REALTIME CURVATURE SENSING MONITOR

Using Heterodyne Detection

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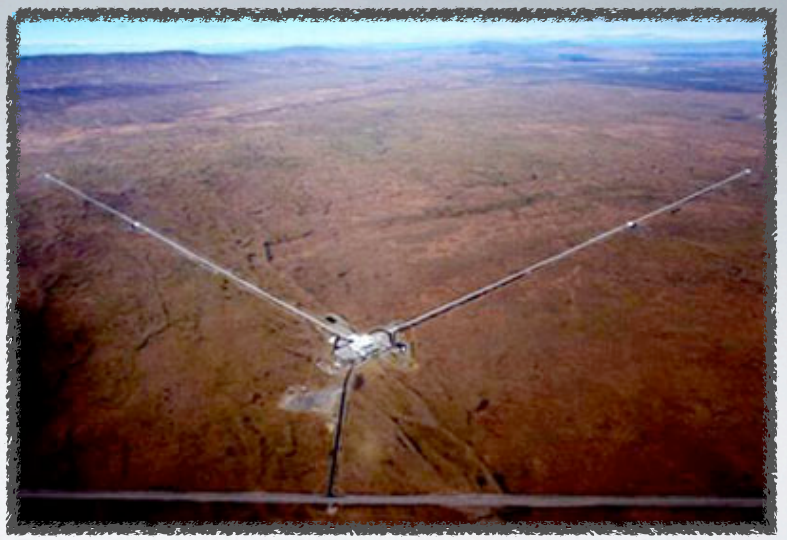
Peter Beyersdorf

OUTLINE

- Motivation
- System Design
- Review of Theory
- Current Status
- Alternate Geometries
- Future Work
- Contributors



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MOTIVATION

- Sensing thermoelastic deformation of the LIGO test mass mirrors allows the Thermal Compensation System to keep the shape of the mirrors close to design parameters.

- Realtime, in-situ curvature monitors are available, but only after the detector has acquired lock.

- Heterodyne detection methods can be used to monitor curvature of the test mass mirrors independent of lock state.

- Heterodyne curvature sensor can be integrated into optical levers currently in use.

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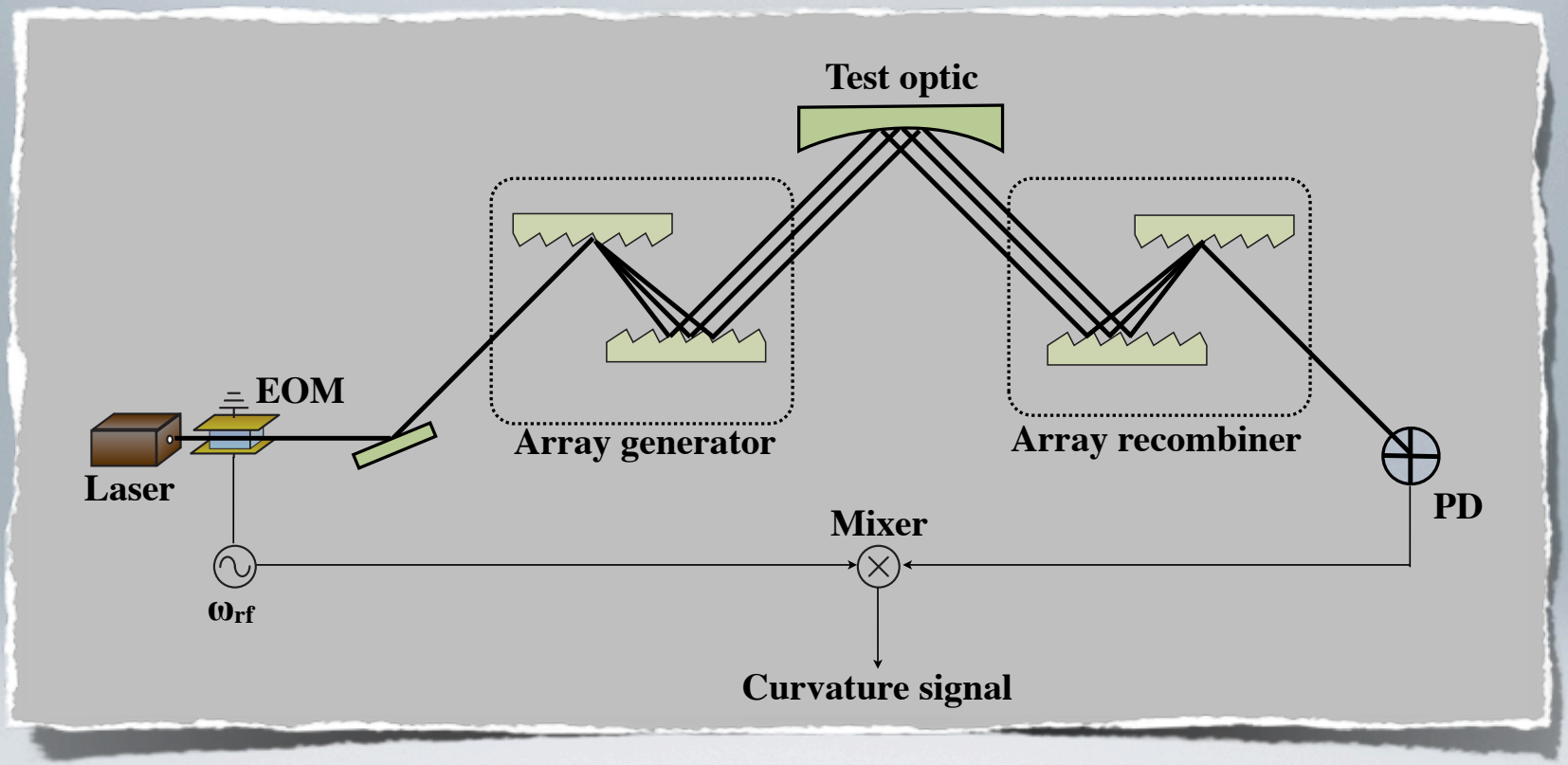
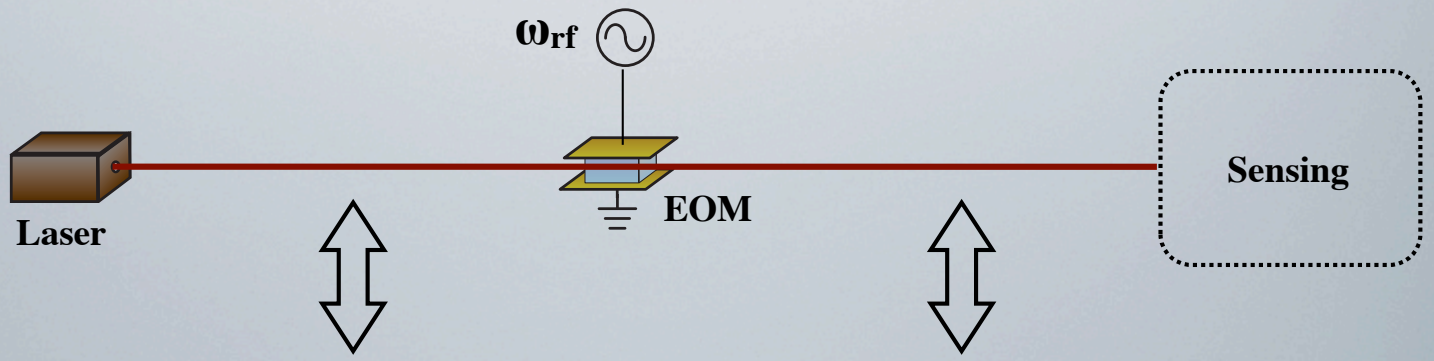
SYSTEM DESIGN

