Current efforts on the TAMA300 detector

National Astronomical Observatory of Japan

Koji Arai
on behalf of the TAMA collaboration

Amaldi6 meeting
2005/6/22
Okinawa

TAMA300: Interferometer GW detector

- TAMA300:

  A 300-m Power-recycled Fabry-Perot Michelson Interferometer
  Site: National Astronomical Observatory of Japan
  (Mitaka, Tokyo)

- Operation of TAMA300

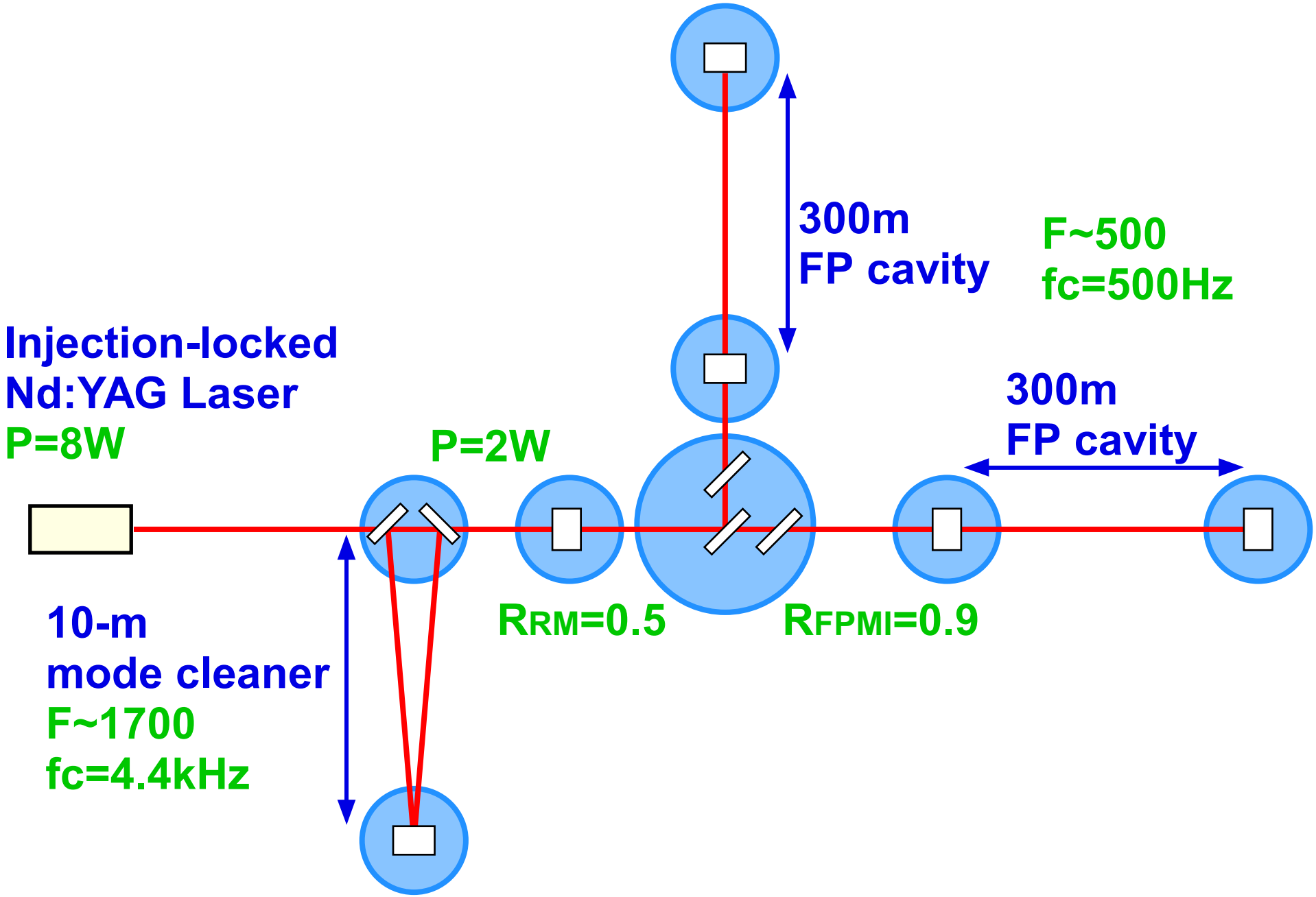
  Fabry-Perot Michelson: 1999~2001
  Power Recycling: 2001~Present

- This talk

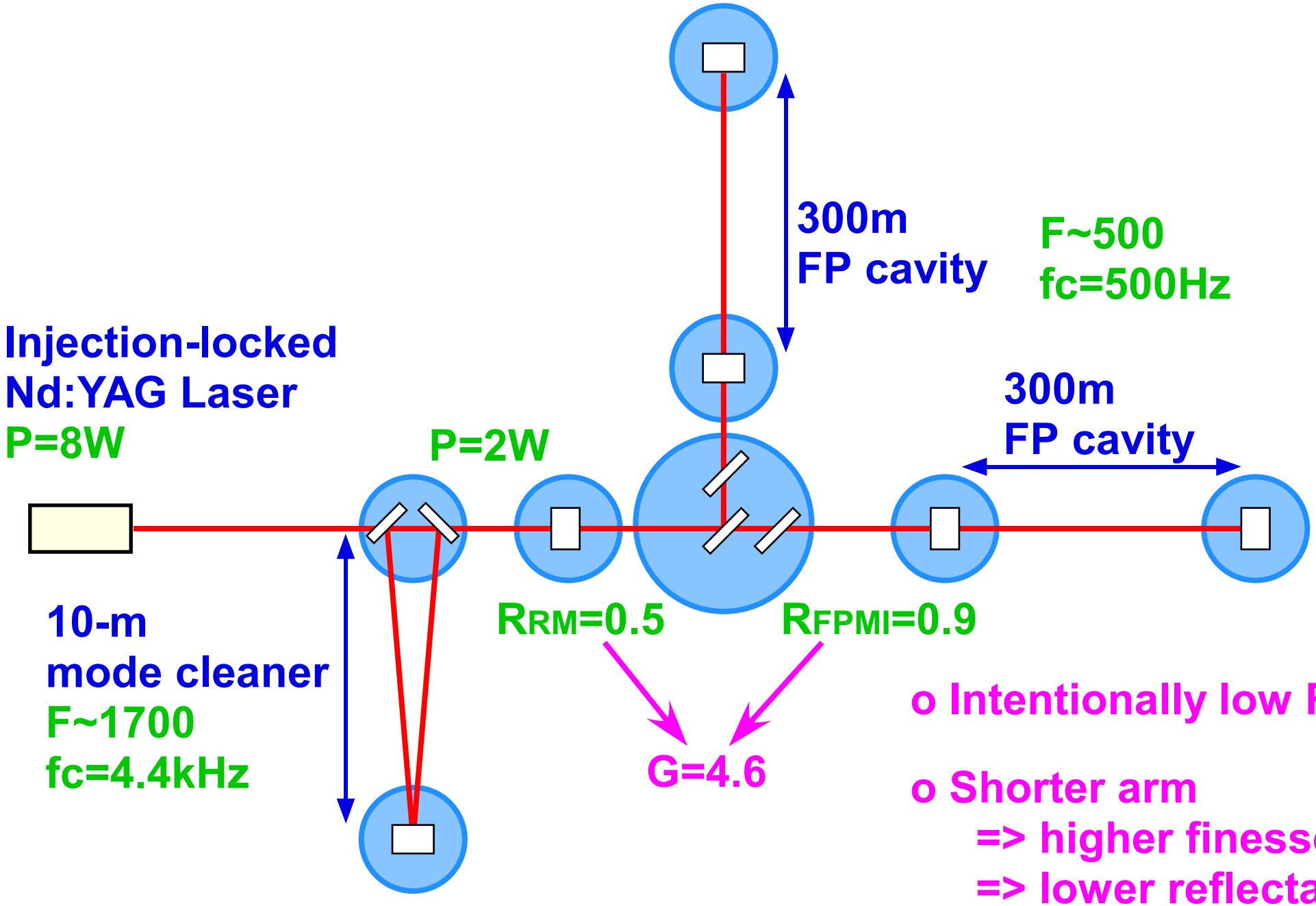
  - Brief introduction
  of the control schemes and the loock acquisition

  - Current effort to improve the sensitivity,
  being focused on the low frequency region (DC-200Hz)
  and the mid frequency region (200Hz-2kHz)

Optical configuration of TAMA300



Optical configuration of TAMA300



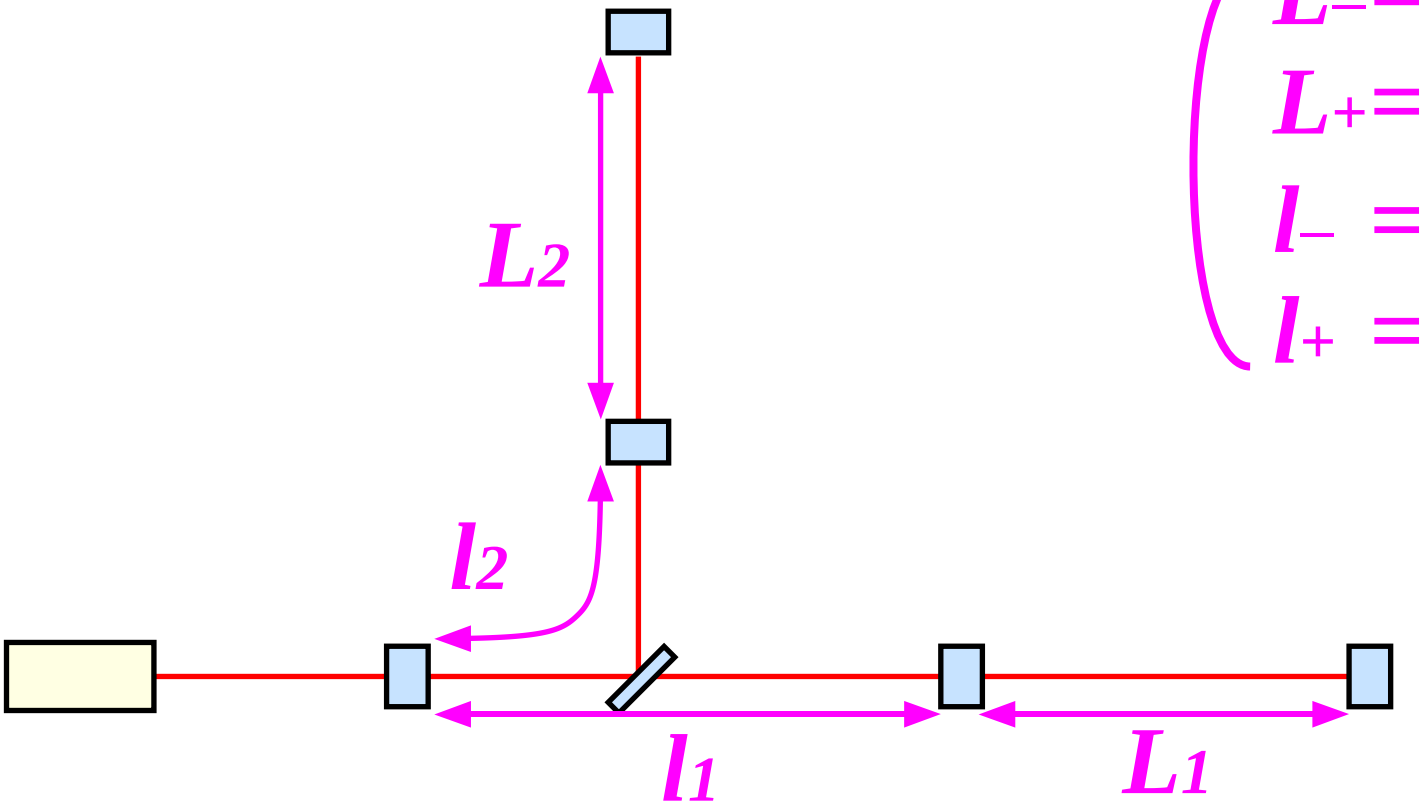
- Intentionally low R_{RM}
- Shorter arm
  - => higher finesse
  - => lower reflectance

