

Cryogenic behavior of LEDs for use in third generation LIGO position sensors and actuators

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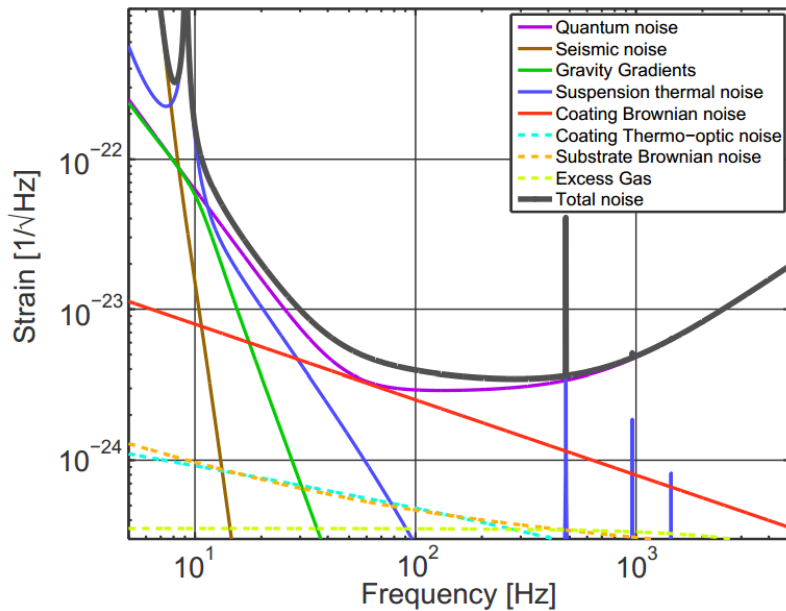
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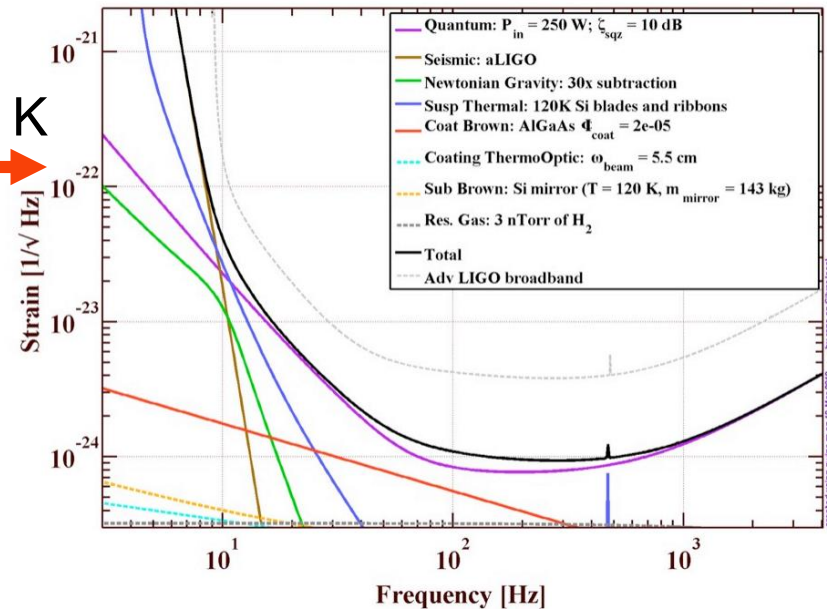


The case for cryogenics



LIGO Scientific Collaboration, Instrument Science White Paper

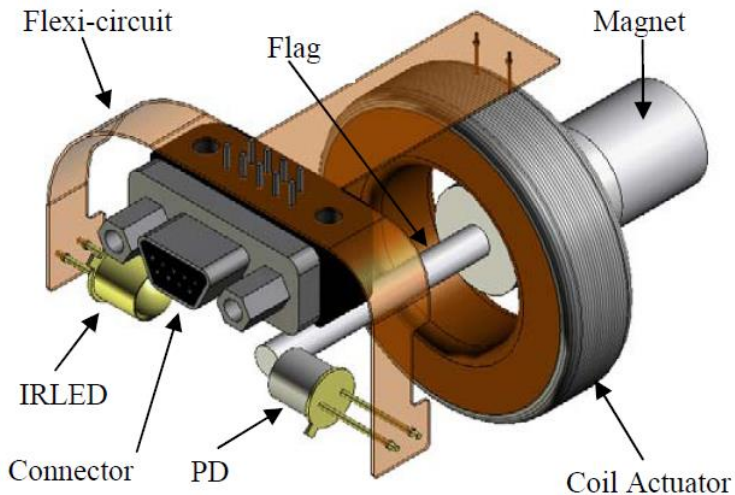
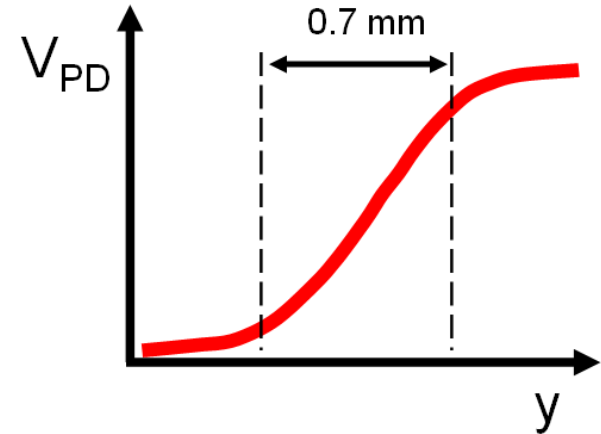
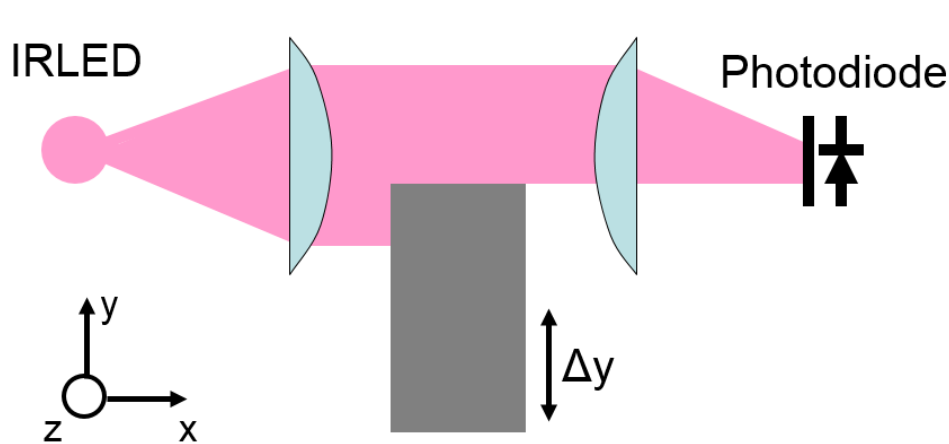
T → 120 K




