Observing Optical Springs With 100g Mirrors

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LIGO-G…

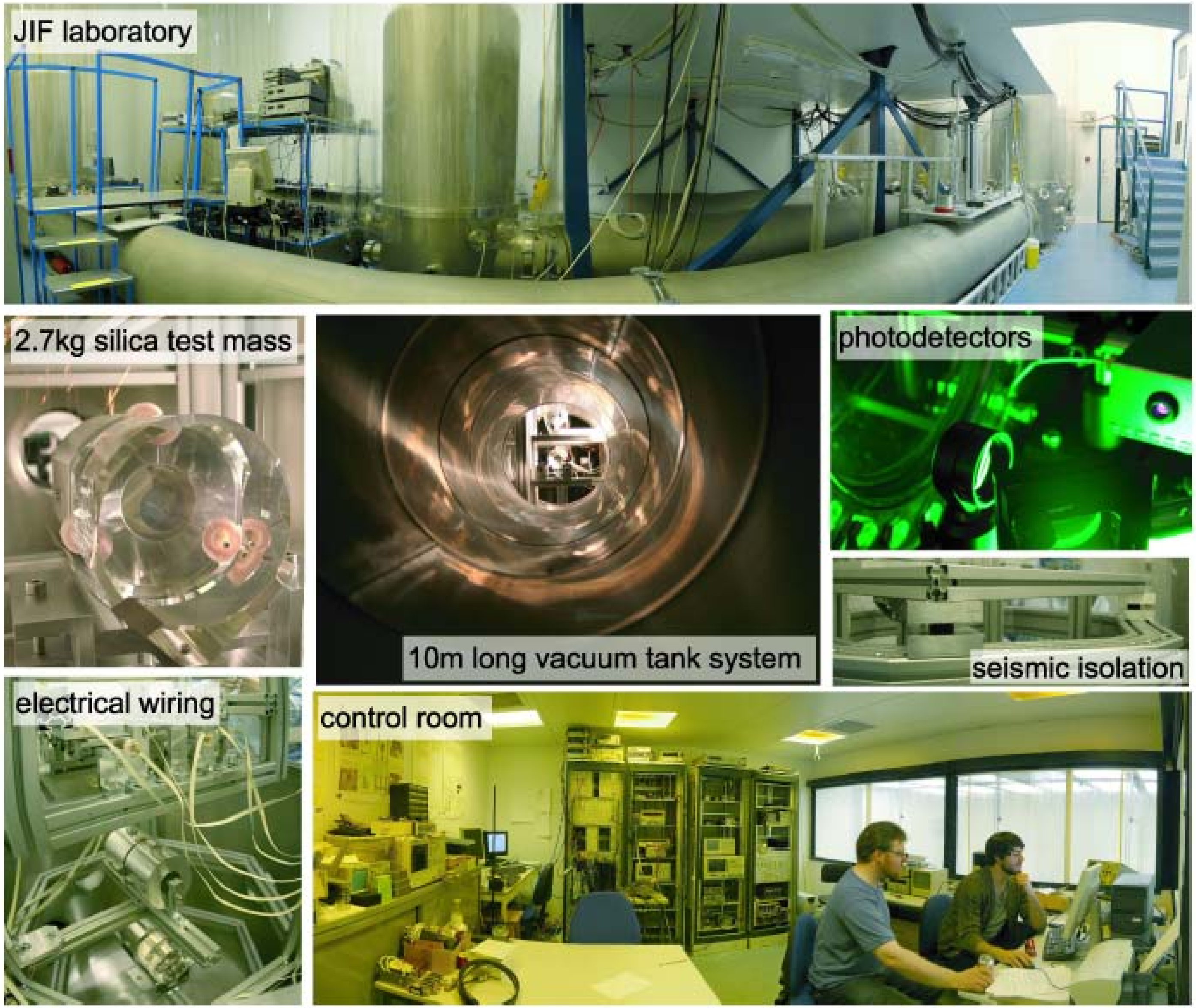
OVERVIEW

- **The Glasgow JIF laboratory**
- **The Experiment…**
  - **Stage 1 : complete**
    - Implement 100g mirror suspension
    - Demonstrate optical springs in a suspended prototype system
  - **Stage 2 : in progress**
    - Increase stored light power & increase spring strength
    - Implement digital controls and local read out sensing
  - **Stage 3 : the shape of things to come**
    - Altered configuration
    - Higher powers, greater rigidity

The Glasgow 10m prototype interferometer

- Ideal test bed for advanced interferometry concepts.

