Reducing Thermal Noise with Mesa Beams

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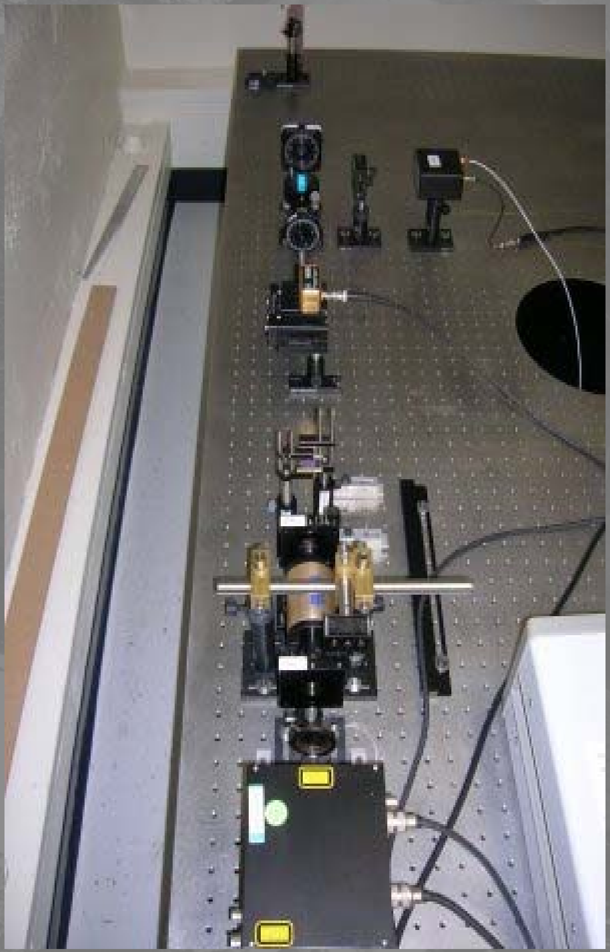
Overview

- Why non-Gaussian?
- Mesa beams
- Previous/ ongoing work
- Possible future work
- Other options

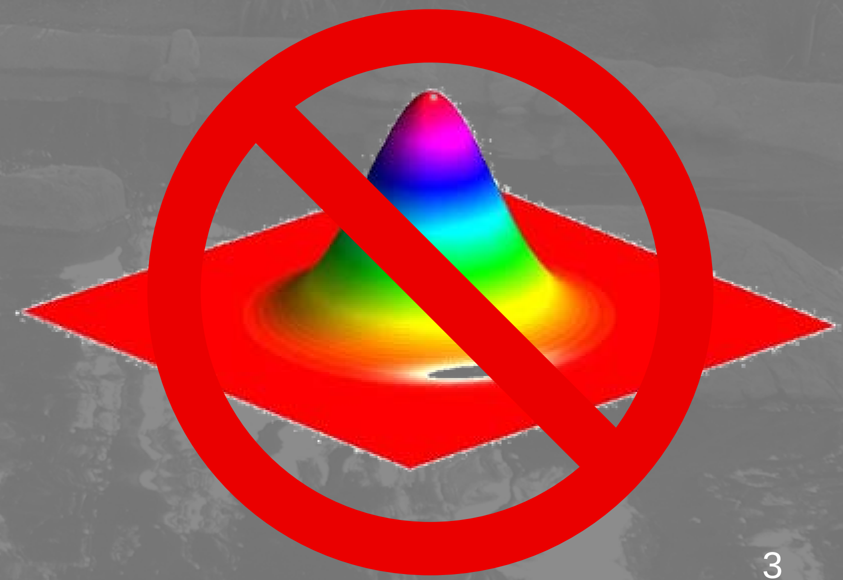


Thermal Noise

- Precision measurements can be limited by fundamental thermal noise e.g. LIGO
- Two approaches to thermal noise
  - change coating
  - change beam

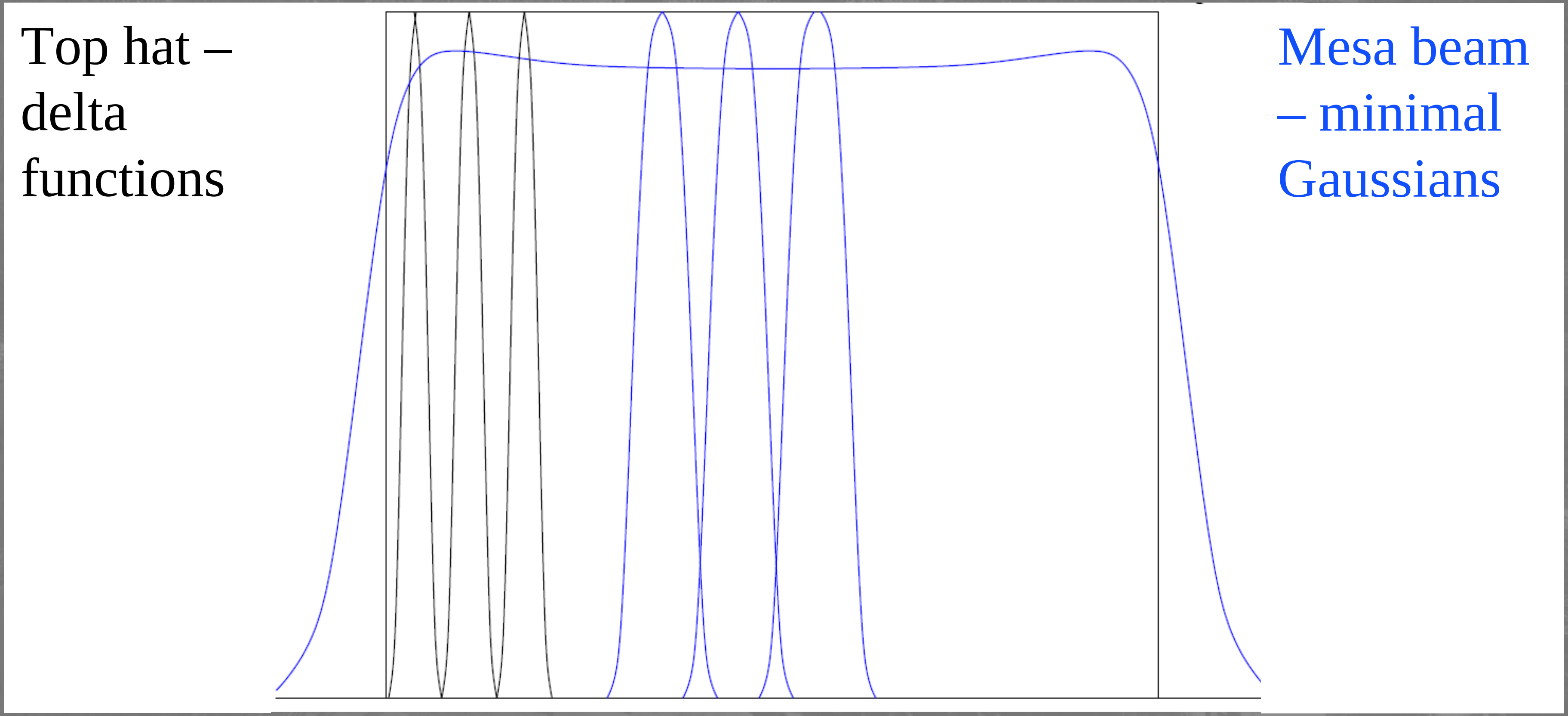
- Thermal noise scales inversely with spot size