Overview



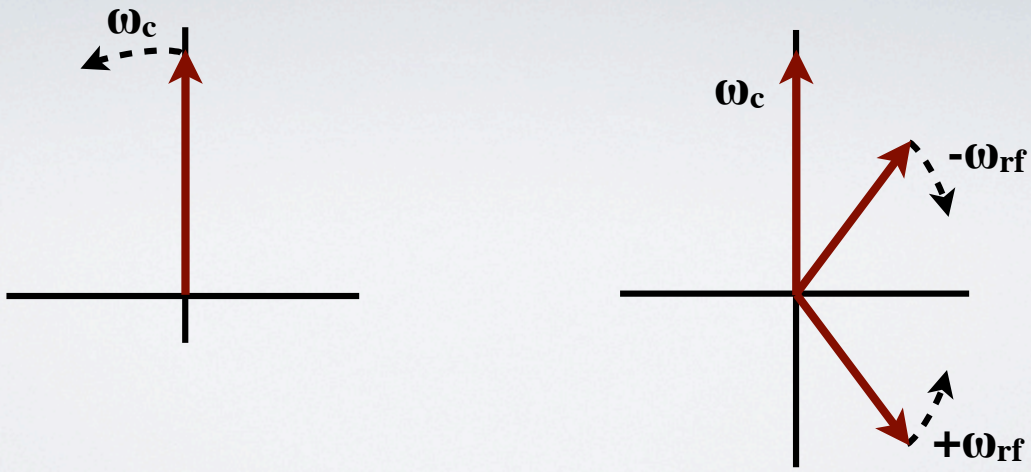
- Expect good common mode noise rejection
  - Phase noise from grating side motion will be common to all 3 beams.
- Calculations indicate a ~1% change in the initial curvature of a 10 km radius of curvature optic can be detected.

THEORY



Power Spectrum:

Phasors:



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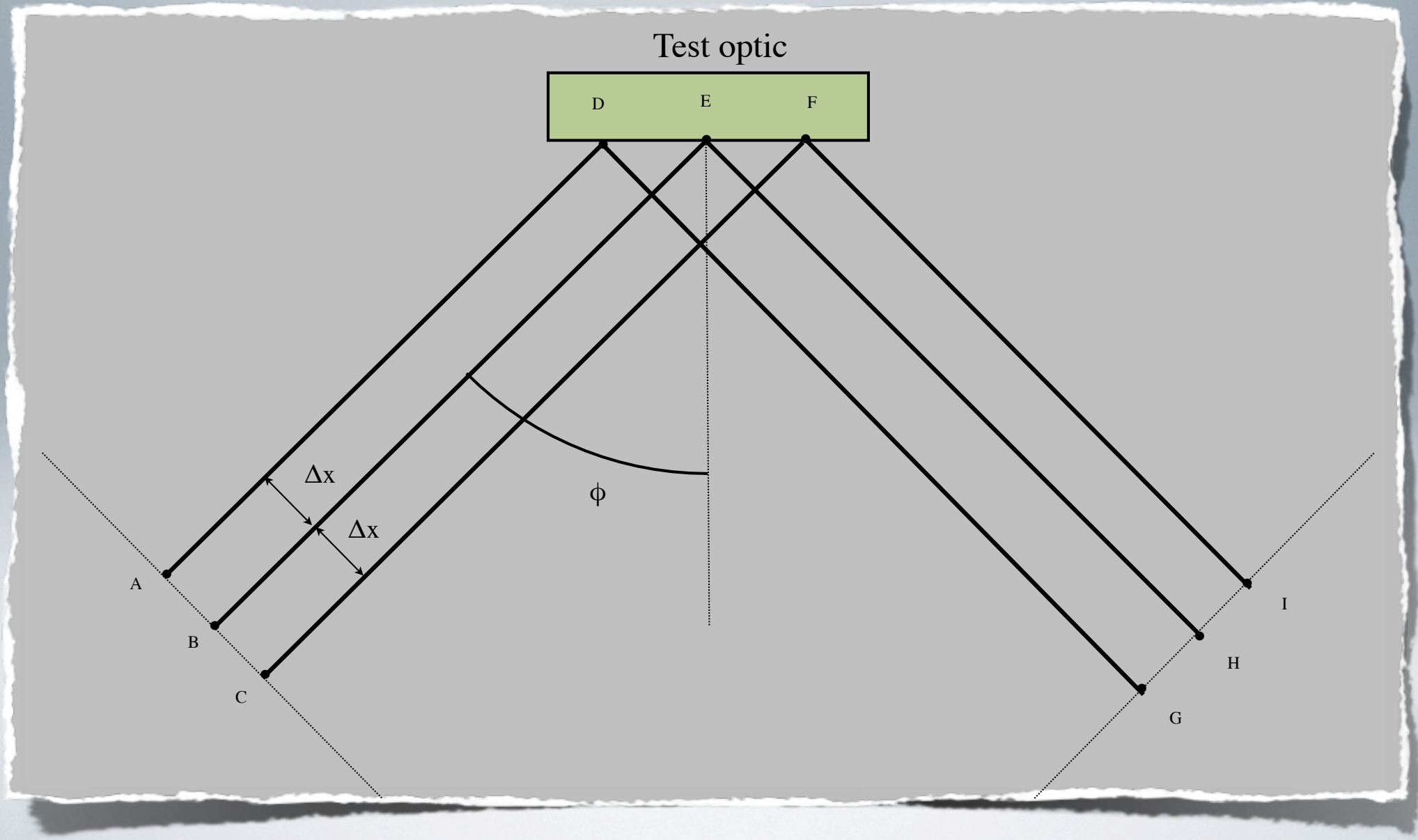
THEORY

