Scattered Light at GEO 600

or

``walking right into the cat´s eye trap´´

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Introduction

- At the end of September excess noise between 100 Hz and 1 kHz was first noticed.
- All October this noise got worse and was clearly the limiting noise in major part of our detection band.
- At this time we were by far not able to reproduce our best sensitivity from September.

In pricipale we had two candidates:

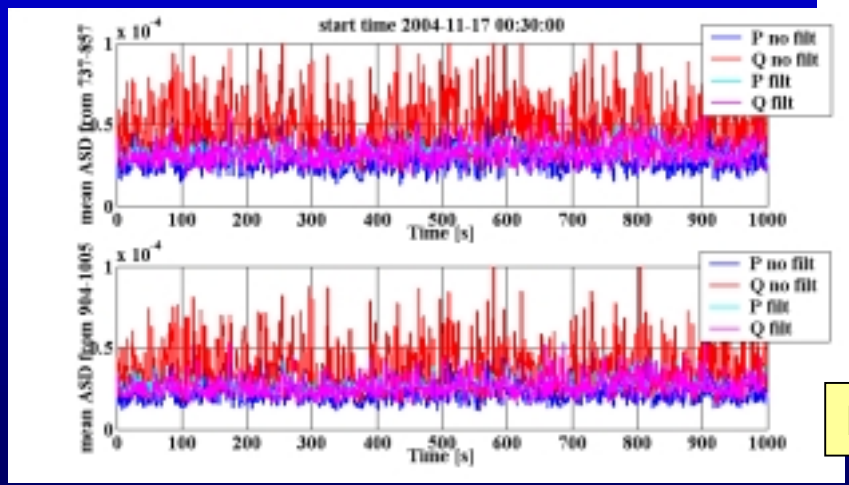
Scattered light (stray light)

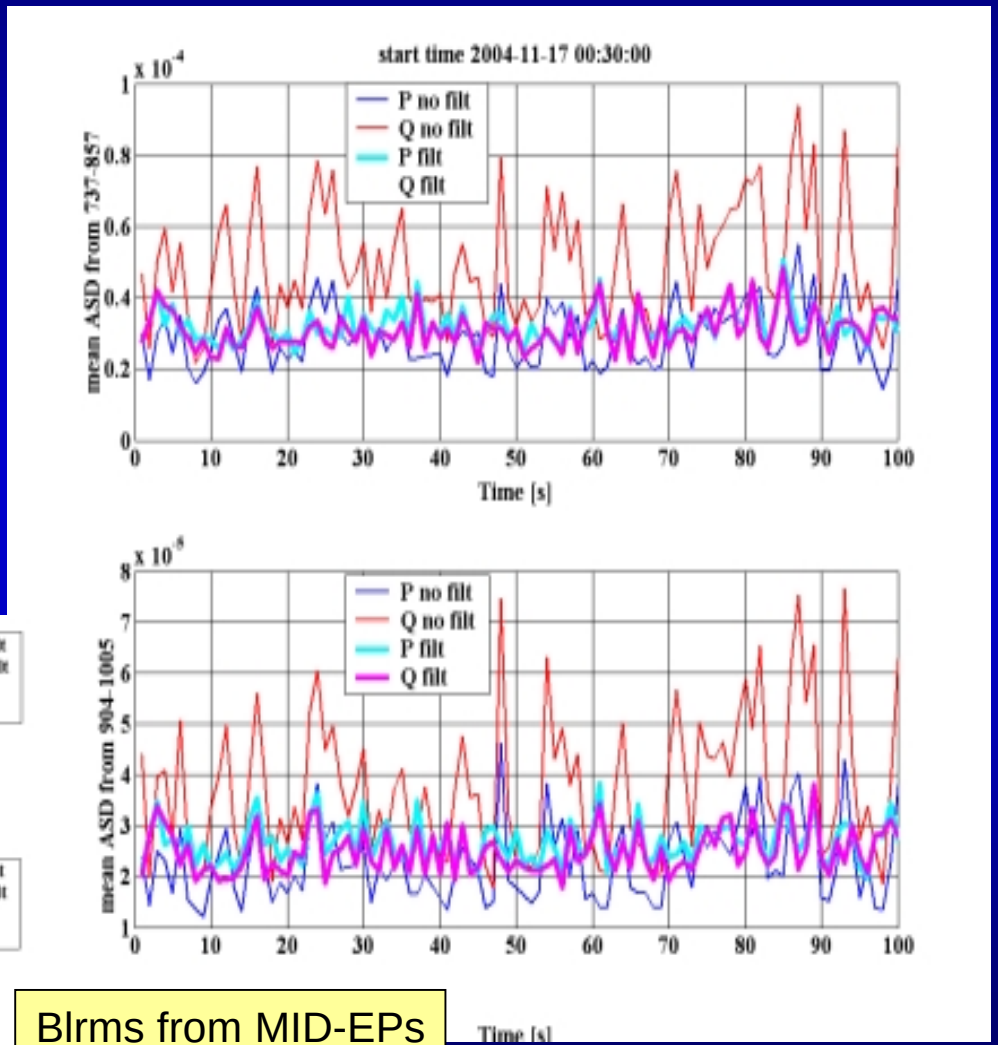
Frequency noise

For various reasons we concentrated on scattered light!

Indicators for scattering

- Noise sounds like scattering (listening to MID-EP gives ‚wooshes‘)
- Nonstationarity of noise on short timescale (noise level varies a lot on seconds scale)

