Power recycling experiment for TAMA300

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TAMA300 Recycling

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02/02/06
2nd TAMA Sympo

- Recycling experiment began in Oct., 2001
- Purpose:

  To improve SNR to NS binaries

  To integrate the technical achievements of the R&D
- Current status:

  Full lock has been achieved

  Recycling gain ~ 4 (designed: 4.6)

  Continuous lock ~ 46min

  Length control with the frontal modulation scheme

  Alignment control for the test masses

Purpose

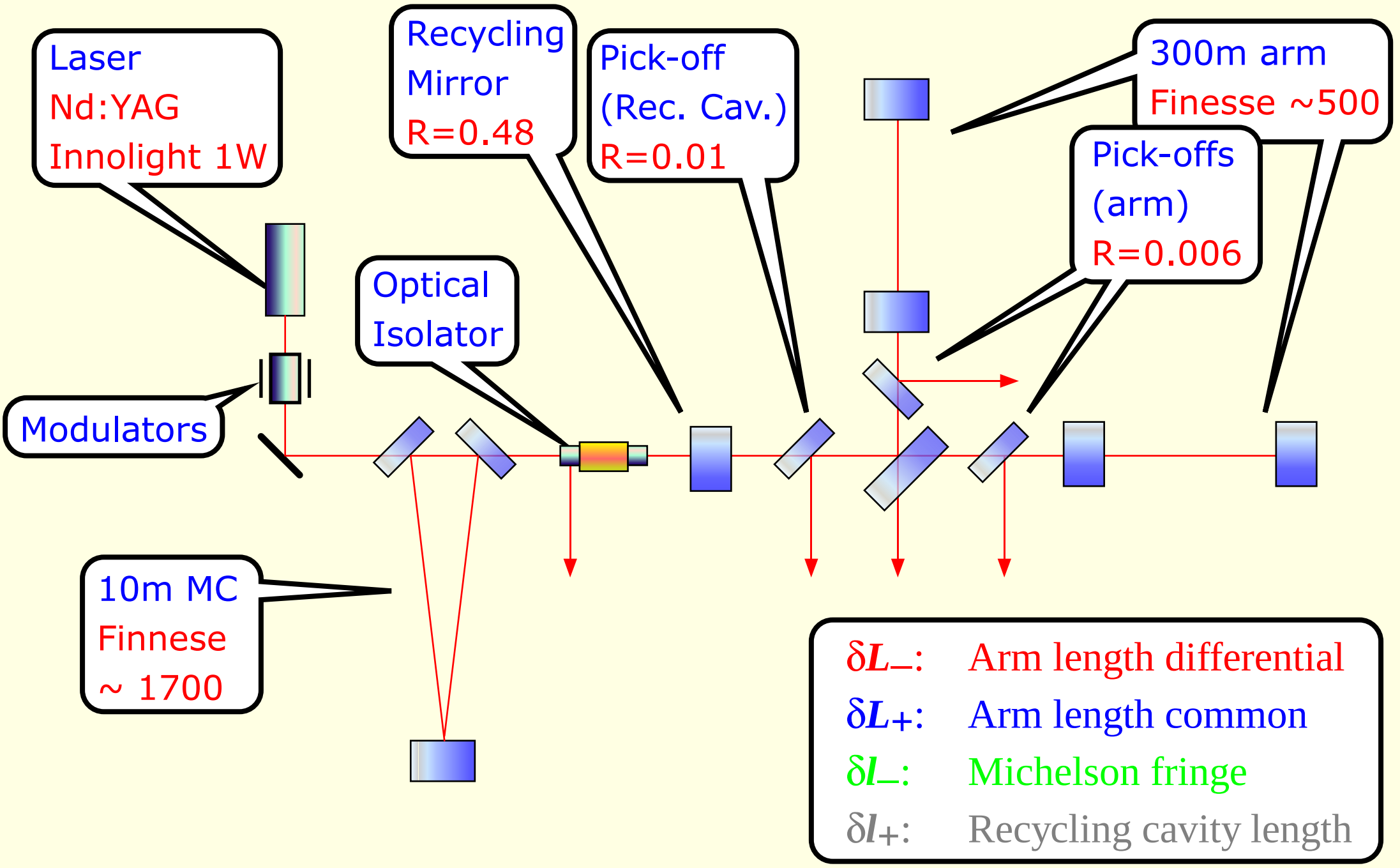
- Scientific motivation
  - To perform observations
    with improved SNR to NS binaries
- 1st step: Low gain recycling (R_{RM}~48%, G~4.6)
  - Target: Faster realization of the full lock
    - > Earlier full operation / observation
    - > Feeding back information to design of high gain recycling
    - > Establishing techniques for diagnoses / analyses
- 2nd step: High gain recycling (R_{RM}~90%, G~10)
  - Target: Optimizing the detector performance