- Fast turn around for rapid, small-scale tests
- Timely validation of various innovative technologies
- Excellent training for students and postdocs



Investigating springs

- As the light power in advanced detectors climbs, optical rigidity becomes an ever more significant influence on the sensitivity and dynamics
- Several different options suggested for improving detector sensitivity through the use of optical springs
- All of these options require the ability to generate and manipulate optical springs reliably
- Experiments targeted at testing the control and dynamics associated with radiation pressure dominated cavities on a prototype (100 g mass) scale
- Will be followed up by low noise experiments at the AEI sub-SQL prototype
  - the 100 g suspensions being made for AEI are a dynamical match to the design developed for the experiments in Glasgow

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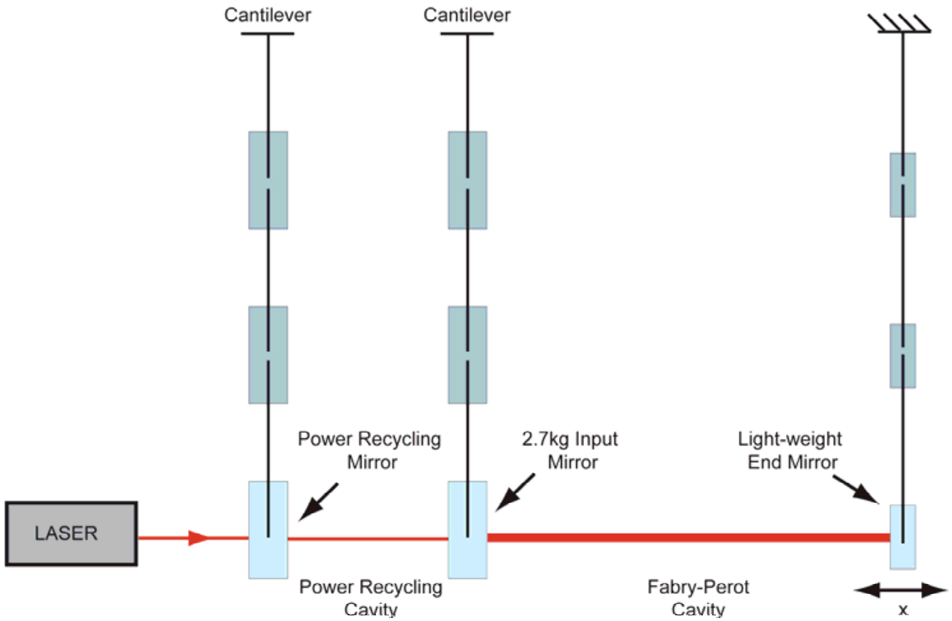
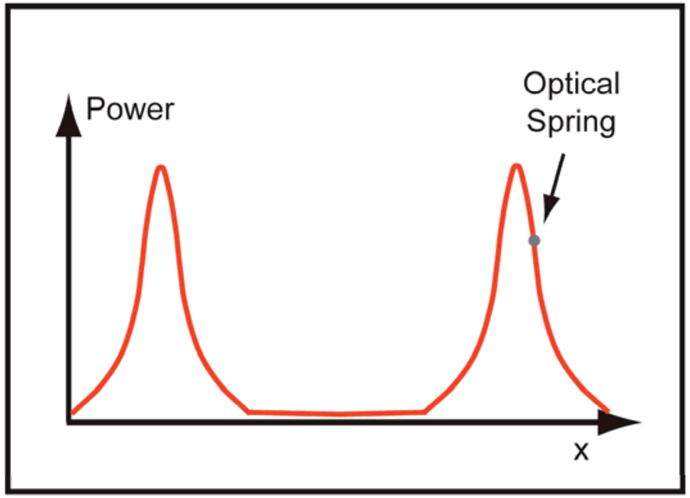
Optical Spring Experiment – Stage 1

Stage 1 aims:

- Create an optical spring in a coupled cavity configuration – analogous to recycling cavities
- 3 mirror coupled cavity configuration – increased arm cavity storage with existing hardware
- Explore the interactions with the control system and spring dynamics
- Assess stability and repeatability – characterise optomechanical response