R Adhikari LIGO-G1200246

- Coating Brownian noise and suspension thermal noise expected to limit aLIGO sensitivity
- Japanese cryogenic interferometer: KAGRA
- 3rd generation detector likely cryogenic
- Subsystems and components must be tested for cryogenic compatibility

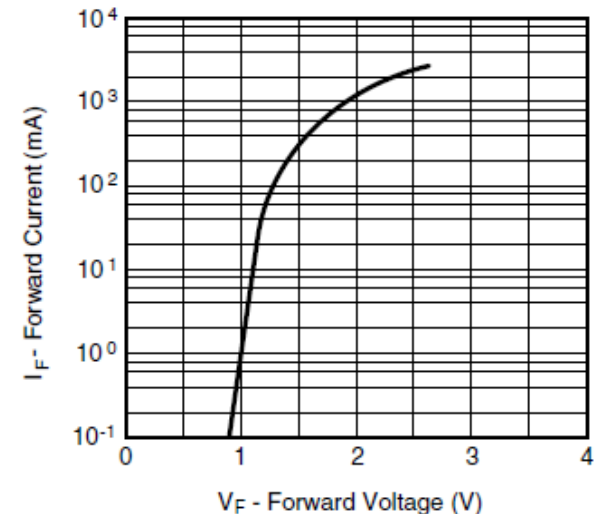
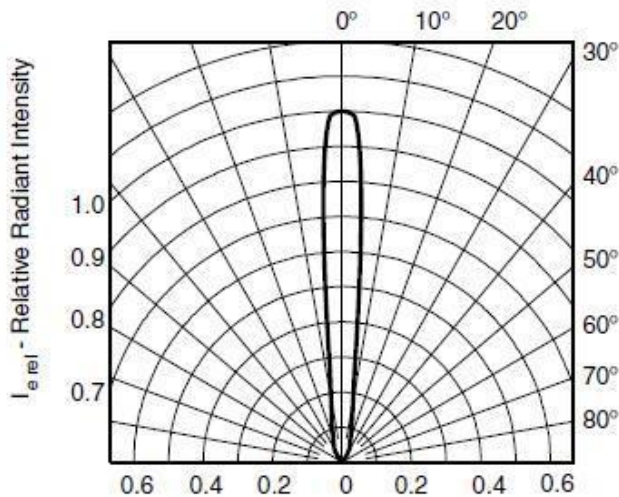
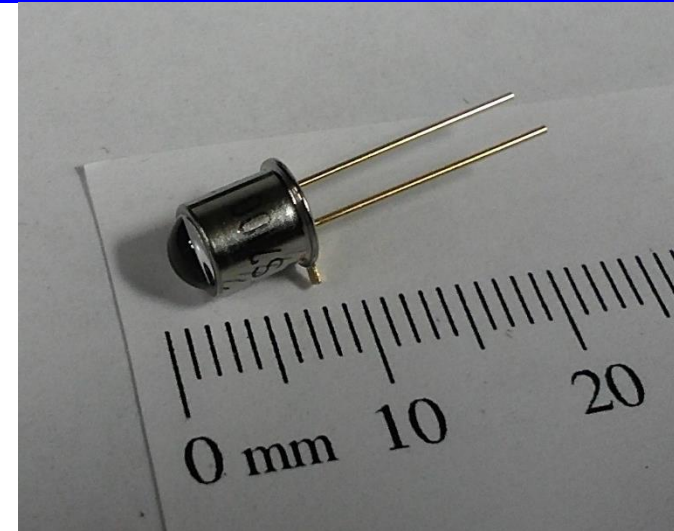
BOSEM



