The Current Status of the TAMA300 Interferometric Gravitational Wave Detector

CaJAGWR Seminar @ Caltech
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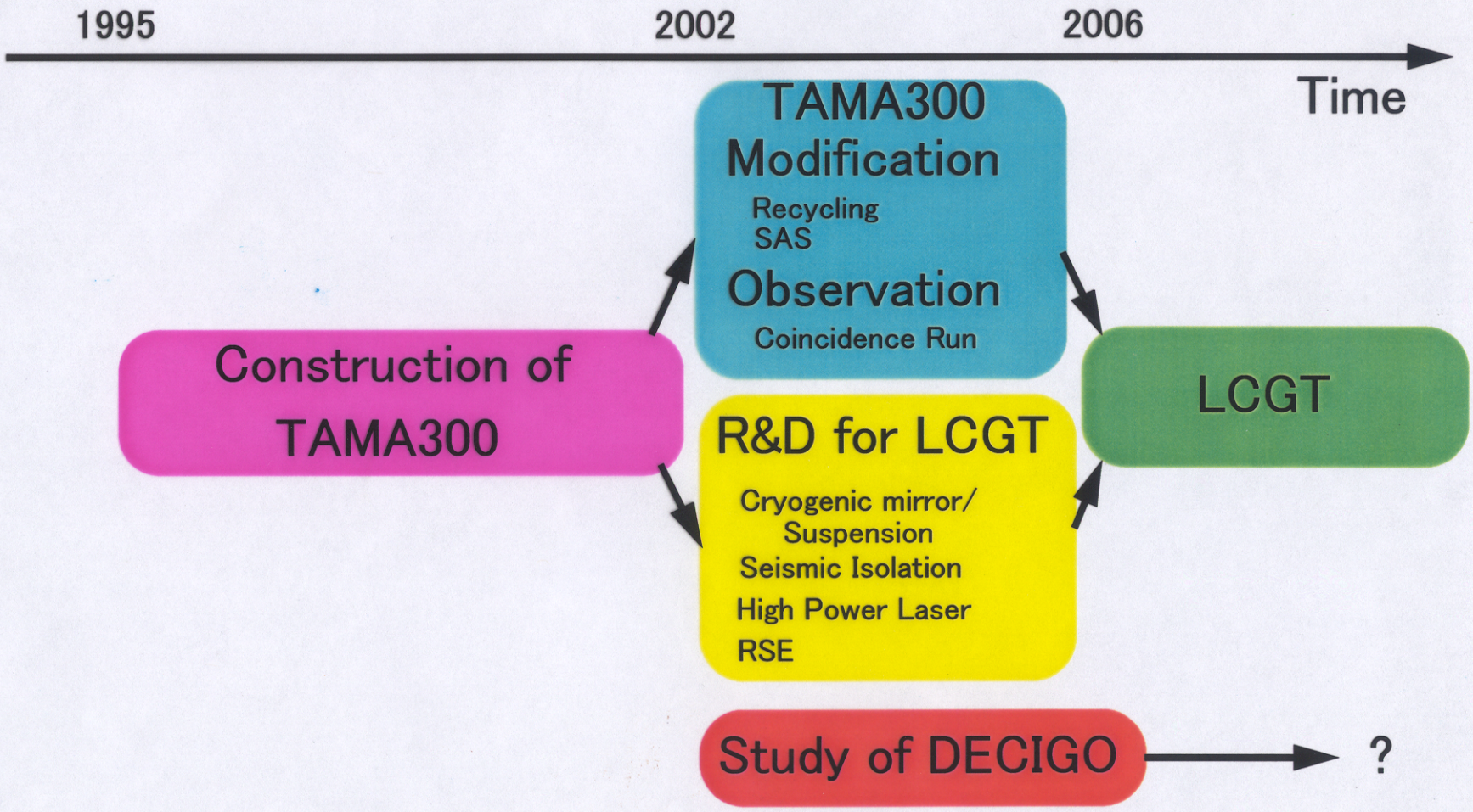
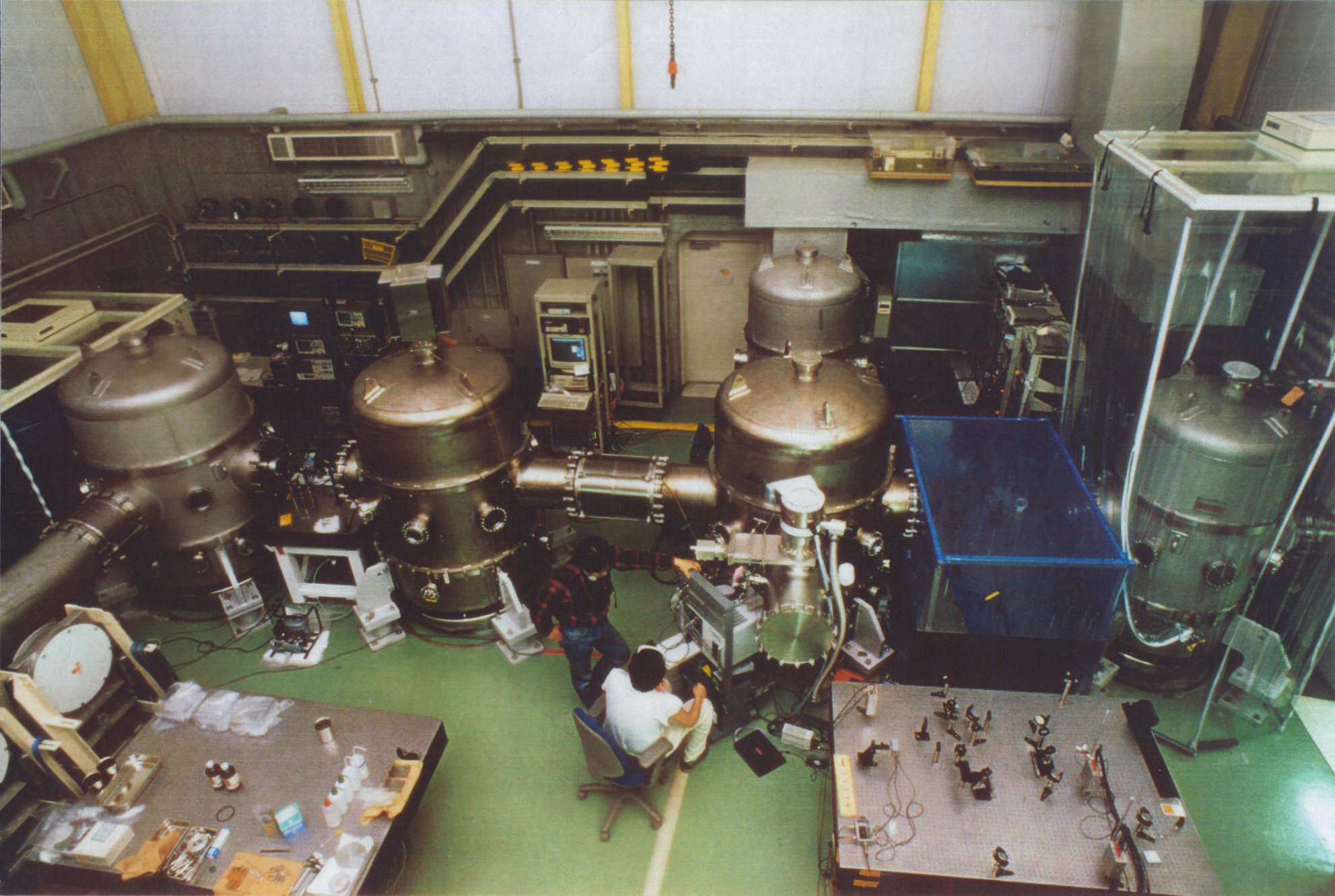
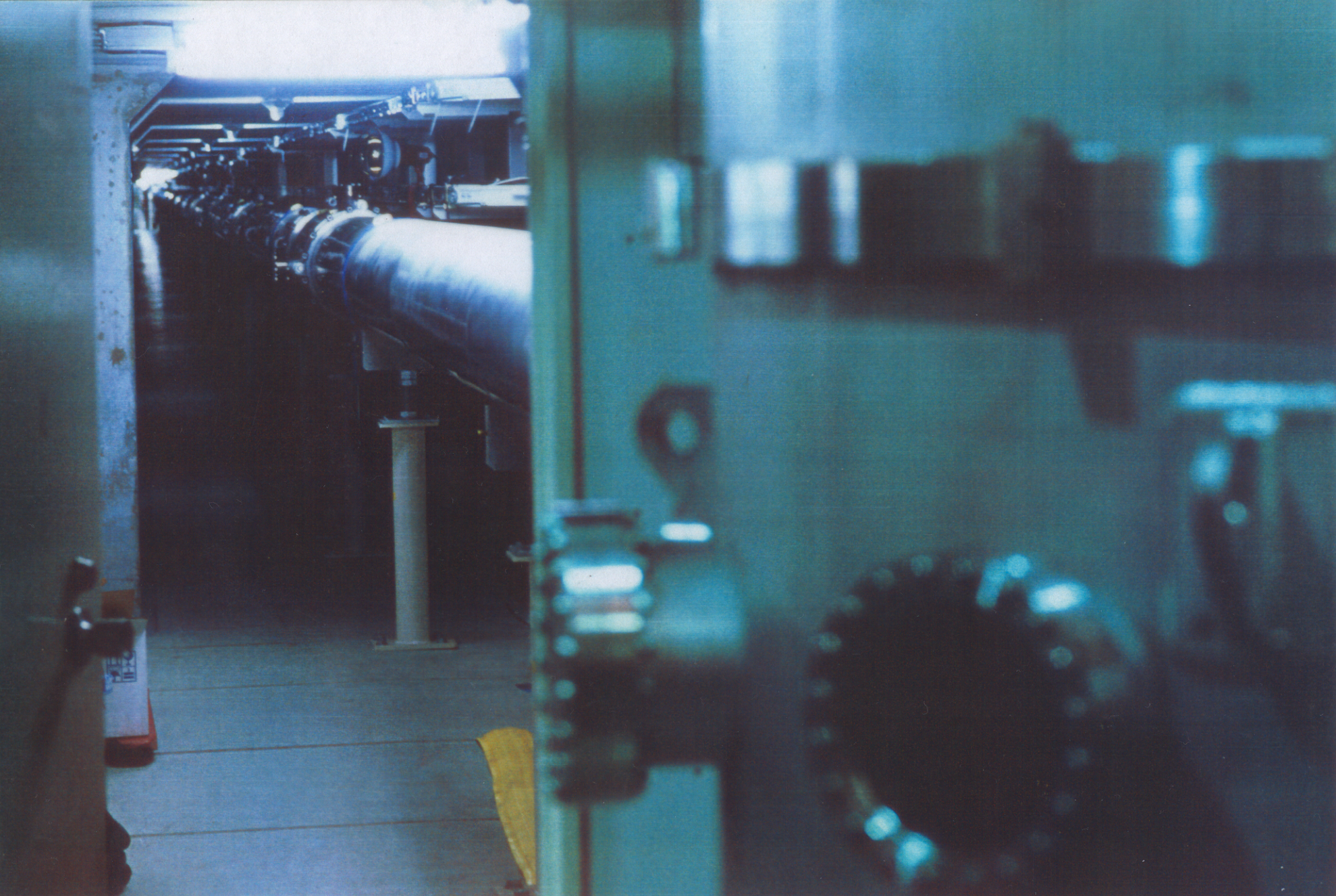
LIGO-G020216-00-Z

