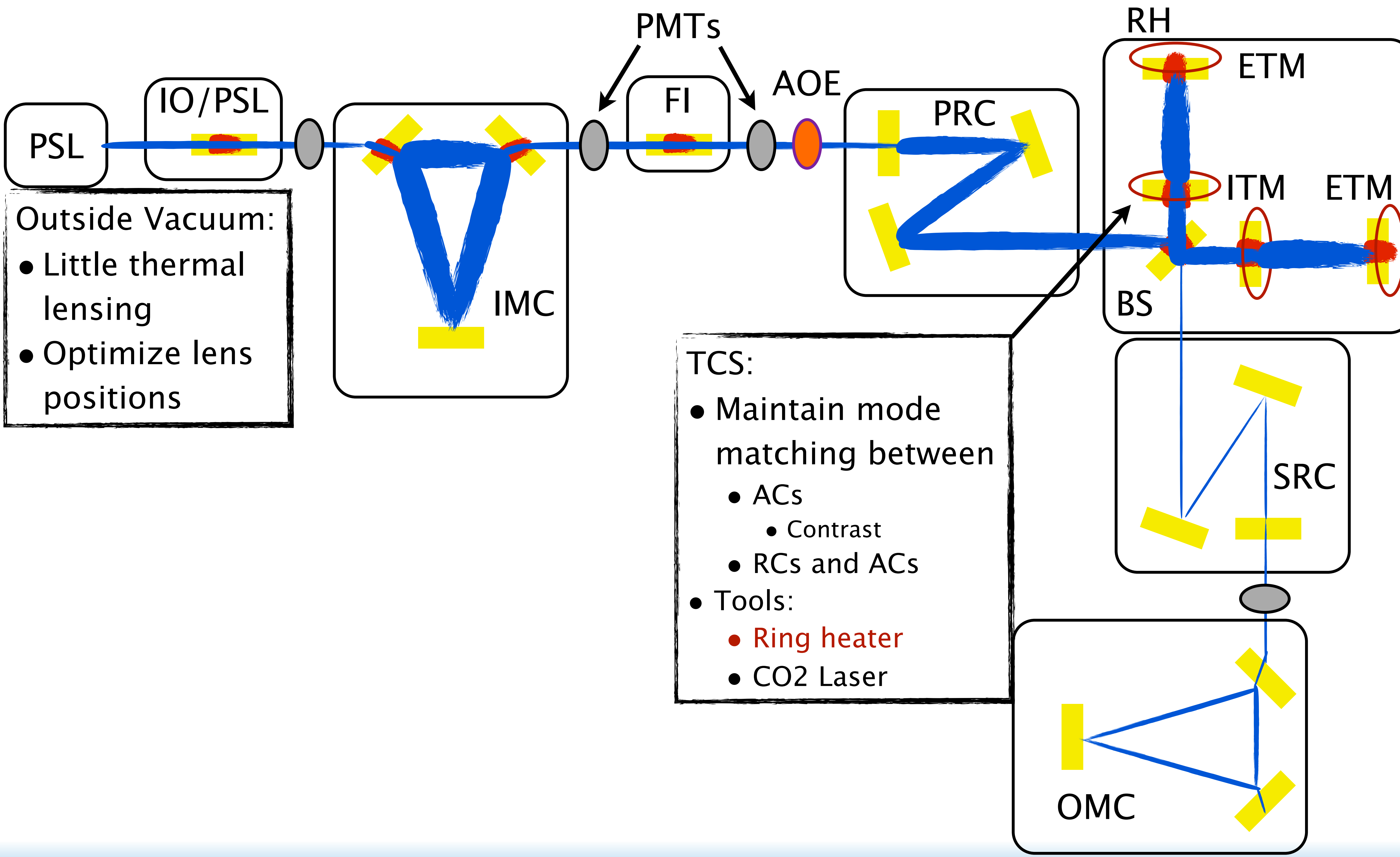
Status of University of Florida Experiments

Content:

1. Thermal Correction System
   a. Ring heater (for Giacomo Ciani)
   b. Adaptive Optical Element (for Paul Fulda)
2. Alignment Sensing and Control
   a. Fast beam pointing (for Daniel Amariutei and Paul Fulda)

Guido Mueller
University of Florida
@ LVC Meeting
Nice, March 2014

Thermal Correction System



Outside Vacuum:

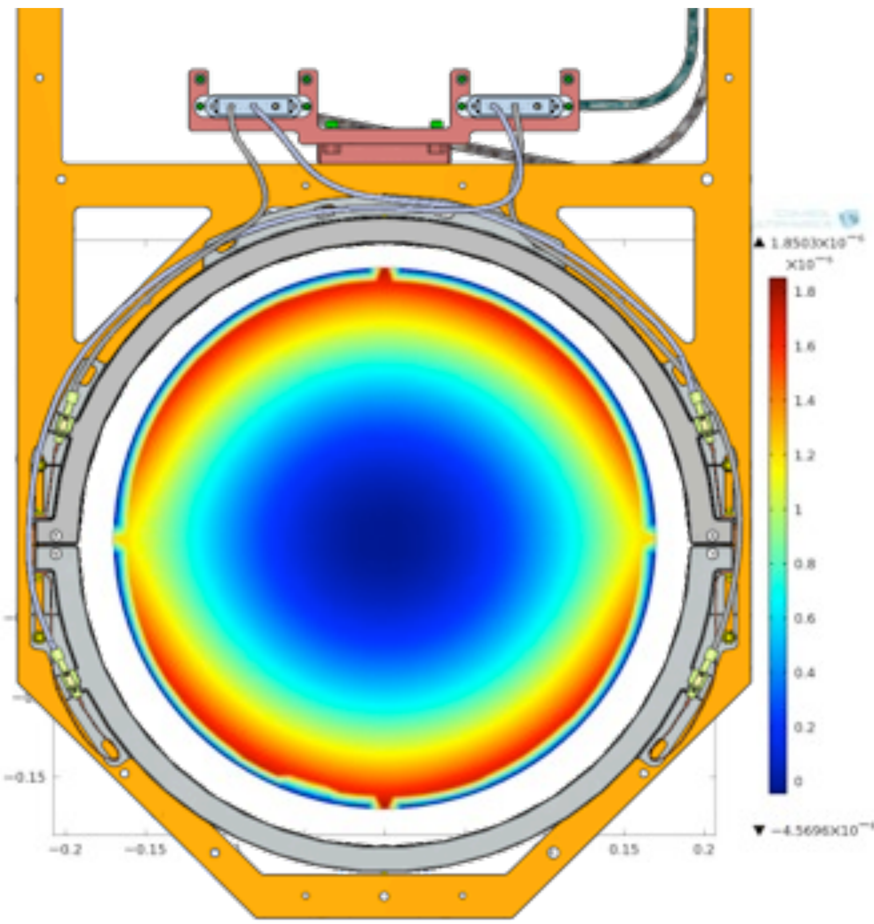
- Little thermal lensing
- Optimize lens positions

TCS:

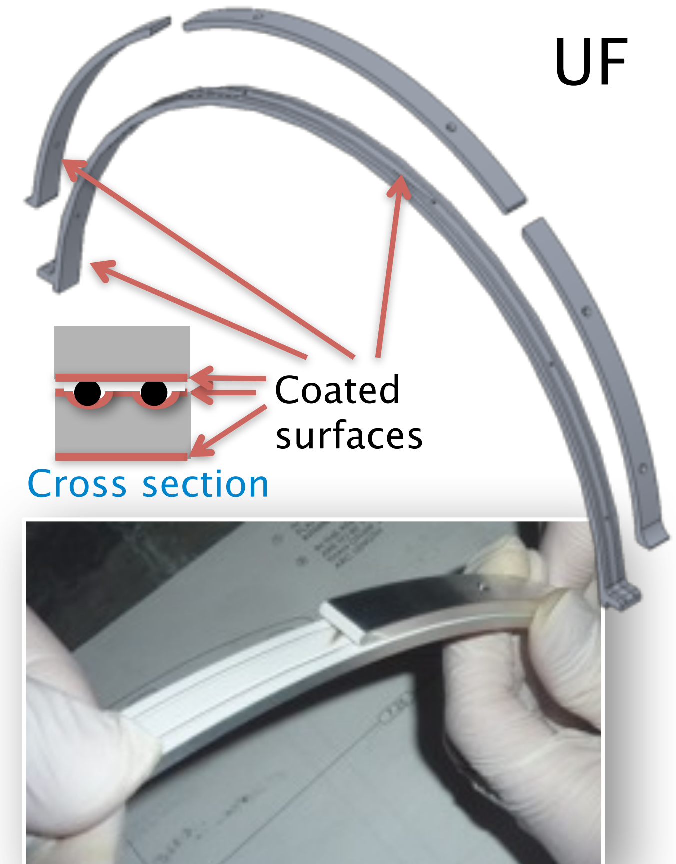
- Maintain mode matching between
  - ACs
    - Contrast
  - RCs and ACs
- Tools:
  - Ring heater
  - CO2 Laser

Ring Heater

aLIGO RH



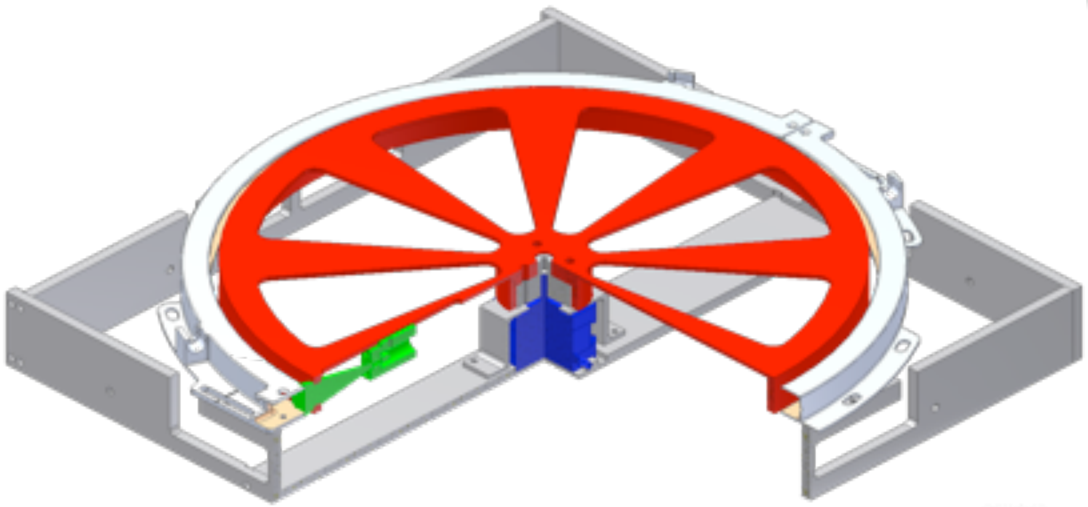
aLIGO RH:
- NiCr wire around glass rod
- Thermal inhomogeneities due to
  - heat sinks
  - winding densities
- brittle (but now installed)



