R&D for Advanced Virgo

Report for the STAC meeting – June 11-12, 2008

The Virgo Collaboration[1]

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1. R&D for AdV

The Virgo Collaboration is pursuing a coherent effort towards a preliminary design of AdV. Well focused R&D is needed to make the right choices and finalize the detector design.

The Virgo Collaboration set up a process to review the R&D in progress. An internal R&D review was held on April 21-22 with the purpose of:

- assess the progress of the R&D projects funded within the 2nd EGO call
- discuss new proposals that fits the AdV framework
- establish priorities among the R&Ds

The main purpose was to have a technical discussion about the NECESSARY developments for the realization of the detector and the R&D lines that can bring IMPORTANT achievements on the sensitivity or robustness sides.

In the following the outcomes of the R&D review and further discussions follows. First, each of the projects is shortly described and commented. Then, a table with the priority summary is shown. For each project, the "deadline" for providing results useful for the realization of AdV is estimated (according to the tentative planning based on the approval in Dec 2008). Finally, a funding priority scheme is proposed.

1.1 PROJECTS FUNDED WITHIN THE 2ND EGO CALL

System design of the optical configuration for AdV
This project is already funded for the 2nd year (fellowship granted to S.Hild at Birmingham University. The PI of the project (A.Freise) has been appointed manager of the OSD (Optical Simulation and Design) AdV subsystem. The study pursued is expected to give a substantial contribution to the definition of the AdV optical configuration.

High Power optical components
The success of this project is essential to AdV. The facility to test the components at high power has been setup in a brand new dedicated lab on site. A collaboration with the Russian Institute for Applied Physics (Prof. Kazhanov) is starting for the study and production of the AdV Faraday isolator.

Detection system upgrade
This project covers two items: DC detection and photodiodes under vacuum. DC detection is the baseline choice for AdV and must be studied. The photodiodes under vacuum have been studied for Virgo+ and the requested funding for this item for 2008 (16.6 kE) should be moved on Virgo+ budget.

Interferometer sensitivity at low frequency
The operation of Virgo has shown that one weak point of the SA design is the lack of control of the two tilt dofs. The development of a sensitive and robust tiltmeter should allow to fix this bug. The first tiltmeter prototypes are being tested on bench. Afterwards, they will be mounted on the test inverted pendulum available on site for the control tests.

This project is challenging but very important. An effort is needed to understand what is the minimal tiltmeter performance required to make tilt control useful.

CALVA
The use of an auxiliary laser to lock AdV is promising. CALVA will be a testbed for this technique and could be helpful for AdV, though it is not on the critical path for the realization of the detector. CALVA has been the largest investment in the 2nd R&D call and it leveraged further investments at LAL (money, human and technical resources).
The results of CALVA will come after the freezing of the AdV design. It is therefore very important that a scheme for the injection of the auxiliary laser is given as soon as possible, in order to include it in the design of the benches.

Marionette reference mass
The case to modify the design of the last stages of the SA rested on the need of reducing the contamination of the mirrors. The proposed re-design of the payload would ease the suspension procedures (reducing the time operators have to spend in the tower) and allow to install a clean air quasi-laminar flux in the tower base. In fact, this case is now weaker, since the new mirrors will be covered by a film of polymer until the very last moment before closing the vacuum chamber. However, it is true that special care will be required in the procedure of suspending a monolithic payload. Moreover, if a 55cm diameter beam splitter is chosen, the BS payload wouldn't fit if the F7 legs are kept. Therefore, a new solution for the payload geometry has to be studied anyway. On the other hand, it should be proven that the hierarchical control and the mirror alignment are made easier by the proposed solution, that more locking force can be reallocated to the upper stages and the actuation noise can be further reduced. A control model to study in detail these aspects is needed and it will help the optimization of the mechanical design.

Coating mechanical losses
This project requested funding for 2007 and lead to good results on the reduction of the coating mechanical losses. LMA proposes to continue the project and has presented new requests (see afterwards).

Fiber laser system
AdV, at least in its first configuration, will use an SSL laser and a standard resonant IMC. The future results on fiber laser/IMC can lead to important upgrades of the detector. The continuation of this R&D is certainly desirable, but it has to be considered on the longer term.

1.2 NEW PROPOSALS

MIRRORS (flatness/cleaning)
It is proposed to realize a new metrology bench to characterize the flatness of the AdV mirrors. It is also proposed to design a new cleaning machine compliant with the larger mirrors. This items are necessary for AdV and must be pursued. It is very important to define the AdV specifications on the required mirror performance (modelling needed) to set the scale of the needed achievements and to understand whether corrective coating will be necessary.