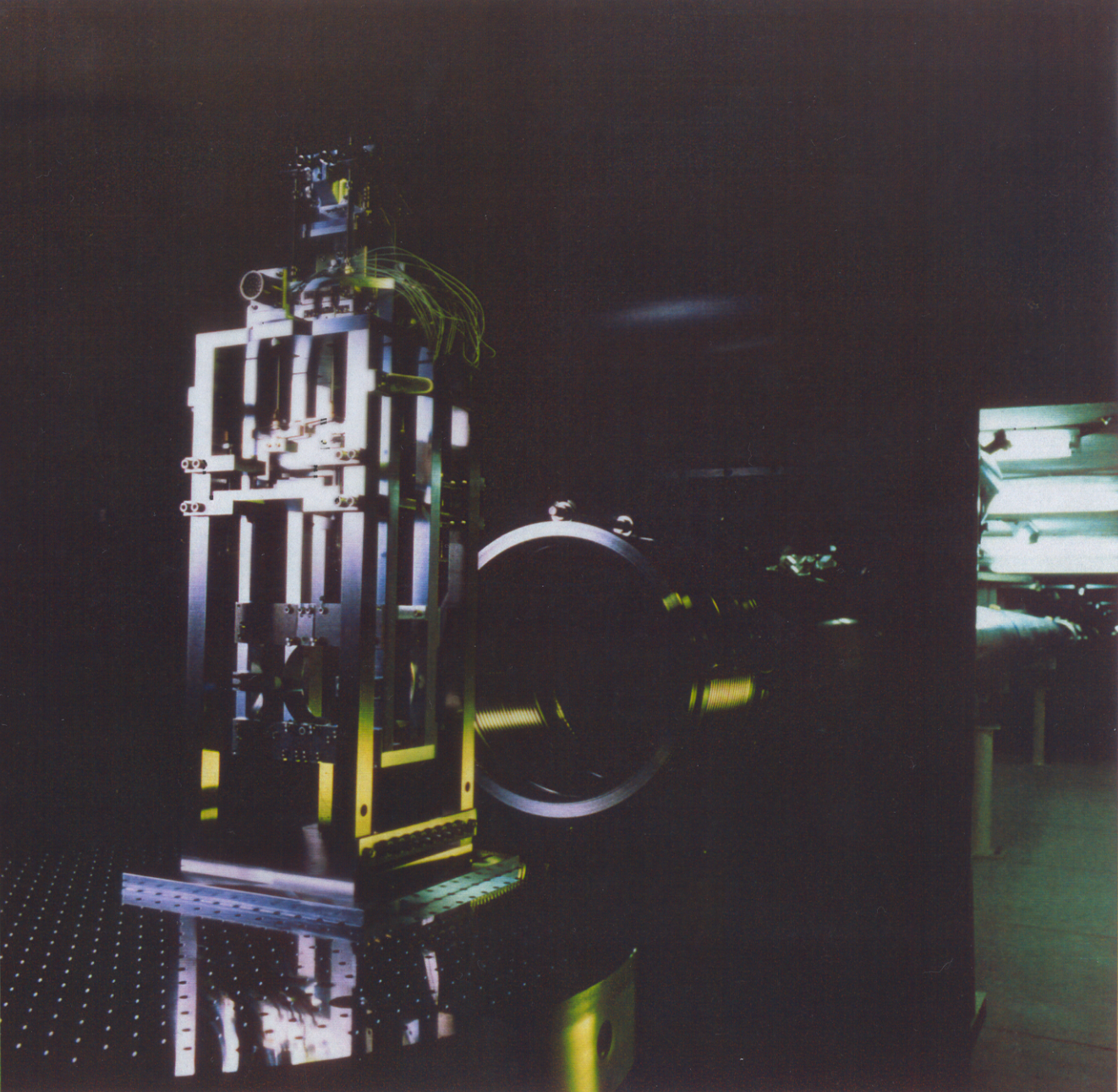
The Japanese GW Program

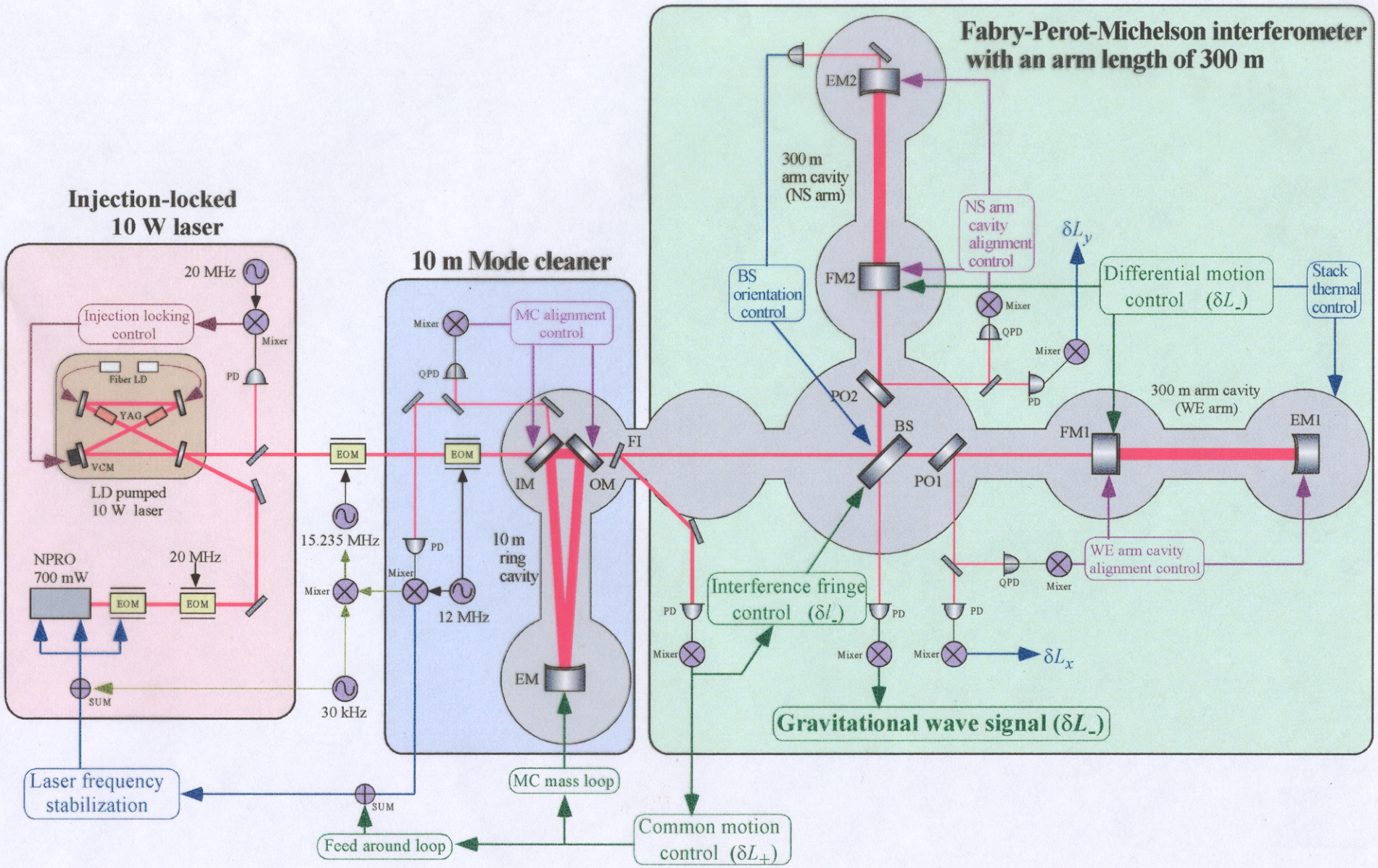


Bird's view of the site

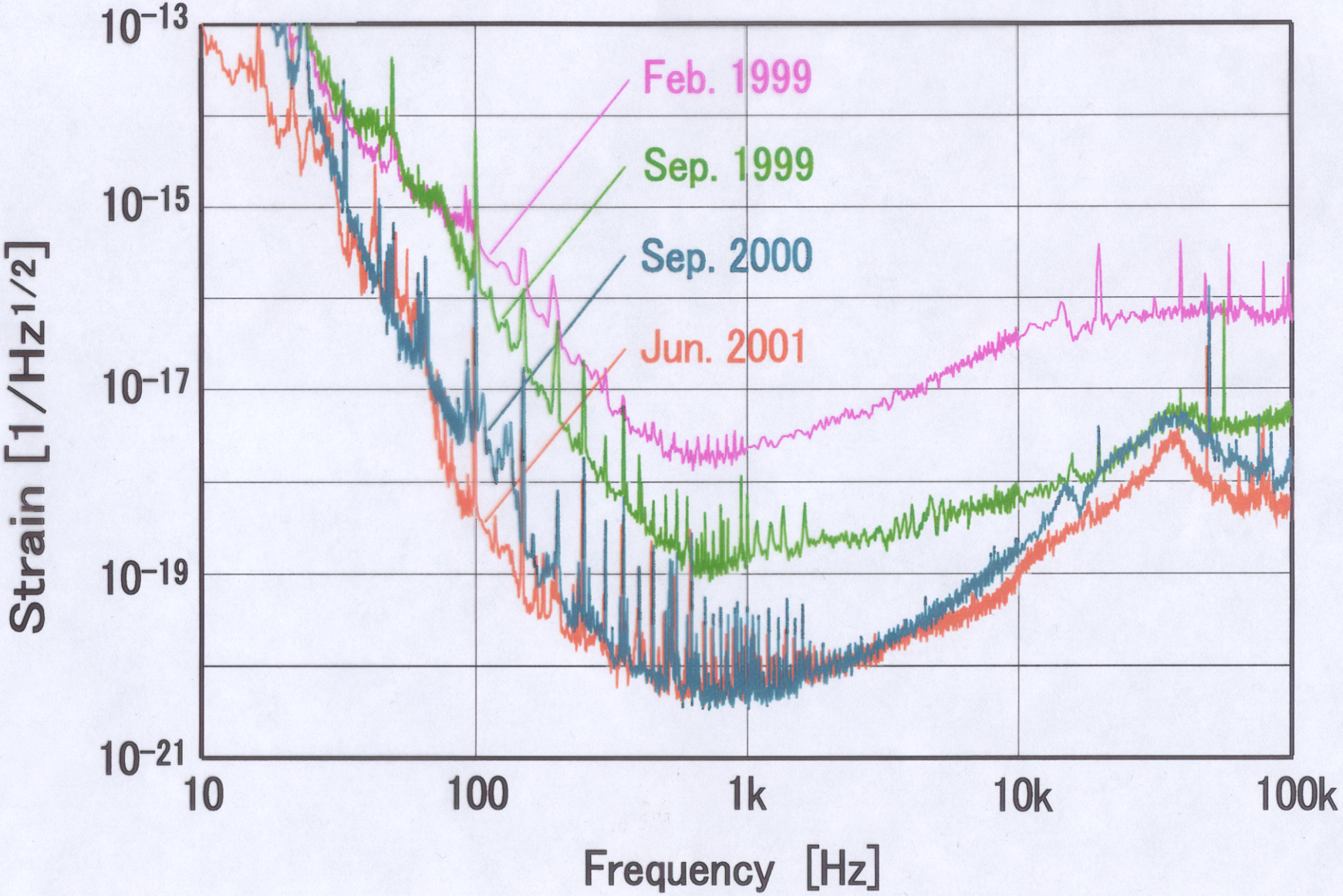




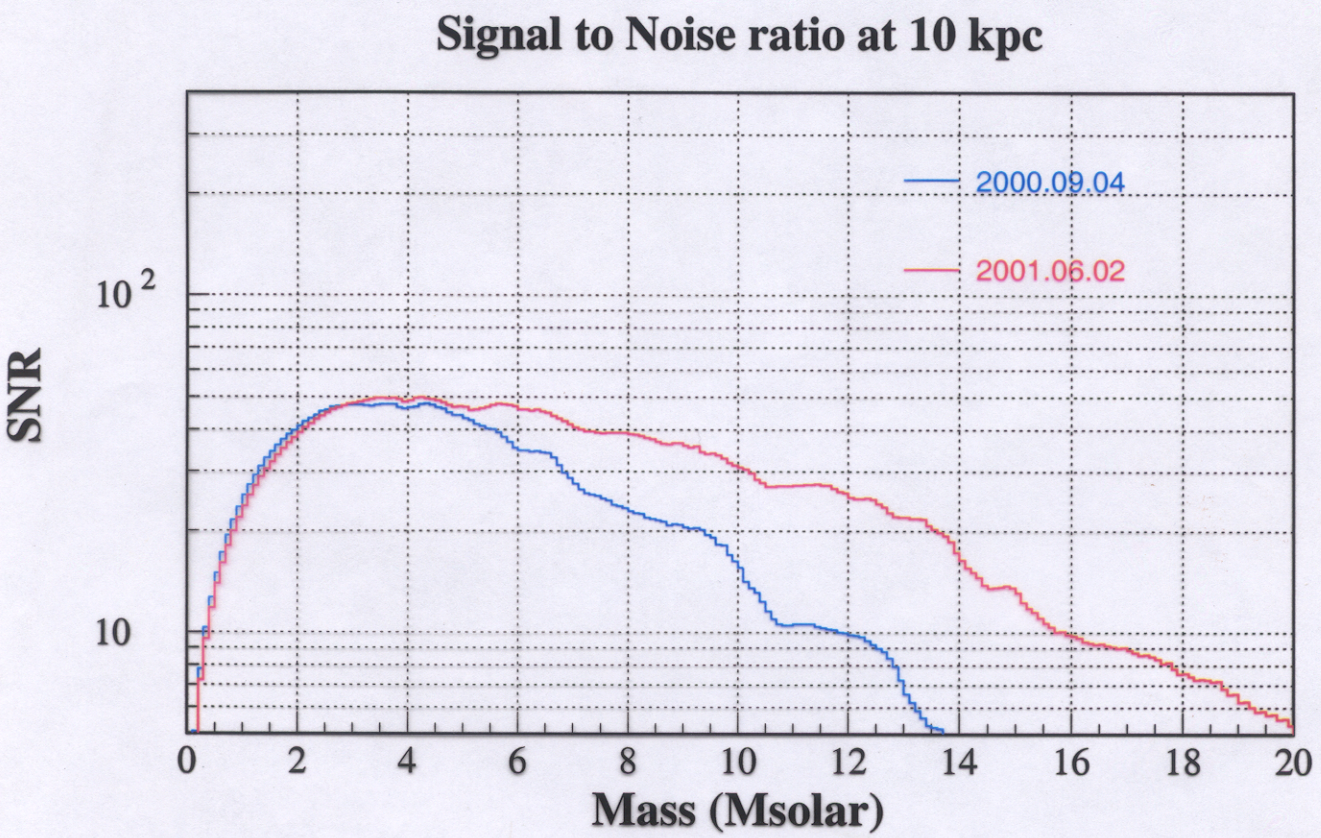



Injection-locked
10 W laser
20 MHz
Injection locking control
Mixer
PD
Fiber LD
YAG
VCM
LD pumped
10 W laser
NPRO
700 mW
20 MHz
EOM
EOM
SUM
30 kHz
15.235 MHz
Mixer
PD
12 MHz
EOM
EOM
10 m Mode cleaner
Mixer
QPD
MC alignment control
IM
OM
FI
10 m
ring
cavity
EM
MC mass loop
Fabry-Perot-Michelson interferometer
with an arm length of 300 m
EM2
300 m
arm cavity
(NS arm)
BS
orientation
control
FM2
NS arm
cavity
alignment
control
δL_y
Differential motion
control (δL_-)
Stack
thermal
control
Mixer
QPD
Mixer
PD
PO2
BS
PO1
FM1
300 m arm cavity
(WE arm)
EM1
WE arm cavity
alignment control
QPD
Mixer
Interference fringe
control (δl_-)
PD
Mixer
PD
Mixer
PD
Mixer
δL_x
Gravitational wave signal (δL_-)
Laser frequency
stabilization
SUM
Feed around loop
Common motion
control (δL_+)

