LAOG)
- Sylvestre Rebattu (OCA)

At the present moment only Pierre Antonelli and Karine Perraut have a significative disponibility.

5.3.2. Status of work

During its first meetings, the OPM group has reviewed the optical elements present on the table and has identified a number of questions to be submitted to the Project Scientist and the IGR, in charge of defining the specifications:

-1- In what order will be implemented the photometric bands ? Will the initial instrument work only in K or should it access imediately to shorter wavelength (H,J,I) ? Even if the wavelengths lower than K are reserved for the ATs (the Strehl ratio in J and I will be quite poor with the 31 actuators AOM), what kind of reservations do we make for their implementation ?

-2- Is it necessary to correct the differential atmospheric refraction ?

-3- Is it necessary to correct the atmospheric dispersion ?

-4- What is the rate of the necessary polarisation correction ?

-5- What is the position of the interface with the FSU ?

-6- What kind of opd modulation is needed ?

Question 5 has been discussed in some more details. It would simplify the optical design to install the separation between the H beam feeding the FSU and the other wavelengths before the spatial filter, but such a large distance between the FSU feed and the recombination point might imply to actively monitor the differential opds between this two points. On the other hand, installing this beam separator as close as possible to the detector, i.e. after the K spatial filter, will damage the performances when observing at wavelengths lower than H: or the spatial filter will be correctly adapted to the science wavelength and too small for the FSU, resulting in a loss of light for the FSU, or it will be optimised for the best fringe tracking efficiency and the quality of the science signal will be damaged by an insufficient spatial filtering. This two questions (use of I,J band, need for a metrlogy between the FSU and the science detector) are currently analysed by the IGR.

Another point discussed in the OPM group are the specifications of the opd modulator. It has been identified that a device introducing one-lambda (2 µm) steps in the opd in less than 1 ms will be difficult (or expensive) to realise and suggested to accept the loss in performances resulting from a linear variation of the opd (0.75 magnitudes). Also the specifications about the acceptable beam tilt during the opd modulator translation critically depends from the spatial sampling of the photometric images. If the photometric image is sampled in the same way as the interferometric one, it could be used to measure small motions of the individual beams and correct the data from the effect of the corresponding losses in image superposition. The required image stability is then of the order of 0.2 pixels, corresponding to a beam stability of 2 arcseconds. If the photometric beam is analysed by a single pixel, it does not contain information about the image position and the image superposition must be maintained at the 1/100 pixel level, which requires a beam stability of 0.1 arcseconds. The optimum sampling of the photometric beams is beeing analysed by the IGR.

5.4 SPE: Spectrograph

5.4.1 Scope and composition

The spectrograph group will study and build the cooled spectrograph which permits to have dispersed fringes on the detector. The resolutions will be 0 (no dispersion), ~100, ~1000 and ~10000. It will also accomodate the photometric beams with resolutions which are still to be defined by the IGR. For the highest resolutions, it is necessary to cool the spectrograph at at least -40°C. Preliminary studies indicated that it would not be more difficult or expensive to cool it down to liquid nitrogen temperature. If this is confirmed, the spectrograph dewar can contain also the detector. The group is based in Arcetri and his members have quite a lot of experience in building this kind of compact cooled spectrographs for infrared observations. The two key people are Sandr Gennari and Franco Lisi. One post doctoral fellow is beeing hired and will contribute to this work. The standard procedure established at Arcetri to build cooleed spectrograph is to make a detailled study in the Observatory and then to subcontract the construction of the Dewar and the cryomechanisms to an industrial company.

5.4.2 Preliminary design

A preliminary design has been based on the following input parameters:

There are 2 perfect incoming beams ("photometric" and "spectroscopic" beam) with pupil image of 40 mm in the same position (near the window of the dewar). The detector is a PICNIC with 256x256 pixels of 40 µm side. Thefield of view is 2"x2" on a 8 m telescope (in this case, with a camera of 800 mm of focal length, we use an area of 40x40 pixels in photometric mode and a stripe of 40x256 pixels in spectroscopic mode).

All the components are enclosed in a cryostat and are cooled to about 70 K. The volume required for optics is about 300x300x450 millimeters.The spectroscopic and the photometric beams (the angle between the two beams is 8.2 deg.) enter the window (plane parallel, not shown in the drawing), pass through the selectable spatial filter, which is located on the pupil image plane and then cross the spectral filter, also selectable by means of a wheel. The spectroscopic beam is reflected by the grating on the first mirror (size 50x50 mm), then on the second mirror (size 20x20 mm), that form the dispersed image on the detector. The photometric beams follows the same geometry, after being reflected by a plane mirror; the undispersed images is focused on a different area of the array.

The grating(s) support could be a critical cryomechanical item; also, the compatibility of the beams positions with the supports of mirrors and the detector mounting must be carefully assessed. The performance of optics is good: the maximum peak-to-valley of wavefront is 0.28 µm, that is about a factor two better than the l/4 required (at 2 µm), to take into account the necessary manufacturing tolerances.

Table 5.4.1: mirror parameters

	mirror 1	mirror 2

radius of curvature (mm)	800	600
constant K	-1.21	
constant A4	$-6.86\ 10^{-9}$	
off axis (mm)	115	43.5
size (mm)	50x50	20x20