Past recycling R&Ds in Japan

- 3m prototype ($G_{achieved}$: 2.9~5.5)
  - Demonstration of recycling for suspended FPMI [*1]
  - Investigation of length sensing/control schemes
    - > Sideband elimination technique [*2] [*3]
    - > 3rd harmonic demodulation technique [*4]
- 20m prototype ($G_{achieved}$: 8~12)
  - Evaluation of the TAMA optics [*5]
  - Investigation of length/alignment control for high recycling gain

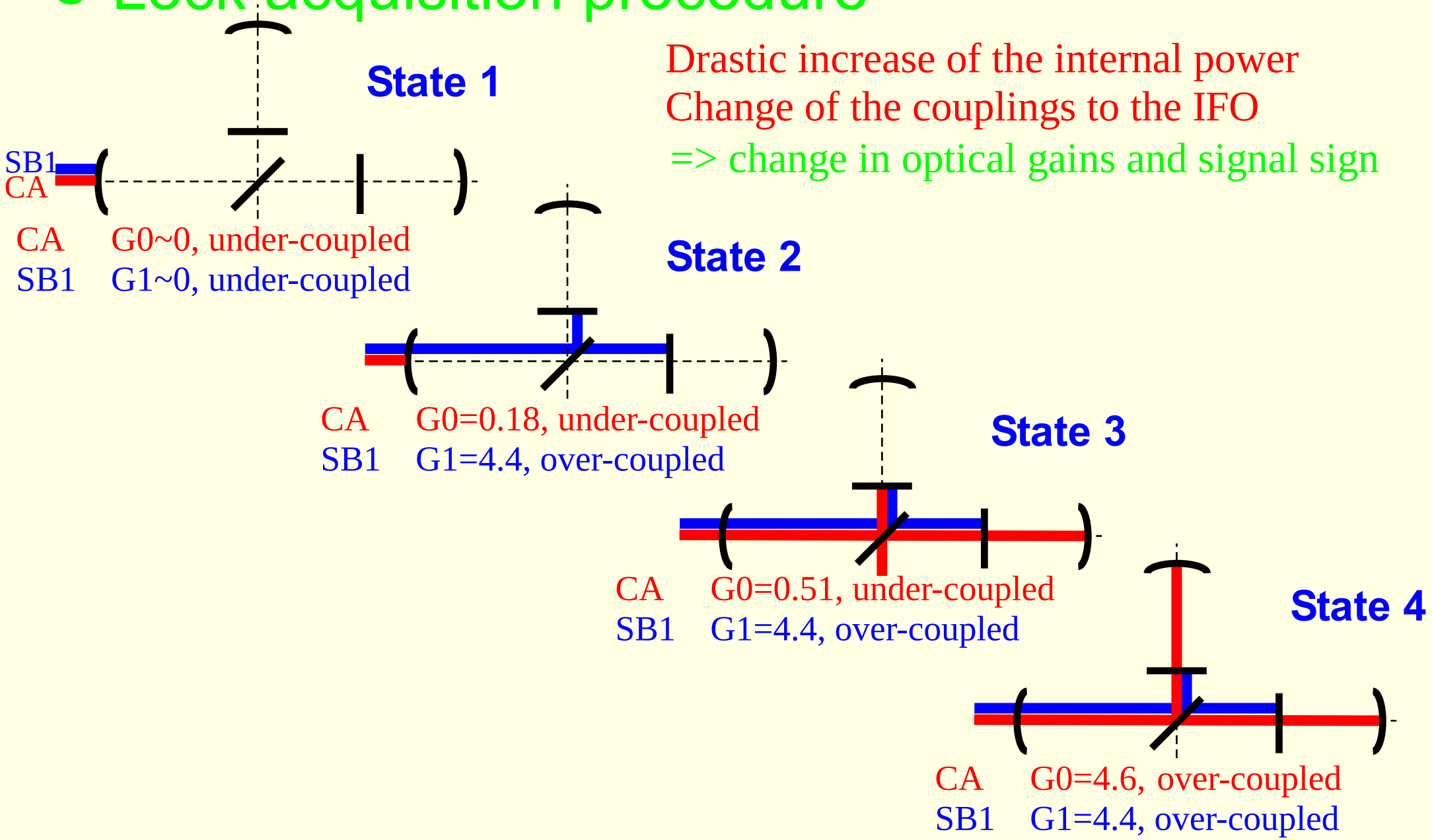
*1 M. Ando, et al, Phys. Lett. A 248 (1998) 145
*2 M. Ando, et al, Phys. Lett. A 237 (1997) 13
*3 M. Ando, et al, Phys. Lett. A 268 (2000) 268
*4 K. Arai, et al, Phys. Lett. A 273 (2000) 15
*5 S. Sato, et al, Appl. Opt. 39 (2000) 25, 4616

Optical configuration



Lock acquisition (1)

