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ESI ALIGNMENT REPORT

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ESI Alignment Report: A. Sheinis
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This report summarizes the methods used to optically align the major components of ESI. We describe the methods used during both integration and commissioning. This report is an effort to paraphrase the entire procedure for historical purposes. For specific details refer to the listed documents and the alignment notebooks.

1. Component Descriptions:

The overall system is described in Epps & Miller 1998, and Sheinis et al 2000.

OSS:

The optical subsystem (OSS) is the optical and mechanical subassembly for the grating, both prisms and both fold mirrors, along with the associated mounting hardware. All these components are mounted onto a steel plate structure which was assembled and aligned off-line on an optical bench. The plate structure was bolted together during initial assembly and has been welded together prior to final alignment, and thus cannot be completely disassembled. Optical components were removed after alignment in Santa Cruz then reassembled at Mauna Kea. The components of the OSS were aligned to an internal axis, defined by the moving prism mounting plate. See Sheinis et al 1998, 1999.

Camera:

The camera is the optical and mechanical system associated with the focussing optics. This system was assembled and aligned as a subassembly prior to its installation into the OSS. See Epps 1998, Sheinis et al 1999. The camera optical design consists of ten lens elements in five lens groups. The camera has an effective focal length of 308 mm. It has an entrance aperture diameter of 287 mm and a final plate scale of 97.7 microns/arcsec on the sky. The collimated beam diameter is approximately 160 mm. The camera's effective f/ratio in imaging mode is thus f/1.93 and slightly faster in spectroscopic modes due to anamorphism.

The camera design is all-spherical and it includes two large CaF_2 lenses. Group #1 is a doublet, group #2 is a CaF_2 singlet, groups #3 and #4 are triplets while group #5 is the field flattener/dewar window. The elements in groups #1 and #3 are optically coupled with a fluid (Cargille laser liquid Type 5610 n(D)=1.5000) to minimize internal reflections. The elements in group #4 are greased together with Dow Corning Q2-3067 optical couplant. The six larger elements were fabricated by TORC and the 4 smaller elements were fabricated by Cosmo Optics Inc., (Middletown, NY). Broad passband AR coatings were applied by Coherent.

The camera mechanical system (CMS) for ESI was designed by Alan Schier, (J. Alan Schier Co., La Crescenta, CA 91214) and fabricated by Danco Machine, DPMS Inc (Santa Clara, CA). It consists of four cells supported within a single large barrel. The mass of the entire camera assembly, consisting of the CMS and the lens elements is approximately 125 kg. The individual cells with their respective lens elements have masses ranging from 5 to 30 kg. The cells locate radially against locating surfaces (lands) on the barrel inner wall and axially against athermalizing spacers. Each cell consists of an aluminum housing, radial athermalizing spacers and a compressive preload spring. Each of the two oil-coupled cells also contains an oil sealing reservoir system. The lens element spacings within the oil-coupled cells are maintained by 0.10-mm Mylar spacers, placed between the lens elements at their edges.

Spaceframe:

In an effort to minimize the effects of flexure in the instrument a "space-frame" structure was adopted as the backbone of ESI. The virtue of the space-frame approach is that all elements carry only tensile and compressive loads. Structures without any bending moments do not have higher order deflection sensitivities to the lengths of its members..

The spaceframe serves as the structure which defines the location of the OSS, collimator, tv guider system, slit and filter wheel assemblies. It is a rigid, welded determinate structure that is mounted to the bearing in a determinate way. The structure is thus mechanically isolated from the bearing flexure. In addition it isolated from the framework that carries the electronics enclosures and the system enclosure. The spaceframe is described in detail in Bigelow and Nelson, 1998.

Collimator:

ESI contains a reflective collimator which is an off-axis segment of an on-axis ellipsoid, figured by TORC, (Tucson, AZ) and coated by Newport Thin Films Laboratory, (Chico, CA). To assist in the alignment and fabrication of the off axis ellipsoid collimator the collimator mirror includes a precision hole along its optical axis. The as-built collimator is a section of a 0.58-m diameter disk that includes the active area and the alignment hole. The collimator is mounted to the spaceframe via a determinate mount. ESI takes full advantage of the virtues of space frame by supporting the collimator without a cell. By gluing 3 Invar pucks at the correct locations to the Zerodur collimator, support can be provided by six struts that attach to these pucks. The mount also contains three computer controlled translation stages that are used to tilt the collimator to compensate for instrument flexure.

The range of focus was set at ±25 mm which gives out of focus images of ±2.30 arc seconds. This range easily accommodates any tolerance buildup and flexure compensation needed and also provides out of focus images for diagnostic purposes.

The flexure compensation precision corresponds to tilt the collimator in sky units of roughly 0.01 arc seconds, or collimator tilts of 0.327 arc seconds. With actuator separation of 1200 mm this corresponds to actuator steps of 3.3 μm.