Figure 5.4.1 Preliminary design of the spectrograph

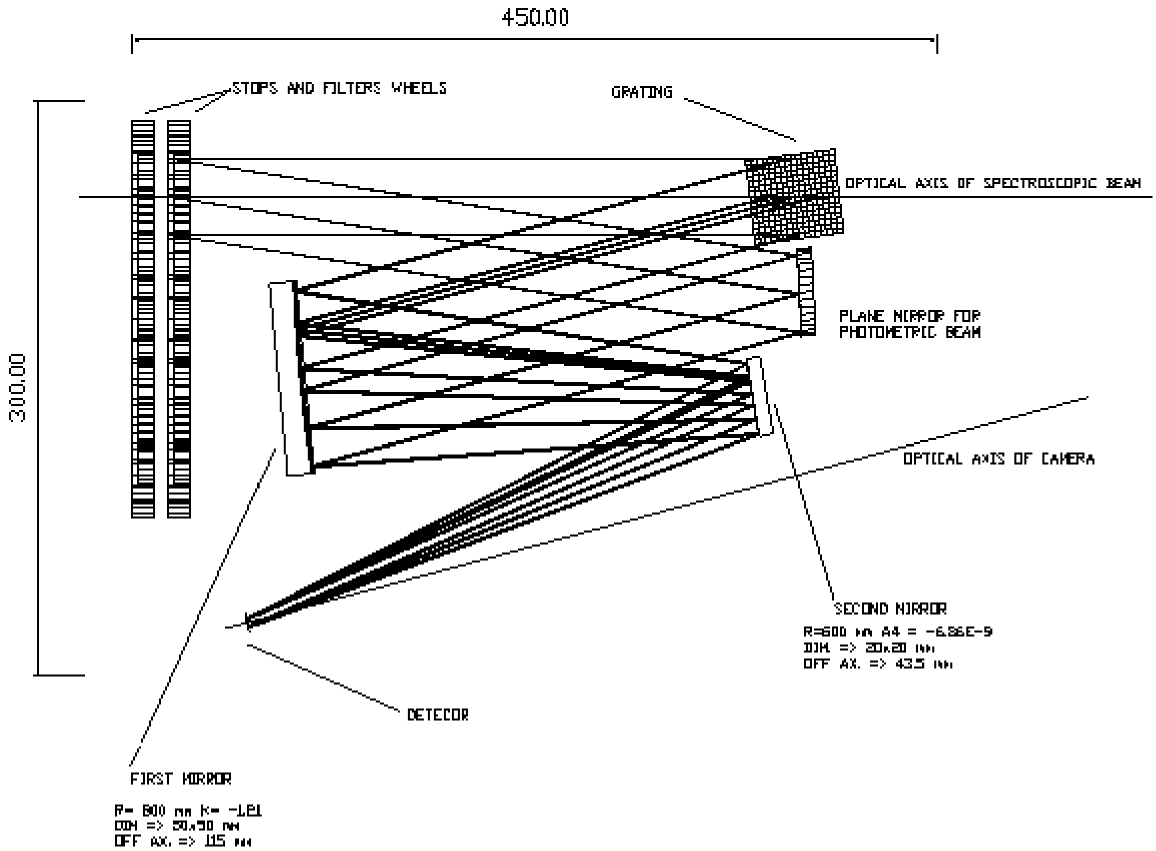


Figure 1: Spectrograph perliminary design

5.5 DET: Detector

5.5.1. Detector group

During the first discussions about the constitution of the AMBER consortium in June 1997, it was decided that the development of the near IR detector for AMBER will result from a collaboration between the OAA and the LAOG. The organisation of this collaboration is described in the AMBER memo AMB-DET-001 and in the paragraph 5.5.5 below). The corresponding members of the DET group are:

- Carlo Baffa (OAA, electronics)
- Gianni Comoretto (OAA, electronics)
- Philippe Feautrier (LAOG, system)
- Étienne Lecoarer (LAOG, acquisition)
- Franco Lisi (OAA, system)
- Panayoti Petmezakis (LAOG, electronic)

In December 98, our colleagues from the MPIfR in Bonn joined the AMBER consortium. In a way quite similar to what is going on in OAA, they are currently finishing a new readout and control electronics for an infrared speckle NICMOS camera with characteristics somehow similar to what is needed for AMBER. This new device will be tested next early spring. Our colleagues from MPIfR wish to apply their work and expertise to AMBER. It has been decided that they will join the Detector Group, to exchange ideas, expertise and proposals with OAA and LAOG. The final organisation of the work will be discussed at the next Detector Group meeting. However, it has been clearly stated that if it is necessary to arbitrate between several comparable proposals, OAA and/or LAOG will benefit from an anteriority privilege. The MPIfR members of the Detector Group are:

- Udo Beckmann
- Michael Geng
- Manfred Heiden
- Walter Solscheid

5.5.2. Detector specifications

5.5.2.1 - Spatio-temporal sampling

A discussion about the way the AMBER data is sampled in the *fringe direction*, in the *spectral direction* when the fringes are dispersed and in *time* can be found in the previous AMBER document (ref [7]) and in the AMBER memo AMB-DET-002. It depends substancially from the observing mode (see paragraph 5.2 and the AMBER memo AMB-IGR-002) which differ essentially by the spectral coverage and the sampling rate. The typical requirements are summarised in table 5.5.1.

Table 5.5.1: Summary on the spatio-temporal sampling requirements

Recombinaison modes	Coaxial	Multiaxial
Number of lines	9 separated	20 consecutives
Number of spectral channels	1, 5, 50-256	1, 5, 50-256
τ_{min} for 1 and 5 spec. chan.	2.5ms	10ms
τ_{max} for 50 to 256 spec.	100s	100s

chan.		

5.2.2.2 - Detector specifications

In order of importance:

1. **Read-out noise**. The read-out noise must be as low as possible, for it is the dominant noise in the wished observing modes. Presently, some instruments reach noise lower than 10 e^-. The manufacturers claim a noise closer to 20 e^-. It seems then mandatory to reach at least the noise specified by the manufacturers and if possible to go beyond and reach 10 e^- even if it is with multiple sampling.

2. **Number of pixels**. Depending on the coaxial or multiaxial modes, we foresee to use 9 separated lines or 20 consecutive lines. The term lines and columns have no importance and therefore one can invert them. One should be able to read only a part of the lines if the spectral resolution allows it. In the wide field application which is to be implemented sometime later, 256 pixels will allow to explore only 0.8 arcseconds if three telescopes including at least one UT are used. To be able to benefit from the 2 arcsecond field, 620 pixels are needed in the fringe direction.

3. **Frame rates**. One can distinguish two types of frame rate. One related to the read-out of the detector, tau_R , and the other to the scientific exposure time, tau_S . The total time tau = tau_S + tau_R must answer the specifications of table 5.5.1.