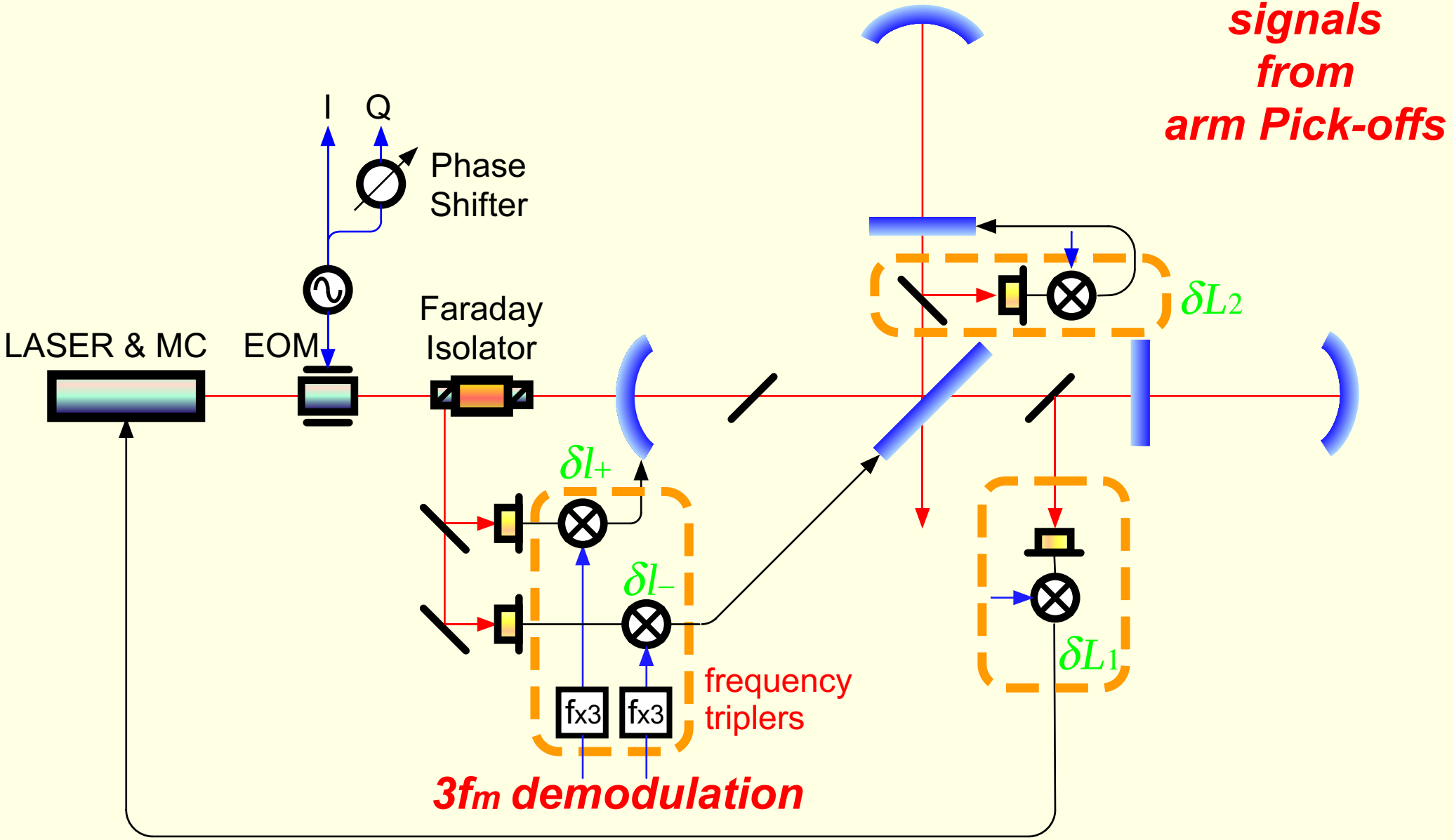
- Lock acquisition procedure



Drastic increase of the internal power
Change of the couplings to the IFO
=> change in optical gains and signal sign

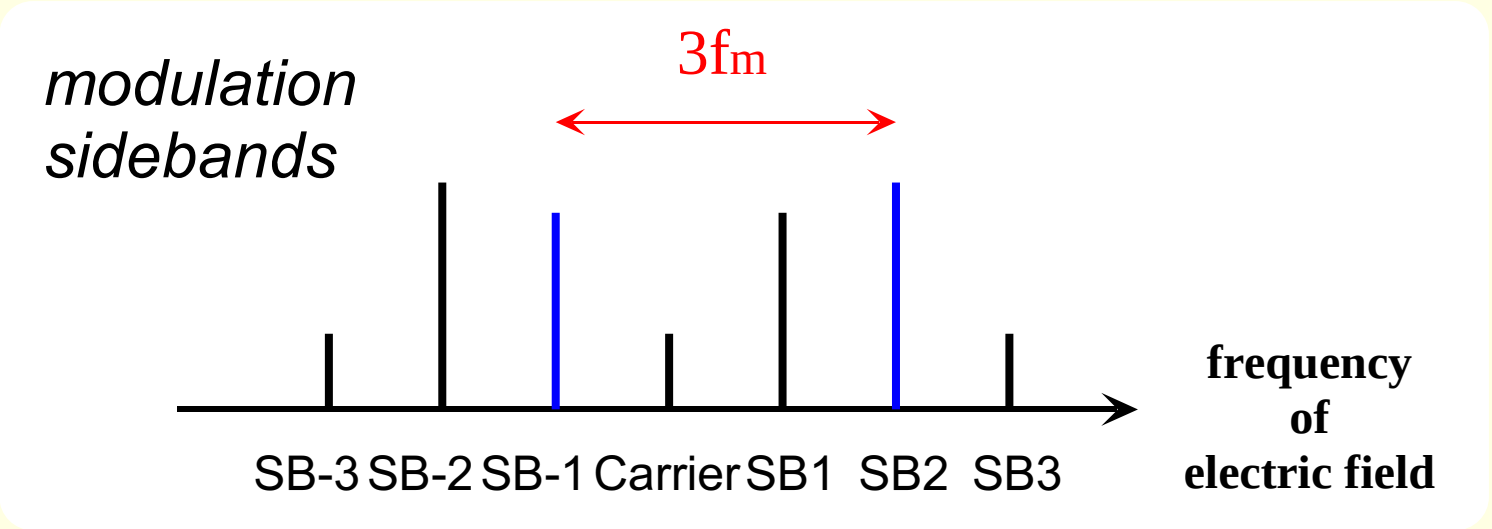
Lock acquisition (2)