The collimator system is described in detail in Radovan et al 1998 and Kibrick 2000.

Triple Wheel:

The triple wheel systems is composed of 3 large wheels, each with slots for up to 5 masks or filters. The forward most wheel is the only at cassagrain focus and this is used primarily for slits and slit masks. The middle wheel is used for the decker and along with the third wheel for filters. The wheel is mounted to the spaceframe via an over-constrained spaceframe structure. The wheels are each dual-encoded, closed loop controlled in rotation, to allow the wheel to be positioned at any azimuthal location.

Coordinates:

All axes refer to local coordinates at each surface. Z axis was always the optical axis, positive in the direction of the light transmission. X axis was chosen along the ruling direction of the grating. Y axis follows from the right hand rule.

Theme:

Both the camera system and the OSS were aligned as subsystems offline. Upon installation in ESI, the OSS was aligned as a unit to the instrument axis.. The collimator is aligned independently to the bearing axis. The slit wheels are taken a fixed reference point such that their position defines the actual field of ESI., i.e. the pointing origin for ESI is determined by the actual slit wheel location to be less than the designed 5 minutes off-axis. Thus the ESI spaceframe was not aligned to the rotator bearing. Only the optic components within the space frame (collimator, TV guider, OSS) were aligned to this axis. Keck personnel were responsible for the alignment of the rotator bearing to the telescope axis. This has been measured to be within 2 arcminutes.

2. Component Alignment:

Camera:

The camera was assembled off-line as a subassembly prior to its installation in the OSS. The cell assembly was conducted in Santa Cruz, and is detailed in the assembly notes compiled by Dave Hilyard at the end of this report. Assembly of the cells into the barrel was conducted twice in Santa Cruz (once prior to oil filling, once after), disassembled for shipping and reassembled in Hawaii

Optical elements were placed in one at a time, using a hand operated overhead crane, with tilts and decenters being measured for each successive element. Lateral registration was achieved by honing the cells to match the line-bored camera lands, with final shimming to minimize error stack up. Tilt and spacing of each optical element were monitored as it was installed. Final alignment was achieved by lateral adjustment of cell #2, using its built-in mechanism. This adjustment was based in the interferometric analysis below.

Once all elements were in place, final wavefront errors were measured interferometrically. The camera was tested in double pass using ZYGO phase measuring interferometer with a reference flat. This was done by projecting the f/0.75 beam of the ZYGO into the focal plane of the ESI camera then autocollimating that beam with the camera onto a reference flat. The interferogram was used to approve the final alignment wavefront error.

Lastly image quality and chromatic errors were evaluated with a star test in the jig, both on and off axis i.e. a single pass star test using a white light collimator.

These tests and results are detailed in Sheinis et al. 1999.

Optical subsystem:

The OSS was assembled and aligned as a unit on a bench off-line. The bolted and welded structure was first measured for deviations from the design. These deviations were accounted for in "prism_positions_8_7_98.dwg". Optics were installed one at a time as per their location in "optics_positions_8_7_98.dwg ". The optical axis for the OSS was established on fixed prism for position and relative to the moving prism mounting plate for angular orientation. These locations are documented in "prism_positions_8_7_98.dwg". **Thus, everything was aligned angularly relative to the moving prism mounting plate and laterally relative to the fixed prism axis.**

We now paraphrase the installation of each component onto the OSS:

A)**Grating:**

Alignment of the X and Y rotation of the grating was achieved on a bench by first measuring the orientation of the grating mounting plate relative to the OSS fiducial (moving prism mounting plate). Tilt about x and y were adjusted relative to the grating mounting plate such that the angles were correct relative to the fiducial plane. This was done by setting the heights of the three grating kinematics on a mill table.

B)**LD Mirror**:

The alignment of the X and Y rotation for the Ldmirror was achieved initially on a bench via the following:

1)Set up an AT aligned axially relative to the LD mirror mounting plate in the OSS. Install the LD Mirror, in place in the OSS.

2) Measure the location of the LD mirror angularly with respect to the mounting plate. A reference mirror placed against the mounting plate will provide the return from the plate. The orientation of the mounting plate relative to the Moving prism mounting plate (our zero reference) was measured via the inclinometer. Adjust the orientation of the LD mirror relative to it's mounting plate by shimming the three kinematic v-blocks until the proper angle was achieved . The proper angle was measured in AutoCad in the 3-D optical layout. Thus, manufacturing errors in the oss plates were compensated. Final alignment was done by measuring the center of the field relative to the Echellette spectrum and compensating of necessary.

3) Small piston errors of the mirror will contribute to beam decenter at the camera entrance aperture. These errors were not likely to impact the image quality.

Fine adjustment of the LD mirror was achieved by comparing low dispersion spectra to theoretical spectra. The location of the spectra pertain to the tilt of the ld mirror.

