

CELT Status

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30 May 2002

CELT status

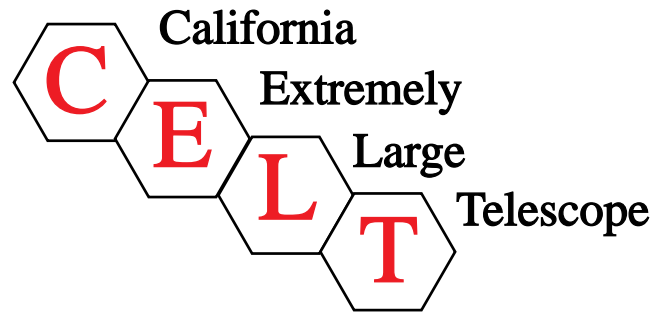
- **What is CELT**
- **Status overview**
- **Requirements summary**
- **Design summary**
- **Primary mirror segmentation**
- **Segment fabrication**
- **Planetary stressed mirror polishing**
- **Interferometric testing**

CELT

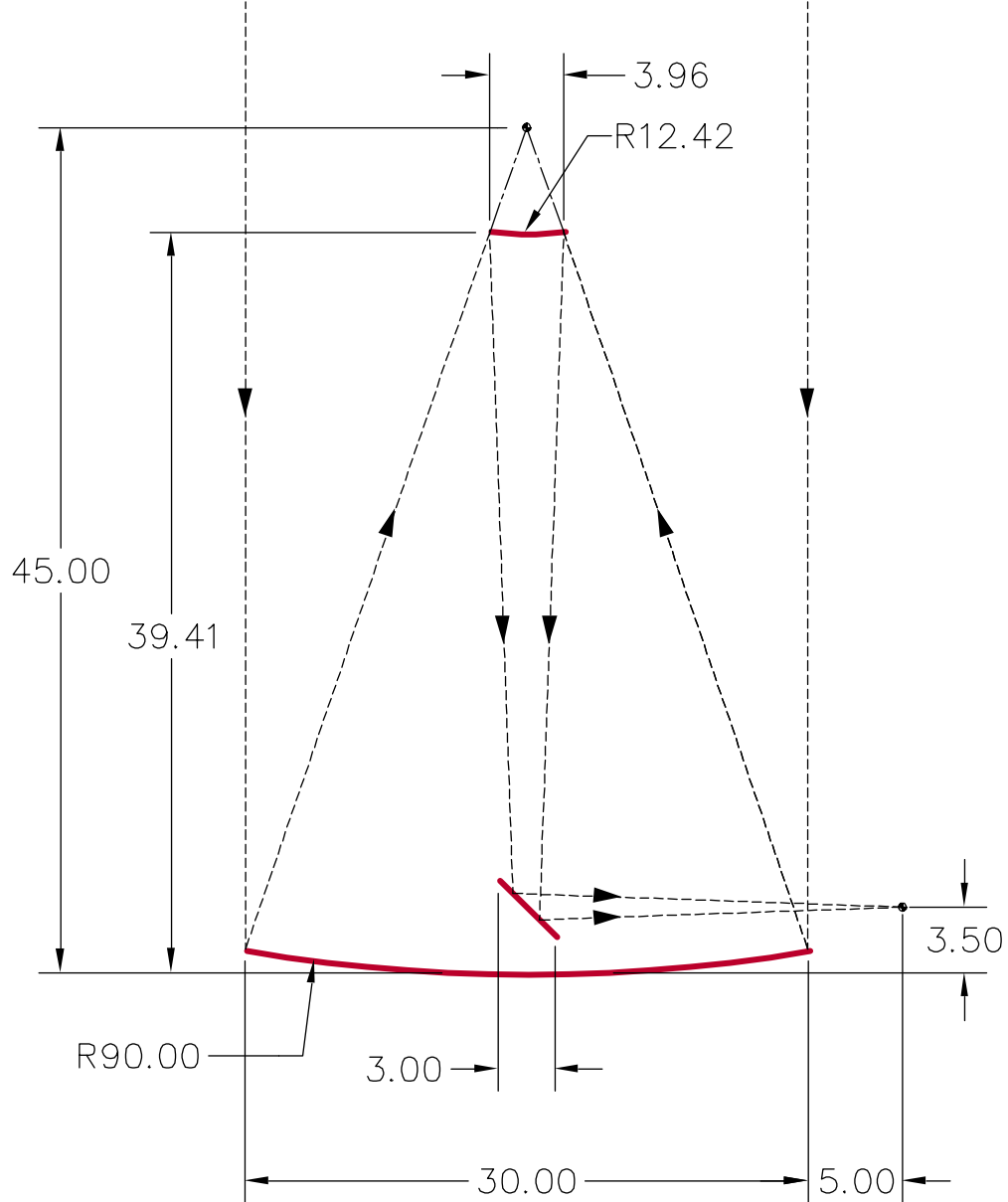
- **California Extremely Large Telescope**
- **Joint project of University of California and Caltech to build a 30-m telescope**
- **Just completed conceptual design (phase 1)**
- **External review 1,2 May 2002**
 - Review committee recommended to the Universities that they proceed with design and construction
- **Phase 2**
 - Technology development
 - Preliminary design
- **Phase 3**
 - Construction

Requirements Summary

- **Aperture: 30m, filled, fully steerable**
- **Field of view: 20 arcmin with 0.5 arcsecond images**
- **On-axis visible light image quality:
0.14 arcseconds (FWHM)**
- **AO compatible (LOAO, MCAO systems)
with rms wavefront goals down to 75 nm**
- **Zenith angles: 0° to 65°**
- **Wavelengths: 300 nm to 30 μ m**
- **Instrument support: Two 15x30m Nasmyth decks**

