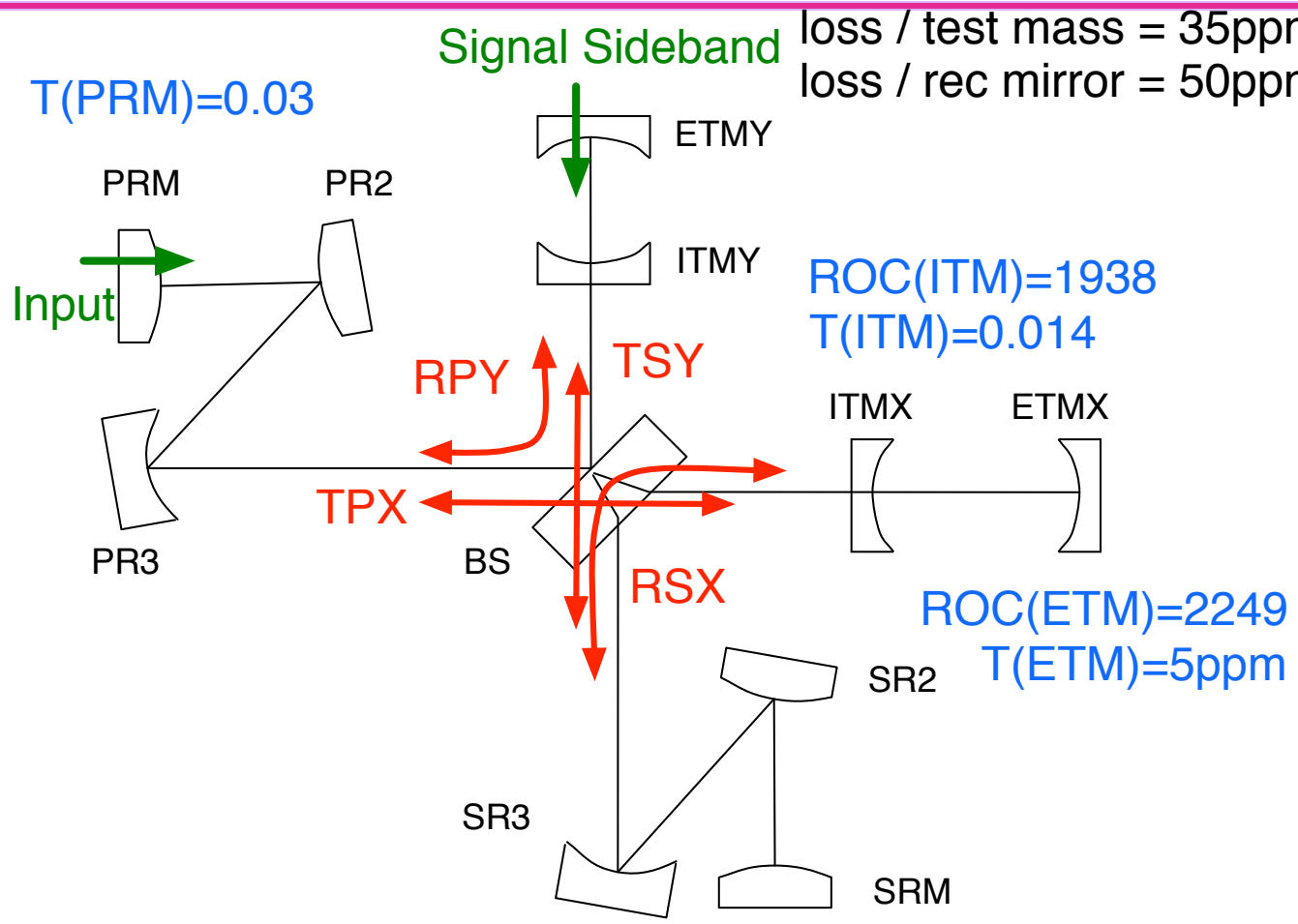
Example and experience using SIS for aLIGO designing and commissioning