4. **Quantum efficiency**. The best as possible: 60% is wished.

5. **Pixel gain**. The gain table must be linear for each pixel but there are no specific and strong specifications on the uniformity of the gain table all over the chip. Of course this gain table must be as good as possible, but this is not clearly a priority. However one needs gain stability on a time longer than the maximum exposure time, i.e. several minutes. To optimize observing time, it would be nice to need only a few gain tables per night. This corresponds to a gain stability of typically a few percent in a few hours.

5.5.3 Available detectors

We have the choice between differents detectors coming from two american manufacturers : Rockwell and Santa Barbara Research Center (SBRC). Both of them are producing 256 x 256 and 1024 x 1024 arrays. Table 5.5.2. summarizes the available detectors, their main performances and their prices.

Table 5.2.2: List of available detectors for AMBER

	256 x 256 array		1024 x 1024 array	
Company	Rockwell	SBRC	Rockwell	SBRC
Name	PICNIC		HAWAII	ALADDIN
Material	HgCdTe	InSb	HgCdTe	InSb
Band(μm)	1-2.5	1-5	1-2.5	1-5
Temperature	77 K	35 K	77 K	35K
Full well (e-)	$2.5\ 10^5$	$5\ 10^5$	$1\ 10^5$	$3\ 10^5$
Noise (e-)	< 20	< 75	9	< 25
Pixel rate (MHz)	0.2	?	<1	0.7

Pitch (µm)	40	30	18.5	27
Price	k$50	k$65	k$150	k$95

From that table, one can conclude that:

- Choice Rockwell/SBRC:

  - The detectors from Rockwell are, according to the data given by the manufacturers, less noisy. This is the main point to take into account if we look at the detector specifications.

  - In addition, the Rockwell detectors are working at nitrogen temperature, due to the material used for the detection (HgCdTe). The cut-off wavelength of this material can be precisely adjusted to 2.5um, which is not the case of InSb which have a fixed cut-off wavelength of 5 microns: this leads to a higher dark current and then a smaller working temperature is mandatory to avoid an excess of dark current. This is a great disadvantage for a camera working on an astronomical site.

- Choice Rockwell PICNIC/HAWAII:

  - the cost of the HAWAII detector is 3 times higher than the PICNIC cost.

  - but the readout noise of HAWAII is 2 times smaller than the PICNIC noise, due to a smaller full well capacity, even if both of then are fabricated on the same wafer with the same technology.

In conclusion:

- the PICNIC detector seems to be, for the moment, the best cost/performances compromise, but the HAWAII array should be also considered when we will have to do the choice, because of a smaller readout noise. It depends mainly on the amount of money affected by the AMBER project to the detectors. If we consider only the technical side, the HAWAII detector is a better choice.

- perhaps the detector performances will be improved in a near future. We know that Rockwell has already fabricated a 128x128 very low noise detector (readout noise of about 0.7 e^-) using InGaAs. Unfortunately, this detector is not yet on the shelves. This information has obviously to be confirmed, but we have to take care of the technical progress made by the manufacturers.

- as a consequence, the science grade detector has to be ordered as late as possible according to the AMBER planning.

5.5.4. Detector ordering

The following delays are given by Rockwell for a PINIC detector:

- time to find a contract agreement : approximatively 1 month
- export licence from the US Government : 1 month
- multiplexer (CMOS detector without the infrared stage for electrical debugging) + engineering detector : about 3 months
- science grade detector : 9 months

5.5.5 Development strategy (from AMB-DET-001)

To discuss the collaboration between OAA and LAOG in the detector group it is sufficient to say that this subsystem must provide:

- an IR detector sensitive in the 1-2.5 µm range, with a minimum size of 256x 256 pixels. The product of choice is the PICNIC by Rockwell, but also the 1024 x 1024 HAWAII is being considered. This latter offers a larger area, important in some specific applications, and a noise which is lower by a factor of approximatively 2, at a cost which is higher by a factor of approximatively 3.

- the associated electronics. This must be capable of fast readout and low-noise. It must also provide the possibility to read only parts of the array when required (sub-arrays, pixels, lines, or mixed).

- capability to write the data to disk at a sufficiently high speed and if necessary provide the data to a computer via a fast link for on-line processing.

OAA has already developed, but not tested, electronics for the NICS instrument of the National Galileo Telescope. Besides, OAA has a large experience of IR detectors driving and reading systems, gained with the IR camera for the TIRGO telescope, named ARNICA. The new electronics to be tested for the TNG seems to be well suited for the applications required by the AMBER project, and in particular it already implements the requirements of fast and flexible read-out and storage schemes. However, while OAA is confident that the readout noise should not be substantially affected in standard operation at slow integration, they cannot qualify quantitatively the expected performance at fast speed. OAA already has an HAWAII detector which will be integrated in the next 3 months, and will allow them to test the electronics more extensively.

LAOG has developped an experience in infrared detection, specially with thermal IR sensitivity detectors, in connection with the Grenoble industrial expertise through SOFRADIR and LETI/CENG. It has built the electronics of the COMIC detector that equips the thermal camera in use with ADONIS at ESO. LAOG is now developing an IR camera for their IONIC experiment, and have ordered a PICNIC detector. Their goal is to develop their own electronics, which shall be based on available experience aimed expecially at a read-out noise as low as possible. The time required for this development cannot be exactly determined yet, but it seems that the two years maximum for a working subsystem allowed by the present AMBER project schedule could be risky.

After these considerations, the AMBER team agrees on the following:

- OAA will proceed to test their electronics as quickly as possible in the near future. They think that this phase should take place approximately by the end of February 98.

- Should the results of these tests be satisfactory and comply to the requirements set forward in the AMBER project, OAA will provide the electronics for the detector subsystem.

- If the tests should show that the read-out noise is larger than the expected figure quoted by the manufacturer, these different scenarios can be realized:

1. the read-out noise is unacceptably large, also at slower frame rates. This would affect operations also for the NICS instrument, and in this case OAA will have to look into the problem and fix it as soon as possible.