- Length sensing for the lock acquisition



Lock acquisition (3)

- 3rd harmonic demodulation for δl_+ and δl_-
  - Photocurrent at the $3f_m$ ~ beating of SB2 and SB-1



  - Robust extraction of δl_+ and δl_-

Contribution of carrier audio-sidebands (mainly by δL_+)

→ Reduced

Amplitudes and signs

→ Less dependent on the couplings of CA and SB1

Lock acquisition (4)

- Signals from arm pick-offs
  - Similar to Pound-Drever-Hall technique
  - Power recycling mixes the information of the arms each other
    > Ratio of the mixing is 50% at most (for R_{RM}=48%, G~4.6).

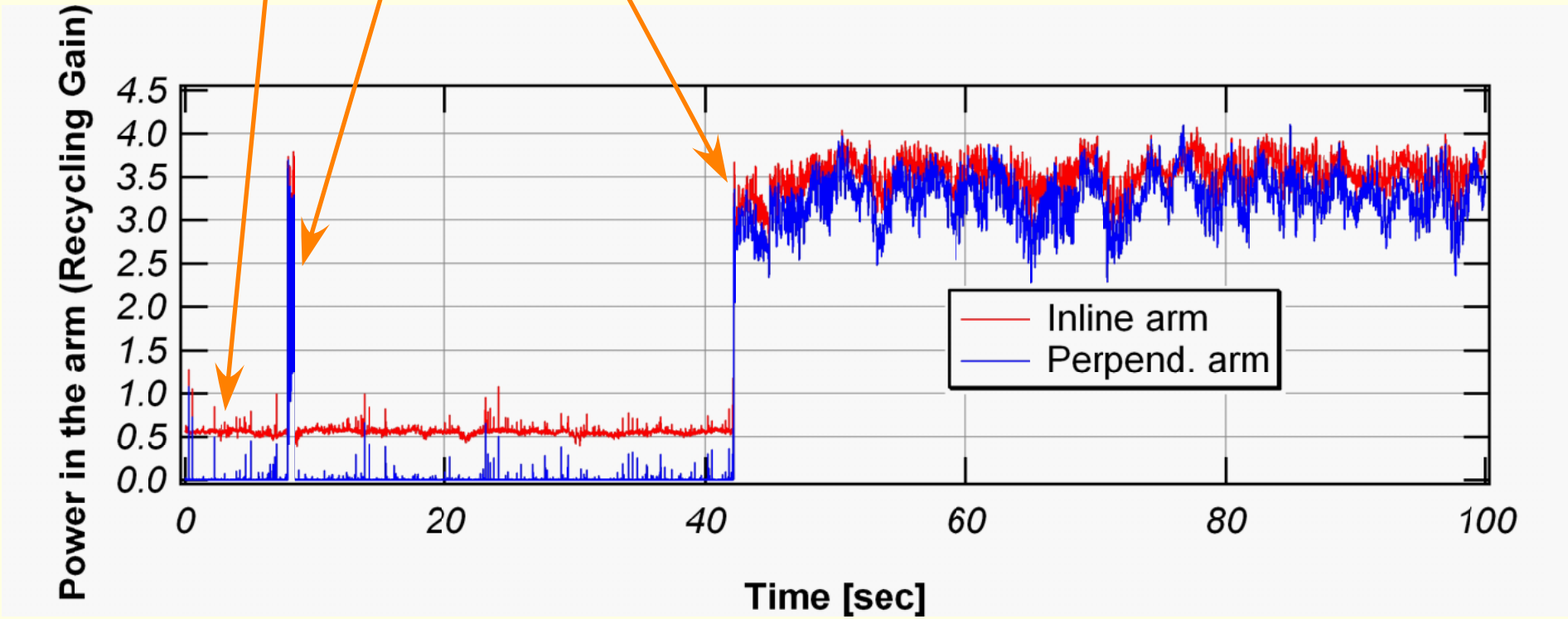
Lock acquisition (4)

- Time-series data of a lock acquisition

Almost stays at State3.
Always trying to lock the other arm.

