The ST7 Interferometric Displacement Sensor
- a progress report -

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ST7 Interferometer people

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- Robert Spero
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- Rosemary Diaz
- Steve Azevedo
- A.K., Interferometer CogE

Acknowledgement

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Disturbance Reduction System

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

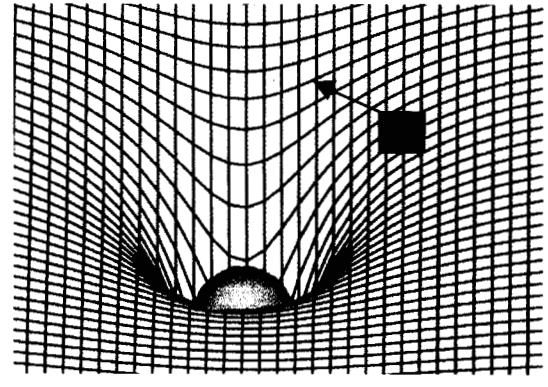
Sensor: Stanford University, Stanford, CA

Thruster: Busek Company Inc. Natick, Mass.

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

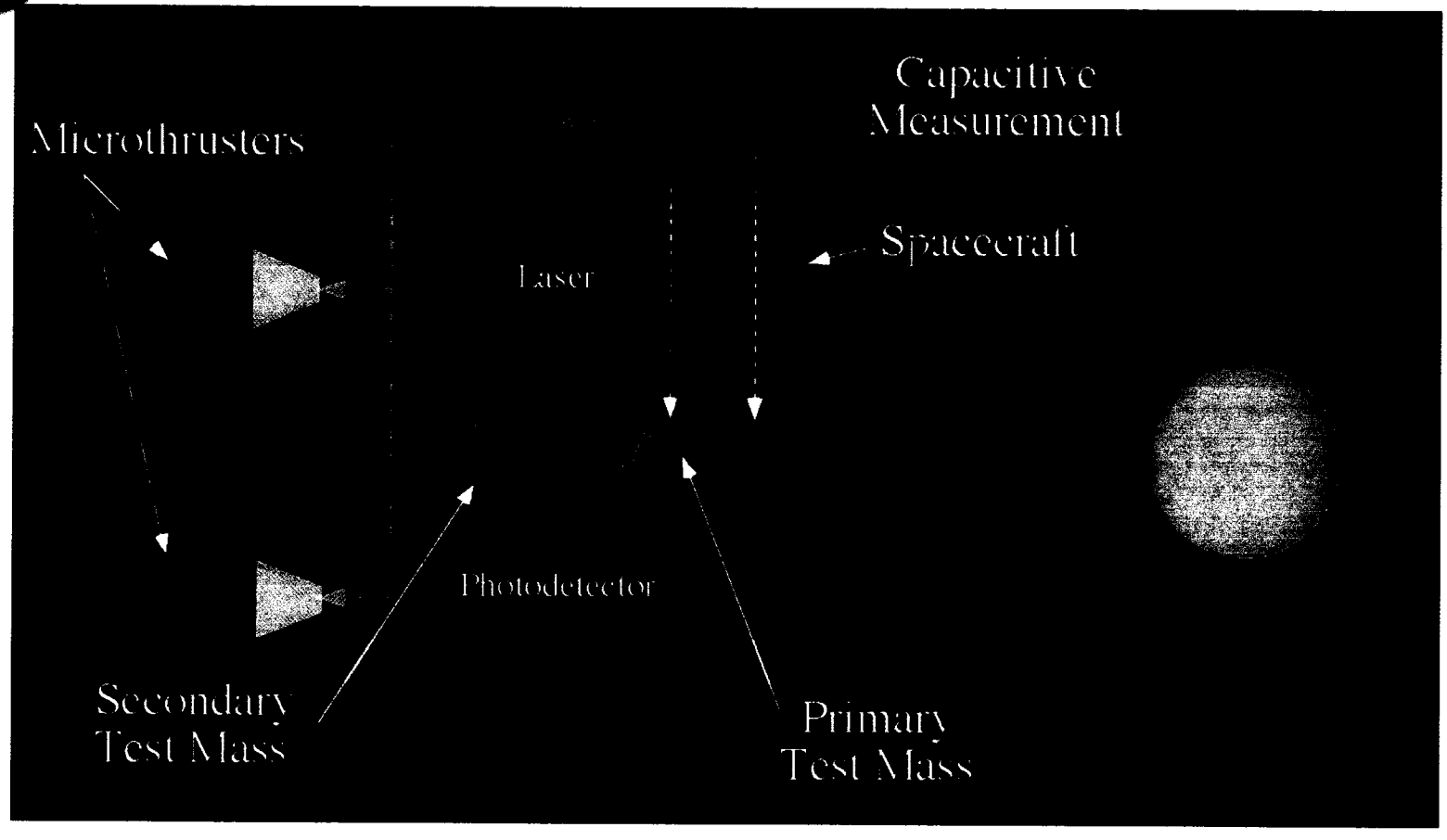