Evolution of Sensitivity of TAMA300

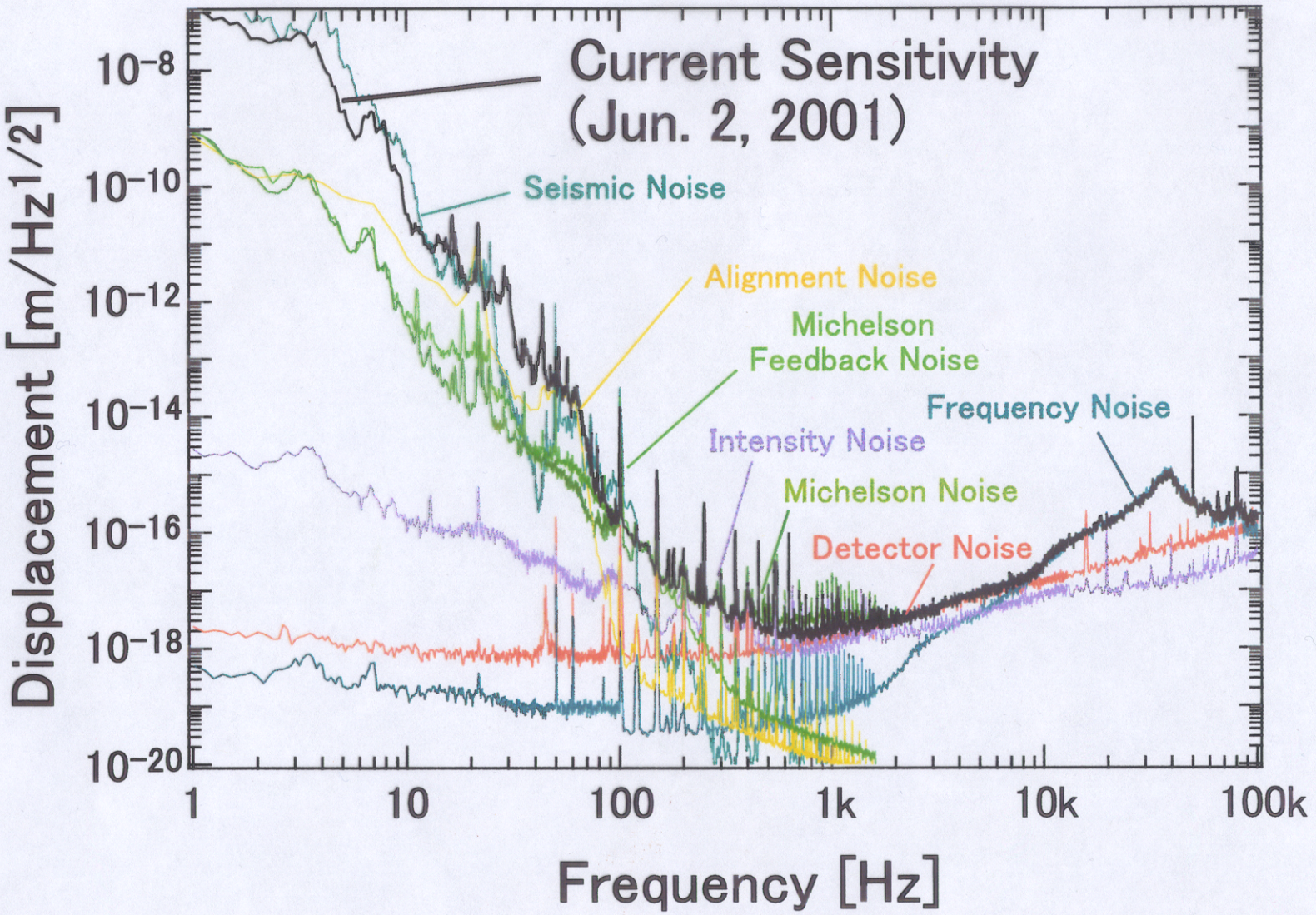


Binary Coalescence



Using Matched Filter

Estimate of Various Noise Contributions



Data Run of TAMA300

Data Run #	Period	Observation Time (Hour)	Sensitivity @ 1kHz (1/rHz)	Operation
1	99/8	10	1.3×10^{-19}	Full Attendence
2	99/9	31	3×10^{-20}	Full Attendence
3	00/4	13	1.3×10^{-20}	Full Attendence
4	00/8-9	160	1×10^{-20}	Partially Automatic Relocking
5	01/3	111	1×10^{-20}	Partially Automatic Relocking
6	01/8-9	1040	1×10^{-20}	Automatic Relocking

Vibration Isolation System

3-layers Stack

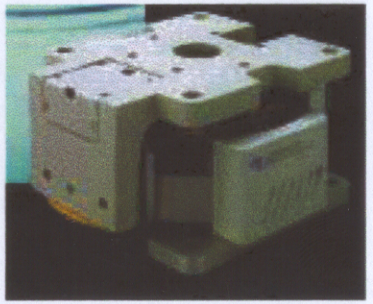
Isolation >10^3 around 300Hz
Vacuum Compatible:
Enclosed rubber with bellows