- Gaussian beams are non-optimal



Mesa beam - Construction

- Idea: Big, flat beams are better
- Achieve compromise between flatness of top and diffraction losses

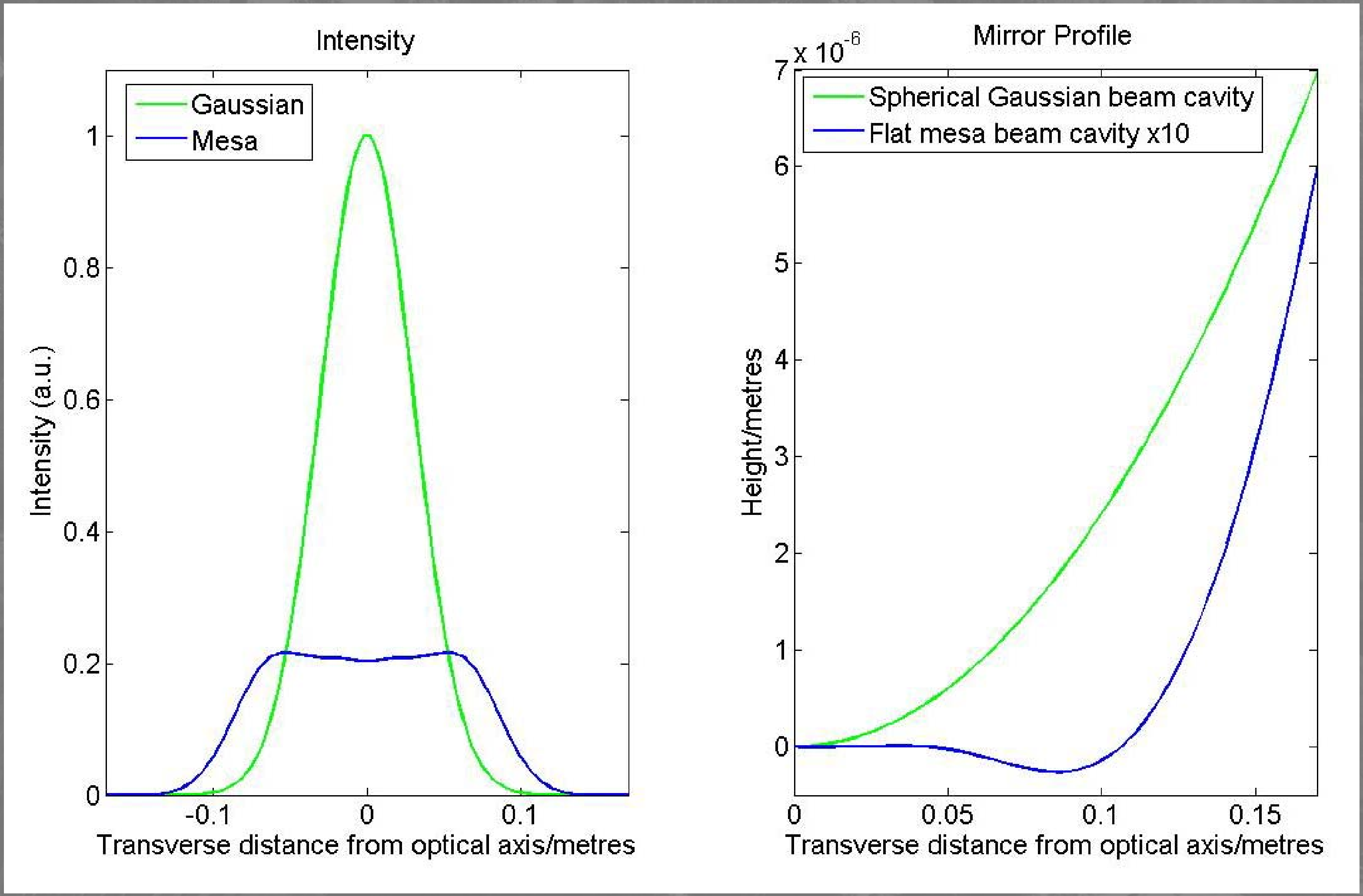


Thermal noise reduction

Noise Source	Fused Silica (34x20cm)
Coating Brownian	~1.9
Substrate Brownian	~1.6
Coating Thermoelastic	~1.9
Substrate Thermoelastic	~2.2

