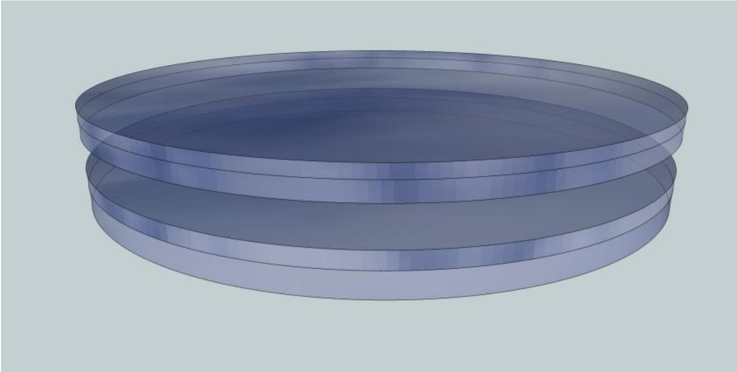
The optical upgrade of the Dark Energy Survey corrector

Design and Manufacture of the Optics

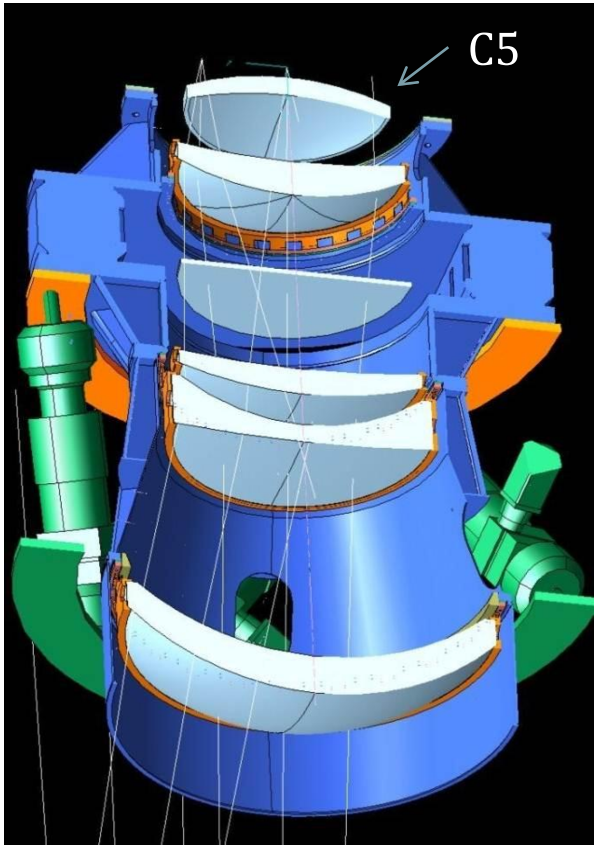
Dr David Brooks
Optical Science Laboratory
Department of Physics & Astronomy
University College London

Introduction

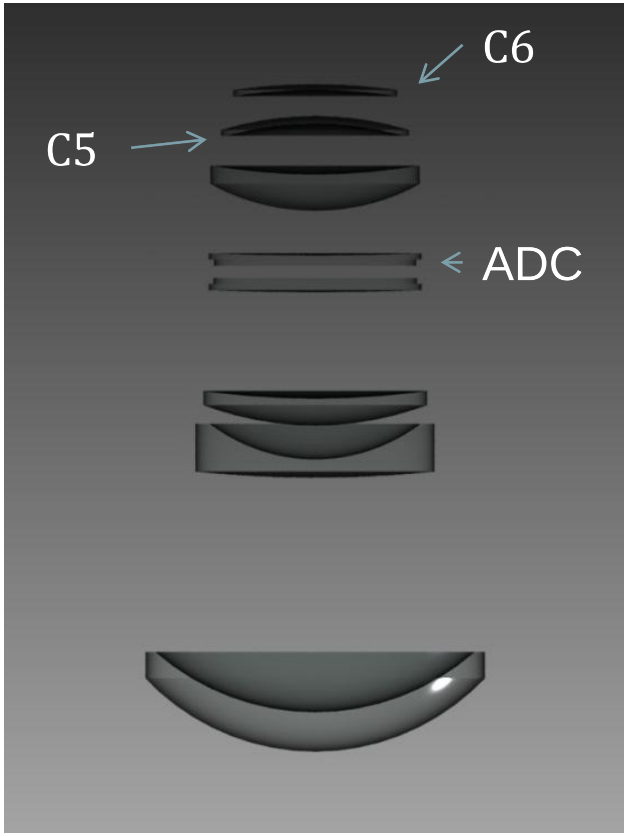
- Optical layout
- Optics costs
- Aspheric surface
- ADC
- Future R &D



