Deformable Mirrors Workshop - Minutes

# Location: Hampshire Hotel, Delft, Netherlands

# Date 21st/22nd March 2013

# Present

Norbert Hubin (ESO),

Mark Casali (ESO),

Gleb Vdovin (Okotech),

Ben Braam (TNO),

Jean-Christophe Sinquin (CILAS),

Remco Stuick (Leiden),

Colin Cunningham (UKATC),

Phil Rees (UKATC),

Christophe Keller (Leiden),

Noah Schwartz (UKATC),

Marc Ferrari (LAM),

Tim Morris (Durham),

Emma Bryce (UWS),

Dirk Soltau (KIS),

Andre Preumont (Brussels),

John Davies (UKATC),

Christian Lucuix (ESO),

Toomas Erm (ESO),

Tommaso Occhipinti (Adaptica),

Frederic Derie (ESO),

Stefano Bonora (Padova),

Daniele Gallieni (ADS),

Roberto Biasi (Microgate),

Rudolf S. Le Poole (Leiden),

Richard Myers (Durham),

Jean-Luc Beuzit (LAOG),

Michel Poulat (CILAS),

Lars Venema,

Jean-Luc Beuzit (IPAG)

Teun Van den Dool (TNO)

Colin Cunningham outlined the aims & objectives of the meeting. The meeting is being held as part of the European Framework (FP7) Innovation network. This was previously known as the key technologies network but has been renamed following a follow on funding application which has been revamped to try to include a greater emphasis on industry involvement

There was a short introduction by all attendees.

John Davies gave a short overview of OPTICON and explained how the innovation network fitted into the overall OPTICON programme and set the scene on the current funding situation.

Norbert Hubin gave a presentation on DM requirements for ELT-VLT and a review of DMs already used by ESO. The presentation is included in the appendix. A list of current technologies was presented and a list of types of adaptive optics. The two were then combined into a table to show how the technologies map to the requirements for the AO types.

The level of confidence in the requirements was believed to be high even beyond the current experience due to extensive modelling.

The telescope effects can dominate over anything else, particularly the wind effect on seeing. This can be hard to predict and greater actuator stroke is being pursued in order to deal with these effects.

Teun Van den Dool gave a presentation on Electromagnetic DM technology to meet future AO demands (see appendix).

The production of low order modes was discussed and it was explained the there is no scope for piston or tip/tilt adjustment.

Deviations from the perfect Zernike shape (open loop) are in the region of 25 nm. The biggest problem is in mounting the membrane. It also needs to be cooled in the presence of a heat load.

Norbert Hubin stated that this technology looks good for medium size MCAO.

The main drawback is that the phase sheet cannot be replaced.

Cross coupling is dominated by the stiffness of the phase sheet. A closed loop system is required to ensure that these effects are controlled.

The pitch of the actuators is determined by the size of the coil.

Power dissipation is of the order of 2 W for the whole mirror.

Noah Schwartz gave a presentation on Development of a high-density DM without hysteresis (see Appendix)

The extension of the actuator can be measured from the capacitance. This is conceptually the same as measuring the charge. The frequency method involves measuring the resonance frequency. The physics behind the frequency method are not yet fully understood but it seems to give encouraging results.

Andre Preumont gave a presentation on Segmented DM for AO (see Appendix)

The mirrors are bimorph Si wafers. It was explained that there is no particular advantage in using SiC as the higher specific stiffness is nullified by CTE mis-match.

The PZT film ends up a concave shape and this was not solved for the mirror presented. This could be solved by gluing PZT patches and then laser cutting.

It was mentioned that Mike Griffith at BAE Systems had been using stacked bimorphs to increase dynamic range and this could be useful to look at.

The stiffness of the membrane is not critical but in a space application it has to survive the launch.

Jean-Luc Beuzit gave a presentation on the activities on FP7, workpackage 1 and on ALPAO work on their behalf (see appendix).

The aim is to reduce the pitch down to 0.8 mm with embedded position sensors between the actuators. The embedded sensors are to control slow drift. The next steps are to increase the number of actuators, simplify the cabling and improve the reliability.

