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The ST7 Interferometric Displacement Sensor
- a progress report -

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ST7 Interferometer people

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Acknowledgement

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Disturbance Reduction System

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- Technology validation of sensor and thrust-producing technologies to control a space vehicles flight path so the payload responds only to gravitational forces.

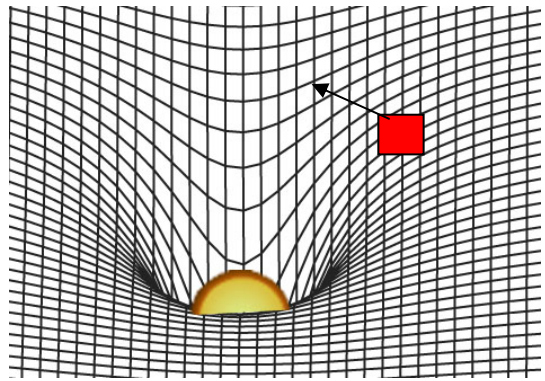
Sensor: Stanford University, Stanford, CA

Thruster: Busek Company Inc. Natick, Mass.

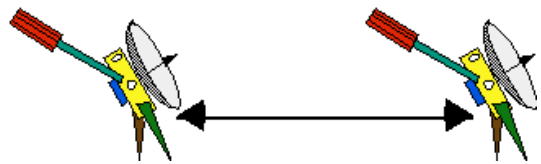
- Launch 2006 as NASA's Space Technology 7 project (ST7)
  - Piggy-backing on ESA's SMART-2 Mission

ST7 Technology Objectives

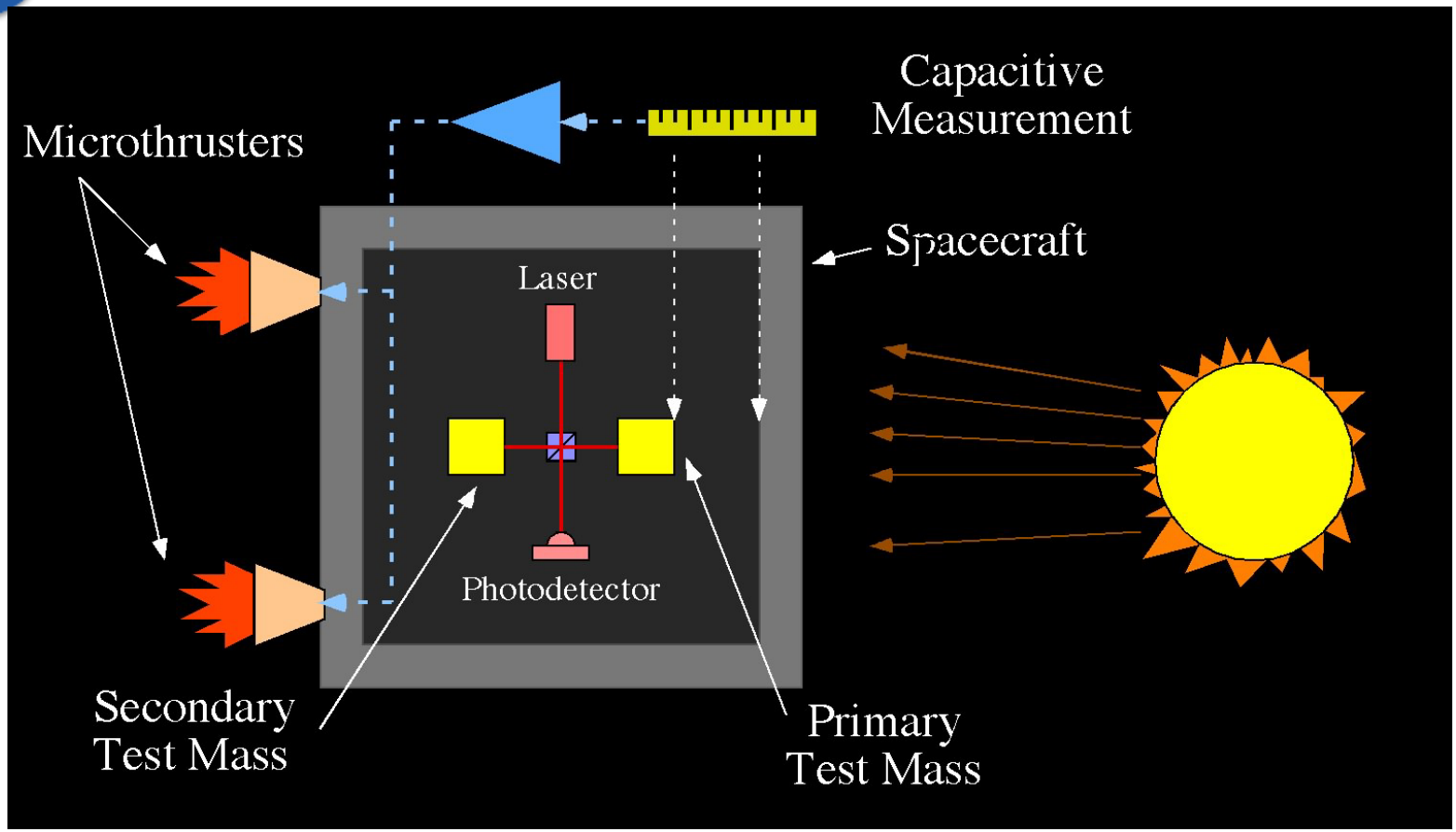
- Validate that a test mass follows a trajectory determined by gravitational forces only within $3x10^{-14}$ $m/s^2/\sqrt{Hz}$
  - Low acceleration noise is needed for study of general relativity, planetary gravity, gravitational waves