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

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

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

	Polishing (Euro)	Coating (Euro)
ADC 1	50,000 to 60,000	15,000
ADC2	50,000 to 60,000	15,000
ADC3	50,000 to 60,000	15,000
ADC4	50,000 to 60,000	15,000
Lens C5	180,000 to 280,000	40,000
Lens C6	50,000 to 60,000	40,000
Sub Total	430,000 to 580,000	140,000
Total (Euro)	570,000 to 720,000	

- 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

	Material (£)	Machining (£)
C5 Cell	20,000	15,000
C6 Cell	18,000	12,000
ADC Cells	5,000	30,000
Bearings & drive system	20,000	10,000
Sub Total	63,000	67,000
Total (£)	130,000	

Other costs,

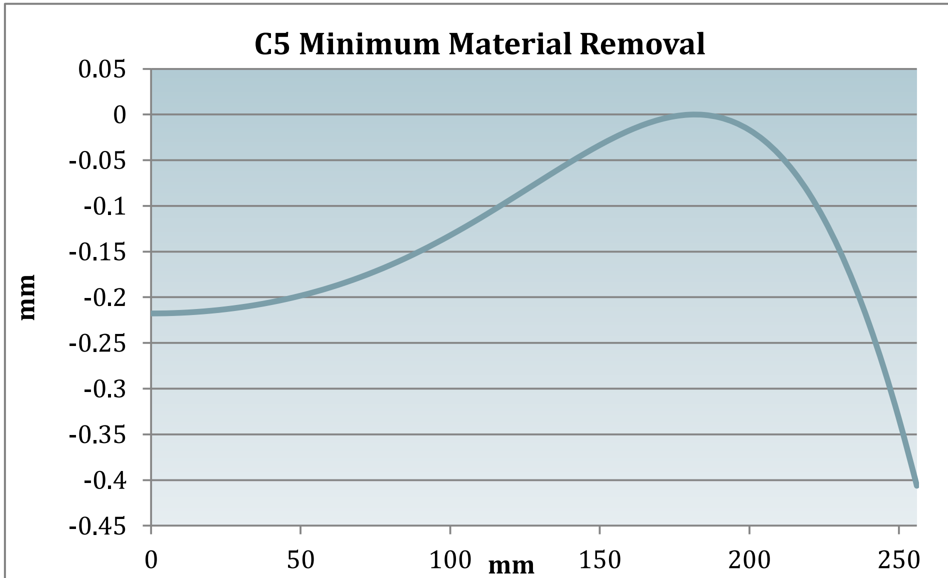
Design, Technical, Transport, Etc

Total Estimated Cost for mechanics and optics

Item	Estimated cost ($)
Optical Materials	344,500 to 407,500
Grinding , Polishing & Coating	730,000 to 920,000
Cells and drive system	210,000
Total ($)	1,284,500 to 1,537,000
Metrology System for fibre placement	1,000,000

UCL Budget	($)
Research & Development	235,000
Total	235,000

C5 Aspheric Surface



BFS		Radius of curvature at vertex			982.454		
		Conic constant			0		
	1.88E-10						
	-7.82E-15						
	3.78E-20						
1/vr					Step size	10	
conic							
					BFS		
	Z Asphere	Z asp + terms		ROC	Z Sphere	Diff Sp/Asp	Dif +terms
	0	0	1004635.36	1002.315	0	0	0
	0.050894286	0.050896163	1004535.36	1002.265	0.04988576	-0.00100853	0.001010404
	0.114515852	0.114525302	1004410.36	1002.203	0.11224645	-0.0022694	0.002278853
	0.318132558	0.318204254	1004010.36	1002.003	0.31182674	-0.00630582	0.006377515
	0.623636793	0.62390524	1003410.36	1001.704	0.61127173	-0.01236506	0.012633507
	1.031123705	1.031832003	1002610.36	1001.304	1.01067102	-0.02045268	0.021160979
	1.54072039	1.542231124	1001610.36	1000.805	1.51014428	-0.03057611	0.03208684
	2.152586089	2.155371435	1000410.36	1000.205	2.10984143	-0.04274466	0.045530002