Schematic - Test Optic



THEORY

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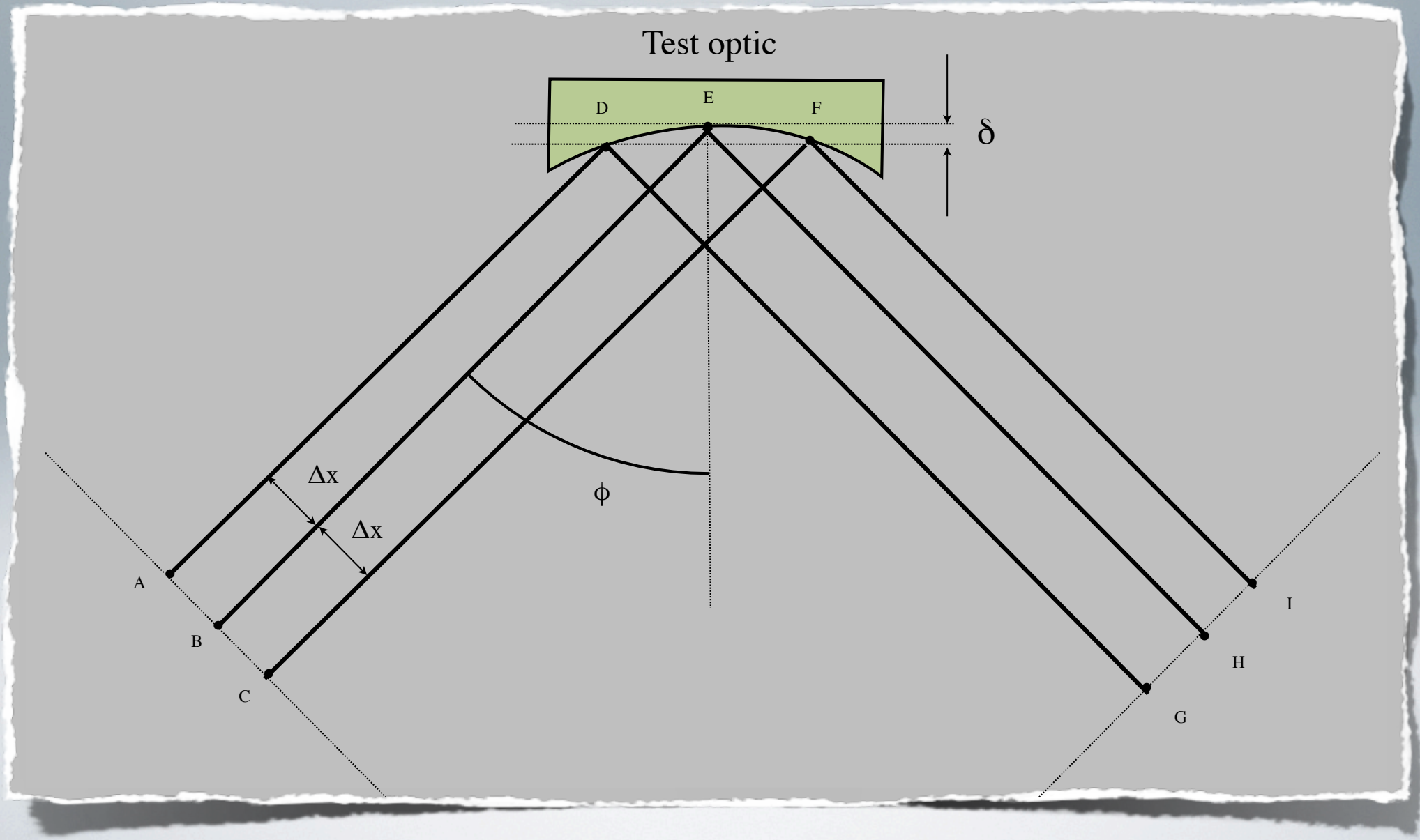
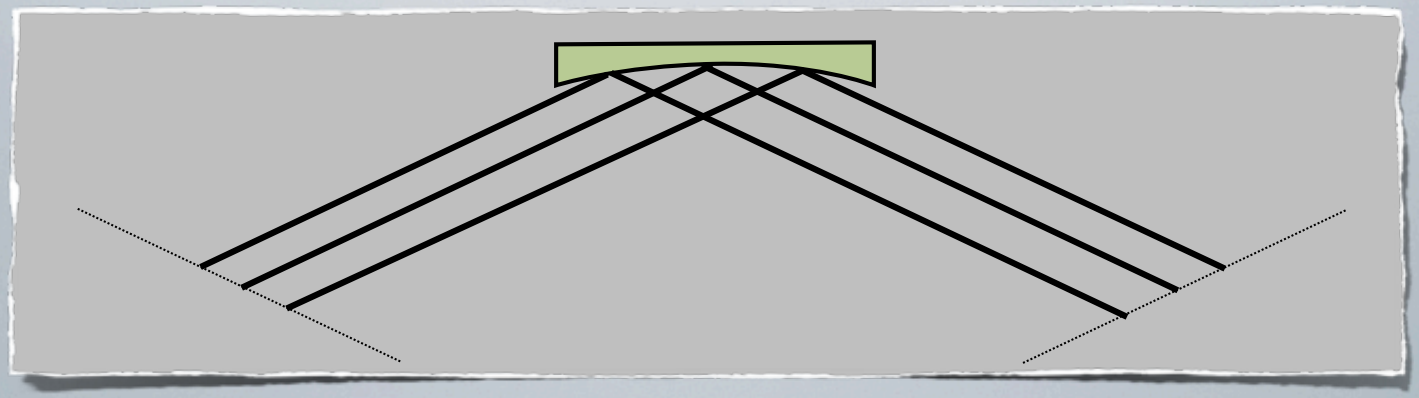
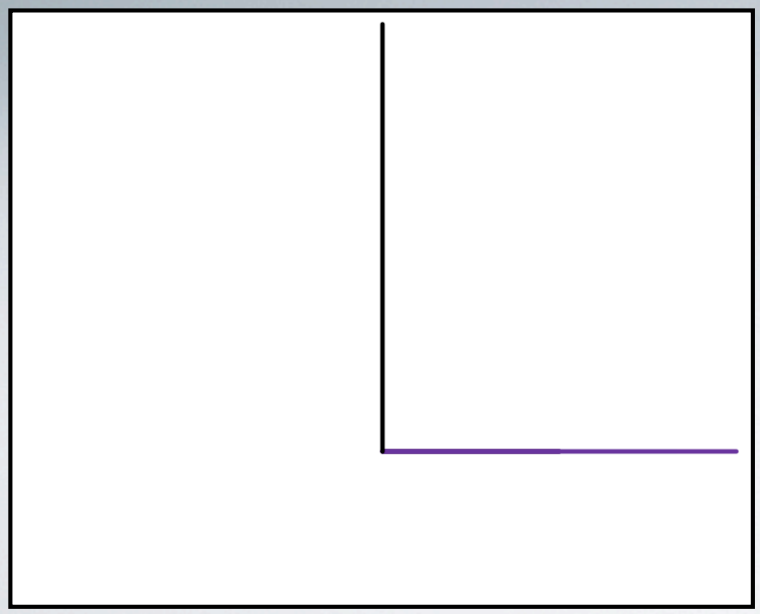


