LIDA

A Detector for Axions and a Testbed for GW Detectors

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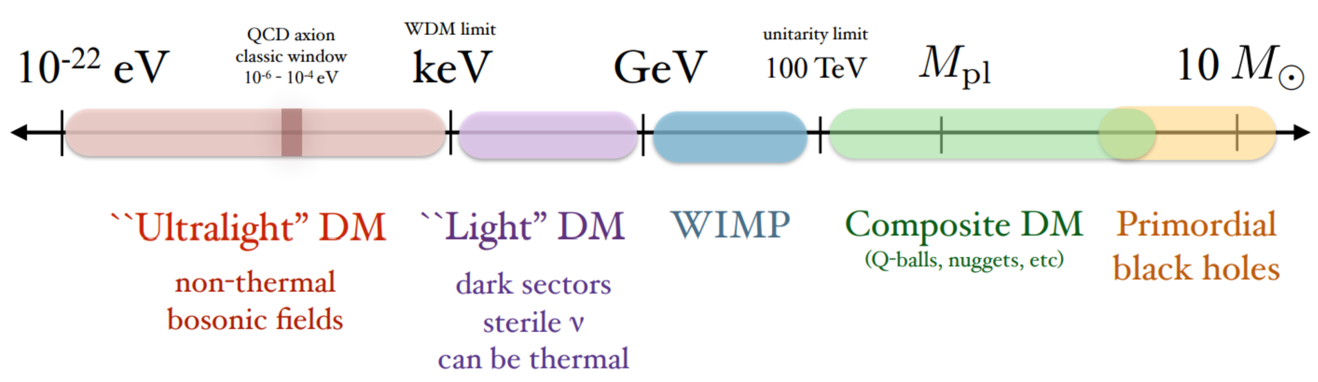
Introduction



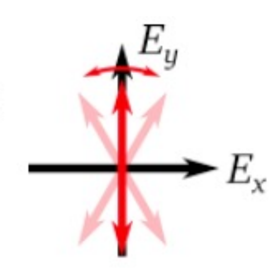
Axions and ALPS are Dark Matter candidate particles originating from the Peccei-Quinn theory originally proposed to solve the CP-Problem in QCD.

We present LIDA - a laser interferometric detector for Axions – capable of resonating high intracavity power searching for Axions and ALPS and acting as a testbed for Gravitational Wave detectors.

Experimental Goals

- Proof of experiment, for scaling up to LIGO to increase sensitivity to Axion or ALP Dark Matter.
- Provide constrains on Axion/ALP particle mass.
- In the best-case scenario, observe a signature for further testing.

Observable effect: Rotation of linear polarisation!