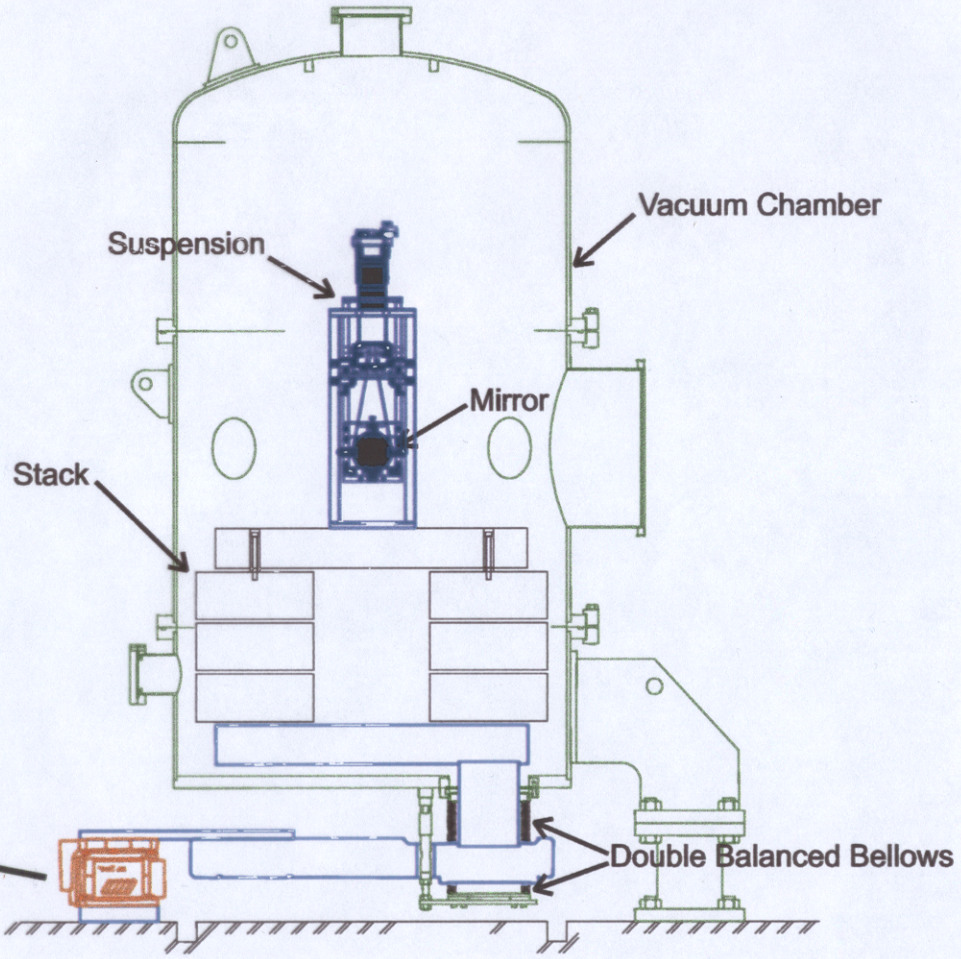
Double Pendulum

Isolation >10^5 around 300Hz
Flexible eddy current damping

Active Isolation

For low frequency (<10Hz)
Commercial pneumatic actuator
Improved RMS displacement





Automatic Operation

Devices

Master Controller

PC + PCI Board (NI 6025E, NI 6711)

Sub Controller

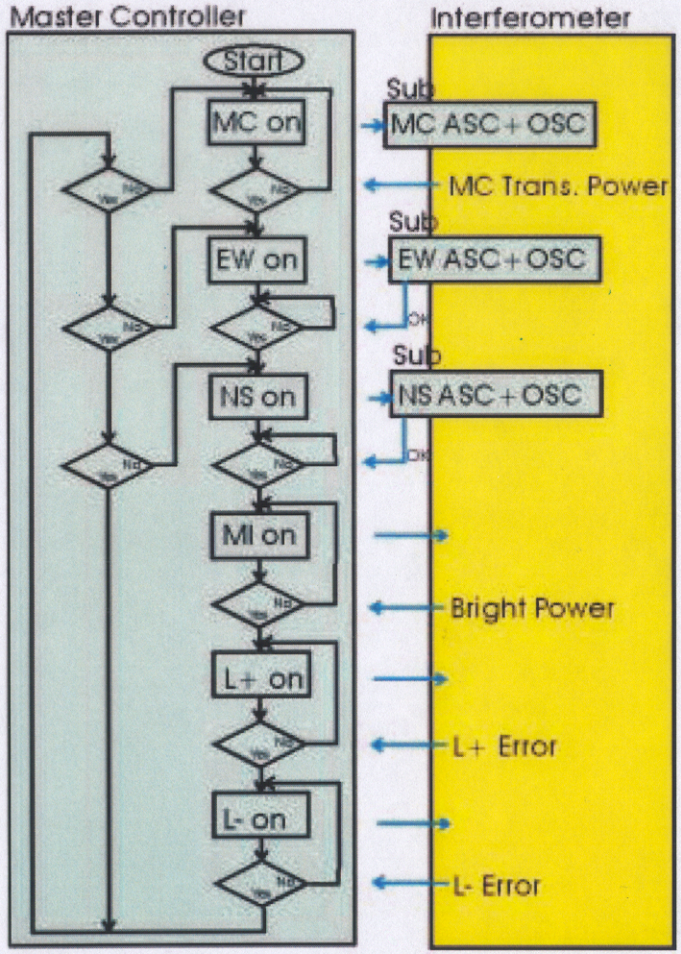
Microprocessor (Hitachi H8/3048)

PC + PCI Board (DT 322)

Function

Sensing of lock status, Switching, Gain adjustment, Offset adjustment, Digital filtering