C) **Moving Prism:** Transitional and rotations were adjusted initially in the gluing process such that the bottom of the prism was flat parallel and normal to the mounting flange in the OSS to about .05 mm over it's length. This was done using gauge blocks relative to the OSS mounting plates.

   Modifications to this alignment was achieved by shimming the strut connections at the translation stage end.

D) **Fixed Prism**: Transition and rotation for this prism were aligned identically to the moving prism, except that the reference surface was the moving prism mounting plate. This compensates for manufacturing errors in the orientation of the fixed prism mounting plate to the moving prism mounting plate. (this was about 6 arc minutes of error)

   Modifications to this alignment was achieved by shimming the strut connections at the translation stage end.

E) **Image Mirror**: aligned identically to the LD mirror. Final alignment was done by measuring the center of the imaging field relative to the Echellette spectrum and compensating of necessary

3.Collimator to ESI alignment:
Focus for the collimator was measured by the following: Set collimator focus by autocollimating between a reference flat clamped to the OSS and a pinhole placed at the slit plane. Then distance from the collimator to the pinhole plane was measured using metering rod and an inside micrometer from center of the collimator active area to the center of the slit. Saggital distance difference was calculated using Zemax ray trace. This was necessary since the collimator was an off-axis segment.

Tilts and centration were measured with an AT in the collimator hole projecting to a near-field target and then collimating off a small mirror. By rotating the cass bearing and recording the position of the target image and the reflected beam from the mirror the tilt and decenter of the AT/collimator pair relative to the bearing axis was determined. Adjustments were made by lengthening or contracting each strut. The amount was determined by moving the collimator mirror the appropriate amount in AutoCad and measuring the strut length change. Care had to be taken to rotate the collimator in AutoCAD about the center target. (note this produced a small focus change since we did not rotate about the collimator vertex.)

4.**OSS to Collimator alignment**:
First the angle and position of the OSS was measured relative to the bearing axis. After the bearing was leveled, the angular orientation of the OSS was measured at the moving prism mounting surface using an inclinometer. The difference between the bearing angle and the moving prism mounting surface should be 40.4 +/- 0.1 degrees about the x axis and 0 about the y axis. Z axis rotations were not considered here as a misalignment in Z rotation was easily compensated by a position angle offset in the cass rotator bearing.

Position of the OSS was determined by measuring the location of a target placed on the fixed prism with the AT placed in the alignment hole of the collimator (collimator should be aligned to the bearing axis previously). The target shows the location of the intersection of the fixed-prism-cover plane and the telescope axis. The model OSS was then rotated and translated in AutoCad about the center of the target, by the appropriate amount. The corresponding strut length changes were then measured in AutoCAD. We then re-shimmed struts on the OSS to achieve the orientation change prescribed by the model..

5.**Camera to OSS alignment**:
Camera angle relative to the bearing axis was measured using the inclinometer. Strut lengths were adjusted to change the camera angle. Camera position was determined by measuring the location of the spot produced on the OSS by a laser that has been bore-sighted to the camera. The laser was place in a fixture at the dewar end of the camera. The

fixture allowed us to align the laser to axis of the camera and then project the beam onto a target placed on the imaging mirror. By varying the strut lengths, we were able to position the camera in angle and position required by these two measurements. The strut length changes were modeled by an identical procedure to that above for the OSS.

Fine adjustment of the camera was achieved by comparing Echellette spectra to theoretical spectra. The location of the spectra pertain to the tilt of the camera.

6.**Slit Wheel alignment:**
Focus for the slit wheel was measured via metering rods from the collimator. Position was measured via an alignment telescope referencing the bearing axis from the front of the instrument. Fine adjustment of the slit wheel was not done as some leeway was allowed in the pointing origin.

7.**TV Guilder alignment :**
The TV guider was aligned in place by placing a laser at the focal plane of the guider camera, using a fixture. The laser was then bore sighted to the guider camera lens and projecting to the center of each mirror down the line. We adjusted each optic such that the spot was centered in the next optic on down the line....

8. **Final System alignment**:
Final system alignment was conducted after system integration on the summit of Mauna Kea. In this way, misalignments introduced in the disassembly, shipping and reassemble of ESI were compensated for. Note, that ESI was reassembled with a new rotator bearing. Since the bearing is an integral part of the ESI system, the new bearing had the potential to greatly impact the alignment.

The final ESI alignment was achieved by projecting a laser and/or collimated crosshair through the entire system staring at the slit plane, ending at the camera. The location of the laser spot/crosshair was compared to that predicted by a Zemax raytrace, by projecting to targets placed at each optical element Down stream of the laser. For this test the grating was replaced with the grating alignment fixture. This fixture consists of an aluminum block of the grating mechanical dimensions with a mirror affixed such that the normal of the mirror is at the blaze angle. In this way light from the laser is reflected at the grating equally about the off-littrow angle. The target drawing list and ray trace for this test is included in appendix II.