- Field Calculator using FFT + integrated analysis tool
- Field
  - » FP, CC with stable recycling cavity and BS
  - » Lock using error signal
  - » Telescope with arbitrary number of elements – lens, mirror, space
- Analysis tool
  - » Mode analysis
  - » Phase map to PSD, PSD to phasemap
  - » Flexible map manipulation
    - – Subtract / add zernike terms from / to phasemaps
  - » Hello-Vinet thermal models

Optical configuration and source only RC + one arm



Main interface

```
SIS>    lock        calcField    signalGen    timeTrace    telescope
SIS>    delL        modeAmp      saveField    mirrorInfo   storeMap
SIS>    summary     simSpec      loadSimSpec  runSpec      help
SIS>    exit
SIS>
SIS>  lock       : Lock the cavity
SIS>  calcField  : Calculate stationary field
SIS>  signalGen  : Generate audio signal by sinusoidal motion of mirrors
SIS>  timeTrace  : Move mirror and save field evolution
SIS>  telescope  : calculate telescope outputs
SIS>  modeAmp    : Decompose a field by LG or HG
SIS>  saveField  : Save field in a file
SIS>  mirrorInfo : View mirror information
SIS>  storeMap   : Store mirror maps
SIS>  summary    : Print summary status
SIS>  delL       : Print and set the cavity length
SIS>  simSpec    : Set simulation parameters
SIS>  loadSimSpec : load simulation setup
SIS>  runSpec    : Set run conditions, like convergence criteria
SIS>  help       : main help
SIS>  exit       : Exit this process
```