TCS

The correction of thermal lensing of the AdV mirors is one of the main concerns for the detector design. A new TCS will be necessary for AdV and a research on this topic must be pursued. A co-PI (V.Fafone) is also the TCS subsystem manager.

In the proposal received, the plan is to:

- use f.e.a. to realize a complete thermal model of test mass and compensation plate
- realize a facility dedicated to the study of thermal effects
- characterize the Hartmann sensor being developed in Australia

The choice of compensation plates (Adv LIGO baseline) could have a strong impact on the detector design, due to the difficulty of suspending them from the existing superattenuators and the concerns about scattered light and associated locking troubles. Therefore, a thorough modelling activity is necessary to understand the possible alternative solutions for AdV and the lines to be pursued. The first part of the proposed R&D (modelling) has started and will go on during the next months, together with the definition of a possible suspension scheme for CP (in collaboration with the PAY subsystem).

SAFE (Super Attenuator Facility @EGO)

The Phase A-B of the SAFE project (test of the new IP and PZT, IP tilt control test) is already embedded in the tiltmeter project. Testing and defining a 6 dofs control strategy on such a facility can save a lot commissioning time. The other issues (IP legs, F0 modifications, MRM test) are at lower priority (and anyway no money is requested for 2008). The facility is likely to be useful to assess the validity of some modifications to the SA mechanics (IP legs, others) and to test the strategy of 6 dof control of the IP, provided that good tiltmeters are available. The integration of the final payload (phase D) is possible, but in the foreseen configuration is not clear what kind of tests can be performed to validate it. The proposed configuration allows a cheap and fast implementation, though a full scale facility would have been desirable.

HOLM (Higher Order Laguerre Modes)

Very interesting and new idea. It promises to reduce thermal noise and thermal lensing of the mirrors at the same time. If feasible, it can ease considerably managing the thermal lensing and allow to relax the requirements for the TCS (one of the main concern for AdV at this stage). A theoretical analysis and a generation experiment are proposed in parallel. Not the baseline for AdV, but a successful R&D can have an important impact in the future, provided that some crucial questions are answered:

- the possibility to provide the necessary control signals (promising results have been presented by S.Chelkowski at the GWADW)
- the effect of the mirror imperfections on the HOLM
- the possibility to generate the HOLM at high power

A general concern remains: never an interferometer has been run with such modes. On the other hand, in case of success, this could be an original feature of AdV. Even if not ready for the start of AdV, pursuing this project might allow to implement HOLM later.

MIRRORS (Coating)

Continuation of the work done so far at LMA on coating noise reduction. Several research directions are proposed:

- continuing the studies on tantala doping exploring new materials
- optimization of the deposition process (DIBS)
- understanding the role of the annealing procedure

- optimized coating design

All the proposed line may lead to AdV sensitivity improvement and should hopefully be pursued. It could be important that the characterization of the produced sample benefits also of the different diagnostics equipments existing in other Virgo labs. The cost is low and this is a continuation of a successful project.

COATING CHARACTERIZATION AND MODELLING

A novel and promising approach is proposed, both theoretical and experimental, to understand the dissipation mechanisms in coating losses. A number of different facilities and diagnostics tool exists in the partecipating labs. A large number of FTE/labs is involved. The cost of the proposal is large, but an important grant might be hopefully received from the Italian government.
It could be important that the proposers demonstrate the validity of the investigation tools and the efficiency of the "industrial" pipeline on one-two samples to convince that an important funding is convenient. A strong connection with LMA activity is necessary.

ELECTROSTATIC ACTUATORS

Electrostatic actuation on the test masses is still an open option for AdV, and is in fact the Adv LIGO choice. Given the impact on the payload design, the choice has to be made soon. If they are chosen, a big effort will be needed to engineer the actuators and this project should go in the "must be done" list. If coil-magnet actuators are kept, there is no reason to pursue this research line within the AdV framework. A dedicated working group has been set to prepare technically the case for the final choice.

SILICA FIBERS

The Glasgow group proposes a study of the silica fibers for AdV. Glasgow has a very long experience in the field and they are taking care of the monolithic payload for Advanced LIGO. In fact, the technology offered to Virgo, at least for what concerns the cylindrical fibers, has been acquired by the Virgo Collaboration. However, an activity to develop the monolithic payload for AdV will be necessary, continuing the effort started for Virgo+. A collaboration and exchange of information with the Glasgow group is desirable.

2. R&D PRIORITIES

2.1 PRIORITY SETS

In this section the projects have been classified in three main sets:

- projects that must be pursued since they address crucial topics for the realization of the detector and are needed to meet the AdV baseline sensitivity;
- project that, if successful, may have an important impact on the sensitivity or the robustness of the detector;
- projects that can provide important results on a longer term.