Length sensing and control

- Recycled Fabry-Perot Michelson Interferometer

  4 longitudinal d.o.f. to be controlled

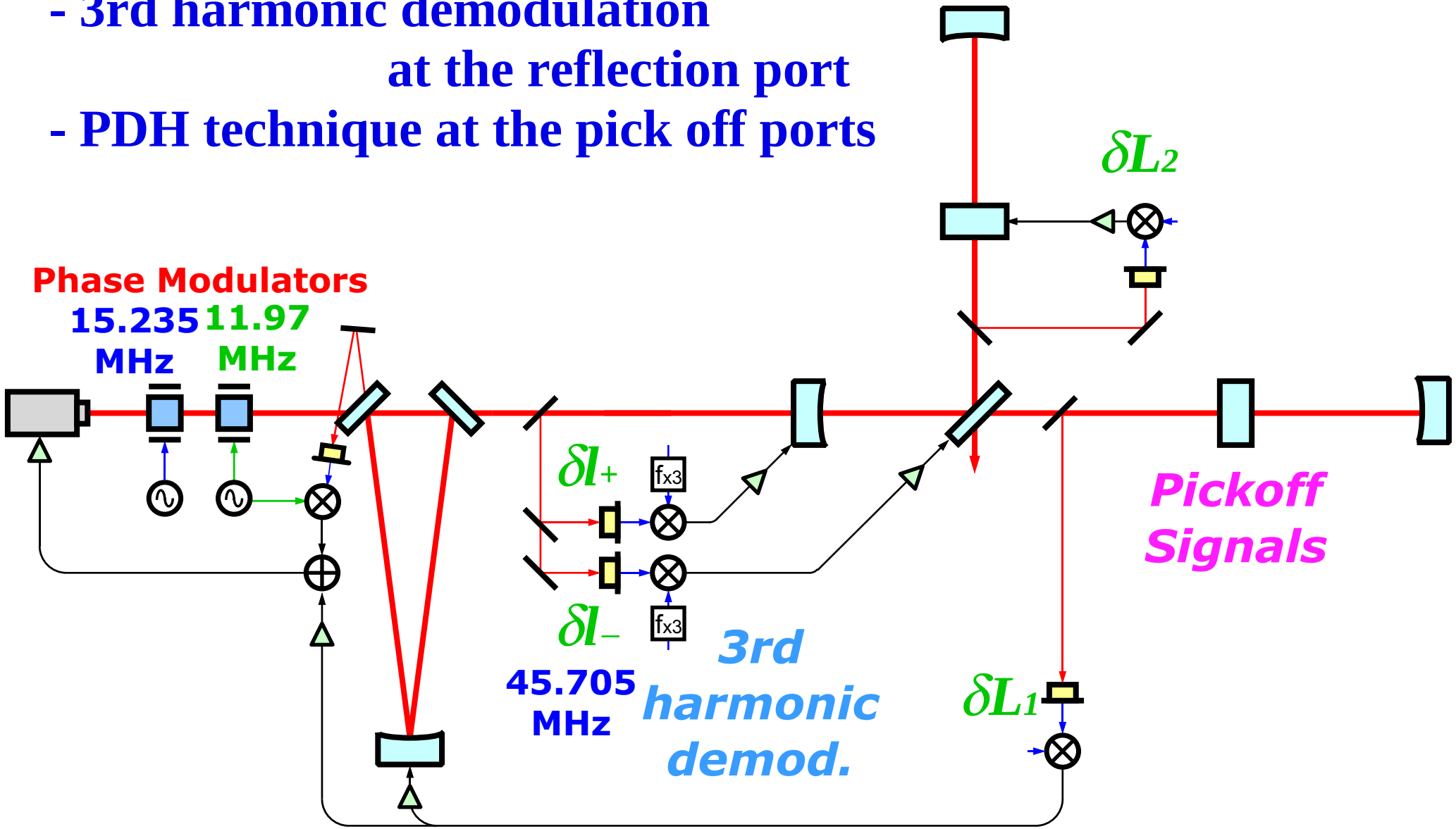
  ~ The optical cavities and the Michelson interferometer must be on the operating point



$$\begin{cases} L_- = L_2 - L_1 \\ L_+ = L_2 + L_1 \\ l_- = l_2 - l_1 \\ l_+ = l_2 + l_1 \end{cases}$$

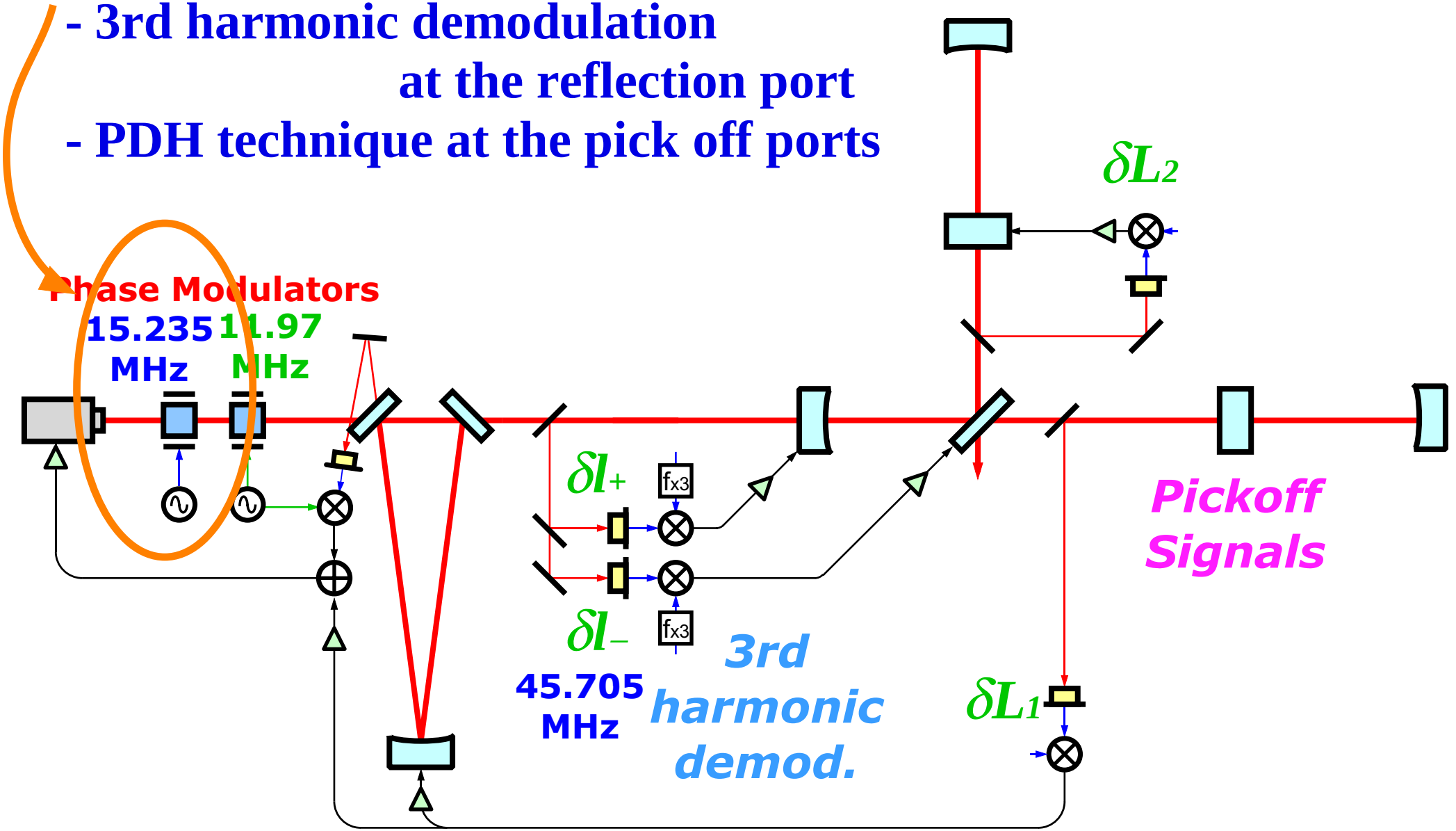
Length sensing and control ~ for lock acquisition

- Based on the PDH technique and Schunupp modulation
  - **single phase modulation at 15MHz**
  - **3rd harmonic demodulation at the reflection port**
  - **PDH technique at the pick off ports**



Length sensing and control ~ for lock acquisition

- Based on the PDH technique and Schunupp modulation
  - **single phase modulation at 15MHz**
  - **3rd harmonic demodulation at the reflection port**
  - **PDH technique at the pick off ports**



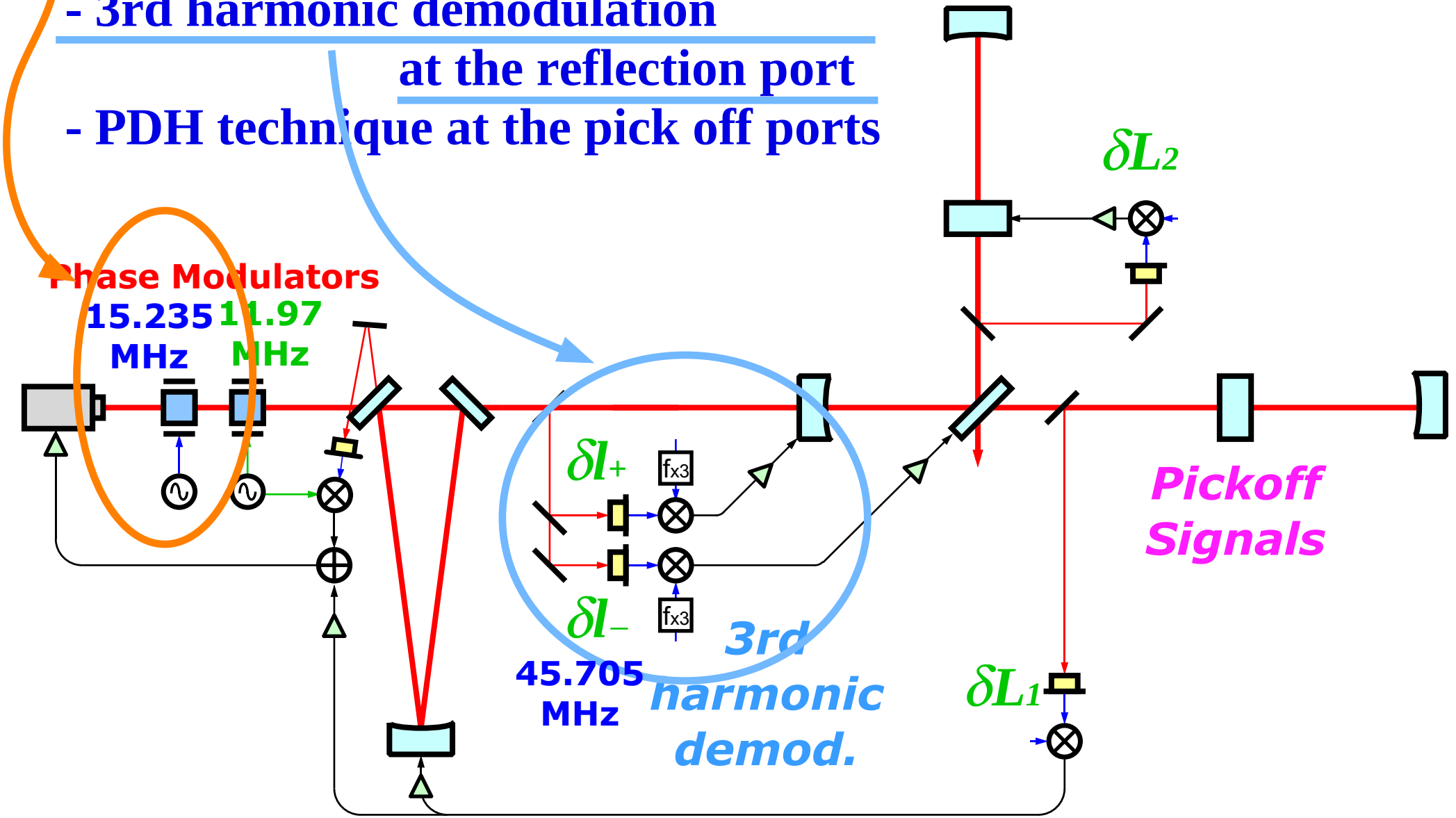
Length sensing and control ~ for lock acquisition