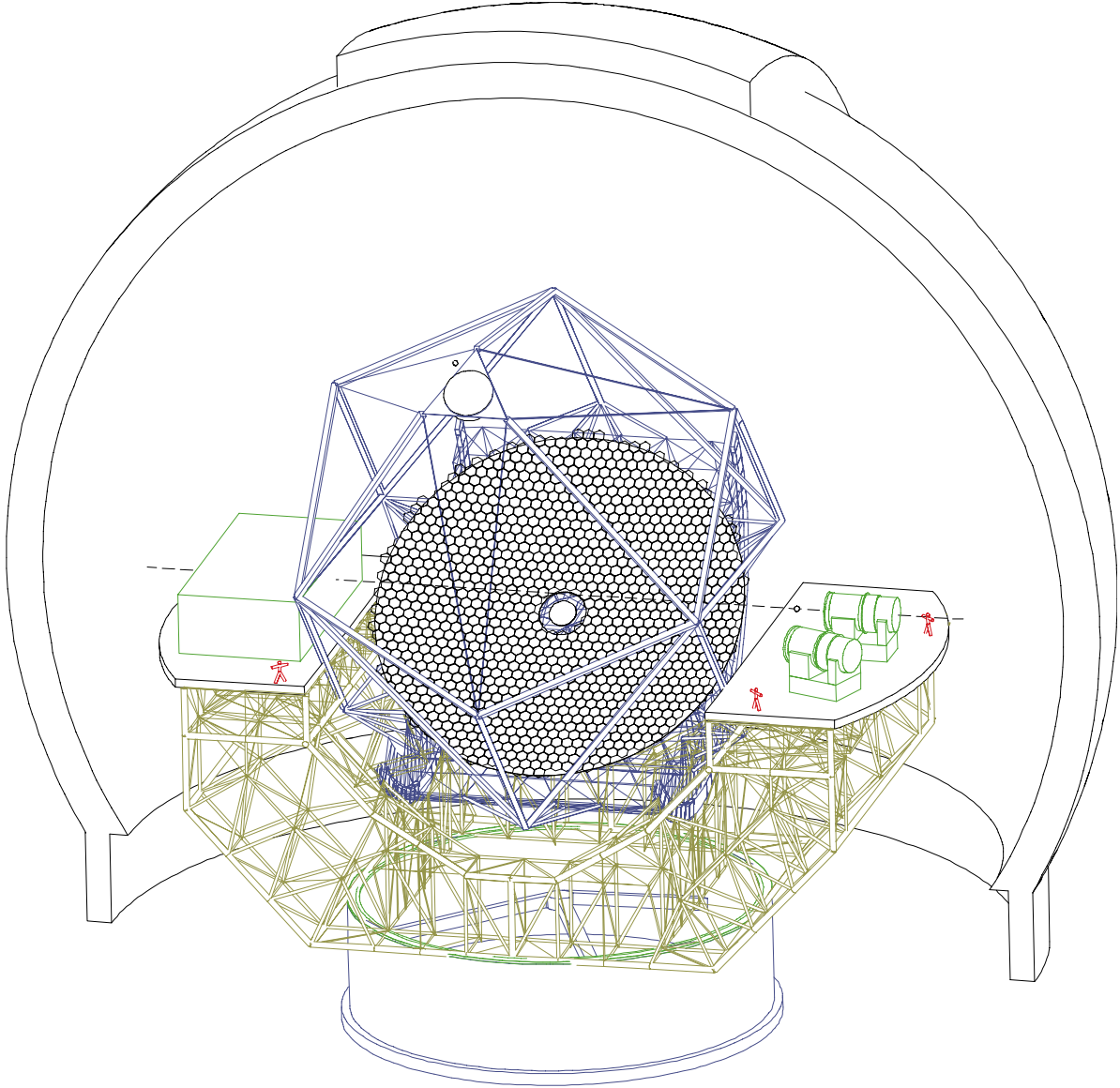


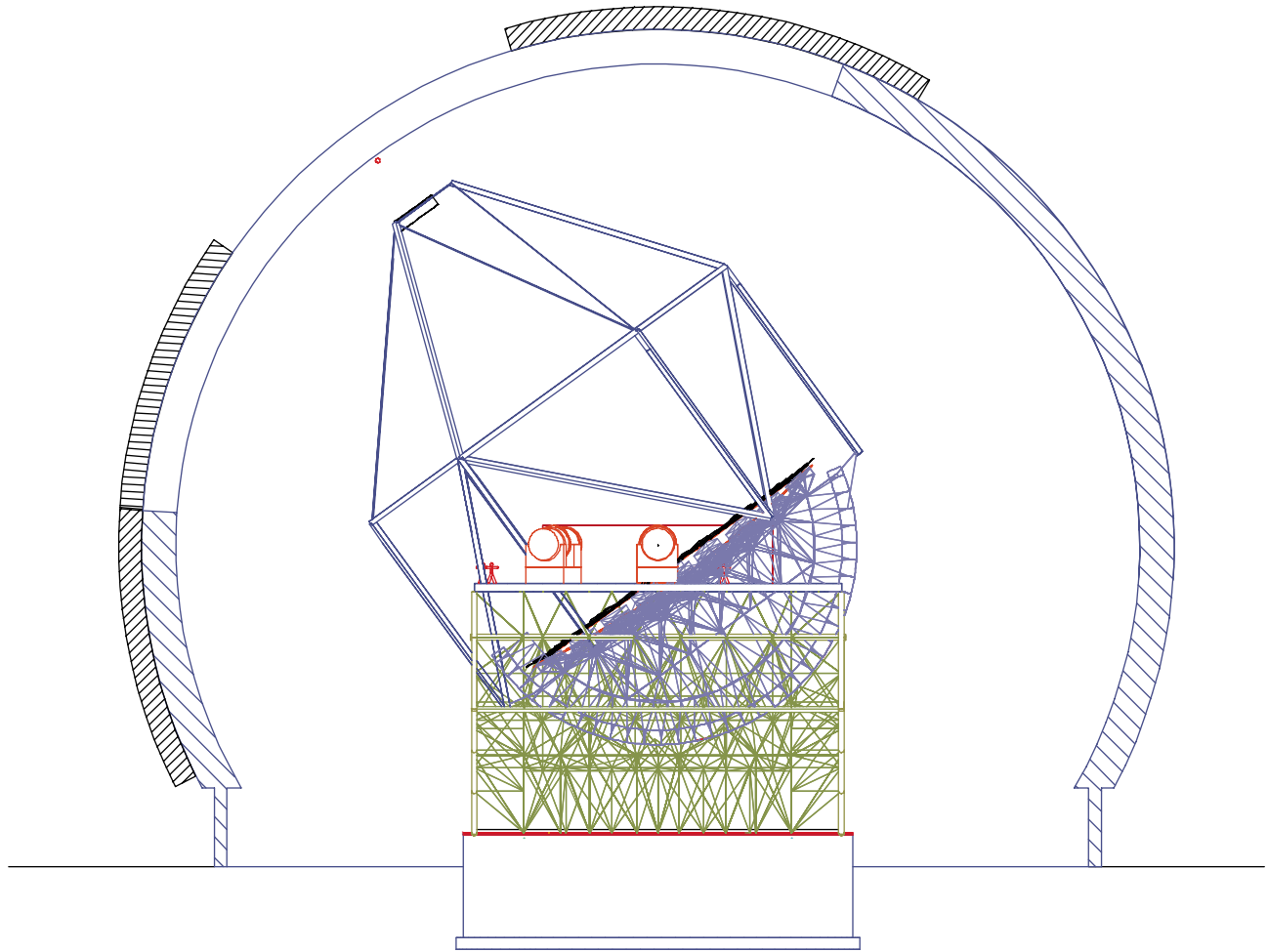
Design Summary

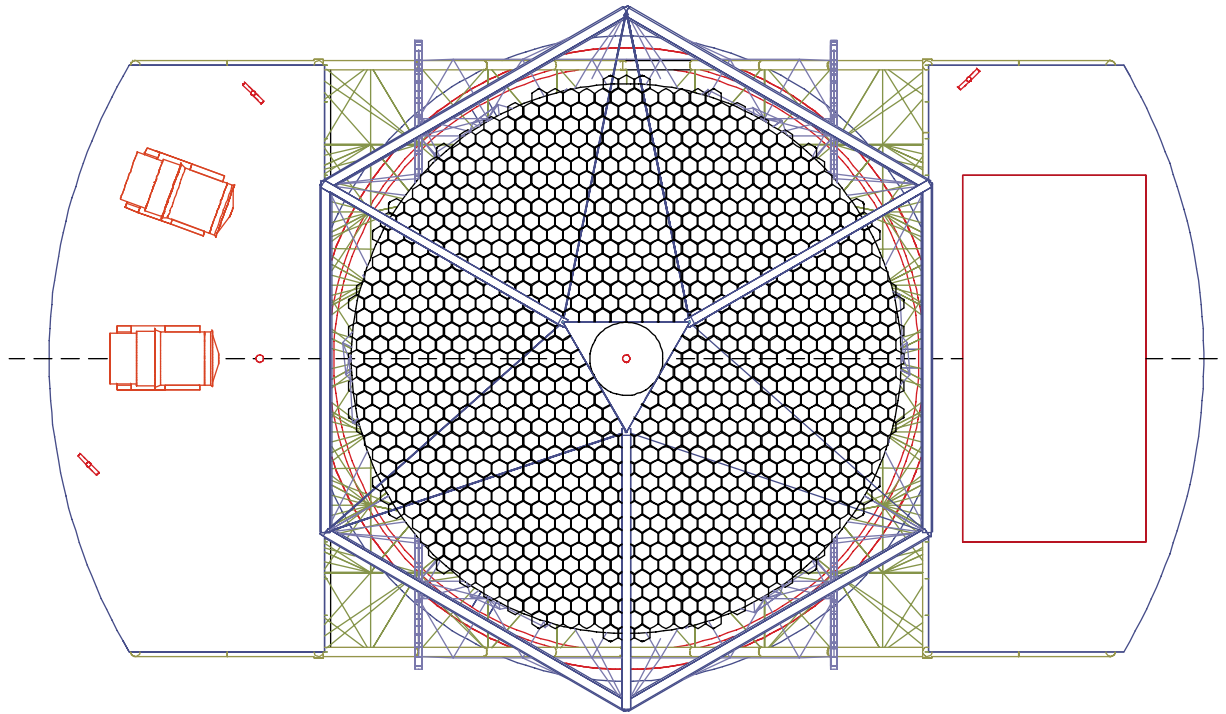


----- light path
 units = meters

Optical layout of CELT showing the primary, secondary and tertiary, and the Nasmyth focus.







This plan view of the telescope shows the upper tube with its blockage of the primary and the Nasmyth platforms with typical instruments placed on them.

Optical Design-1 Key Parameters

- **Diameter of Primary ($D=2R$)**
- **Focal length of primary (f)**
 - $k = \text{radius of curvature} = 2f$
 - $f\# = f/D$
- **Segment size (a)**
- **Segment thickness (h)**
- **Location of elevation axis**
 - In front of primary
 - Well behind the primary