Online help

Calculate fields

Analyze results

Modify conditions

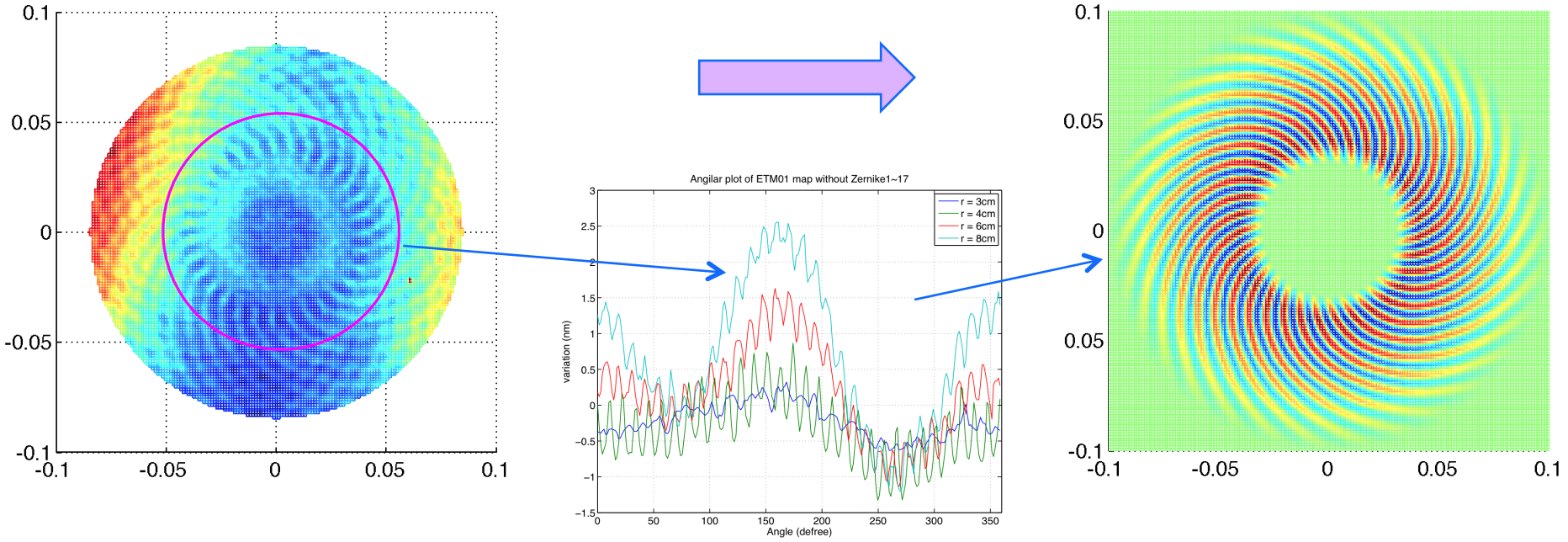
A simple simulation senario

- Interferometer spec
  - » ITM.opt.HR_phase = THERMOELASTIC(w on ITM, abs in ITM, abs in coating)
    + DATAFILE("ITM01.dat",-5)
- Action
  - » Lock => lock and calculate field
  - » Summary
    - – ETM HR
      (in base) : w = 0.0619634 R = 2245 z = 2160.28 z0 = 427.8068 w0 = 0.01203704
      (in fit) : (wX,wY)=(0.06195, 0.061667) R(x/y) = (2248.252, 2251.826) (x0,y0)=(0.02517 , 0)
      power / HMfrac = 228.6095 / 0.1827
      (out fit) : (wX,wY)=(0.06195, 0.061667) R(x/y) = (-2251.263, -2247.691) (x0,y0)=(-0.02517 , 0) power / HMfrac = 228.5973 / 0.1853
  - » Mode analysis
    - – Hermite or Laguere mode expansion with arbitrary number of modes
  - » Modify map and repeat for the new configuration

LMA ETM01 coating accepting test
short wavelength spiral pattern

Measured at Caltech – Z1~Z17

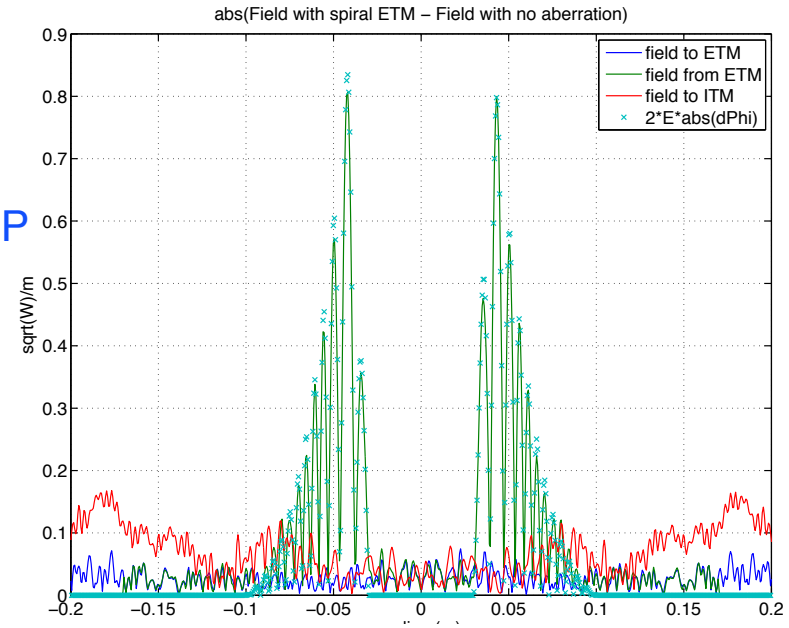
P-V 1nm



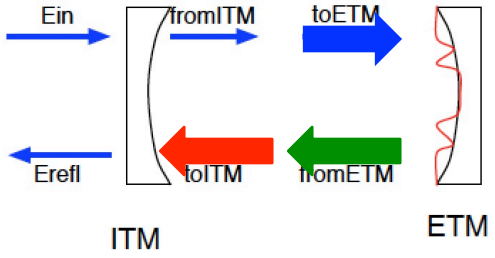
Using matlab to extract the spiral pattern, and use it as the phasemap in SIS