Appendix I. Camera assembly notes.

Assembly of E.S.I Optics into Cell #1

David Hilyard

1.0 Cell and Lifting Stack Set-up

1.1 Use 2 lab jacks, one on top of the other and bolted together, knobs opposed for access.

1.2 On top of lab jacks place 7" diameter spacer disk topped with concave tool, faced with felt polishing pad material. (Tool radius = 318.mm, steeper than the 421.76,, convex lens radius, so contact is around rim of concave tool.) Total disk spacer height = 6".

1.3 Center Cell #1 on rotary table as it sits on 3 (interferometer) spacers, 12" tall, using the best reference edge of the cell. (The one with the least amount of run-out, and out-of-roundness.) Center to </= .001".

1.4 Center spacer disks inside cell to </= .001".

1.5 Place 2 sheets of plastic film on top of the padded surface of the concave tool to act as "bearing" for shifting Ele. #1 on the pad.

2.0 Optic Handling

2.1 Place R1 of Ele. #1 down on cork ring that has been covered with brown lens tissue.

2.2 Clean R2 surface of Ele. #1 and R1 surface of Ele. #2, and blow with dry nitrogen.

2.3 Place mylar shim, that has been slightly smeared with Cargille fluid for easier postioning, onto the R2 surface of Ele. #1, and center by eye.

2.4 Using the 6" diameter hand held suction cup, attach cup to R2 of Ele. #2.

2.5 Blow off Ele. #2 R1 side.

2.6 Carefully lift Ele #2 with hand held suction cup and, with assistance, center over Ele. #1 and shim and lower to rest on shim. Carefully adjust centering, watching for displacement of the shim and adjusting appropriately..

2.7 Remove suction cup.

2.8 Pick up doublet and place on concave spacer disk inside cell, raised high on jacks for accessibility. (R1 of Ele.#1 goes down on concave disk.)

2.9 Center on spacer disk by eye. (Note: a circle drawn on the R1 side of Ele. #1, centered before hand, may aid in centering on concave disk.)

2.10 Center doublet on spacer disk, first by rolling on spacer disk for gross adjustment, and then by tapping jacks for final adjustment.

2.11 Check and adjust El. #2 to center on Ele.#1, by carefully rolling on shim.

2.12 Final check and adjust centering of each lens, one to another, doublet and cell to </= .001".

2.13 Lower doublet into cell, using widely splayed fingers and hands for feeling and finessing fit, if necessary.

3.0 Cell Retaining Rings Assembly

3.1 Place folder tabs around retaining ring with O ring in place to hold O ring from falling when ring faces downward, as in cell # 3.

3.2 Screw in three screws for handling retaining ring, and lower ring into cell.

3.3 Install wave spring in recessed groove and use threaded ring to press the retaining ring, with radial O ring, evenly into cell. Use shims to measure between metal of cell and glass at O ring interface. Adjust to </=.002" difference.

3.4 Remove threaded ring and wave spring and then remove folder tabs from retaining ring, cleaning any residual adhesive from cell.

3.5 Re-install wave spring, pusher ring and threaded ring to obtain correct O ring compression spacing, adjusting for .002" tilt of ring seat, with correct compression.

Assembly of E.S.I. Optics into Cell #2

David Hilyard

1.0 Cell and Lifting Stack Set-up

1.1 Place 12" diameter by 6" thick aluminum disk (surplus material on hand) on lab jack, covered with black contact paper and place 6 double thick self sticking felt pads around edge of disc to support slightly convex surface of singlet calcium fluoride lens. Raise the jack to close to it's limit.

1.2 Place Cell #2 on 3 risers, (interferometer shims), 9 inches tall, with aluminum support disc on jack in the center.

1.3 Use indicator to center outside of cell on Walter rotary table to </= .001".

1.4 Center inner ring, indicating delrin edge arcs. (Jeff had to center each arc first, by loosening the hold down screw, rotating the pad so it zeroed, edge to edge, then tightening the screw. Inner ring centered to outer ring by .002".

1.5 Final adjust inner ring, indicating delrin to <.0005".

2.0 Optic Handling

2.1 Place calcium fluoride lens Ele. #3 on the felt pads on the aluminum support disc and center by eye.

2.2 Indicate edge of Ele. #3 and center to </= .0005".

2.3 Slowly lower Ele. #3 on jack, into cell between the delrin edge arcs. (Delrin edge arcs have a slight lead-in taper to aid in positioning and ease of installation.)

2.4 Use gloved hands and splayed fingers to feel the fit as it's lowered into the cell. (It was hard to "feel" the fit, because of the weight and size of the lens, but the lens lowered all the way to the mylar shim resting on the cell land, without any problem.)