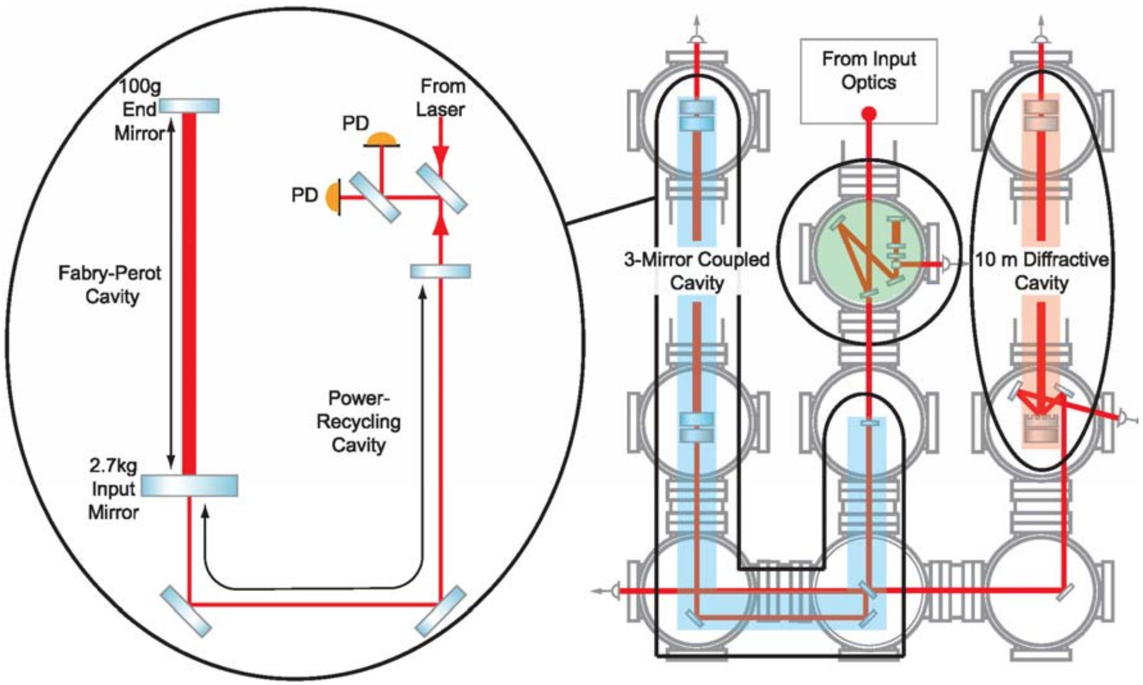




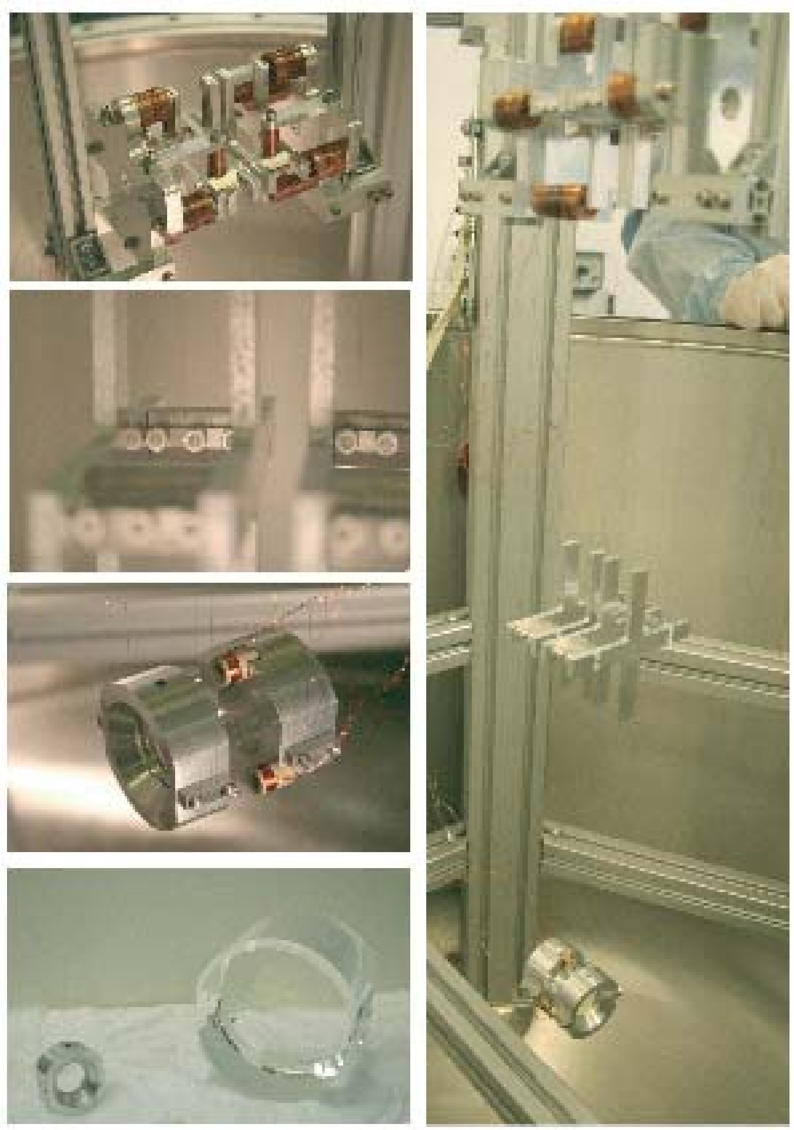
Optical Spring Experiment

System design:

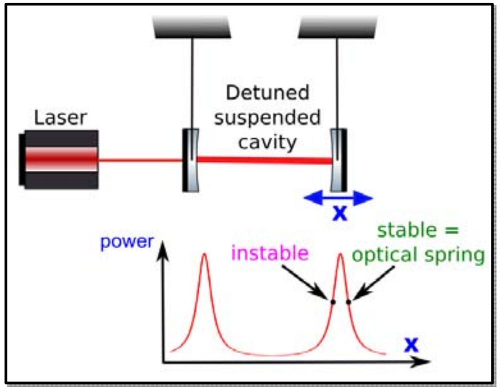
- Triple stage light-weight suspension design featuring passive eddy-current damping.
- 100g end test mass (with fused silica mirror).
- Detuned Fabry-Perot cavity - optical spring.