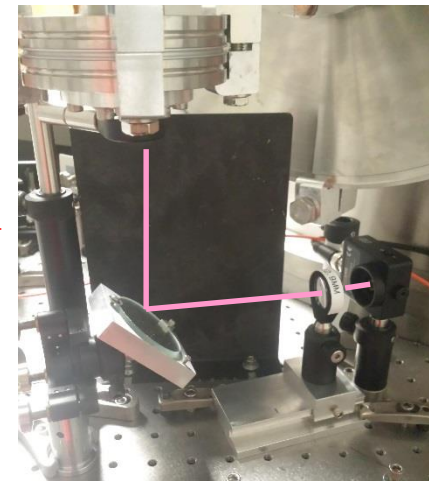
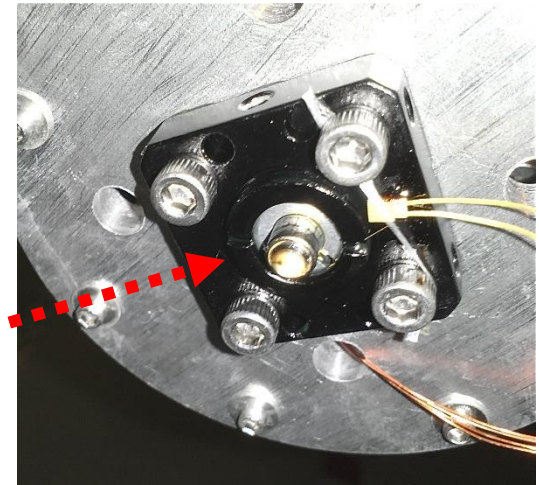
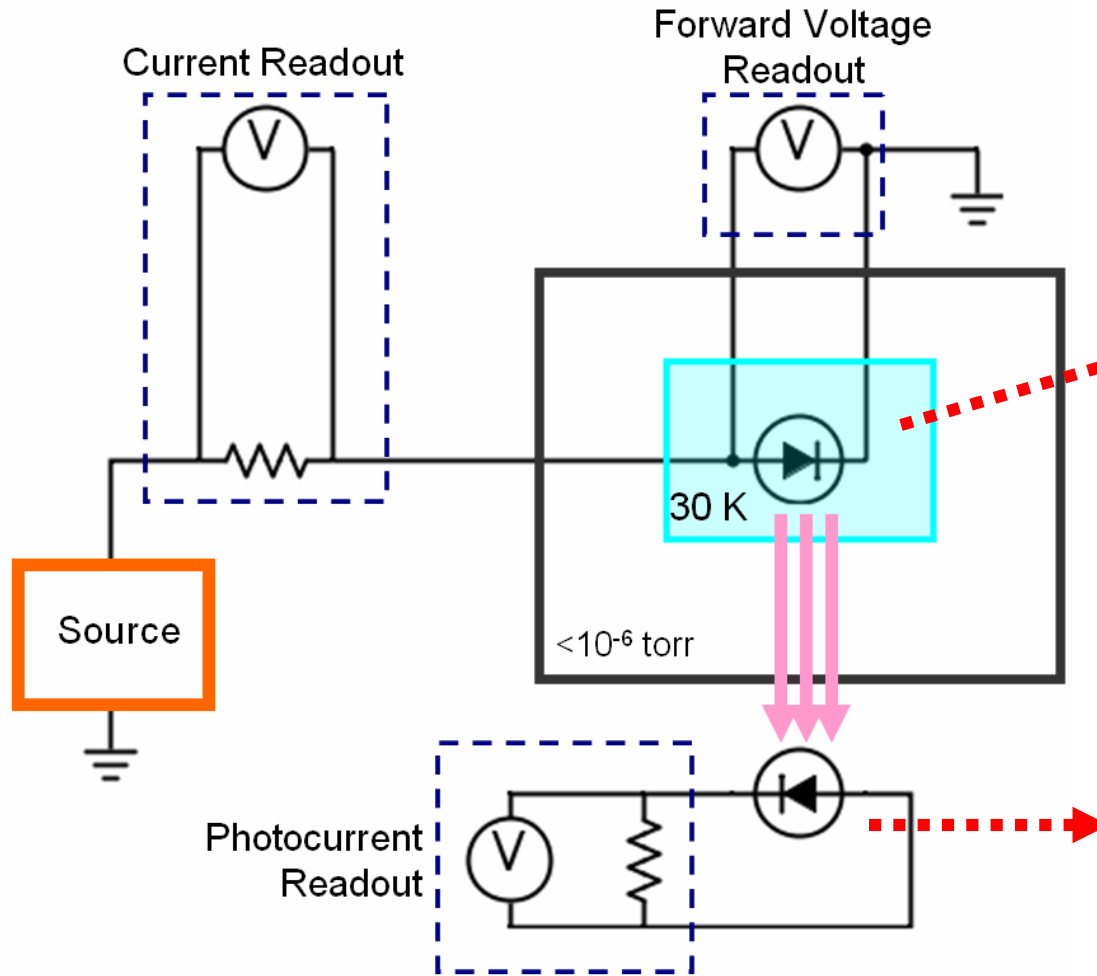
- Shadow detectors and actuators throughout LIGO suspensions
- Displacement of flag read as change in photocurrent:
 - sensitivity of $\sim 10^{-10}$ m/Hz^{1/2} at 10 Hz[†]
- Current through coil actuates on flag magnet

Vishay TSTS7100

- GaAs (III-V) IRLED
- Used in BOSEM:
 - 950 nm
 - Narrow intensity profile
 - Good noise performance
 - Relatively low forward voltage at 35 mA
- Cryogenic concerns: noise, efficiency, lifetime, profile, spectrum