2. the read-out noise is unacceptably large, but only at fast frame rates. This would affect operations for the AMBER instrument, and in this case someone will have to look into the problem and fix it as soon as possible.

3. the read-out noise is large, but not by a dramatic factor with respect to the figure quoted by the manufacturer (for example, $50e^-$ for a PICNIC detector). In this case, OAA will look into the problem and try to fix it only if it does not require a huge effort in manpower. Otherwise, initial operations will have to deal with this problem, which presumably will affect only some modes of observations. LAOG is then ready to invest manpower into the problem and OAA will provide them with the hardware and necessary assistance to carry out an improvement, provided that it does not imply a substantial redesigning of the electronics.

Therefore, it is foreseen that OAA will provide the electronics at least for the first 1-2 years of lifetime of AMBER, providing that the first tests show encouraging results. In any case, LAOG will pursue their own developments and if their electronics will be better suited, it will be integrated into AMBER at a later time.

5.6 AOM: Adaptive Optics

5.6.1 Description and expected performances

The Adaptive Optics Modules are the decisive features allowing AMBER to perform singlemode interferometry in the K band with the UTs and in the H_α region with the ATs. The system proposed for AMBER is based on the Roddier design with a sensor of the wavefront curvature activating a dimorph mirror. It has been originally studied by A. Blazit with the help of the ONERA for the GI2T interferometer. For cost and delay reasons it has been choosen to have only 31 sensing areas and actuators. A realistic and even a little bit pessimistic simulation of its performances (see ref [4] page 37) gives the values summarised in table 5.1

Table 5.6.1: performances of 31 actuators AO modules

Telescope & photometric band	max. Strehl ratio S_{max}		V mag. for Strehl		V mag. for Strehl ratio=0.5	
% of time with a better seeing	20%	60%	20%	60%	20%	60%
UT in K	0.3	0.12	14	12	15	14
AT in K	0.9	0.79	16	13	20	15.5
AT in H_α	0.2	0.06	9.5	9.5	11	10

The AO module has the following components:
- the active dimorph mirror
- the vibrating mirror forming intra and extra focal images on the entrance of the wavefront sensor
- a combination of prims glued on a field lense dividing the wavefront in 31 sensing areas
- 31 cooled avalanche photodiodes with their readout electronics
- a real time calculator computing the tensions applied to the active mirror
- a controler of the real time calculator to set the algorithms and their parameters
- an user interface with the controler (software installed in a work station)

The dichroic plate(s) feeding the wavefront sensor with all or a fraction of the visible light, the various static optics adjusting the positions and magnifications of the pupil and image planes, the calibration sources and the mechanical structure supporting the components are part of the OPtomechanical Module. An integration and test bench is beeing built for the GI2T AOs and will be used for AMBER together with the facilities (atmospheric turbulence simulator...) offered by ONERA.

A PNHRAA working group led by G. Rousset from ONERA showed that the components of one AO module can be purchased for slightly less than 1 MF, if a serie of at least 4 modules is ordered. This assumes that A. Blazit successfully develops his wavefront sensor where the 31 photodiodes and their electronics are integrated in a single cryostat. The more conservative solution based on the individually cooled and optical fiber fed photodiodes commercially available implies an additional cost which could reach 700 KF per module.

5.6.2. Organization

5.6.2.1 Participants

Alain Blazit	OCA
Christophe Verinaud	OCA
André Glentzlin	OCA
Pierre Antonelli	OCA
Gilbert Mars	OCA

Pierre Yves Madec	ONERA
Didier Rabaud	ONERA
Béatrice Sorrente	ONERA
Frédéric Cassaing	ONERA

5.6.2.2 Collaboration between ONERA, GI2T, AMBER

The development of the AMBER AO modules is based on the convergence of three combined efforts.

- ONERA is currently developing its own AO system based on curvature sensing. They plan to test with their atmospheric turbulence simulator a system with 13 actuators. This will validate their general study and particularly their real time calculator, algorithms, integration, calibration, test and control procedure. They have internal motivations and budget for this operation. They have a specific interest in AMBER but their main goal is observing satellites with GI2T equipped with AOM by the end of 2000 (see AMBER memo AMB-AOM-001).
- Alain Blazit and the GI2T team have been working for two years now on a 31 actuators system for GI2T. The single difference between this system and the ONERA one is the integrated wavefront sensor developed by Blazit to reduce cost. The funding for this two modules has been asked to OCA, the PACA region (they provided almost all funds needed for module#1) and INSU and is not included in the AMBER budget.
- AMBER needs two AO modules identical to the GI2T ones. The single differences with GI2T will be in the mechanical and software interfaces between the AO modules and the interferometers.

5.6.2.3 Main tasks

The main tasks of this operations are:

ONERA tasks:

O1- The General Study of the AO Module at ONERA (Cassaing, Madec, Rabaud, Sorrente): sizing, simulations, real time processing, ONERA user interface.

O2- Industrialisation of the Real Time Processor by the company Shakti under ONERA supervising (Rabaud).

O3- Static Integration at ONERA with a 13 APD&actuators system (Cassaing, Madec, Sorrente). This includes the installation of all components on an optical bench, their adjustment and the calibration of the sensor/actuator relation. ONERA will invite OCA/AMBER people to participate to this integration in order to get trained.

O4- Dynamic Integration at ONERA with the turbulence simulating tank (Cassaing, Madec, Sorrente). This includes a full test of the system with a realistic turbulence and a validation of its performances. ONERA invites OCA/AMBER people to participate to this integration in order to get trained.

Tasks common to GI2T and AMBER:

C1- Full tests of the the integrated wavefront sensor (Blazit, Verinaud, with a punctual help from Antonelli and Glentzlin). If this test is not satisfactory by next spring, it will be necessary to switch to more expensive sensors for AMBER based on separated APDs). This work is progressing well, with in particular a succesfull test of the readout electronics in November 97 (readout noise ~ 100 events/s).