- Based on the PDH technique and Schunupp modulation

- single phase modulation at 15MHz

- 3rd harmonic demodulation at the reflection port

- PDH technique at the pick off ports



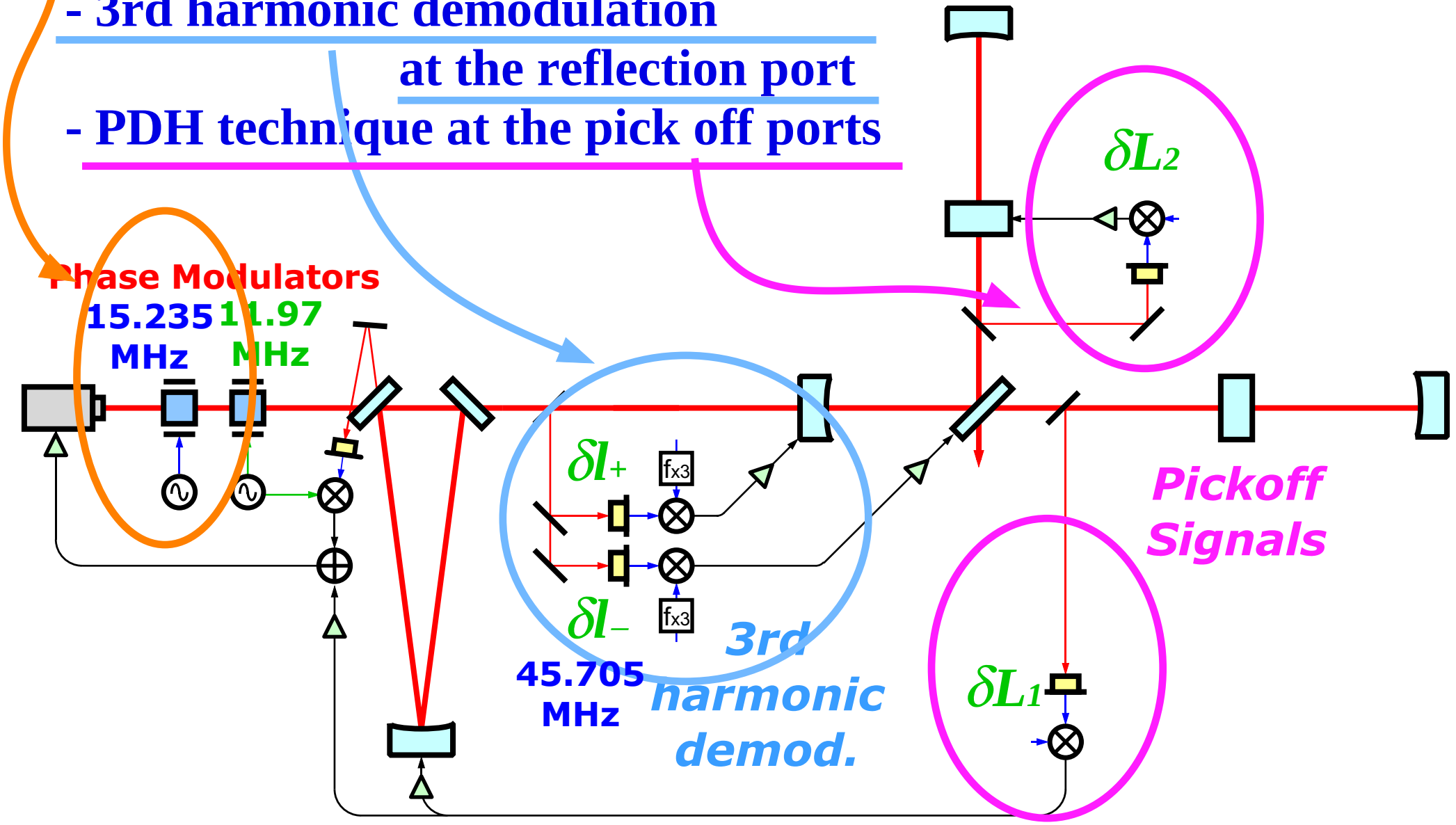
Length sensing and control ~ for lock acquisition

- Based on the PDH technique and Schunupp modulation

- single phase modulation at 15MHz

- 3rd harmonic demodulation at the reflection port

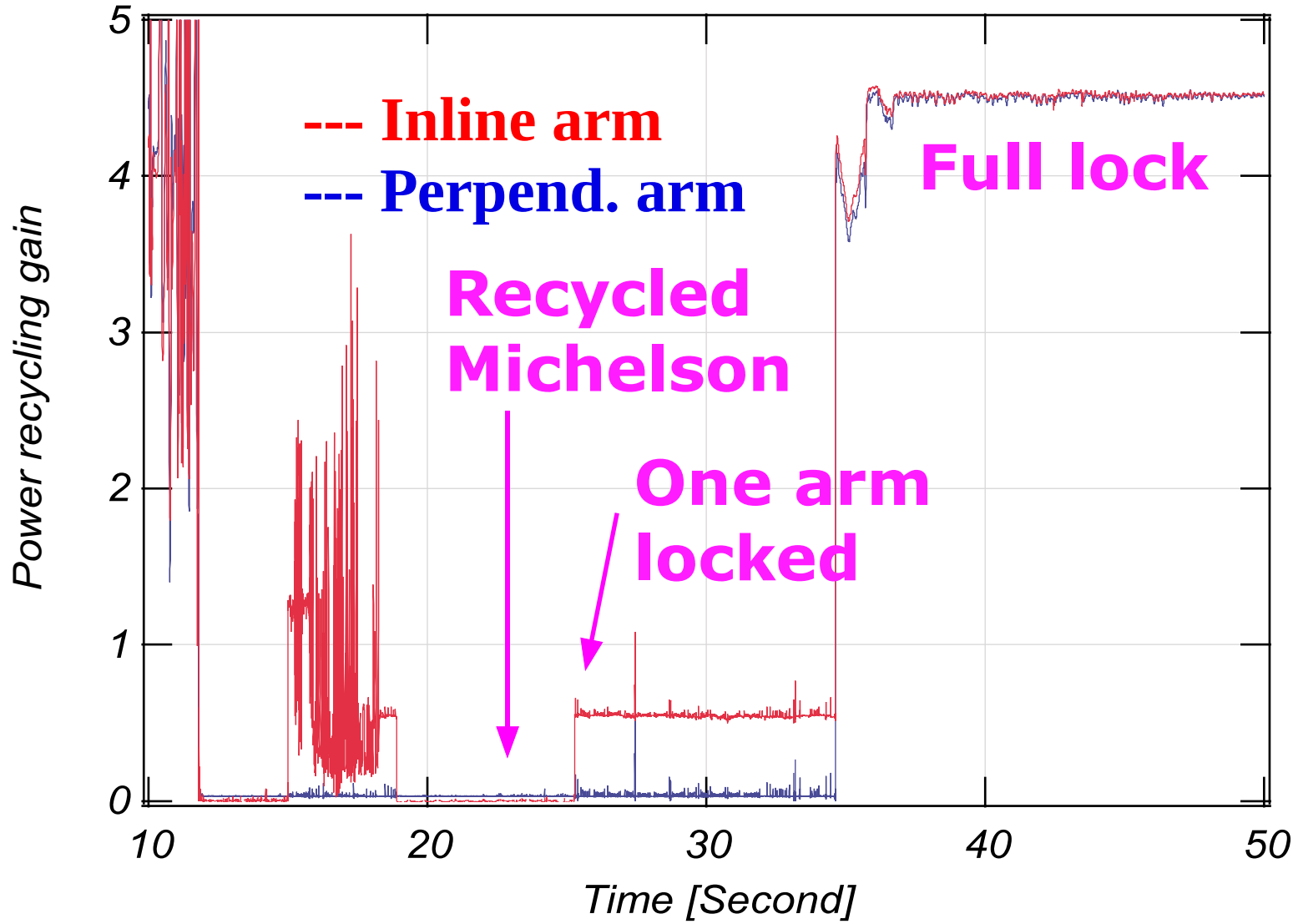
- PDH technique at the pick off ports



Lock acquisition

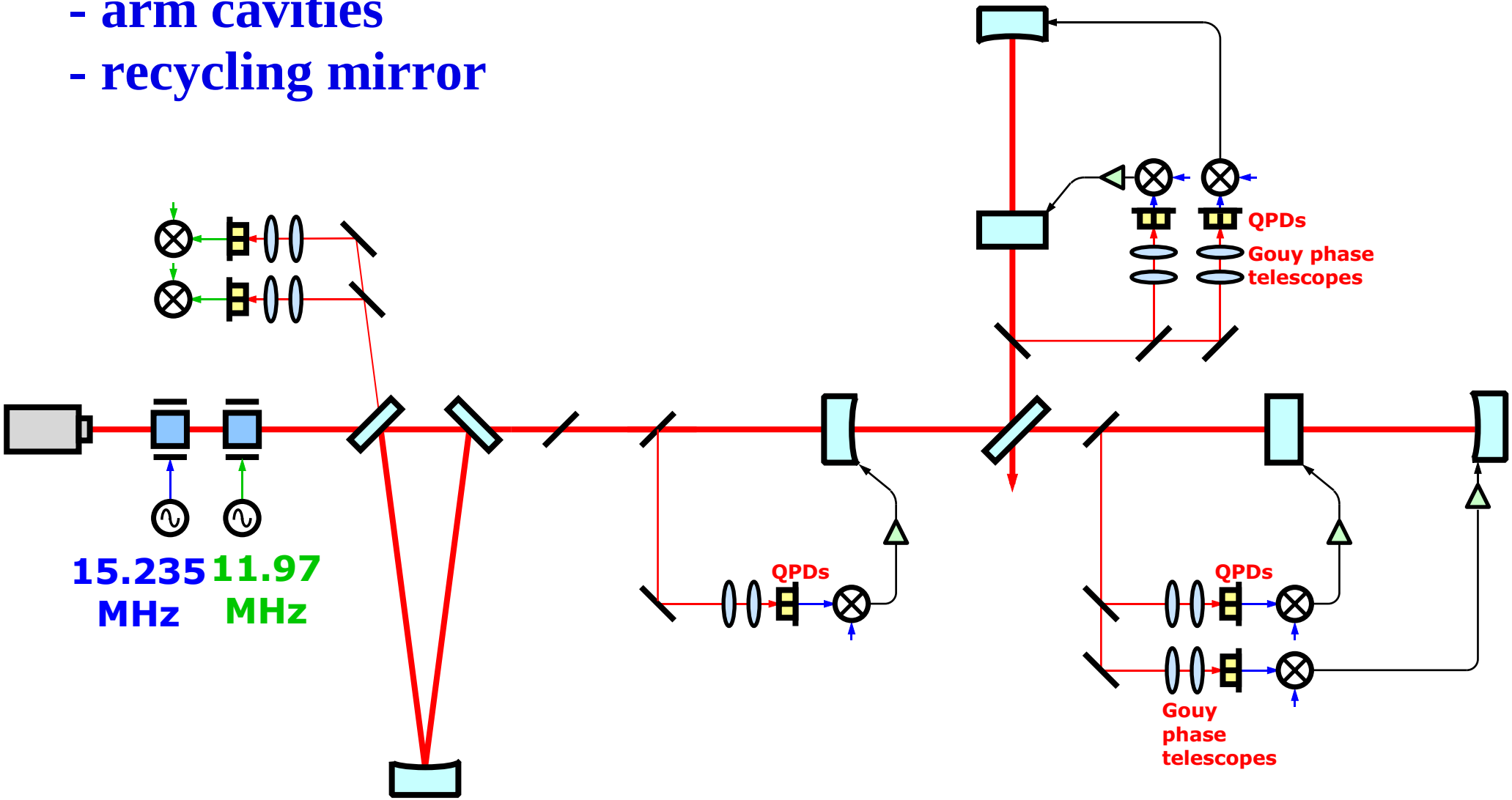
- Typically the lock is acquired within minutes