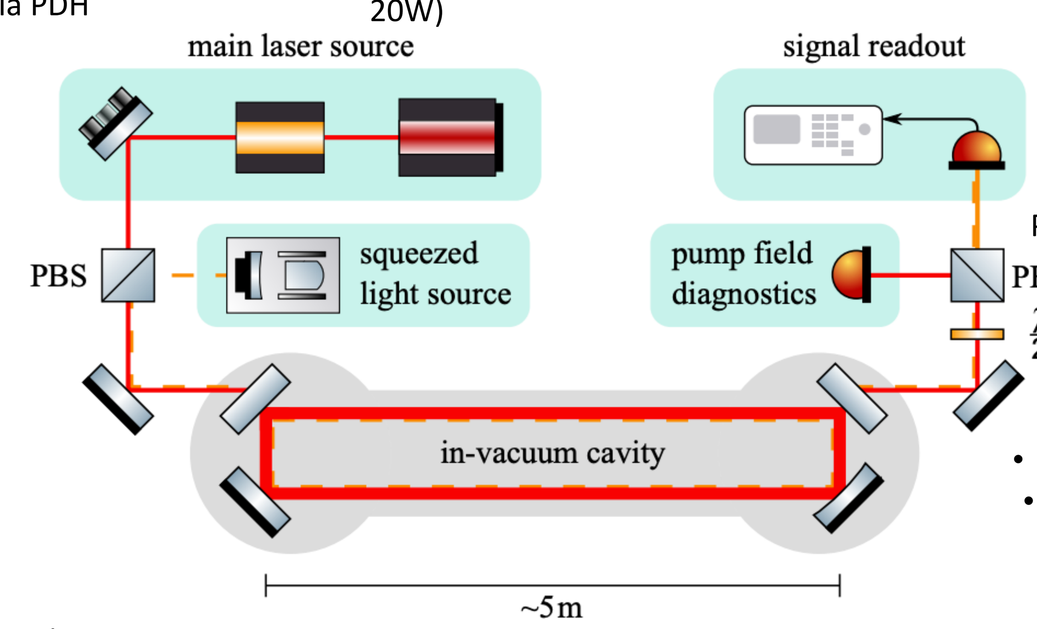
Experiment

Power stabilization via EOAM

Laser frequency lock to cavity via PDH

neoLase neoVan laser amplifier (up to 20W)

Coherent NPRO Mephisto Laser (1064nm, 300mW)



EOAM: electro-optic amplitude modulator

PBS: polarising beam splitter

PDH: Pound-Drever-Hall

P-pol: finesse 2000, linewidth $14kHz$

S-pol: finesse 74000, linewidth $400Hz$

P-/S-pol detuning $500kHz$

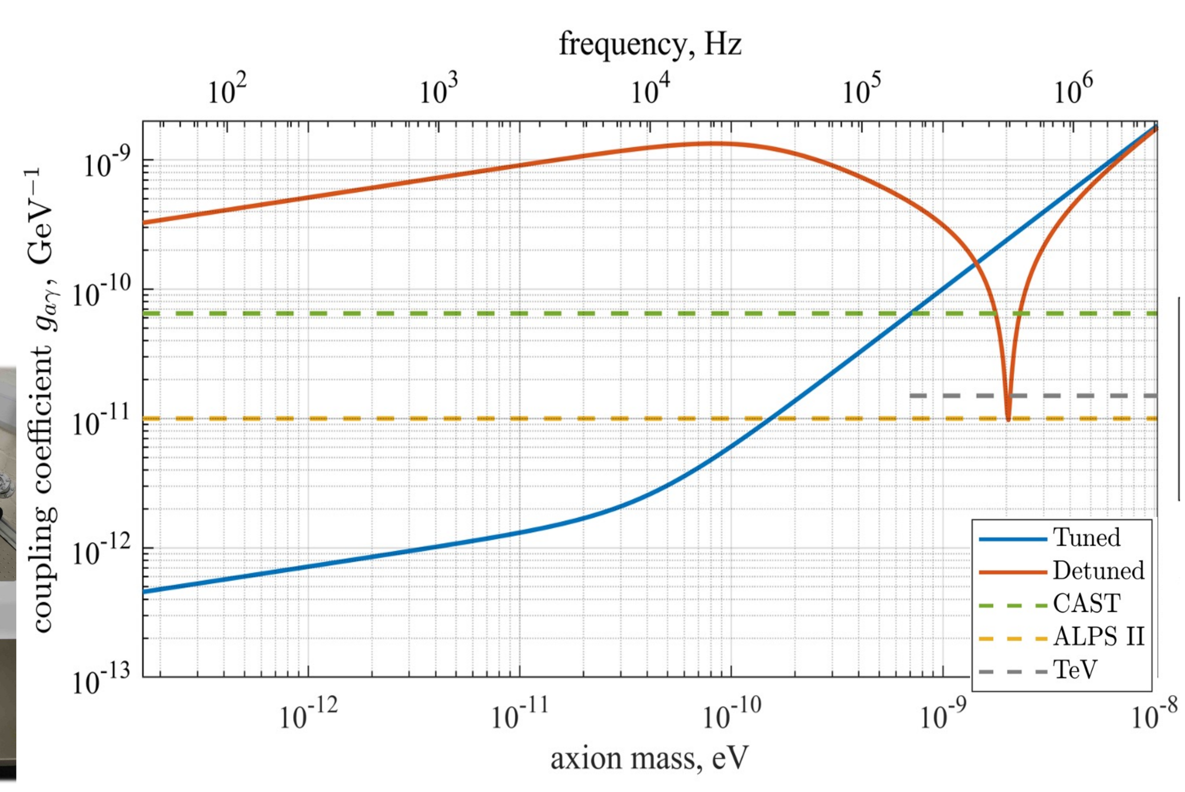
One cavity mirror has ROC 10.2m. The cavity would be unstable otherwise.