NECESSARY

High power input optics	in progress
Detection upgrade	in progress
Optical configuration	in progress
AdV mirror flatness/cleaning	new project
TCS studies	new, modelling in progress, exp. part to be discussed in fall
Tiltmeter	in progress

IMPORTANT

COULD IMPROVE THE DETECTOR ROBUSTNESS

CALVA	in progress – *scheme for aux. laser injection needed*
HOLM	new project - *can improve robustness with respect to lensing but interferometer operation to be demonstrated*
MRM	in progress – *can improve cleanliness and payload integration procedure but hierarchical control benefits to be demonstrated*
SAFE	new project

PROMISE BETTER SENSITIVITY

Coating developments (LMA)	continuation of a previous project
HOLM	new project
Coating characterization and modelling	new project

LONGER TERM

R&D FOR AdV upgrades

Fiber laser/IMC	(in progress)
HOLM	*(if not ready for AdV this project can be pursued for further upgrades)*
Coating char.and mod.	*(if not ready for AdV this project can be pursued for further upgrades)*

OPTION (either very urgent or not needed)

Electrostatic actuators	continuation of a previous project

2.2 R&D RESULTS vs AdV PLANNING

In this section we discuss the relations between the tentative planning of AdV (given the constraints assumed so far: start of installation mid 2011, start of commissioning 2013) and the timelines of the R&D projects defined NECESSARY or IMPORTANT. We outline what is, for each project, the limit to provide useful results:

High power input optics	end 2009
Detection upgrade	end 2009
Optical configuration	early 2009 for mirror ROC, early 2010 for mirrors R/T
AdV mirror flatness/cleaning	early 2010
TCS studies	late 2010
Tiltmeter	late 2010
CALVA	late 2012, but aux laser injection scheme by end 2008
MRM	end 2009
HOLM	inputs for ROC by early 2009. Late results for AdV upgrades
Coating	early 2010. Late results for AdV upgrades
Coating char. and modelling	early 2010. Late results for AdV upgrades
SAFE	SA modifications by end 2010. Control strategy by end 2012

2.3 R&D 2008 PROPOSED FUNDING PRIORITIES

We ask the STAC to review the list of priorities defined. We hope that it is endorsed and proposed to the Council as a necessary step towards the realization of AdV. We believe that the projects labelled “Necessary” must be funded even if the resources are scarce. In the case of the TCS proposal we believe that the efforts in the next months must be focused on modelling aimed to define the best scheme for AdV, but an experimental effort must be started immediately after. With respect to the original proposals an effort has been done to reduce the required amount of money and to postpone to 2009 all the expenses not vital for the projects.

We hope that the projects defined “Important” can be funded as extensively as possible.
Three of them (Coating-LMA, HOLM, Coating char. and mod.) may have a direct impact on the sensitivity:

- the development of doped coating at LMA has been successful so far. Each further reduction of the losses has a direct impact on the AdV sensitivity. There is time till the end of 2009 to gain. We propose that this project is continued.
- HOLM can tackle thermal lensing and thermal noise. Though it is still far from actual implementation, and it is unlikely that HOLM are used since the beginning, we think it is wise to start this R&D, given the limited cost. It could provide, in the next year, the solution to further reduce thermal noise and to cope with high power.
- Coating characterization and modelling: this ambitious project should be seen as a long term effort. It might receive an important grant from the Italian government, which should allow to start the activity anyway. A partial support is asked to EGO and should be considered if the grant is obtained.

Three of them are focused on improving the detector design or easing its operation/robustness:

- CALVA has started an important and costful activity. To be continued but, given the delay due to the asbestos removal (see CALVA report) a reduction of the funds for 2008 should be explored.
- MRM is aimed at re-designing the payload. To be continued, but we recommend that a control aspects are studied before the realization of the prototype.
- SAFE: no money is asked for 2008. To be evaluated and funded next year.

The availability of a fiber solution for the laser amplifier/IMC is a promising option for the upgrades of AdV. We hope it could be continued, even with a reduced funding.

The use of electrostatic actuators will be decided next fall. If they are chosen an intensive engineering activity will be needed, otherwise no funding should be foreseen.

3. ATTACHED DOCUMENTS

R&D progress reports

- CALVA
- Marionette reference mass for GW detectors
- Interferometer sensitivity at low frequency
- Fiber solutions for advanced interferometers
- System design of the optical configuration for AdV
- Detection system upgrade
- Coating mechanical losses
- High power input optical components for AdV

New R&D proposals

- R&D for advanced mirrors
- Thermal compensation system
- Generation and optical performance of high order Laguerre-Gauss modes
- Coating characterization and modelling
- SAFE – Super Attenuator Facility at EGO
- Electrostatic actuators for mirror control