TITLE

Incomplete

Analysis of an all reflective, non Gaussian mode interferometer

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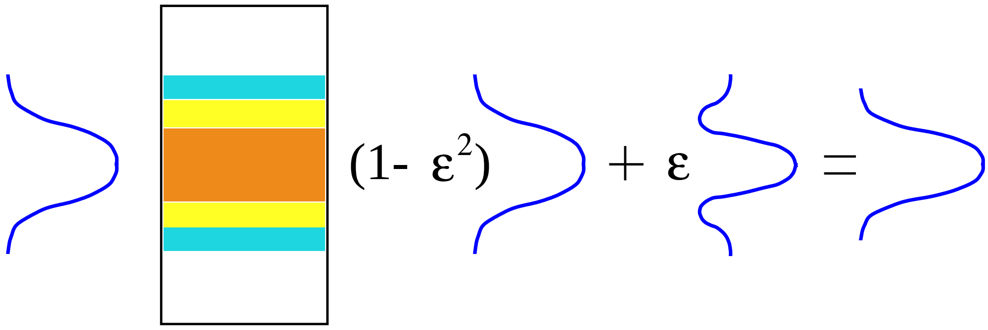
Table of Content

Thermal deformations

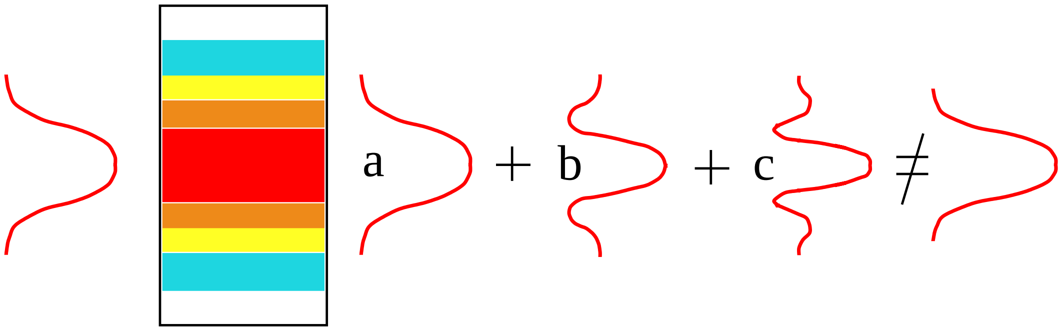
$$n(x,y,z) = n_0 + \frac{dn}{dT}\left[T(x,y,z) - T_0\right] \qquad \frac{dn}{dT} \approx \frac{10^{-5}}{K}$$

$$T(x,y,z) = T(I(x,y,z), \ldots)$$

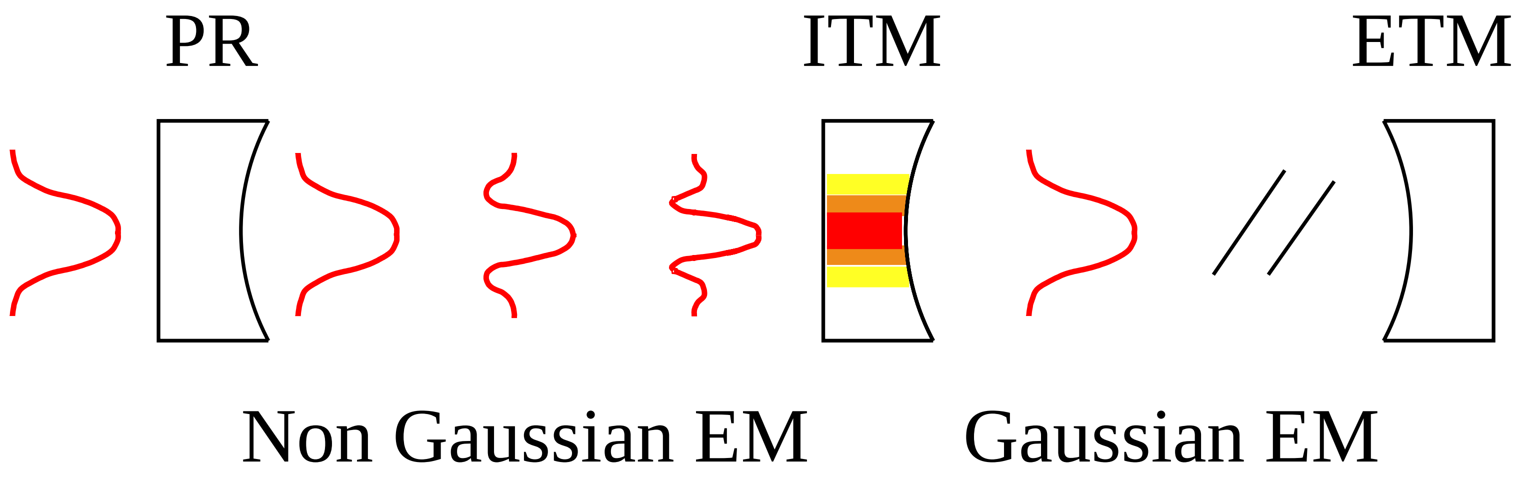
Thermal lens:



Thermal deformation:



Mode matching between PR and Arms



Mode matching between PR- and Arm cavity difficult.

THERMAL DEFORMATIONS IN IFO

List of Problems:

- **mode matching into PR-cavity**
- **mode matching PR- into arm cavities**
- **asymmetric arms**
- **mode matching between sidebands and carrier**
- **thermal noise**
- **...**

results in:

- **more reflected light at PR-mirror**
  $\Rightarrow$ increased shot noise at bright port
- **reduced visibility of Michelson**
  $\Rightarrow$ increased shot noise at dark port
- **higher losses in PR-cavity**
  $\Rightarrow$ lower power built up
- **lower power in the arms**
  $\Rightarrow$ smaller signal
- **...**

IDEA

All Reflective interferometer

Old Idea

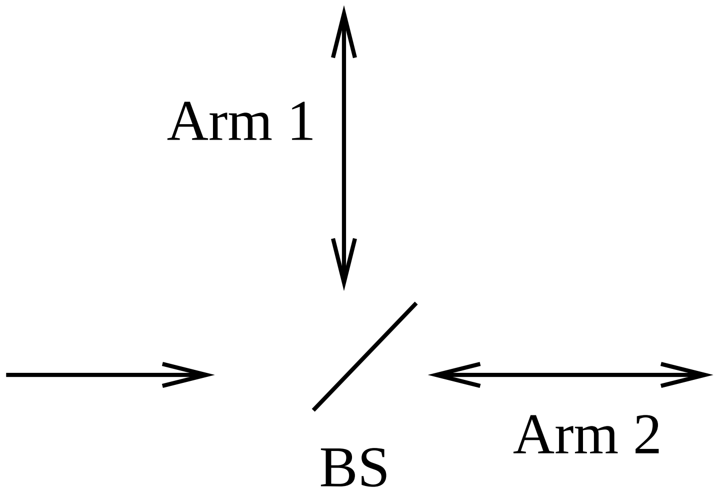
What do we need ?

- **large carrier built up (5000)**
- **strong signal**

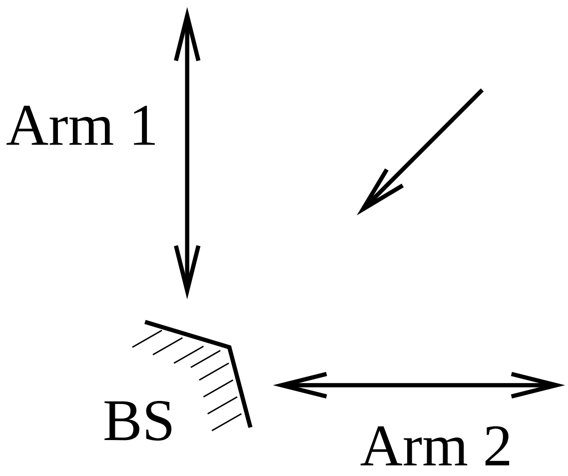
What do we like ?