6.00E+01	1.84E+00	1.81E+00	2.86E-02	0.1890854			60	-0.18909
6.50E+01	2.16E+00	2.12E+00	3.39E-02	0.1837616			65	-0.18376
7.00E+01	2.50E+00	2.46E+00	3.98E-02	0.1779254			70	-0.17793
7.50E+01	2.87E+00	2.83E+00	4.61E-02	0.1715714			75	-0.17157
8.00E+01	3.27E+00	3.22E+00	5.30E-02	0.1646991			80	-0.1647
8.50E+01	3.69E+00	3.63E+00	6.04E-02	0.1573136			85	-0.15731
9.00E+01	4.14E+00	4.07E+00	6.83E-02	0.1494267			90	-0.14943
9.50E+01	4.61E+00	4.54E+00	7.66E-02	0.1410582			95	-0.14106
1.00E+02	5.11E+00	5.03E+00	8.55E-02	0.1322364			100	-0.13224
1.05E+02	5.64E+00	5.55E+00	9.47E-02	0.1229993			105	-0.123
1.10E+02	6.19E+00	6.09E+00	1.04E-01	0.1133958			110	-0.1134
1.15E+02	6.77E+00	6.66E+00	1.14E-01	0.1034863			115	-0.10349
1.20E+02	7.37E+00	7.25E+00	1.24E-01	0.09334376			120	-0.09334
1.25E+02	8.00E+00	7.87E+00	1.35E-01	0.08305468			125	-0.08305
1.30E+02	8.66E+00	8.51E+00	1.45E-01	0.07271962			130	-0.07272
1.35E+02	9.34E+00	9.18E+00	1.55E-01	0.06245404			135	-0.06245
1.40E+02	1.00E+01	9.88E+00	1.65E-01	0.05238887			140	-0.05239
1.45E+02	1.08E+01	1.06E+01	1.75E-01	0.04267099			145	-0.04267
1.50E+02	1.15E+01	1.14E+01	1.84E-01	0.0334636			150	-0.03346
1.55E+02	1.23E+01	1.21E+01	1.93E-01	0.02494638			155	-0.02495
1.60E+02	1.31E+01	1.29E+01	2.00E-01	0.01731558			160	-0.01732
1.65E+02	1.40E+01	1.38E+01	2.07E-01	0.01078387			165	-0.01078
1.70E+02	1.48E+01	1.46E+01	2.12E-01	0.005579991			170	-0.00558
1.75E+02	1.57E+01	1.55E+01	2.16E-01	0.001948228			175	-0.00195
1.80E+02	1.66E+01	1.64E+01	2.18E-01	0.000147606			180	-0.00015
1.85E+02	1.75E+01	1.73E+01	2.17E-01	0.000450852			185	-0.00045
1.90E+02	1.85E+01	1.83E+01	2.15E-01	0.003143076			190	-0.00314
1.95E+02	1.95E+01	1.93E+01	2.09E-01	0.008520149			195	-0.00852
2.00E+02	2.05E+01	2.03E+01	2.01E-01	0.01688677			200	-0.01689
2.05E+02	2.15E+01	2.13E+01	1.89E-01	0.02855418			205	-0.02855
2.10E+02	2.25E+01	2.24E+01	1.74E-01	0.04383752			210	-0.04384
2.15E+02	2.36E+01	2.35E+01	1.55E-01	0.0630528			215	-0.06305
2.20E+02	2.47E+01	2.46E+01	1.31E-01	0.08651345			220	-0.08651
2.25E+02	2.58E+01	2.57E+01	1.03E-01	0.1145264			225	-0.11453
2.30E+02	2.70E+01	2.69E+01	7.03E-02	0.147388			230	-0.14739
2.35E+02	2.81E+01	2.81E+01	3.23E-02	0.1853785			235	-0.18538
2.40E+02	2.93E+01	2.93E+01	-1.11E-02	0.2287576			240	-0.22876
2.45E+02	3.05E+01	3.06E+01	-6.01E-02	0.2777579			245	-0.27776
2.50E+02	3.17E+01	3.19E+01	-1.15E-01	0.3325787			250	-0.33258
2.55E+02	3.30E+01	3.32E+01	-1.76E-01	0.3933789			255	-0.39338
2.56E+02	3.32E+01	3.34E+01	-1.89E-01	0.4062672			256	-0.40627