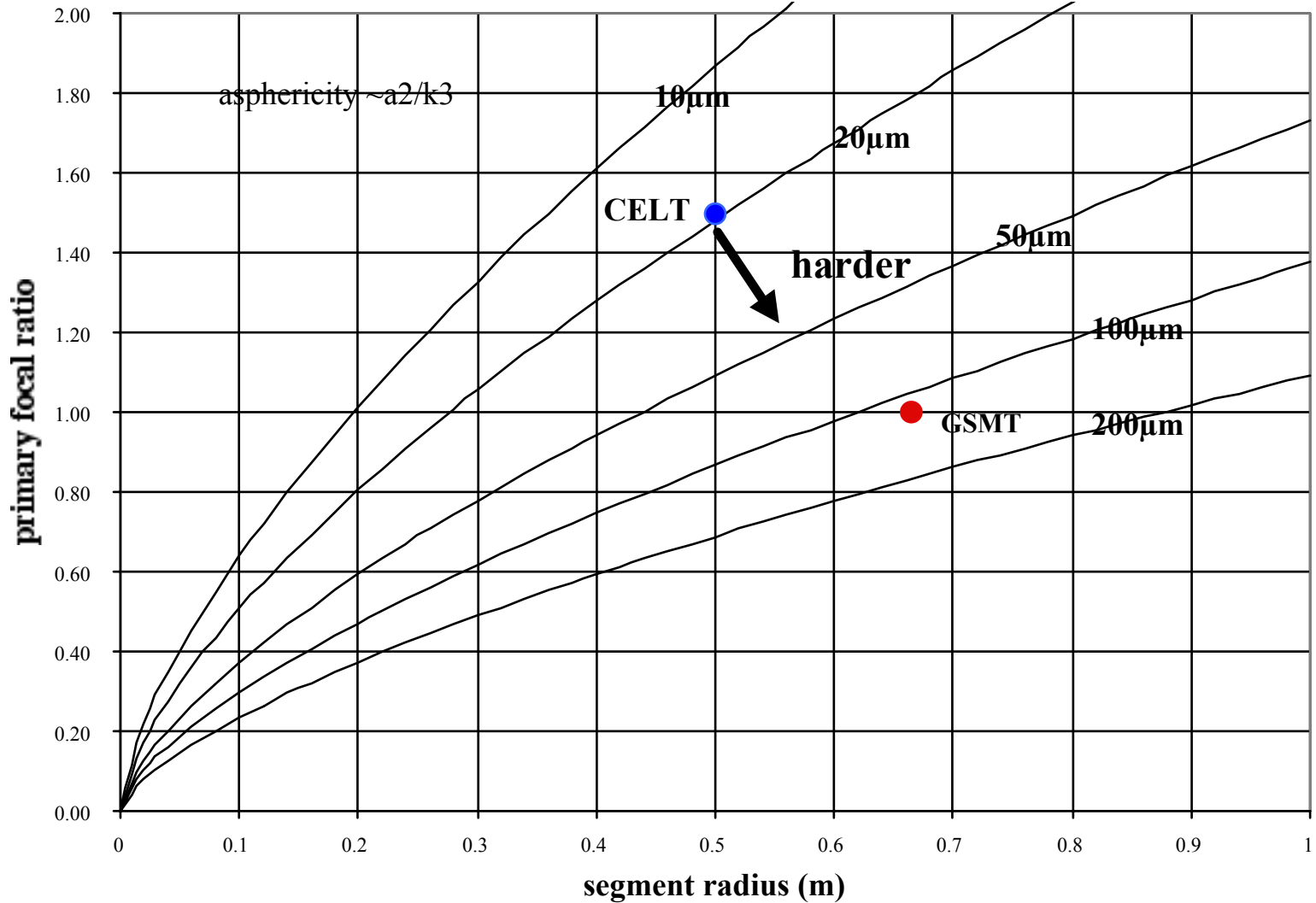
Optical Design -2 Design Drivers-1

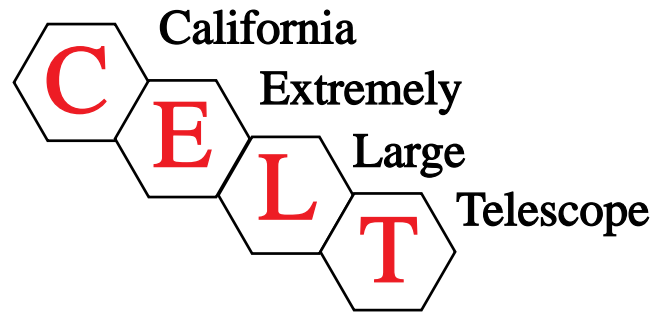
- **Size (cost) of enclosure**
 - Driven by primary focal length
 - Location of elevation axis
 - Possibility of prime focus instrumentation
- **Segment fabrication difficulty (cost)**
 - Driven by asphericity of segment (total aspheric departure)
 - Asphericity $\sim a^2R^2/k^3$
 - Segment size (handling, tooling, etc.)
- **Segment passive support (difficulty $\sim a^4/h^3$)**
- **Segment alignment (driven by gravity, thermal)**
 - Tolerances \sim asphericity $\sim a^2R^2/k^3$
 - CELT sensitivity: ~ 1 nm rms /mm radial, 30 nm rms/ mm at edge- rotation
 - Structure stiffness

Optical Design-3 Design Drivers-2

- **Primary active control system cost (# parts, etc.)**
 - $\sim N_{\text{sensor}} \sim 2N_{\text{actuator}} \sim 6N_{\text{segments}} \sim a^{-2}$
- **System reliability (component MTBF, etc.)**
 - Again $\sim a^2$ (of course we want high reliability, but harder with more parts)
- **System complexity (# segments, etc.)**
 - Again, $\sim a^{-2}$
- **Scientific instruments**
 - Efficiency of optical feed (# of reflections, elevation axis position)
 - Available space (elevation axis position)

asphericity vs focal length, segment radius





Primary Mirror Segmentation

Primary Segmentation - 1

• Hexagonal Segments radius = a and thickness = h

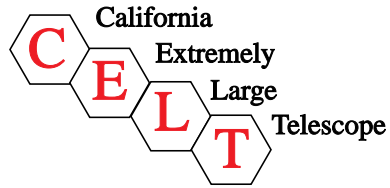
– Choosing a, h requires a complex tradeoff of many costs

– Larger radius means larger

- Asphericity in surface figure ($\sim a^2$)
- Gravity-induced deflection on a support, ($\sim a^4/h^2$)
- handling weight ($\sim a^2 h$)
- sensitivity to position errors in the array ($\sim a^2$)

– Smaller radius means larger

- number of active control actuators and sensors
- complexity of the wavefront sensor & alignment camera
- complexity of control software



Primary Segmentation - 2

- **Larger thickness means larger**

- forces for intentional deformation during fabrication
- cost of the blank material
- thermal inertia in the telescope
- mass for the support structure (the telescope)

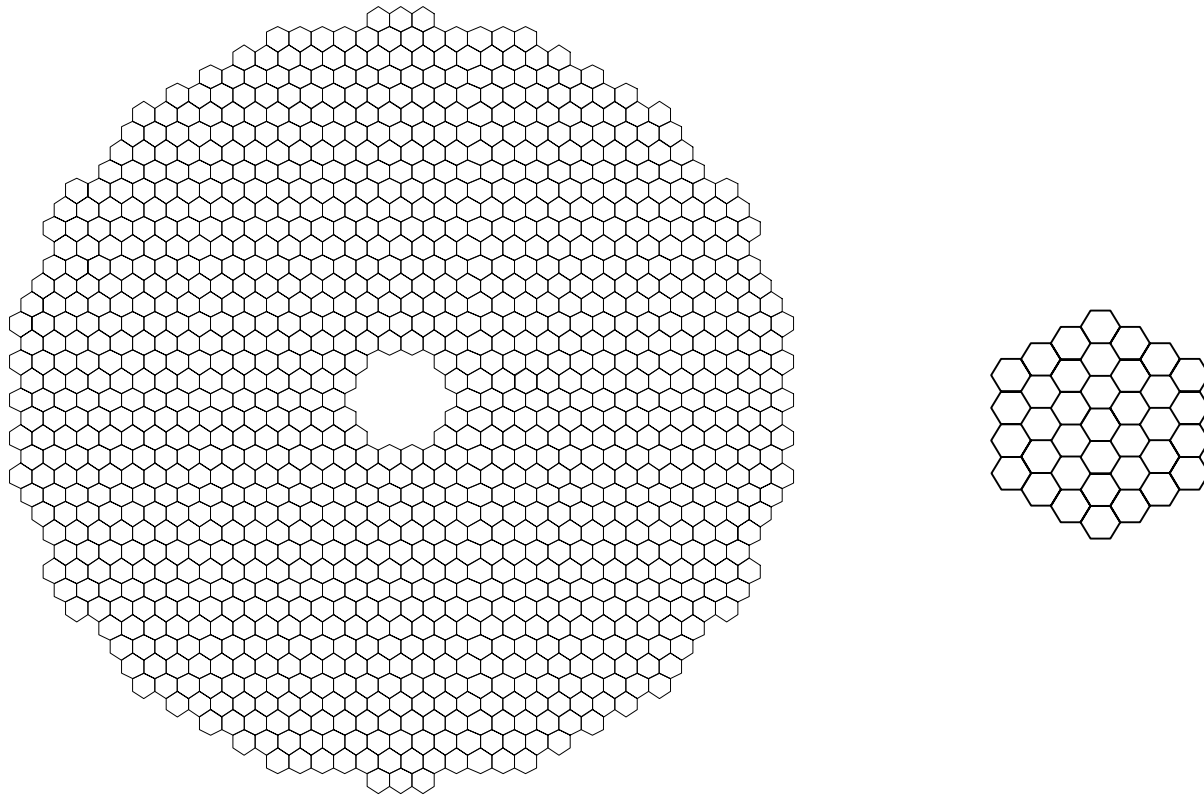
- **Smaller thickness means larger**

- number of support points for gravity-induced deformations

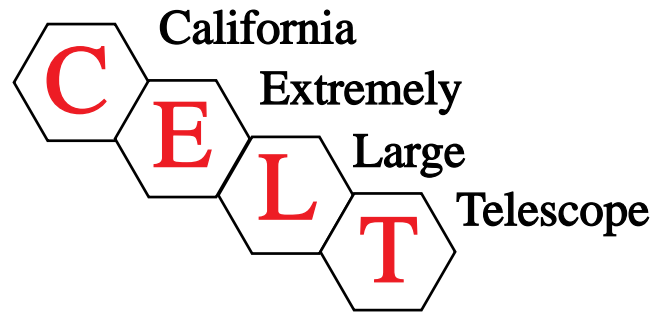
- **We are still collecting estimates of costs & cost variations.**