  ~ need good pre-alignment



Alignment sensing and control

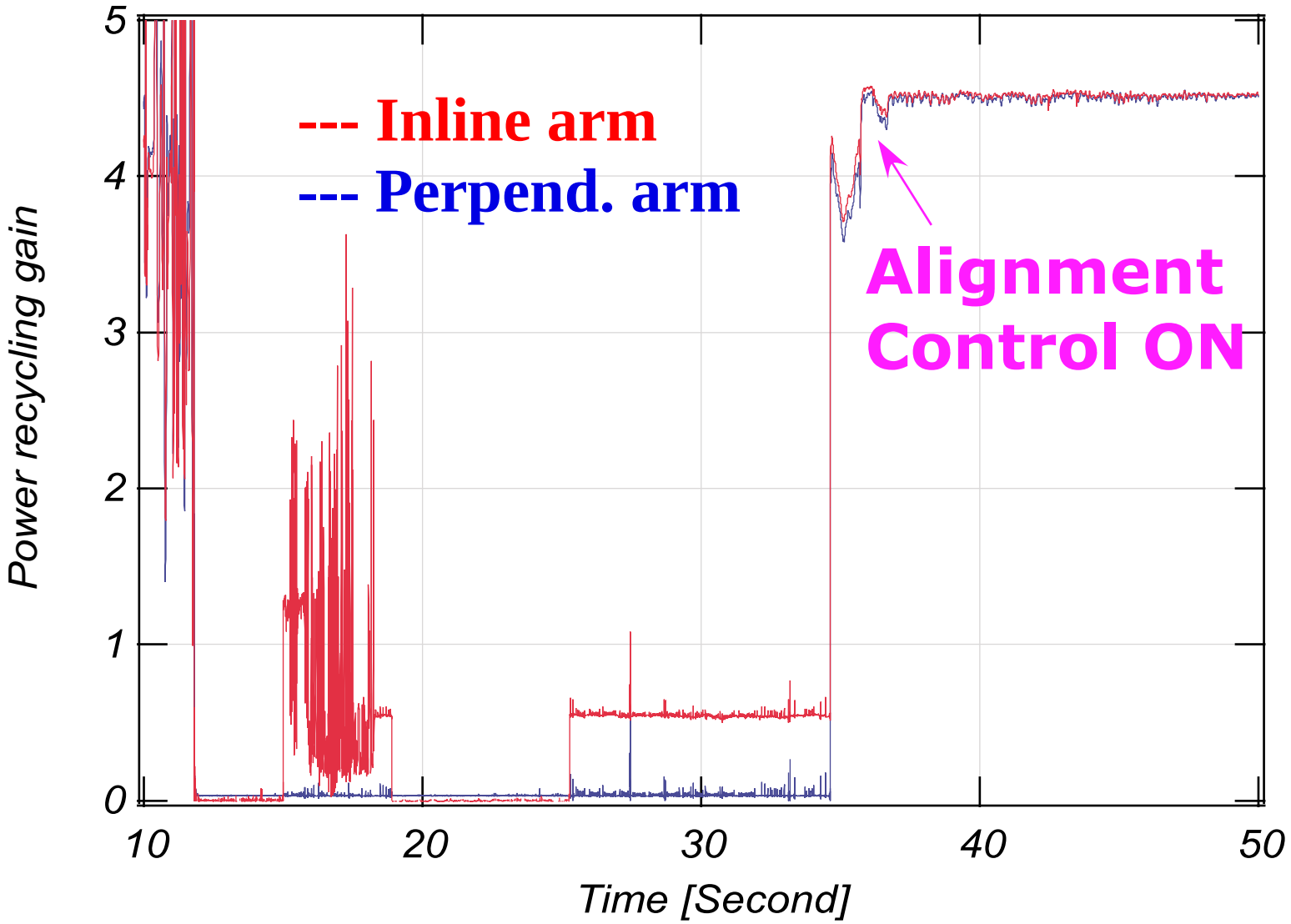
- Wave front sensing technique
  - **mode cleaner cavity**
  - **arm cavities**
  - **recycling mirror**