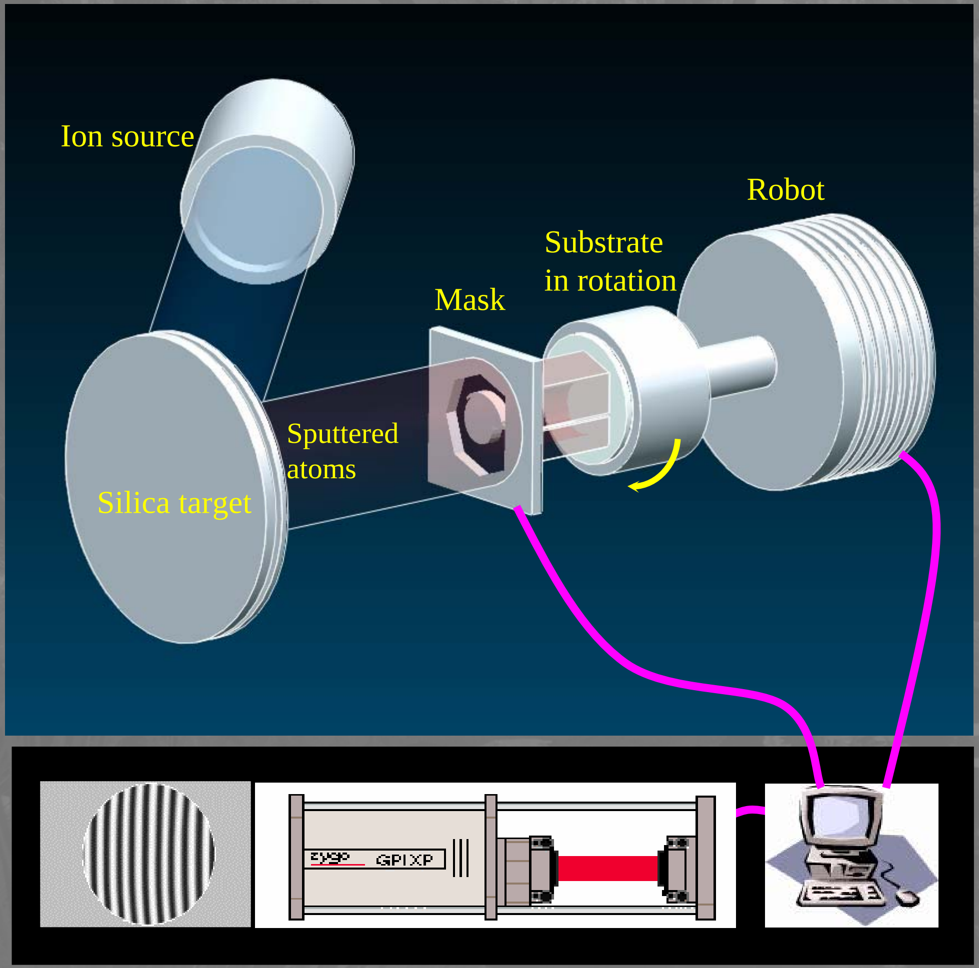
- Ratio of displacement noise Gaussian/Mesa in mHz$^{-1/2}$
- Single fused silica test mass
- Conclusion....noise down by x2
- No measured values yet

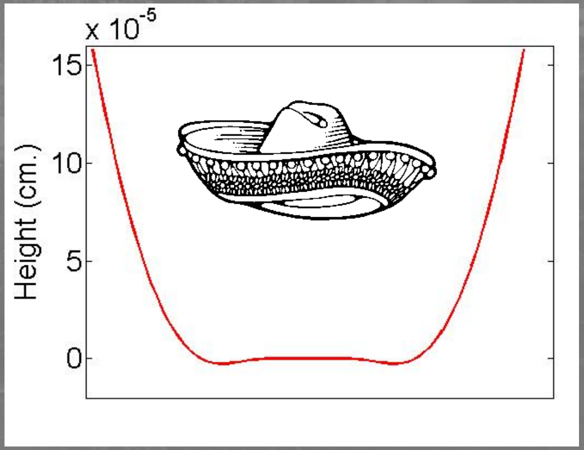
Comparison



Intensity
Gaussian
Mesa
Intensity (a.u.)
0
0.2
0.4
0.6
0.8
1
-0.1
0
0.1
Transverse distance from optical axis/metres
Mirror Profile
x 10^-6
Spherical Gaussian beam cavity
Flat mesa beam cavity x10
Height/metres
0
1
2
3
4
5
6
7
0
0.05
0.1
0.15
Transverse distance from optical axis/metres