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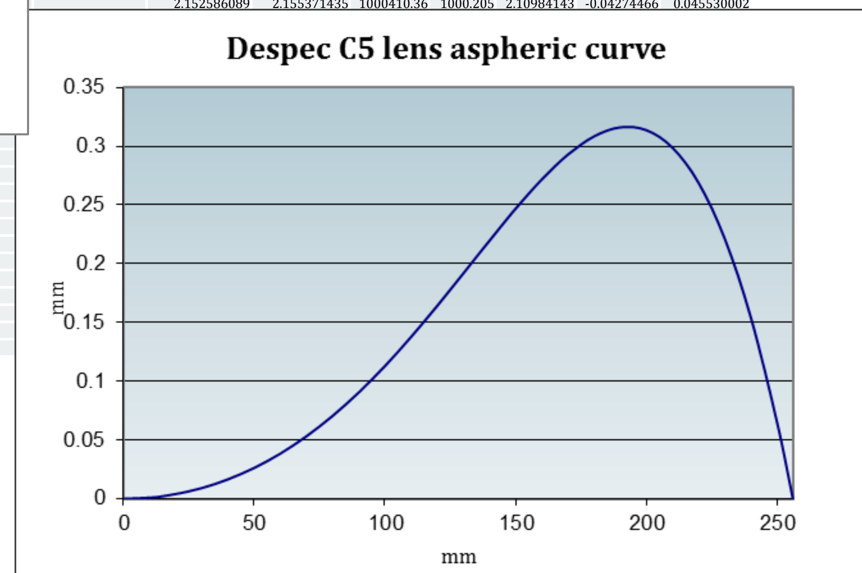


Edge slope = 7μ / mm

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 manufactures 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/O_2 , 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 use 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.

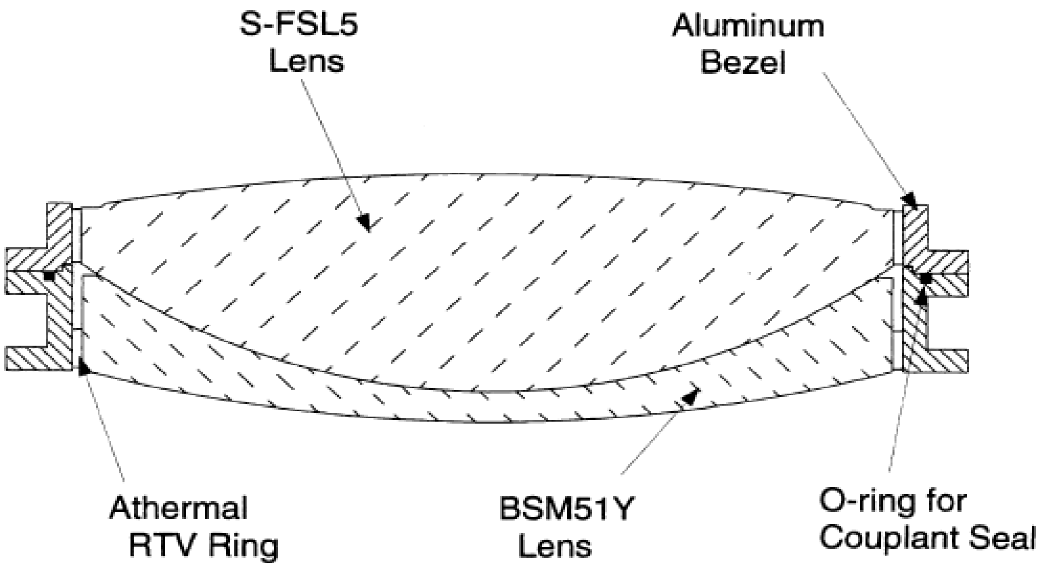
Advantages and Limitations of Elastomer Adhesive

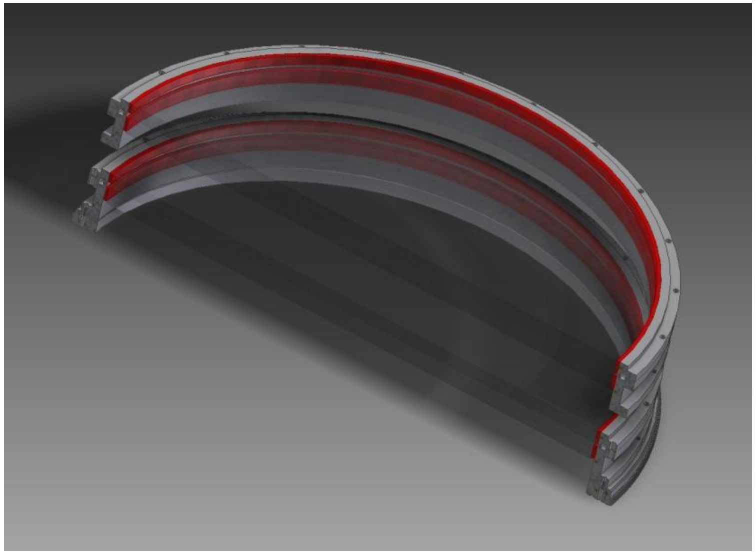
Sylgard 184 requires a primer, Dow Corning 92-023 or 1200 os, (I did not notice a primer used when bonding the ODI ADC). It allows alignment and checking of the assemblies before bonding has cured and has a very slow cure time. RTV needs to be filtered to remove particulates. Difficult to undo

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.