- **For now, Keck experience leads us to a reference segment design**

	CELT	Keck
• a	0.5 m	0.9 m
• h	0.045 m	0.075 m

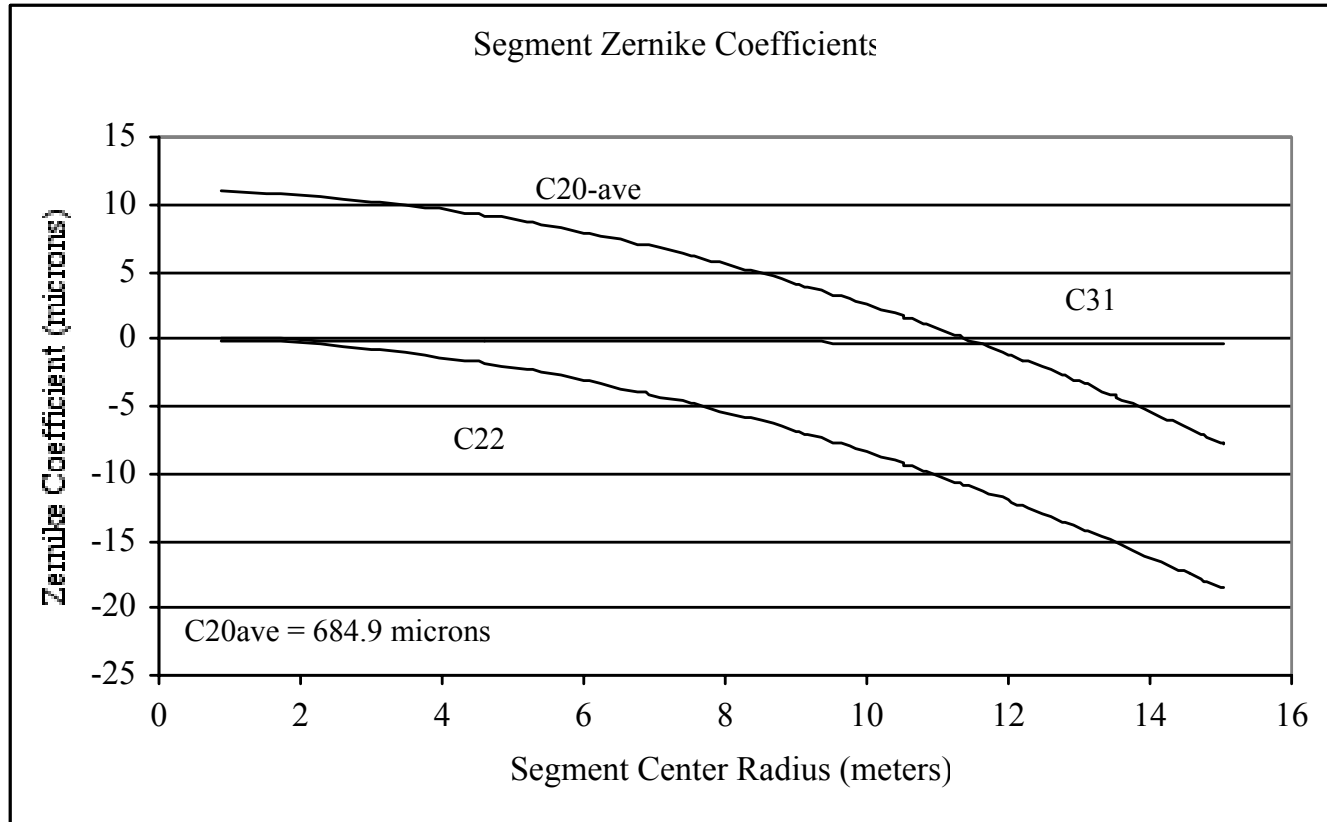


The primary mirror segmentation showing 1080 segments. The Keck primary mirror is shown to the same scale for comparison.



Segment Fabrication

Segment asphericity



Segment surface Zernike Coefficients (μm) versus segment-center radius (m).

Primary Segment - Fabrication-1

Proposed Segment Fabrication Process for CELT

Process

- Convex Side Grind and Polish
- Planetary Stressed-Mirror Grind
- Planetary Stressed-Mirror Polish
- |
- Cut Hexagon
- Mount on passive support
- Ion Figure
- Mount in cluster
- Install clusters in Telescope
- |

Test

- Spherometer
- 2-D contact probe array
- 2-D contact probe array
- point-diffraction interferometry
- point-diffraction interferometry
- point-diffraction interferometry
- metrology
- metrology
- Shack-Hartmann Test

Primary Segment - Fabrication-2

- **Goal:** < 22 nm rms surface error
- **Risk:** Cost of fabrication will be much higher than expected.
- **Changes from Keck that we expect will substantially reduce costs:**
 - Planetary polishing will be used to polish several segments simultaneously.
 - Contact testing during polishing will use a 2-D array of probes instead of a 1-D array that must be repeatedly re-positioned.
 - In-house fab option and/or competition will be used from the beginning as a means of controlling costs.
 - Testing will be more reliable (shorter pathlength) and more rapidly processed.
 - In Phase 2, work on eliminating the need for warping harnesses by redistributing the error budget.

Primary Segment - Fabrication-3

- **Phase 1 results**

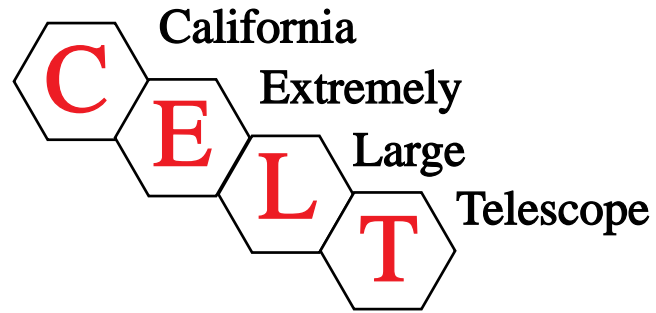
- Made initial contacts with candidate industries.
- Made initial FEA of stressing fixture effect on blank.
- Created an initial design of stressing fixture:
 - forces and moments set by robot
 - rides on top of each blank on a planetary polisher
- Created an initial design of a point-diffraction interferometer for optical testing.

Primary Segment - Fabrication-4

- **Phase 2 - Milestones To Mitigate the Cost Risk**
 - Complete FEA and stressing fixture design.
 - Complete study of point diffraction interferometry including error budget, costs, and schedule.
 - Complete a systematic investigation of alternative
 - blank materials,
 - figuring methods (fabricate one or more segments)
 - testing methods.
 - Design, build, and test prototype of 2-D contact probe test tool.
 - Build and use an engineering model stressing fixture to polish a blank.

Primary Segment - Fabrication-5

- **Phase 2 - Milestones To Mitigate the Cost Risk (cont'd)**
 - Hire an optics manager and/or consultant experienced with mass production.
 - Revisit candidate industrial polishing firms with results of above tasks to obtain their input on options and relative costs.
 - Develop a detailed in-house-fabrication model for each fabrication step.
 - Select a cost-optimized path for segment fabrication with a detailed WBS and costs.