Mirror Construction

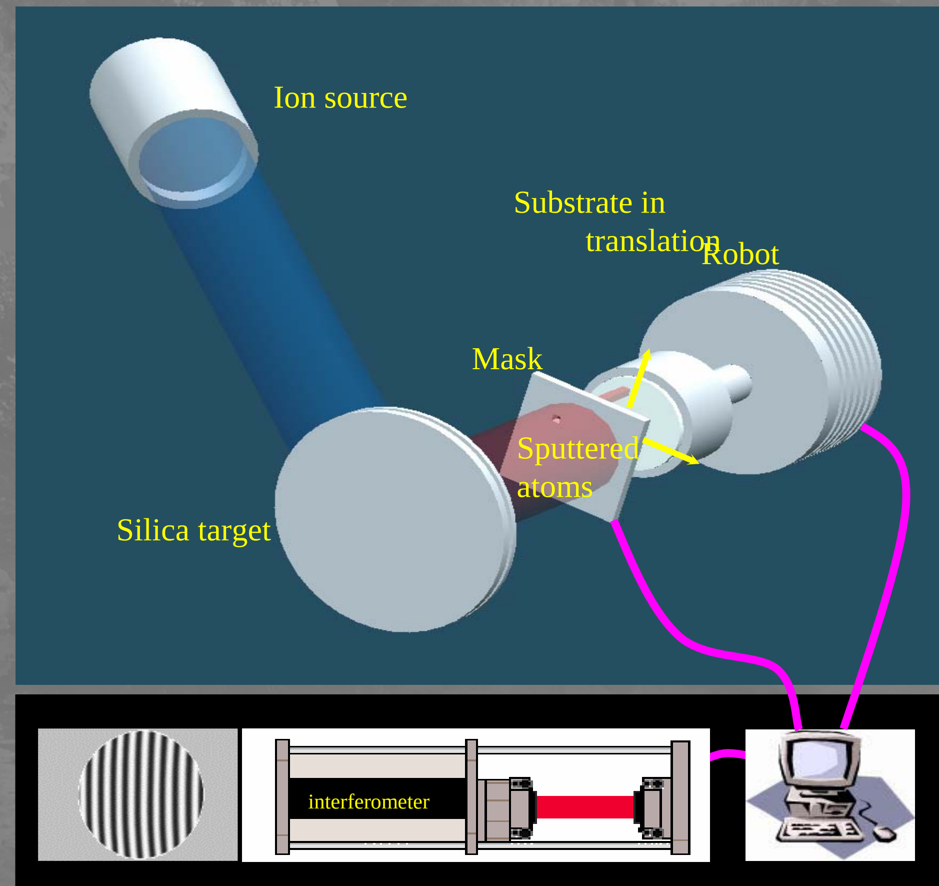




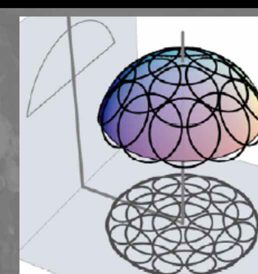
- Two step process
- Step 1
  - » Rotation gives rough shape
- 500 nm/mm

Mirror Construction

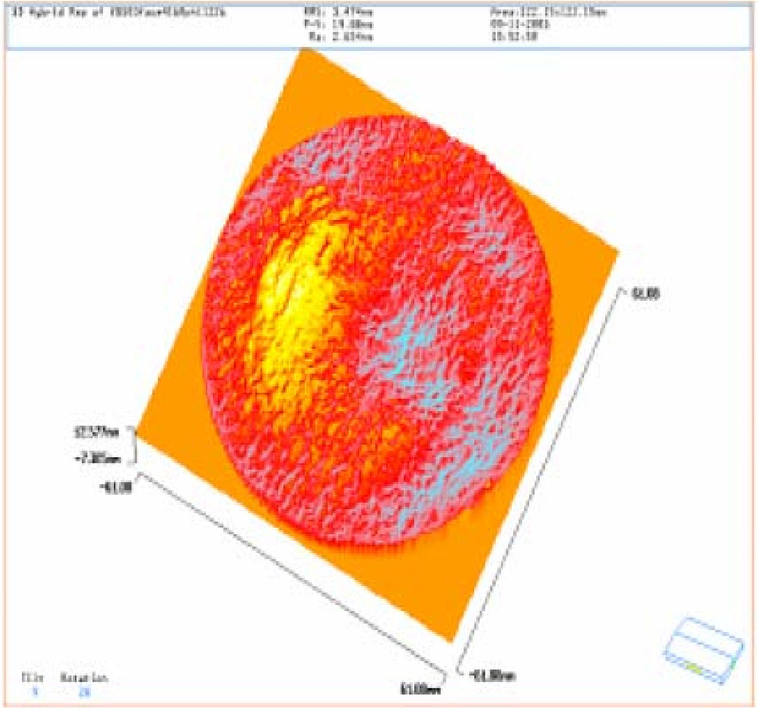
- Stage 2
- Atomic pencil
- Large diameter optics are easy
- Technique limited by metrology
- Magnetorheological finishing is also an option
- Subaperture stitching interferometry

