Design and Manufacture of the Optics

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Introduction

- Optical layout
- Optics costs
- Aspheric surface
- ADC
- Future R &D
The Optical Layout

Present DES Design

Proposed Despec Design
New Components

• Original C5 to be replaced with new aspheric component.
• New additional C6
• New 4 element atmospheric dispersion corrector.
• Each new component will require a support cell
• ADC will require a rotary drive system.
• Metrology system for the fibre positioner.
Glass Manufacture’s

- **Corning**, HPFS C1 grade, C5 $33,000, C6 $30,000, 12 weeks.

- **Heraeus**, Superasil 312, C5 €15,000, C6 €35,000, 22 weeks.

- **Schott**, N-BK7 2,200, LLF1 £137,700, 1 year.

- **Ohara**, S-BSL7 €14,000, S-TIL1 & PBL1Y no bid
## Material and Grinding Costs

<table>
<thead>
<tr>
<th></th>
<th>Material ($)</th>
<th>Grinding ($)</th>
<th>Time Scale (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC1 N-BK7</td>
<td>1,900</td>
<td>13,000</td>
<td>7 to 8</td>
</tr>
<tr>
<td>ADC2 LLF1</td>
<td>100,000</td>
<td>13,000</td>
<td>48 to 52</td>
</tr>
<tr>
<td>ADC3 N-BK7</td>
<td>1,600</td>
<td>13,000</td>
<td>7 to 8</td>
</tr>
<tr>
<td>ADC4 LLF1</td>
<td>100,000</td>
<td>13,000</td>
<td>48 to 52</td>
</tr>
<tr>
<td>Lens C5 HPFS</td>
<td>33,000</td>
<td>13,000 to 40,000</td>
<td>12 to 14</td>
</tr>
<tr>
<td>Lens C6 HPFS</td>
<td>30,000</td>
<td>13,000 to 40,000</td>
<td>12 to 14</td>
</tr>
<tr>
<td>Sub Total</td>
<td>249,500</td>
<td>78,000 to 132,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total ($)</strong></td>
<td><strong>344,500 to 407,500</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ADC grinding not undertaken by glass manufacturer, flat stock supplied. LLF1 specially cast due to size, new stand alone melt.
### Fine Grinding, Polishing & Coating Costs, ROM

<table>
<thead>
<tr>
<th></th>
<th>Polishing (Euro)</th>
<th>Coating (Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC 1</td>
<td>50,000 to 60,000</td>
<td>15,000</td>
</tr>
<tr>
<td>ADC2</td>
<td>50,000 to 60,000</td>
<td>15,000</td>
</tr>
<tr>
<td>ADC3</td>
<td>50,000 to 60,000</td>
<td>15,000</td>
</tr>
<tr>
<td>ADC4</td>
<td>50,000 to 60,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Lens C5</td>
<td>180,000 to 280,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Lens C6</td>
<td>50,000 to 60,000</td>
<td>40,000</td>
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<tr>
<td>Sub Total</td>
<td>430,000 to 580,000</td>
<td>140,000</td>
</tr>
<tr>
<td>Total (Euro)</td>
<td>570,000 to 720,000</td>
<td></td>
</tr>
</tbody>
</table>

- Time scale 16 to 18 months
- Testing, depends on accuracy required, test plate, CGH, Ofner corrector etc.
- Coating, Anti reflection.
- DES C5 cost €55,000, Coating €35,000
# C5, C6 Cells & ADC Costs

<table>
<thead>
<tr>
<th></th>
<th>Material (£)</th>
<th>Machining (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C5 Cell</strong></td>
<td>20,000</td>
<td>15,000</td>
</tr>
<tr>
<td><strong>C6 Cell</strong></td>
<td>18,000</td>
<td>12,000</td>
</tr>
<tr>
<td><strong>ADC Cells</strong></td>
<td>5,000</td>
<td>30,000</td>
</tr>
<tr>
<td><strong>Bearings &amp; drive system</strong></td>
<td>20,000</td>
<td>10,000</td>
</tr>
<tr>
<td><strong>Sub Total</strong></td>
<td>63,000</td>
<td>67,000</td>
</tr>
</tbody>
</table>

| Total (£)              | 130,000      |               |

**Other costs,**

Design, Technical, Transport, Etc
## Total Estimated Cost for mechanics and optics

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Materials</td>
<td>344,500 to 407,500</td>
</tr>
<tr>
<td>Grinding, Polishing &amp; Coating</td>
<td>730,000 to 920,000</td>
</tr>
<tr>
<td>Cells and drive system</td>
<td>210,000</td>
</tr>
<tr>
<td><strong>Total ($)</strong></td>
<td><strong>1,284,500 to 1,537,000</strong></td>
</tr>
<tr>
<td>Metrology System for fibre placement</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UCL Budget</th>
<th>($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Development</td>
<td>235,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>235,000</strong></td>
</tr>
</tbody>
</table>
Edge slope = $7 \mu / \text{mm}$
Alignment Tolerance's

- The alignment tolerances on Decam were tight, I know because I worked to them.
- Adding another asphere is possibly achievable, however the placement tolerance will have to be looked at in some detail.
- Numbers required for the alignment and the focal plain.
Considerations on Constructing the ADC

All the new optics are thin and the optical manufacturers do not like that, some have suggested a 50% thickening of all elements.

The main consideration is how to support the optics during manufacture and during assembly. Having high aspect ratio components make the manufacture, that is fine grinding, polishing and testing very difficult.

Not just the distortion in mounting and handling in manufacture but also ensuring that the components do not move during gluing.