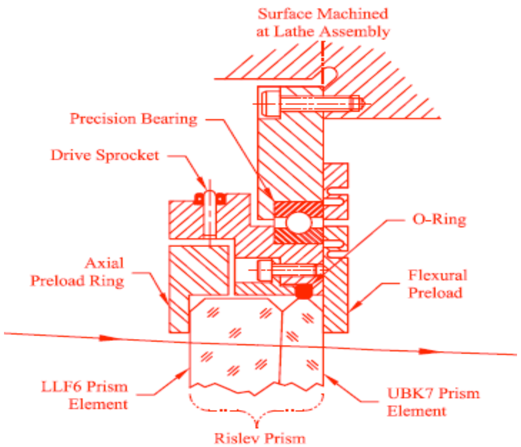
Oiled ADC designs

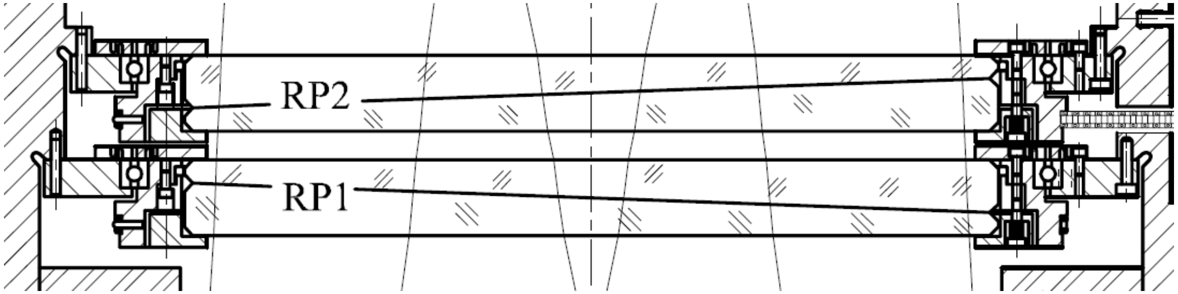




Section through possible
Despec ADC design

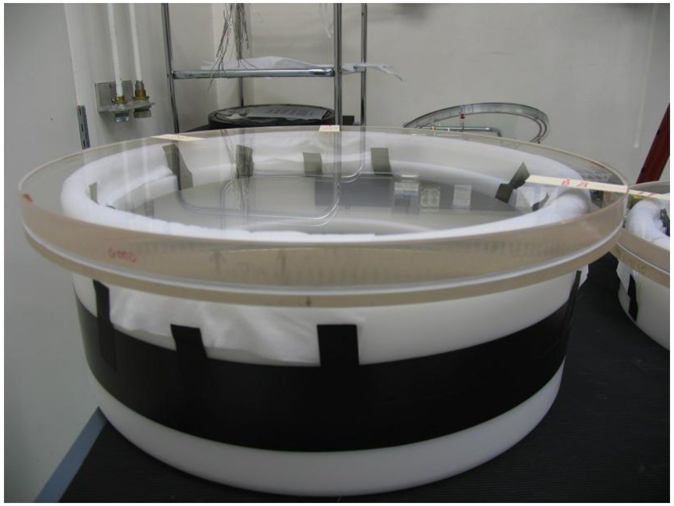
Glued ADC Designs





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

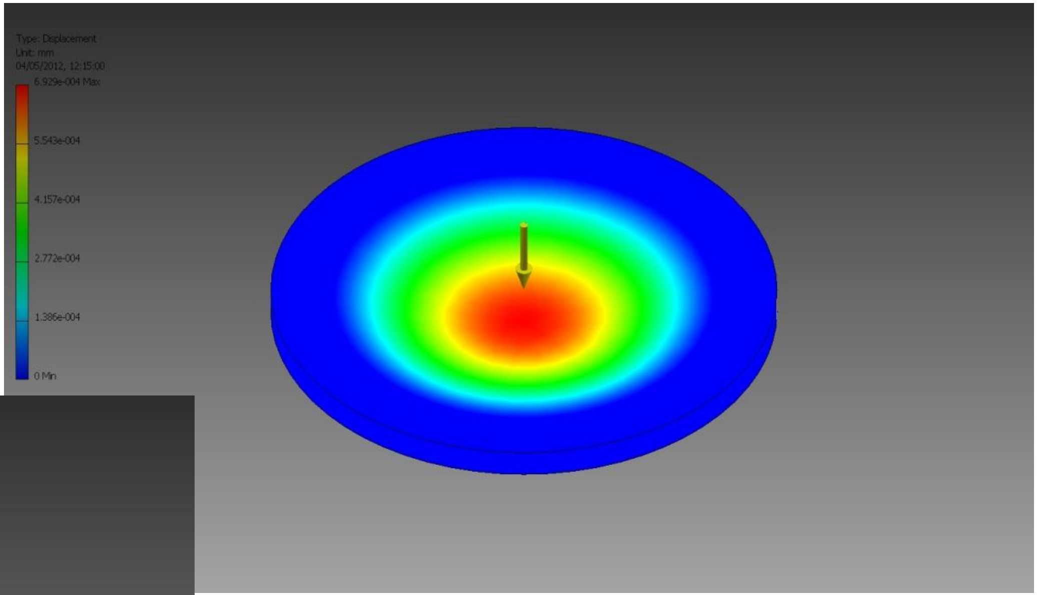
- Optimise optical design for ease of manufacture.
- Optics need to be thicker, by a high percentage
- Work with polishing companies on testing of optics.
- Look at other optical glasses (N-BK7, CTE to high)
- Investigate the best possible coupling material.
- Develop coupling methods.
- Monitor any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