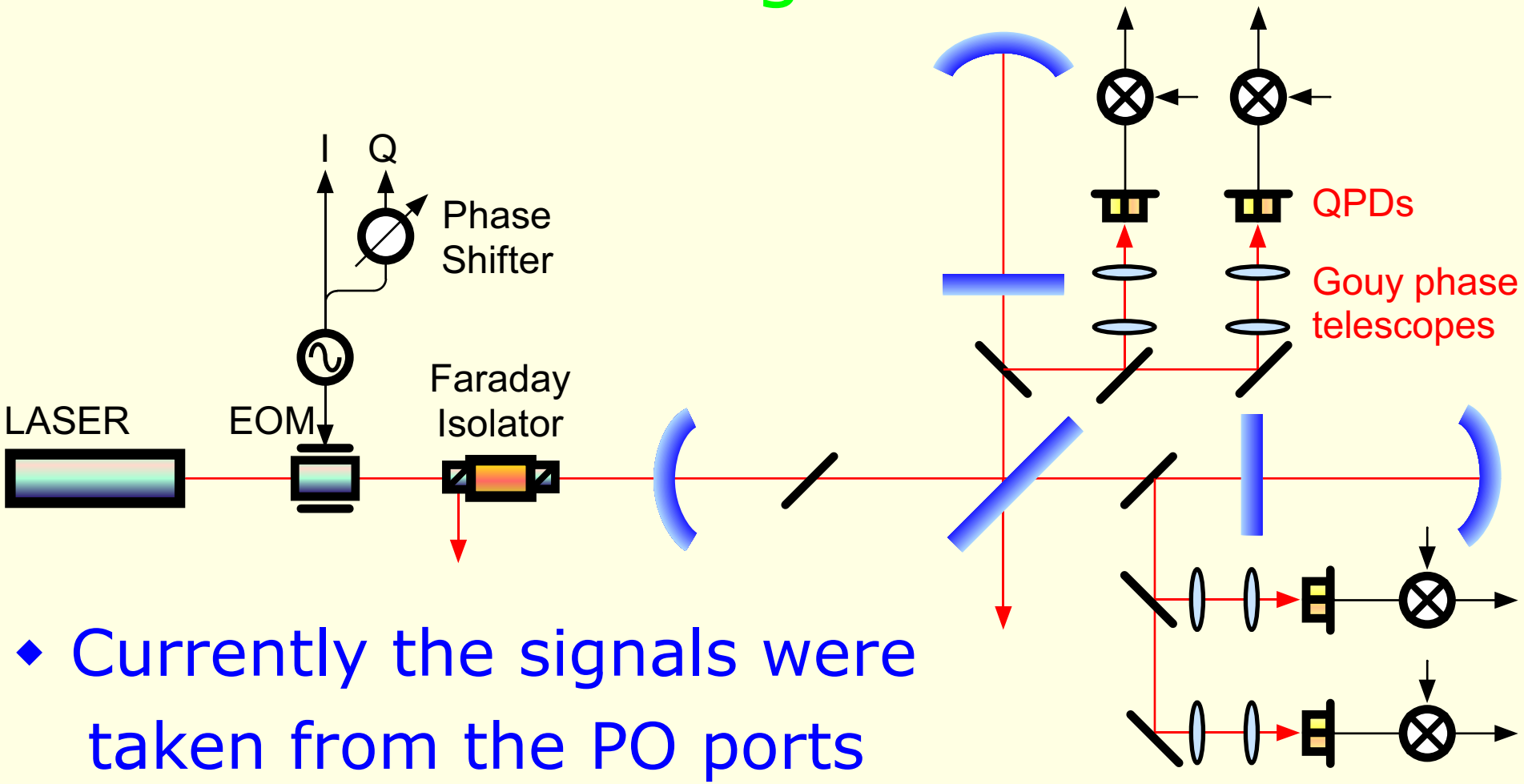
Lock attempt failed

Locked!



Alignment control (1)