3.0 Cell Retaining Rings Assembly

3.1 Check horizontal runout of the cell and compare it to the horizontal runout of the lens. (This reveals if the lens is seated properly on the cell land.)

3.2 Install retaining ring with shoulder bolts/ springs/washers.

3.3 Flip cell over and use thin plastic shim (.0005"-.001") to feel misfit of seat of lens against land/mylar shim.

Assembly of E.S.I. Optics into Cell #3

David Hilyard

1.0 Cell and Lifting Stack Set-up

1.1 Use 2 Newport lab jacks, (from the Instrument Lab), one on top of the other.

On jacks place lifting stack of aluminum spacer and convex aluminum tool faced with polishing pad and finally topped with 2 cut-outs of .002" thick plastic sheeting
(to facilitate easier centration of the doublet assembly by rolling it on the padded tool.)

1.2 Place cell on 3 interferometer shims, 12" tall, on top of Walters rotary table, and center using the 3rd edge from the top as a reference surface. Center to <.001".

1.3 Center top aluminum convex tool of lifting stack inside cell by indicating edge of tool, to <.001".

1.4 Raise lifting stack up as high as possible without lifting cell.

2.0 Optic Handling

2.1 Place Ele. #5, steep convex side down in a cork ring covered with brown lens tissue. Place mylar shim on shallow concave surface, (up-looking) on Ele. #5. Place Ele. # 6 on mylar shim/Ele. #5, and center by feel. Do not use tape around doublet, since the shim protrudes from the edge. Flip over doublet, using one person with gloved hands. Use stack of Zygo Transmission Sphere boxes as a pedestal for placing the flipped doublet, then immediately return to table level, after flip. Doublet will now be sitting on a cork ring with the steep convex side of Ele. #5 up.

2.2 Anchor aluminum disk riser/convex tool to jack by using 3 screws to capture base.

2.3 Stand on box (to get to the proper level), lift up the doublet, turn and place the doublet on the concave plate/stack inside the cell. Center the doublet by indicating both lenses, centering one to the other, and centering doublet by rolling the concave surface of Ele. #6 on the convex tool that has been faced with polishing pad material (felt) and topped with 2 sheets of plastic film. Center </= .001", and if necessary use tapping on jacks to achieve centration after loosely centering by rolling on the convex tool.

2.4 Re- check the centration of the cell, and adjust if necessary.

2.5 Test lower doublet into cell to feel for centration. Raise again and continue with procedure.

2.6 Place mylar shim on convex side of Ele. #5. Center by eye, adjusting with Q-tips.

2.7 Place two PVC parallels on the cell edge, outboard of Ele. #5 diameter. Set the concave side of Ele. #4 down on parallels, resting on the flat annulus. Center by eye.

2.8 Center Ele. #4 on parallels to </= .001" by tapping and sliding the lens on the parallels.

2.9 Re-check the centration of the cell and adjust if necessary.

2.10 Raise up the doublet on it's stack to pick up Ele. #4 on it's concave side. Three people watching and helping the shim stay centered as it is folded into the concave surface was helpful, though once the shim was centered by eye, little adjustment was needed to make the shim fold nicely into place.

2.11 Remove the PVC parallels.

2.12 Lower the jacks with triplet stack while one person with gloved hands, places both hands on the convex side of Ele. #4, feeling and finessing the fit as it's lowered.

(The edge of Ele. #4 comes in contact with the edge of the cell delrin before the edge of Ele. #6 dose.)

3.0 Cell Retaining Rings Assembly

3.1 Place folder tabs around retaining ring with O ring to hold O ring from falling when O ring/retaining ring faces downward. (These are standard folder label tabs, cut into about 1/2" wide tabs. The natural shape and clamping action made just the right devise for holding the O ring in place. About 12 of these were placed around the ring.)

3.2 Screw in 3 screws for holding retaining ring and lower into cell.

3.3 Install wave spring in recessed groove in ring, and use threaded ring to press the O ring/retaining ring with radial O ring, into cell evenly. The use 3 push screws thru the threaded ring to push the radial seal ring evenly down against glass so that the folder tabs rest on the glass surface.

3.4 Use plastic shims to measure how evenly the O ring held by the folder tabs seats against the glass. If within .001" to .002", remove the tabs and let O ring rest against the lens. (The final assembly was done without the radial O ring in place to start. The captive radial groove was relieved to allow installation of the radial O ring after the ring was in the cell. Then the O ring was fitted in by several fingers pushing the O ring into place evenly. This procedure avoided rolling of the radial O ring during installation, which made it difficult to achieve even spacing from the lens surface.)

3.5 Assemble wave spring and screw threaded push ring until even spacing between metal and glass at O ring intersection is achieved. Compress to .001"-.002" gap, evenly.