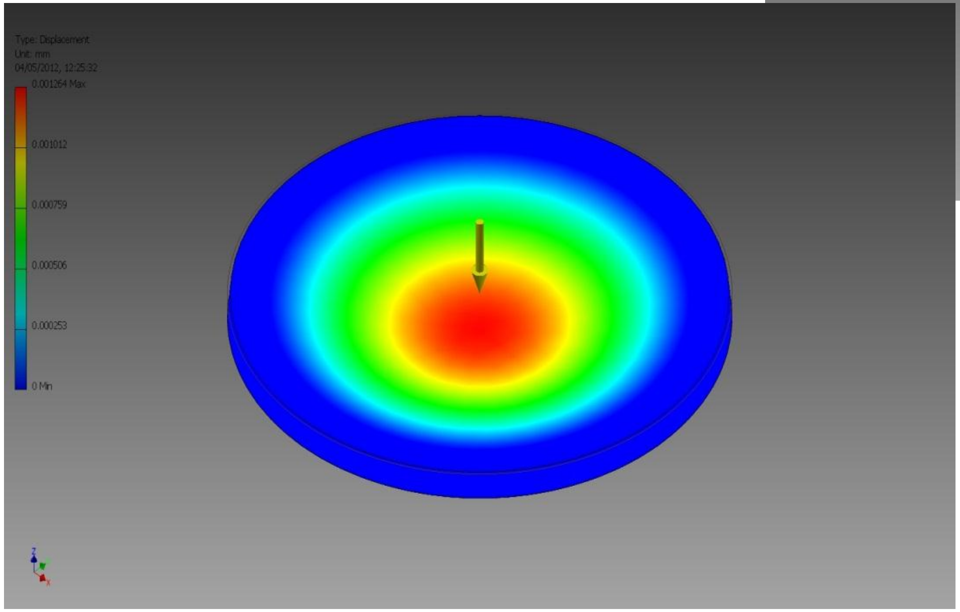
End, Thank You

Dr David Brooks
Optical Science Laboratory
Department of Physics & Astronomy
University College London