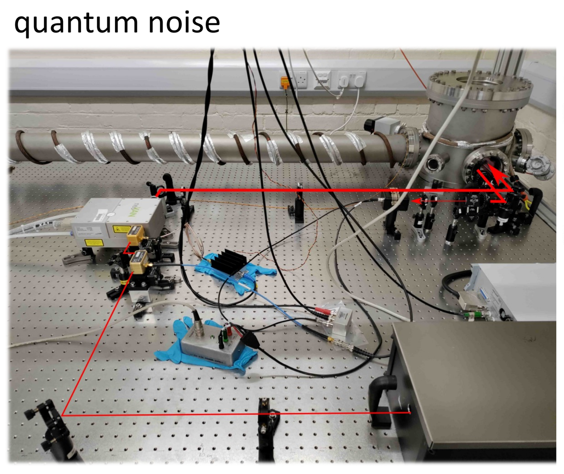
Pending

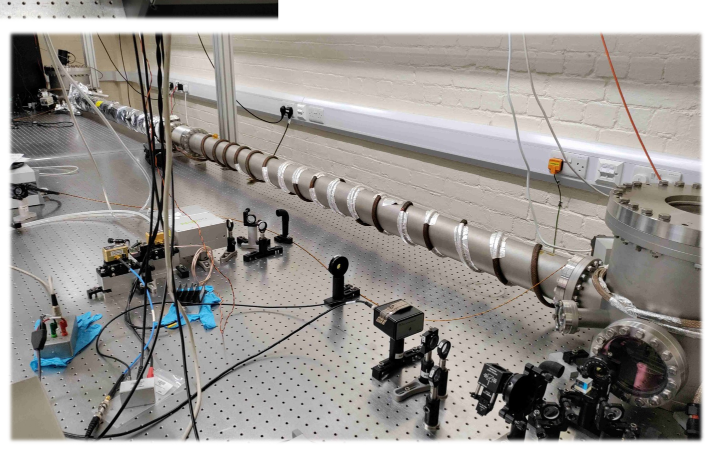
- Auto-alignment control
- Squeezed light source

Meeting our Design Parameters:

— **200 kW** intra-cavity power to enhance signal
— **5 m** baseline to increase interaction time
— vacuum system
— **6 months** integration time for larger SNR
— **$10\ dB$ squeezed light** to reduce quantum noise