ST7 Technology Objectives

- Validate that a test mass follows a trajectory determined by gravitational forces only within 3×10^{-14} m/s^2/$\sqrt{\text{Hz}}$
  - Low acceleration noise is needed for study of general relativity, planetary gravity, gravitational waves



- Validate spacecraft position control to an accuracy of <10 nm/$\sqrt{\text{Hz}}$
  - 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.

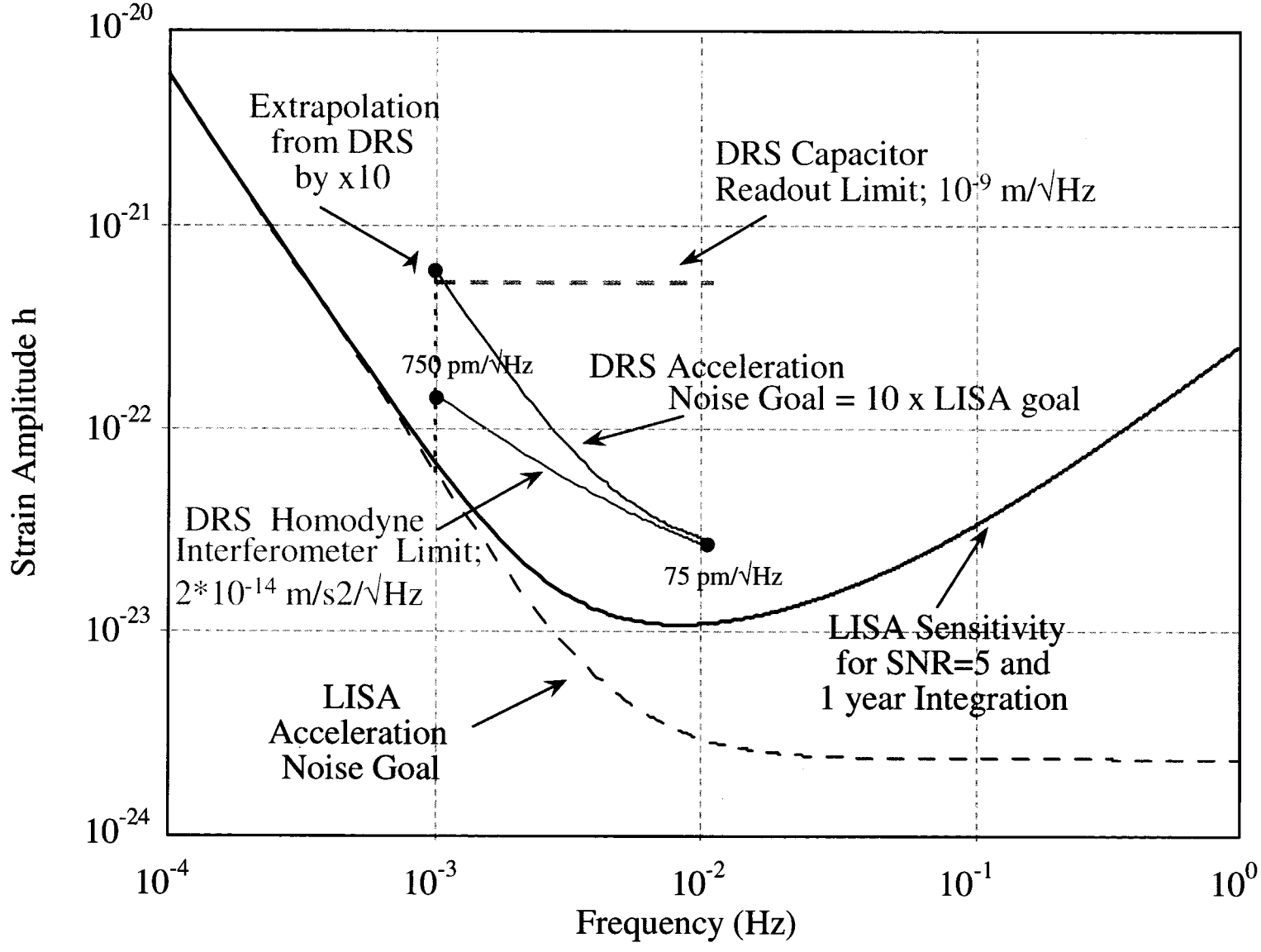
Required DRS Performance

- LISA requirement @ 1 mHz: $3*10^{-15}$ m/s^2/√Hz
- Proof mass sensor noise: 1 nm/√Hz
- Interferometer noise requirement : (1/3 of error budget) 250 pm/√Hz @ 1 mHz
- ST7 goal @ 1 mHz: $3*10^{-14}$ m/s^2/√Hz