- Validate spacecraft position control to an accuracy of <10 $nm/\sqrt{Hz}$
  - Spacecraft position control is required for separated-spacecraft interferometers which do not use internal delay lines



ST7 Concept



- The DRS instrument package consists of
  - Two gravitational reference sensors
  - Microthrusters for spacecraft position control
  - Interferometer to measure the distance between the two test masses.

Required DRS Performance

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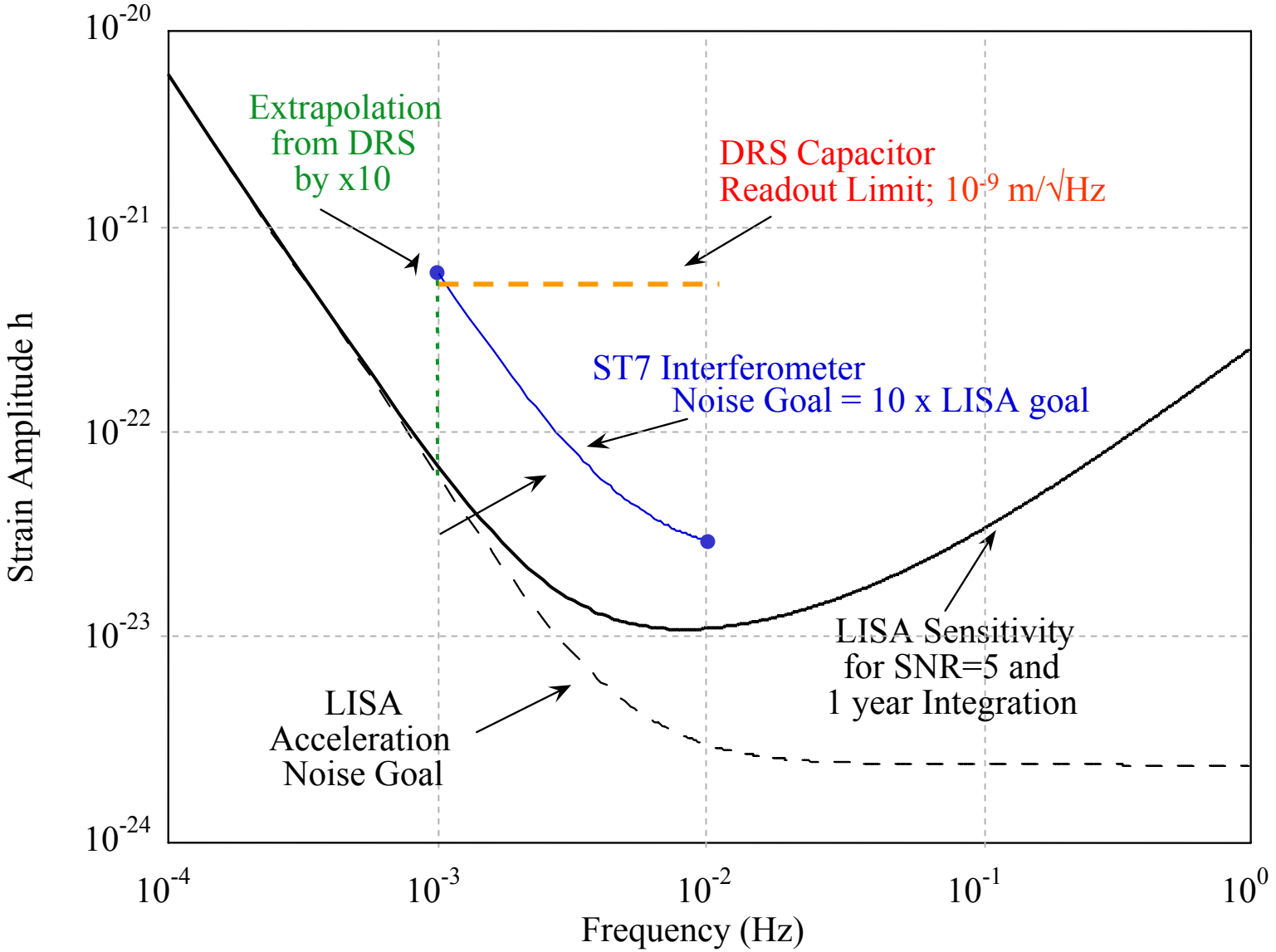
- LISA requirement @ 1 mHz: $3*10^{-15}$ m/s^2/√Hz
- ST7 goal @ 1 mHz: $3*10^{-14}$ m/s^2/√Hz
- Proof mass sensor noise: 1 nm/√Hz
- Interferometer noise requirement : 280 pm/√Hz @ 1 mHz
  (1/3 of error budget)