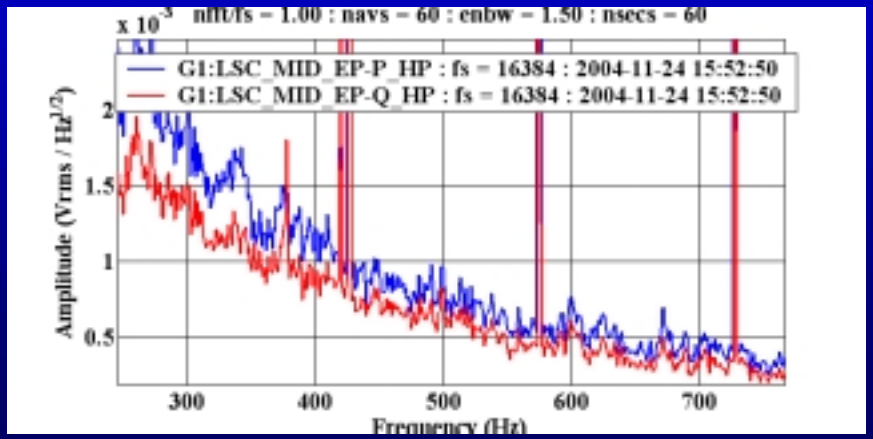


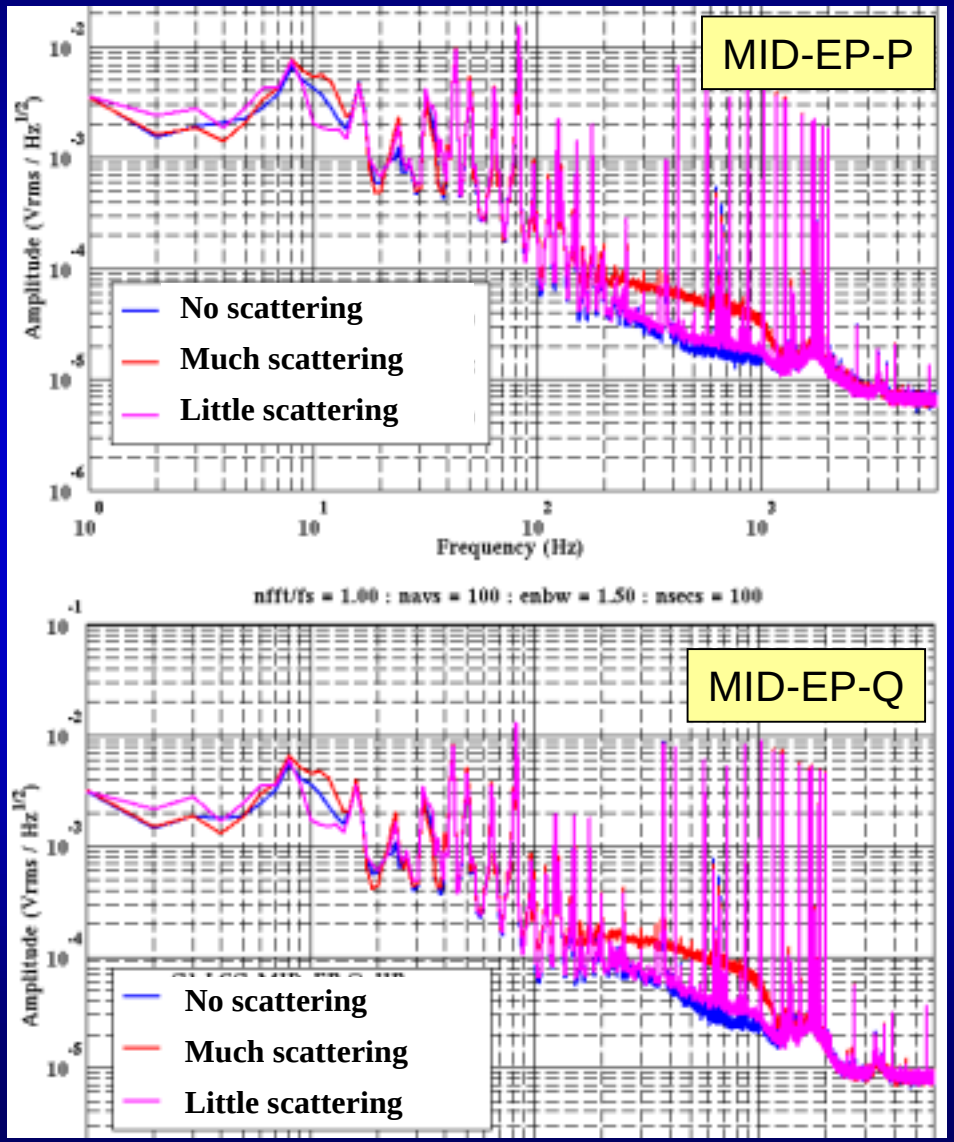


Blrms from MID-EPs

Indicators for scattering

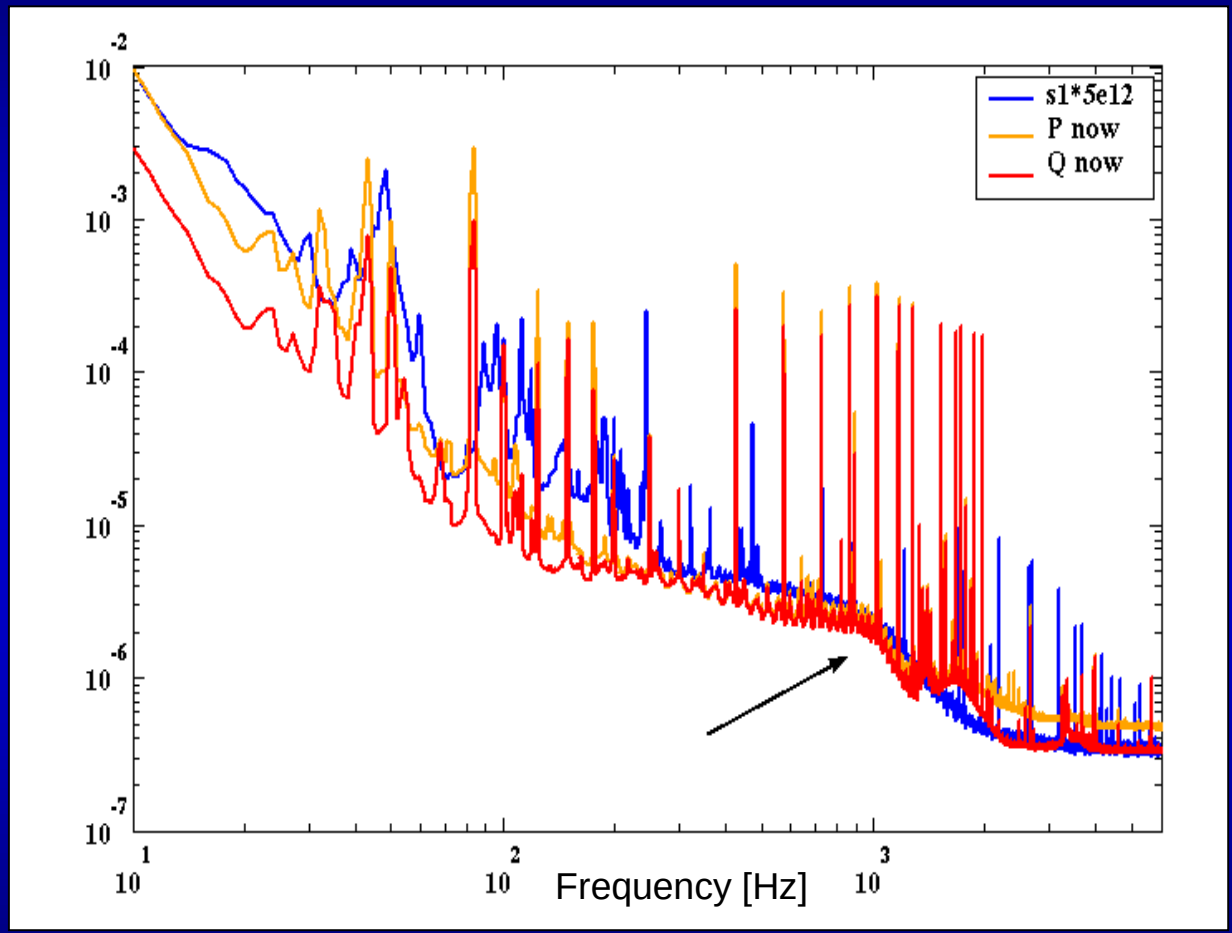
- In MID-EPs the noise shape looks like a shoulder
- The noise shoulder is nearly smooth (apart from a few lines no structure or features in it)





Similarities to S1

- In S1 we already had problems with stray light (blue curve).
- Now the shape of the MID-EPs is roughly the same.
- In S1 the source of scattering was found to be on the detection bench (and was reduced by replacing optics)



Conclusion: confident that the shoulder was caused by scattering

What are we looking for ?

- Light that leaves the main beam
- Gets a phase shift in respect to main beam
- Reenters main beam and gets detected at the dark port.

Simple picture (without possible (?) enhancement in SR-cavity):
To get scattered light at 1 kHz we need a phase shift of roughly $2000\pi/s$.

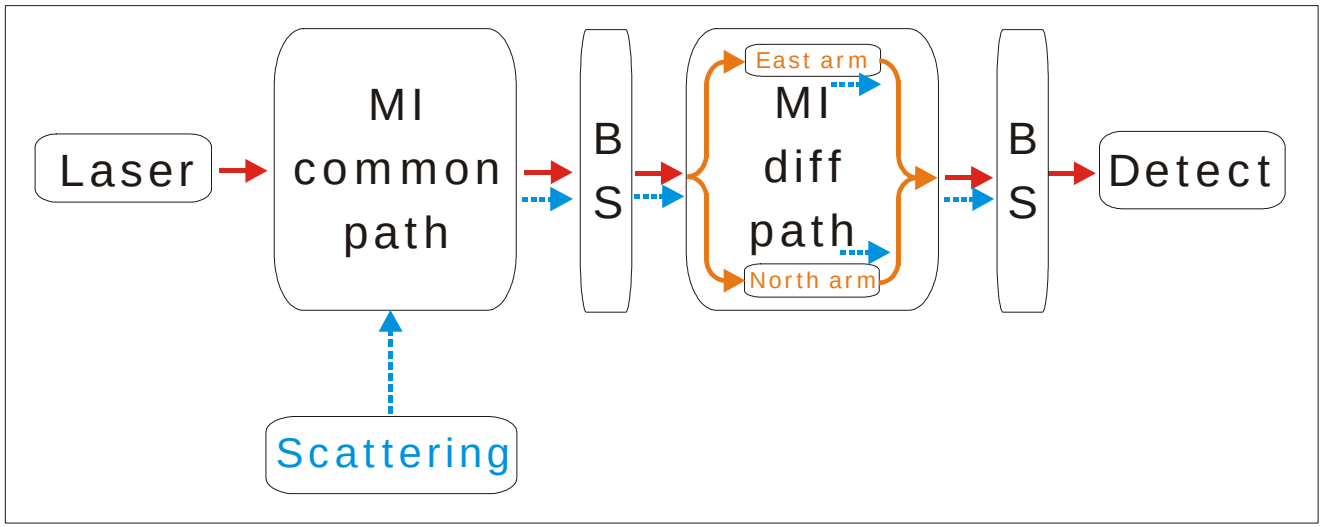
Two possiblities:

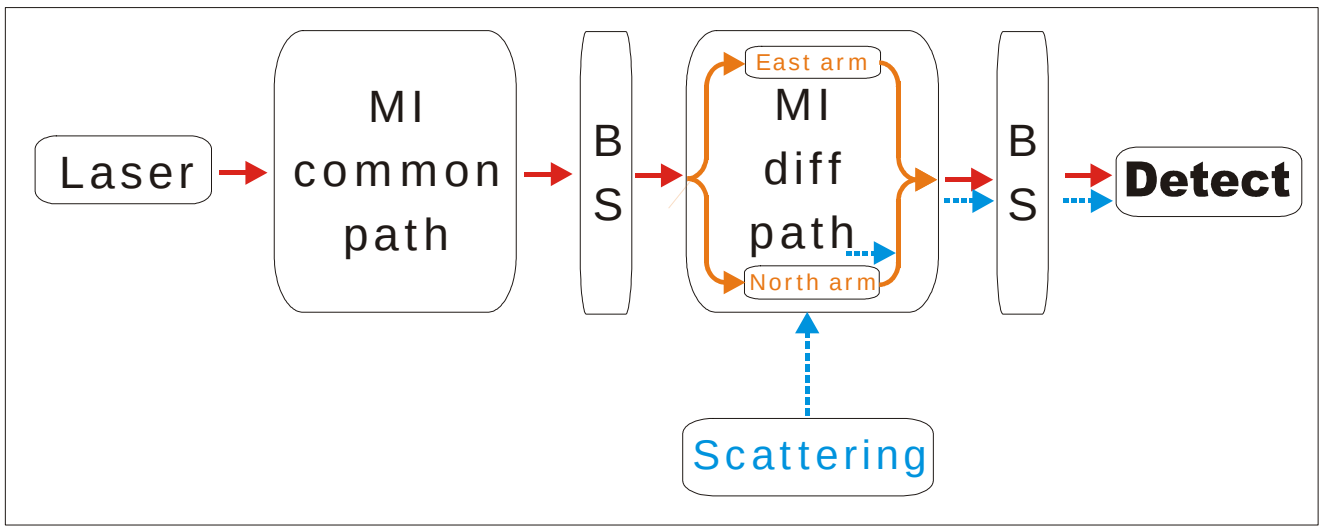
- Component moving at low frequency about many fringes = 1mm/s
- Component moving a little but very fast (1kHz)

We worry just about a very small light level !

PROBLEM: NONLINEARITY

Scattering in common and diffrential path



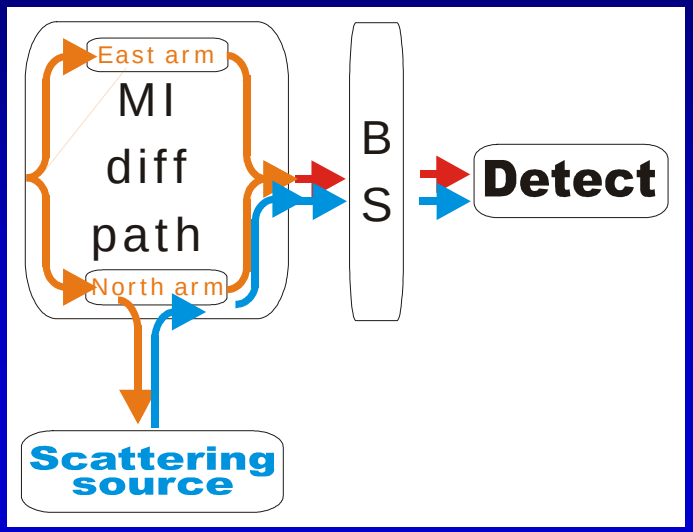


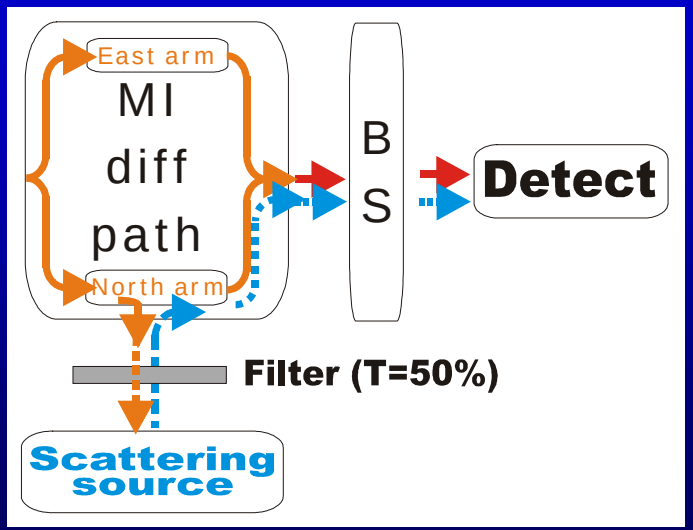
Scattering in common path path would be less ``effective´´ than in the differential path !

Identifying the scattering source

The filter experiment:

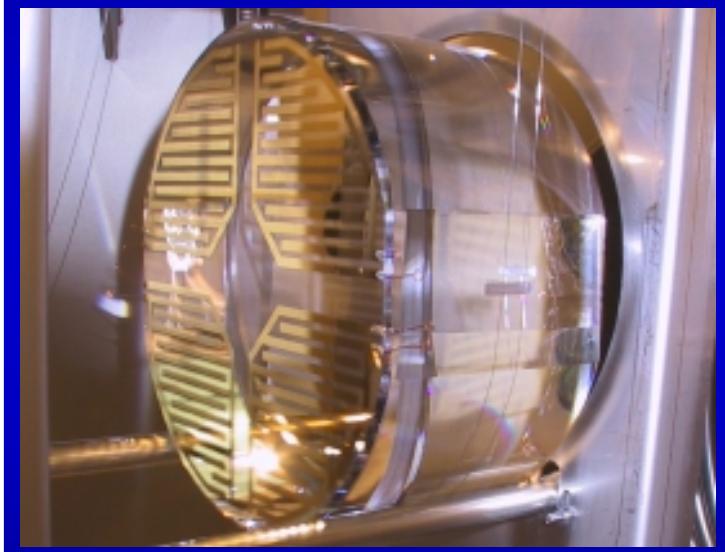
- **Putting an absorbtion Filter (T=50%) in the path between IFO and potential scattering source**
- **Light amplitude at source and scattering will be reduced by a factor sqrt(2)**
- **Scattered light amplitude going back into IFO is attenuated by sqrt(2) again at filter**
- **In summary an exact factor of 2 less scattered light in IFO**