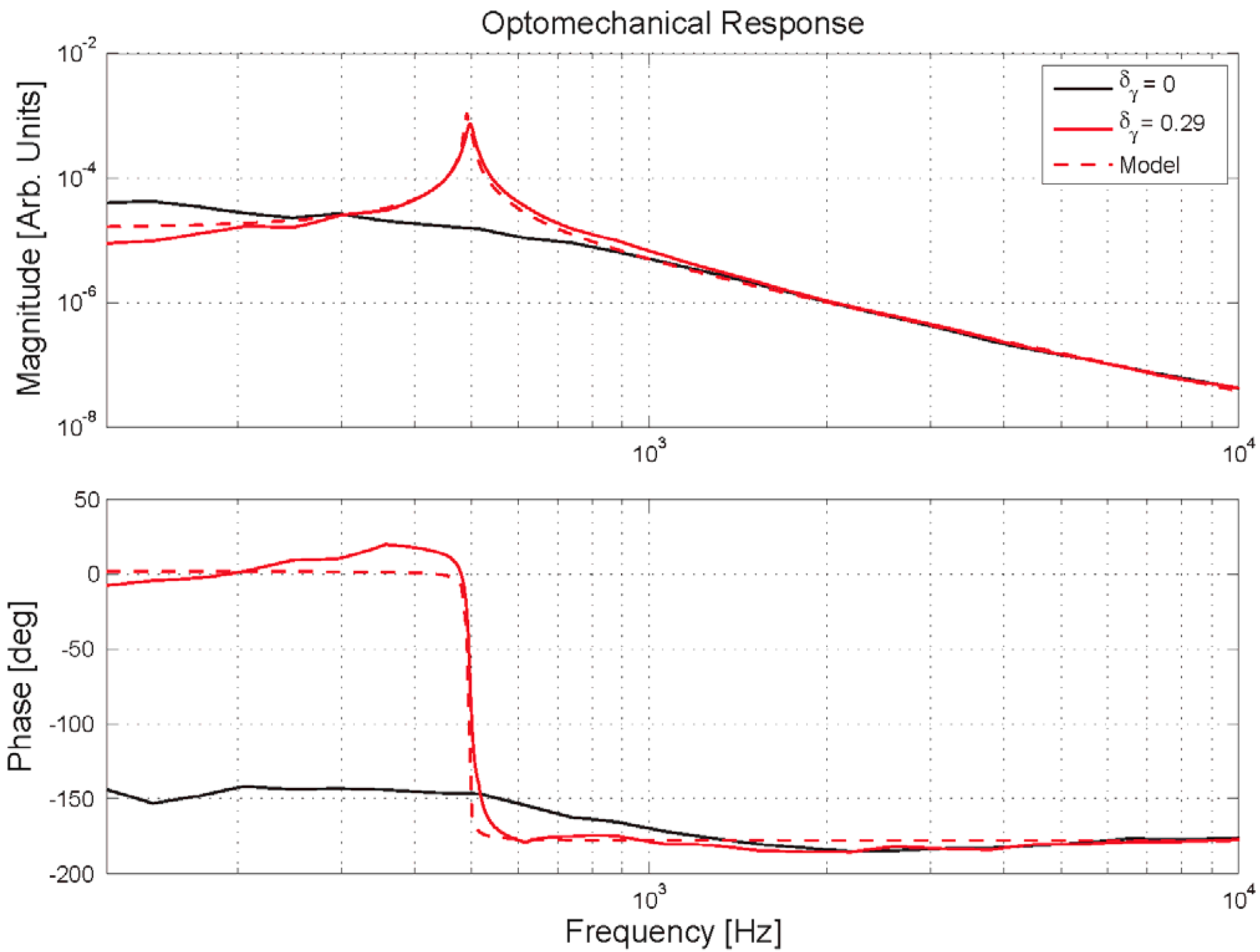
Radiation Pressure Experiment



Spring!



- **Clear optical spring effect with cavity detuning**



- 496 Hz spring frequency
- Spring constant K = 9.4×10^5 N/m