- **Symmetry**

BEAMSPLITTER

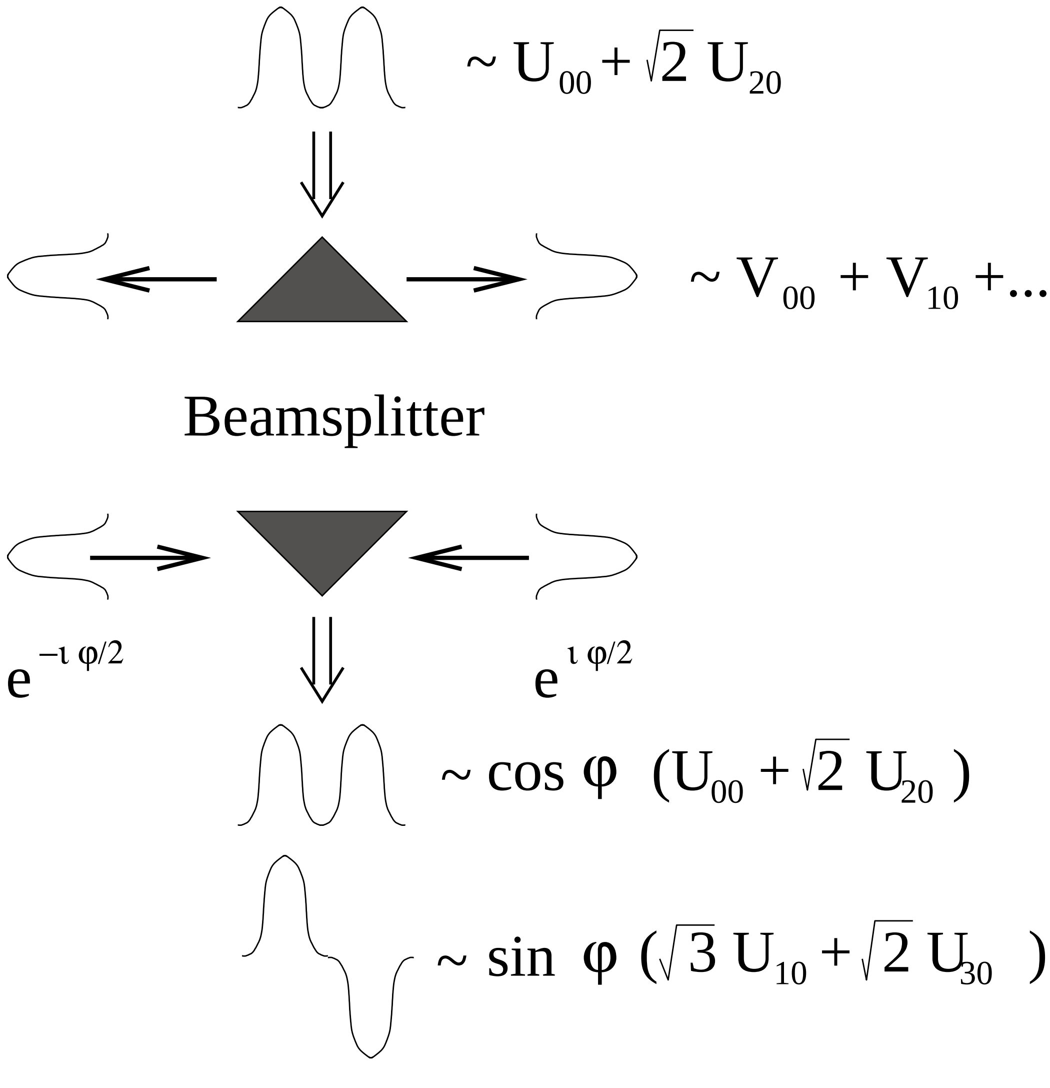


Not Symmetric.



Symmetric.