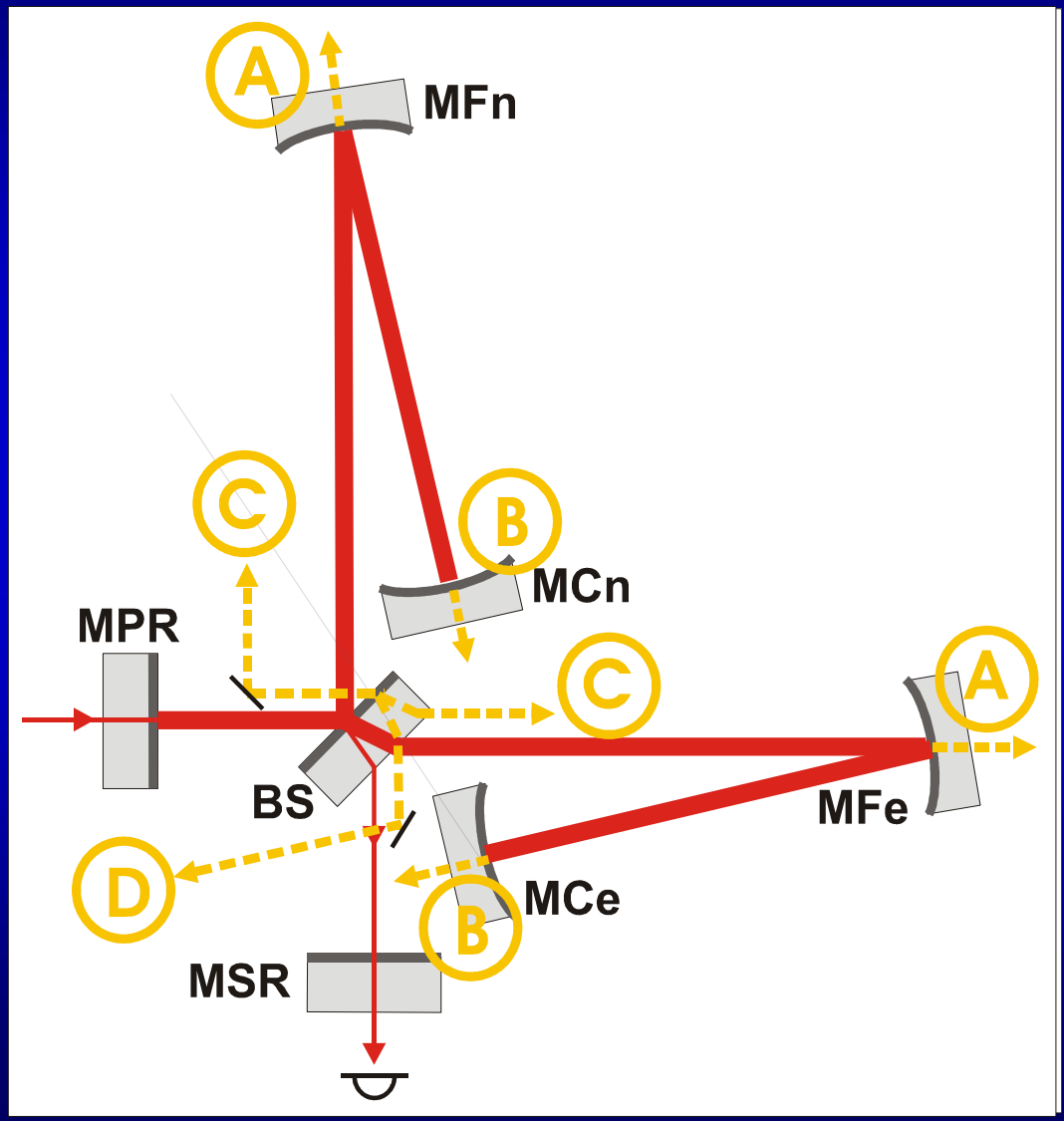
Possible differential scattering points

B → Transmission through the inboard mirrors: scattering from ESDs?



No problem so far !

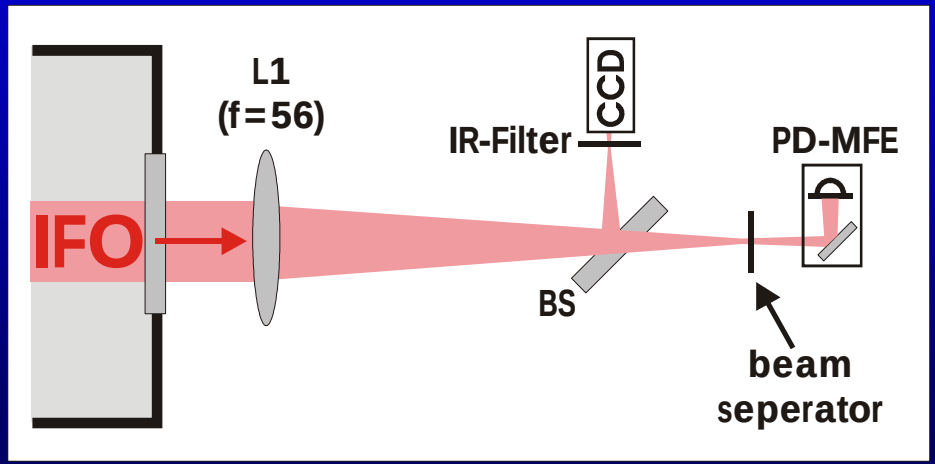
C → Both beams seem to be properly dumped !

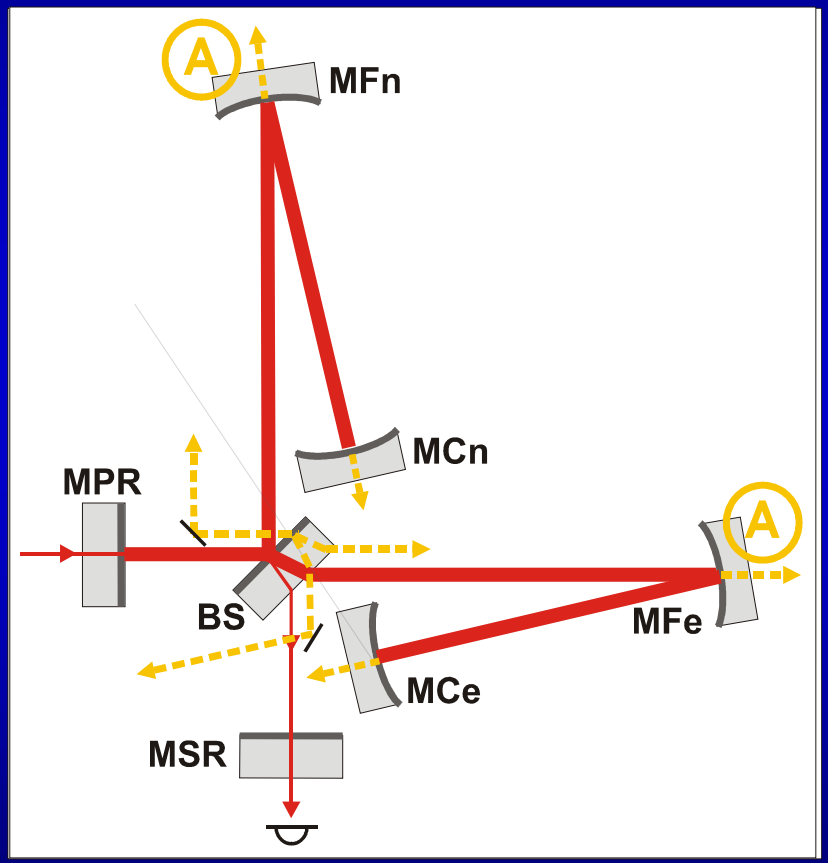


Scattering from the endstations

By listening to MID-EPs we could already hear a noticeable influence from tapping IR-Filter and CCD.

But wasn´t the origin of the shoulder !