C2- Construction of an integration, calibration and test bench at OCA (Verinaud, Blazit, one of OCA mechanical engineers, usable for final tests with the OHP (Haute Provence Observatory) 152 cm telescope.

C3- Static integration at OCA of module #1 (Verinaud, Blazit, others TBD from AMBER OPM and ICM groups...) with ONERA advices and limited help.

C4- Development of an OCA/GI2T user interface with the advices of ONERA people (Rabaud, Sorrente): they will train and assist OCA people but will not actually define or write software for the OCA interface (Mars (tbc), new OCA computer engineer -recruitment in progress-).

C5- Dynamic integration at OCA of module #1 (Verinaud, Blazit, others TBD from AMBER OPM and ICM groups...) ended by tests at the 152 cm OHP telescope.

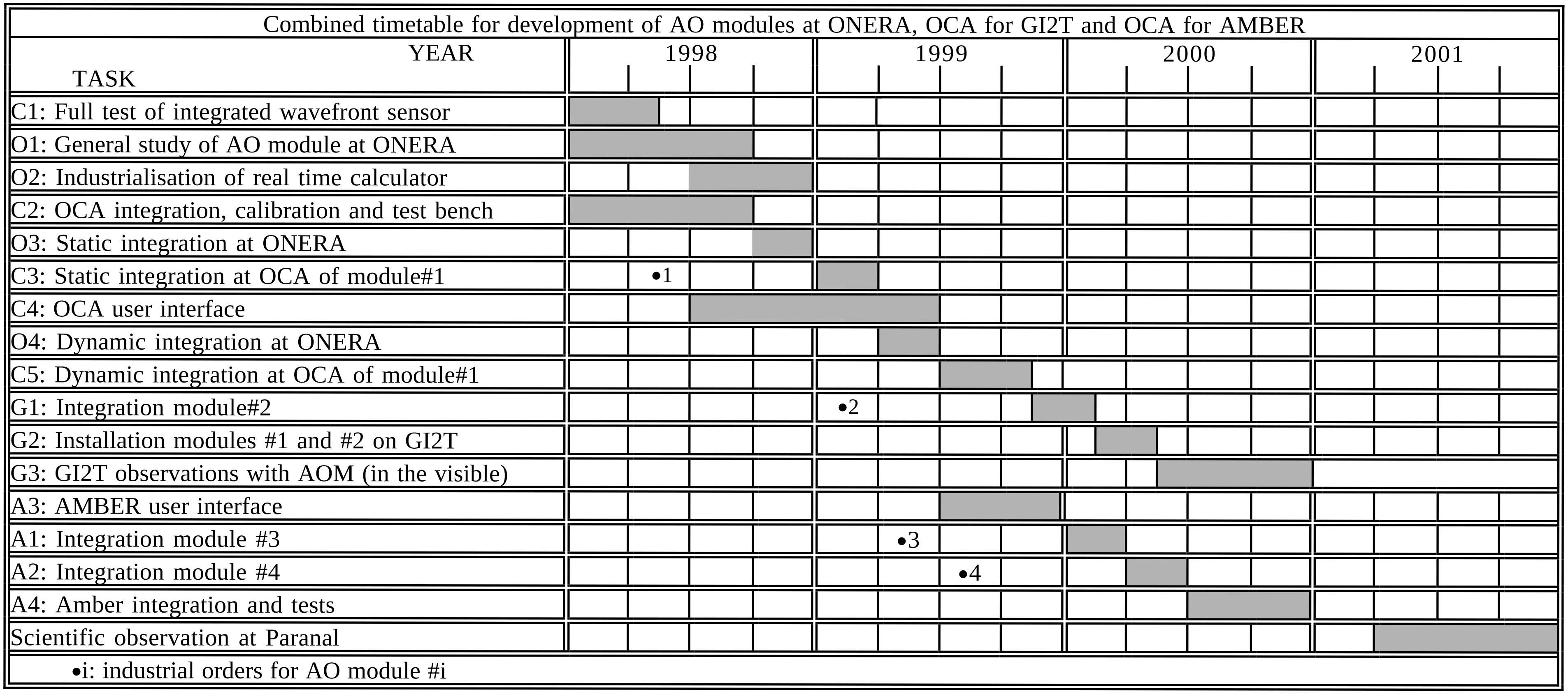
Tasks specific to GI2T:
G1- Integration and tests of module#2 which is a copy of module#1.
G2- Integration of modules #1 & #2 and interfacing with GI2T
G3- Interferometric observations with AO modules with GI2T in the visible.

Tasks specific to AMBER:
A1 and A2- Integration and tests of modules #3 & #4 which are copies of modules #1 and #2.
A3- Development of the AMBER user interface as similar as possible to the GI2T one (Mars (tbc), new OCA computer engineer).
A4- Integration in AMBER and AMBER laboratory tests.

5.6.2.4 Timetable

The following time combines all three projects.

Remark: one might fear that the training of OCA/AMBER people at ONERA during ONERA integrations would be insufficient to allow them to realise rapidly the integrations at OCA with the limited assistance proposed by ONERA. We will try to associate to AMBER someone with experience in the integration of this kind of AO system or to obtain a higher level of ONERA help (which would imply paying for the engineer time).



Combined timetable for development of AO modules at ONERA, OCA for GI2T and OCA for AMBER

YEAR TASK	1998				1999				2000				2001			
C1: Full test of integrated wavefront sensor	▨	▨														
O1: General study of AO module at ONERA	▨	▨	▨													
O2: Industrialisation of real time calculator			▨	▨												
C2: OCA integration, calibration and test bench	▨	▨	▨													
O3: Static integration at ONERA				▨												
C3: Static integration at OCA of module#1		•1			▨											
C4: OCA user interface			▨	▨	▨	▨										
O4: Dynamic integration at ONERA						▨										
C5: Dynamic integration at OCA of module#1							▨	▨								
G1: Integration module#2					•2			▨	▨							
G2: Installation modules #1 and #2 on GI2T									▨	▨						
G3: GI2T observations with AOM (in the visible)										▨	▨	▨				
A3: AMBER user interface							▨	▨								
A1: Integration module #3						•3			▨							
A2: Integration module #4							•4			▨						
A4: Amber integration and tests											▨	▨				
Scientific observation at Paranal														▨	▨	▨

•i: industrial orders for AO module #i

5.6.3 Use of ESO Adaptive Optic Modules in the UT Coudé trains

Recently it has been announced that ESO might place AO modules in the Coudé trains of the two UTs first used for interferometry. This modules would have about 64 actuators and therefore would provide a better Strehl ratio with similar limiting magnitudes. The date of scientific operation of this two modules might be as early as March 2001.