UF RH:
- Alumina coated Al
- NiCr wires clamped
- Flexible
- Compatible with current shield
- Still need final RGA scan

Requirements:
- Astigmatism in reflection (AC side) < 3nm over ~8cm
- In transmission (RC side): Undefined

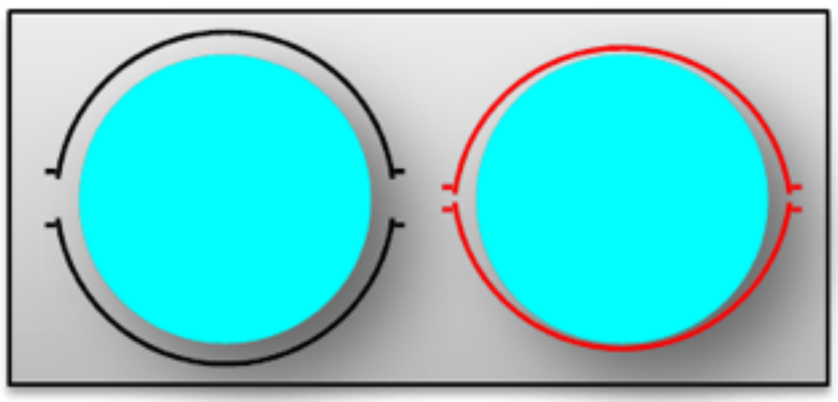
Ring Heater

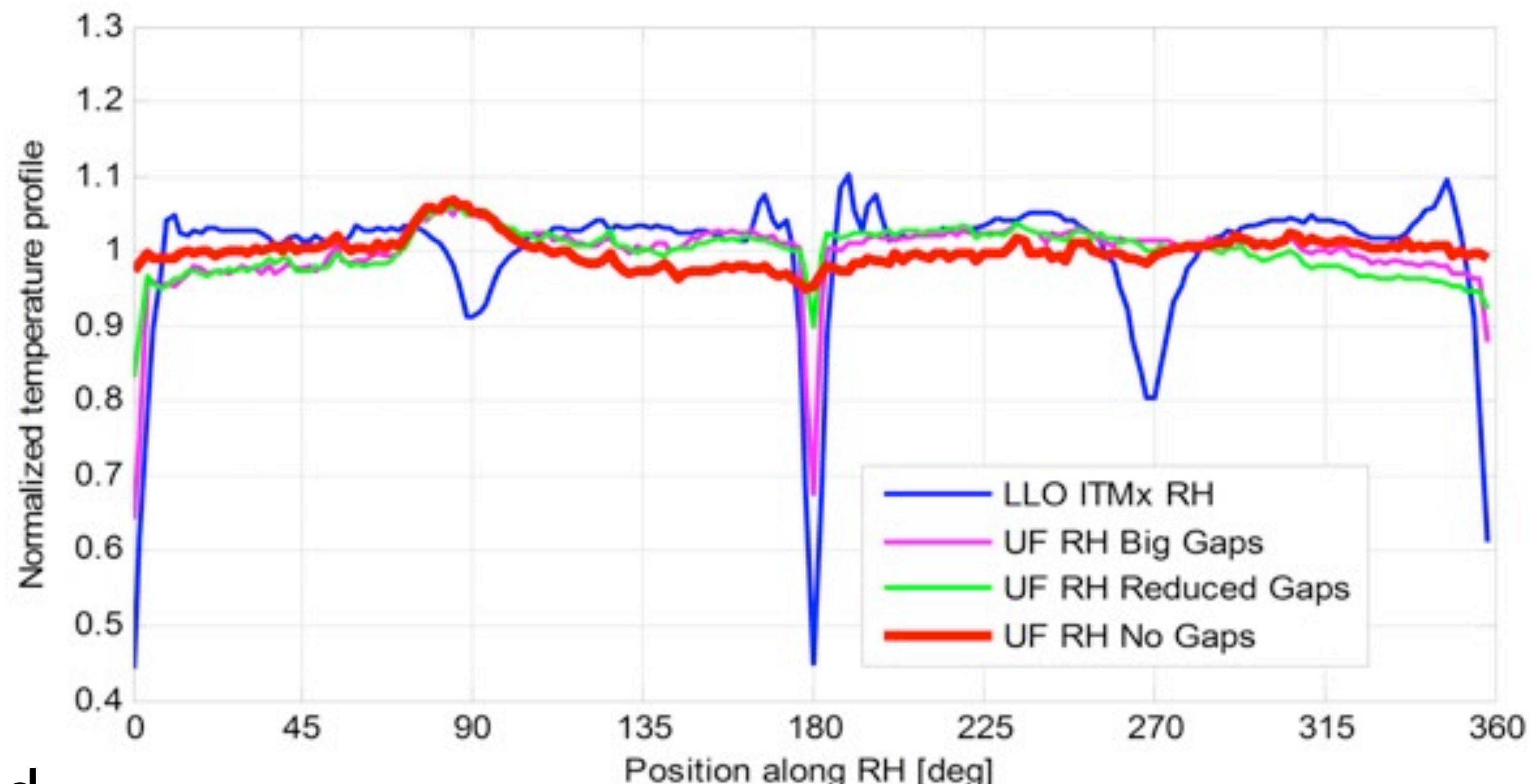


Characterize Ringheater at UF:

- aLIGO RH
  - Measure and match to minimize astigmatism
  - Best units: ~15nm

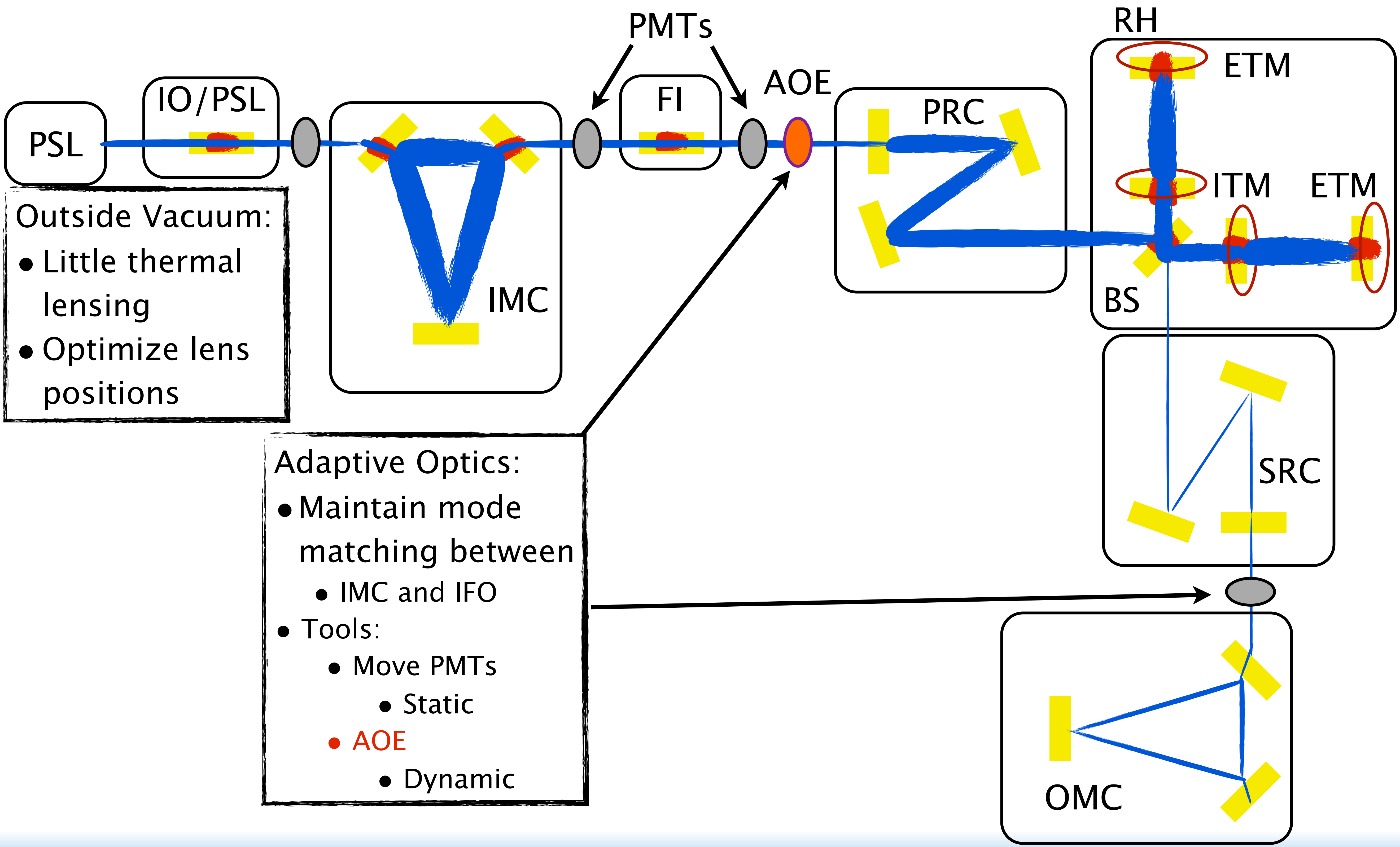
UF: with and w/o gap:





Better, but probably not needed.