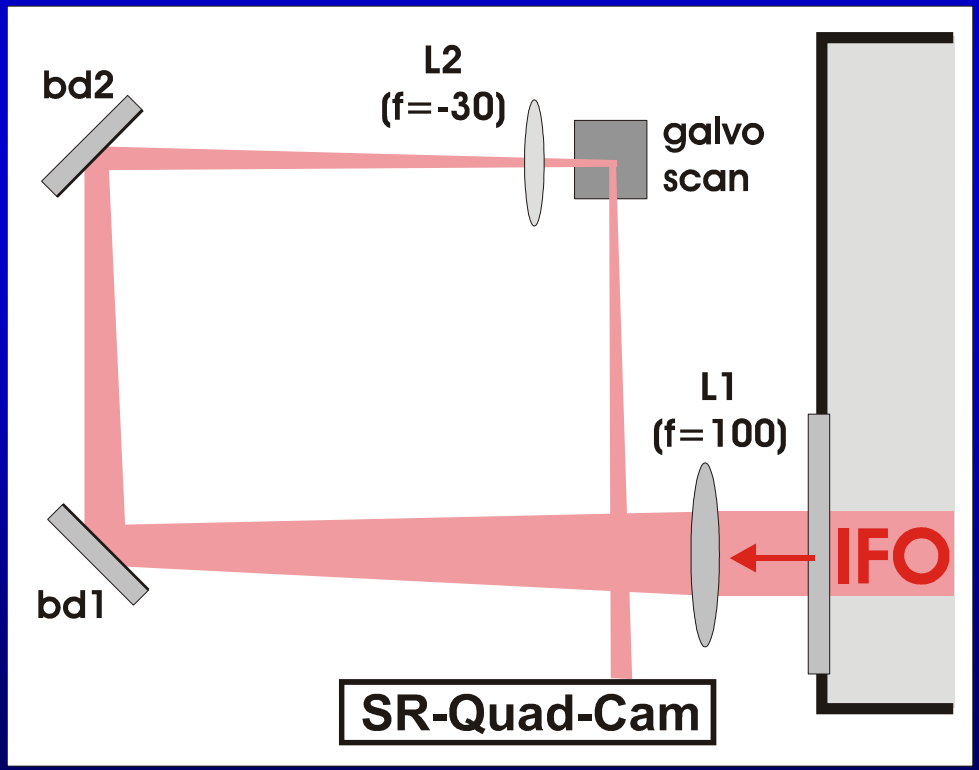


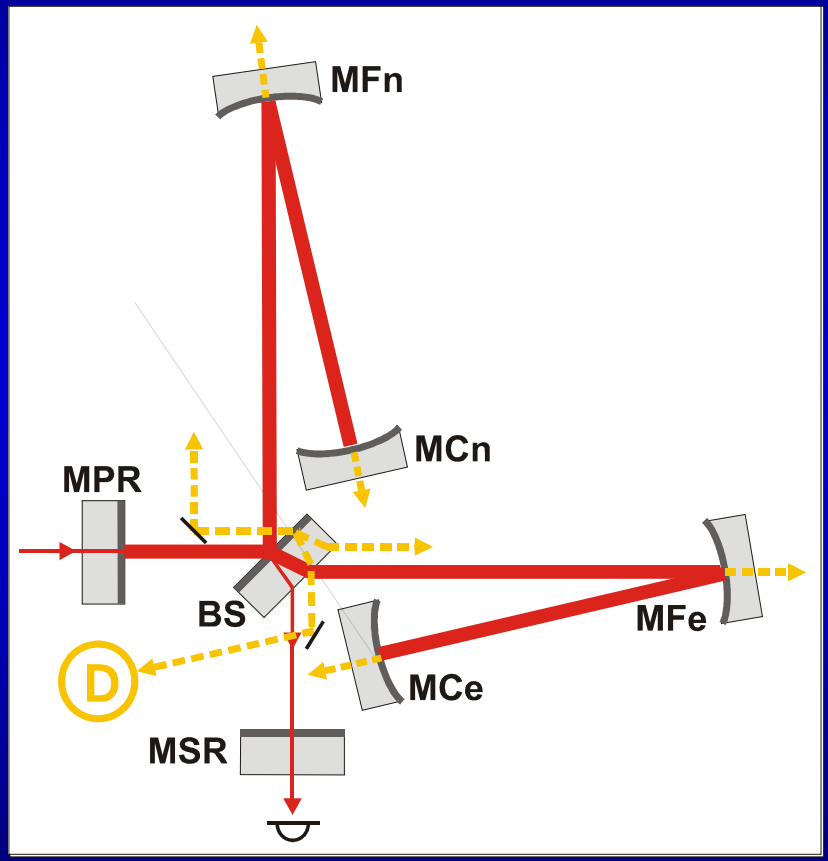


Scattering on SR-Bench

Filter experiments showed that the scattering source is at the SR-bench!

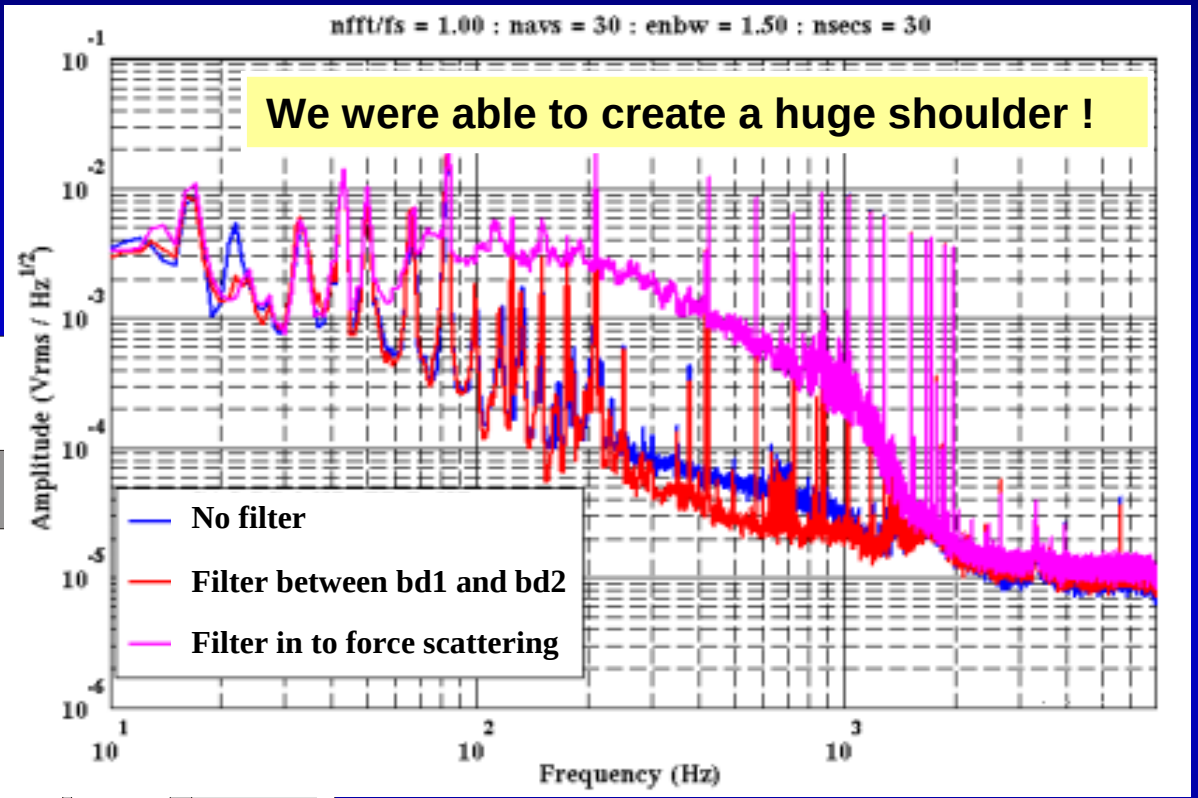
Hard to determine the exact cause / optical component