Assembly of E.S.I. Optics into Cell #4

David Hilyard

1.0 Procedure for Grease Coupling Triplet

1.1 Couplant used is Dow Corning Q2-3067 Optical Couplant.

1.2 Measure out and weigh Q2 couplant required for gap between Ele. #7 and Ele. #8

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(2.4 grams includes contingency), and gap between Ele. #8 and Ele. #9 (1.6 grams includes contingency) and evacuate under vacuum for at least 30 minutes. (Evacuation of the couplant helps remove bubbles from the mass.)

1.3 Clean and set Ele. #7 (meniscus) in a cork ring protected with brown lens tissue, so that the concave side is up, and is stable in the ring. Clean Ele. #8 and final blow the interface surfaces of both lenses with dry nitrogen.

1.4 Place the Q2 couplant for that gap at the center of the concave surface.

1.5 Set Ele. #8 into Ele. #7's concave surface and begin working couplant to even distribution until there's a uniform layer to the edge. Work out the bubbles and begin checking the gap with plastic shims at the edge, outside the clear aperture. (It may be required to flip the lenses over, and back and forth in order to better work the gap to the correct thickness and remove all the bubbles.)

1.6 When a uniform gap is achieved (.0015" to .002"), center the lenses to each other and wipe the excess grease away with a dry Kimwipe. Gap goal is .002".

1.7 Then carefully clean the edges with methanol to de-grease the edges, being careful not to get near the gap interface with the methanol, since it may wick into the grease and weaken the coupled interface.

1.8 Use vinyl tape around the edge of the doublet to hold the lenses centered to each other while coupling the next surfaces.

1.9 Place greased lenses Ele. #7 and Ele. #8 so that the convex surface of Ele. #7 is in a cork ring.

1.10 Clean the surface of Ele. #8 (which is facing up) and the surface of Ele. #9 to be coupled, and blow the surfaces with dry nitrogen.

1.11 Place the Q2 couplant for this interface at the center of Ele. #8's surface.

1.12 Bring Ele. #8 down against Ele. #7 and begin working the distribution to achieve an even layer to the edge, removing the bubbles and achieving the correct gap by judging the shim resistance at the edge. Gap goal is .003".

1.13 Clean edges, de-grease with methanol, being careful about gap contamination.

1.14 Clean surfaces, de-grease surfaces, remove tape and adjust centration of the lenses to each other by eye and by feel.

2.0 Cell and Lifting Stack Set-up and Optic Handling

2.1 Place cork ring stack in center of cell. (Delrin edge arcs have already been locked in place and machined to fit lens diameters with a .001" to .002" clearance.)

2.2 Place triplet on cork ring so that Ele. #9 is down on ring, and the first to go into the cell.

2.3 Place shim in cell at lens land.

2.4 Cell is on 2 lab jacks, side by side, that can be raised so cell moves up around triplet stack.

2.5 Slowly raise cell on jacks, shifting the lens stack and coupled interfaces to fit into delrin edge arcs. (Since lenses are small and easy to maneuver, it is not necessary to indicate the lenses and cell into each other for perfect centration as in the other cell assemblies. This fit can be accomplished by feel and careful movement of the lens stack as it is going into the cell.)

2.6 After the cell has been raised around the triplet stack and the proper fit is achieved by manually shifting the lens into the cell, clean the top surface of Ele. #7, install the shim and retaining ring, the shoulder bolts/springs and screws to finish the installation.

Appendix II: Associated Drawing List:

Targets:

camera_align_target.dwg	Camera target for 670nm axial beam
target_fixed_prism_9_22_98.dwg	fixed prism target for 670nm axial beam and for alignment telescope placed on telescope axis
target_grating_9_22_98.dwg	grating target for 670nm axial beam
target_collimator_9_22_98.dwg	collimator target for 670nm axial beam

Autocad scripts:

ray_670nm2.scr	autocad script to create 670nm beam in keck world coordinate system.

Alignment rays:

align_ray670_7_14_99.dwg	AutoCad dwg of 670nm alignment ray in Keck world coordinate system
axial_ray_031899.dwg	AutoCad dwg of axial ray in Keck world coordinate system

Alignment drawings:

prism_positions_8_7_98.dwg	actual prism locations relative to as built OSS
optics_positions_8_7_98.dwg	optics locations in world coordinates
EALIGN2.dwg	camera test 1
EALIGN3.dwg	camera test 2

Appendix III: Tooling List
A) Instrument Alignment:

1) Alignment fixture, Collimator boresite:

This fixture attaches to the collimator. It has a locating hole precision bored to accept an alignment telescope (AT). The axis of the hole is aligned to the instrument axis and is coincedent with the axis of the collimator parent. The fixture resides at Keck

2) Davidson D-275:
Alignment Telescope/autocollimator

3) Davidson D-271:
Alignment Telescope/autocollimator

4) Cohu Lab Camera (or equivalent):
This camera was required to view the alignment telescope reticle with both higher precision than the naked eye and in locations that cannot accept the size and weight of a human being.