- In good agreement with Simulink model

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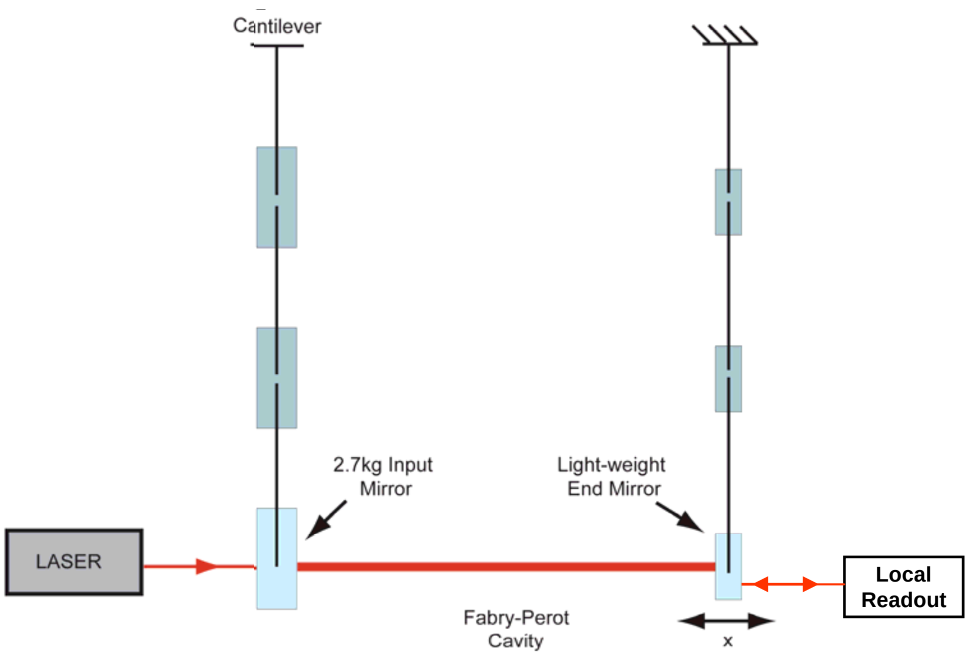
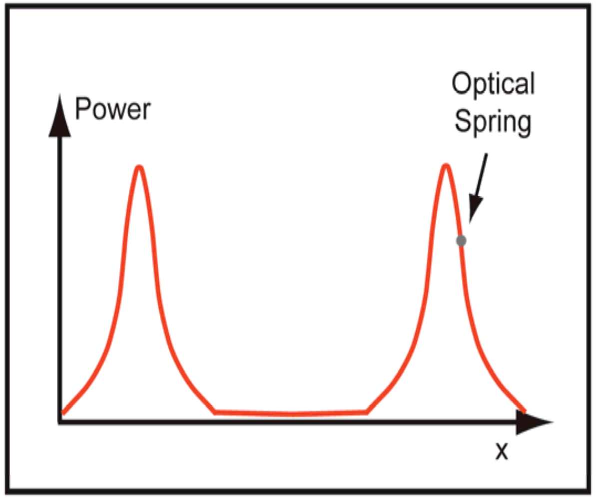
Optical Spring Experiment – Stage 2