If this is confirmed, AMBER could start interferometric observations with the UTs in the K band without its own AO modules. It would still need it for H_α observations in the visible and the very near infrared and also to improve the Strehl ratio of the ATs in the infrared (the gain in Strehl ratio in the K band is about a factor 3, from 0.3 with a tip-tilt to 0.9 with a 31 actuators A0). Then, the orders, integration, implementation on AMBER of the AO modules #3 and #4 (tasks A1 to A4) can be delayed by one to two years. However, the planning for the equipment of GI2T with AO modules #1 and #2 should be kept about the same. Having tested with GI2T long baseline interferometric observations with telescopes equipped with partially correcting AO modules will guarantee the good use of the UTs by AMBER. To be fully usefull, this test should be completed by the end of the year 2000.

For AMBER to rely on the ESO AO modules it is necessary that a link is established in ESO plannings between the dates of first interferometric operations and the dates of avalaibility of the two AO modules. The members of the AMBER consortium would bitterly regret to see the scientific operation of their instrument with the UTs substancially delayed by changes in ESO AO modules planning.

5.7 ICM: Instrument Control

5.7.1. Participants to the ICM subsystem

- Etienne Lecoarer (LAOG, coordinator)
- Michel Dugué (OCA, after 10/98)
- Daniel Kamm (OCA, after 10/98)

This working group is clearly understaffed.

5.7.2. Goal of ICM

The primary function of ICM is to be the MAIN OPERATOR of AMBER. Therefore ICM interfaces with all other subsystems as well as with the rest of VLTI and with the observers. There are therfore needs for a common language and ressources.

The list of subsytems which interacts with ICM is the following:

- optomechanics
- infrared detector (in the long term visible detector)
- adaptive optics
- VLTI control system (VLTICS)
- (FSU: normally the communication with the FSU should be through the VLTICS)
- data archives
- user(s)
- observing support software (OSM) for the observing preparation and the data reduction
- on-line databases (OLDBs)
- quick-look anylisis + monitoring system

5.7.3. ICM philosophy

The philisophy of ICM development is based on a general multi-platform, network-based control system. We can then use industry standard like VME or PCI buses. We will insert the instrument control in the general VLTICS with a Local Control Unit dedicated to the instrument and an Instrument Workstation. The communications with the VLTICS will follow the recommendations by ESO, but we have not yet decided whether the internal architecture will follow the ESO VLT recommendations or wil take advantage of homemade developments. The debate must take into account the following criteria:

- implied hardware
- what already exists in our institutes (experience and software)
- ESO support on site
- costs
- manpower needed
- easy implementation
- time for realization
- portability
- maintenance

5.7.4. Control system architecture

It will be defined by next April with the help of people working on the PFSU and NAOS.

5.8 OSM: Observing Support Module

5.8.1. Members of the group:

- Éric Aristidi - UNSA
- Udo Beckmann - MPIfR
- Philippe Bério - OCA
- Marcel Carbillet - OAA
- Pierre Cruzalèbes - OCA
- Margit Dornseifer - MPIfR
- Albrecht Dress - MPIfR
- Gilles Duvert - LAOG
- Thierry Forveille - LAOG, coordinator
- Markus Georges - MPIfR
- Karl-Heinz Hofmann - MPIfR
- Jean-Louis Monin - LAOG
- David Mouillet - LAOG
- Eddy Nussbaum - MPIfR
- Éric Thiébaut - CRAL
- S. Ragland - OAA

5.8.2. The goal of OSM

This subsystem in fact consists in all software functions that should assist the astronomer to use this instrument, in opposition to the software functions dedicated to the direct operation (control) of the instrument (subsystem ICM).

We identified the following classes of functions:

- to support the preparation of observations:
    - number of required configurations, u-v coverage
    - exposure times, SNR estimations,
    - observability constraints
    - TBD
- to support the running of observation (relevant on-line information)
    - relevant information: in order to estimate whether the expected performance is achieved, problem occurs, ...: This will be the task of the Real Time Processor: The OSM group, together with the IGR must define its functions and the RTP group will realise the implementation.
- to obtain (instrument independnt) complex visibilities from raw data: on the basis of raw data, observing conditions, instrumental configuration.
- to provide with standard tools for image restauration.

Note that this list is certainly preliminary and only aimed at precising the extent of the subsystem. We already identified a large range of work to be done on this subject and various corresponding capabilities:

- (complete) functional analysis of the subsystem (definition of the astronomer supposed to use this soft, extensive list and characterization of the functions to be provided, context of use, data flows, interfaces,...)
- definition of algorithms for visibilities estimations (implies the definition of observing procedures), link with interferometric group.
- definition of algorithms for image reconstruction (note that this may be implemented only for late 2002, when at least 3 beams are recombined)
- software and hardware architecture design
- implementation of the algorithms
- other: TBD

It is underlined that this group should take benefit from already existing tools or experience derived from radio interferometry, and from experience on IR and V observations.

One the first task of OSM is the coding of a simulation tool in order to make some critical choices at the conception level (spatial filtering, visibility estimator,...).

5.8.3. Software constraints

5.8.3.1 OSM with the ESO VLT software

Generally speaking, ESO asks to the different VLT instrument consortia to provide procedures and scripts that can be used in a data reduction pipeline as well as for interactive work. These procedures must be written in ANSI C and integrated in a package whose form is defined by MIDAS (cf. the document MID-SPE-ESO-11000-0001/1.3).

