Telescope Development for Space-based Gravitational Wave Observatories

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Telescopes for Space-Based Gravitational-Wave Observatories: High-level Summary

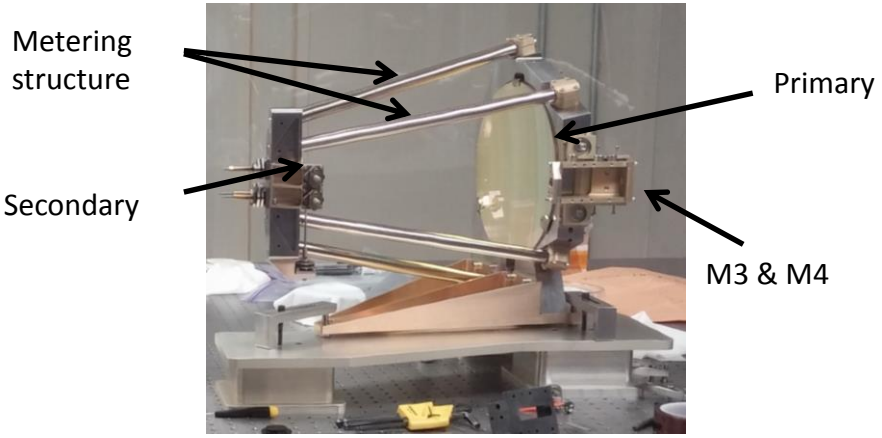
Objectives and Key Challenges:

- Establish a complete telescope design meeting optical, mechanical, thermal, and manufacturability requirements for possible US contribution to the eLISA L3 mission
- Fabricate and test a prototype
- Validate stray-light model
- Verify dimensional stability

Significance of Work:

- First demonstration of a validated scattered-light model, and combined with previous demonstration of dimensional stability, provides a firm basis for realistic engineering-model design for a flight-qualifiable off-axis telescope.

Off-axis Prototype Model
Afocal modified Cassegrain



Approach:

- Use SGO-Mid and the ESA eLISA concepts as a reference
- Generate requirements per the ESA/SRE "Yellow Book"
- Use outside vendor design study results
    - (off-axis SiC recommended)
- Fabricate a prototype from the design
- Validate stray light model
- Need another iteration to demonstrate stability

Key Collaborators:

- NASA Goddard optics branch
- Mechanical contractor Justin Ward
- Postdoc Shannon Sankar and Prof. Guido Mueller

Current Funded Period of Performance:

- Oct 2012 – Sep 2015 NASA HQ SAT grant: scattered light
- Oct 2015 – Sep 2017 follow-on SAT grant: dimensional stability

Recent Accomplishments:

- ✓ Signed prototype model contract
- ✓ Prototype CDR
- ✓ Prototype telescope delivered to GSFC
- ✓ Aligned prototype telescope at GSFC

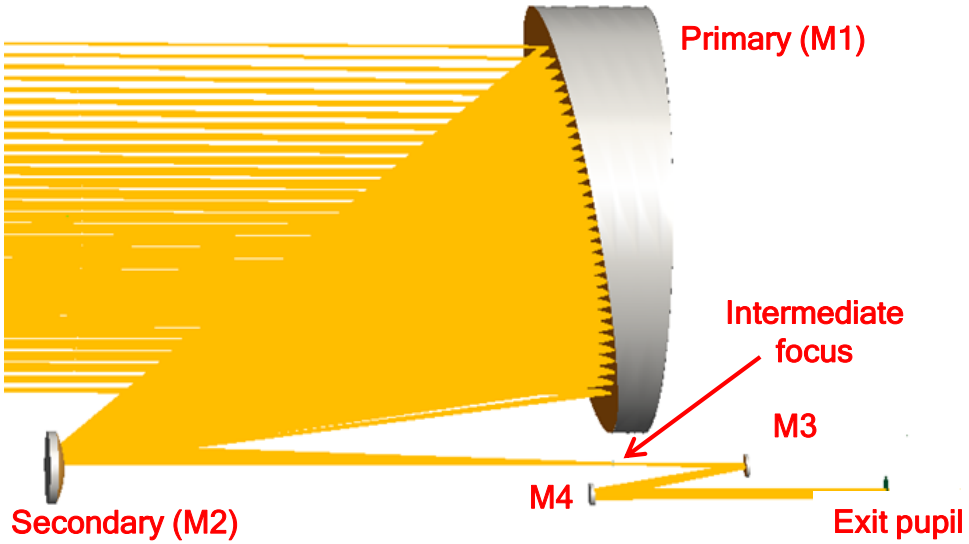
Next Milestone:

- Validate system-level scattered-light model (Sep 2015)

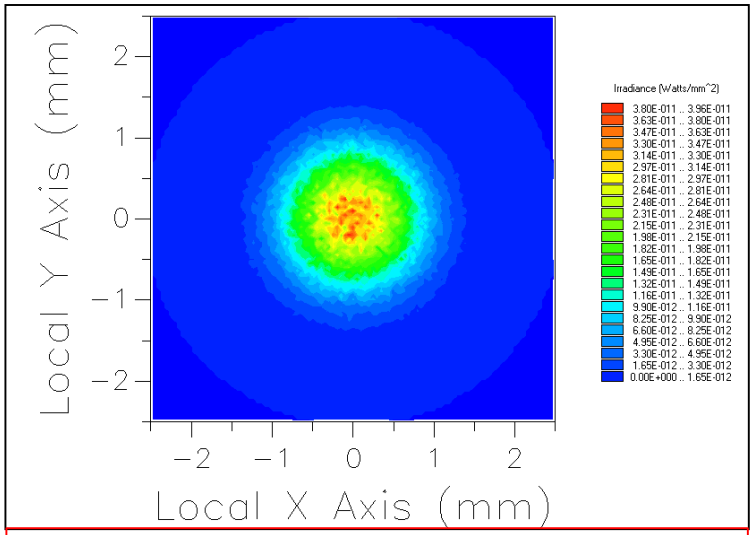
Applications:

- Flagship gravitational-wave missions (eLISA)
- Laser ranging; precision metrology applications
- Laser communications

Scattered Light Analysis



Pupil Plane Scatter Irradiance



Mirror	RMS surface roughness (Å)	MIL-STD 1246D CL
M1	15	300
M2	15	200
M3	5	200
M4	5	200

Conflicting accounts of on-orbit levels

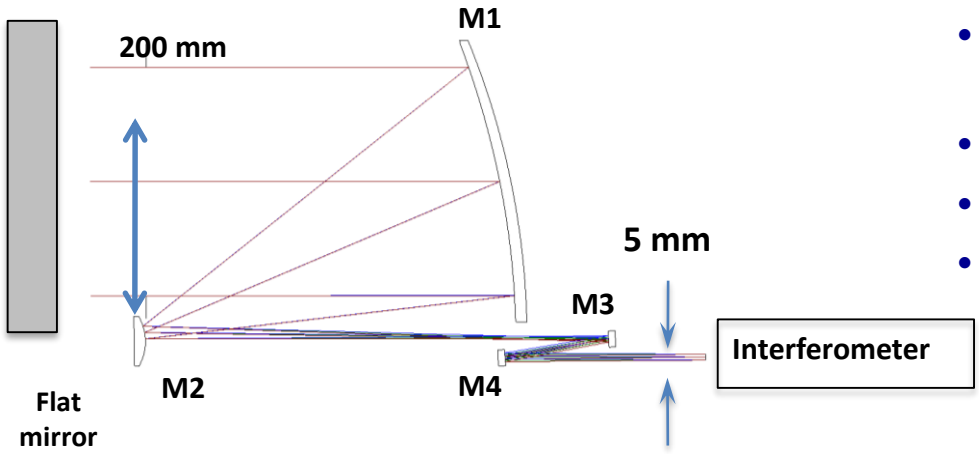
- Source power = 1W
- Total power on the detector = 6.6×10^{-11} W → (barely) meets specification of less than 10^{-10}

mirror	Path#	# Rays	Power %	Power	1st scatter surface
3	7	2291695	74.947	4.9421e-11	.20140417_elisa_baseline.M3.Front
4	3	2711030	23.053	1.5201e-11	.20140417_elisa_baseline.M4.Front
2	11	2565386	1.9733	1.3012e-12	.20140417_elisa_baseline.M2.Front
1	14	1399213	0.026184	1.7266e-14	.20140417_elisa_baseline.M1.Front
Totals		8967324	100	6.5941e-11	

M3 and M4 contribute most of the scattered light on the detector

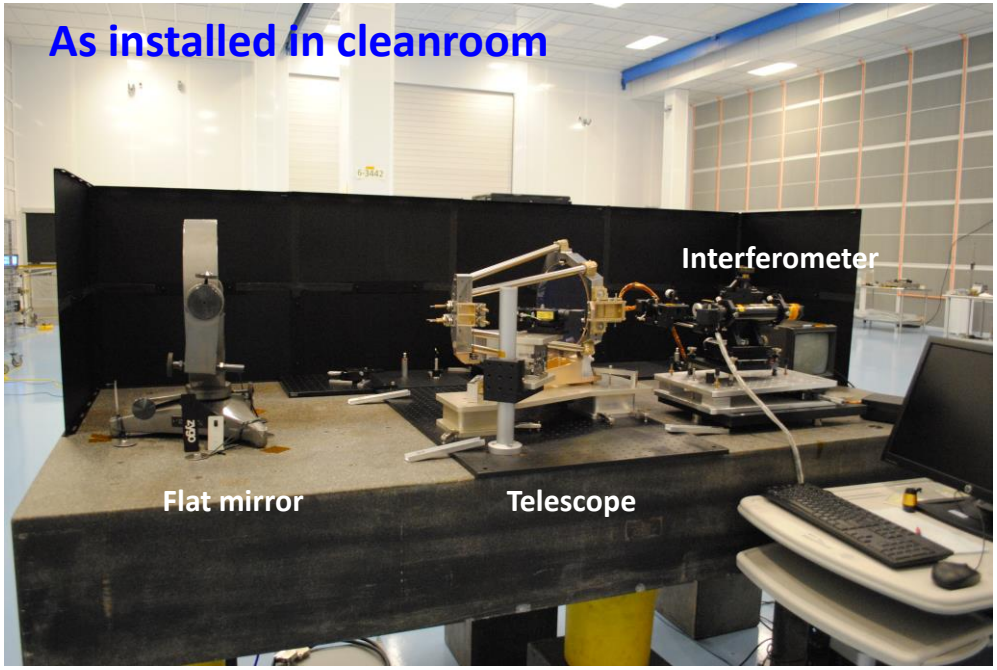
Optical Test Setup: Current Status

Optical Layout



- Telescope to be tested double-pass from the small aperture side
- Currently aligned to better than $\lambda/30$
- Room temperature operation only
- Seems to be stable under normal lab conditions

As installed in cleanroom



- Currently installing 1064 nm laser and test equipment
- Verify the same alignment at 1064 nm as with 633 nm interferometer
- Next step is to start measuring scattering