LMA ETM01 coating accepting test short wavelength spiral pattern

- SIS analysis to understand the effect by this pattern
- Round trip loss ~ 6ppm ⟵ OK
- Any other effects
  - » Field aberration due to this pattern
    - – Field in FP with this map – Field in idealistic FP
    - – Very fine grid sizes to make sure FFT is OK
  - » Mode analysis if any mode could dominate
    - – No dominant mode for LGpm (2p+m<25) and HGmn (m+n<25)
  - » If ITM has similar pattern, can they interfere
    - – ITM = MAPPING (DATAFILE("ETM01pattern.dat"), "-x","y") * 0.5
    - – Loss = loss by ETM + loss by ITM no additional by interference

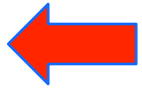


spiral pattern on ETM



LMA ETM01 coating accepting test long wavelength central plateau

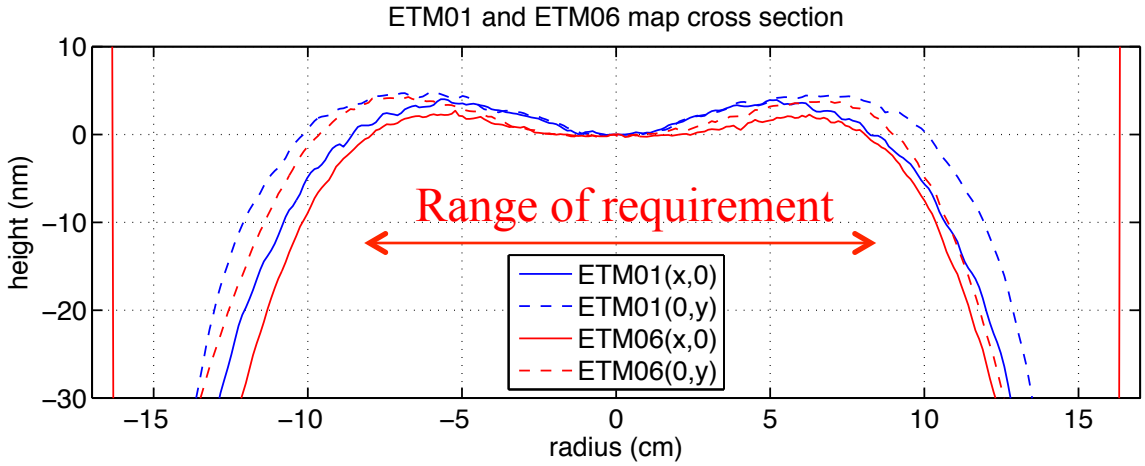
- Old coating system, one at a time
  - » The beam size on ETM is larger than that on ITM and the plateau size on ETM needs to be 20% wider, when coating to coating variation is taken into account
- New coating using the planetary system, a pair at a time
  - » Higher order mode, mostly LG20, in the FP cavity is ~100ppm
    - – Better than old, 120ppm, and two ETMs will be "identical", but is this **good enough?**
    - – The plateau size is around the same as the old one
    - – Astigmatism uncertainty due to the substrate is not a major issue
    - – Asymmetry in the far outside is better (smaller) in the new coating
  - » Coupled cavity simulation
    - – LG20 in PRC is ~2000ppm increase by the ETM coating aberration
    - – LG20 in SRC shows no increase of LG20 by the mode healing
      - Stable signal recycling cavity kills LG20 in SRC