Experimental Setup

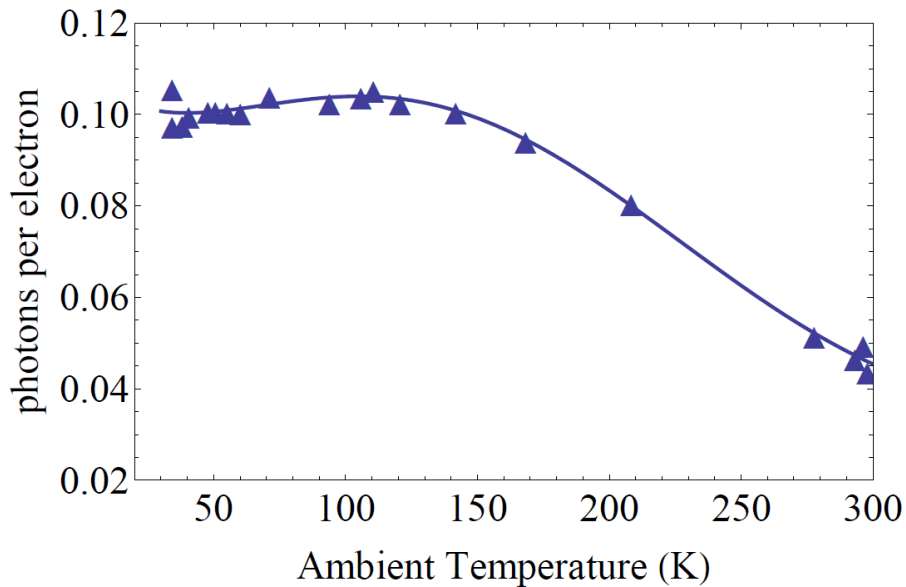


Cryogenic LEDs

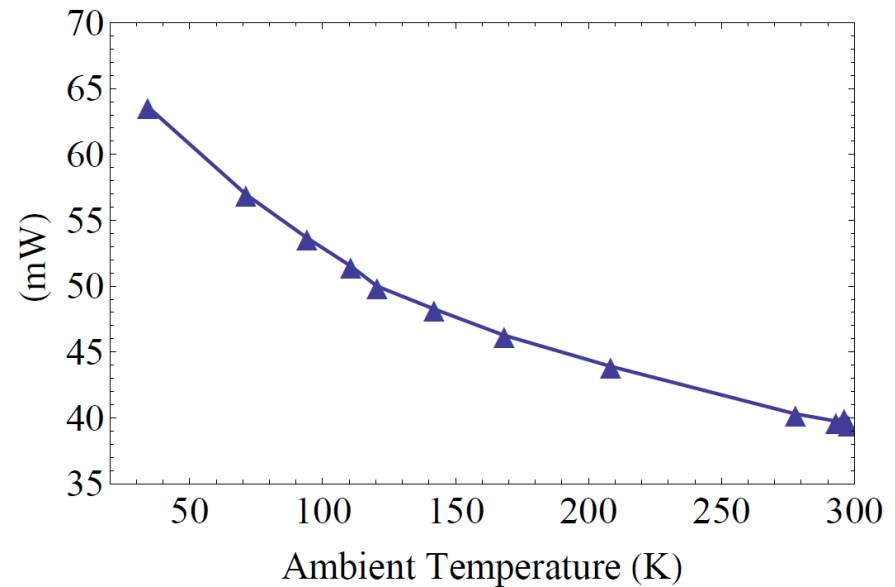
Efficiency and Heating

- Both external quantum efficiency and heating from the diode at 35 mA increase from 300 K to 30 K
- Not accounting for possible profile changes

External Quantum Efficiency, 35mA

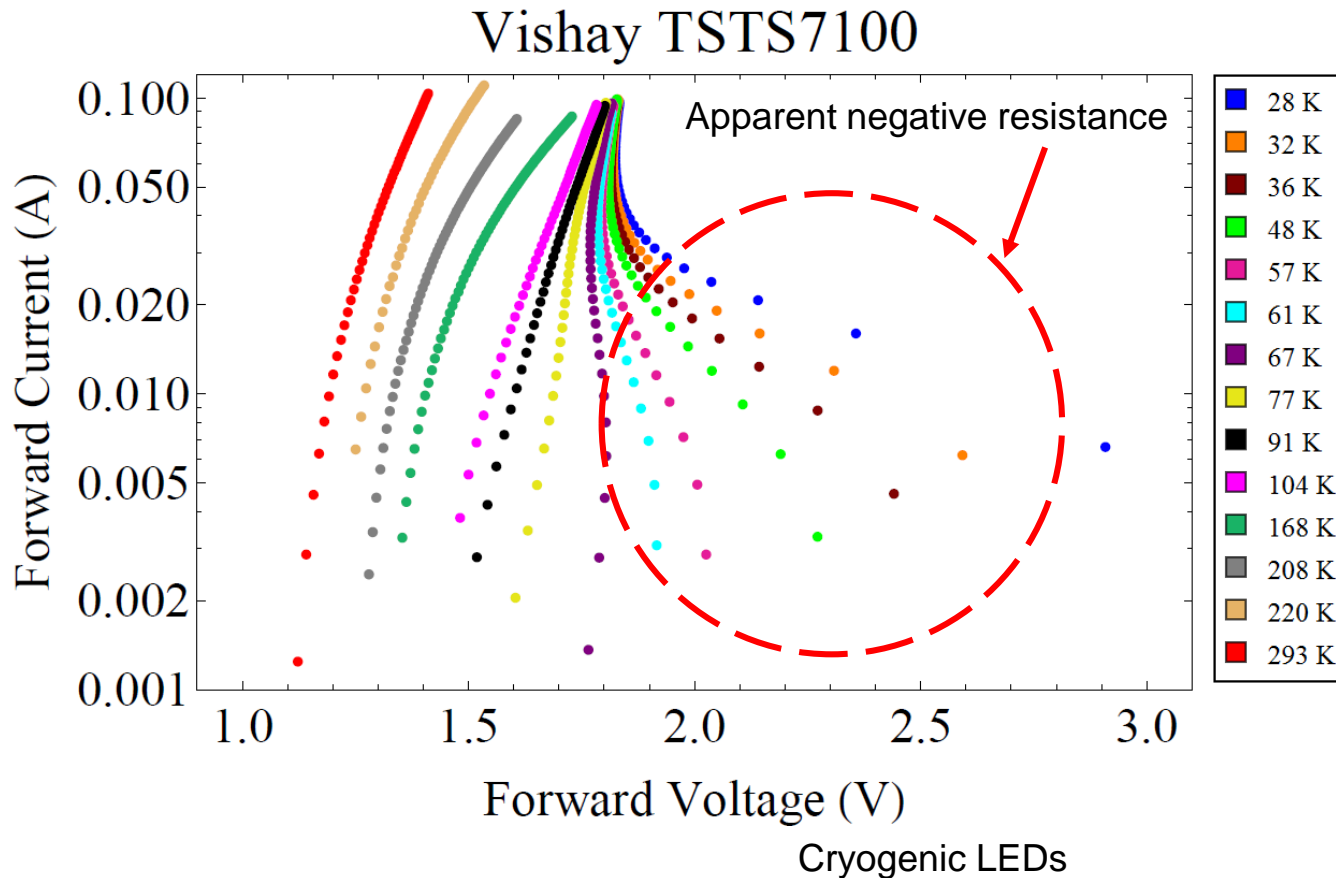
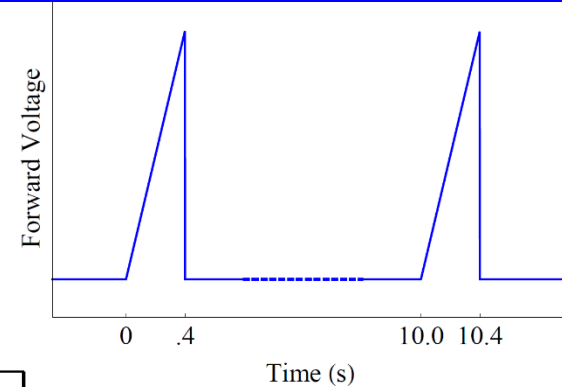