The membrane gas been de-scoped from the FP7 funded work due to the time-scale required for the development.

There had been discussion of 40 K actuators but this has been parked as the focus now is on producing an on-sky demonstrator.

The main reason for the slow drift is the electronics.

A patent has been applied for on the sensor and this cannot be discussed.

Colin Cunningham led an open discussion by asking the meeting if we should continue working on a broad range of technologies or concentrate effort on a particular favourite.

Some responses were that IPR issues made collaboration quite difficult and also that there were in fact 3 different sets of requirements for the different types of AO and it is not clear that one technology will fit them all. XAO particularly seems to have requirements that are unique and not easily translatable to other applications.

The fact that so much open-loop work is taking place was questioned. Open loop technology is however applicable to all application areas and is more applicable to industrial products.

It was suggested that the technology for actuators is useful as a generic technology and it is easier to scale down-wards from the more demanding requirements. For example, development of a large number of actuators would allow small actuator number mirrors to be easily developed. There was some disagreement with this on the basis that the optimum technologies depend on the application.

The example of microscopes was raised. Here there is a need for a 3-D PSF, aberration correction at high speed as the object is moving. This requires higher stroke and speed. For microscopy the solution needs to be really cheap so that the concept can be applied to a wide market. Astronomical mirrors are unlikely to achieve this.

Could the same result be achieved without a mirror? The wavelength coverage becomes a problem with any transmissive system.

The electronics seem to be a problem with a DM concept. Using a different method of creating a shape would be interesting to pursue.

Fast laser pulse shaping was suggested as another application area. TNO have been looking at this but have not found any industry partners who are interested. The Netherlands already have a programme looking at the microscopy and military application areas. It would be interesting to look at how this type of national program could be rolled out into the wider EU.

Reliability was discussed. This is a key requirement but is really a manufacturing issue and it is better to look at the basic technology first.

Segmentation is a good idea but need to consider the edge effects. It would be interesting to look at matching the edge effects to those in the primary mirror (for E-ELT).

The requirements on reliability vary with the application. Generally it is OK to operate with a few failed actuators but for XAO this is not acceptable.

Day -2

Dirk Soltau gave a presentation on Experiences with DMs in solar telescopes & ground optical stations (see appendix).

There is an upper limit on the useful number of actuators due to the ability to measure the wavefront. This is conventionally believed to be only realistic using a Shack-Hartmann sensor.

The number of actuators is defined from the required strehl ratio. This is not agreed universally but is in the region of 70-80%.

Tim Morris gave a presentation on Requirements that tomographic AO (MOAO/LTAO) places on DMs based on CANARY experience (see appendix).

The point was made that good open loop performance is still needed even if the mirror is being operated in closed loop.

There are quasi-static aberrations in the system which are not fully understood. They are either from the telescope/system or from the DM. These dominate the open loop stability and are of the order of 5 minutes for Canary observations.

During an observation, the other error sources such as gravity seem stable. There are slow changes which need calibration. This adds an overhead which would be nice to remove with an insensitive DM.

Focal plane sensing could help but the centre of rotation of the WFS is not on the centre of field rotation. Also, there are normally not enough bright targets. An MCAO system could use focal plane sensing but this would have calibration overheads.

Tommaso Occhipinti gave an introduction to the Adaptica company (see appendix). He expressed the opinion that deformable lenses were an important next step.

Stefano Bonora gave a presentation

The equivalent number of actuators is limited by the stiffness of the membrane.

The light stability of the illumination is a limiting factor in this prototype and this requires more work.

The maximum stroke is 10 µm with a residual error that depends on WFS but is not known exactly. In principle the mirror is linear.

Gleb Vdovin gave a presentation on a New concept for a 50+k actuator DM.

Existing technologies and performance were presented as well as some new ideas.

The paraffin idea is slow but has large stroke, could be useful in high-contrast imaging. With the visco-elastic concept, the air has to be completely removed which creates practical difficulties. These ideas are only concepts at the moment and need some funding to take them forward. The first step would be to demonstrate that the structures are feasible to fabricate and that they achieve real deformations.