Stage 2 aims:

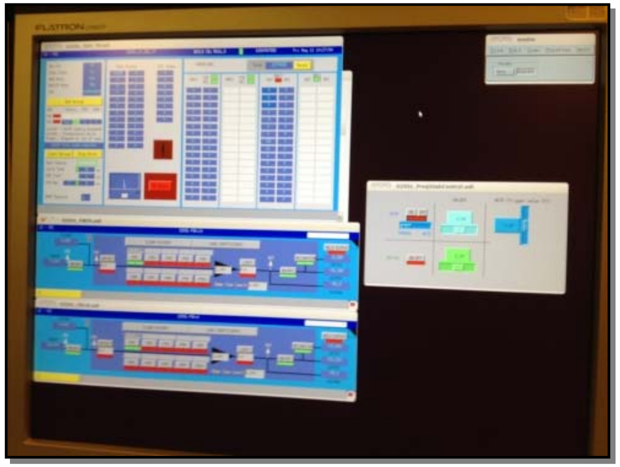
- Simplify the optical system – single high finesse optical cavity
- Improved stability through higher gain control loop and autoalignment
- Increase circulating light power
- Implement 'optical bar' style local readout – stage one used in-loop measurement





Progress

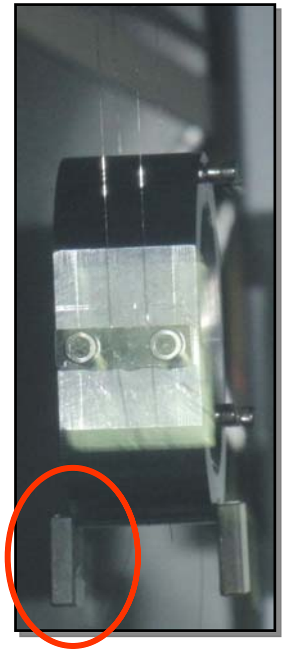
- 'Power recycling' mirror removed
- 2.7 kg input mirror replaced by a more highly reflective mirror
- Cavity ringdown measurements indicate finesse around 8000 (double the effective finesse of the coupled cavity)