Lock acquisition

- Alignment control

for the arm, UGF: 5~10Hz, for the RM, UGF: ~10mHz



Length sensing and control ~ for low noise mode

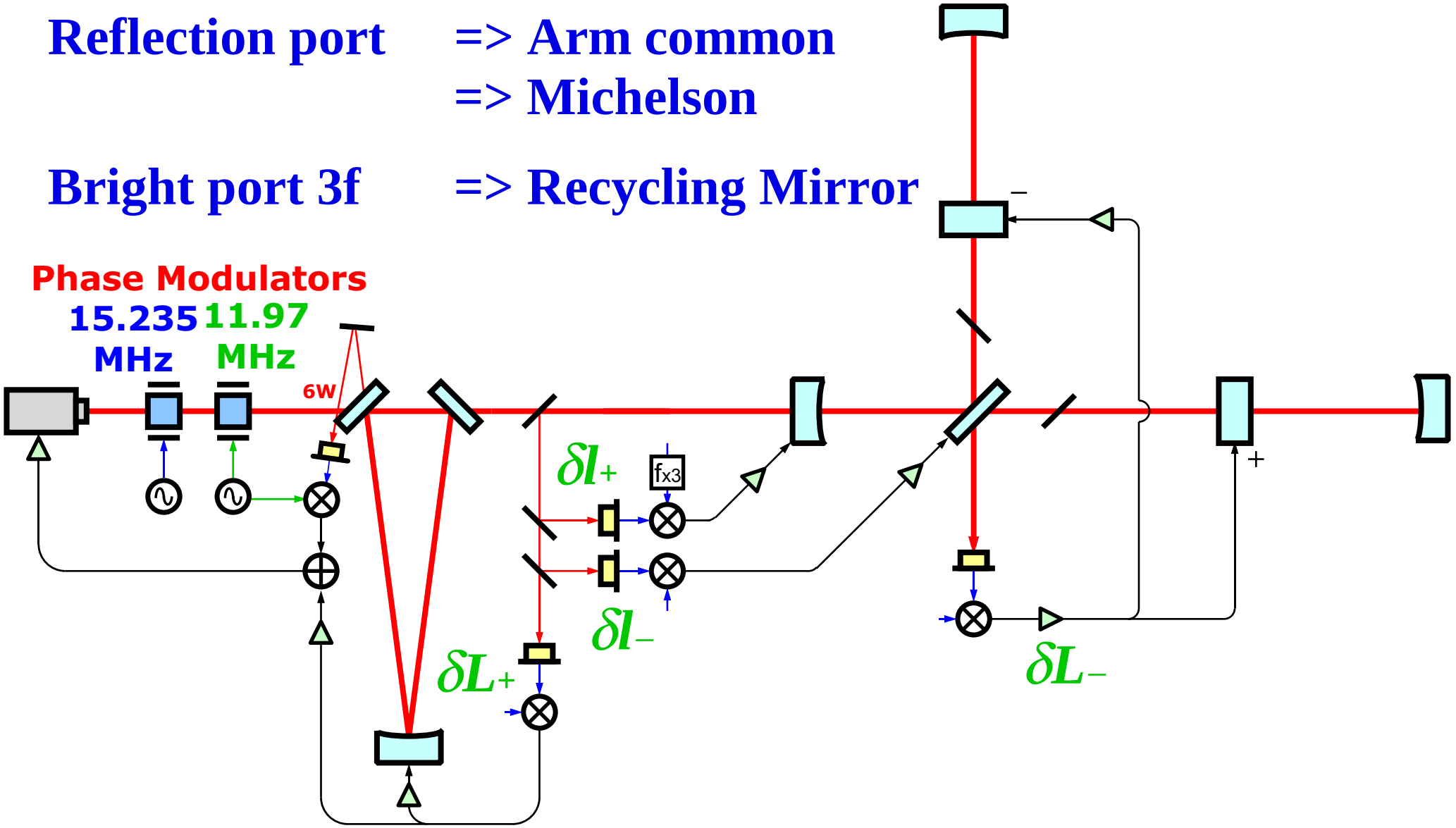
- Common/differential separated control

Dark port => Arm differential

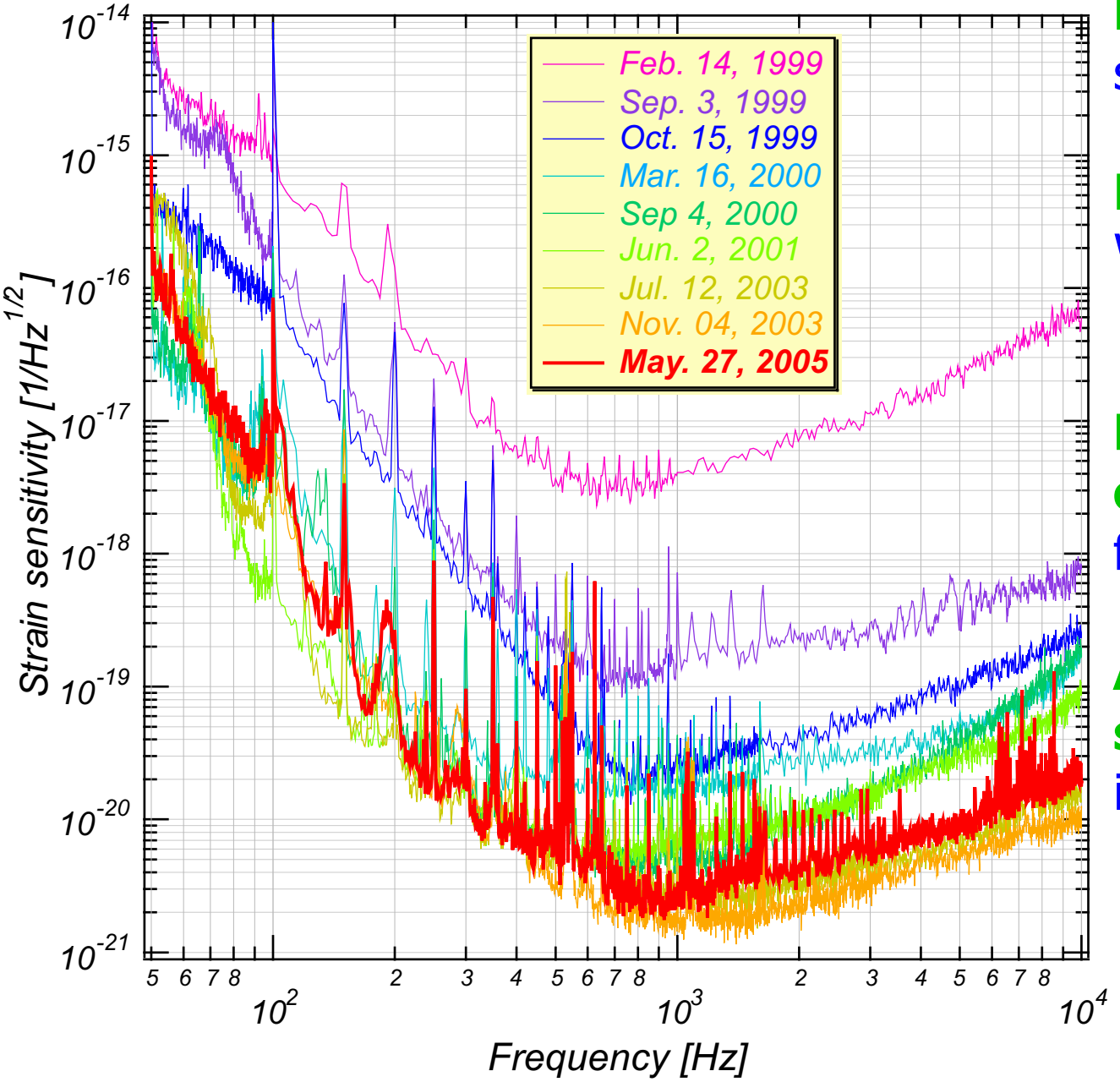
Reflection port => Arm common

=> Michelson

Bright port 3f => Recycling Mirror



Sensitivity history



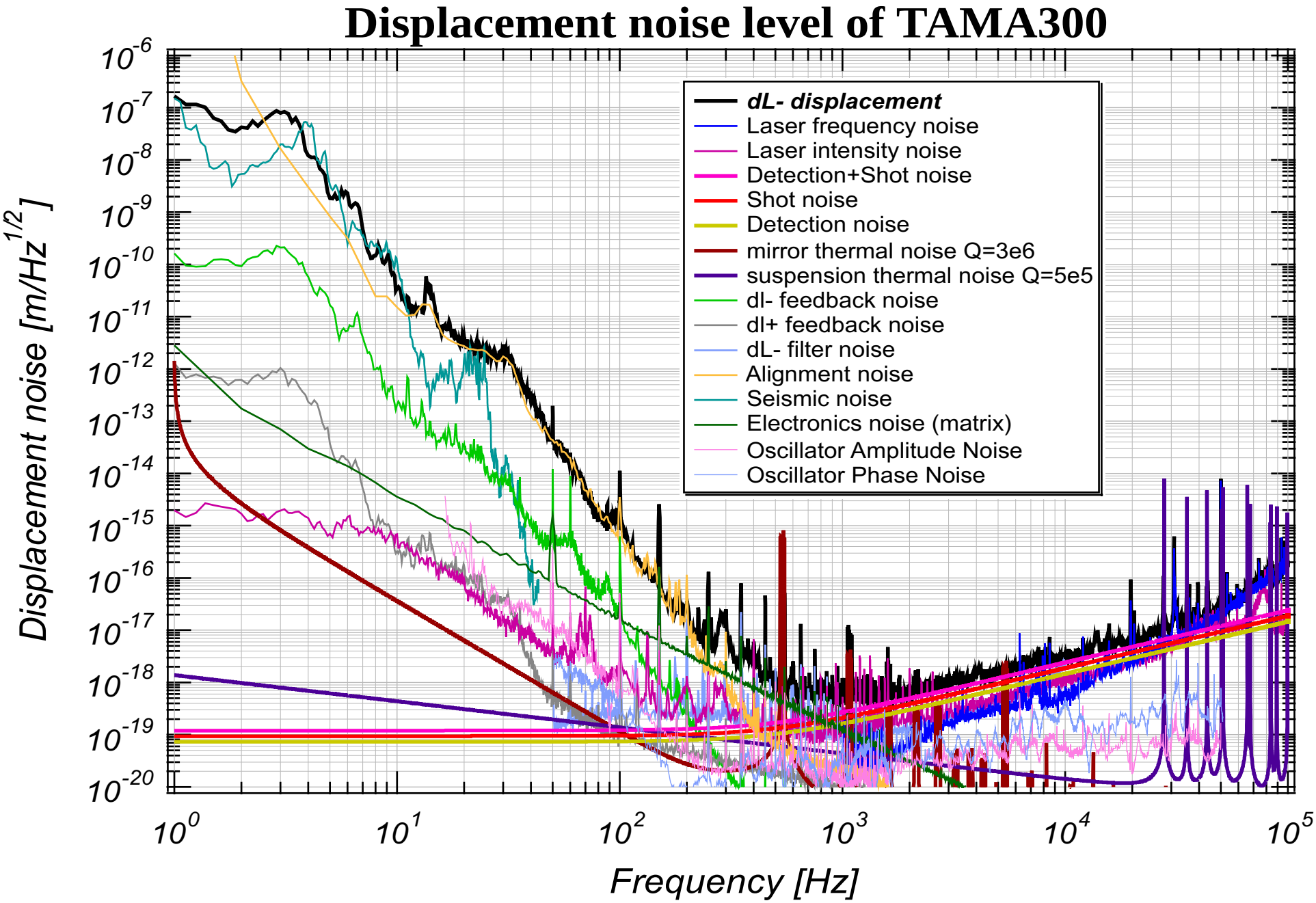
No apparent improvement
since 2003/11~ (S3)

Last year:
Worked with
Recycled Michelson

Restoration
of the full interferometer:
from 2004 autumn

Approached to the previous sensitivity level
in the end of March

Noise budget



Current understanding about TAMA sensitivity

- ***Low frequency***

  Seismic noise (DC~20Hz)

  Noise from alignment servos (20Hz~200Hz)

- ***Middle frequency***

  Not known well (200Hz~2kHz)

  Scattering noise

  Electronics noise

- ***High frequency noise***

  ~ shot noise (2kHz~50kHz)

SAS: Seismic Attenuation System

- ***Development of SAS***

Collaboration with

Caltech and **Universita' di Pisa**

- ***Installation***

'05 summer:

1 SAS for one of the end mass

'05 autumn/winter:

The other 3 SASs

- ***Target***

To improve seismic-related noise

direct or indirect noise couplings

Stabilize of the IFO

To ease lock acquisition

SAS: Seismic Attenuation System

- ***Development of SAS***

Collaboration with

Caltech and **Universita' di Pisa**

- ***Installation***

'05 summer:

1 SAS for one of the end mass

'05 autumn/winter:

The other 3 SASs

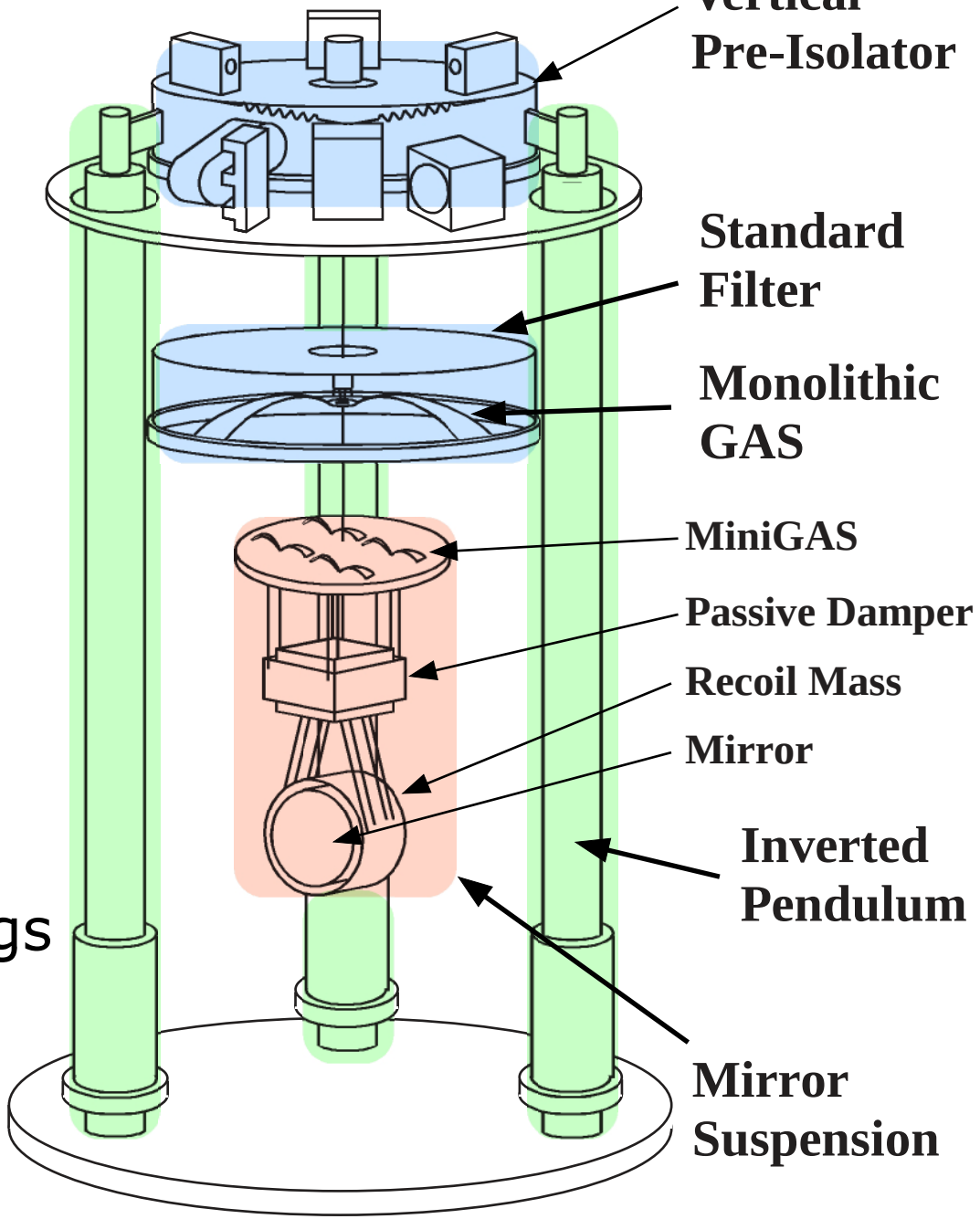
- ***Target***

To improve seismic-related noise

direct or indirect noise couplings

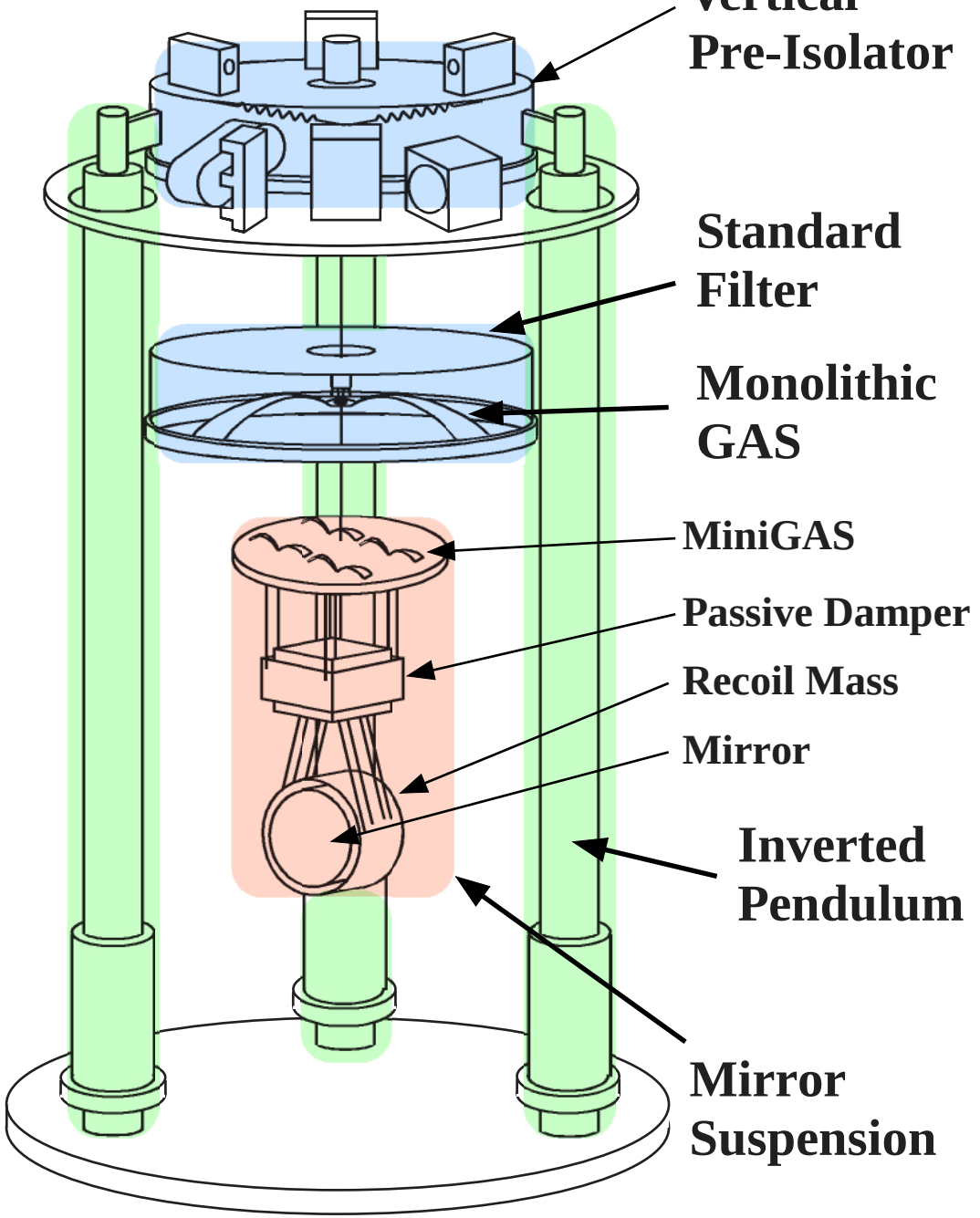
Stabilize of the IFO

To ease lock acquisition

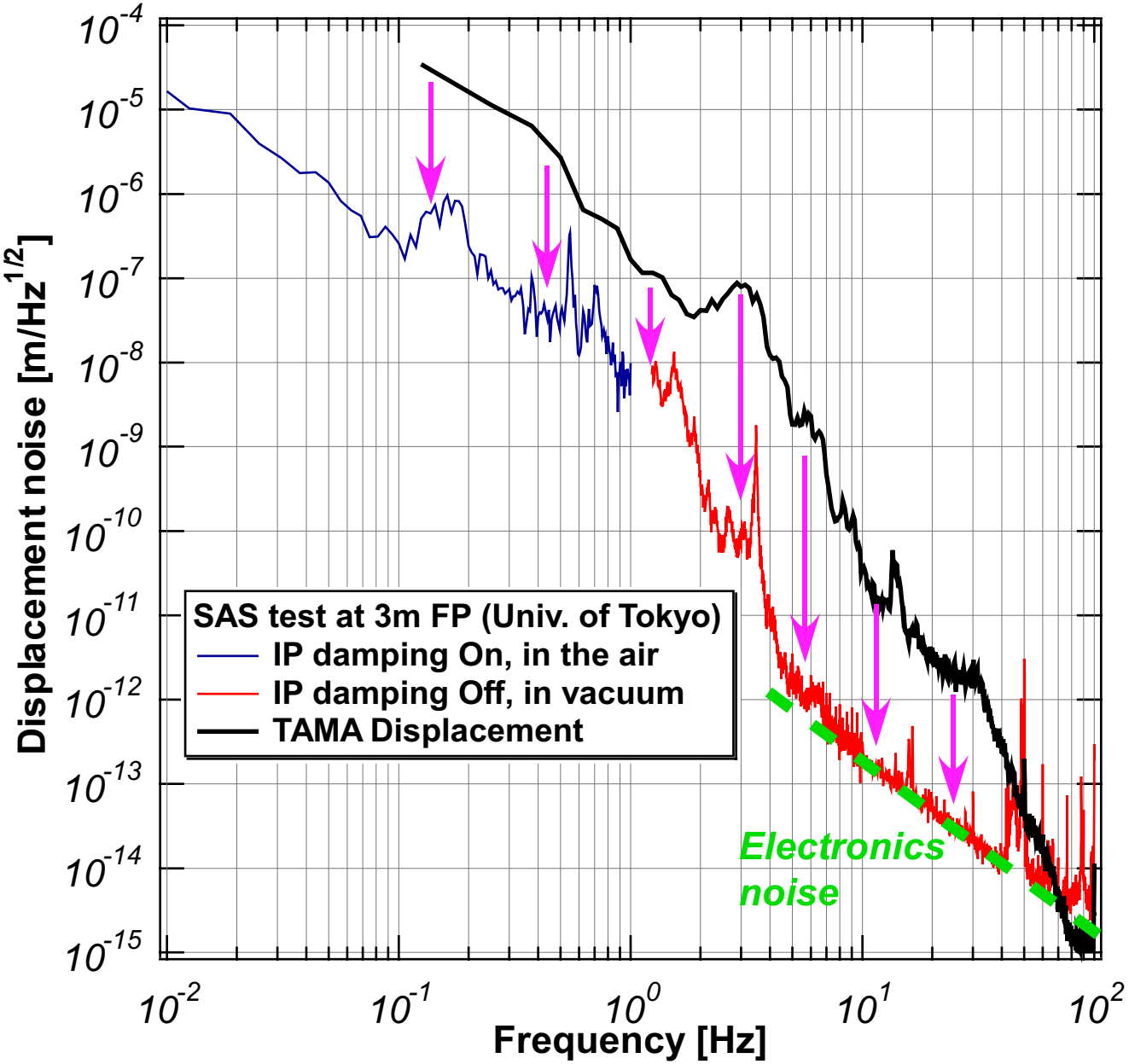


SAS: Seismic Attenuation System

- ***Inverted Pendulum***
  - Horizontal isolation
  - Resonant frequency:
    - Currently 70-80mHz
    - To be 30mHz
- ***MGAS***
  - Vertical isolation
  - Resonant frequency:
    - To be 0.4~0.5Hz