Jean-Christophe Sinquin gave a presentation on Specifications and technology developments for next generation of High Order Deformable Mirrors at Cilas (see appendix)

He stated the belief that the piezo array technology will meet the requirements form current AO systems. Development activities focussed on gerenating properly controlled, quality product. This requires a lot of effort.

Piezo-stacks are used in the car industry at the moment but the material is not the same.

Jean-Luc Beuzit gave a presentation on behalf of L’Observatoire de Paris on Tip-tilt mirror development at LESIA (see Appendix)

At low temperatures the material properties change. CTE management with the back plate is difficult. Piezo hysteresis is good and insensitive to temperature.

Roberto Biasi gave a presentation on the activities at Microgate (see appendix).

The handling of the shell is complicated. After receiving from the manufacturer it is never touched. Special tooling is required throughout the processing steps. It needs to be supported at all times. Bias magnets pull the shell against the body to protect it when the power is off.

Mark Casali led an end of meeting discussion by asking the question how do we get these ideas to converge? Is it still valid to keep all of them running.

The requirements were reviewed again. The XAO particularly looks unfeasible from what has been presented. The stacked array technology appears suitable for everything but the last 2 columns in the table but these have important science cases attached.

The point was made that the TRLs of the different technologies are quite different which makes fair comparison very difficult. It is expensive to raise the TRL of some of the less mature ideas. How long would it realistically take to investigate some of the newer ideas? The USAF has spent millions getting us to where we are.

Productionisation also needs to be considered and this needs funding. There is a network in France looking at synergies between different areas and OPTICON should consider the same idea. An example is the South African AO in medicine and industry meeting.

It was suggested that high density DMs could be used to make a range of corrections simultaneously.

A discussion about modularity followed. The phase sheet should probably be a single piece but it is important that this is replaceable. The phase sheet could be segmented and matched to the telescope. Alternatively the primary mirror could be a DM. This would be expensive and only correct a single layer however it could allow for a relaxed requirement on the rest of the DMs in the system. Segmented mirrors may fit better to the wavefront and need fewer actuators so this idea should not be discounted.

A nice solution would be a phase compensating column but this would be chromatic and then places the difficulty on how to measure. The WFS is currently responsible for about 50% of the error in the system and the WFS signal/noise drops with the number of layers. The 50% contribution is thus a consequence of the design decision to use a number of layers that leads to this value. It would be nice to have more but this would cost.

A focal plane sensor would be better.

The feeling from CILAS was that the priority should be on funding new ideas. How could this be arranged? We need to co-ordinate some of the national funding agency initiatives with the European ones such as PHOTONICS 21. The difficulty is convincing them that this really is photonics.

**ACTION Colin Cunningham to form a group to take a proposal to PHOTONICS**

The state of development in America was discussed and it was believed that there was no real co-ordination there and that Europe was ahead (apart from MEMS). This is a strong argument to take to the EU that this lead should be maintained through funding.

NSF has funded yield improvements in MEMS and vertical applications. It is probable that the assumptions about densities of MEMS systems could be better than presented by N Hubin and they may have potential for MOAO .

Xinetics and Boston micromachines are working in the area.

Adaptica argued that money is needed to build demonstrators and this only needs to be quite small. Ironically it can be easier to get large grants than small ones from the EU. The smaller proof-of-concept studies are easier to get through national funding bodies.

ESO are setting up a programme which should be in place by the middle of 2013. It would be <<€1M but could be used to lever funds out of national agencies such as the Dutch who will put up 75% of funds if 25% comes from elsewhere.

ESO could set up a roadmap group to look at the technology steps that lead to a working DM.

**ACTION Phil Rees Co-ordinate with ESO to define a roadmap to a E-ELT DM**

Mark Casali asked if more money would increase the pace of development. There was some disagreement about this and it depends on how much parallel working could be done.

Some final points were stated that the membrane stiffness will dominate increased actuator number and that E-ELT instrument mirrors must be in the region of 40 mm .

The meeting concluded with thanks to all attendees from Colin Cunnigham.