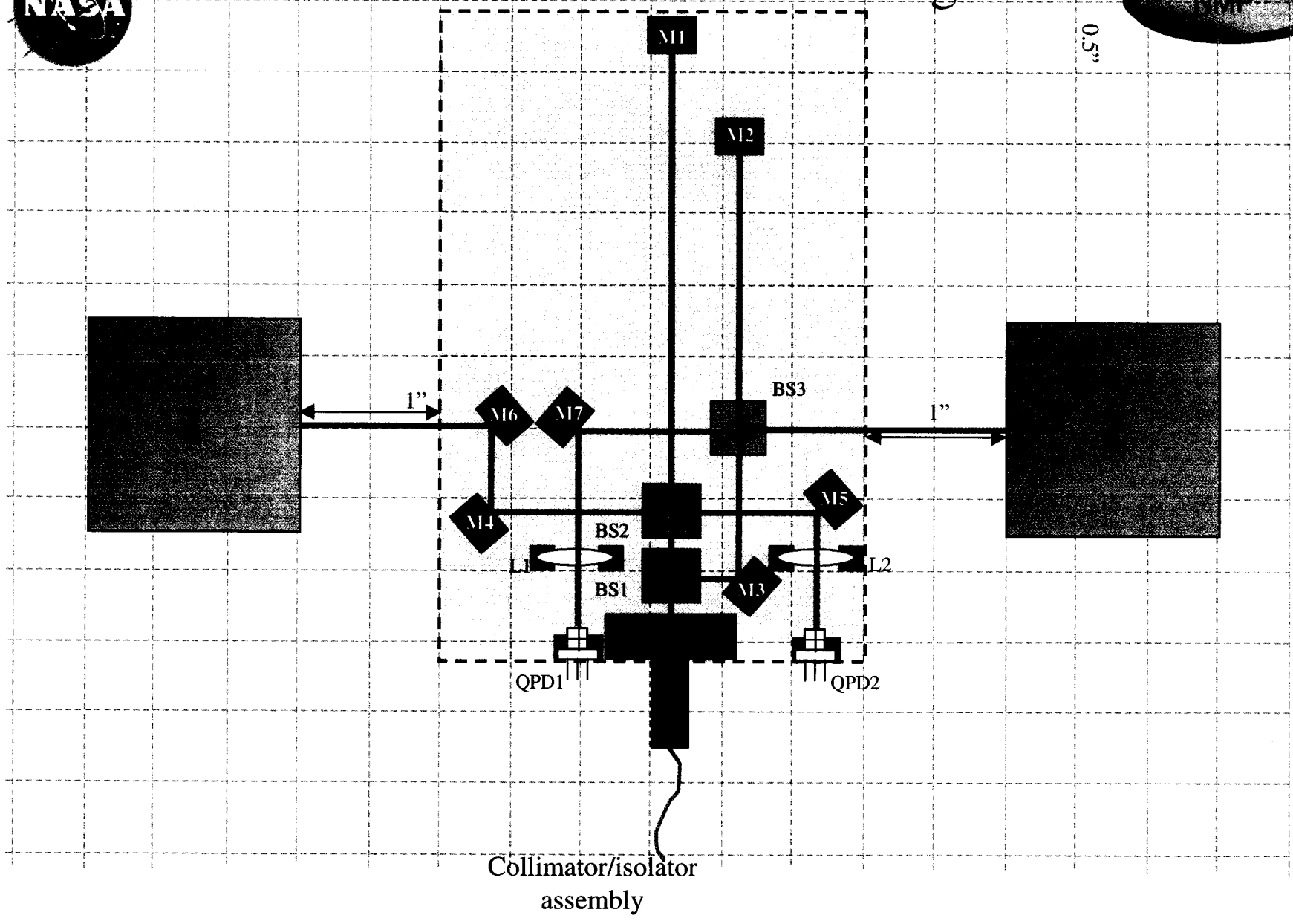
- LISA requirement @ 10 mHz: $1.5*10^{-14}$ m/s^2/√Hz
- Interferometer noise requirement: (1/3 of error budget) 25 pm/√Hz @ 10 mHz
- ST7 goal @ 10 mHz: $1.5*10^{-13}$ m/s^2/√Hz