Thermal Correction System



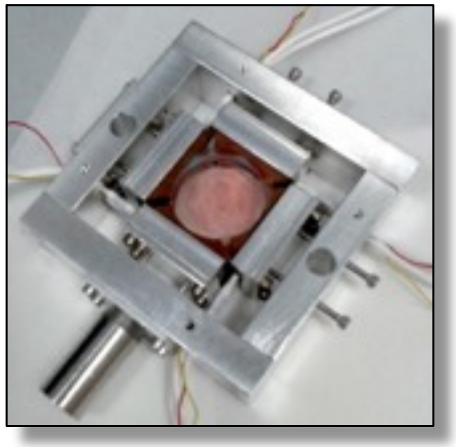
Outside Vacuum:

- Little thermal lensing
- Optimize lens positions

Adaptive Optics:

- Maintain mode matching between
  - IMC and IFO
- Tools:
  - Move PMTs
    - Static
  - AOE
    - Dynamic

Adaptive Optical Element



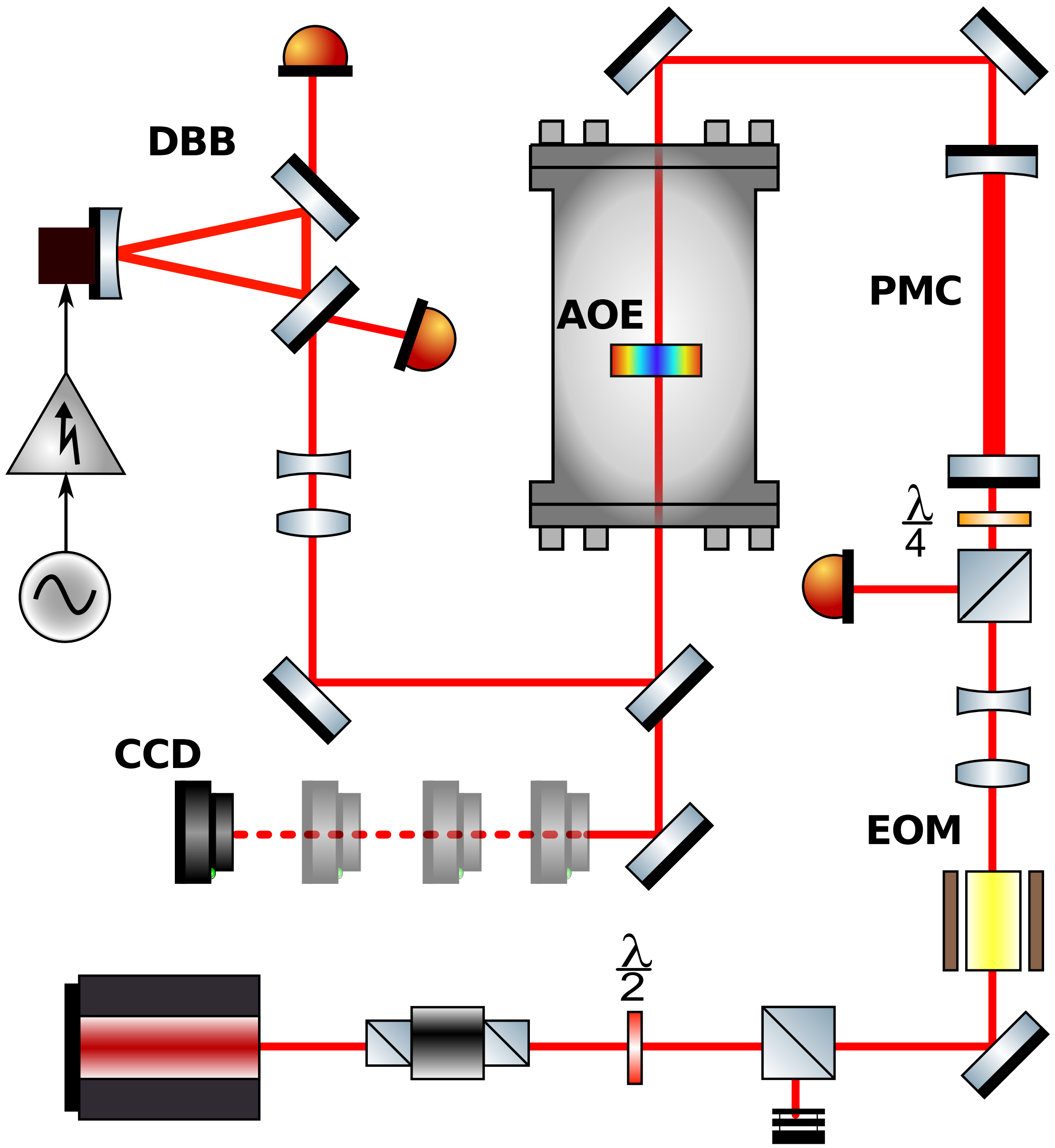
- Useful in two places:
  - Mode matching from IMC to PRC.
    - Must deal with high transmitted power (>50W).
    - Required optical power < $1/zR_{IMC}$ ~ 0.1 D.
  - Mode matching from SRC to OMC
    - Low transmitted power.
    - Required optical power ~0.15 D [1].
- Heat load to HAM table should be <1W.
- Should not add higher-order distortions to transmitted beam (mode purity >99%).
- Vacuum compatible, reliable actuator.

[1] LIGO-G1301154 S. Ballmer

Adaptive Optical Element

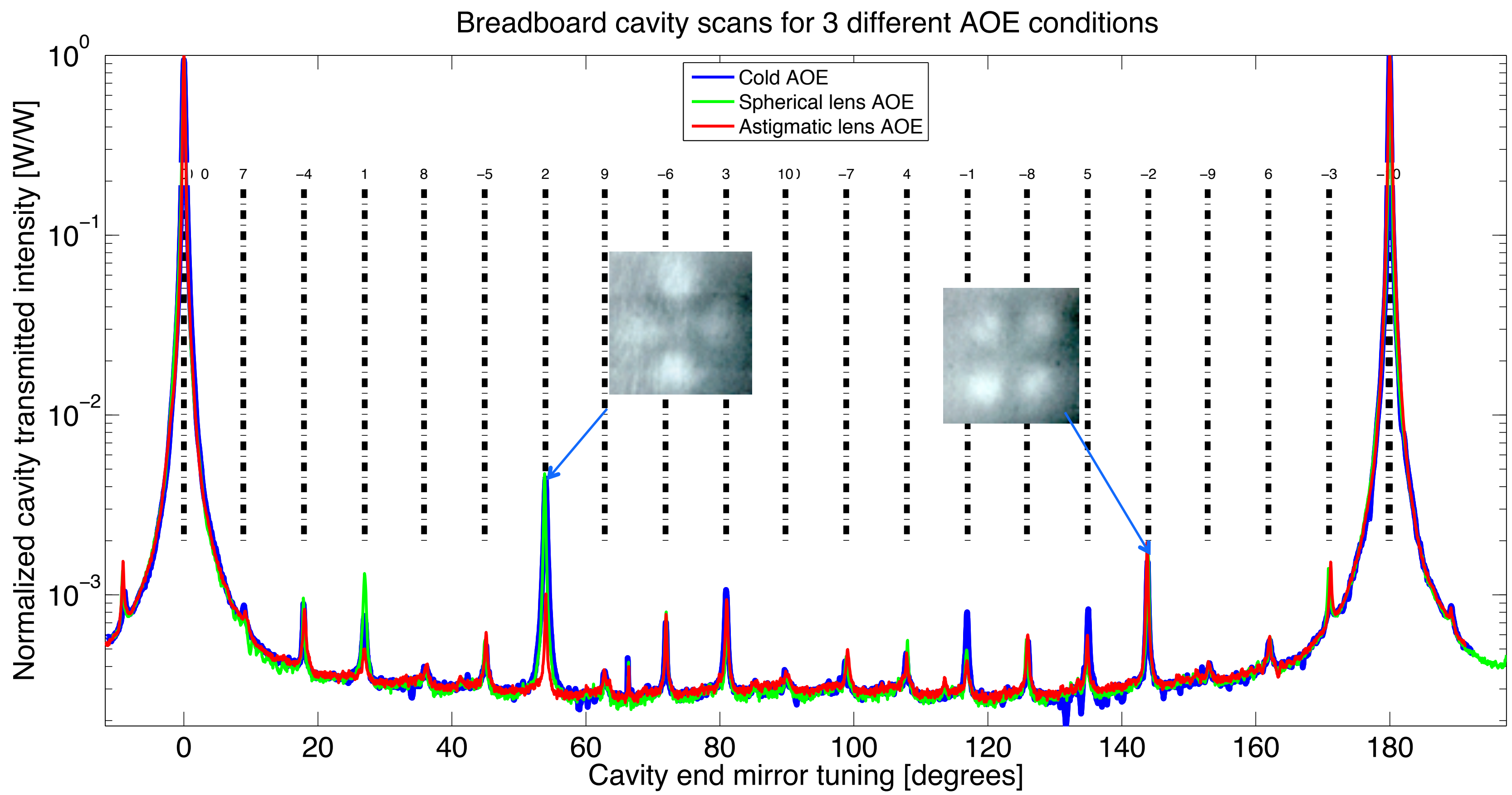
Testing in vacuum: DBB mode purity and range measurement

- Diagnostic breadboard of aLIGO PSL design used.
  - Consists of triangular PMC cavity with PZT mirror.
- Scan cavity and observe higher-order mode peaks.
- Perform beam scan to find beam parameters.
- Actuate AOE at different levels, re-mode match and repeat scan, observe change in HOM content.
- Calculate AOE focal length.