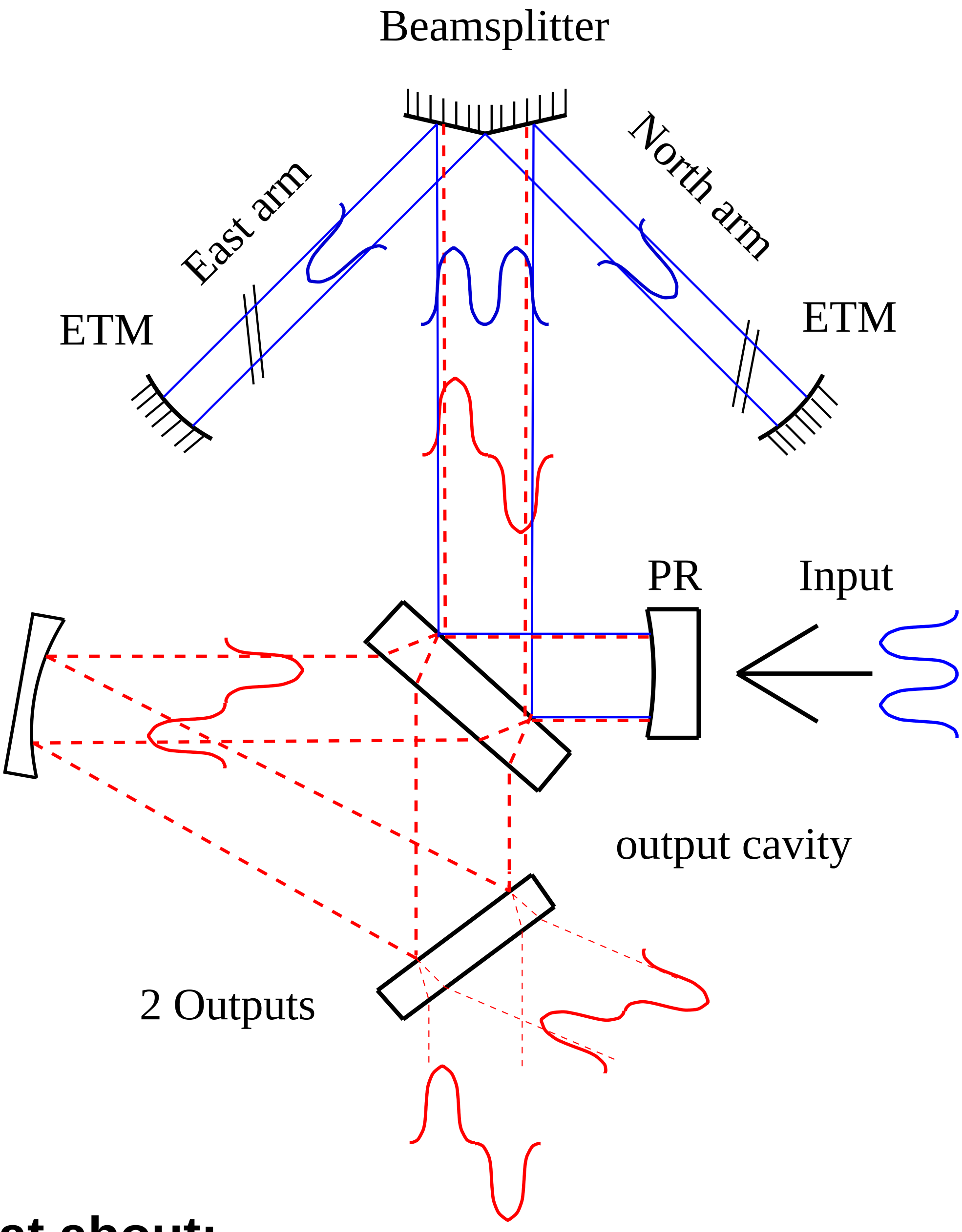
BEAMSPLITTER



Intensity in the center = 0
First Derivative in the center = 0

Result: No diffraction

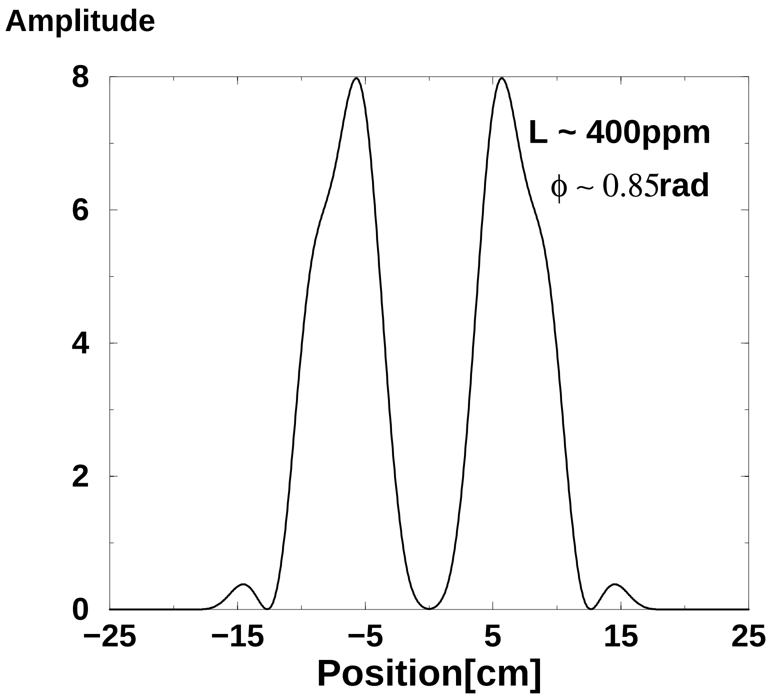
ALL REFLECTIVE IFO



What about:

- **the real eigenmode ?**
- **large carrier built up ?**
- **signal strength ?**

even Eigenmode

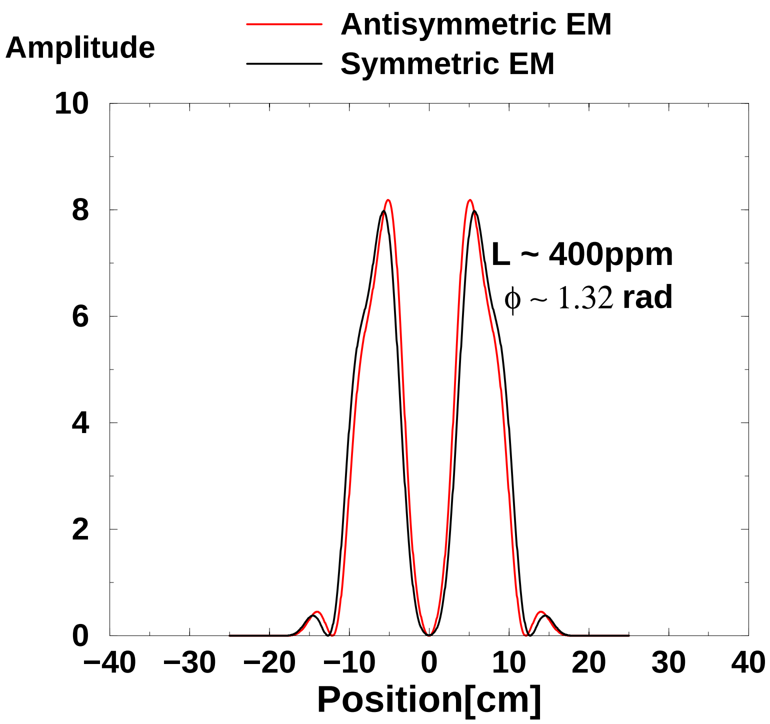


Calculated with:

- **2 sets of 20 Hermite-Gaussian eigenmodes**
- **one set for PR-arm (only even modes contribute,** $w_0 = 6\ cm$**)**
- **one set for each long arms (all modes contribute,** $w_0 = 4.18\ cm, \quad z_R = 5.16\ km$**)**
- **two sets for each arm separated by** $9.3\ cm$
- **incl. Gouy phases in propagation**

EIGENMODES

odd Eigenmode



Same calculation except:

- **only odd modes contribute in PR-arm**

Recycling Factor > 1000.
Used only limited number of modes!

Different resonance frequencies
(similar to Gouy-phase).

SIGNAL

Phase difference between the two arms couple even and odd modes.

$$\Rightarrow$$

Gravitational waves generate sidebands in mode with opposite symmetry.

If Carrier field is in even mode: Signal field is in odd mode:

Amplitude of Signal field:

$$A_{odd} = \delta\phi \; A_{even}$$

As good as a Michelson !!

CHECK LIST

What do we need ?

- **large carrier built up (5000)**
- **strong signal**

Open questions ?