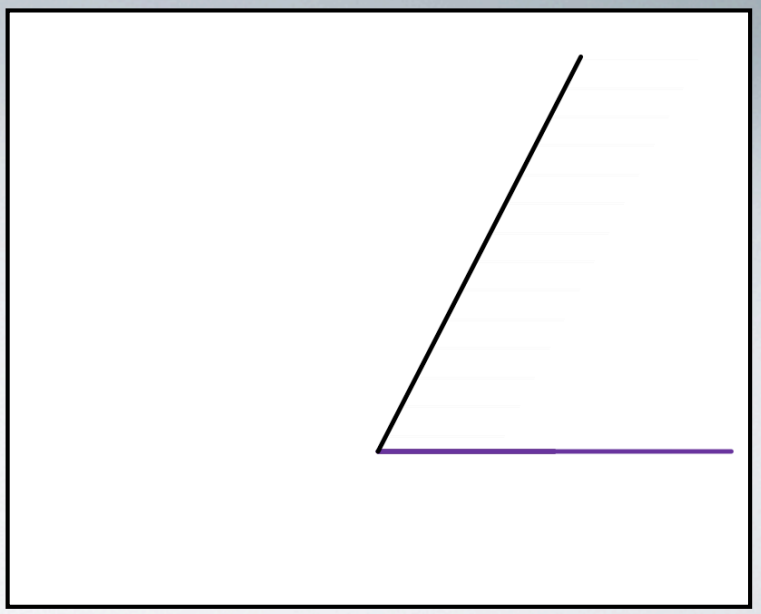
THEORY



Pure Phase Modulation



Slight Amplitude Modulation



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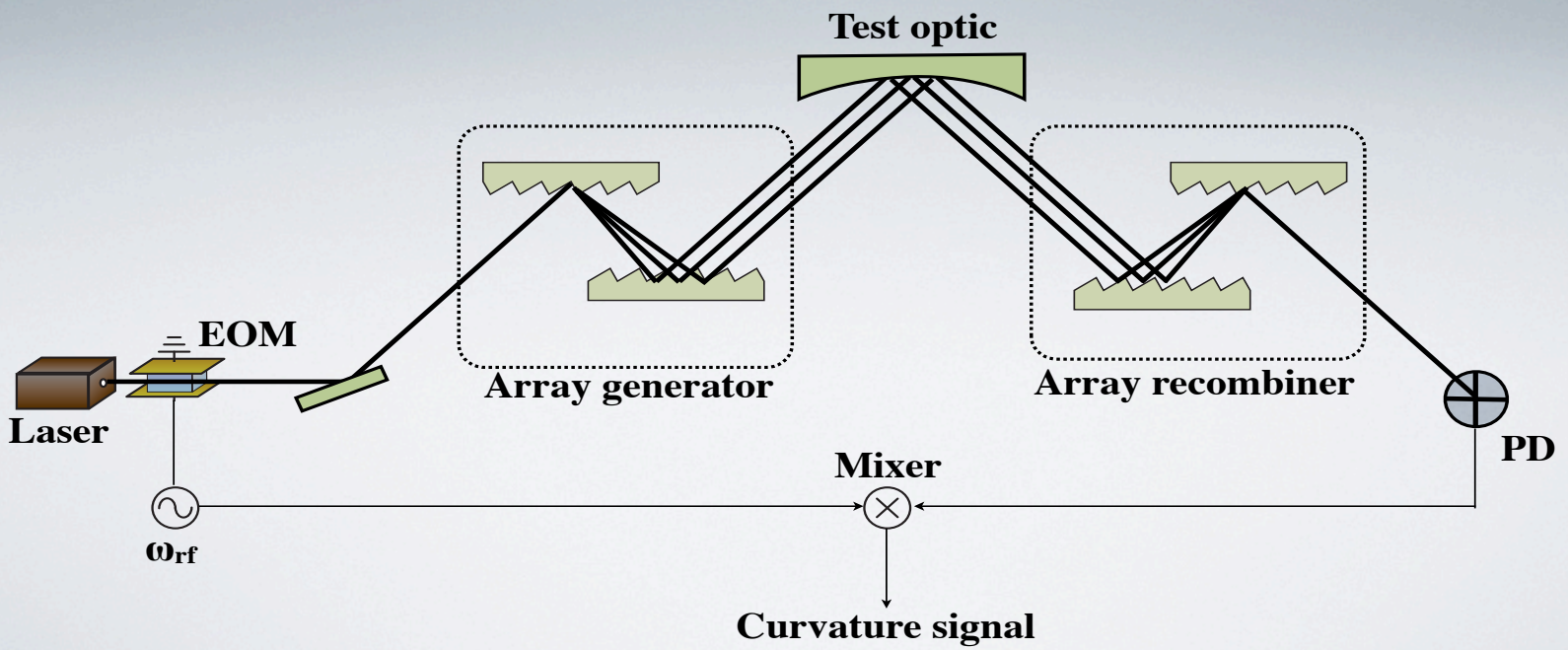
SYSTEM DESIGN

Specifications

- Laser: 632.8nm HeNe
- EOM: $LiNO_3$
- ω_{rf}: 1.8 GHz
- Gratings: 1,200/mm
- Detector: 2GHz, Si
- Test Optic: flat gold coated BK7 (back polished)