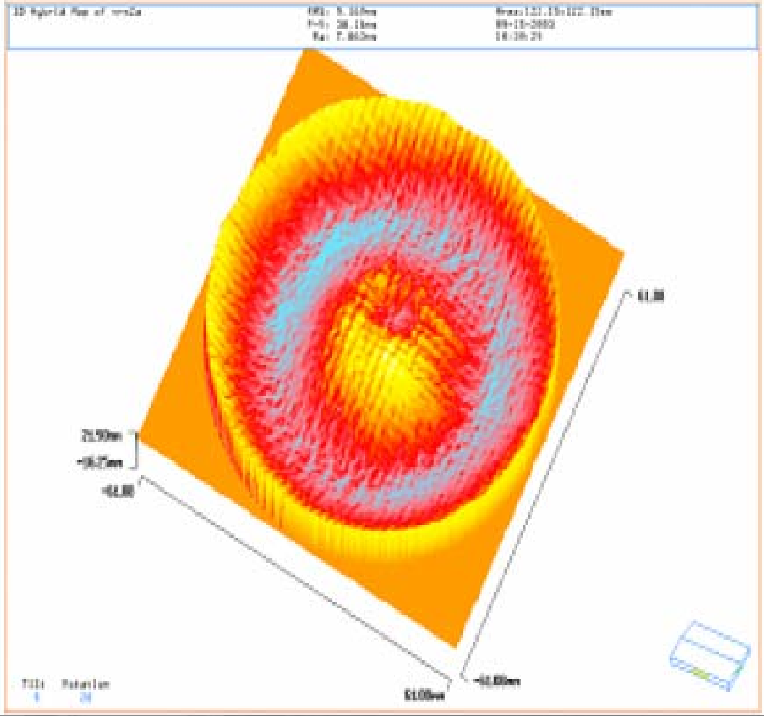


QED Technologies



MH Coating

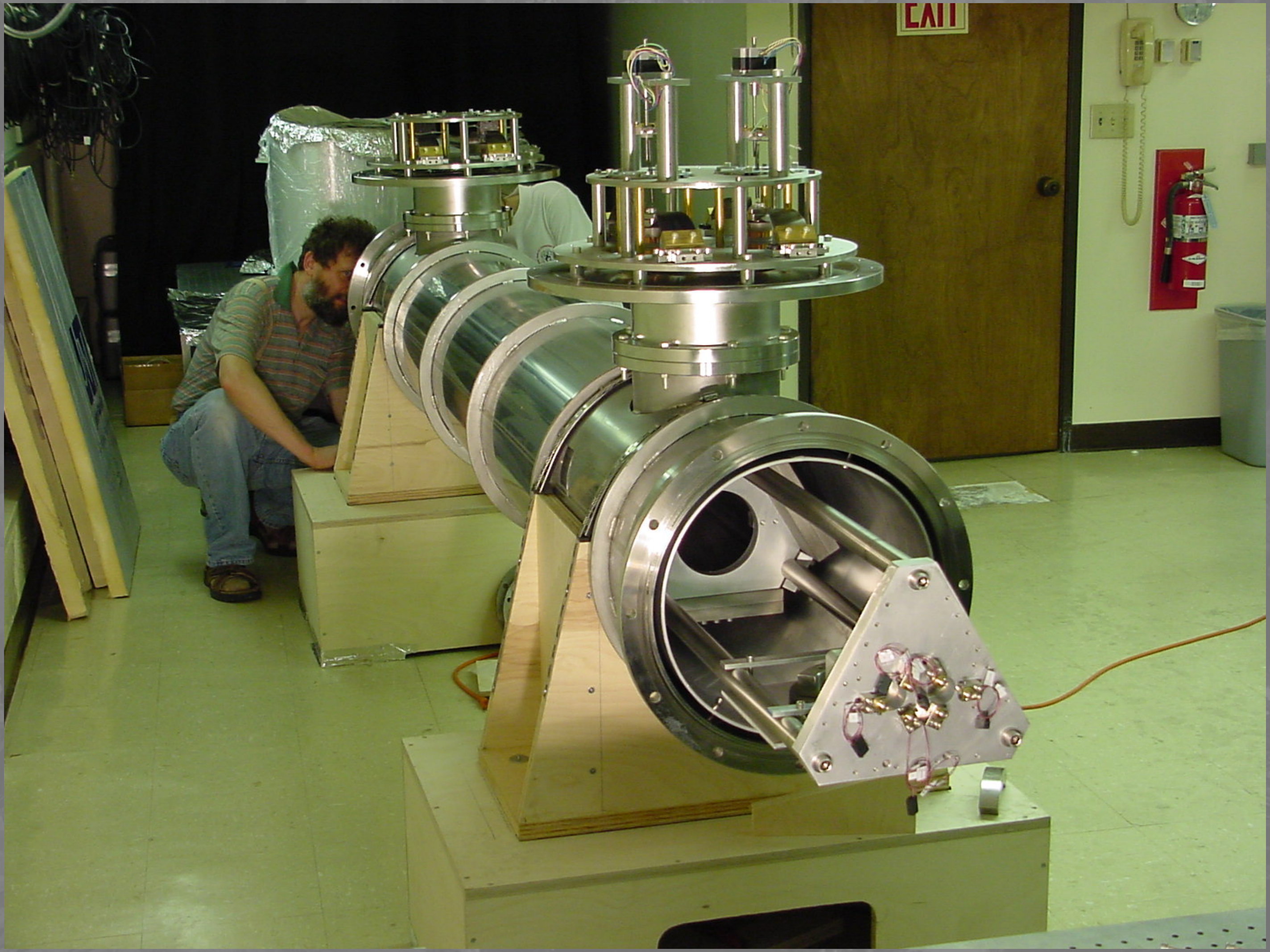




- Before corrective coating
- After

Experiment

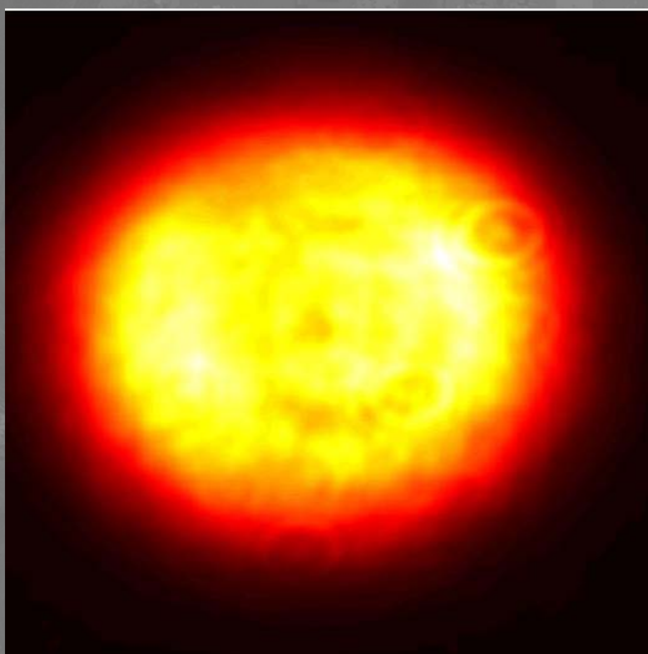
- Design and construction of single prototype cavity
- Begin evaluation of mesa beams as an option for future GW detectors