Planetary Stressed Mirror Polishing

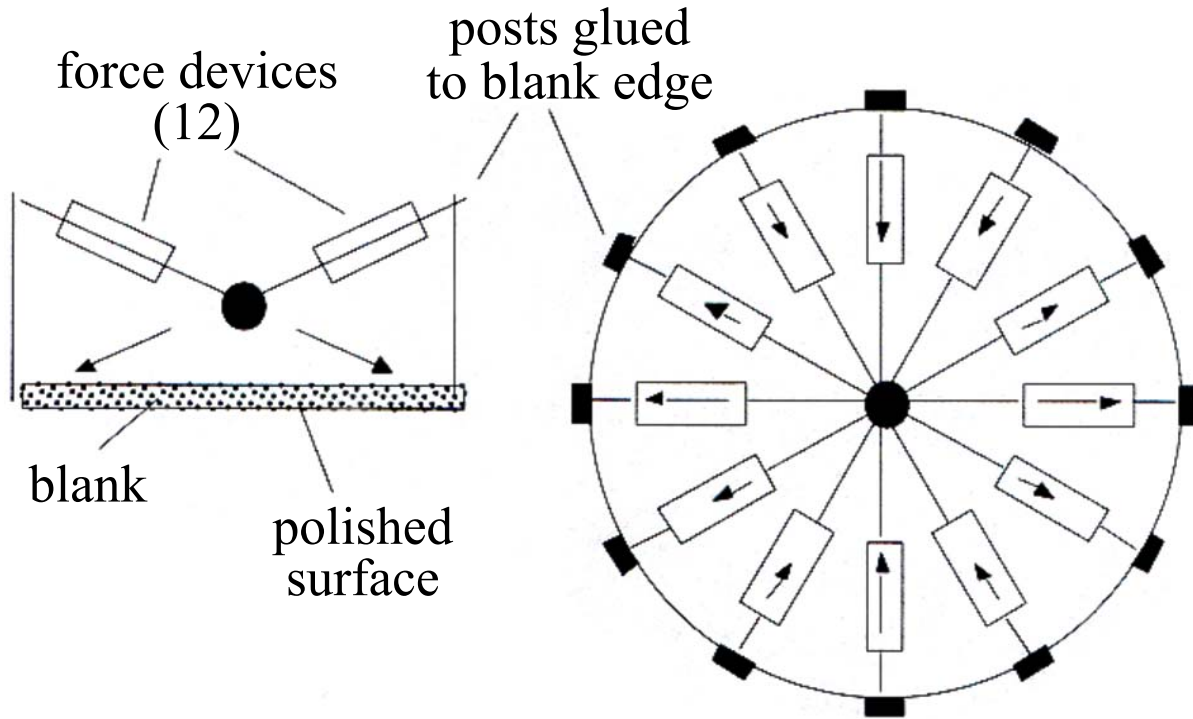
Planetary polishing to produce 1000 segments



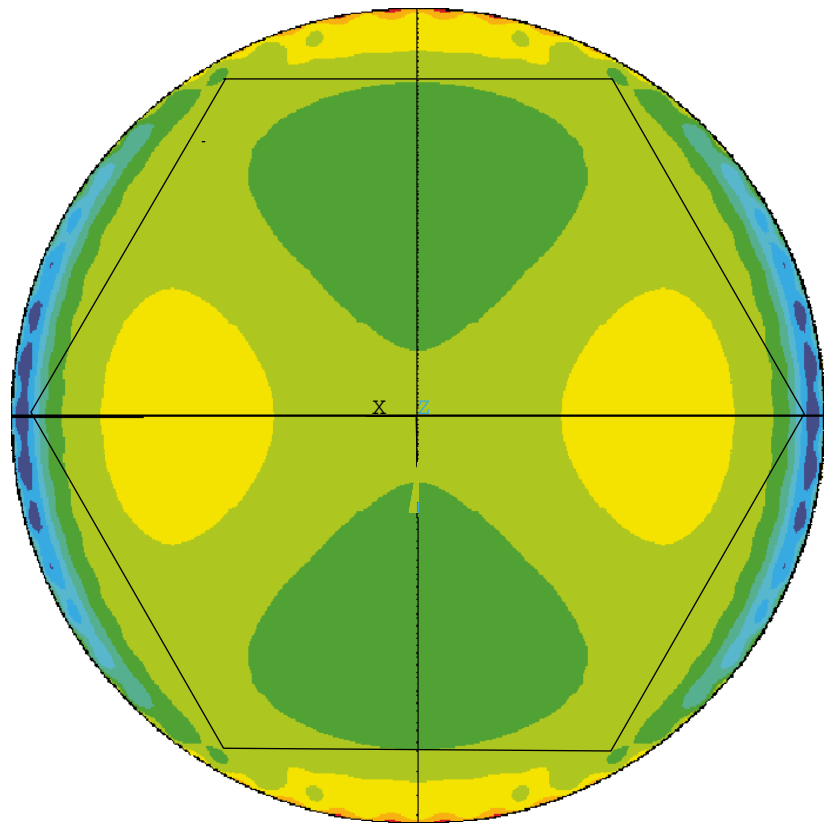
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segment fabrication

Proposed CELT Stressed Mirror Polishing Set-up



Arrows indicate force direction and magnitude required to create / remove astigmatism