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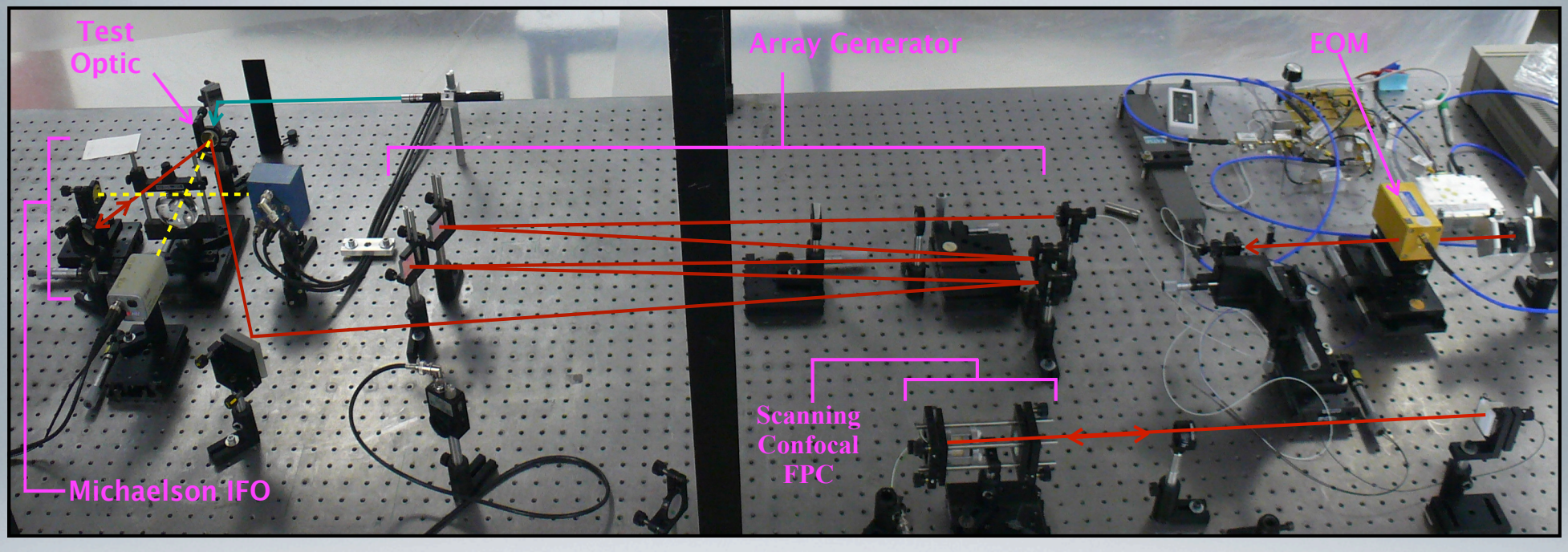
SYSTEM DESIGN

Optical Bench Layout



- Current configuration retro-reflects curvature beam back through test optic and array generator.
  - 2x pass test optic so that array generator & recombiner are identical

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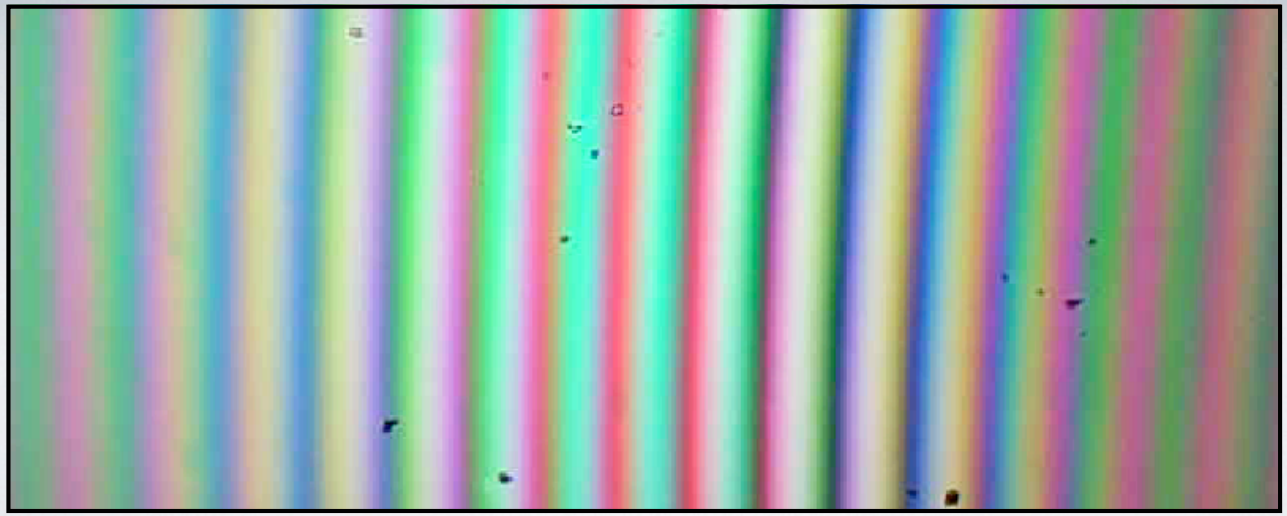
SYSTEM DESIGN

Calibration

- White light Michaelson interferometer to independently verify and calibrate measurements.
  - RGB LED as light source for interferograms
  - Multiple wavelength source means height is determined unambiguously