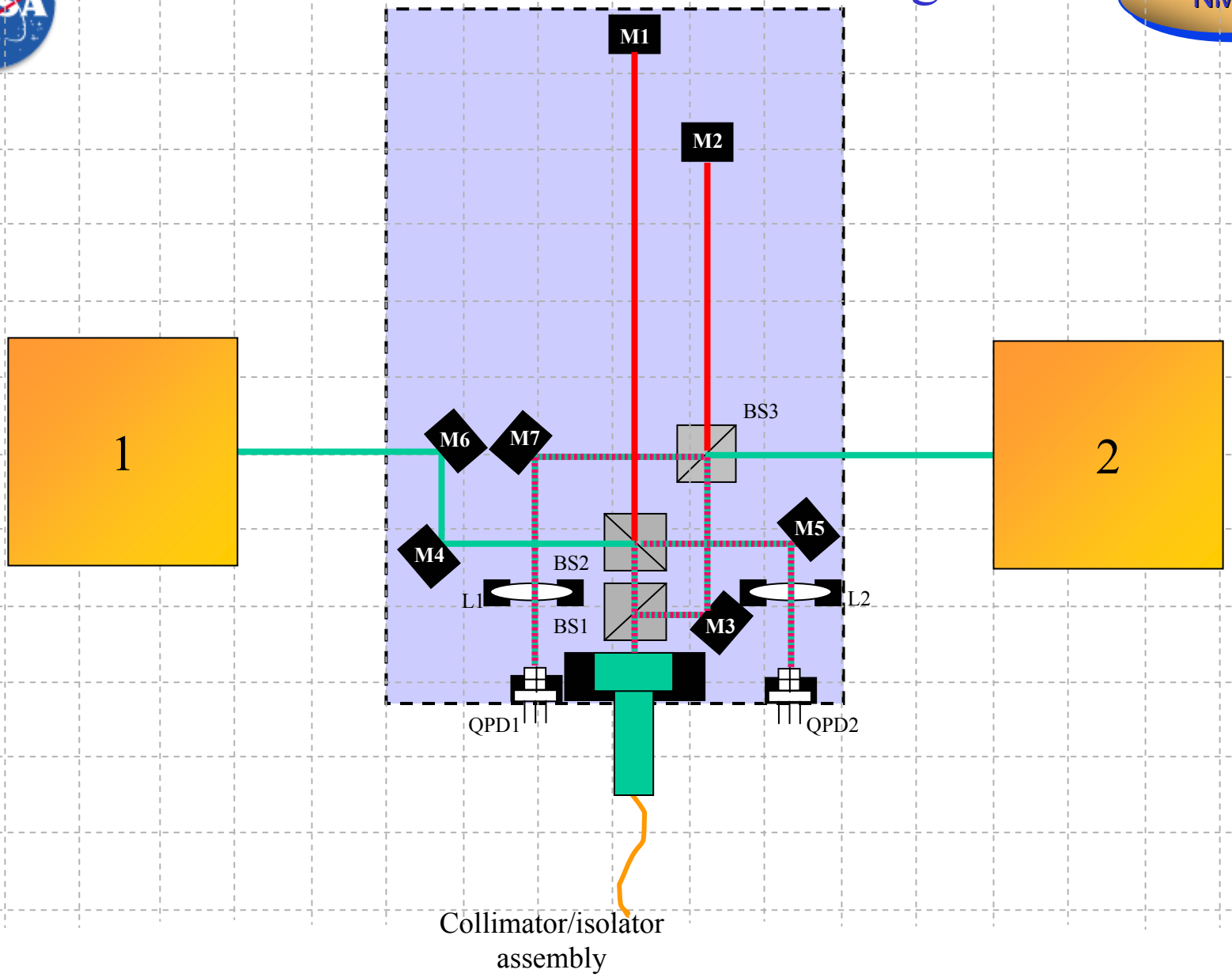
- LISA requirement @ 10 mHz: $1.5*10^{-14}$ m/s^2/√Hz
- ST7 goal @ 10 mHz: $1.5*10^{-13}$ m/s^2/√Hz
- Interferometer noise requirement: 30 pm/√Hz @ 10 mHz
  (1/3 of error budget)

- $a = (2\pi f)^2 * 5*10^{-10}$ m/√Hz ~ $2 * 10^{-14}$ m/s^2/√Hz @ 1 mHz
- $a = (2\pi f)^2 * 1*10^{-9}$ m/√Hz ~ $4 * 10^{-14}$ m/s^2/√Hz @ 1 mHz
- $4 * 10^{-12}$ m/s^2/√Hz @ 10 mHz)
- $a = (2\pi f)^2 * 5*10^{-11}$ m/√Hz ~ $2 * 10^{-13}$ m/s^2/√Hz @ 10 mHz

DRS Performance Limits



Interferometer Baseline Design



Laser Frequency Noise

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- Flight laser noise measured: ~1.5 MHz/√Hz @ 10 mHz
  ~7 MHz/√Hz @ 1 mHz
- Interferometer pathlength mismatch: $\Delta L \sim 0.5$ mm
- Laser noise -> path noise: $\tilde{x}(f) = \Delta L * \tilde{\nu}(f)/\nu_0$
  @ 10 mHz ~ 3 pm/√Hz
  @ 1 mHz ~ 12 pm/√Hz

Compare to:

- Interferometer noise req'd: 30 pm/√Hz @ 10 mHz
- Interferometer noise req'd: 280 pm/√Hz @ 1 mHz