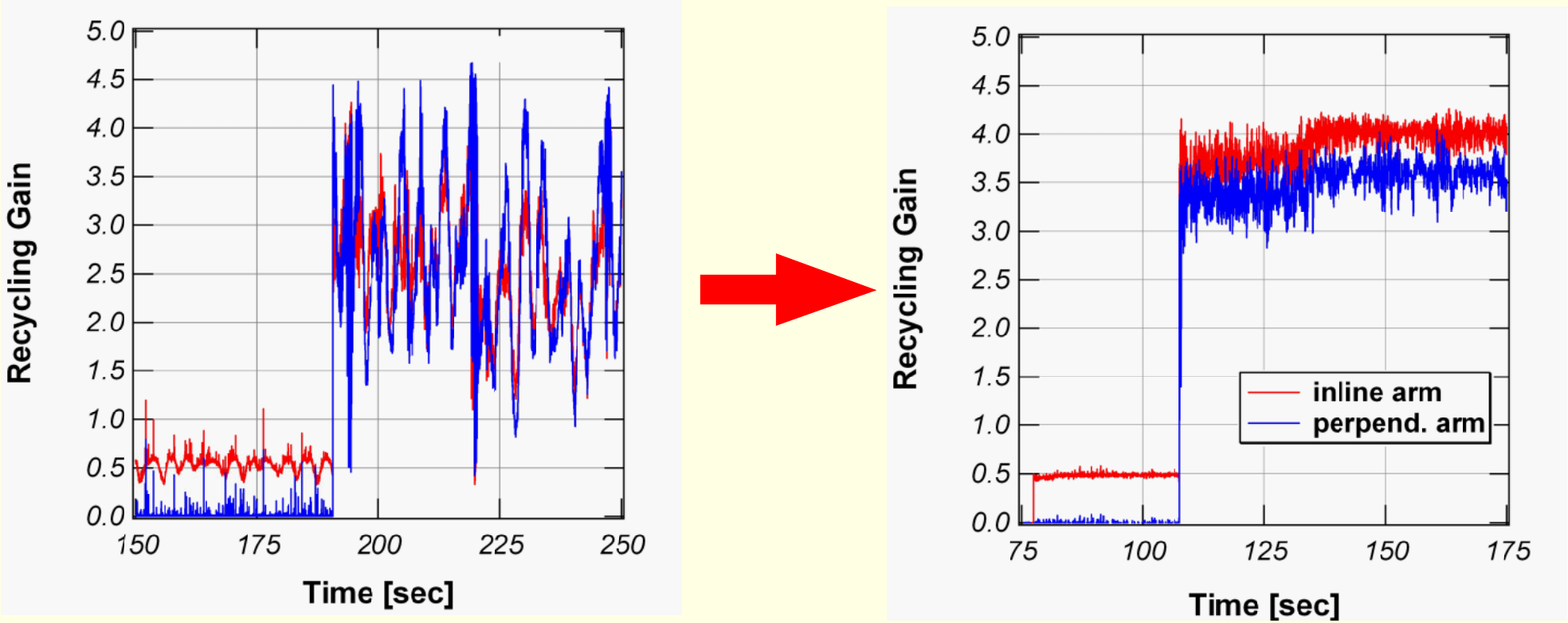
- Wave Front Sensing for the test masses



- Currently the signals were taken from the PO ports
- Eventually it will be replaced to the common differential control

Alignment control (2)

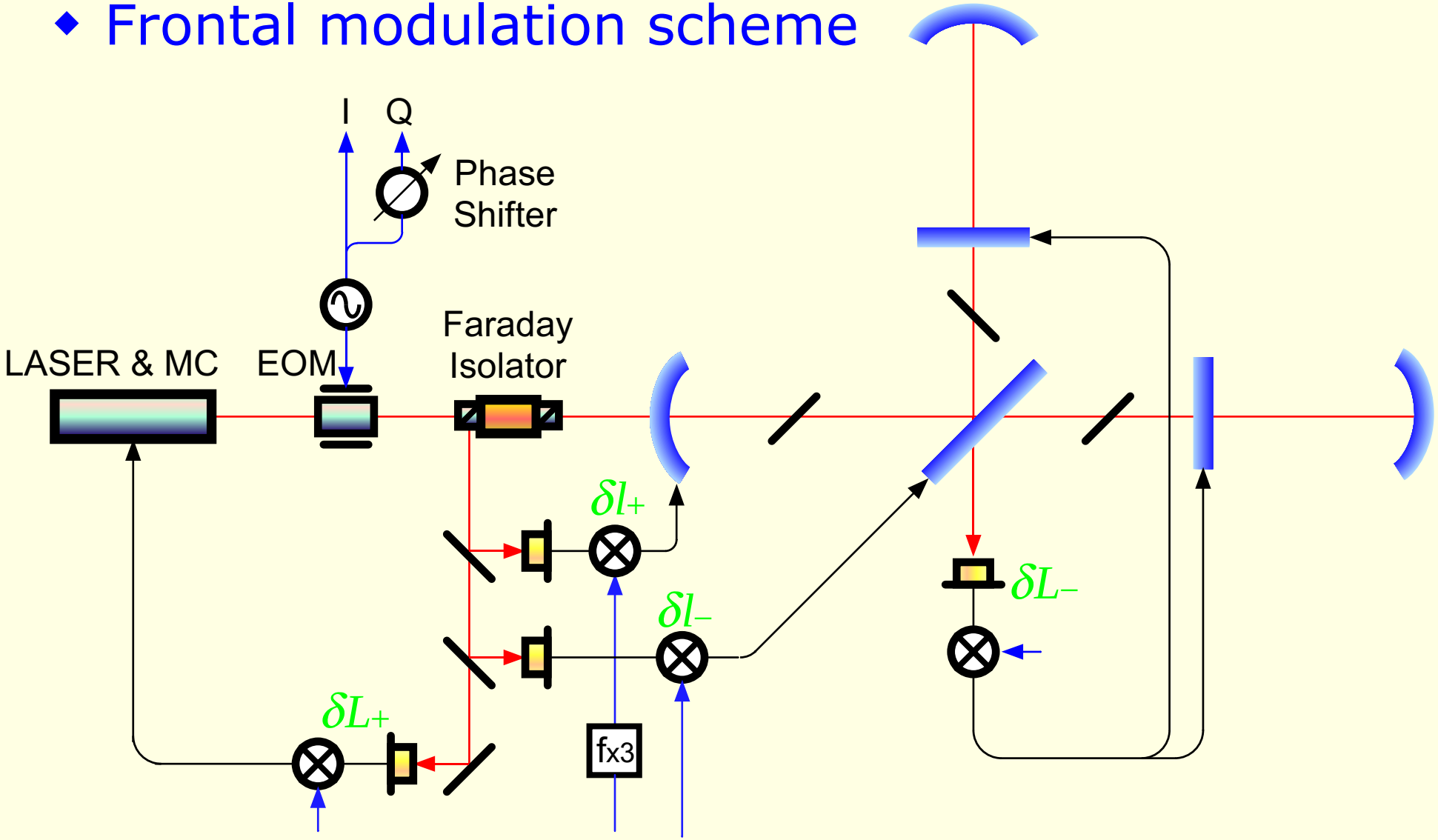
- Stabilizing gain fluctuation by WFS
  - Without WFS
  - With WFS