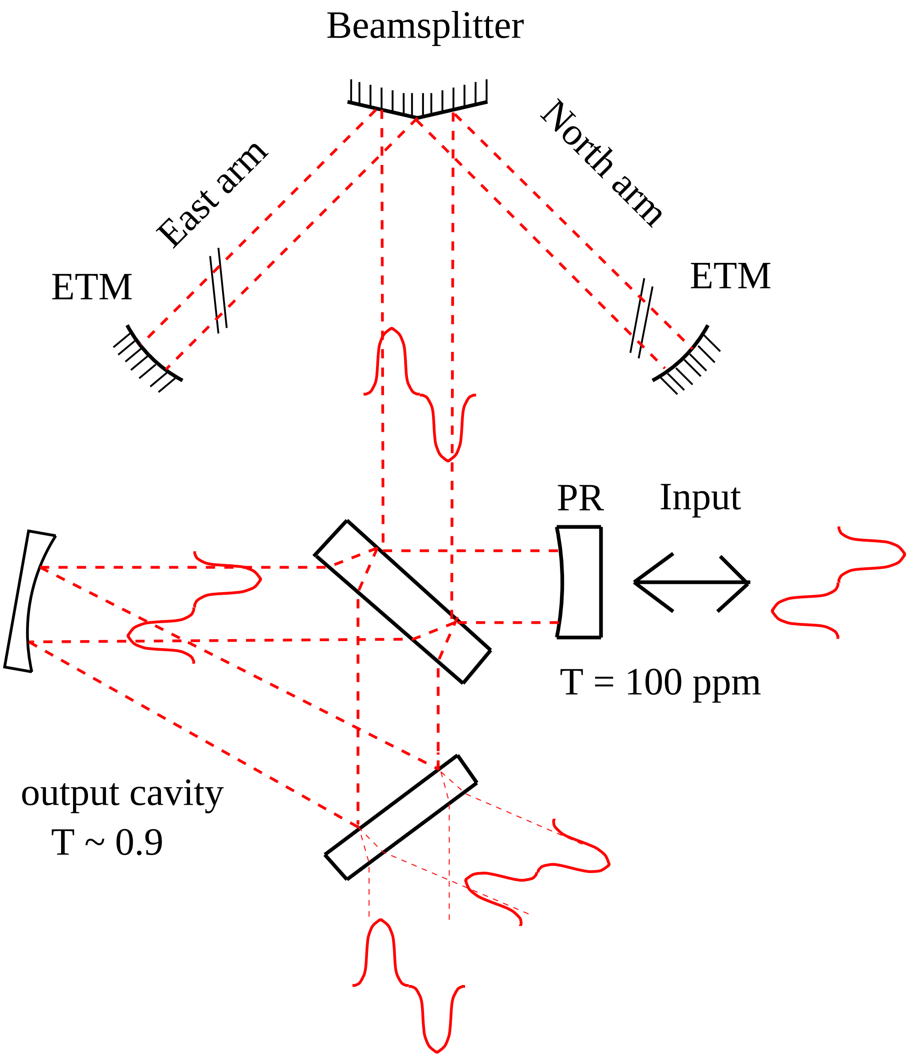
- **Realistic beamsplitter ? (Losses)**
- **Fluctuations in the input field ?**
- **Modematching from laser into IFO ?**
- **Signal Recycling ?**
- **...**

FLUCTUATIONS IN INPUT FIELD

Noise in the input field:

1. **Frequency: not sensitive, white light IFO.**
2. **Amplitude: ? (always second order)**
3. **RFAM: ? (dito)**
4. **Phasefront fluctuations**