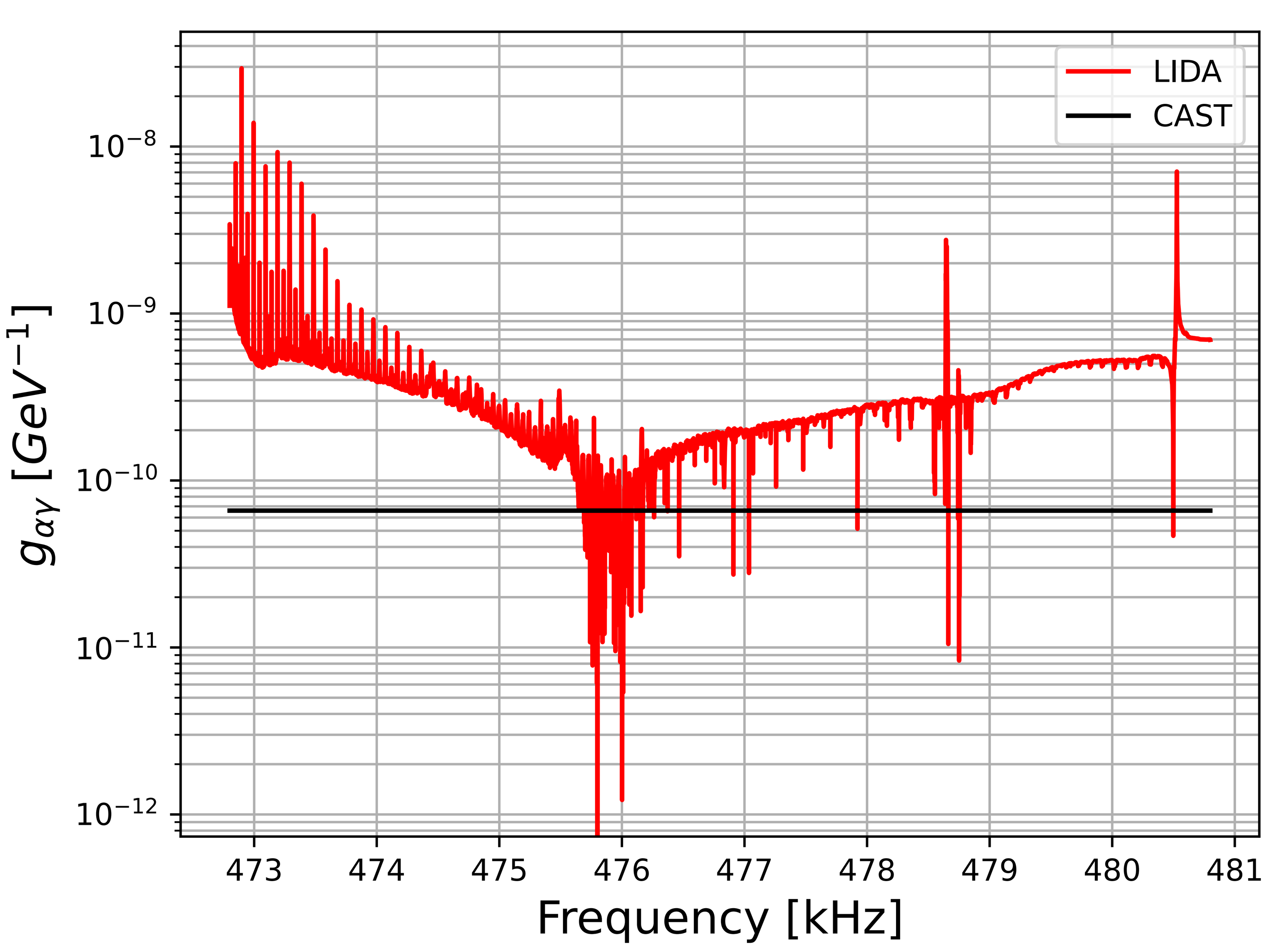


CAST: CAST Collab., Nature Phys. **13**, 2017
ALPS II: R. Baehre et.al., JINST **8**, 2013
TeV: K. Kohri et.al., Phys. Rev. D **96**, 2017

Current Results

Most Sensitive E-Run Parameters

Pump polarisation: S
Intra-cavity power: 65 kW
Detuning: 476 kHz
Input pump power: 5 W
Integration time: 87 hours
Squeezing level: 0 dB