Heat Released, 35mA



I-V Characteristic Curve

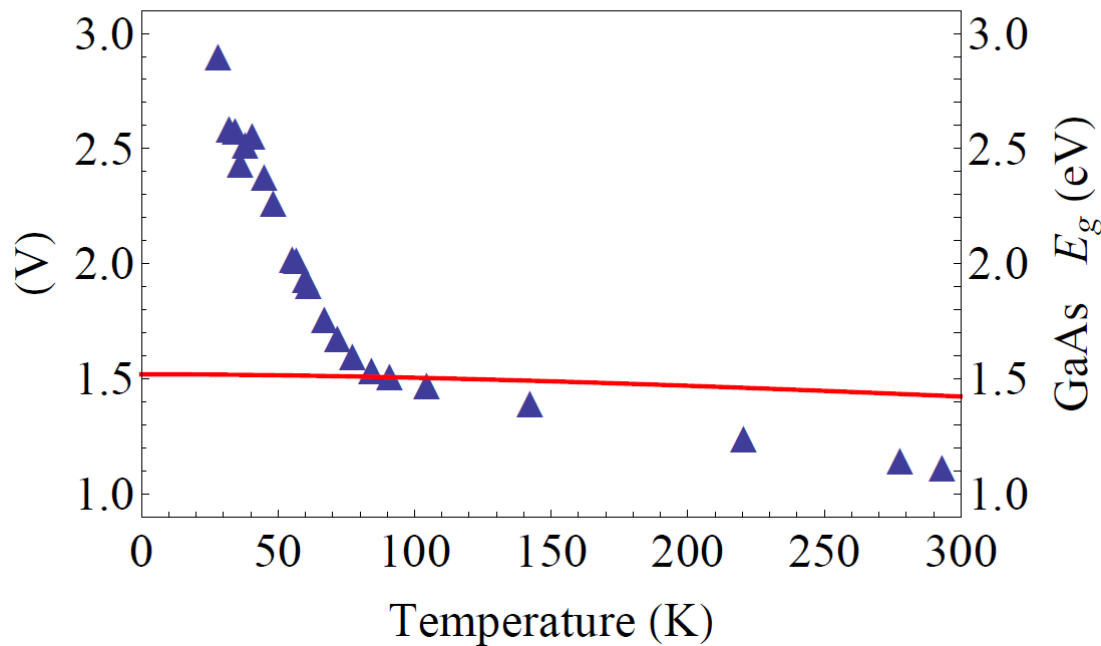
400 ms right triangle pulse, 4% duty cycle to prevent drift