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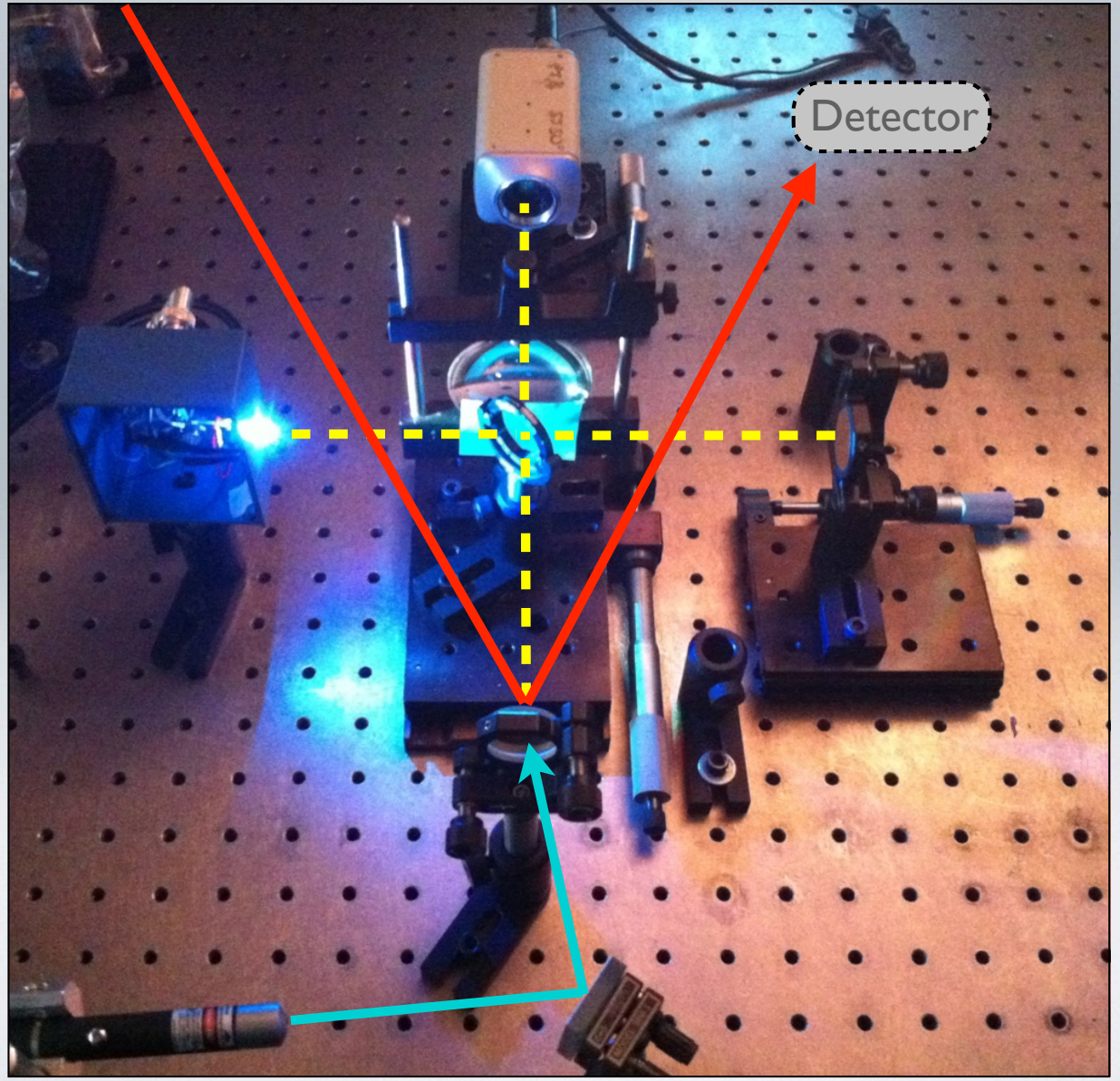
SYSTEM DESIGN

White Light Interferometer



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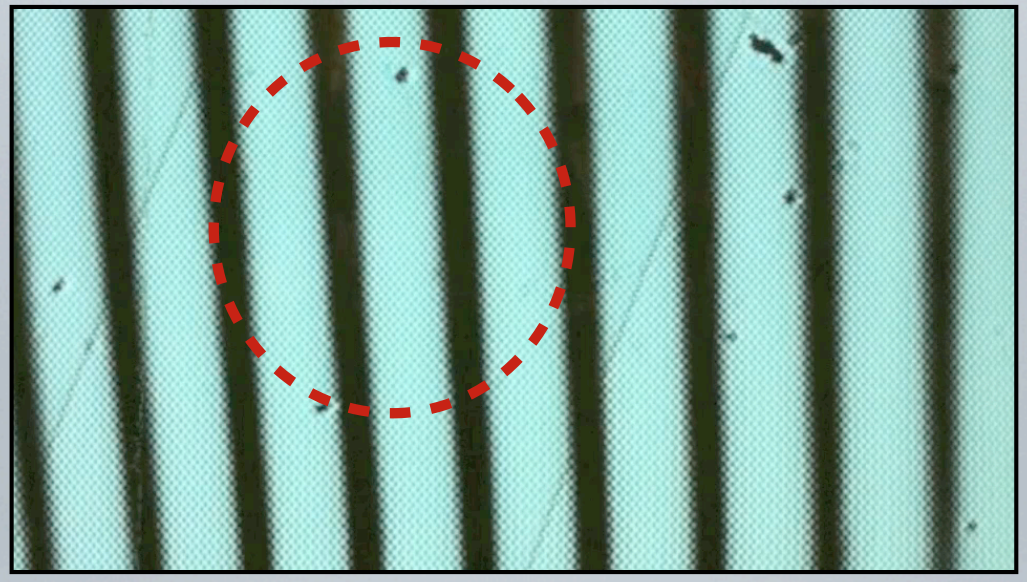
SYSTEM DESIGN