As far as AMBER is concerned, the data structure can have a very specific form. It makes more sense then not to start a priori from software constraints, but to adapt the software to this structure. Concerning the I/O format for example, tha data should be in a very standard format like FITS in order to get advantages of software already written (e.g. image reconstruction)

5.8.3.2. Data volume

Order of magnitude:
- 4 points per fringe
- frequency 100 Hz
- 1000 spectral elements
- 4-bytes per data element

which leads to 1.6Mb/s

5.8.3.3 Use of the OSM software

The adopted philosophy is to develop a software for the community which has taken part to AMBER. The software will then be operational on a limited number of sites. There are no reasons a priori to limit the use of this software outside the AMBER community, but the group does not commit itself in distributing and supporting the AMBER OSM software elsewhere.

5.8.4. OSM output

The objective of the OSM software is to provide all possible information on the source which is independant of the instrument. In clear, in means it will provide calibrated measurements.

This information is:
- with 2 telescopes:
  - the amplitude of the complex visibility of the object in function of u,v and lambda
  - the phase difference between two spectral channels (one of them being the reference channel, choosen at a particular wavelength or built by averaging a range of channels)
- with 3 or more telescopes:
  - the previous information for each baseline
  - for each combination of 3 telescopes, the phase closure

In principle, with all the previous information, the observer could use his own tools/models/softwares to get the desired astronomical information. However, if it appears that some operations are specific to the instrument or are almost systematically applied, then it would be considered to include them in the OSM software.

5.8.5. Data and performance simulations

OSM has started to work on the different modules needed to simulate the data flow:

- object	(Aristidi)
- atmosphere	(Mouillet, Malbet)
- telescopes	(Forveille, Duvert)
- adaptive optics	(Mouillet)
- fringe tracker	(TBD)
- beam combiner	(Berio)
- spectrograph	(Cruzalebes)
- detection	(Monin)

The general set-up of the simulation tool is done by Forveille and Duvert.

5.9 RTP: Real Time Processing

The real time processor (or monitor) runs a small, fixed part of the software defined in the OSM in real time simultaneously with the data acquisition. It is intended to have permanently a reliable estimate of the quality of the data which is beeing recorded. In some cases, to be defined in the System Definition Phase, informations might be send from the RTP to the ICM. For example, in a blind mode when fringes are not detectable on individual exposures, the real time processor could integrate the power spectrum of one spectral channel or the cross spectrum between two channels and deliver every few seconds a coherencing signal send to delay lines through the ICM. It also possible to have some systematic real time processing before recording the data (for example detector corrections). Ultimately, it should be possible, at least for some observing modes, to record only a small number of parameters per spectral channel and integration sequence (visibilities, relative phases, phase closures...) but this can happen only after quite some time of real exploitation of the instrument, when we will be really sure that we master all parameters affecting the data and will probably require a real time processor with increased capacities.

During our recent discussions about the entrance of our MPIfR colleagues in the AMBER consortium, it has been decided that the real time processor will be built at the MPIfR where they have developed something similar for real time image reconstruction from speckle masking.

The specifications of the RTP should be defined by the Interferometric and the OSM groups by next May.

5.10 INT: Integration, calibration and testing equipment, end-to-end simulations

This module contains all optomechanical elements needed to align and to calibrate the instrument. It will be in charge of the system integration and tests. It will develop the simulation tools started by the OSM in an end-to-end simulation used to test the software, simulate the observation and estimate the performances and therefore the feasability of the astrophysical programs.

This module is currently in stand by. The specifications of the INT equipment will be defined mainly by the Instrument Definition Team in the System Definition Phase.

Chapter 6

Timetable

The preliminary and still approximate general timetable combines the plannings of each subsystem and integrates them in a general planning with the following important dates:

- May 1998: End of selection of observing modes thanks to the combined work of IGR, SGR and OSM. Choice of solution for DET after the tests in OAA and MPIfR. The integrated wavefront sensor has been fully tested.
- July 1998: Full definition of project (**Final Concept Revue**). Hard points have been identified and concept of solution has been selected. Software architectures for OSM, ICM, RTP have been selected and first evaluation of volume of work has been made. At this point precise cost estimates can be made, although it would be simpler to make it for the:
- November 1998: **Preliminary Design Revue**. Hard points have been solved, detailled system analysis is finished. All interfaces are analysed. There is a decomposition in elementary tasks. Precise timetable is known.
- April 1999: **Final Design Revue**, all orders can be issued
- July 2000: **Manufacturing and Integration Revue**, all subsystems have been integrated and tested and it is possible to start the global integration and tests of AMBER.
- December 2000: **Shipment to Paranal** where after 3 months of local laboratory and siderostats tests, we expect to start observations.
- April 2001: **Observations with the UTs**.

For reasons explained in the subsystem reports, it is desirable that the orders of the Detector chip and of the spectrograph cryostat and cryomechanisms be issued immediately after the PDR.

AOM has its own planning (see 5.6) but the FDR is a critical milestone: this the deadline to decide if AMBER will use ESO AOM or its own modules for observations with the UTs.

General Timetable

Year	1998				1999				2000				2001				2002
Term	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	
SGR	final choice of observing modes. Discussion of hard points.	key programs			preparing observing programs and schedules with models of sources and simulations of interferometer						revise obs. schedules according to tests			**04/2001 Observations with the UTs**			
IGR			functional analysis with OSM		test plan	end-to-end simulations			tests				**Paranal labo. and side-rostats tests**				
OPM	entrance optics	points.	preliminary design and cost estimate		final design	construction			int & tests		Global Tests of Amber						
SPE	preliminary design		final design and cost estimate		<spectrograph order spectrograph delivery>				spe int								
DET	choose solution (tests at OAA and MPIfR)		preliminary design and cost estimate		<chip order final design	construction				det int							
AOM	wavefront sensor tests		order module #1		order module #2	order module #3	order module #4	ohp tests	int#3	int#4	(GI2T tests AO+Interf)						
ICM	choose architecture functional analysis		preliminary design and cost estimate		final design	construction first tests (AOM, FSU)			tests with OPM, DET								
OSM	simulations and start functional analysis		functional analysis with IGR		final design	construction					tests with simulated data						
RTP		functional analysis	preliminary design and cost estimate		final design	construction					Global Tests						
INT	functional. analysis.		preliminary design and cost estimate		final design	construction end-to-end simulations				OPM tests							
SPE V						< Start of visible components studies											AT1
DET V																	
FSU		MIR	END	Assistance to ESO for Final Fringe Sensor Unit detector upgrade proposal..		detector upgrade.											
		07/98> FCR>		**11/98> PDR>**	**04/99> FDR>**					**06/2000> MIR>**		**12/2000> go to Chili>**		**<04/2001 <Observations**			