I-V Characteristic Curve

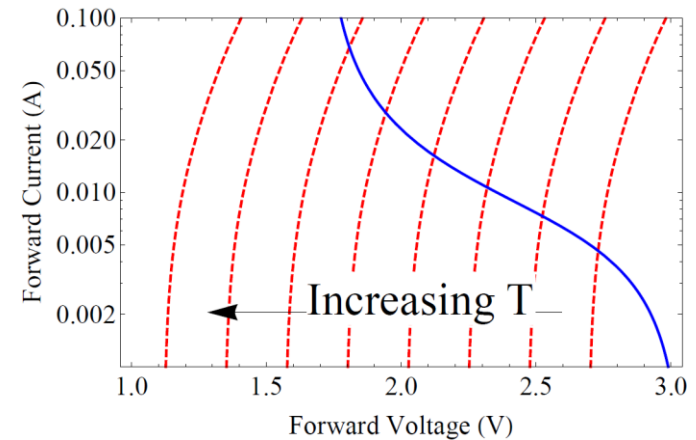
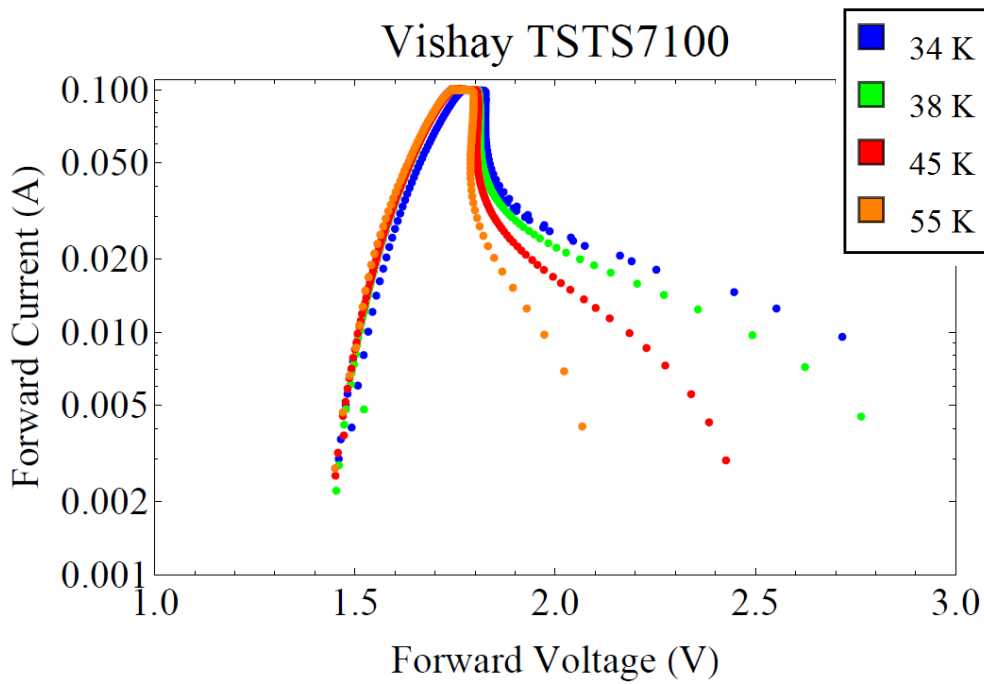
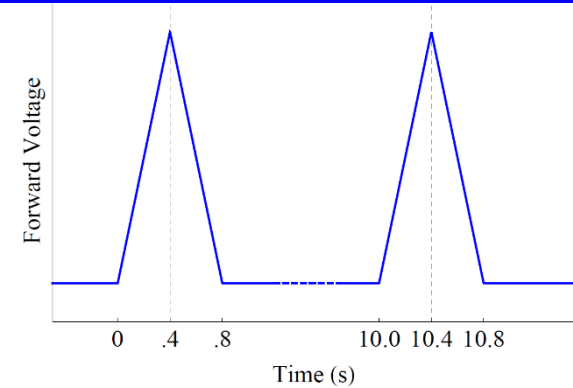
Activation forward voltage increases ~ 2 V from 300 K to 30 K

Activation Forward Voltage



I-V Characteristic Curve

- Apparent negative resistances are due to heating
- 800ms isosceles triangle pulse (8% duty cycle)
- LEDs heat up and drop along different I-V curve



Future Work

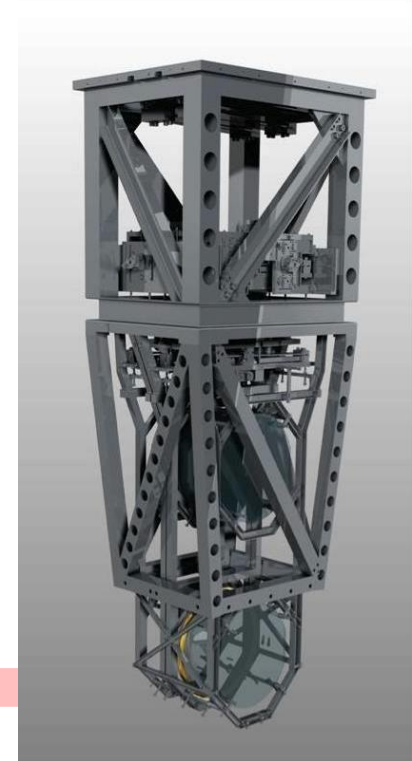
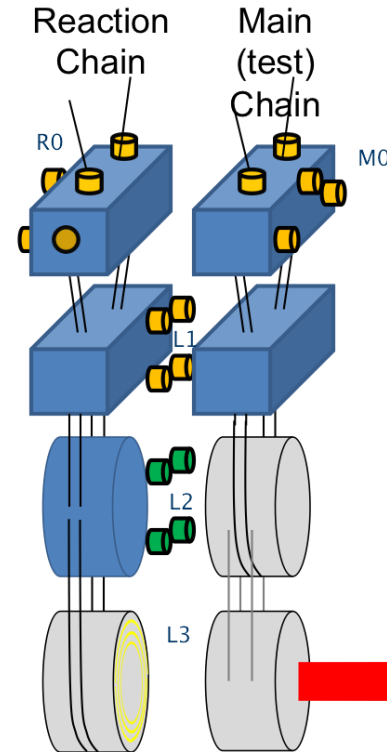
- Continued LED characterization:
 - profile
 - spectrum
 - lifetime
- Photodiode characterization:
 - intensity response
- LED & photodiode:
 - displacement sensitivity
 - noise performance
- Cryogenic BOSEM testing