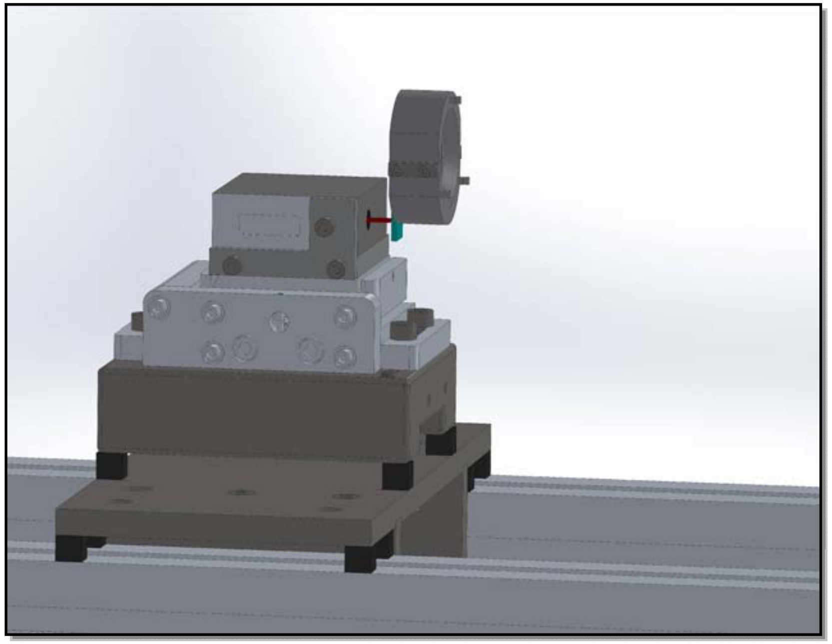


- Taking this opportunity to upgrade our sensing and control hardware
- CDS digital controls are now implemented
  - Cavity locking gain and offset tuning controls tested and operating
  - Wavefront sensing and feedback controls undergoing testing/characterisation

More Progress

- Incident power to cavity increased from 150mW to current maximum 600mW
- Local readout sensor electronics and mechanics ready for installation





- EUCLID interferometric sensor developed at the University of Birmingham
  - Vacuum compatible
  - 20 pm/sqrt(Hz) sensitivity at 10Hz

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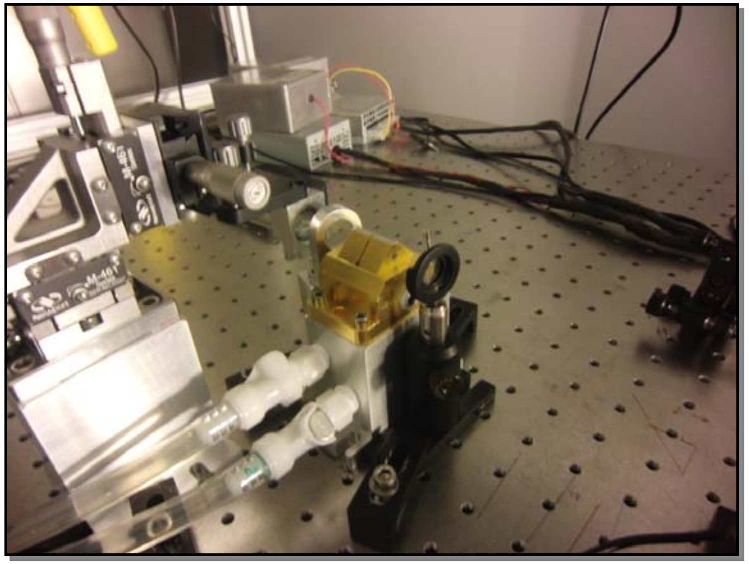
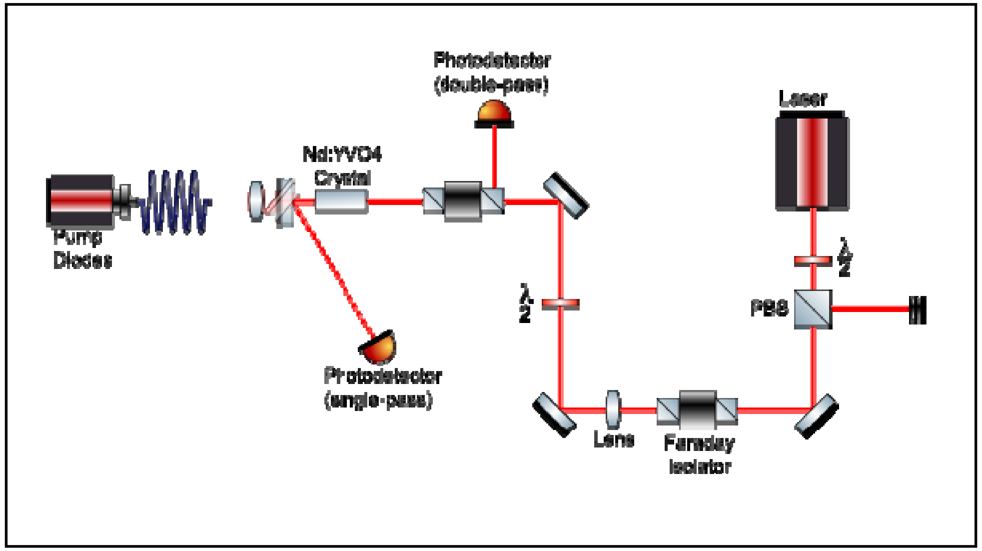
Stage 3: Taking it Further