Thermal Deformation



- Test optic made from flat BK7 substrate with gold coating.
- Violet laser pointer (100mW, 405nm) illuminates test optic from back.
- Gold coating strongly absorbs 405nm light, causing a thermal deformation on the surface of the test optic
- Deformation visible in interferogram

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CURRENT STATUS

- Complete:
  - ✓White light interferometer
  - ✓Thermal deformation
  - ✓Assembly of Electronics (RF, DC)
  - ✓Successful 1.8 GHz EOM operation
  - ✓Scanning confocal Fabry-Perot cavity to characterize sidebands
  - ✓Matlab code to analyze interferograms
  - ✓Assembly of array generator and recombiner

- In Progress:
  - Matlab code to automate capturing interferograms
  - Debug demodulation electronics
  - Collect data

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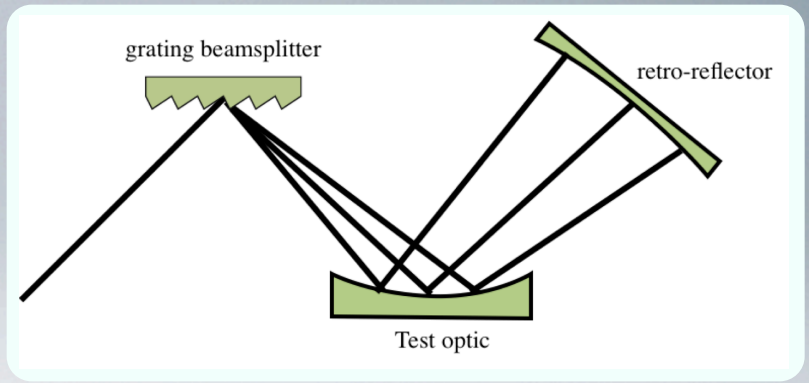
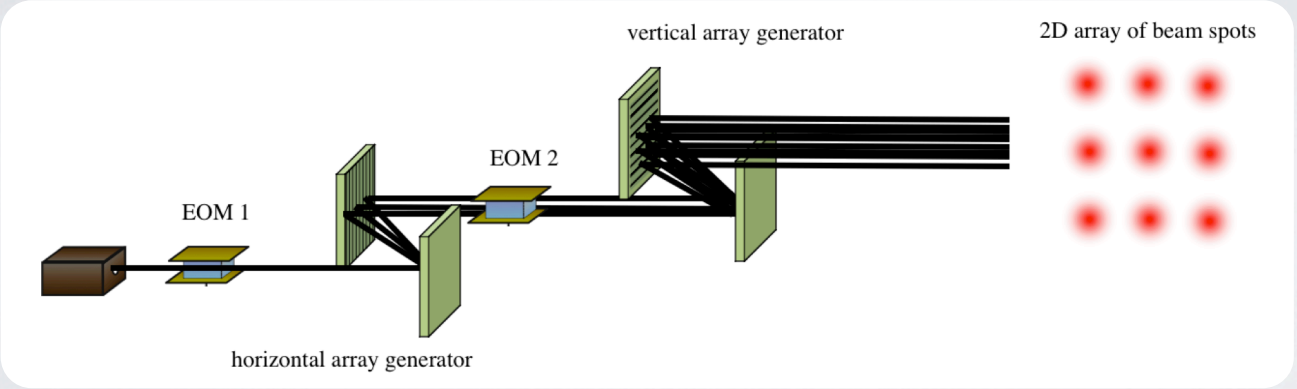
ALTERNATE GEOMETRIES

- One grating + Retro Reflector
- Two array generators oriented perpendicularly to each other with 2 EOMs yield 2D array
- Use laser diode as light source:
  - Changing λ can be used to scan position on mirror





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FUTURE WORK

- NSF's East Asian and Pacific Summer Institutes grant.
  - International research abroad for grad students
  - Advanced testing at High Optical Power Test Facility in Gingin, Australia
  - Test system on optics comparable to aLIGO and future GW detectors

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CONTRIBUTORS

- Funding provided by NSF
  - Dr. Peter Beyersdorf, Principle Investigator
  - Mark Cordier, Graduate Student
  - Forest Miles, (former) Undergrad Student

- Additional funding provided by NSF REU program
  - Cynthia Vazquez, summer internship
  - Jesus DeHaro, summer internship

SUMMARY

- Realtime, in-situ curvature monitoring for TCS, independent of lock state.
- Curvature converts pure phase modulation to slight amplitude modulation.
- Good common mode noise rejection.
- Other geometries can probe more of the mirror surface if desired.
- Much work remains, stay tuned.

THANK YOU

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