Chapter 7

Budget

7.1 Elements for a budget estimation

A lot of elements still have to be defined in the present system definition phase. Some of them can have an important impact on the final budget which will therefore cannot be perfectly defined before the Final Concept Revue during the summer 1998 or the Preliminary Design Revue in November 98. What follows are approximative estimations based on the information avalaible now and on the PFSU and REGAIN experience[2]. The following numbers must be used very cautiously as a general frame for the organisation of the consortium, the negociations with the sponsoring agencies and the system definition work.

Table 7.1: Budget Evaluation

Component	***Low (KF)***	***High (KF)***	***Low subtotal***	***High subtotal***
Low order AO modules (31 actuators)[3] (x2)	1000		**2000**	
Detector, acquisition, processing			**1000**	
Chip	300			
Electronics	300			
Cryostat	100			
Acquisition and data storage	100			
Real time processor	100			
Off-line processing	100			
Optomechanics			**1050**	**1650**
For each beam[4]: (x3)	200	400		
Cylindrical optics	50			
Spectrograph (optics, standart mechanics, calibration sources)[5]	200			
Cooling the spectrograph[6]	200			

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[2] Let us note that this two projects have been kept within their initial budgets.

[3] Assumes that the Blazit integrated wavefront sensor passes succesfully its spring tests.

[4] At GI2T/Regain the cost was about 300 KF by beam but some of Regain functions (pupil stabilisation, field rotation...) are not needed in AMBER which, on the other hand, might have some specific functions (spatial filter with fibers...)

[5] The GI2T/Regain spectrograph, which is substancially more complex than the AMBER one had a cost of 330 KF

[6] OAA estimation; if the cooling is made with liquid Nitrogen (our OAA colleagues say that it is not really much more expensive or complex), the spectrograph cryostat can be used as detector cryostat.

Control electronics[7]	350	650	**350**	**650**
Calibration and test equipment[8]	500		**500**	
Consortium operation	600	700	**600**	**700**
TOTAL			**5500**	**6500**
			6000 ± 10%	
Evaluation for the visible part of AMBER				
Spectrograph			**300**	**500**
Detector			**700**	**1300**
Modifications and additions in each beam (x3)	50	100	**150**	**300**
TOTAL for the visible			**1150**	**2100**
			1600 ± 30%	

7.2 Budget in 1998

In 1998 a critical date will be the November Preliminary Design Revue when the final and precise budget will be known. Before this date, the expenses will be limited to travel and some laboratory tests (for example to assess the exact performances of the piezos to be used for the opd modulation). We proposed to our main funding agency, which is INSU, to wait until the FCR or better the PDR to allocate the full budget. Some elements will be completely defined and probably designed at the PDR (November 2, 1998) such as the detector chip and the spectrograph (see the chapter about the spectrograph subsystem) and should be ordered before the end of the year.

INSU budget:	
Before the PDR:	
Operation of the consortium (travel expenses):	150 KF
Laboratory tests and prototypes	100 KF
After the PDR:	
Operation of the consortium for the 2nd semester	100 KF
Order of the IR Science detector chip	150 KF
First orders for the optomechanics and the control subsystems	400 KF[9]
OA Arcetri budget:	
Travel expenses for the Italians[10]	
Ordering the spectrograph cryostat	350 KF
MPIfR Bonn budget:	
Travel expenses for the Germans[11]	
First orders for the real time processor	175 KF

7.3. Financing plan

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[7] The PFSU cost was of 400 KF (not including software licenses)

[8] The PFSU "Piston Generator Assembly" used to qualify its performances costed 360 KF. In the case of AMBER it will be necessary to add spectral and OA calibrations

[9] This expense can probably wait until the *very* begining of the year 1999 without delaying the project. But in such a case the budget asked to INSU in 1999 will be very heavy (1900 KF).

[10] It will probably simplify the operations if our Italian and German colleagues to take care of their travel expenses on their Institute contributions. Of course they will use the general budget if necessary.

[11] Same as previous note

	1998	**1999**	**2000**	**2001**	**2002**	
INSU	900	1500	500 *300*	*1000*	*300*	2900 *1600*
PACA Region[12]		250	250	*possible*		500
Rhône Alpes Region[13]		200	300	*possible*		500
MPIfR Bonn[14]	175	350	350	175 *possible*		1050
OA Arcetri[15]	350	350	350	*?*		1050
ESO	One part of the 800 KDM "VLTI instrumentation budget" at ESO should be used for AMBER					
TOTAL	1425	2650	1750 *300*	175 *1000*	*300*	6000 *1600*

The numbers in straight characters are for the near IR part of AMBER while the *numbers in italic are for the visible part of AMBER*

It is important to remember that all subsystems must have been integrated and tested at the Manufacturing and Integration Revue of July 2000. This assumes that all components have been delivered at the very latest in the first weeks of 2000. Therefore, almost all the budget must have been made available at the very beginning of 2000. It is even likely that a too large proportion in 2000 would already imply delays.

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[12] Must be asked for in 1998. Numbers in the table are estimates of what can be reasonably expected.
[13] Same as previous note
[14] 50 KDM in 1998 and 2001, 100 KDM in 1999 and 2000.
[15] 100 KDM in 1998, 1999 and 2000.