PHASEFRONT FLUCTUATIONS



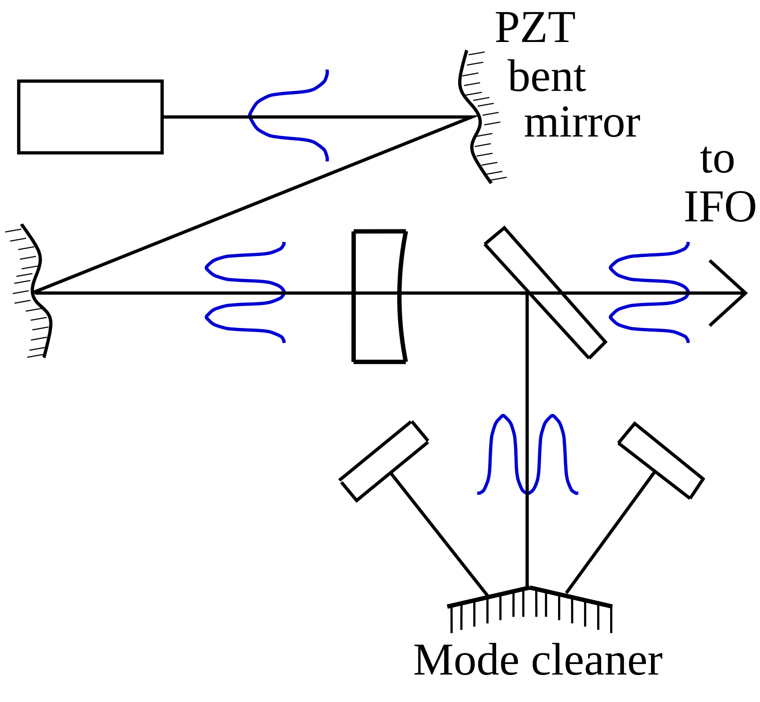
$$\frac{T_{Odd}}{T_{sig}} = 1e - 4 \qquad R_{Odd} \approx 1$$

still

$$\frac{E^{in}_{odd}(f)}{E^{in}_{even}} \leq \frac{10^{-10}}{\sqrt{Hz}}$$

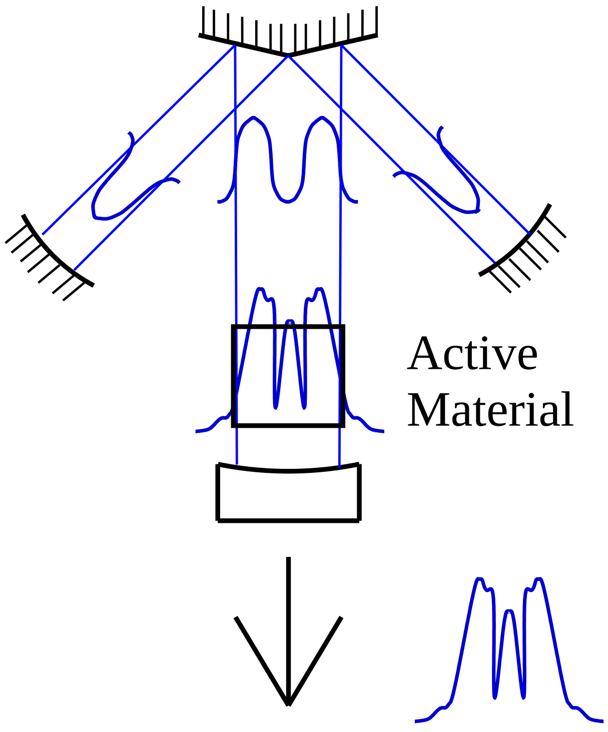
need feedback and korrelation.

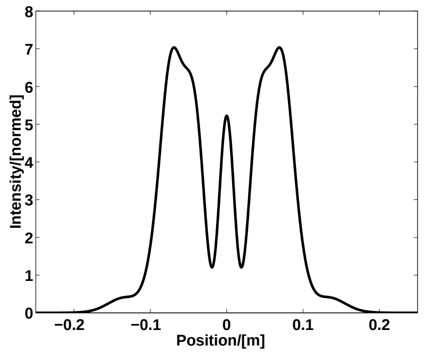
Possible solutions:
1. Adaptive mirror (PZT array to deform surface) between laser and modecleaner.