Adaptive Optical Element

- Positive results shown at ~-0.05D (f~-20m) actuation:



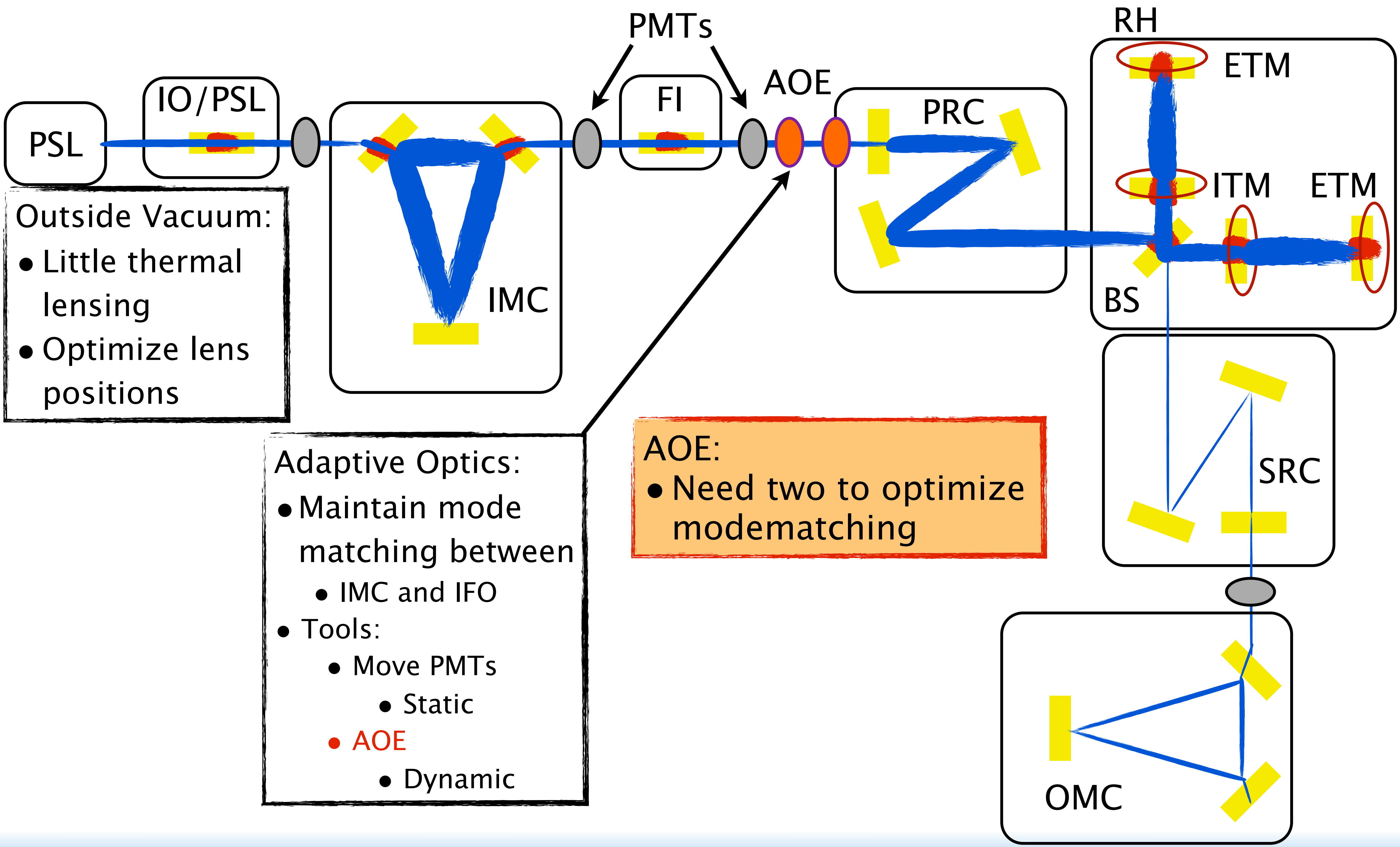
- Mode purity actually increased by astigmatic AOE heating.

Adaptive Optical Element

Conclusions and next steps

- Design performed well in vacuum from mode purity and dynamic range perspective.
- Power in too much (>10W to reach ~0.5D) though.
- Implement improvements in design:
    - Use optics with polished barrel.
    - Use reflector to direct radiated heat to tank walls rather than bench.
    - Try micro-etching heater material (NiCr) directly on optic barrel (alternative design).
- Run up to high-power again with recent alterations check power efficiency.
- Test for full vacuum compatibility at Caltech facility.

Thermal Correction System



Outside Vacuum:
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Adaptive Optics:
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    - Static
  - AOE
    - Dynamic

AOE:
- Need two to optimize modematching

Thermal Correction System

Case studies:

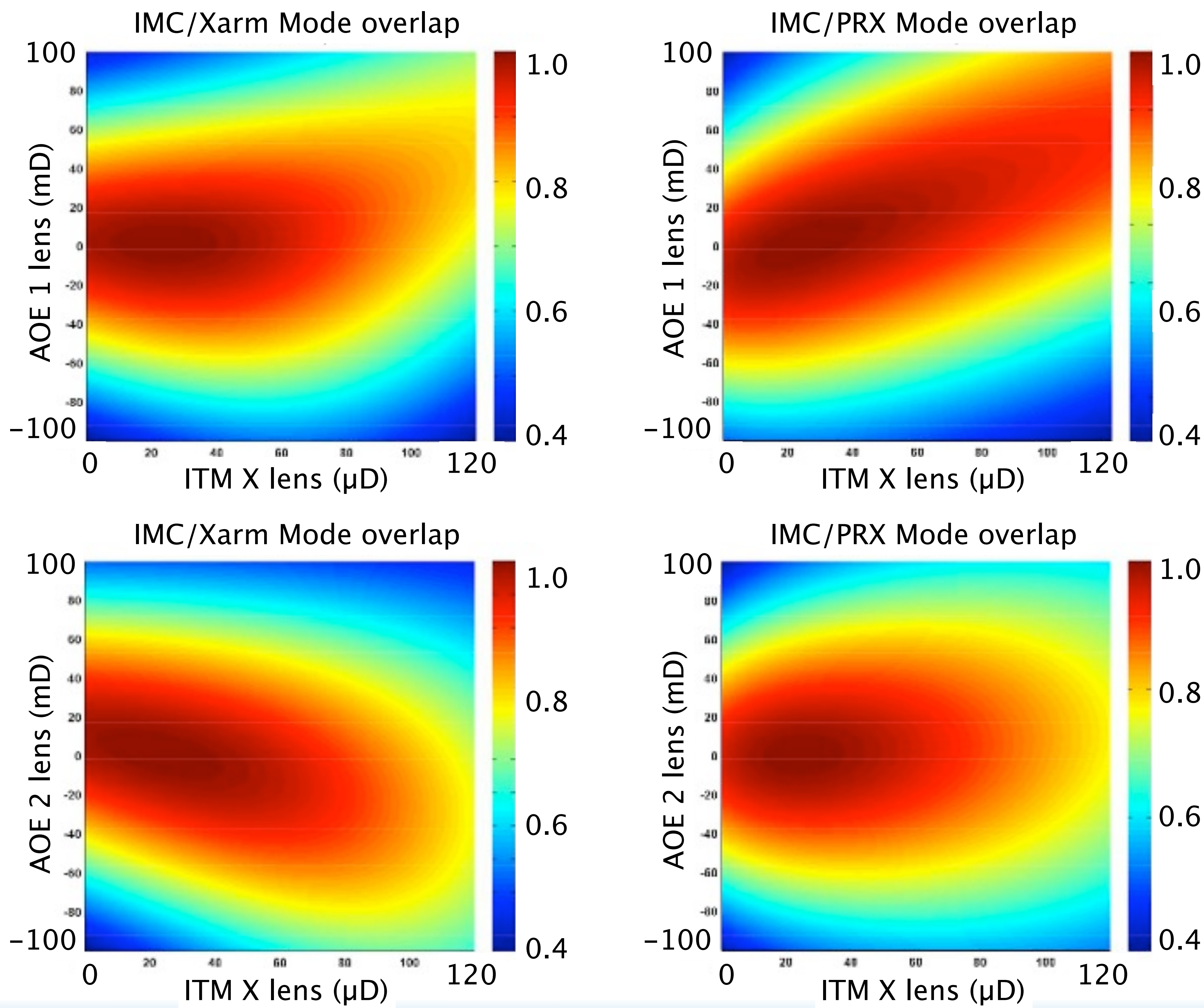
Thermal substrate lens
- Changes PRC mode
- Changes MM into AC from IMC

Note:
The mode matching between PRC and AC is fairly insensitive to substrate thermal lens

1μD ~ 1W input power

Assume no RH, no CO_2

Try to maintain MM from front end with different power levels



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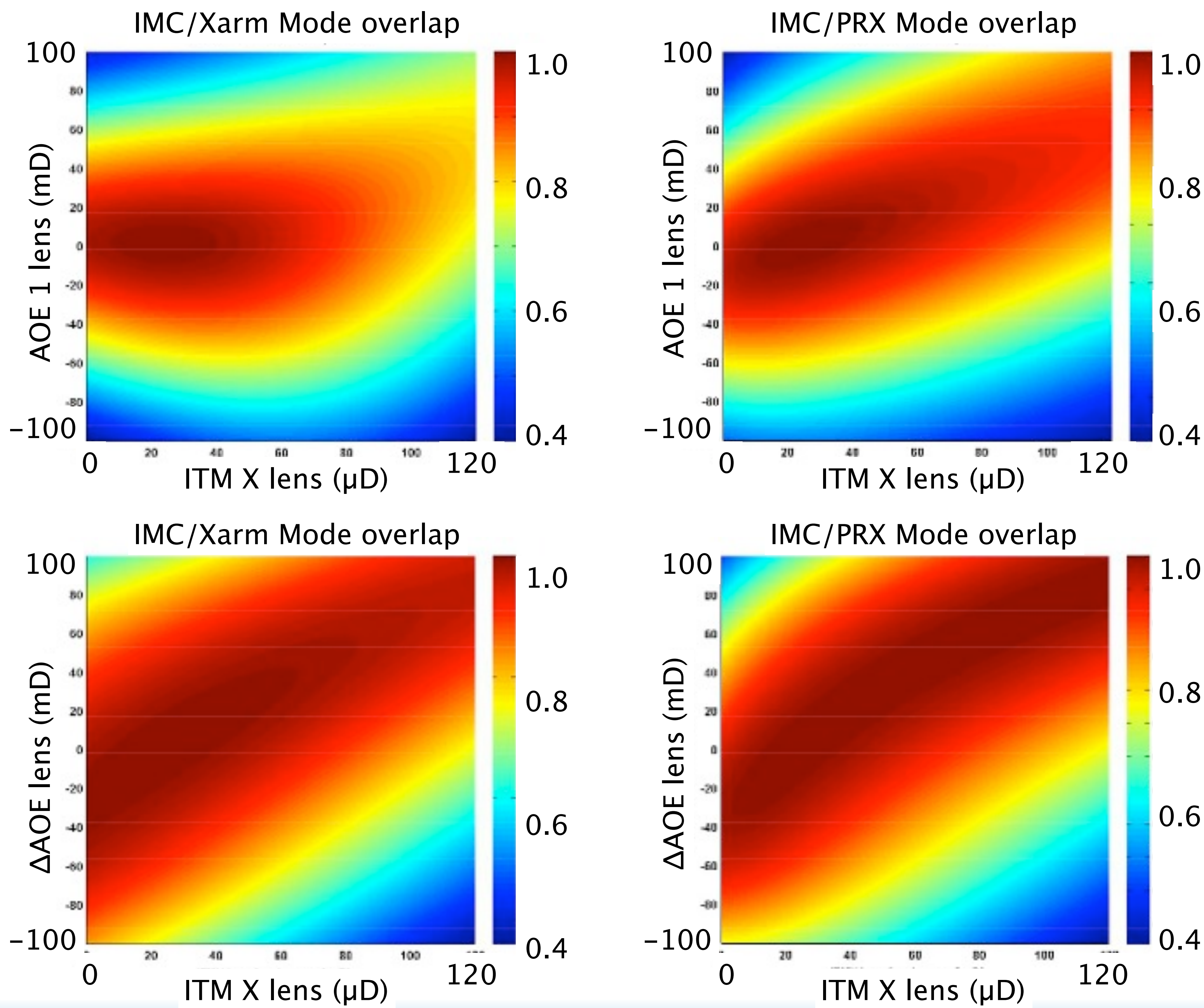