High Intensity Effects

Maximum values achieved

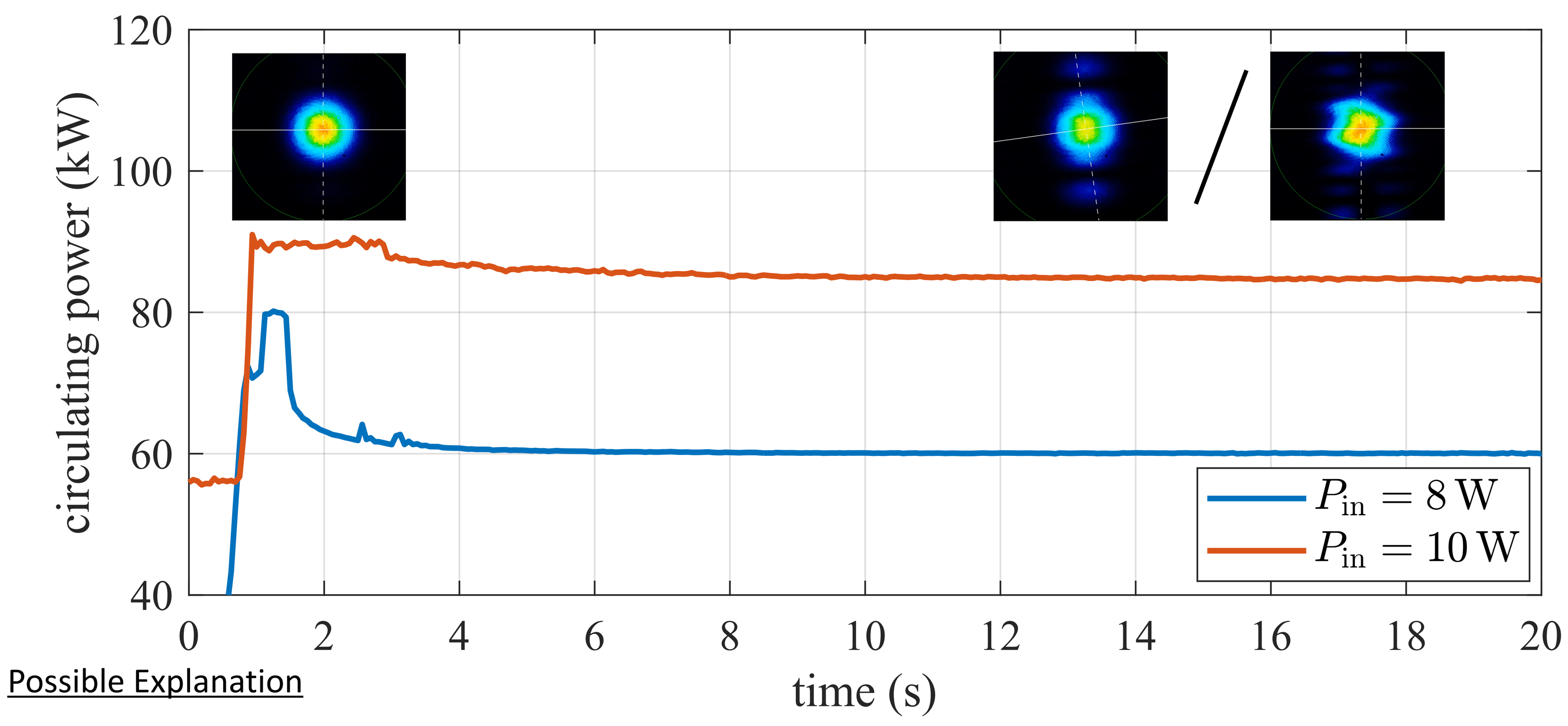
- Waist: 1.3 mm average (slightly astigmatic with 1.5 mm and 1.1 mm)
- Circulated $104\ kW$ stably for 2 seconds. This corresponds to $3.9\ MW\,cm^{-2}$
- Dropped to $98\ kW$, meaning $3.7\ MW\,cm^{-2}$

Current values for E-runs

- Waist: 1.3 mm average, similarly.
- Circulated $65\ kW$. This corresponds to $2.5\ MW\,cm^{-2}$
- This remains stably in lock for over days! Drifts are hardly observed.

Thermal Effects

- Mode remains same for high circulating power for short duration of time. Mode becomes distorted from TEM00 later.
- Circulating power fluctuates and stabilizes to a lower value.
- Fluctuations in readout noise is observed after drop in circulation power.
- This effect is only seen for high injected power (above 5 W) and not for any injected power below.



Possible Explanation

- Input mode is TEM00 but not 100% mode-matched. Other modes could therefore be excited in the cavity.
- Since different circulating modes have different thermal effects on the lenses, it is possible these are causing differential heating and changing the eigenmode of the cavity.
- However, thermal effects are expected to be happening slowly, whereas these effect are quicker.

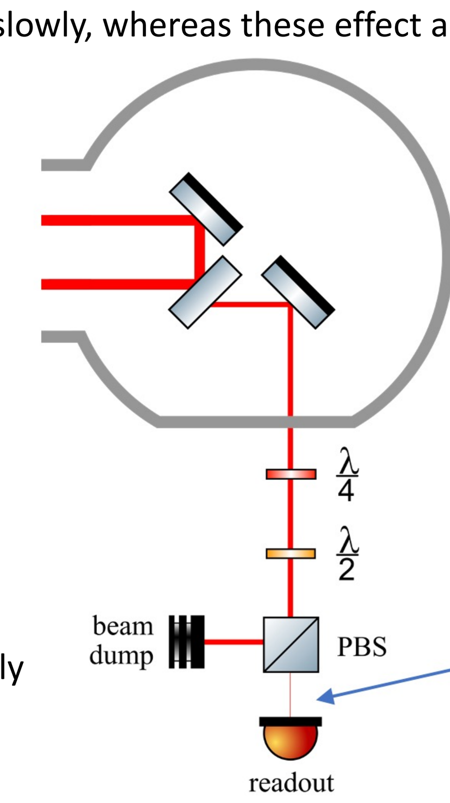
Unexplained Mode

Power on readout photodetector minimised via half- and quarter-waveplates:

• Residual light is in orthogonal polarisation and resembles a Hermite-Gaussian $HG_{1,0}$ mode.