Gravity deflection on 29mm plate

Edge constrained

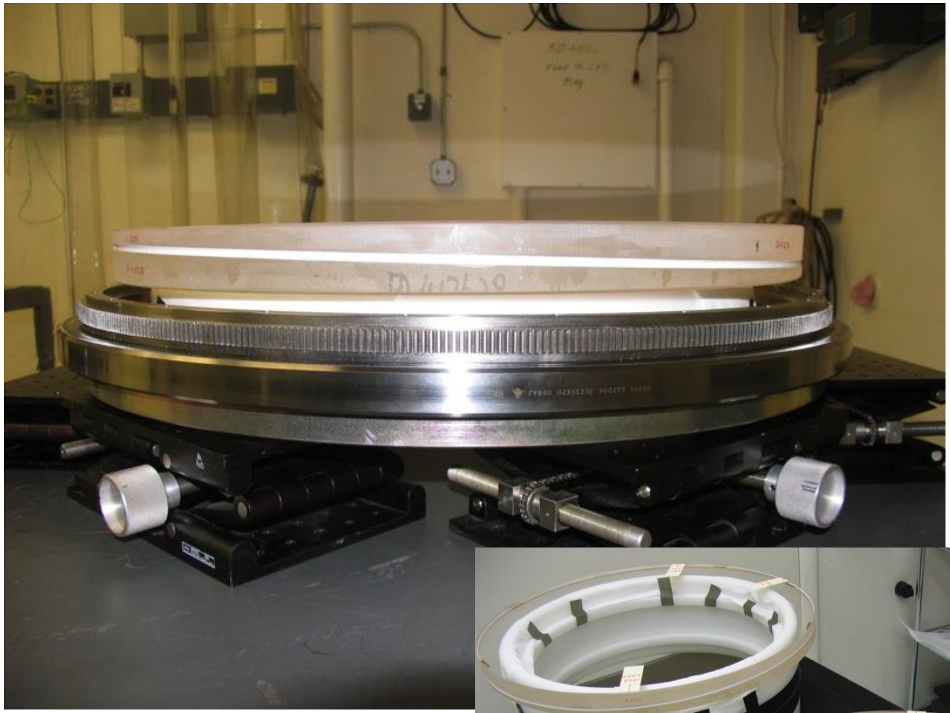


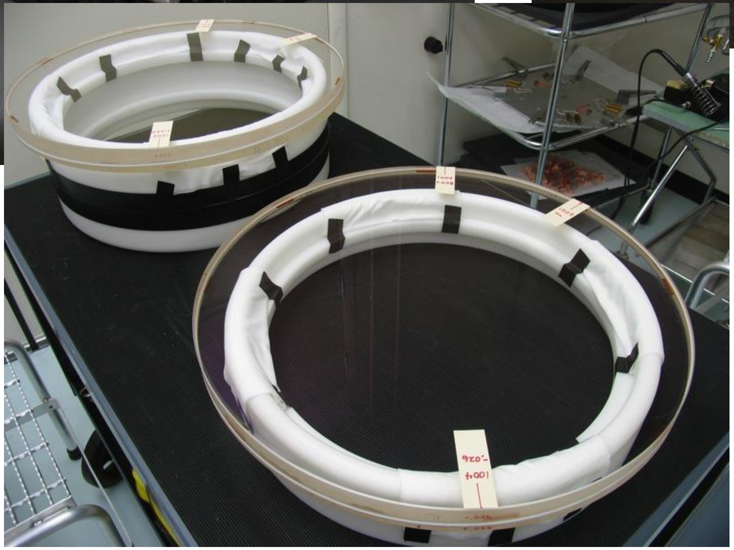


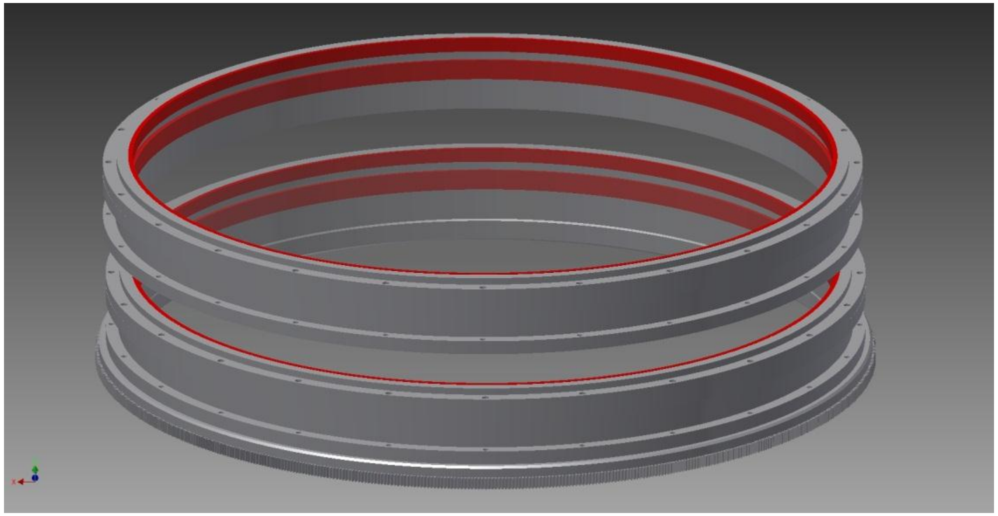
Corner constrained

Bonding the ODI Atmospheric Dispersion Compensators with Sylgard 184

Gary A. Poczulp