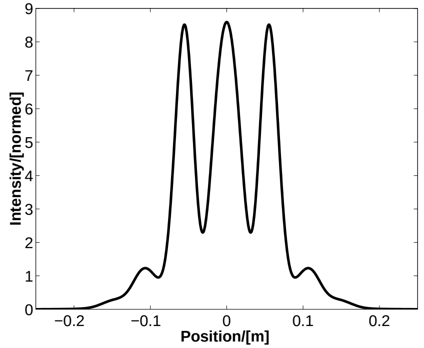
LASER GENERATES THAT MODE

2. Active Medium in similar cavity:

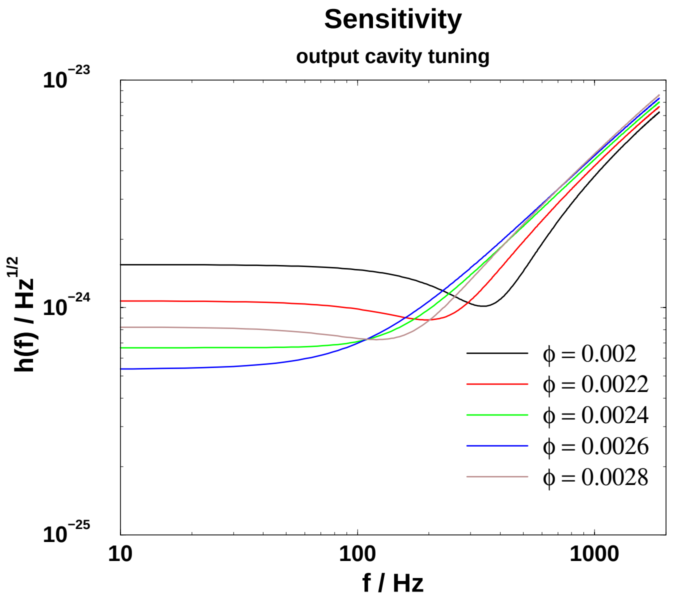


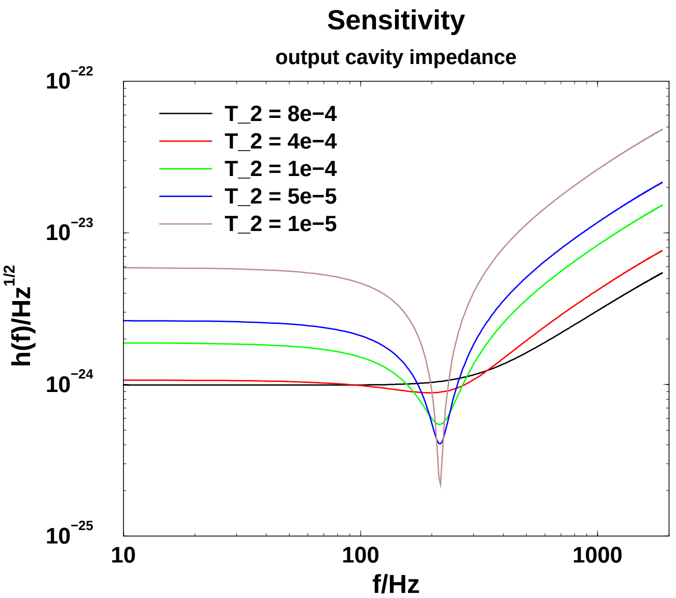


virtual distance from BS: 3 km



virtual distance from BS: 7 km





Parameters:

$$T_{PR} = 1e-4, \qquad T_E = 1e-4,$$
$$T_1 = T_2 = 4e-4, \qquad \phi = 0.0022$$

Conclusion, Summary

Started with a crazy idea.

Turned out that:

- **power recycling with huge built up seems to be possible**
- **strong signal will be generated**

in that all reflective interferometer.

Advantages:

- **no thermal deformations**
- **opaque materials can be used as test masses**
- **White light interferometer → insensitive to frequency noise**
- **only 3 longitudinal degrees of freedom:**
  1. **power recycling cavity**
  2. **differential length (signal)**
  3. **output cavity**

Maybe its still crazy. But who knows ...

Symmetric Mode, Details

Components of the symmetric mode in the PR-arm:

$$
\begin{aligned}
a_0 &= 0.49273399672754 + 0.00000000000000i \\
a_2 &= 0.70059645889068 + 0.42308917680596i \\
a_4 &= -0.01938038605036 + 0.13521420060614i \\
a_6 &= 0.00271052307004 - 0.19400074036661i \\
a_8 &= -0.05077097275544 - 0.05075063820006i \\
a_{10} &= 0.06311030767672 - 0.04665033499560i \\
a_{12} &= 0.00548363034008 + 0.10894392958308i \\
a_{14} &= -0.05022178170505 - 0.05451065543835i \\
a_{16} &= 0.04315208551419 - 0.00239366081310i \\
a_{18} &= -0.01868831077499 + 0.01221423408068i
\end{aligned}
$$