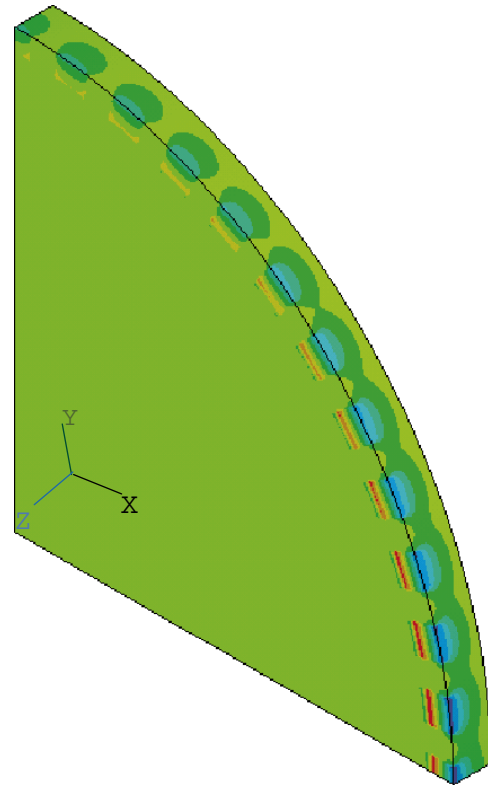


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/EXPANDED
UZ (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.757E-07
SMN =-.754E-07
SMX =.545E-07
-.754E-07
-.609E-07
-.465E-07
-.321E-07
-.176E-07
-.320E-08
.112E-07
.257E-07
.401E-07
.545E-07

```

Finite-element predicted deformation non-quadratic Residual Surface (units are meters).



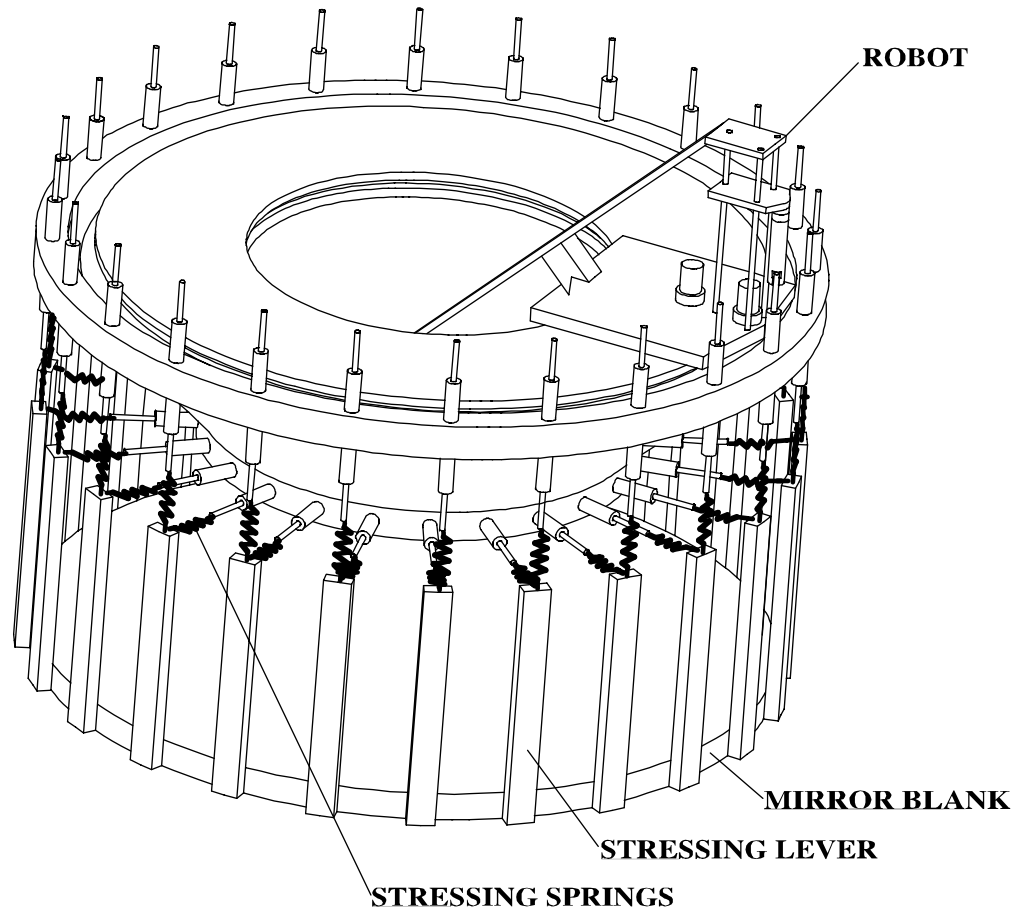
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PowerGraphics
EFACET=1
AVRES=Mat
DMX =.373E-04
SMN =-.296E+07
SMX =.218E+07

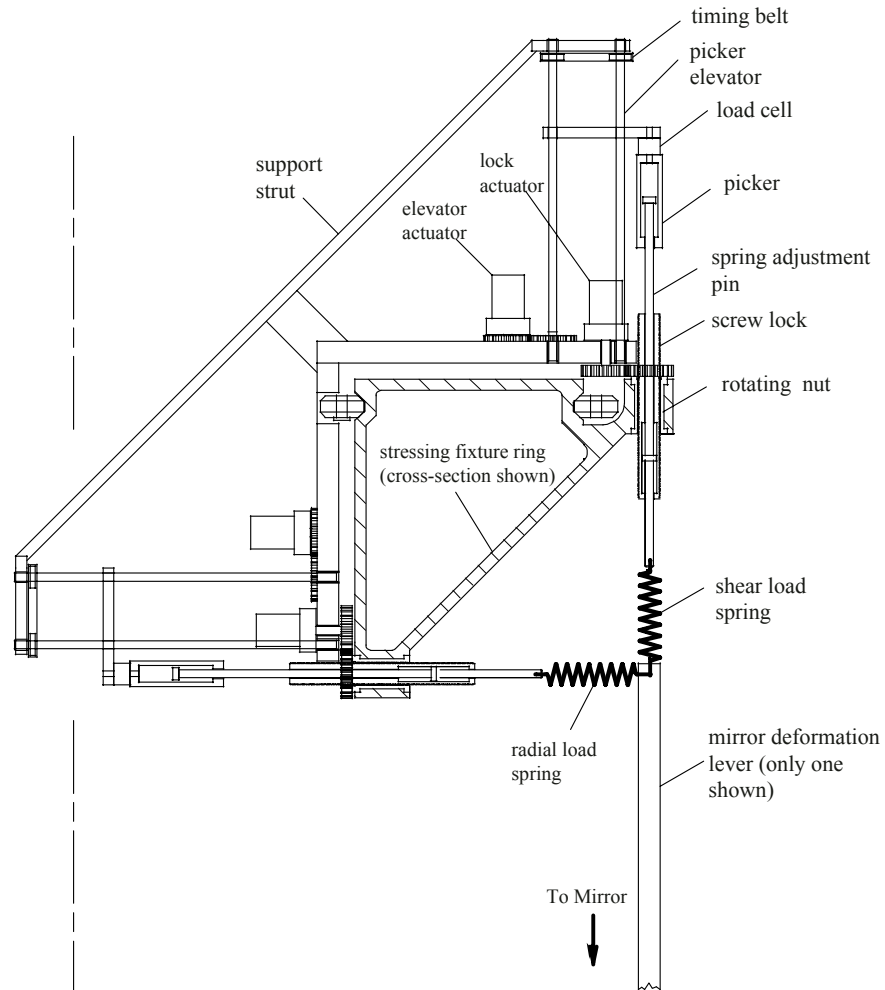
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Dark Blue	-.296E+07
Blue	-.238E+07