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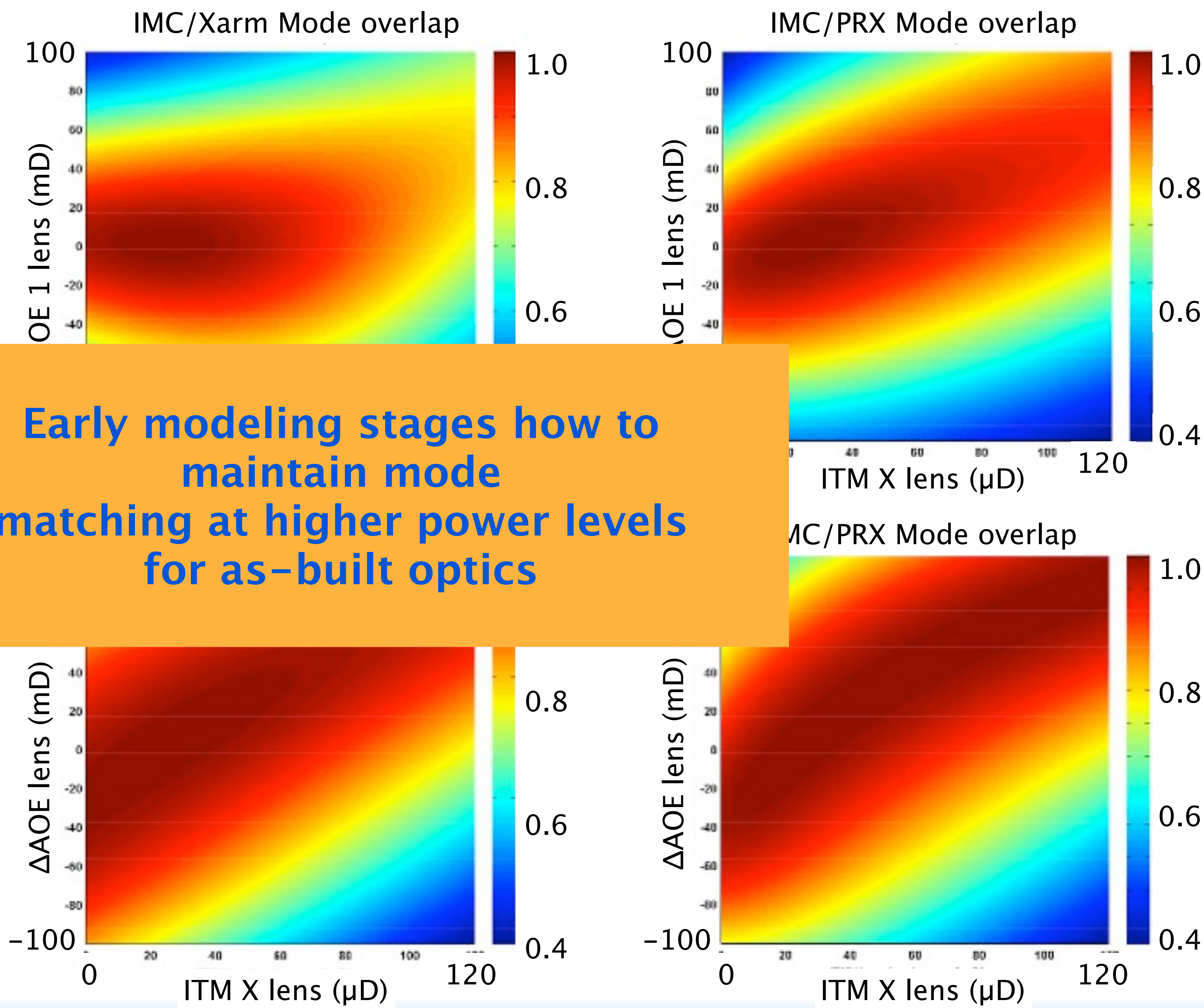
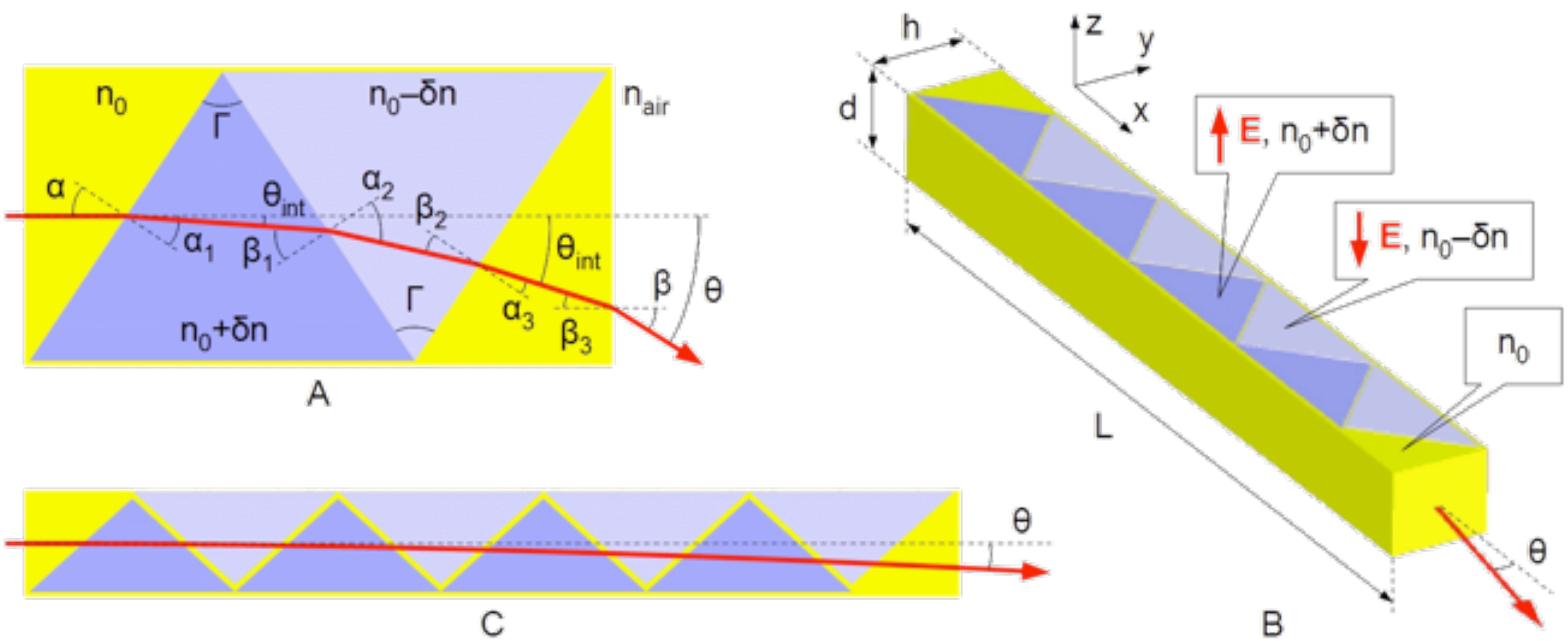


Early modeling stages how to maintain mode matching at higher power levels for as-built optics

Fast Beam Pointing

Motivation:
- Enable larger bandwidth in alignment servo systems
- Generate 10-mode at RF-frequency to enlarge design space for alignment sensing

How it works:



Idealized!

- electro optic effect:

$$\delta n = \frac{n_0^3 r_{33} E}{2} = \frac{n_0^3 r_{33} V}{2d}$$

- changing the voltages will change the deflection angle:

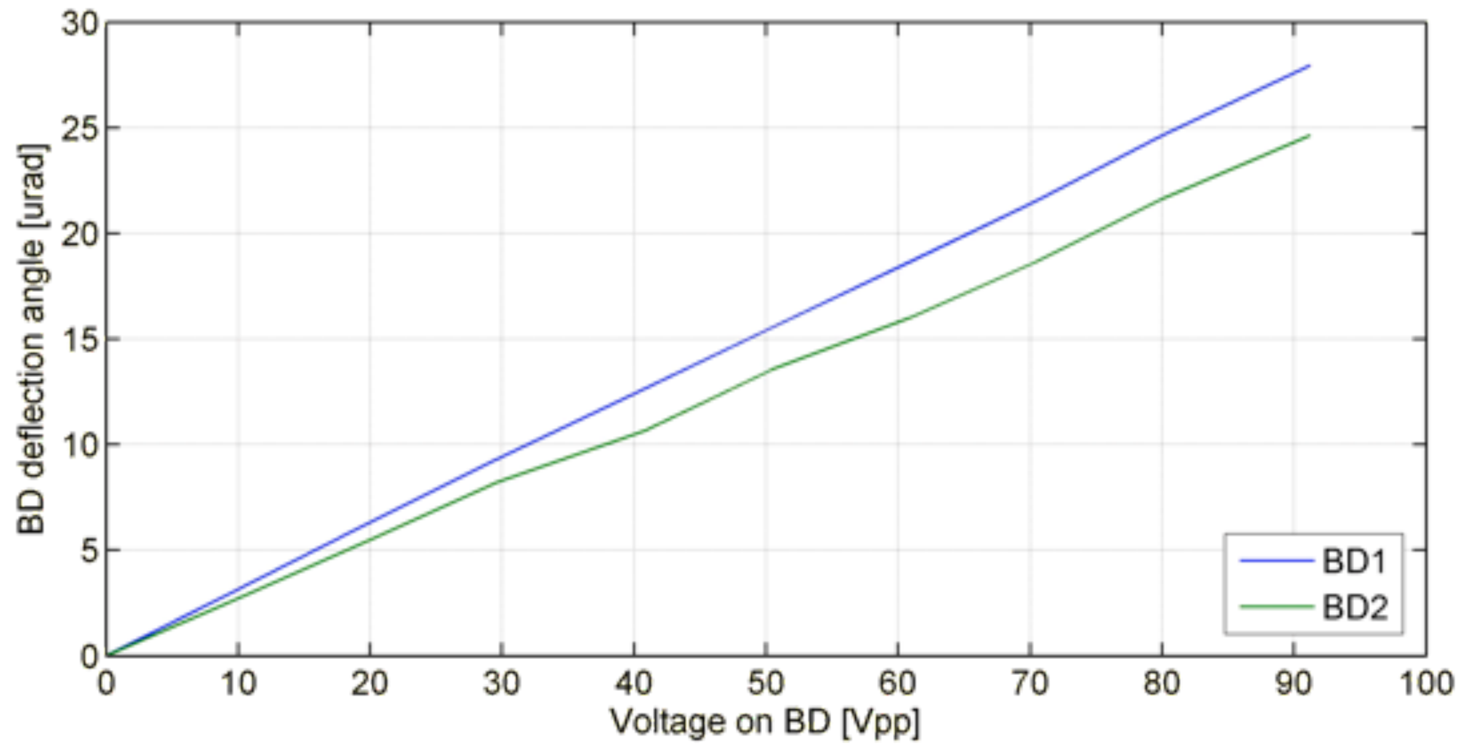
$$\theta = \frac{2L\delta n}{h} = \frac{n_0^3 r_{33} LV}{hd}$$

Fast Beam Pointing

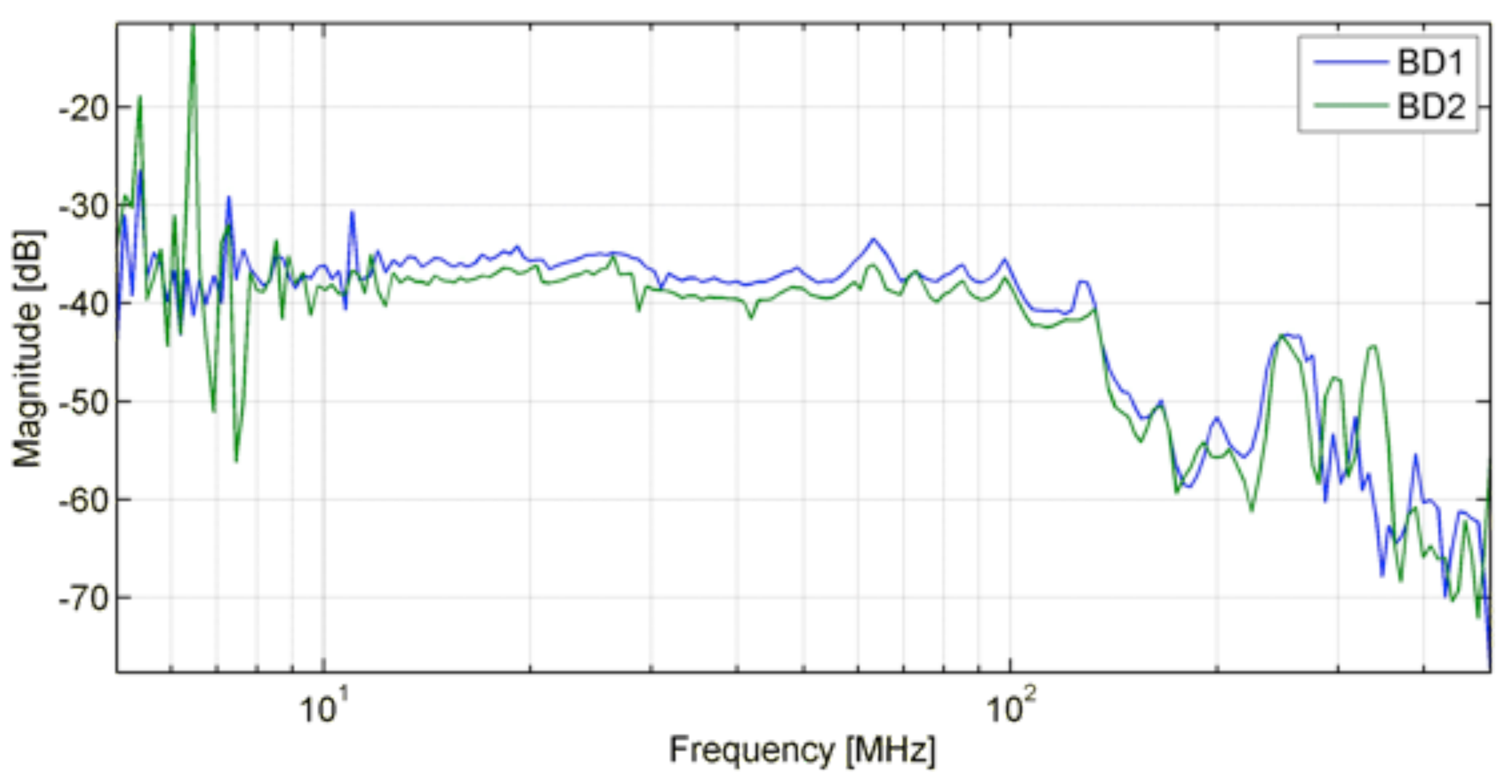
Basic Results:

• deflection efficiency
BD1: 0.30 μrad/volt
BD2: 0.27 μrad/volt

Divergence angle ~ 2mrad



• wide bandwidth response for 28 Vpp applied on crystals



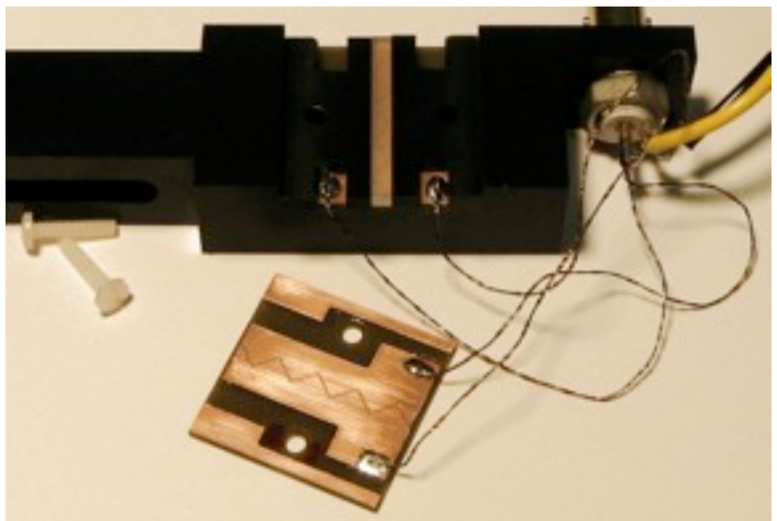
Fast Beam Pointing

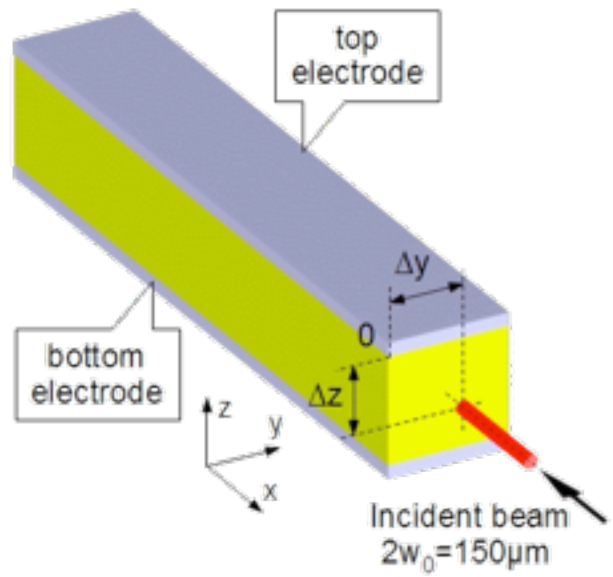
Testing it:

$LiNbO_3$ crystal

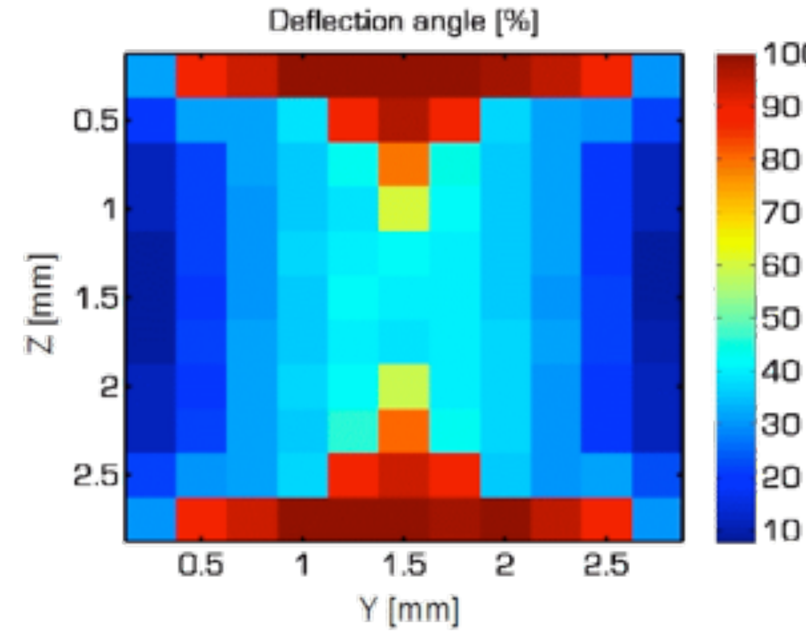
$n_0 = 2.232$

$r_{33} = 32.8$ pm/V

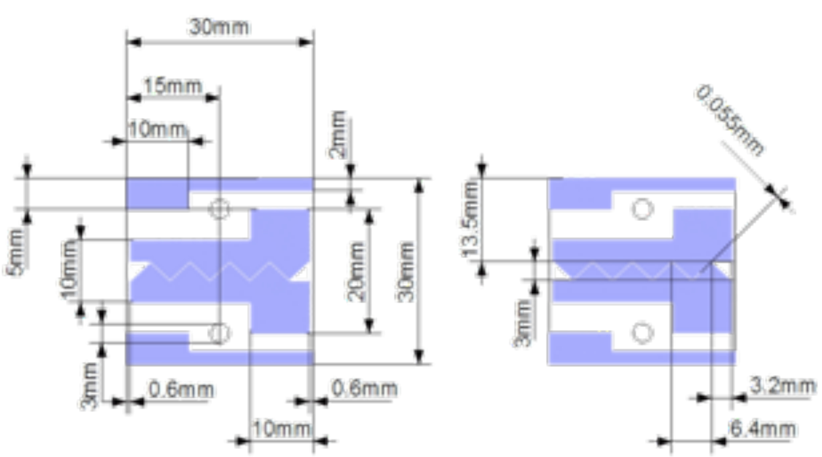




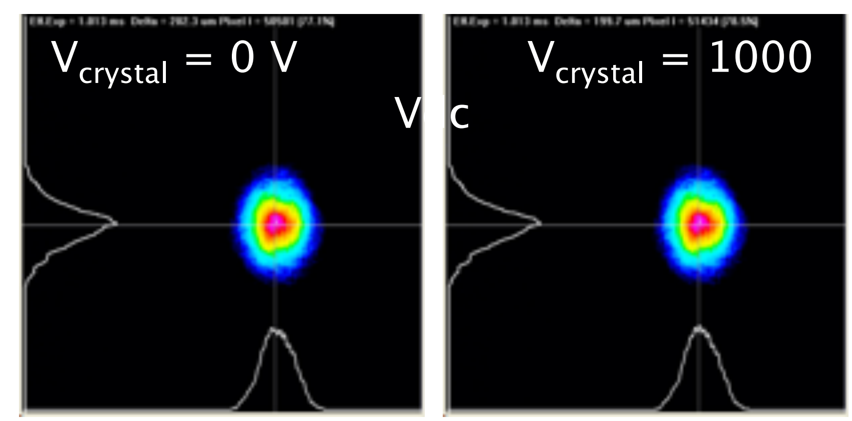
A



B



- **Mapping of the crystal:** deflection angle measured as function of laser beam position inside the crystal
- **Gaussian profile:** no observed change
- **Polarization:** no observed change



- the electrodes are milled in the Cu layer of PCB, with a 55 μm width gap between the two interposed rows
- thin layer of dielectric lacquer applied (dielectric strength 48 KV/mm)
- black delrin holder and spacers (dielectric strength 5.735 KV/mm)

Using it...

Potential applications:

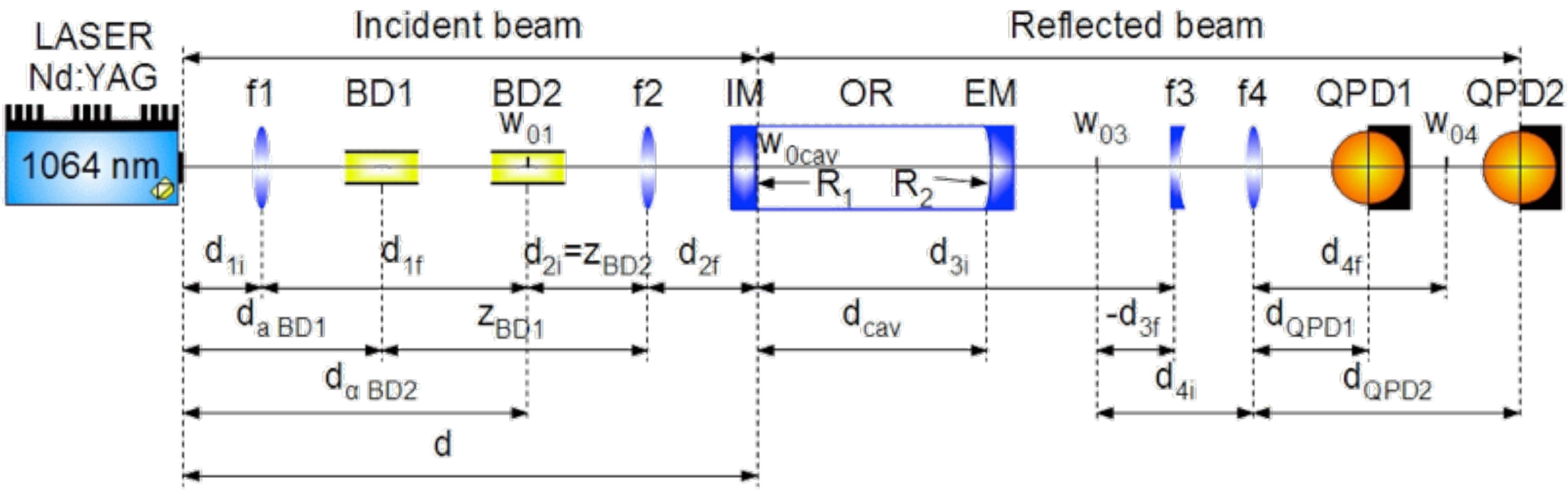
1. Fast feedback actuator for ASC
   - Possible location: from PSL table into IMC
     - Note: We would need four elements
       - two dimensions
       - two Gouy phases

2. Generate ASC signals for simple cavity
   i. PDH-style:
     - Generate 10-mode
     - Reflect off cavity
     - Detect with single element PD

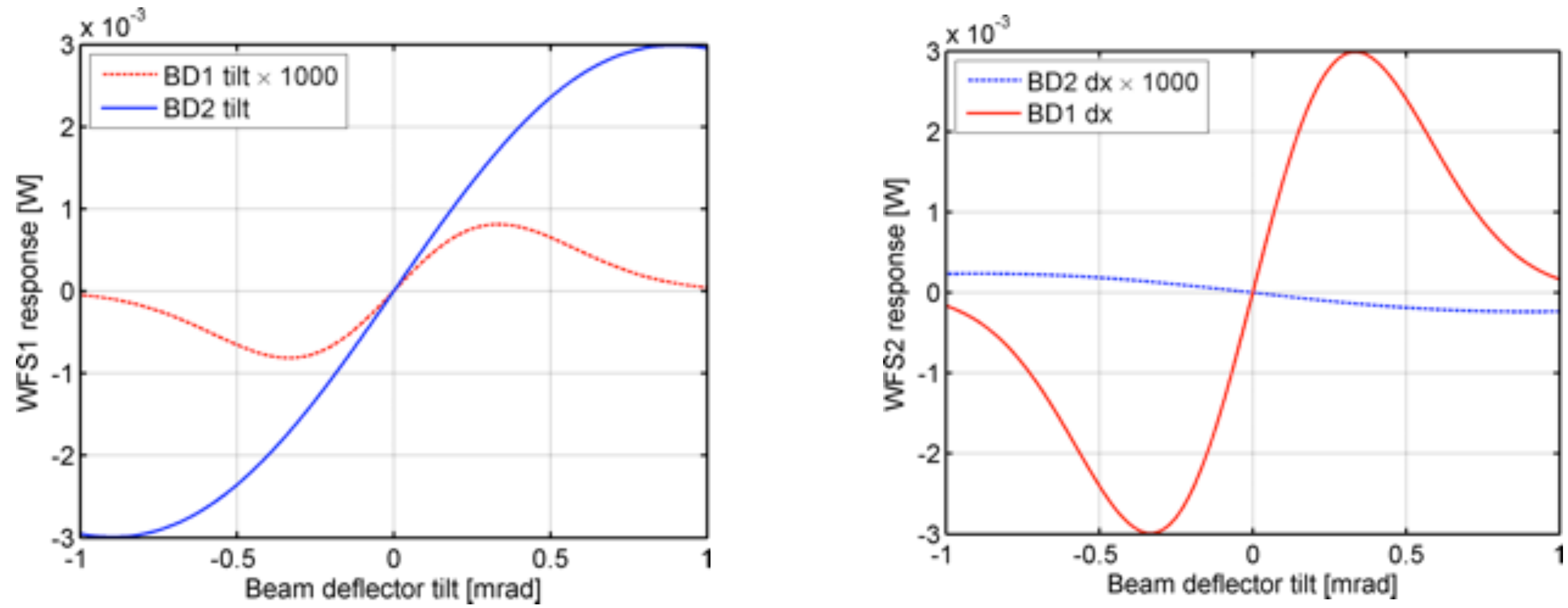
   ii. Anderson-style:
     - Generate 10-mode to be resonant in cavity
     - Detect in transmission with single element PD

3. Generate ASC signals in coupled cavities/Advanced LIGO setup
   - Finesse modeling ... (no idea yet if that works/helps)

Fast Feedback Actuator



Finesse-Model



One-dimensional experiments:

Diagonalize WFS:

- BD1 -> QPD1
- BD2 -> QPD2

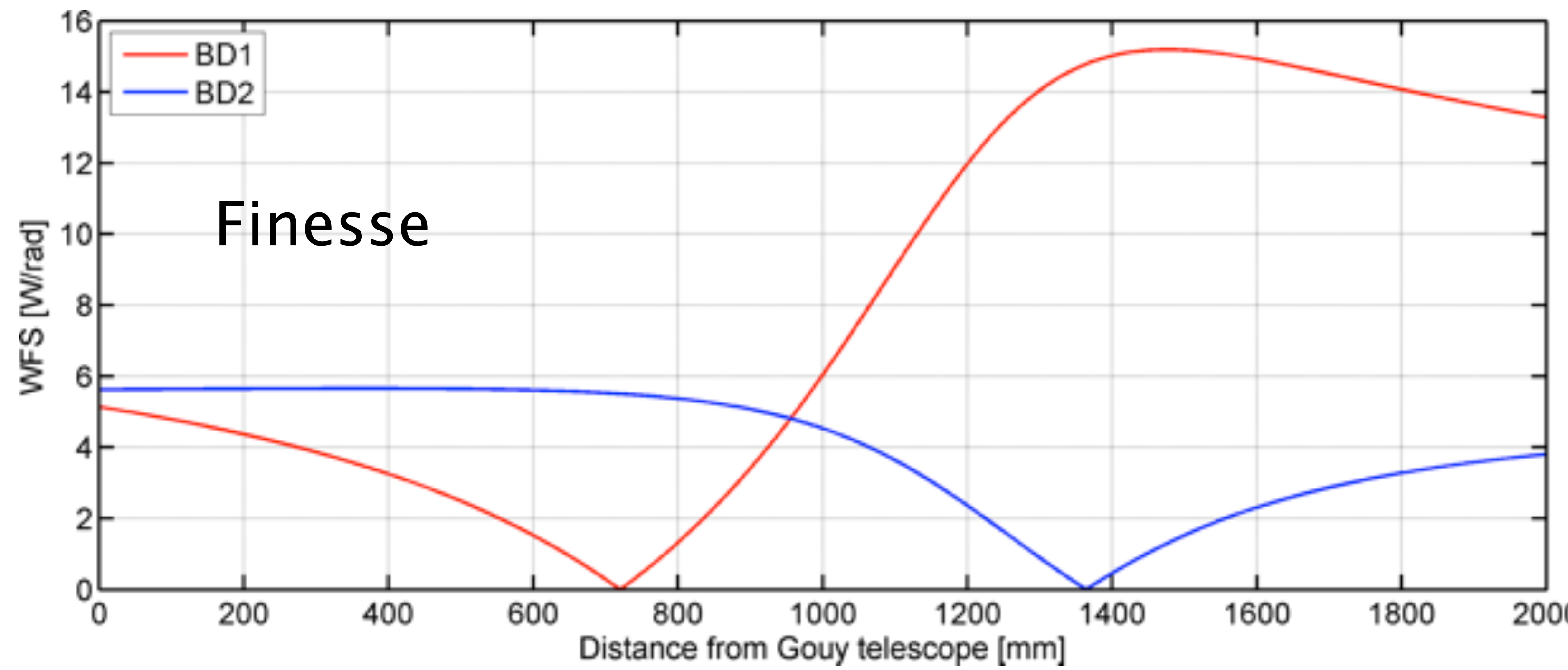
Fast Beam Pointing

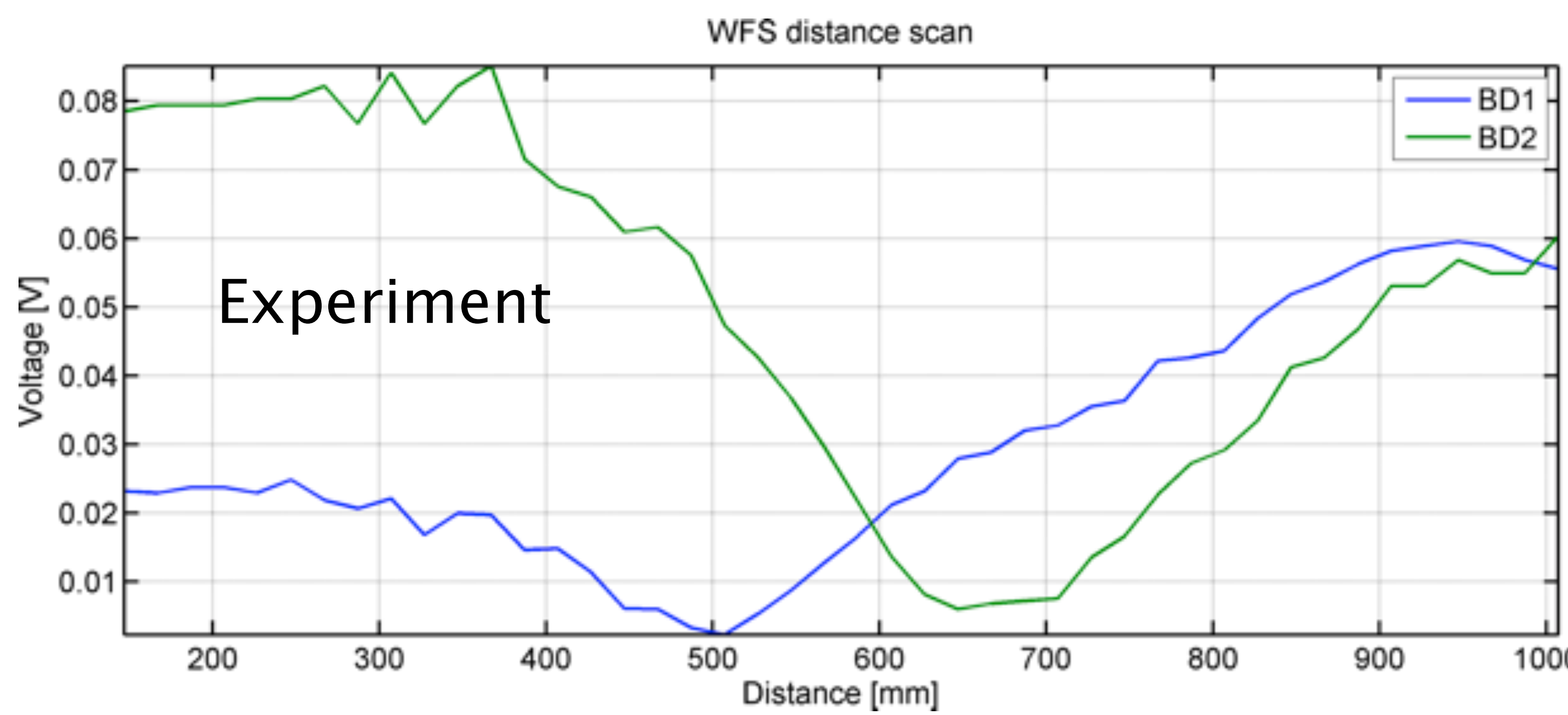
Diagonalize WFS:
- BD1 -> QPD1
- BD2 -> QPD2

Tuning of
QPD1 location

Qualitative agreement pretty good.

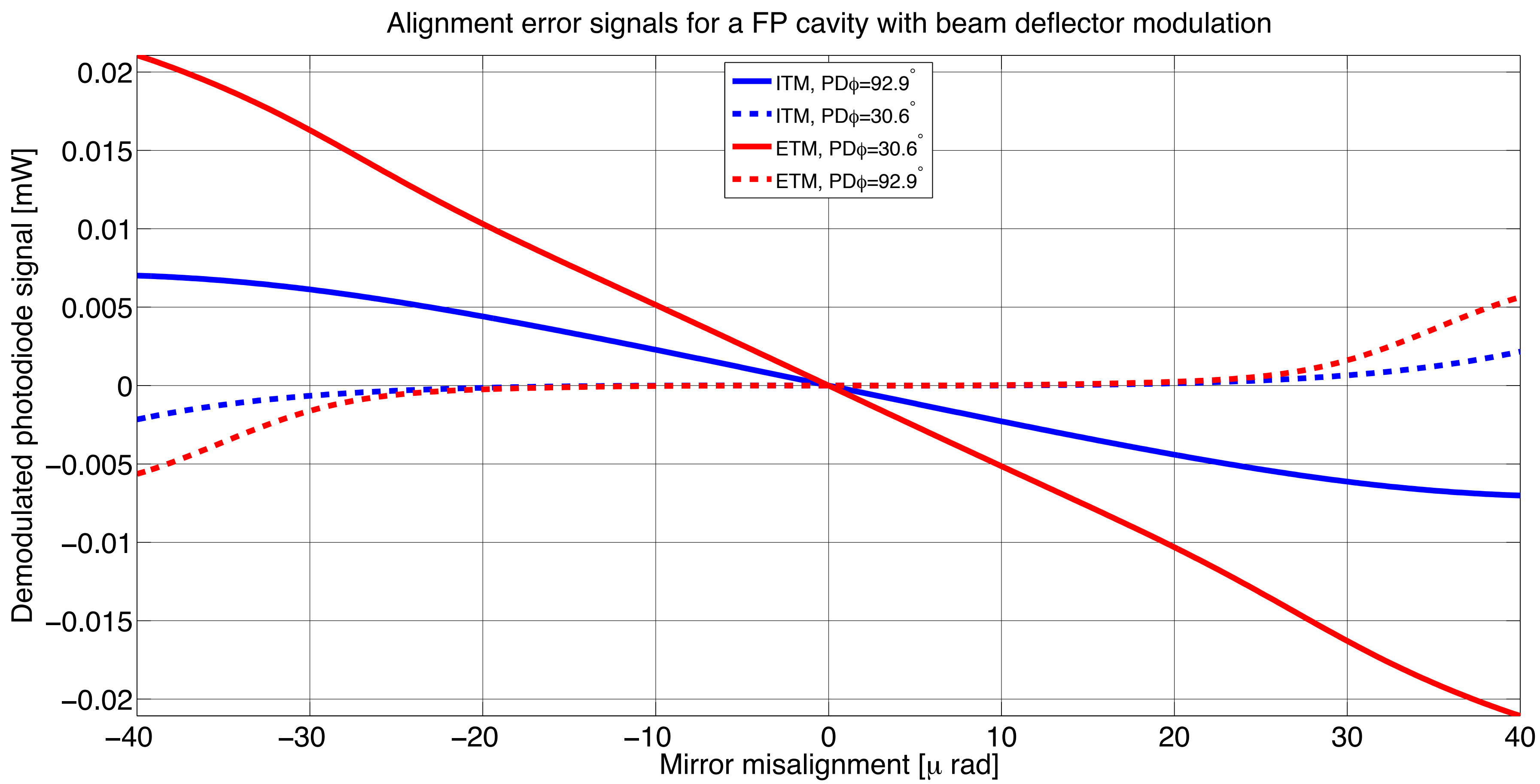
Hope to close loops soon





Alignment Sensing

- Finesse simulations for an aLIGO IMC-like linear FPC



Hope to be able to look at these ideas again since we are done with IO ...

One 10-SB on resonance in reflection allows to separate misalignment or ETM and ITM (single cavity)