- $a = (2\pi f)^2*5*10^{-10}$ 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 Requirements

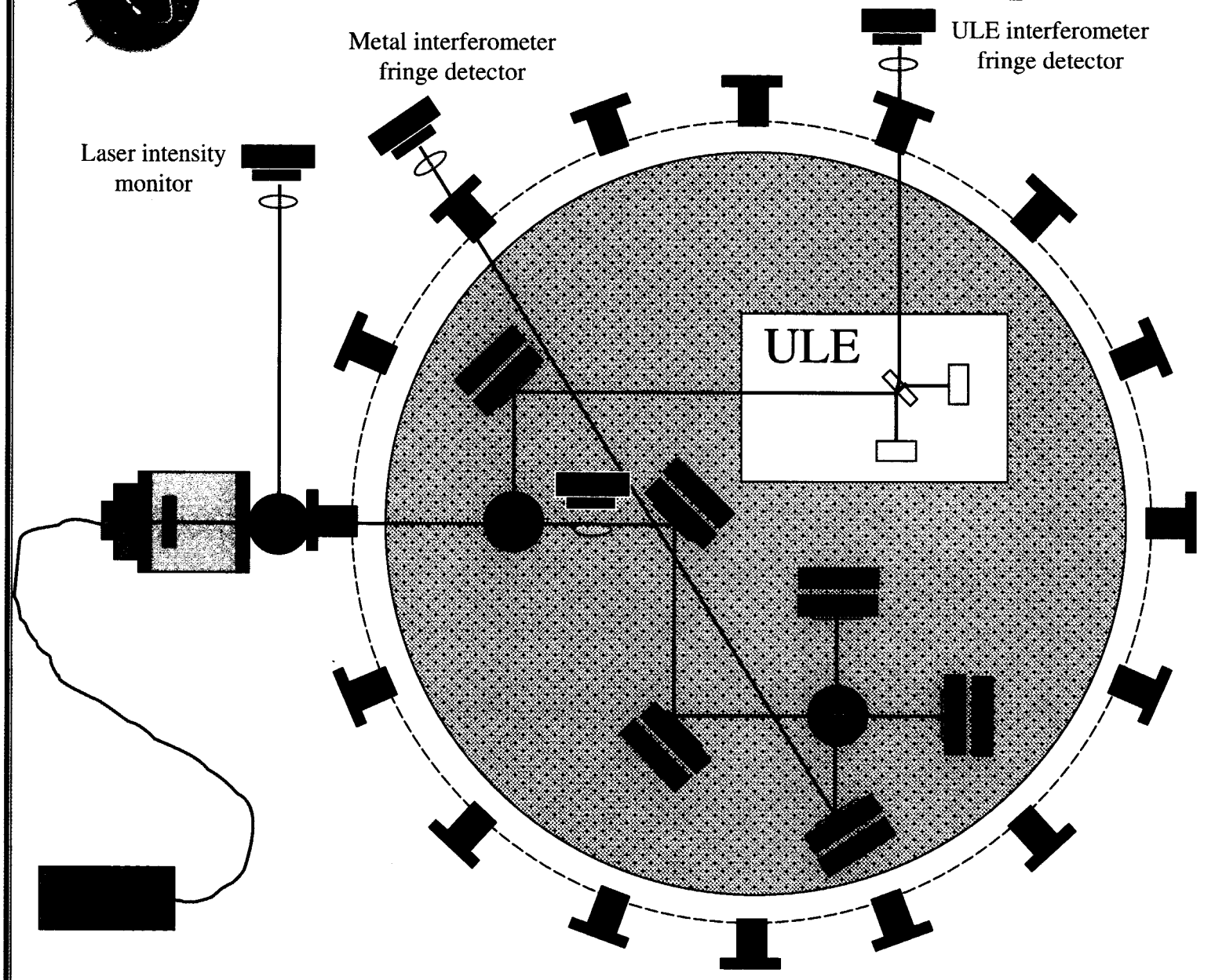
- Average unstabilized laser noise seen: ~5.5 MHz/√Hz @ 10 mHz
- ~30 MHz/√Hz @ 1 mHz
- Interferometer pathlength mismatch: $\Delta L < 1$ mm

- Laser noise -> path noise: $\Delta x = \Delta L * \Delta \nu / \nu$
  - @ 10 mHz < 20 pm/√Hz (avg.)
  - @ 1 mHz < 100 pm/√Hz (avg.)