What AR coatings are require, any Mil specification, Mg/F2, Si/O2, Solgel.

N-BK7 optical glass has a transmission curve rising at precisely the wavelength that most UV curing cements require for cure. Bonded N-BK7 elements have lower resistance to heat, humidity, and mechanical stress than fused silica when using the same light source, length of exposure, and distance from substrates. Possible distortion problems.
Optically coupling the ADC components

ADC joint,

This is critical as any distortion caused by the gluing will show as a wave front error. The joints can be air gap, cemented, oiled. Each has its merits and should be investigated to establish the best possible for this application.

Types of cement

- **Dow Corning** RTV type two part elastomer, Sylgard 184.
- **Norland** cements, noa 60, General purpose adhesive for bonding doublets, prisms or mounting components. noa 61 Preferred adhesive for military optics. Meets MIL-A-3920. Used for optics exposed to temperature extremes. Low shrinkage. UV curing refractive index 1.56
- **Lensbond** cements UV curing (uv-69, uv-71, uv-74) refractive index 1.55, transparent from 0.4 to 2.5 microns.
- **Milibond**, Type UV-69 A one component, ultraviolet curing cement. Cure is achieved by using an ordinary sun lamp. Type J-91 A general purpose, one component, water white, 100% solids ultraviolet curing optical cement. This cement meets the requirements of MIL-A-3920.
- **Dymax** optical adhesives Ultra Light-Weld® OP-4-20632 is a clear UV/Visible light-curable fibre optical assembly adhesive designed for rapid, durable bonding of fibre optic couplings and prisms.
- **Cargille oils**, They can produce any refractive index and viscosity required.
ADC Coupling Problems

- **Adhesive failure** occurs when the cement separates from the glass surface. It is seen as a shiny area in reflected light. It can be any shape and can be identified by the presence of Newton rings, or a colour fringe.

- **Cohesive failure** occurs when the cement pulls away from itself. This can be identified by the fern-like voids, called feathering, appearing along the edge of the lens or sometimes in the interior.

- **Haze, Fog or Discoloration of Bond Layer**, Generally caused by some kind of contamination, reaction to mixing vessel, humidity, or solvent.
Optically decoupling the ADC components

UV Curing Cement removal

Several methods can be used to remove the adhesives. Lens bond decementing agent and Milsolve to name two. The easiest and simplest method is to immerse the lens in a solvent such as methylene chloride. Usually small lenses can be separated easily before it is cured by an overnight soak. The glass can be heated in oil or other medium until the bonds break and the glass separates, this would be done at around 200°C. However these are high aspect ratio elements that will be extremely difficult to separate if there is a problem, with a high risk of total failure.

RTV

This can be removed with acetone, however the diameter of the ADC is large and the gap small, which will make this a long process that could effect the coating.

Oil

Ease of separation and cleaning.
Pros and Cons of Coupling Agent

Advantages and Limitations of UV Glue

There are many advantages to using UV curable optical cements. They are used in a wide variety of opto-mechanical assemblies. It allows alignment and checking of the assemblies before bonding and has a quick cure time to hold the alignment in place. It works in a wide variety of compounds to produce bonds that function in a large range of temperatures from -60° to 180°C. UV systems curve substrates at low temperatures. Difficult to undo.

Advantages and Limitations of Elastomer Adhesive

Sylgard 184 requires a primer, Dow Corning 92-023 or 1200 os, (I did not notice a primer used when bonding the ODI ADC). It allows alignment and checking of the assemblies before bonding has cured and has a very slow cure time. RTV needs to be filtered to remove particulates. Difficult to undo.

Advantages and Limitations of Oils

They can go waxy and opaque at low temperatures. Possibility of leaks. Easy removed and replenished. Requires a reservoir of oil to compensate for temperature and topping up from time to time. Also will require lens spacers to maintain correct gap.
Oiled ADC designs

Section through possible Despec ADC design

S-FSL5 Lens

Aluminum Bezel

Athermal RTV Ring

BSM51Y Lens

O-ring for Couplant Seal
Glued ADC Designs

ADC on the Wide-Field Corrector for the Mayall Telescope

MMT wide field corrector

WIYN 3.5m One Degree Imager ADC
ADC Mechanics & Glass handling

- Rotary position sensing mechanism
- Geared drive system
- Precision bearings
- Lens cells

Nickel iron for the C5 & C6, Stainless steel for the ADC.

Handling of the glass

The glass for the ADC is thin and will distort under its own weight due to gravity. Thus care must be taken to ensure that the mounting sub-straight is supported correctly without any distortions. Any edge supporting ring will probably distort the glass. Fixture for holding the glass and vacuum lifting structure will be necessary to hold the glass during the gluing and curing procedure.
Future R & D

• Optimise optical design for ease of manufacture.
• Optics need to be thicker, by a high percentage
• Work with polishing companies on testing of optics.
• Look at other optical glasses (N-BK7, CTE to high)
• Investigate the best possible coupling material.
• Develop coupling methods.
• Monitor any optical distortion due to glue.
• Design handling equipment.
• Determine the optical alignment procedure.
• Fibre positioning metrology system.
End, Thank You

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Gravity deflection on 29mm plate

Edge constrained

Corner constrained
Bonding the ODI Atmospheric Dispersion Compensators with Sylgard 184

Gary A. Poczulp
Despec

MMT wide field corrector, ADC sub assembly
Large size slewing ring bearing

Despec ADC glass

Gemini ADC & image stabilizer

The Keck -1 Cassegrain ADC