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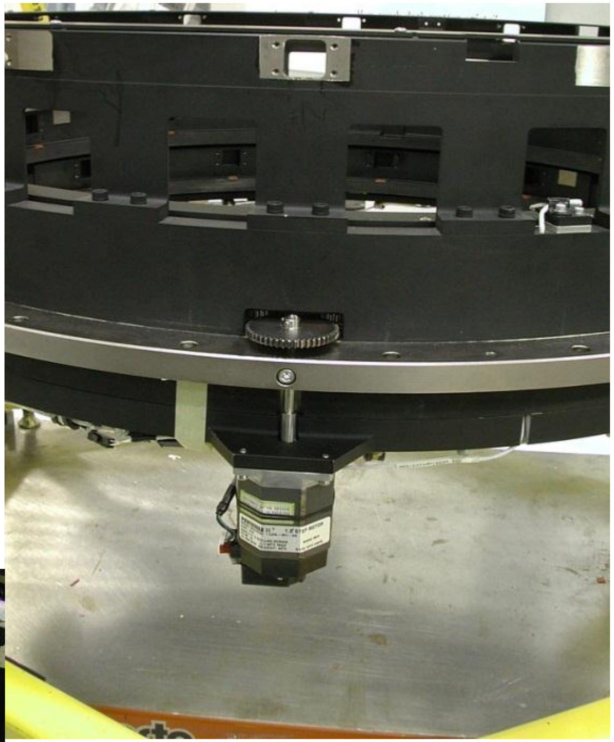
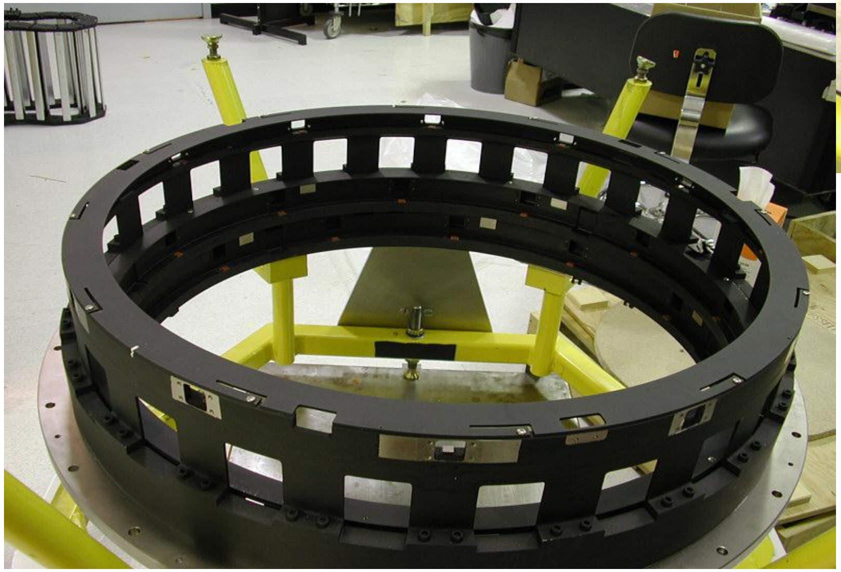
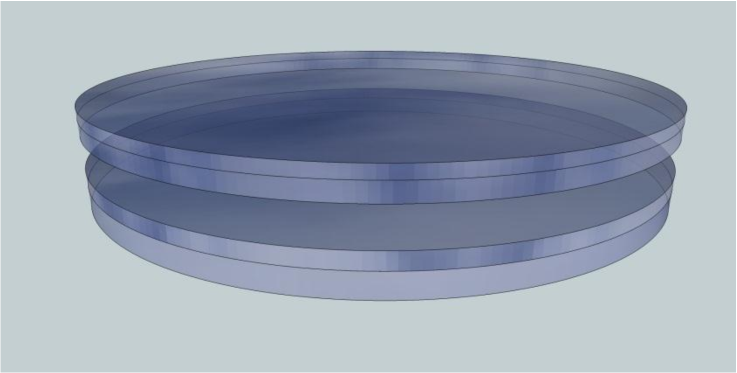


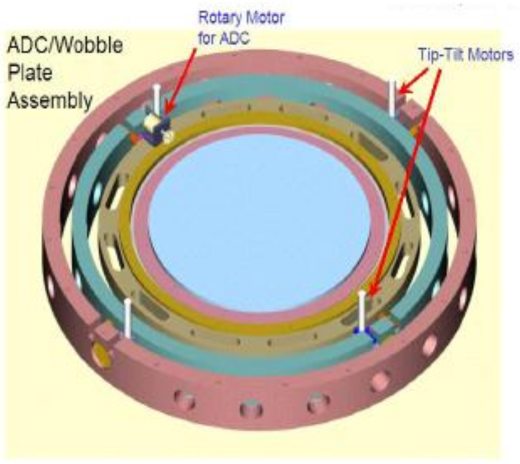


MMT wide field corrector, ADC sub assembly

Large size slewing ring bearing



Despec ADC glass



Gemini ADC & image stabilizer

The Keck -1 Cassegrain ADC