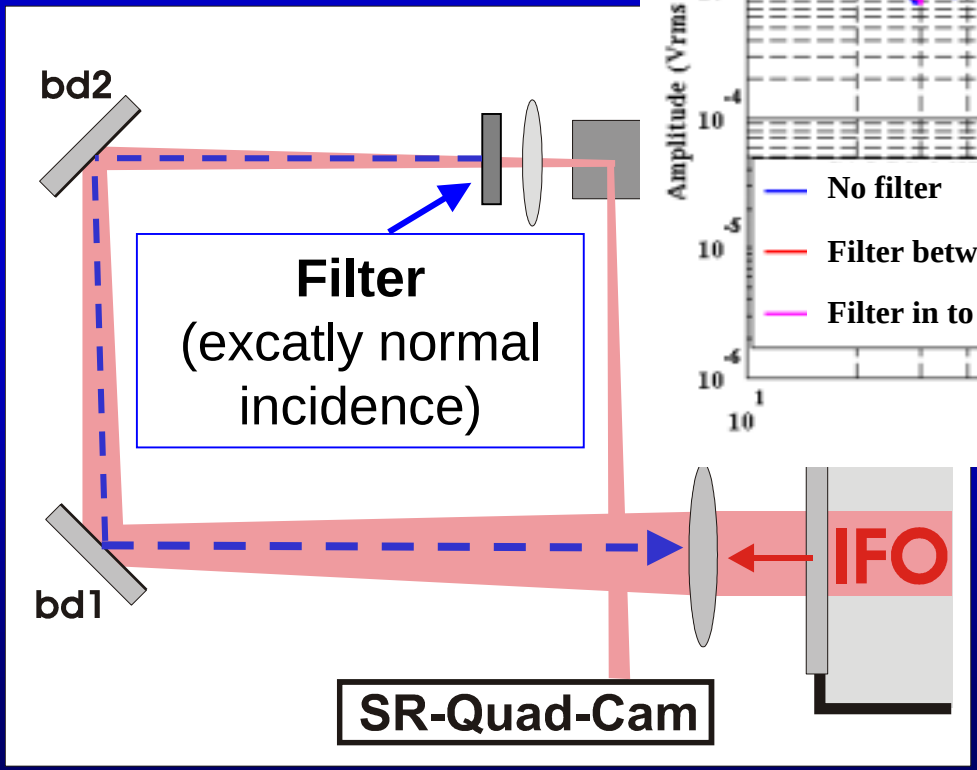




Forced scattering

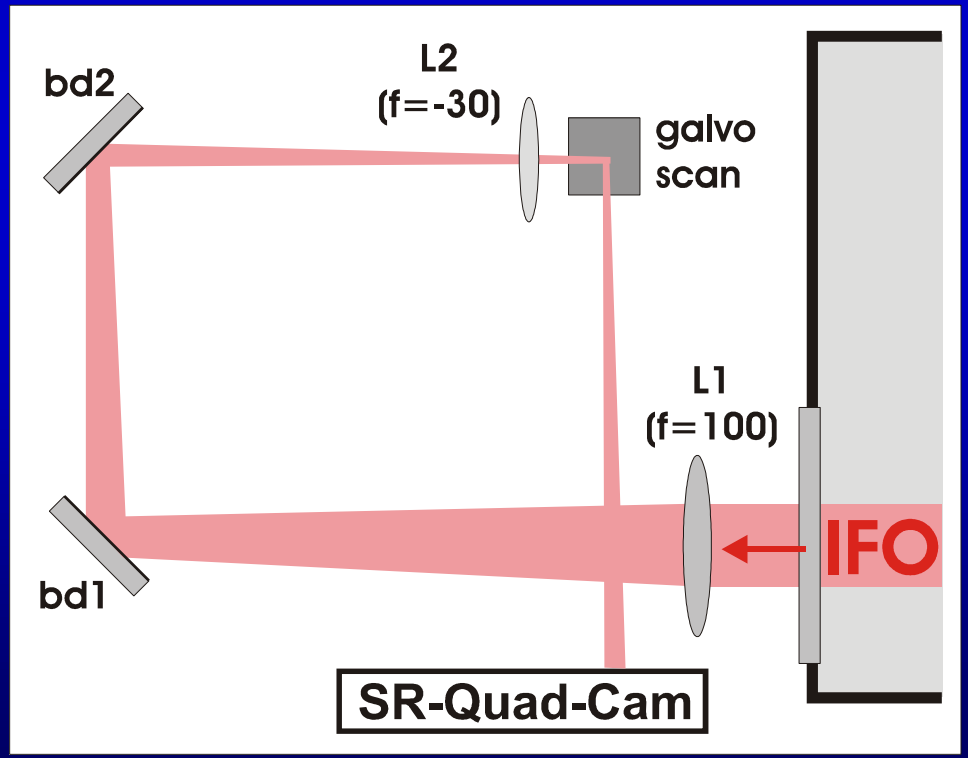
Used a filter (located near the waist) to intentionally force backscattering





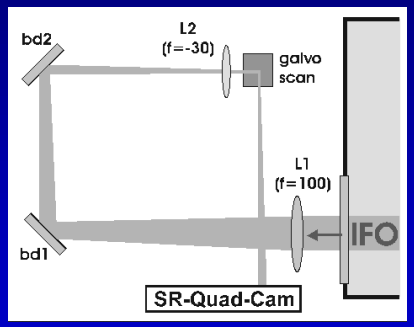
Cat's eye effect:
Light scattered at the waist automaically reenters the Mode of the IFO

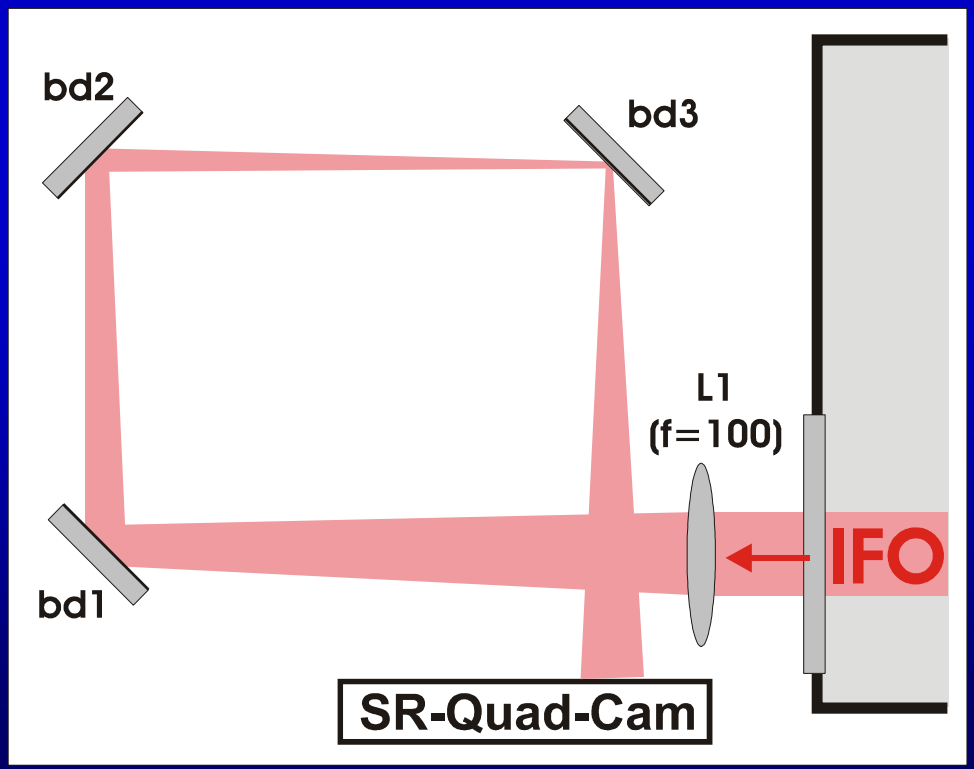
Changed the optical setup at SR-bench



- Tried different alignments through L1 and L2
- Replaced bd2 with ion-sputtered mirror