Extra Material

LIGO suspensions

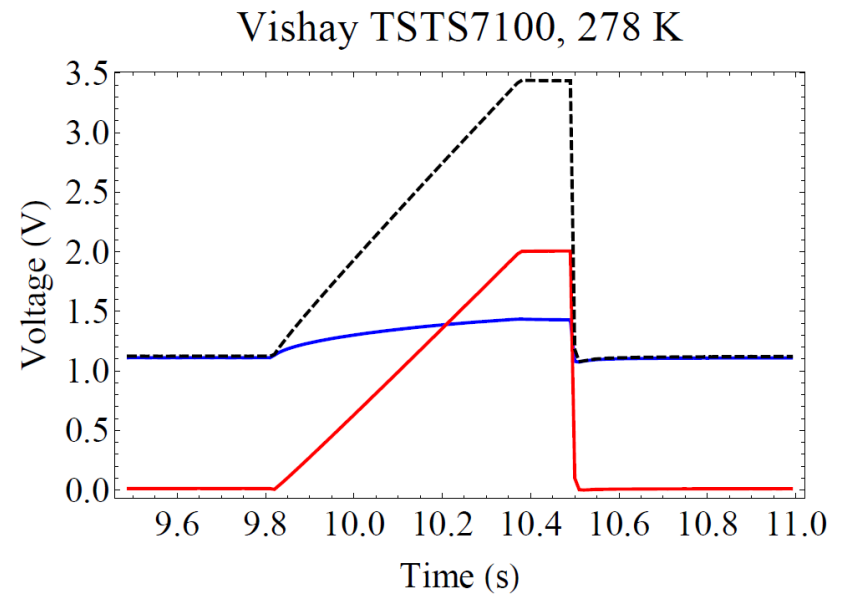
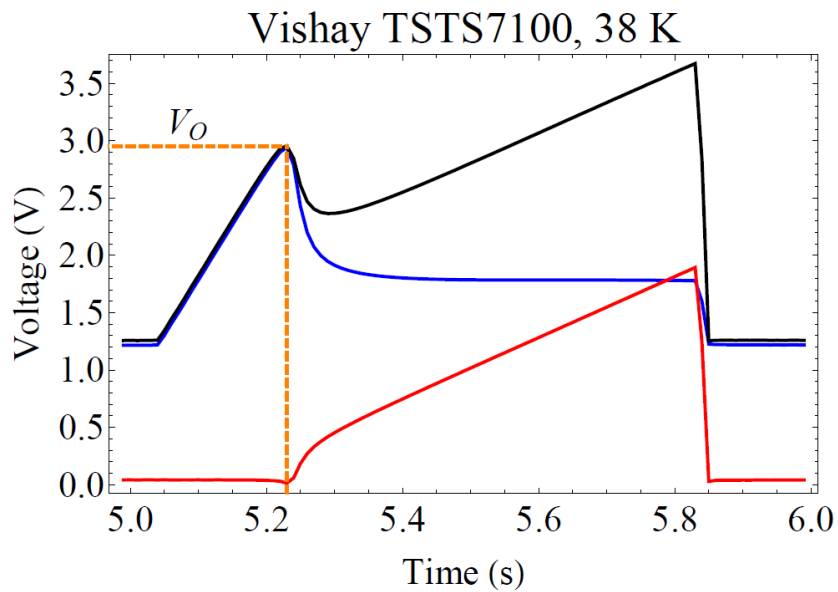
Series of active and passive components decouple LIGO optics from ground motion