Image relay lens and tube for above camera:
Required to relay alignment telescope reticle to camera
Frame grabber for above camera.

5) Inclinometer

6) Alignment fixture: Slit plane

This fixture emulates a slit mask, and fits into the slit wheel. It allows a laser or autocollimator to be placed in the slit plane and be projected at the instrument axis either back towards ESI or from ESI to the telescope. The fixture resides at Keck.

7) Alignment fixture: focal plane
This fixture fits onto the camera in place of the dewar mounting plate. It allows a laser or autocollimator to be placed in the focal plane and be projected at the instrument axis from ESI to the telescope. The fixture resides at Keck

8) Alignment fixture: Collimator focus.

This fixture emulates a slit mask, and fits into the slit wheel. It allows a pinhole and the cohu camera to be placed in the slit plane, in order to autocollimate from the collimator to a reference flat and back to the slit plane. The fixture resides at Keck

B) Camera Alignment:

1) Zygo Mark IV (or equivalent)Interferometer:
Required to test the moncromatic wavefront quality of the assembled camera.

2) Holding Fixture for Camera Tube:

3) Centering Apertures for camera Tube:

4) Alignment Microscope:
For the camera star test.

5) 6 inch projecting telescope (collimator)
For camera star test.

6) reference flat

7) cohu camera

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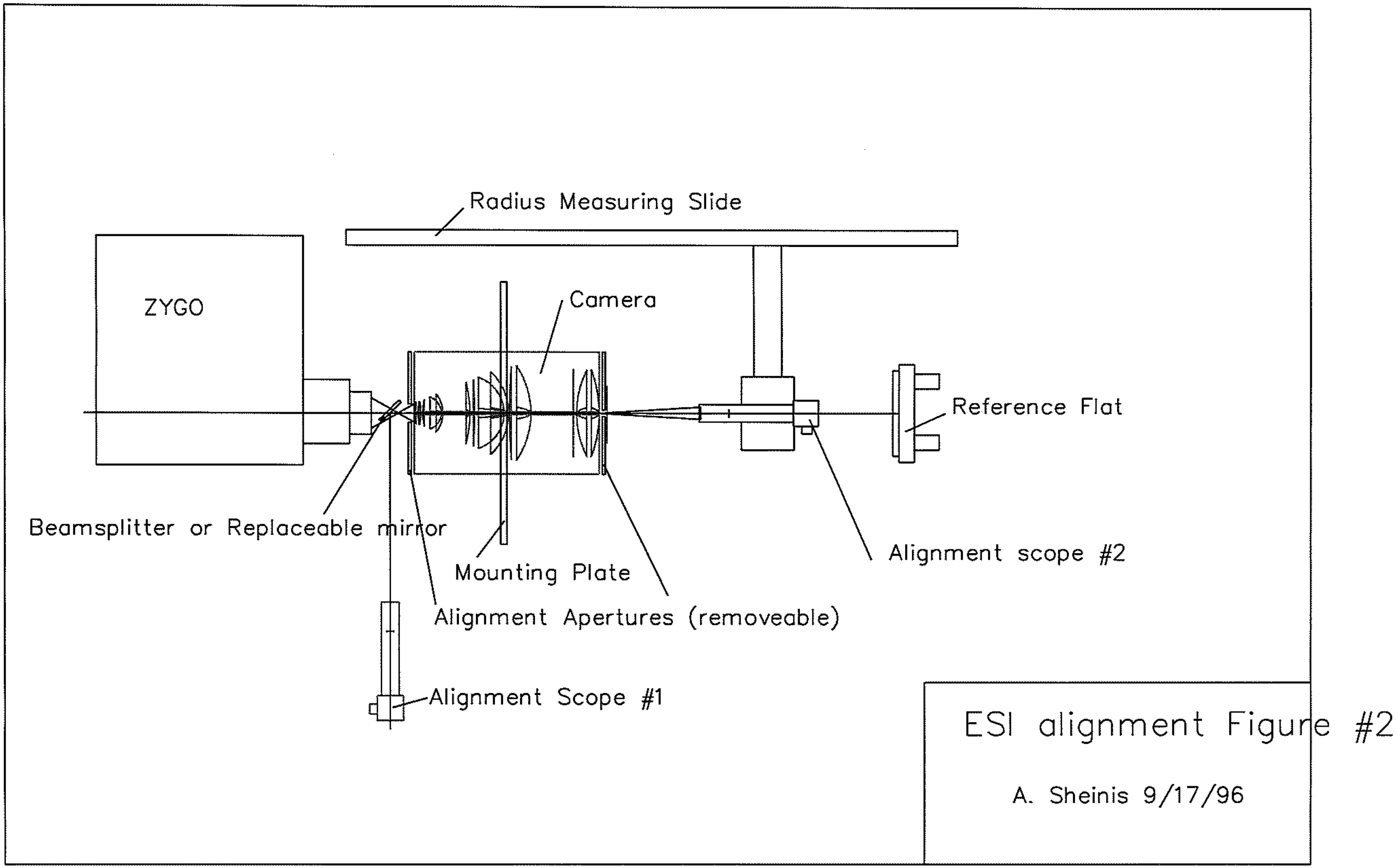
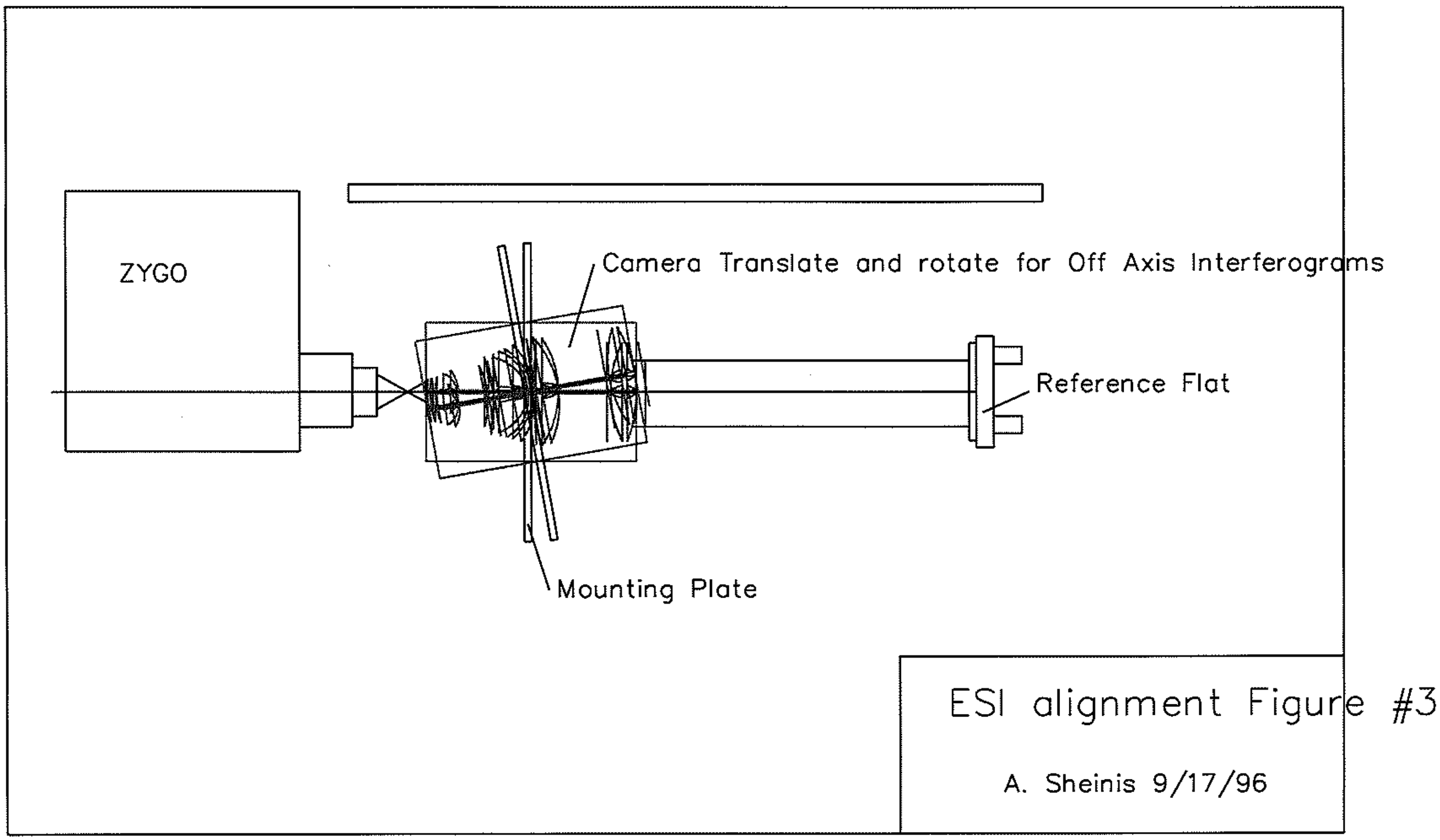

Radius Measuring Slide
ZYGO
Camera
Reference Flat
Beamsplitter or Replaceable mirror
Mounting Plate
Alignment scope #2
Alignment Apertures (removeable)
Alignment Scope #1
ESI alignment Figure #2
A. Sheinis 9/17/96


ZYGO
Camera Translate and rotate for Off Axis Interferograms
Reference Flat
Mounting Plate
ESI alignment Figure #3
A. Sheinis 9/17/96