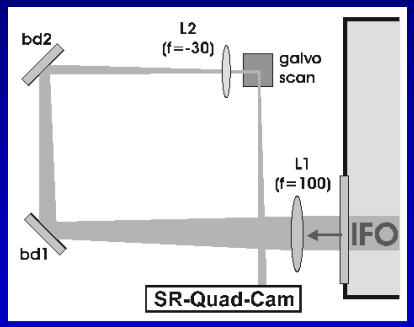
Changed the optical setup at SR-bench

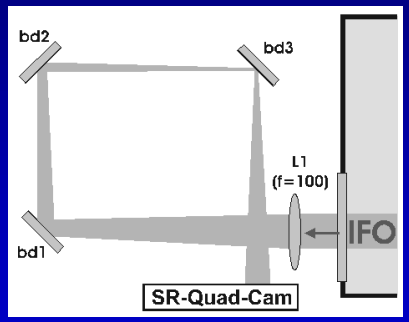


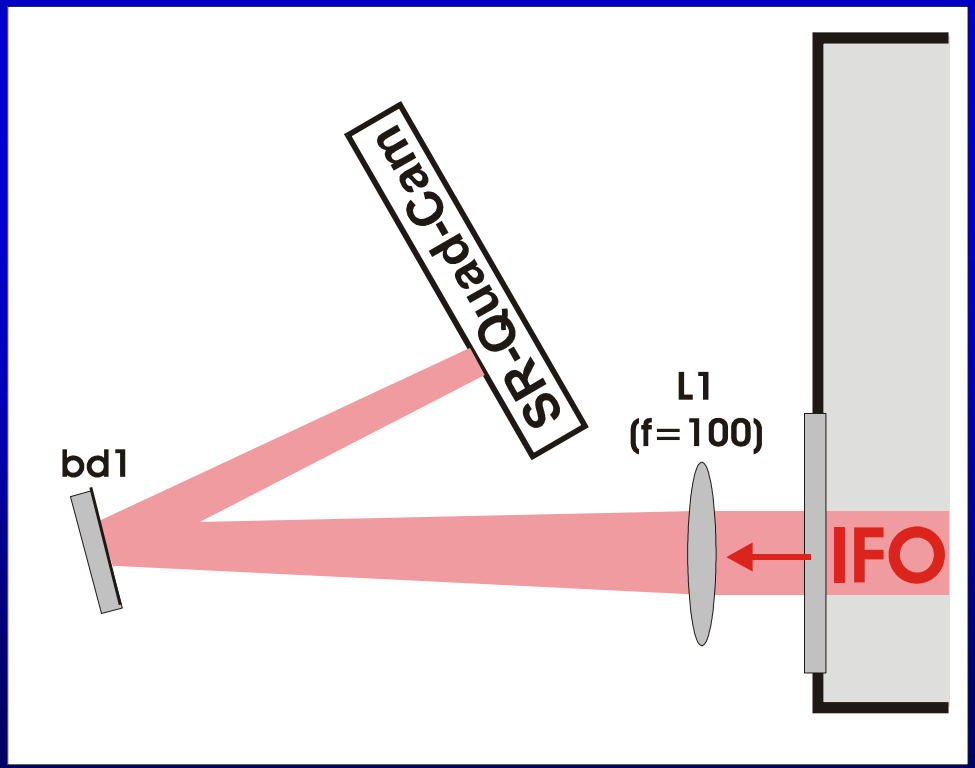


- Tried different alignments through L1 and L2
- Replaced bd2 with ion-sputtered mirror
- Replaced the scanner (poor quality mirrors) with a mirror and removed second lens

Changed the optical setup at SR-bench







- Tried different alignments through L1 and L2
- Replaced bd2 with ion-sputtered mirror
- Replaced the scanner (poor quality mirrors) with a mirror and removed second lens
- Ended up with a very simple setup:
  - only two components left
  - no waist !

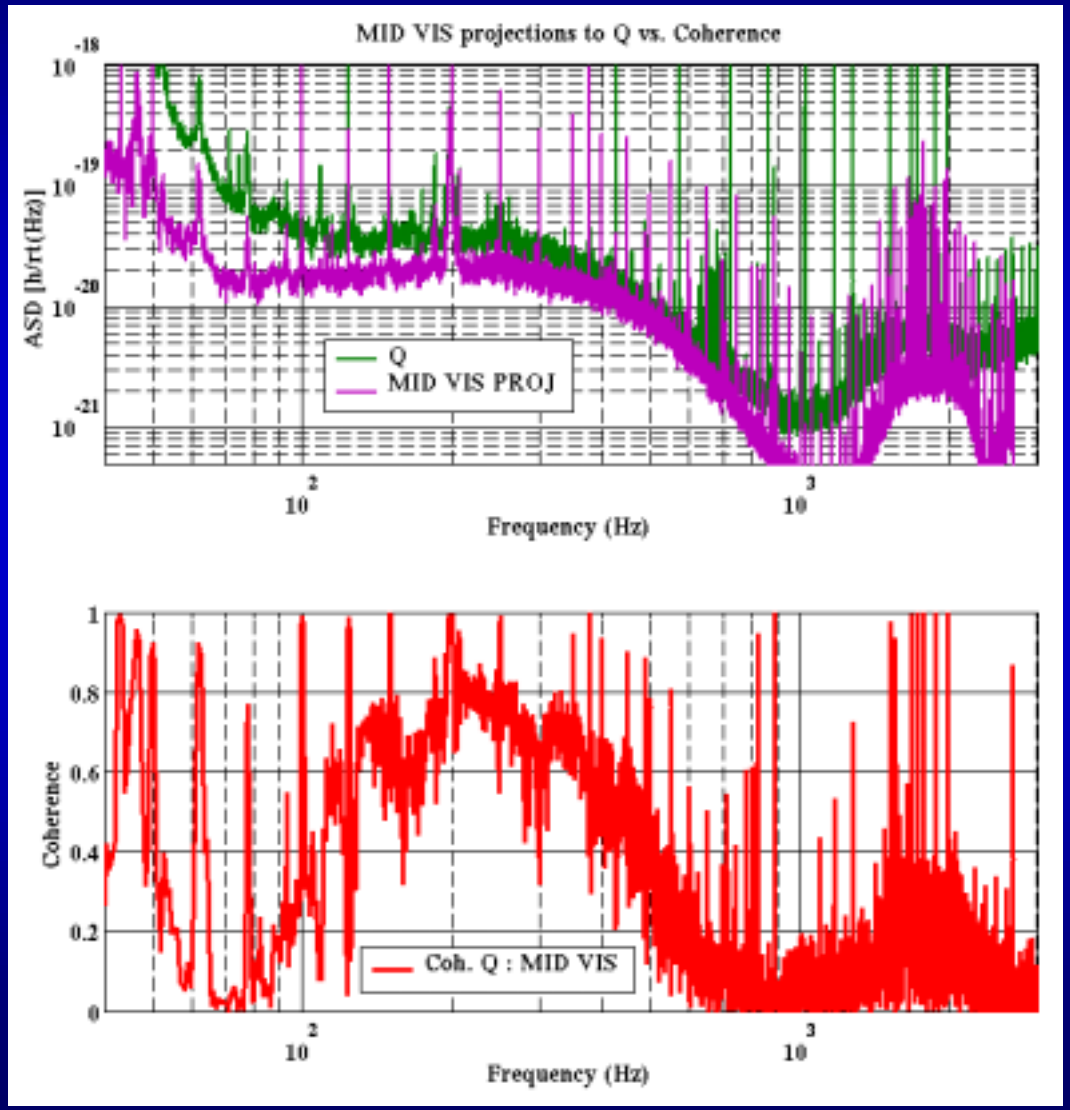
Known amplitude noise coupling

We are still not sure about the coupling path ☹ !!