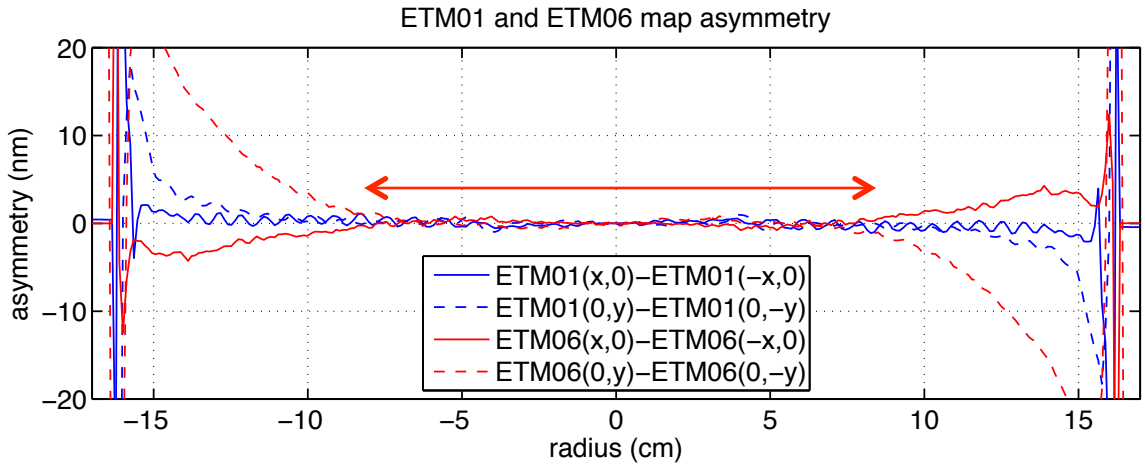


Cross check by other tool is appreciated very much

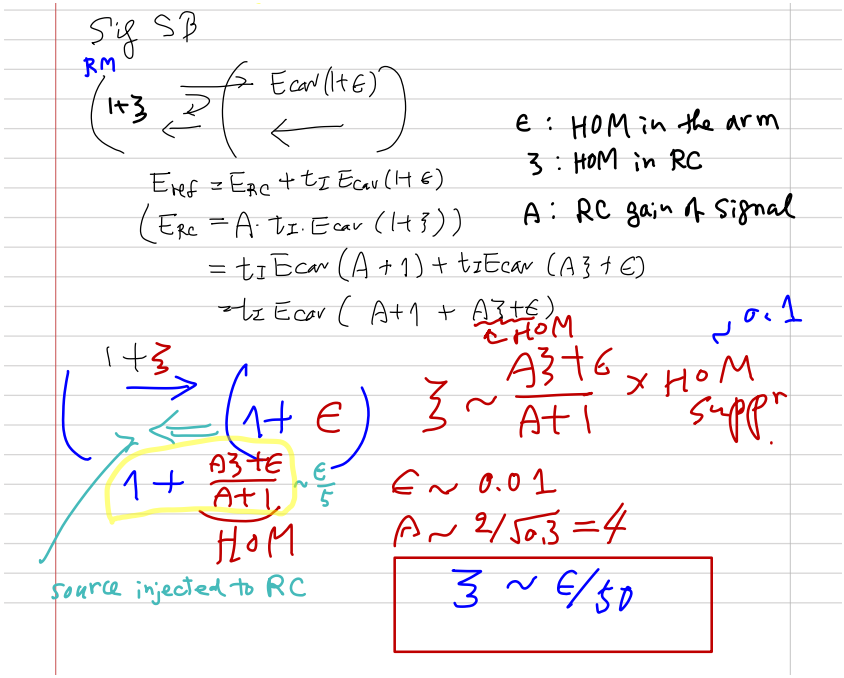
ETM01 (new using planetary) vs ETM06 (old)