Suspension will serve as cooling mechanism for optics

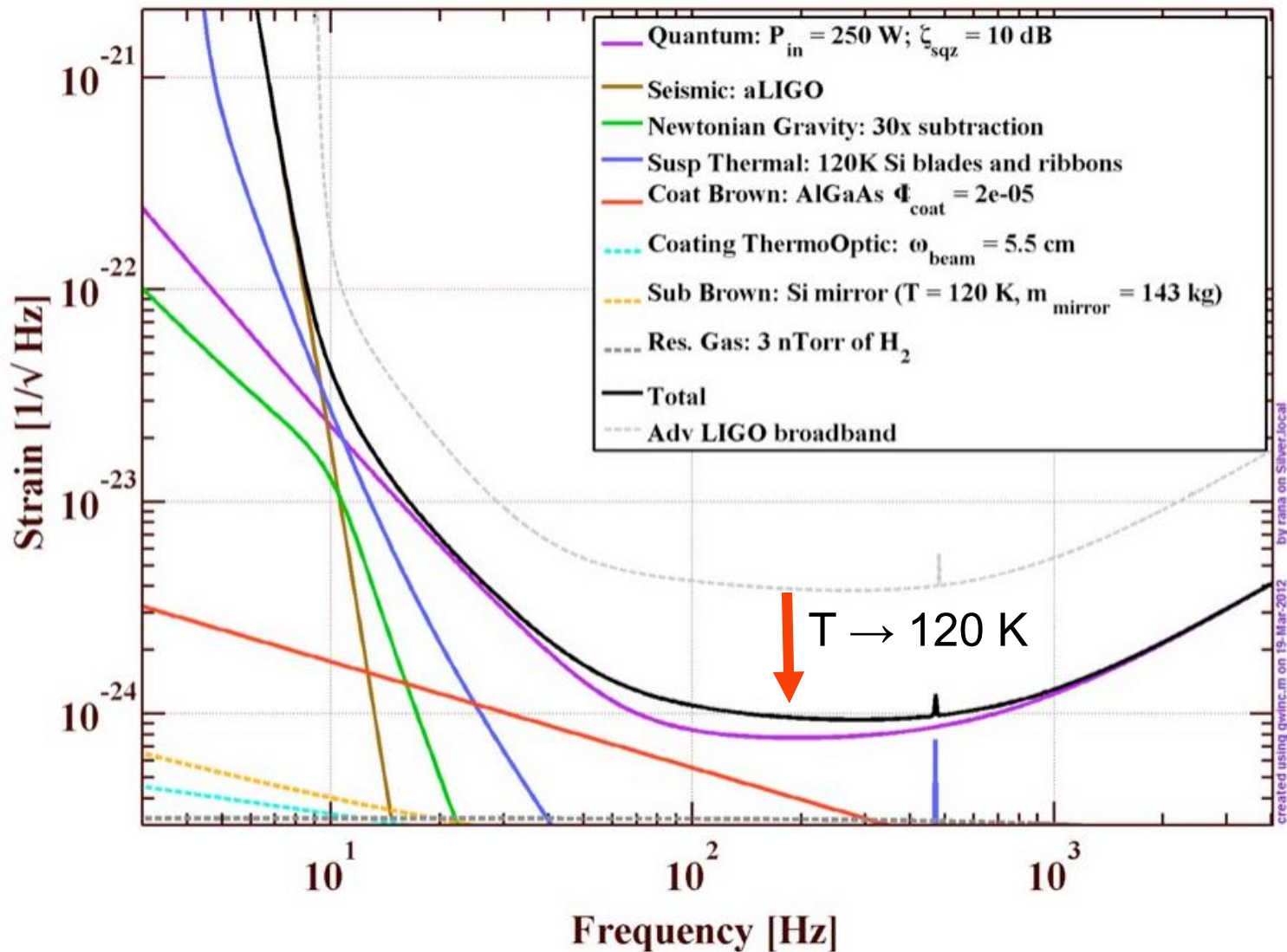


<https://awiki.ligo-wa.caltech.edu/aLIGO/Suspensions/OpsManual/QUAD>

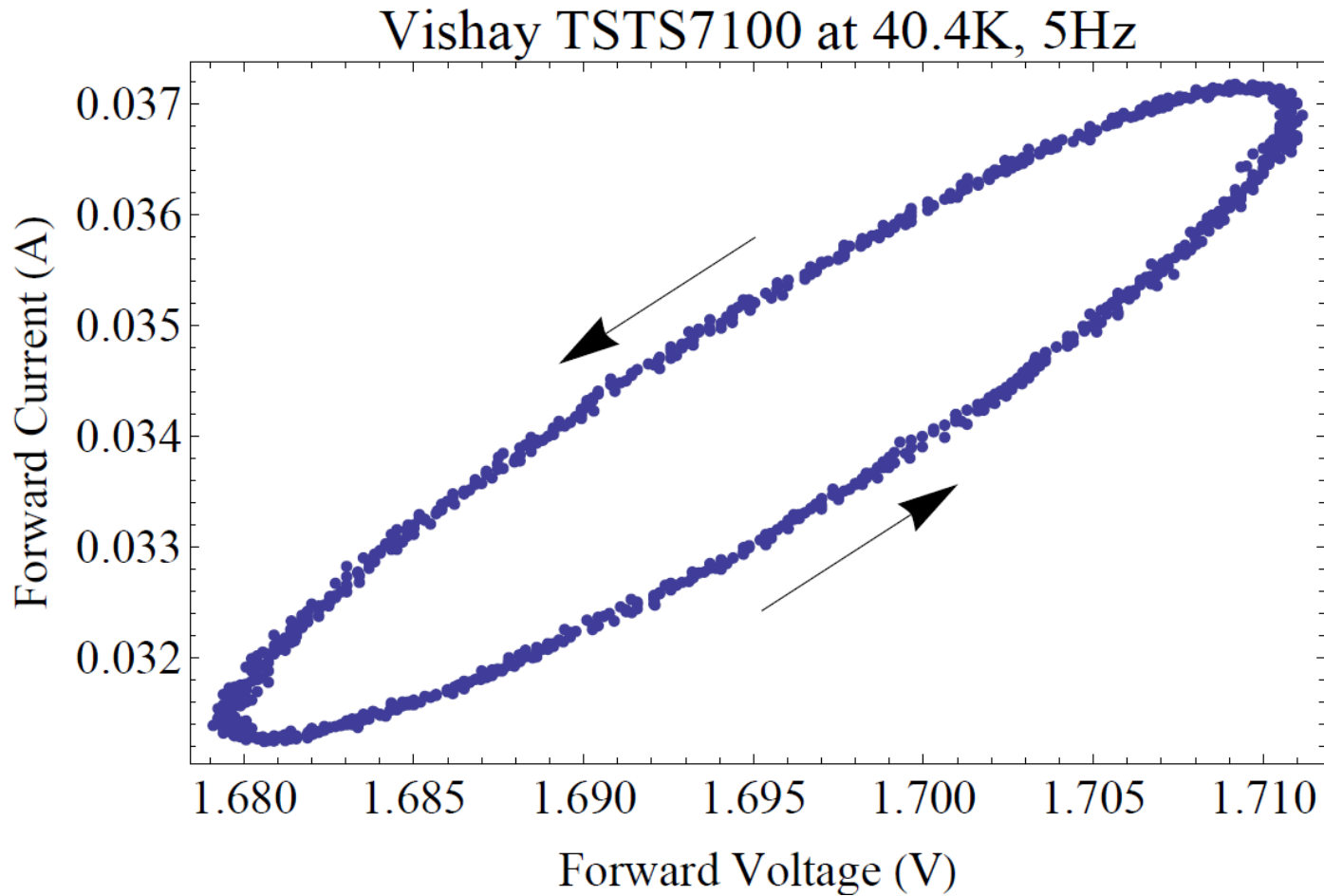
I-V Time Series



The case for cryogenics



Hysteresis



Freezing out recombination