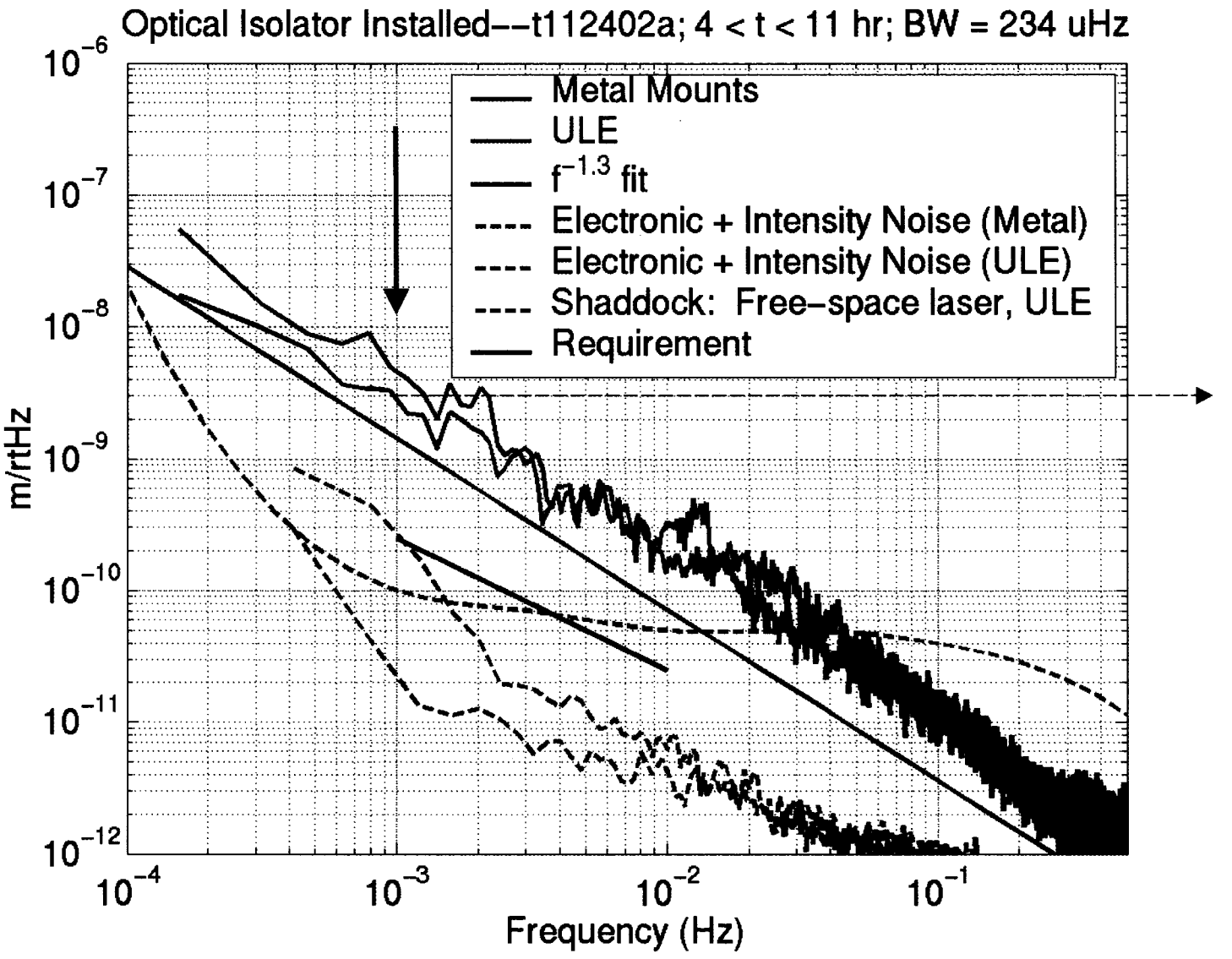
Compare to:

- Interferometer noise req'd: 25 pm/√Hz @ 10 mHz
- Interferometer noise req'd: 250 pm/√Hz @ 1 mHz

Vacuum Chamber Setup



Results


Optical Isolator Installed--t112402a; 4 < t < 11 hr; BW = 234 uHz
Metal Mounts
ULE
$f^{-1.3}$ fit
Electronic + Intensity Noise (Metal)
Electronic + Intensity Noise (ULE)
Shaddock: Free-space laser, ULE
Requirement
m/rtHz
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Frequency (Hz)