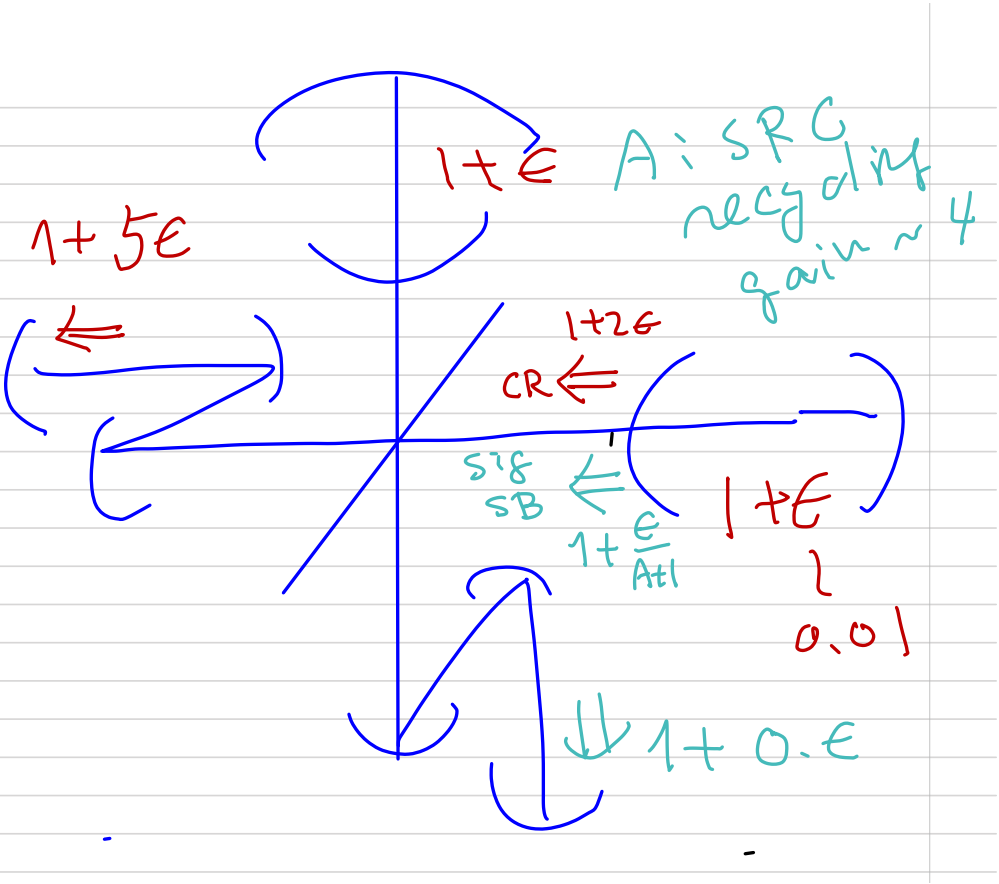
Tilt, Power, Astigmatism subtracted



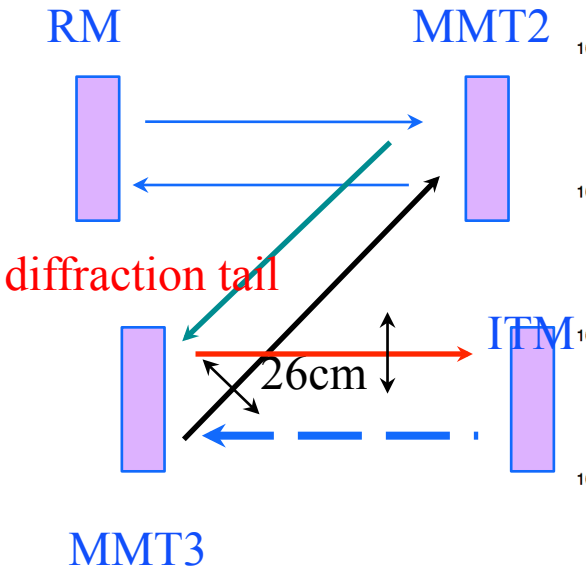


LMA ETM01 coating accepting test long wavelength central plateau

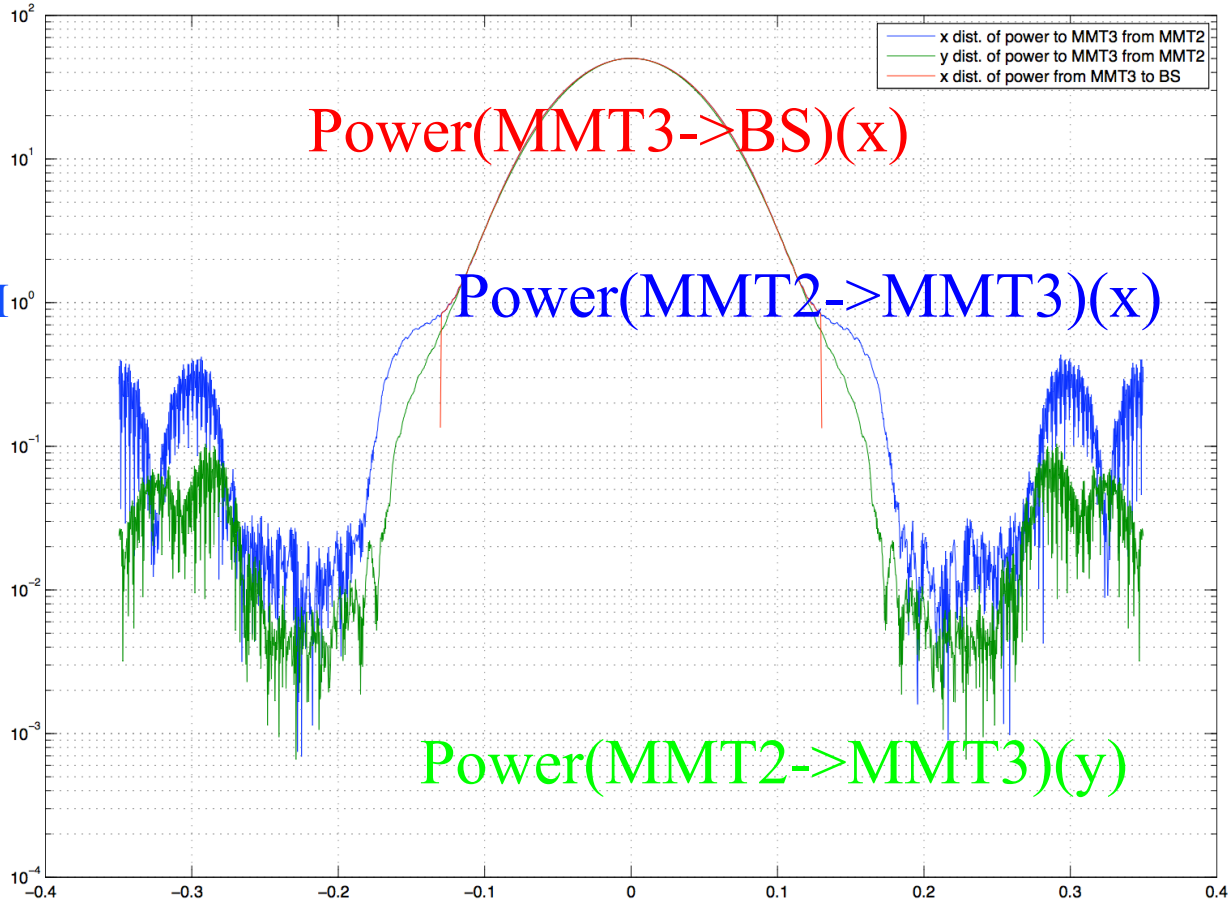