• So far, unexplained…
Measured $TEM_{0,0}/HG_{1,0}$ ratio: ~ 600
Expected $TEM_{0,0}/HG_{1,0}$ ratio: $> 10^7$

• Limits operating power as residual light must be sufficiently below PD saturation limit.

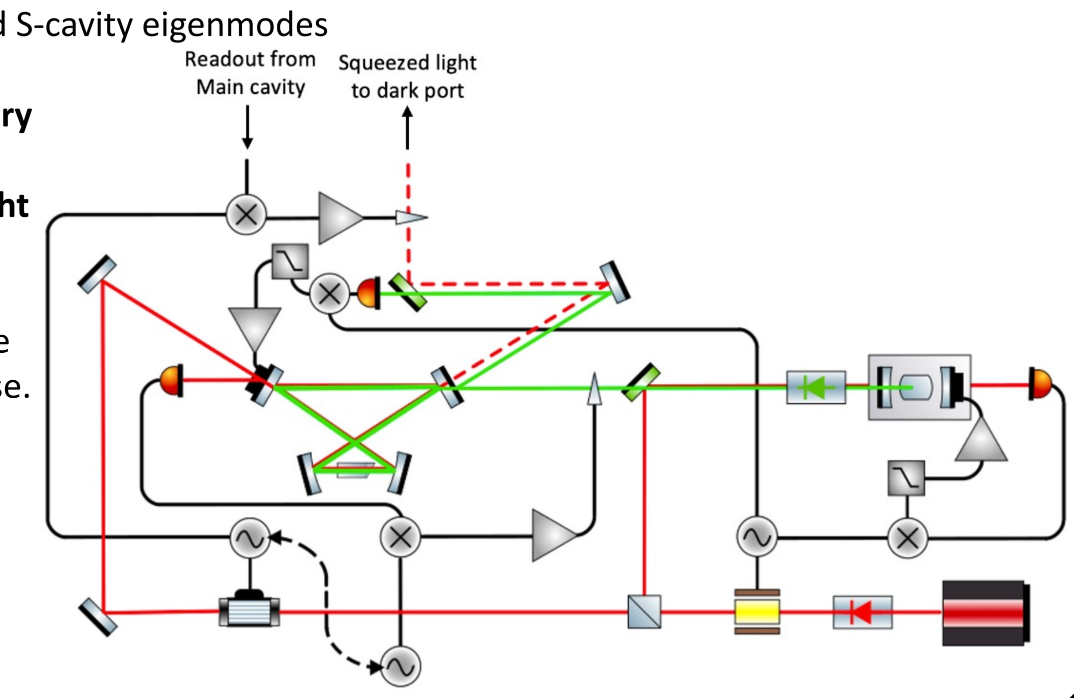


Birefringence effects

- Effects of cavity non-planarity may be causing birefringence effects where S-polarization is mixing into P-polarization.
- Both viewport have small amounts of stresses on them. Input viewport is fine and cavity filter effect rejects other polarization. However, output viewport is causing some birefringence effects which may be causing some polarization mixing.
- Cavity is not completely planar. This also contributes to mixing in the of the S- and the P-polarisations.

Future Work

- **Optimise sensitivity** in current configuration.
- **Understand** (and possibly prevent) thermal effects, readout noise fluctuations and modes in the output field
- **Reduce the detuning** of the P- and S-cavity eigenmodes
- Optimise the **plane cavity geometry**
- Start construction of **Squeezed light source**
- R&D of the mode-matching for the main cavity to filter out technical noise.
- **Increase intracavity power** for higher sensitivity



Conclusion

- We currently resonate averages of 65 kW, or 2.5 $MW\,cm^{-2}$
- At these high circulating powers, we see thermal effects, mode-hopping, some unexplained modes and birefringent effects.
- Future work aims to investigate these fluctuations and increase stability at higher powers. Furthermore, introducing squeezed light to increase our sensitivity.

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