- The alignment servos were activated even during the lock acquisition

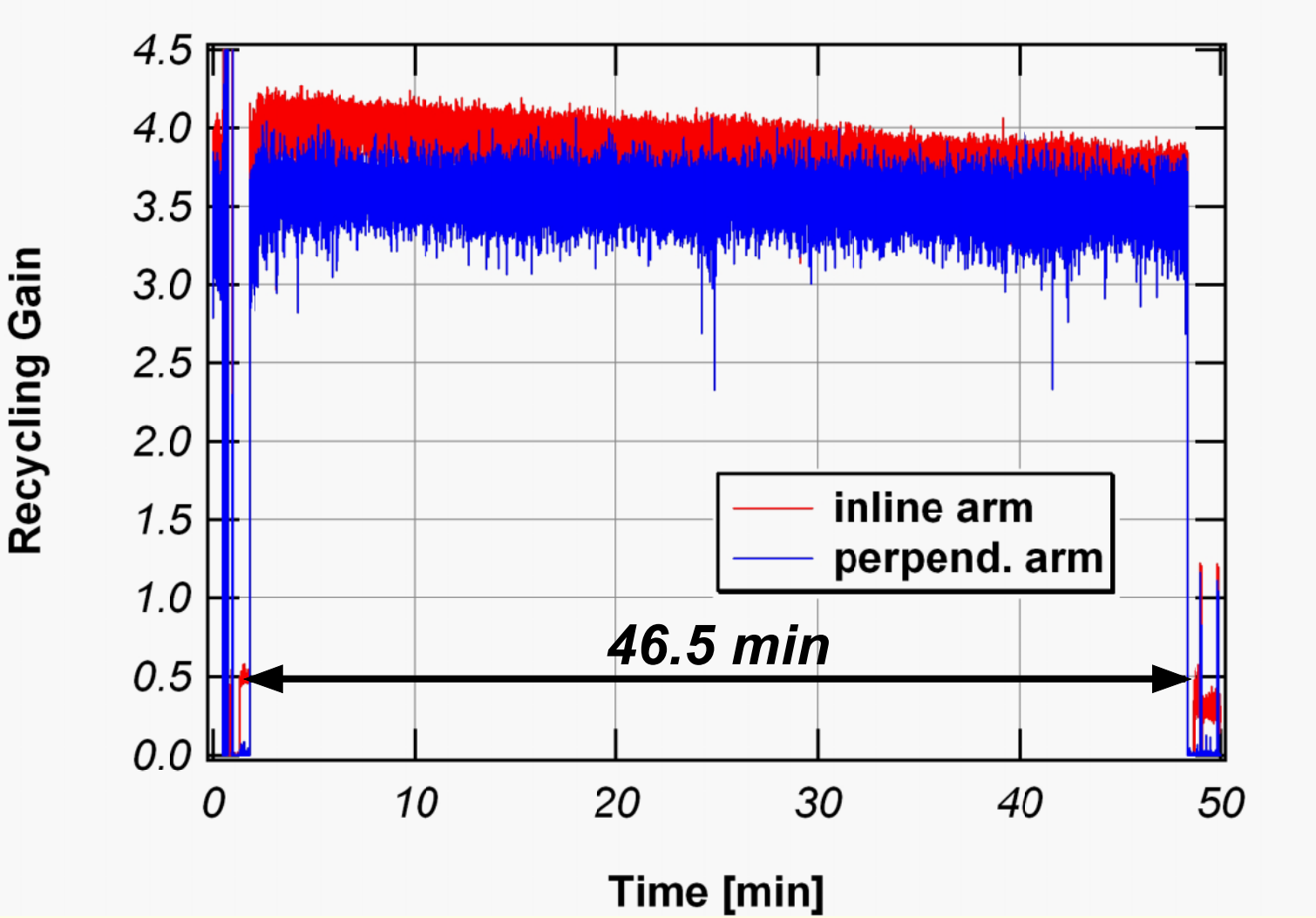
Operating mode

- Length sensing for the operation
  - Frontal modulation scheme



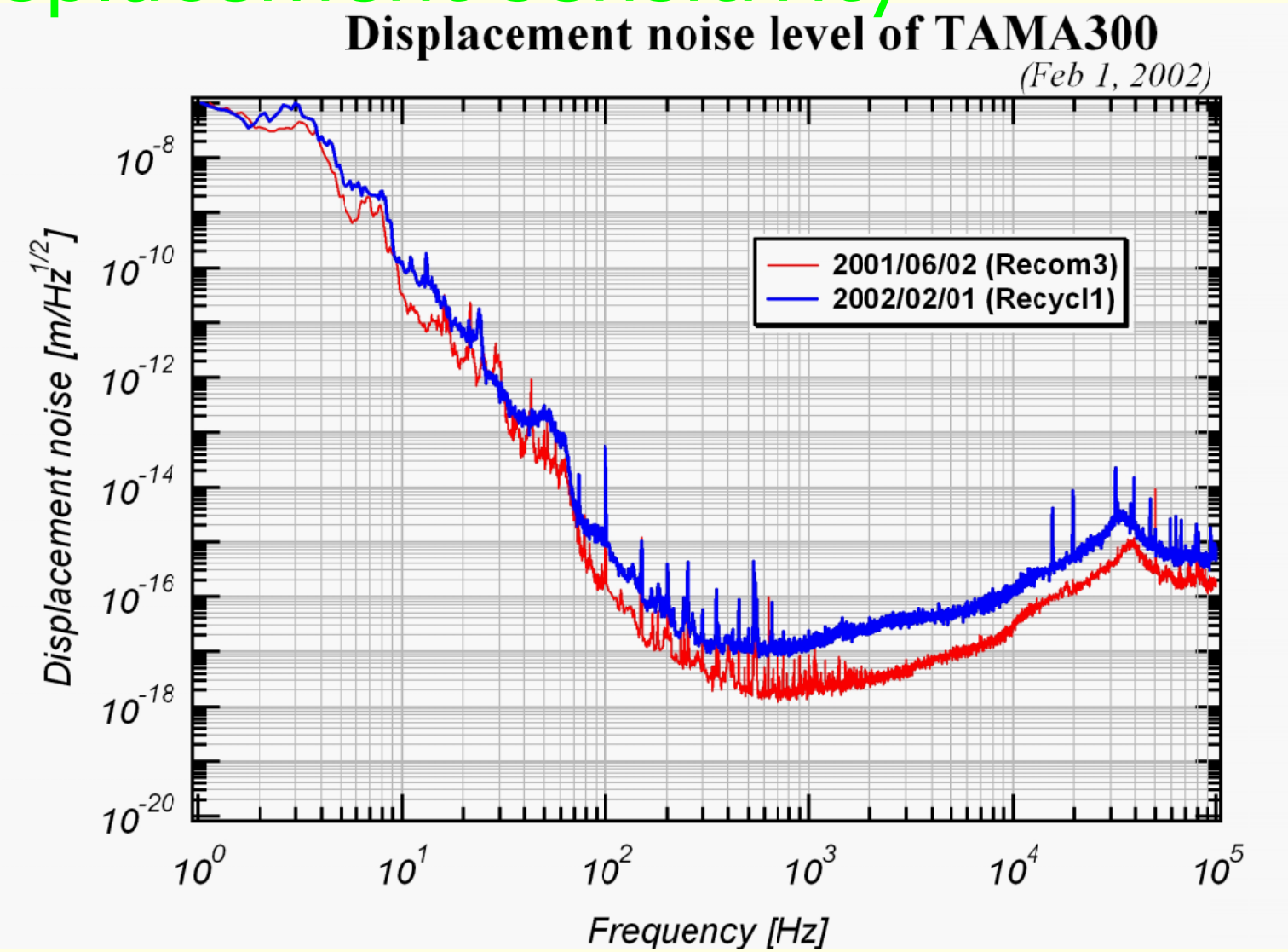
Stability

- 46 min. of continuous lock
  - Current most longest lock stretch



Sensitivity

- Displacement sensitivity



1×10^{-17} m/sqrtHz ~ 7 times worse than the FPMI best

Plans for improvement

- Drift control
  - Optical axes control
- Alignment
  - Common-differential sensing/control
  - Sensing matrix diagonalizing
- More power in the arm
  - Introducing high power laser to the IFO
  - Characterizations for the high gain recycling
- Noise issue

Summary

- The recycling experiment
  - began 4 months ago
- The full lock has already been achieved
  - Arm lock by auxiliary length signals
  - 3rd harmonic demodulation
- Stability ~ 46min continuous lock
  - The stability was much improved
    by the alignment control
- Sensitivity ~ under investigation
  - Still x7 worse than the best