- Already working on the next step… and we have a couple of interesting plans on the horizon…

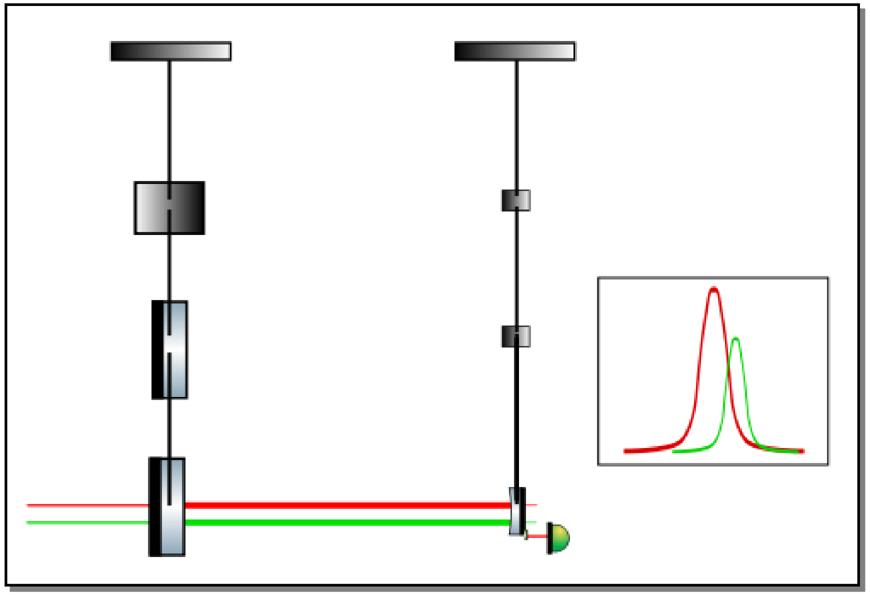
- Upgrade – higher power laser
  - Several Watts of input power possible
  - Instantly provides the potential for stronger springs

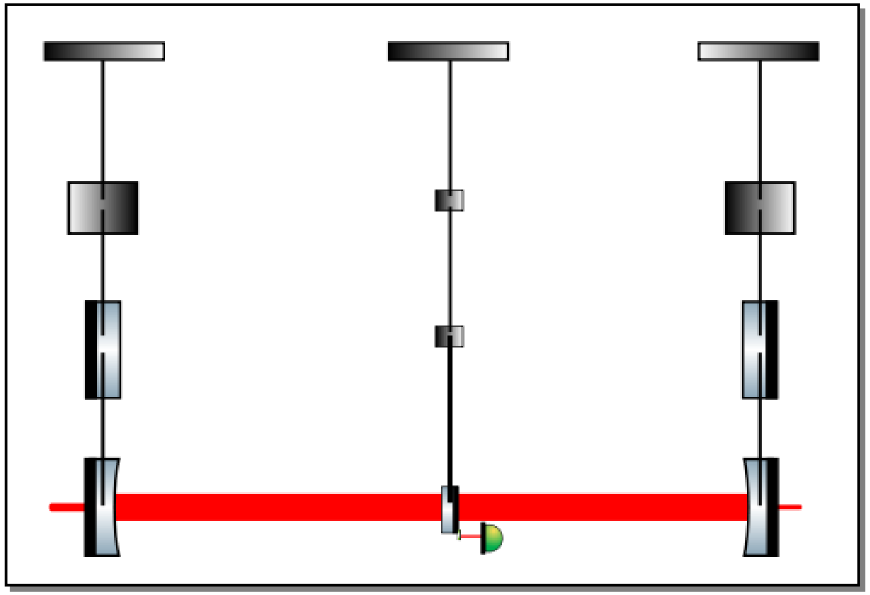




New Topologies

Two obvious extensions currently being simulated and considered





- Dual carrier
  - One cavity with controllable spring condition and two stable, high-power lasers
  - Interesting dynamics
- Dual Cavity
  - Two cavities with common light mirror
  - Double mode
  - Similar to original optical bar

Conclusions

- First stage of the project is complete
- Creating and observing springs is achievable on a prototype scale
- Second stage with local readout, digital controls and more power online soon
- Currently simulating configurations and considering options for the next stage