Light Blue	-.181E+07
Teal	-.124E+07
Green	-672614
Light Green	-101956
Yellow	468702
Orange	.104E+07
Red-Orange	.161E+07
Red	.218E+07

Finite-element predicted axial stress distribution (units are Pa).

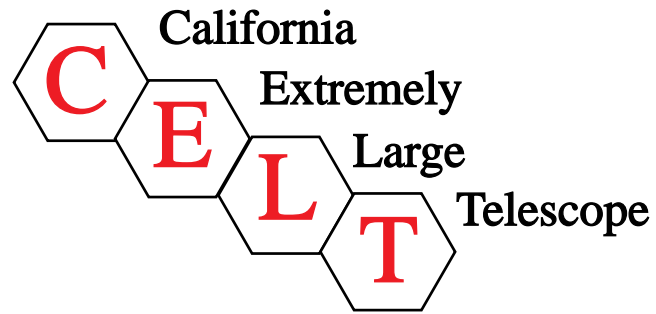


Stressing fixture showing the blank and levers bonded to the back at the edge.

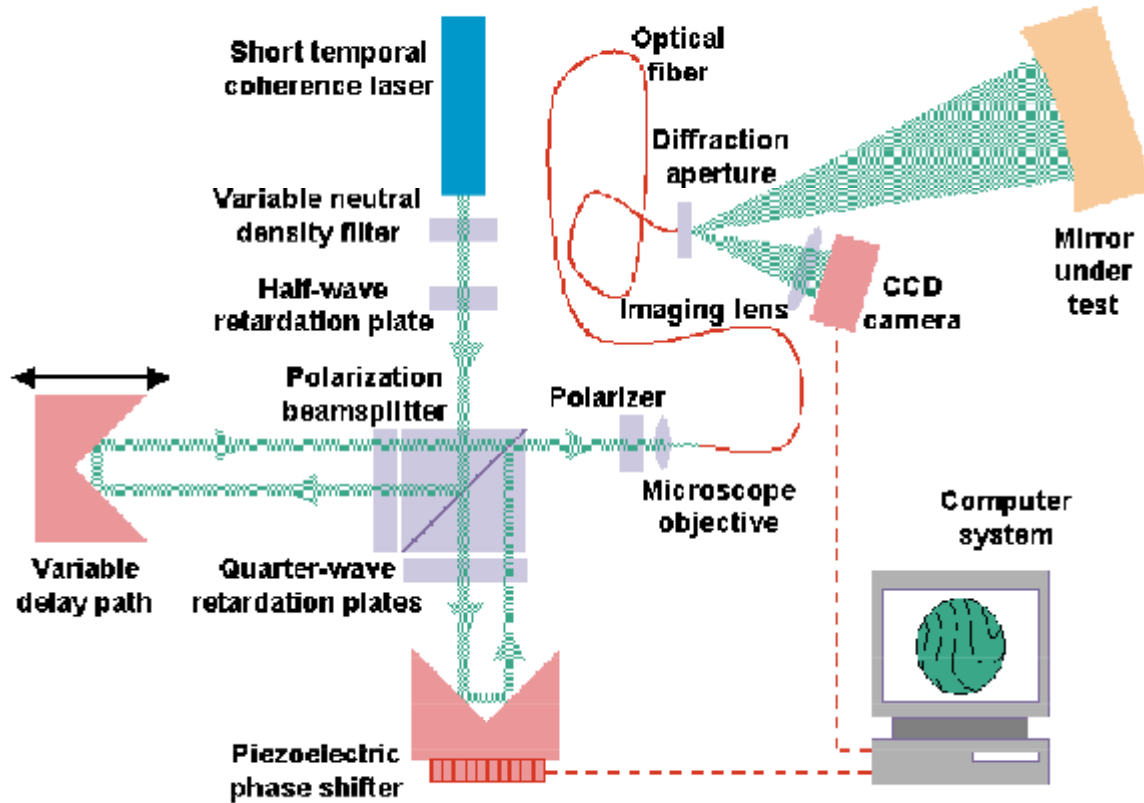


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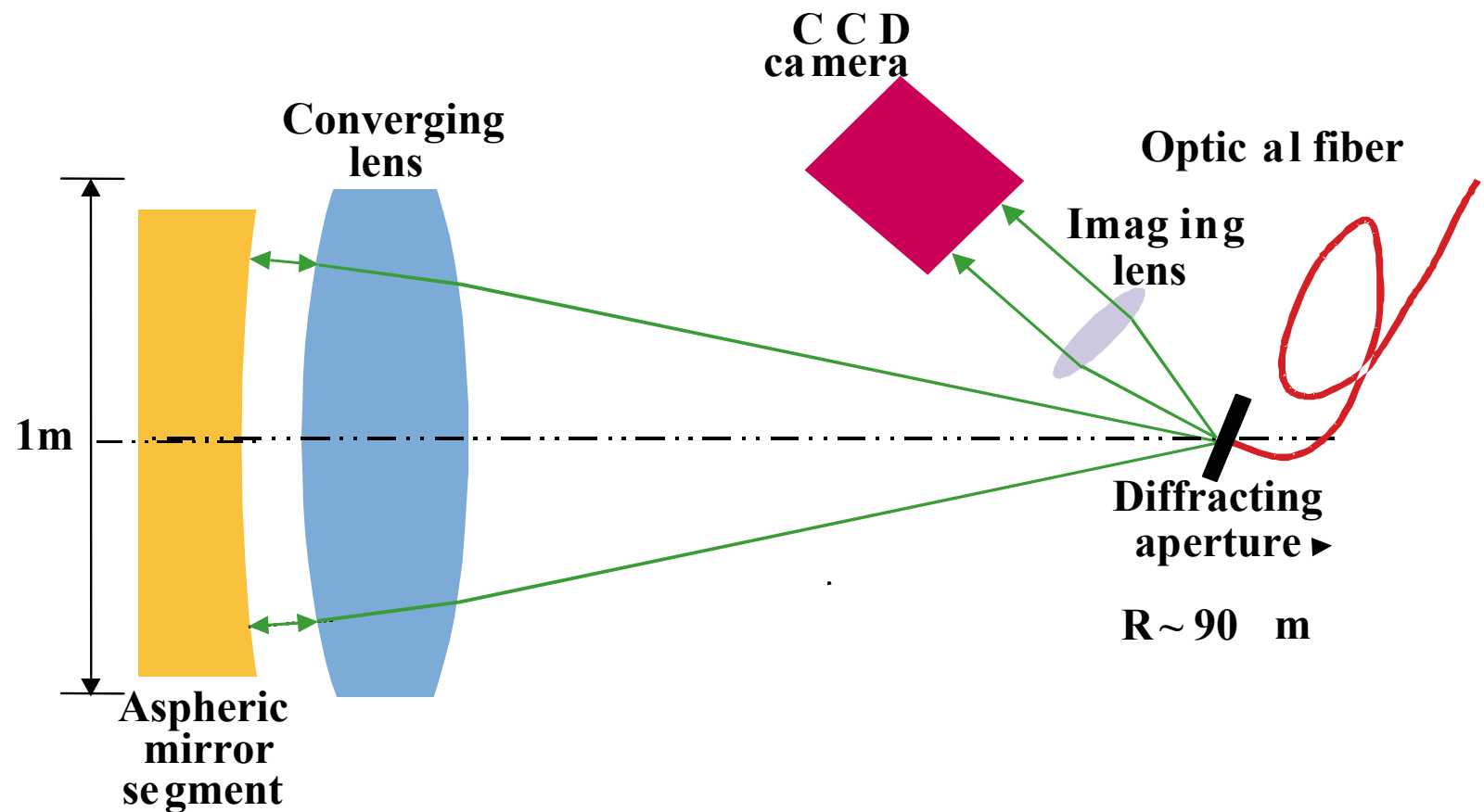
The mechanism on the right is used to adjust the spring loading of the stressing fixture.



Segment Testing - Interferometric



Layout of point diffraction test.



Converging lens used to shorten the length of the interferometer.