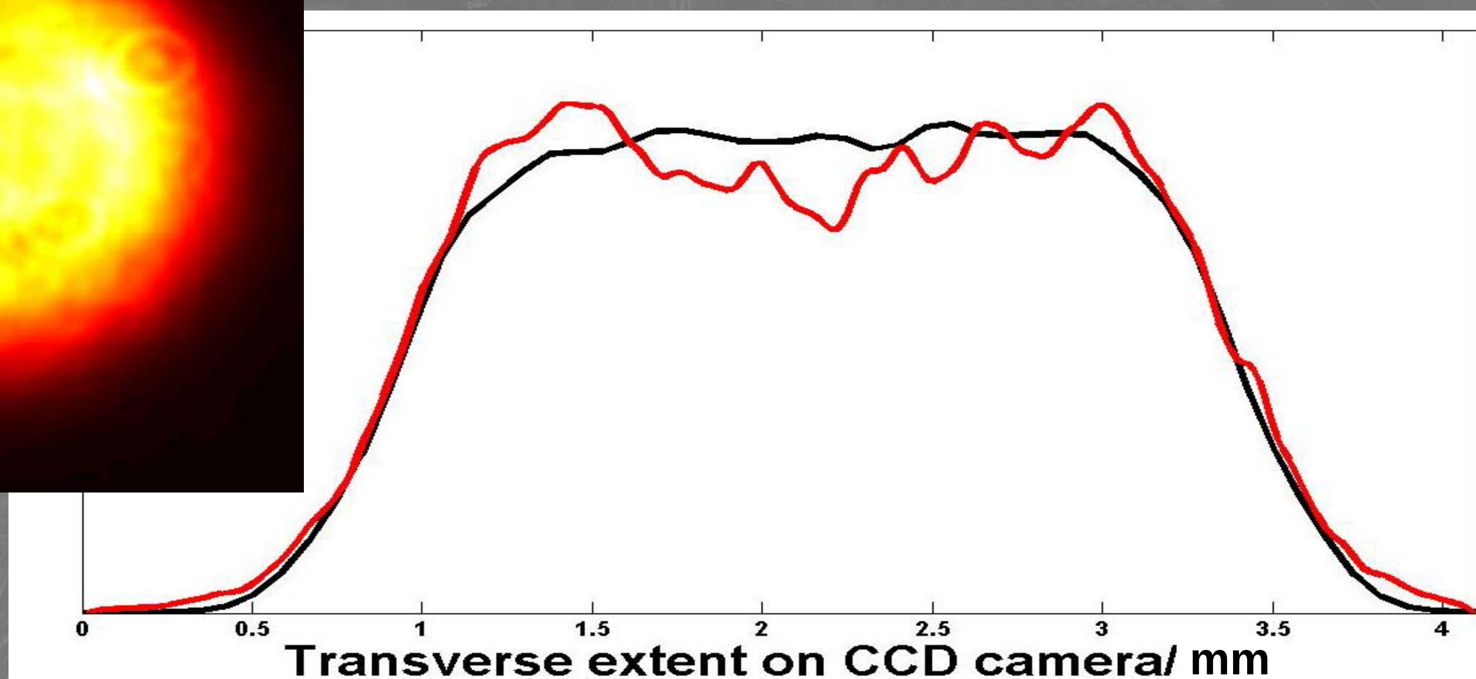


Fundamental

SIMULATION – idealised optics and alignment

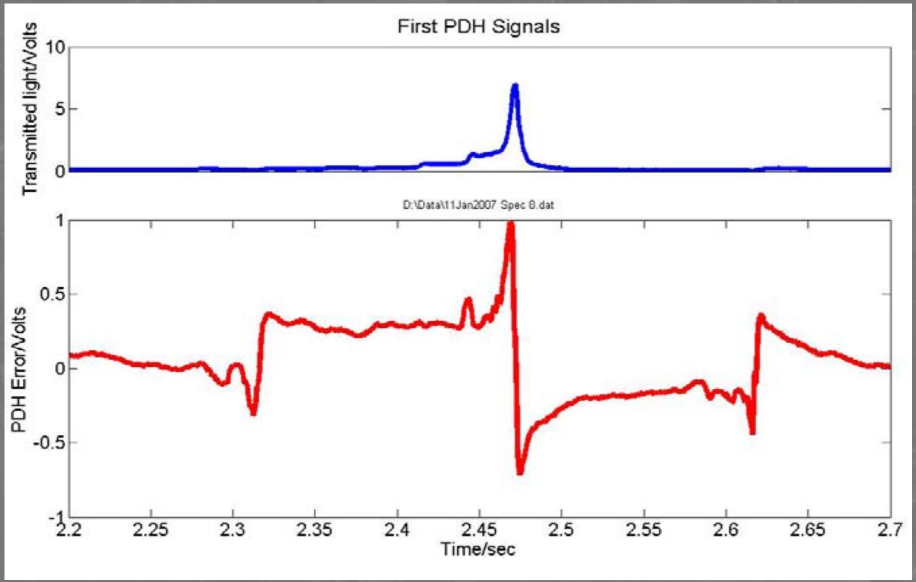
EXPERIMENTAL DATA





Coupling and Locking

- Theoretical coupling with Gaussian beam:
  - **~94% at MH mirror**
  - **~91% at waist**