Why ROC(ITM) < ROC(ETM)
Power loss on RM3

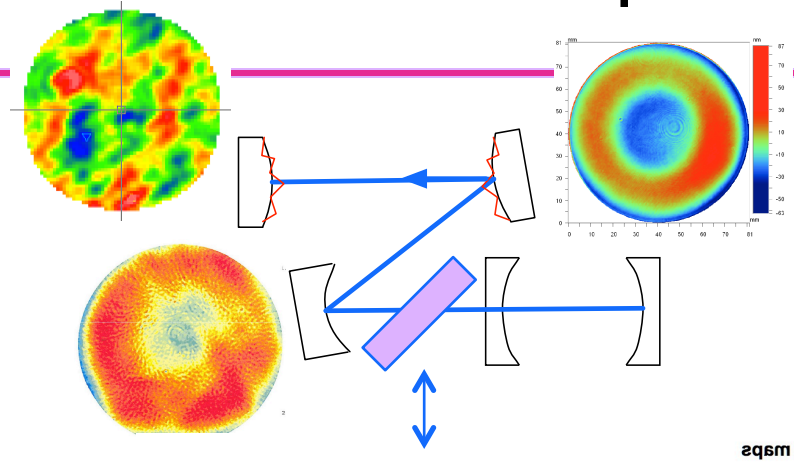


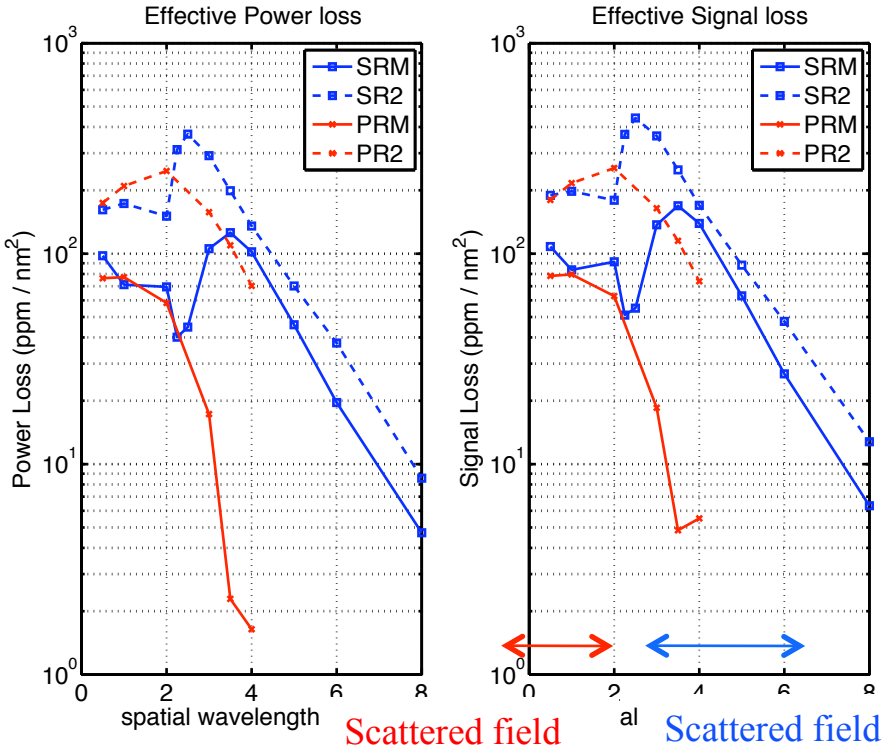
loss = 330ppm
(energy outside of
MMT3 surface)

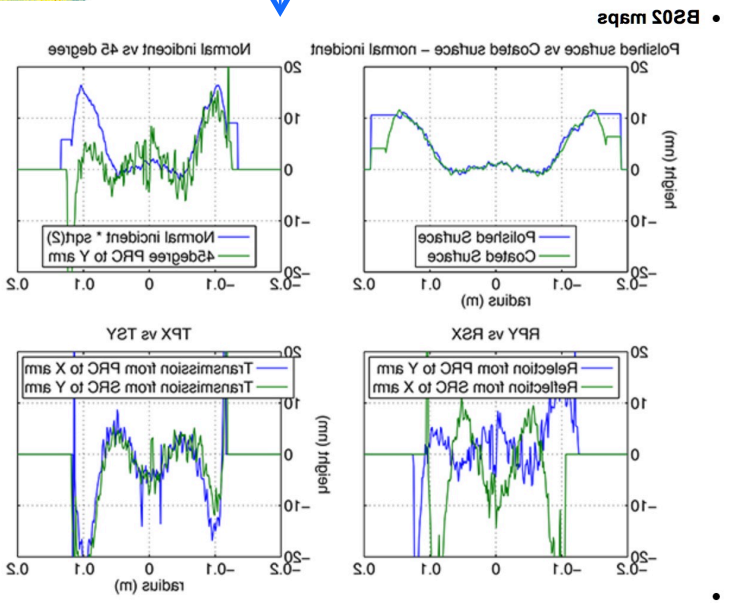


Loss function
not so beautiful mirror maps

$$1 - \frac{P(a\ \sin(2\pi \cdot f \cdot r))}{P(no\ aberration)}$$







Scattered field lost out of cavity

Scattered field stay in cavity and reused