SAS: Seismic Attenuation System



Test@3mFP

Displacement

10^{-8} m/Hz$^{1/2}$

->

10^{-11} m/Hz$^{1/2}$

RMS Velocity

3.7 μm/s

->

0.3 μm/s

Expected: lower seismic/alignment noise, easier lock acquisition

Noise between 100Hz and 1000Hz

- ***Limiting noise source*** ~ not known
- ***Scattered light noise***

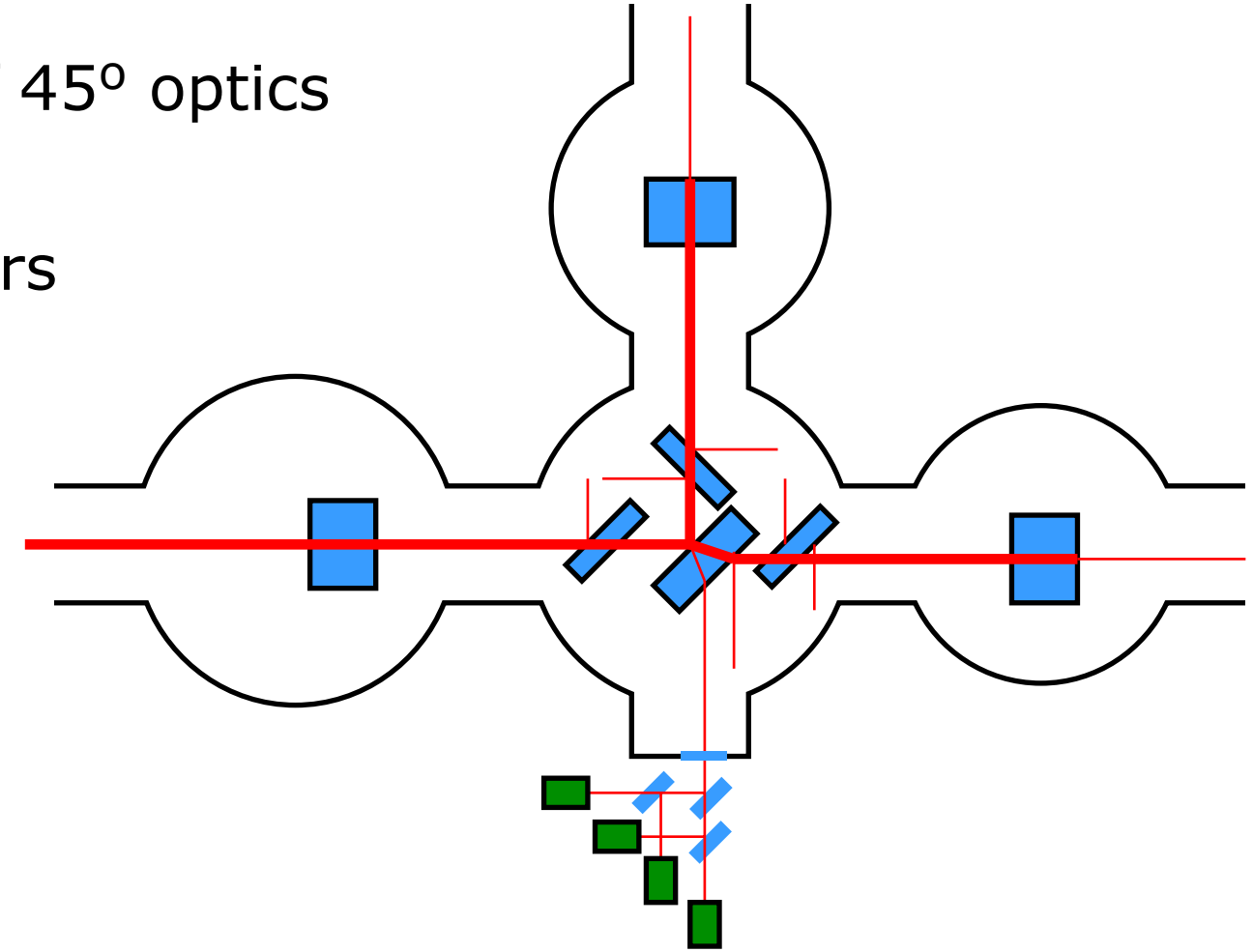
Michelson part of TAMA300: complicated

Pick-off mirrors

Internal reflections of 45° optics

Optical window

Multiple photodetectors



Noise between 100Hz and 1000Hz

- ***Limiting noise source*** ~ not known
- ***Scattered light noise***

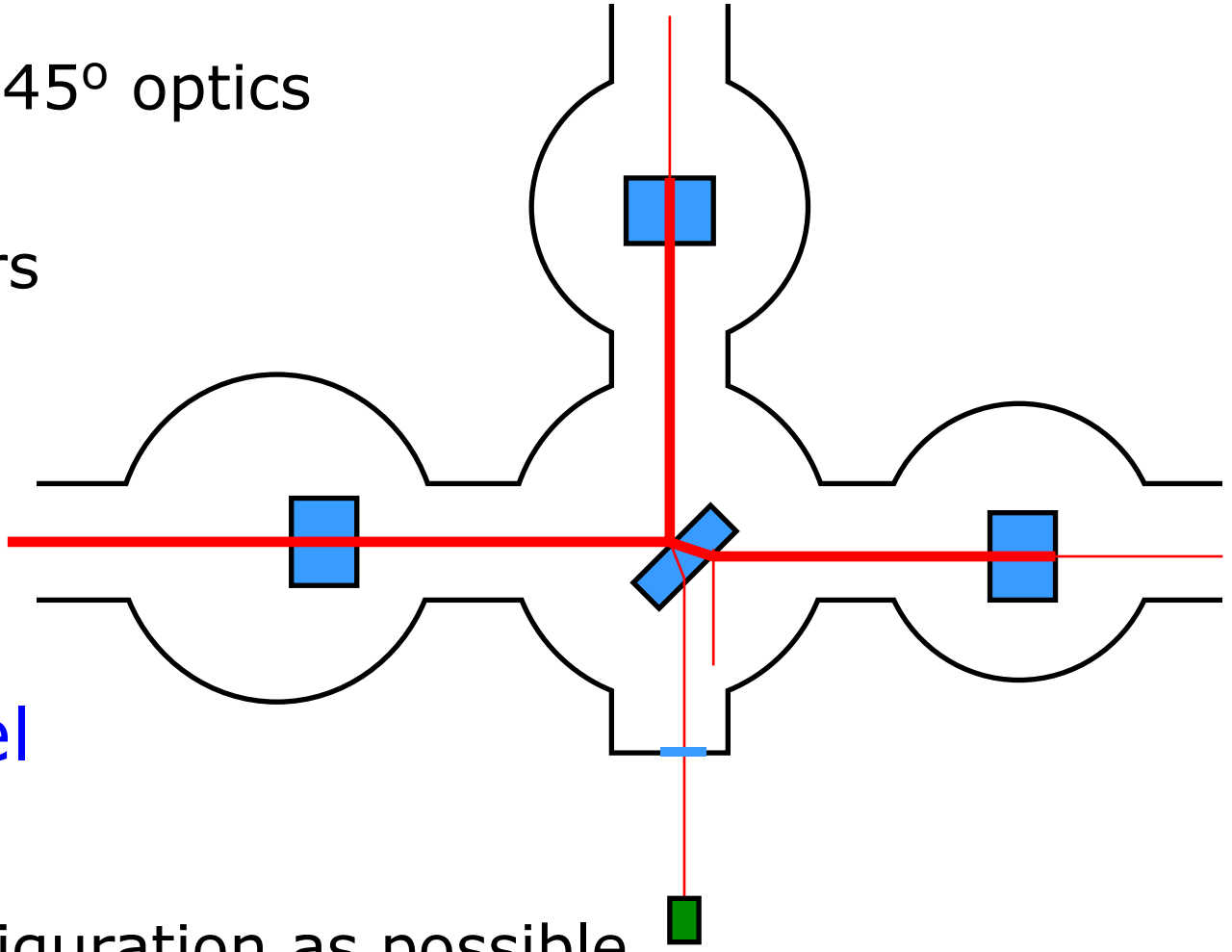
Michelson part of TAMA300: complicated

Pick-off mirrors

Internal reflections of 45° optics

Optical window

Multiple photodetectors



Investigate noise level

of the Michelson part

with the simplest configuration as possible

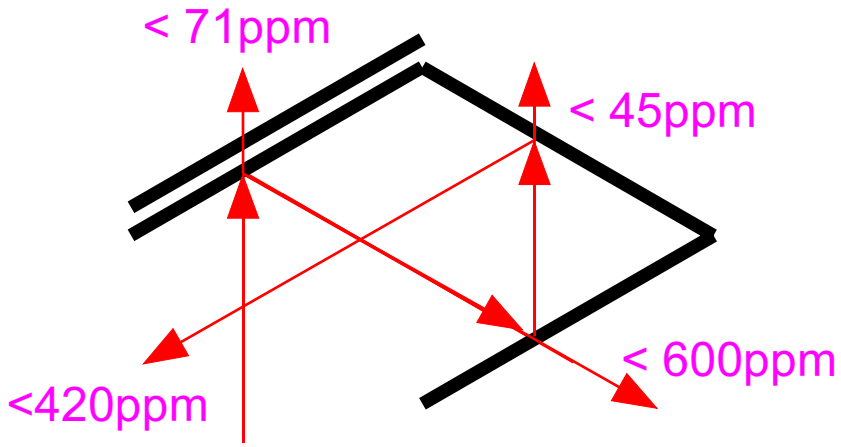
Scattered light noise

- **Beam dump with ND filters**

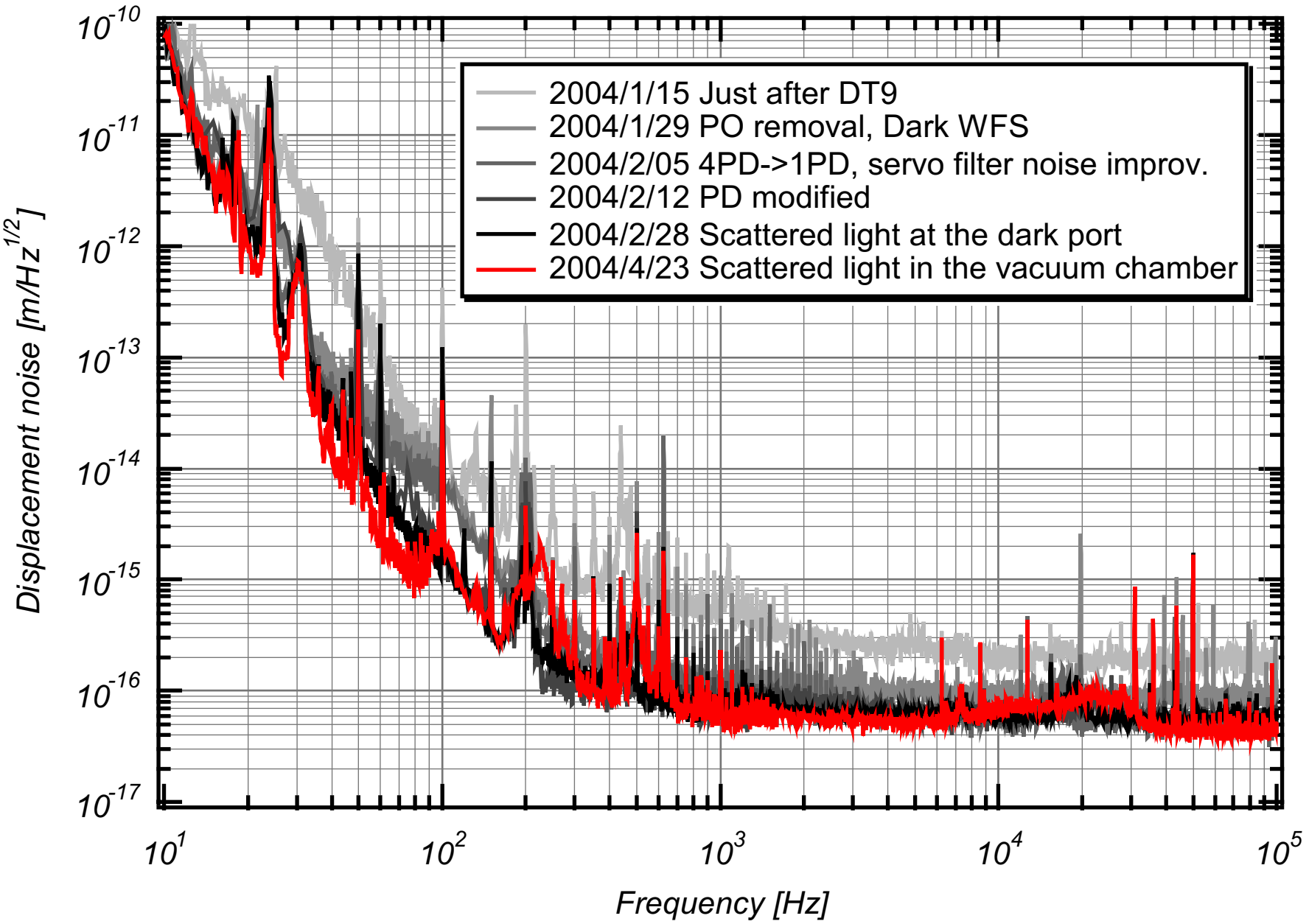
Combining commercial ND filters in a diamond shape

~ not blewster angle reflection
  but larger apperture
  (40mm with 2inch ND)