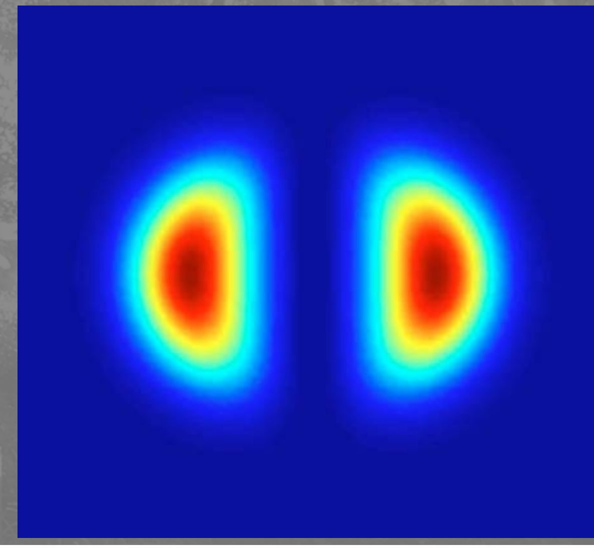


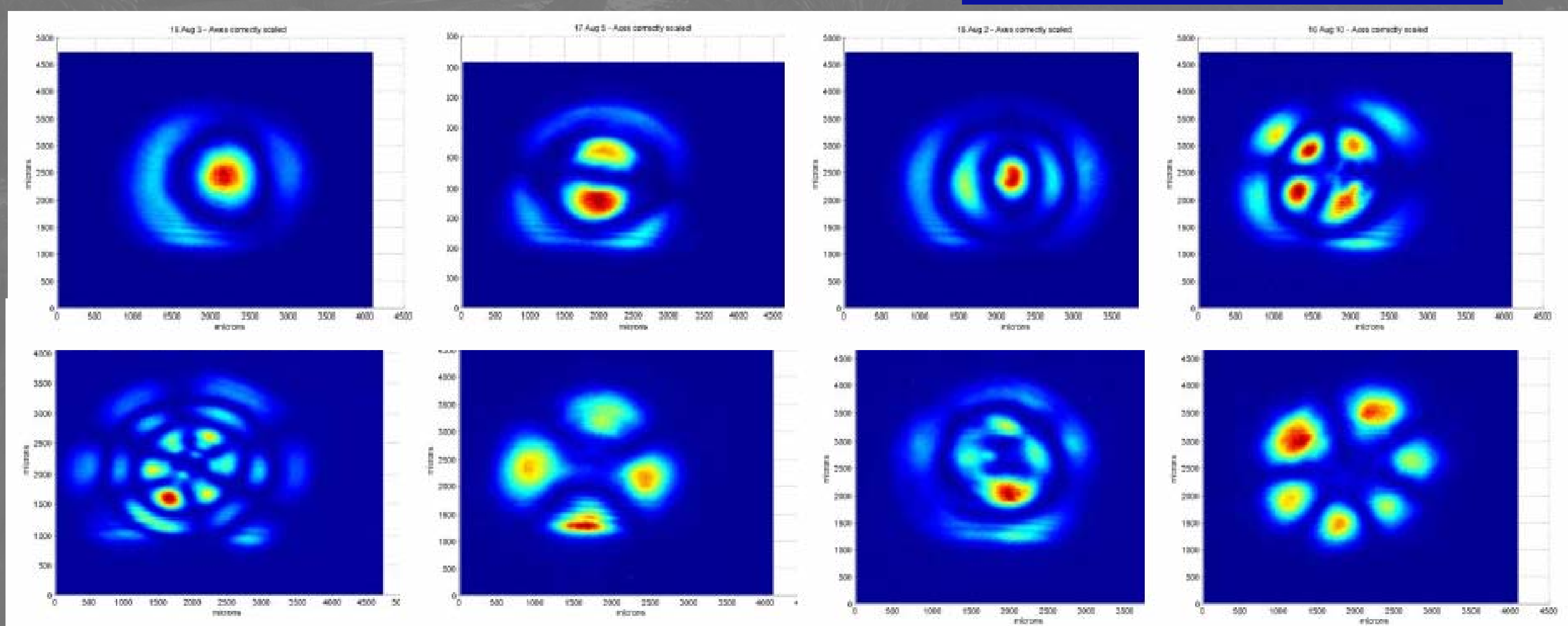
- Pound Drever Hall locking

- Standard techniques still work

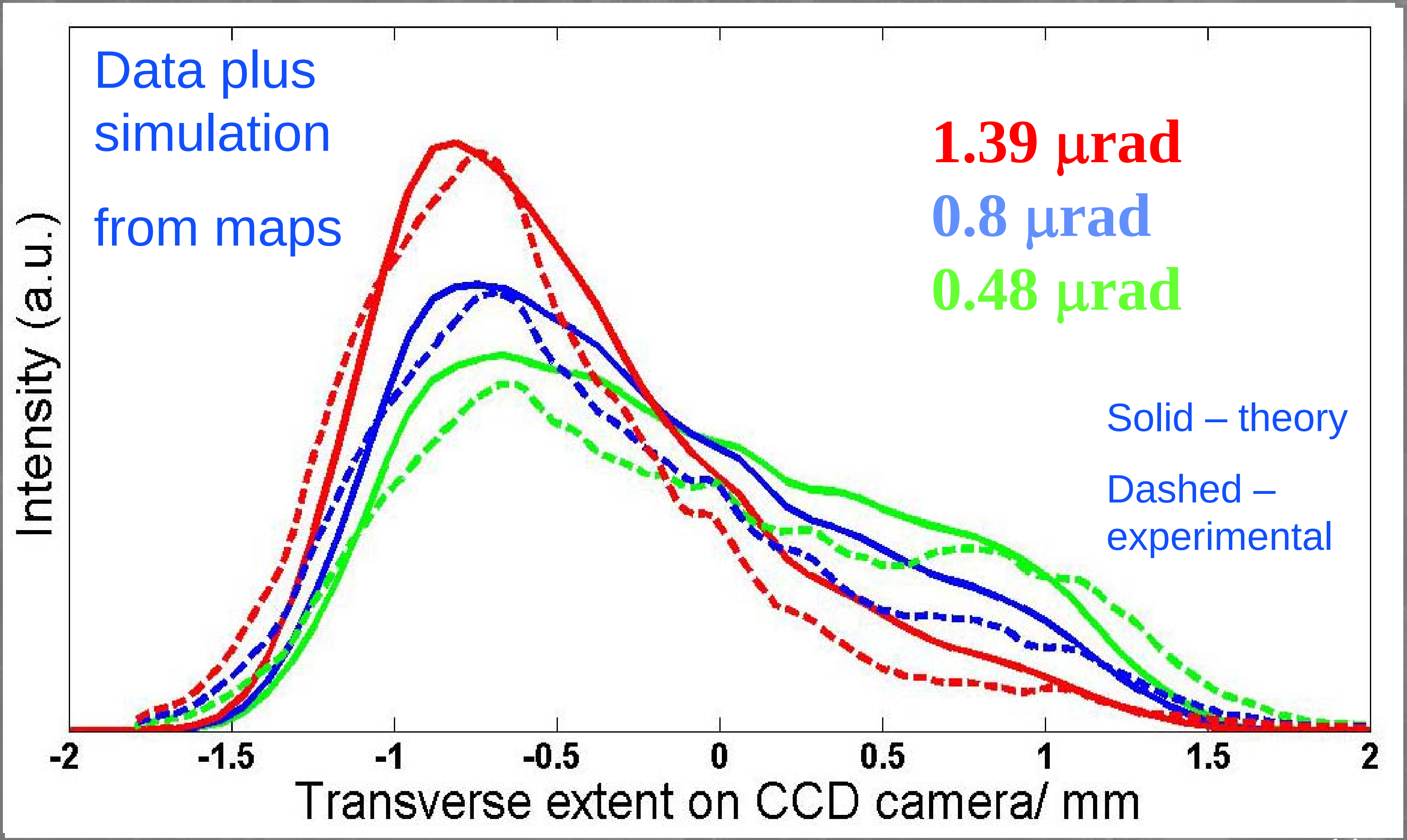
Higher order modes

- Odd contribution upon mirror tilts is just like $HG_{01/10}$
- ‘Hermite’ and ‘Laguerre’ families as for GB
- Differential wavefront sensing
  - » successfully modelled - student project



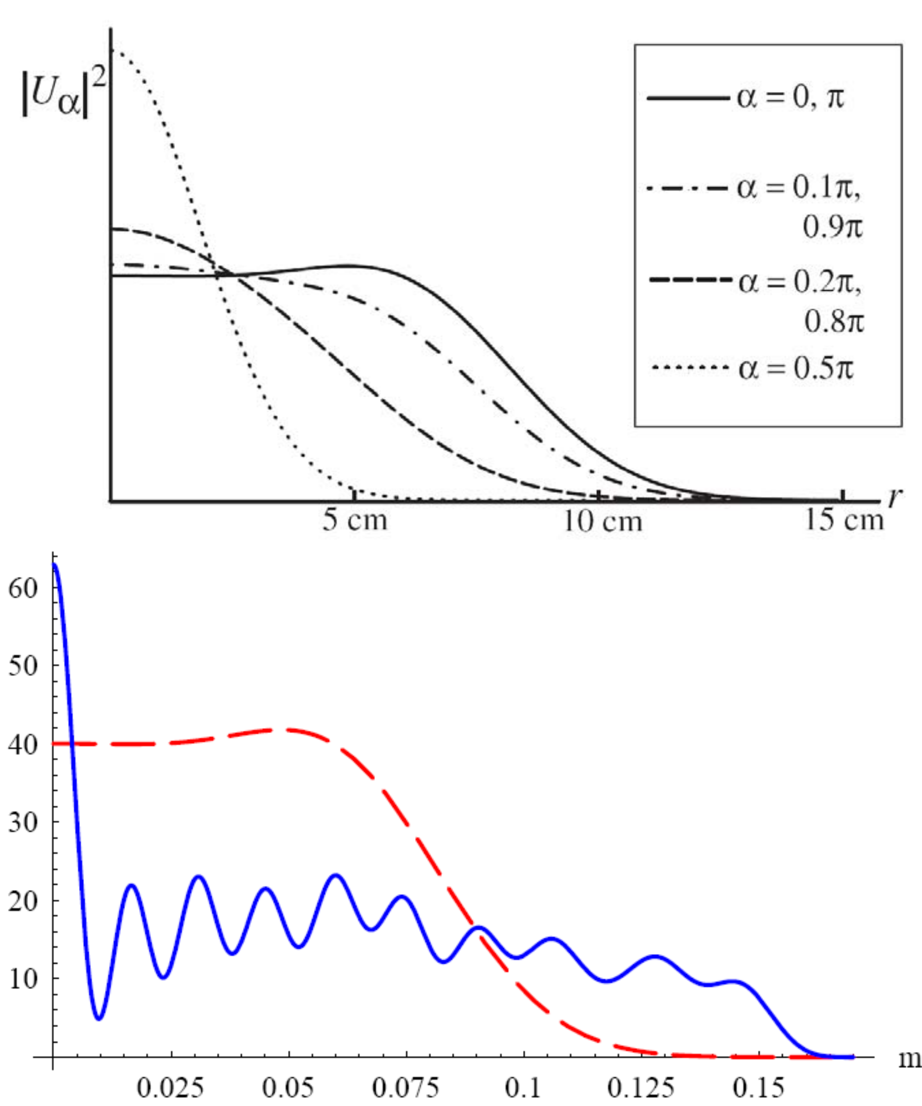


Mirror tilts



Alternatives

- Mesa beams are non-optimal
- Hyperboloidal beams
  - finite mirror effects
- High order LG modes
- Conical beams
- Fully optimised beams



Summary

- Mesa beams can reduce thermal noise effects by around a factor of two
- Work is ongoing to study the properties of these beams
- Moderately more susceptible to cavity perturbations
- Standard techniques still applicable
- There are other options but (to me) at present seem less favourable
- Main hurdle is construction of small optics


Thank you