Laser frequency noise

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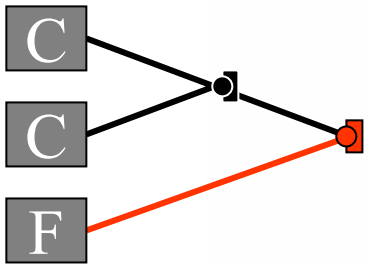
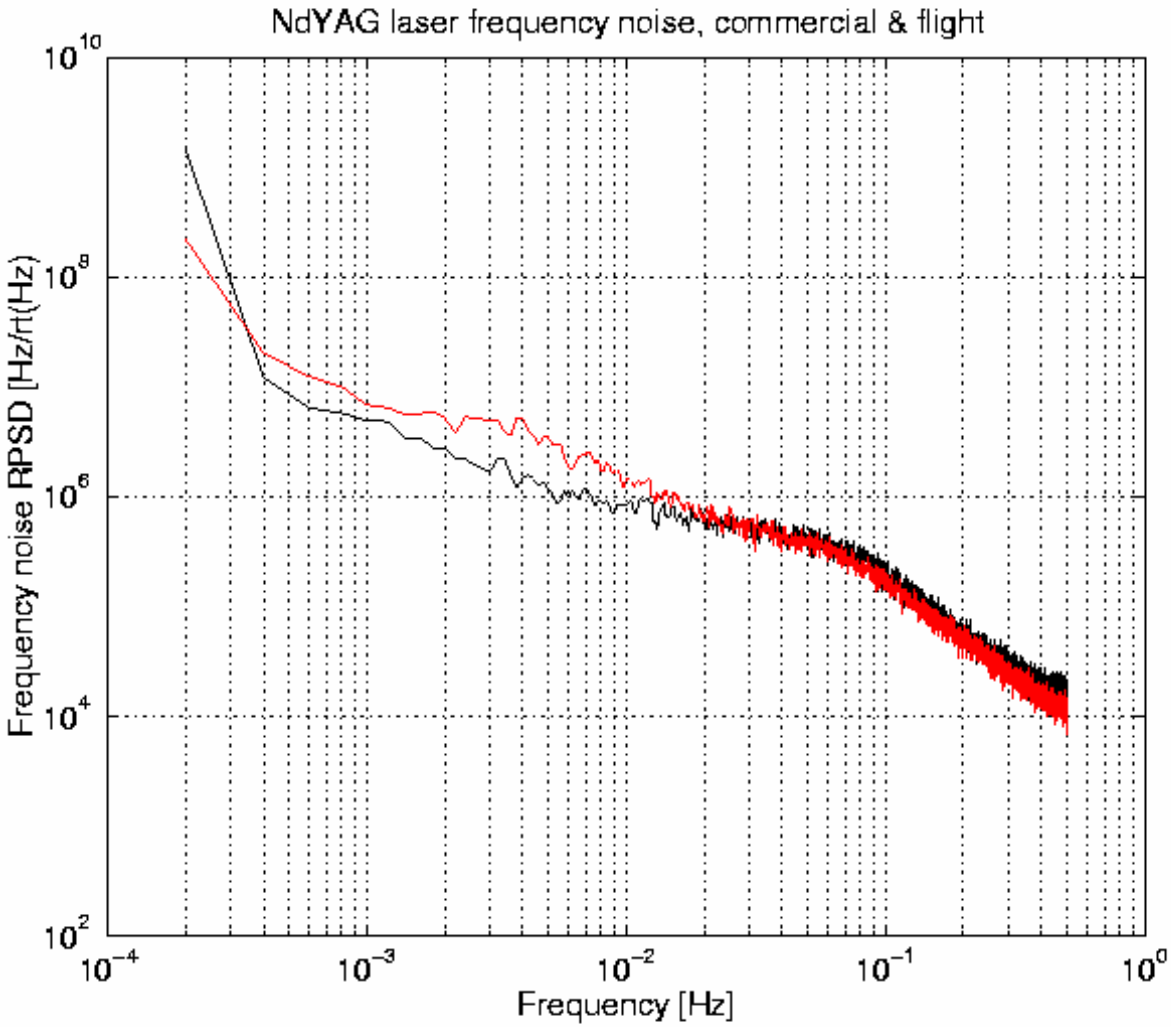
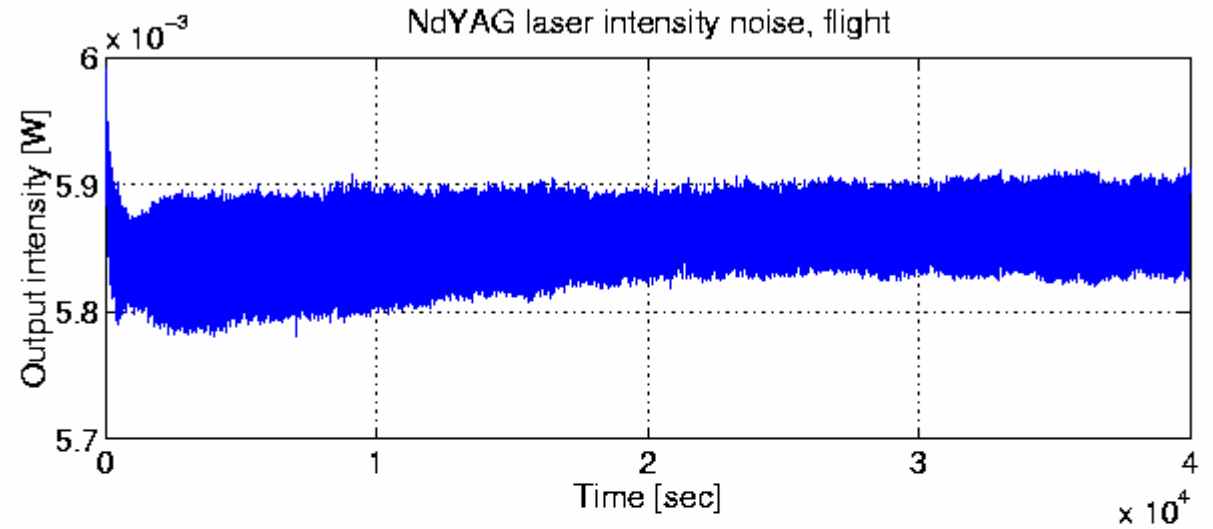
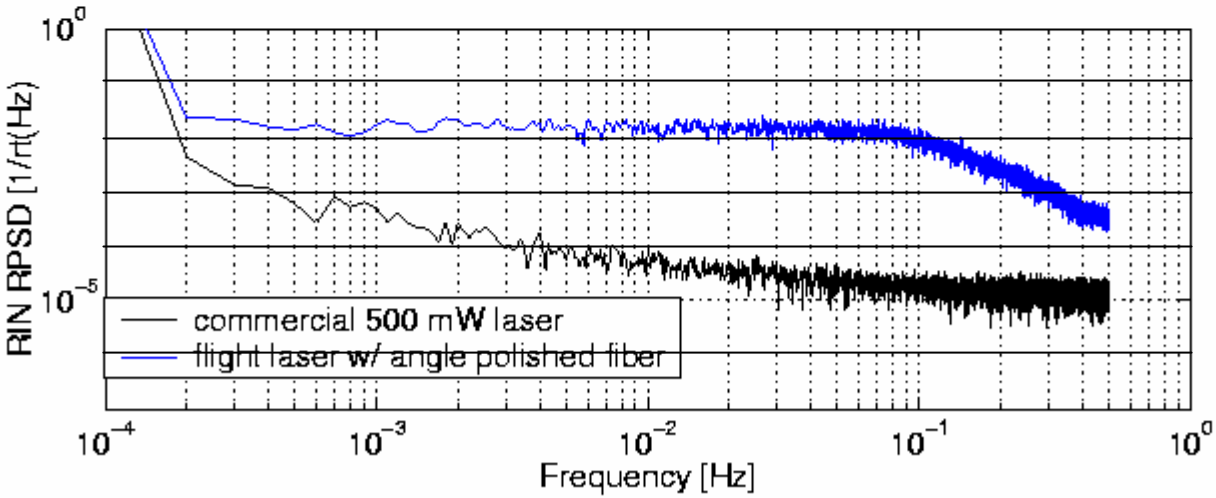