~ vacuum compatible

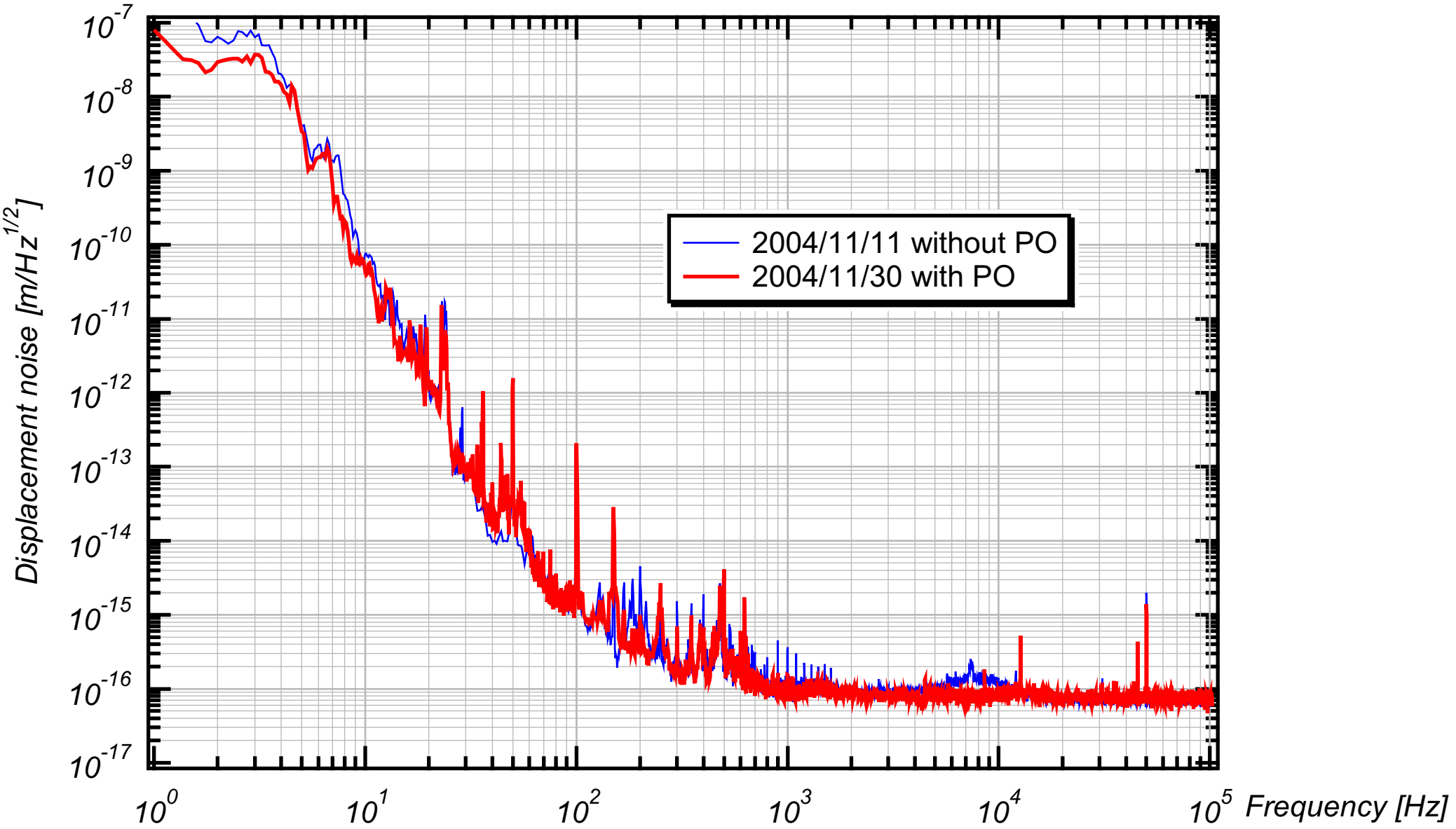


Recycled Michelson experiment



Displacement noise: improved with the simplified RMI

Recycled Michelson experiment



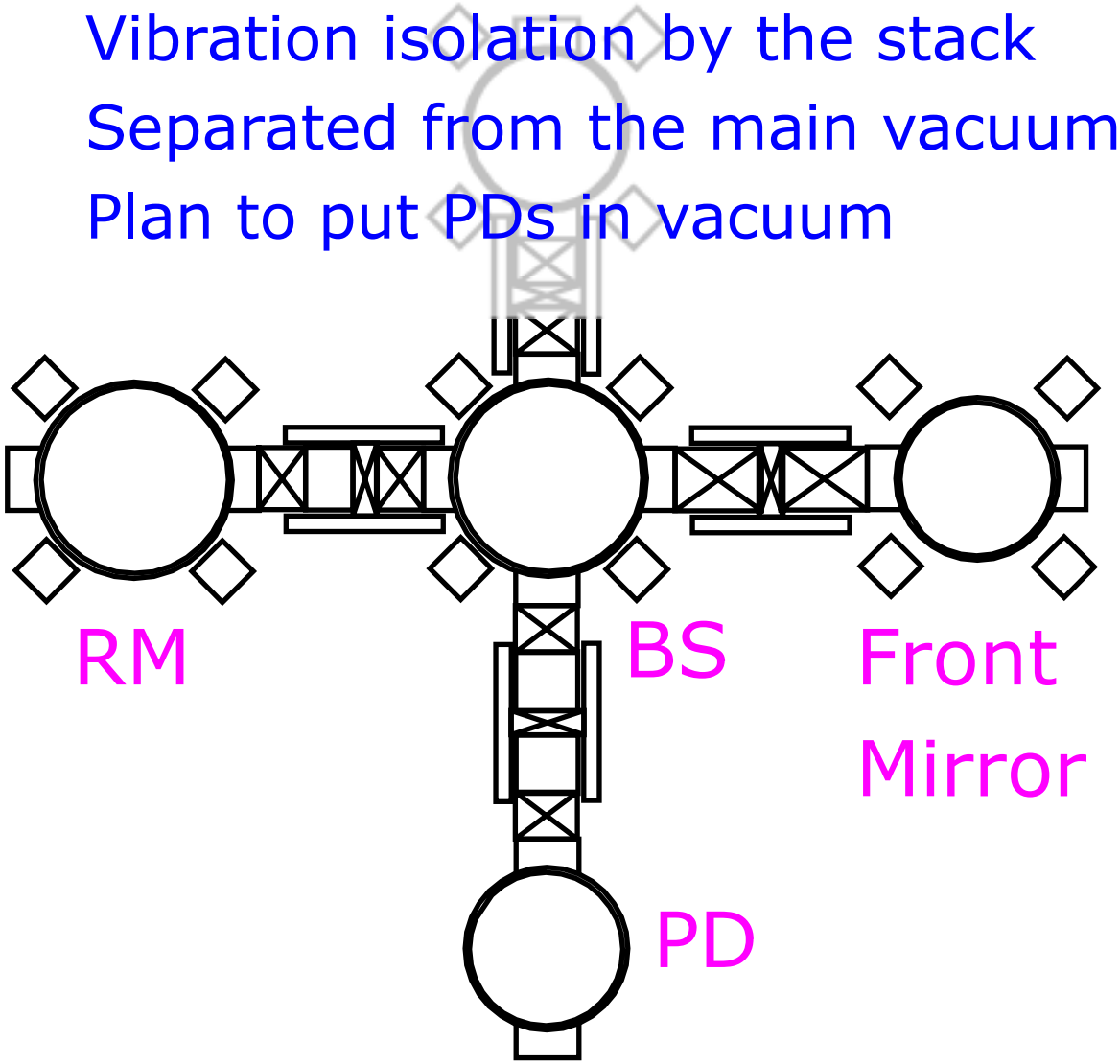
Reinstall the pick-offs

- Stray beams cared by the ND beam dumps

The noise level was kept at the best

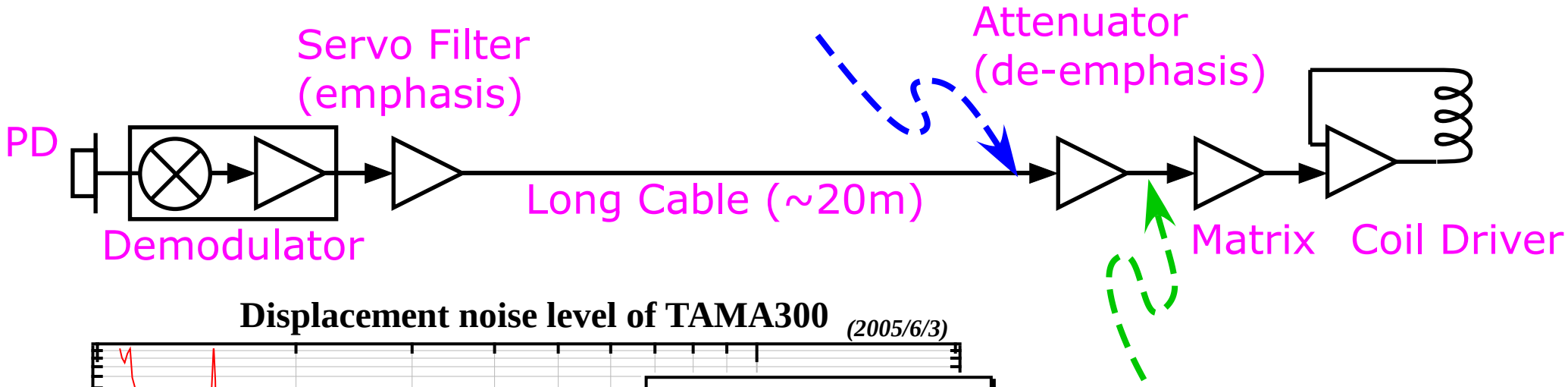
PD vacuum chamber at the dark port

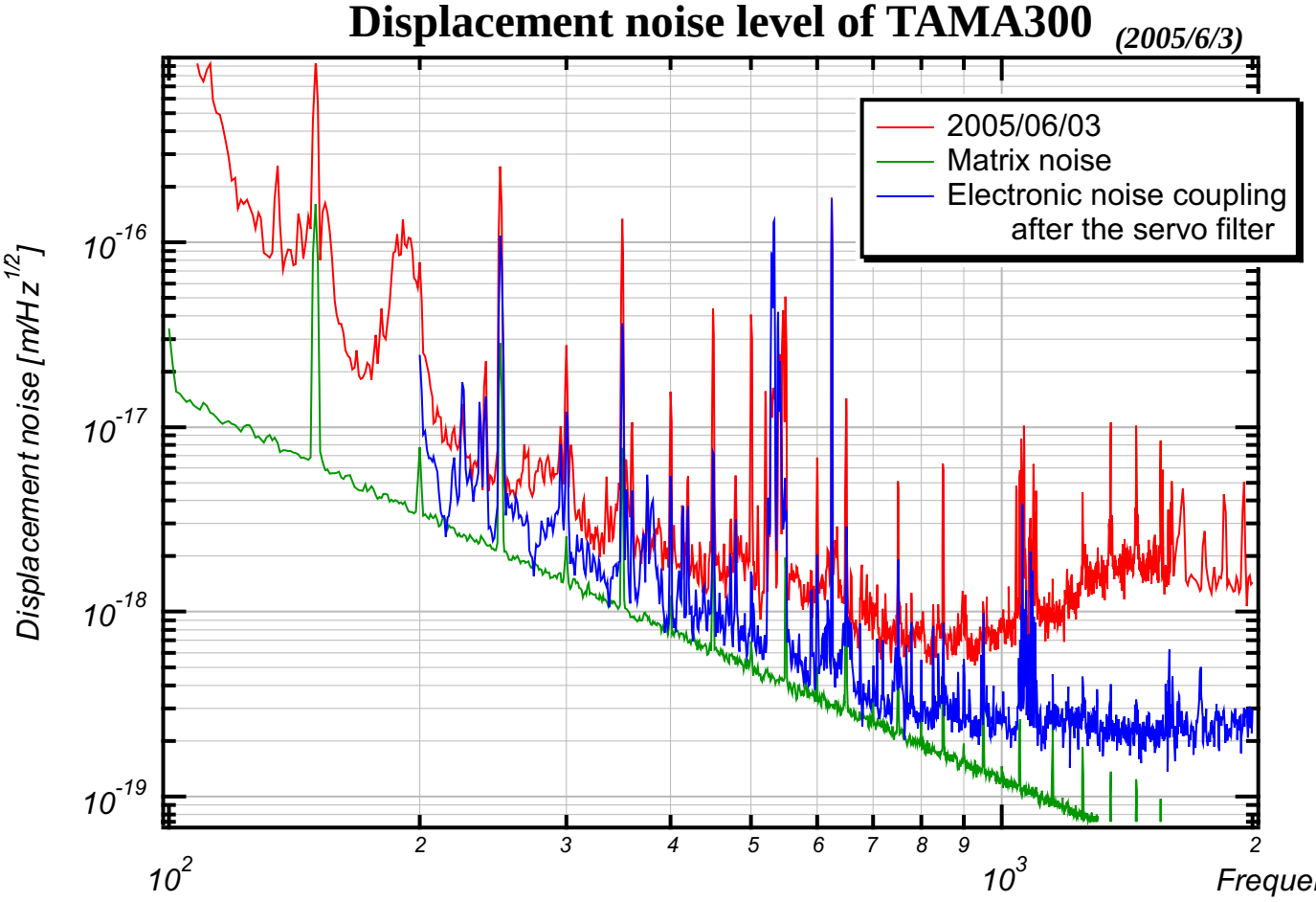
- **To suppress the vibration of scattering objects**
  - Avoid acoustic exicitation
  - Remove an effect of dusts
  - Vibration isolation by the stack
  - Separated from the main vacuum
  - Plan to put PDs in vacuum



Electronic noise

- **dL- servo chain**





Electronic noise / noise coupling

very close

(but not dominating)

=> need to put frequency responce to the coil driver

=> Consider lock issue

Summary

- ***Interferometric GW detector TAMA300***
- ***Efforts focused on noise hunting***
- ***Low frequency (DC-200Hz)***

  Seismic noise (DC~20Hz)

  Noise from alignment servos (20Hz~200Hz)

    SAS is going to provide the improvement

    Installation shortly

- ***Middle frequency (200-2kHz)***

  Essentially unknown

  Scattering noises investigated with RMI

    learned how to deal with them / PDs in vacuum

  Electronics noise

    redesignation of the gain distribution