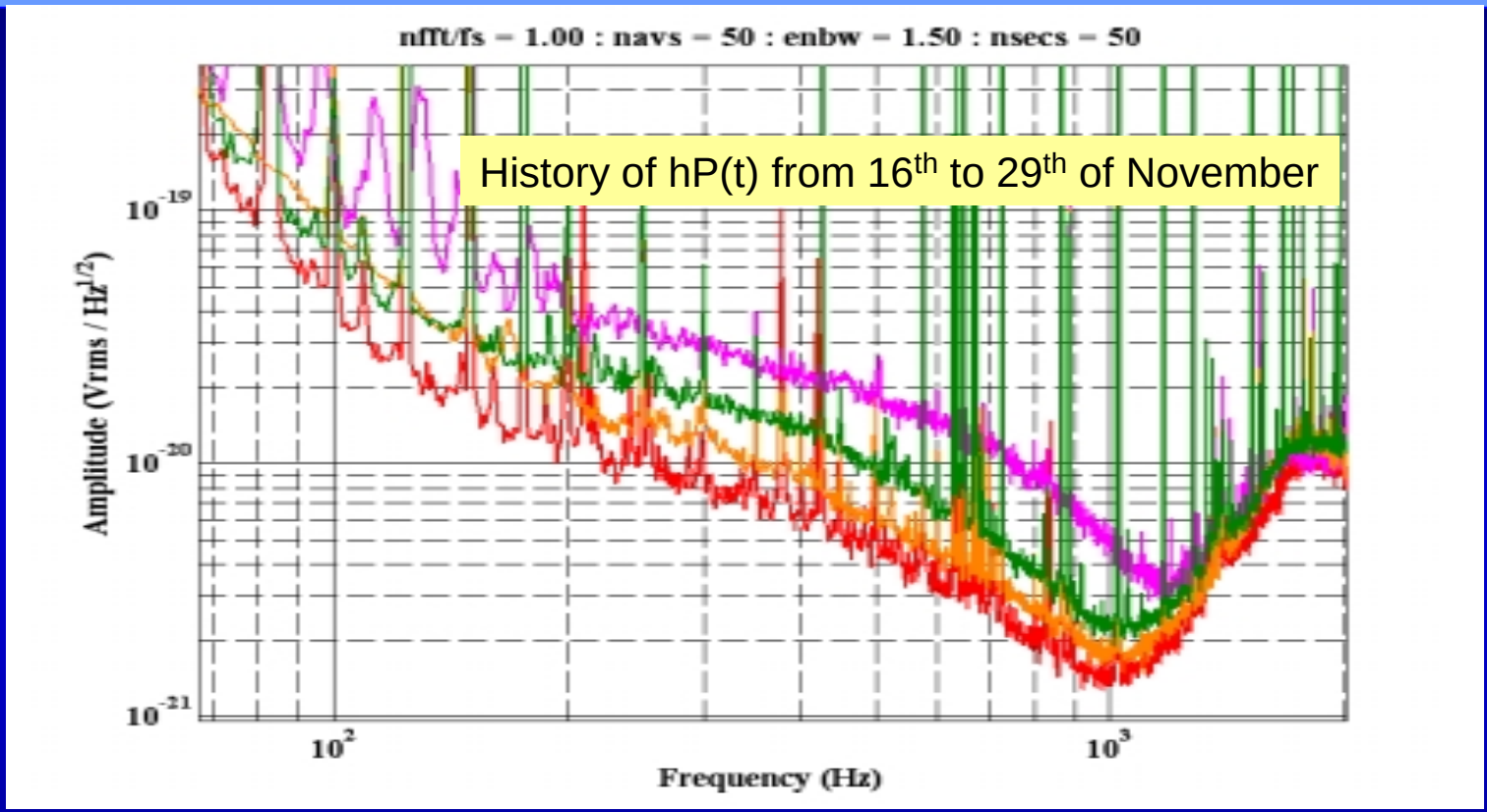
Unfortunately our detector knowledge from this time was limited by a DAQs crash and consequences:

- didn‘t record important channels
- no noise projections for nearly three months

One exemplary explanation of the shoulder: amplitude noise coupling



Scattering history



Due to the changes at the signal recycling bench we were able to improve sensitivity by a factor of 3 to 4 from 100 Hz to 1 kHz.

Since then we had no indication for any further scattering

⇒ could carry on commissioning and improving sensitivity as before !!

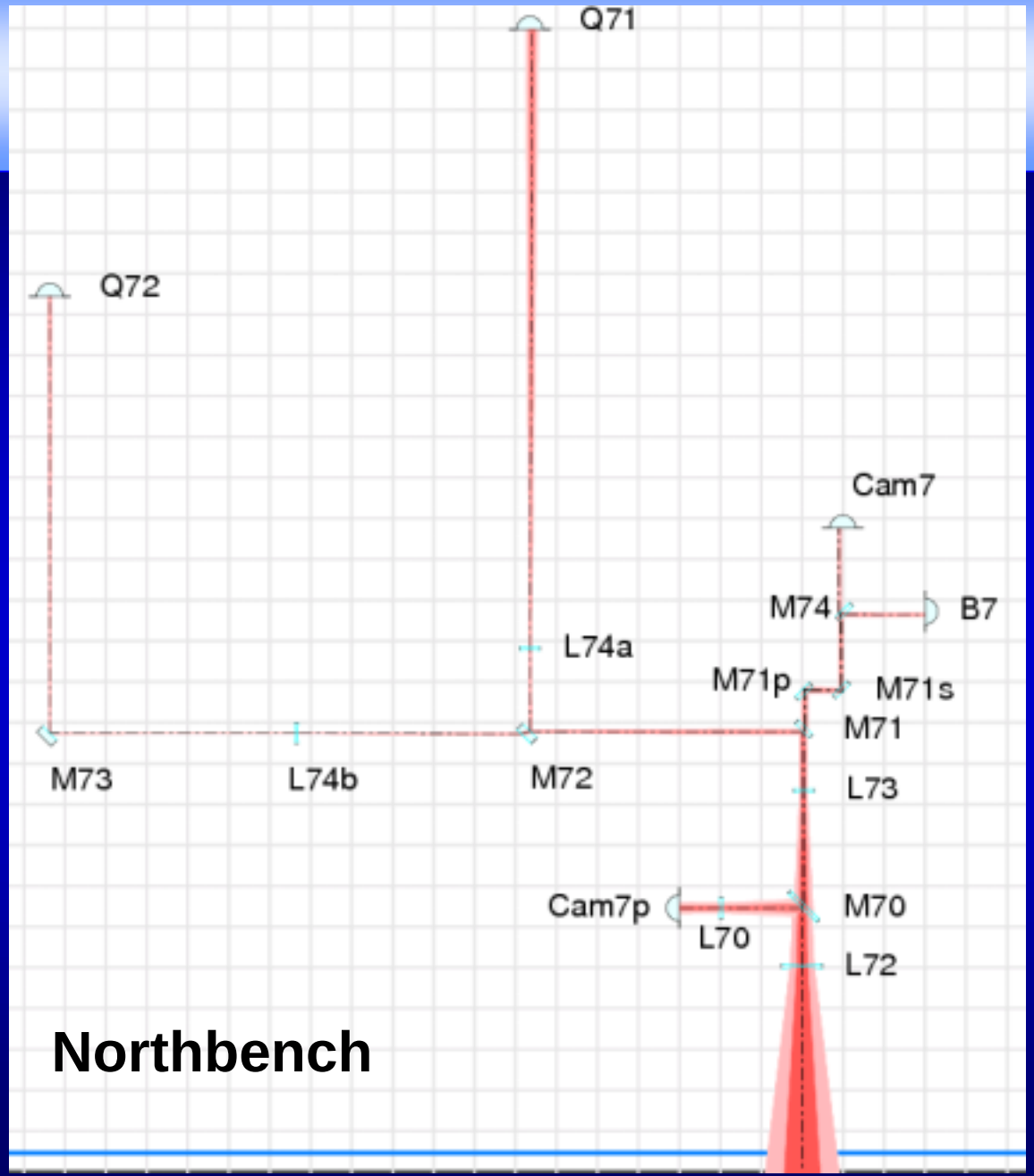
Conclusion

- Try to avoid beam waist wherever it is possible
- Especially in differential beam paths

If you can´t avoid having a waist:

- **Don‘t place any optics near the waist !**
- **Use high quality optics**

And be always aware of the cat´s eye trap!


Q71
Q72
Cam7
M74
B7
L74a
M71p
M71s
M71
M73
L74b
M72
L73
Cam7p
M70
L70
L72
Northbench