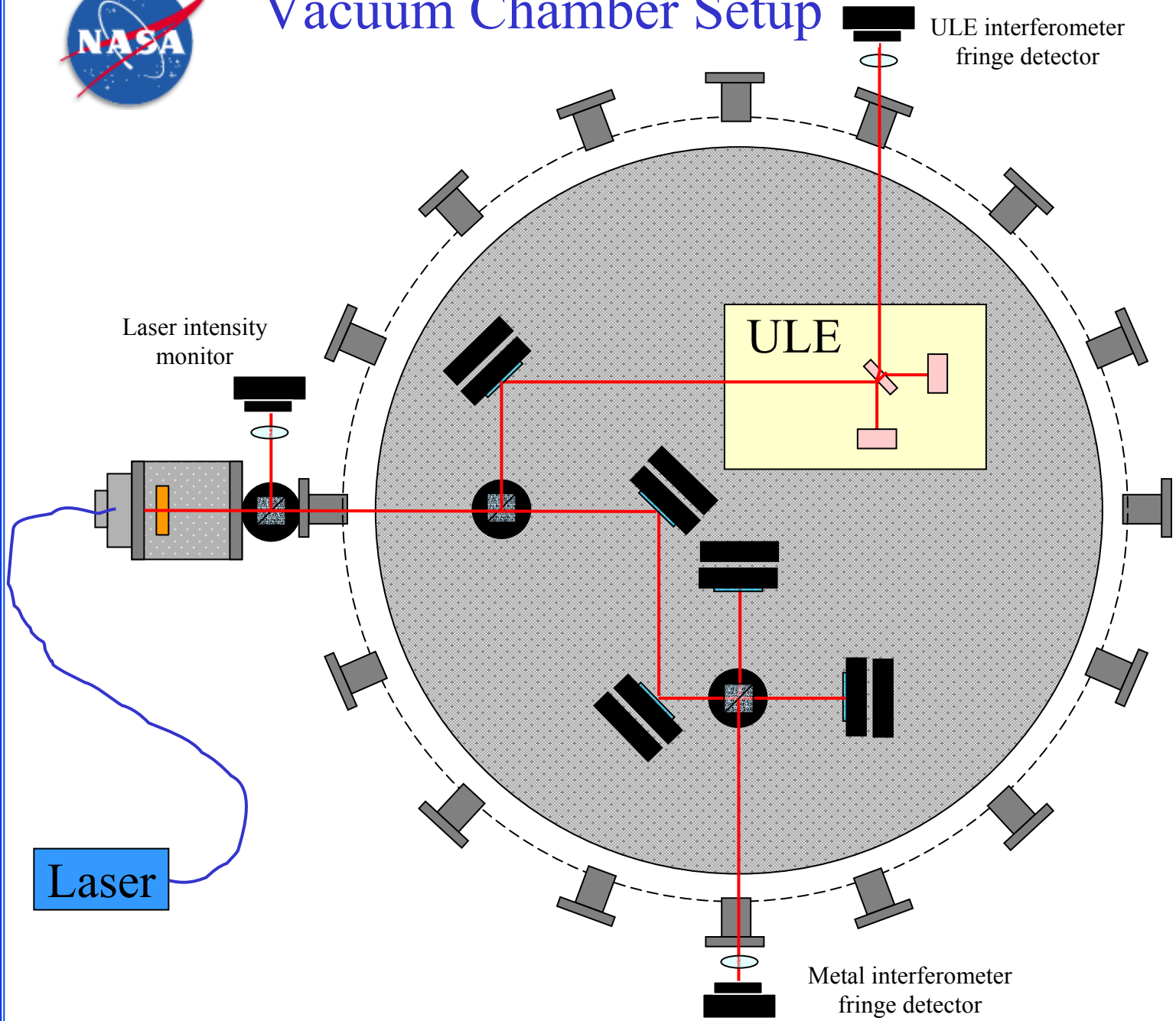


Laser intensity noise





Vacuum Chamber Setup



Interferometer Results