Automatic Operation for TAMA300



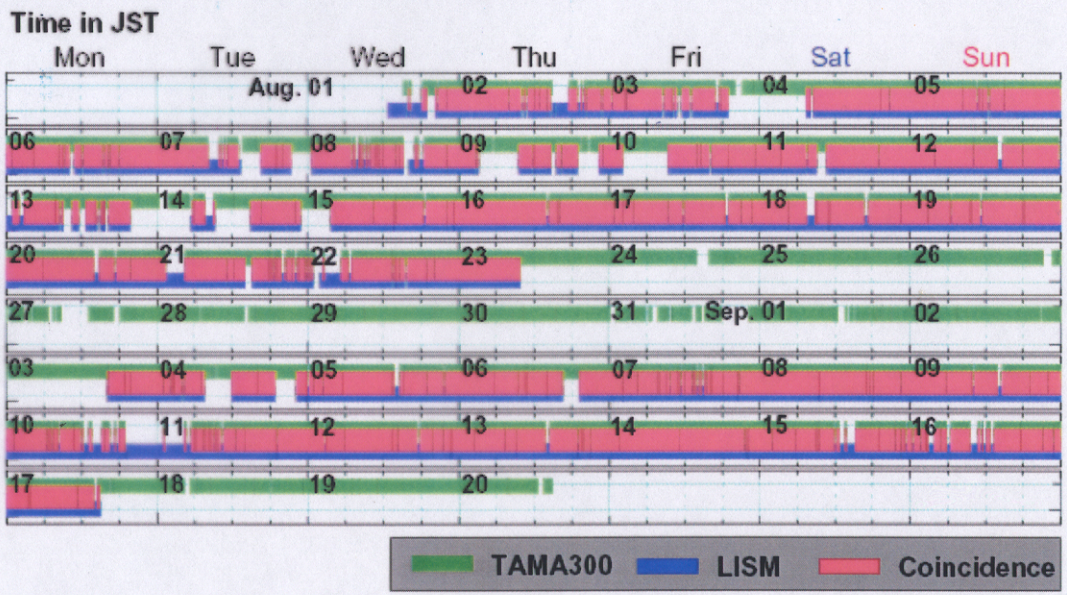
Data Taking 6

Summary

Period	Aug. 1 ~ Sep. 20, 2001 (1200 hours)
Total Observation Time	1038 hours
Duty Cycle	86.5%
Shift Participants	65 people

Coincidence Run with LISM (20m interferometer in Kamioka)

Overlap Locking Time	~700 hours



TAMA300 Recycling

- Installation began in Oct. 2001
- Plan:

  1st step: Low gain recycling (RRM~48%, G~4.6)
  2nd step: High gain recycling (RRM~90%, G~10)

- Current status:

Full lock has been achieved

Recycling gain ~ 4 (designed: 4.6)

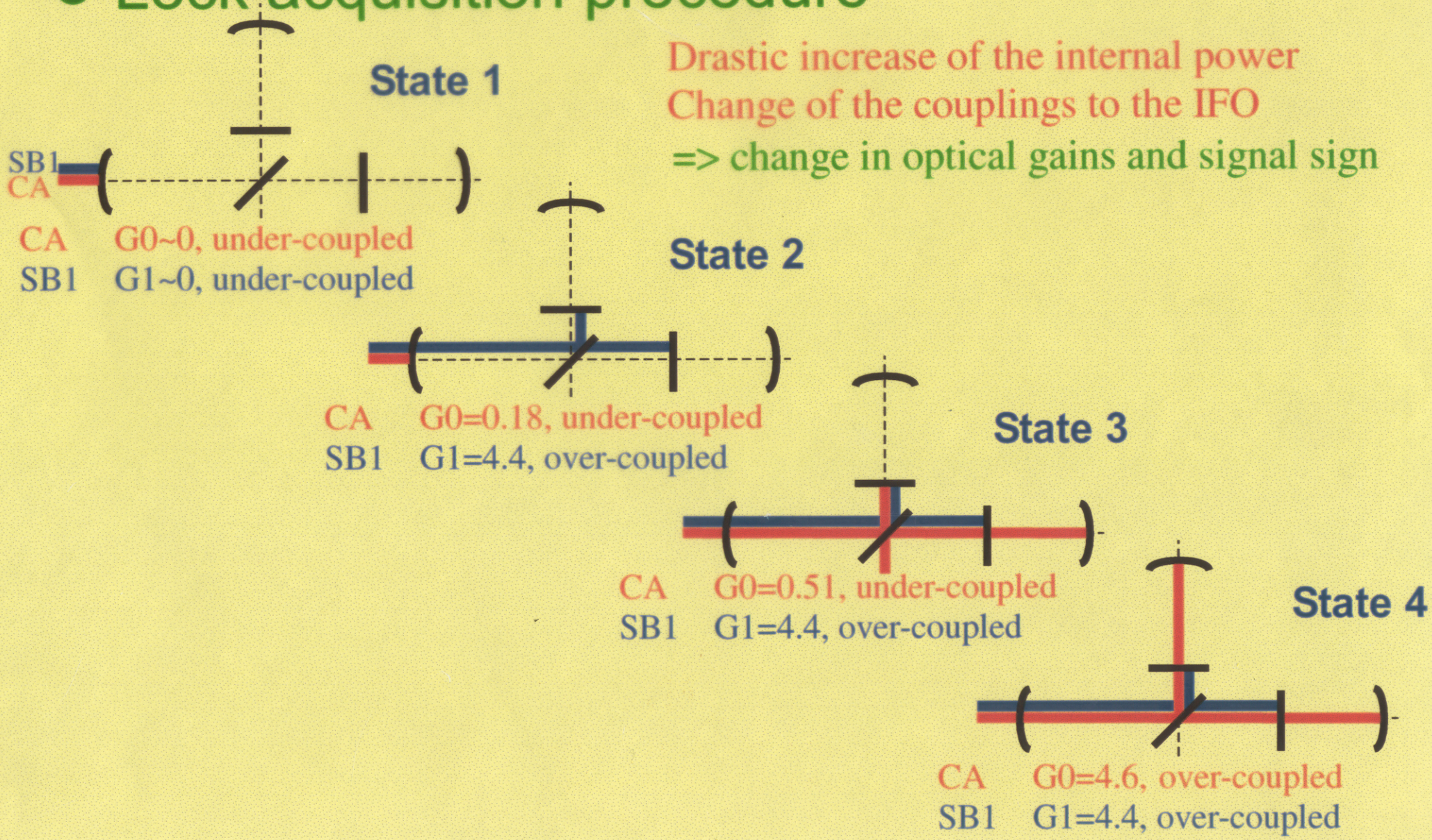
Continuous lock ~ 2 hours

Length control with the frontal modulation scheme

Alignment control for the test masses

Lock acquisition (1)

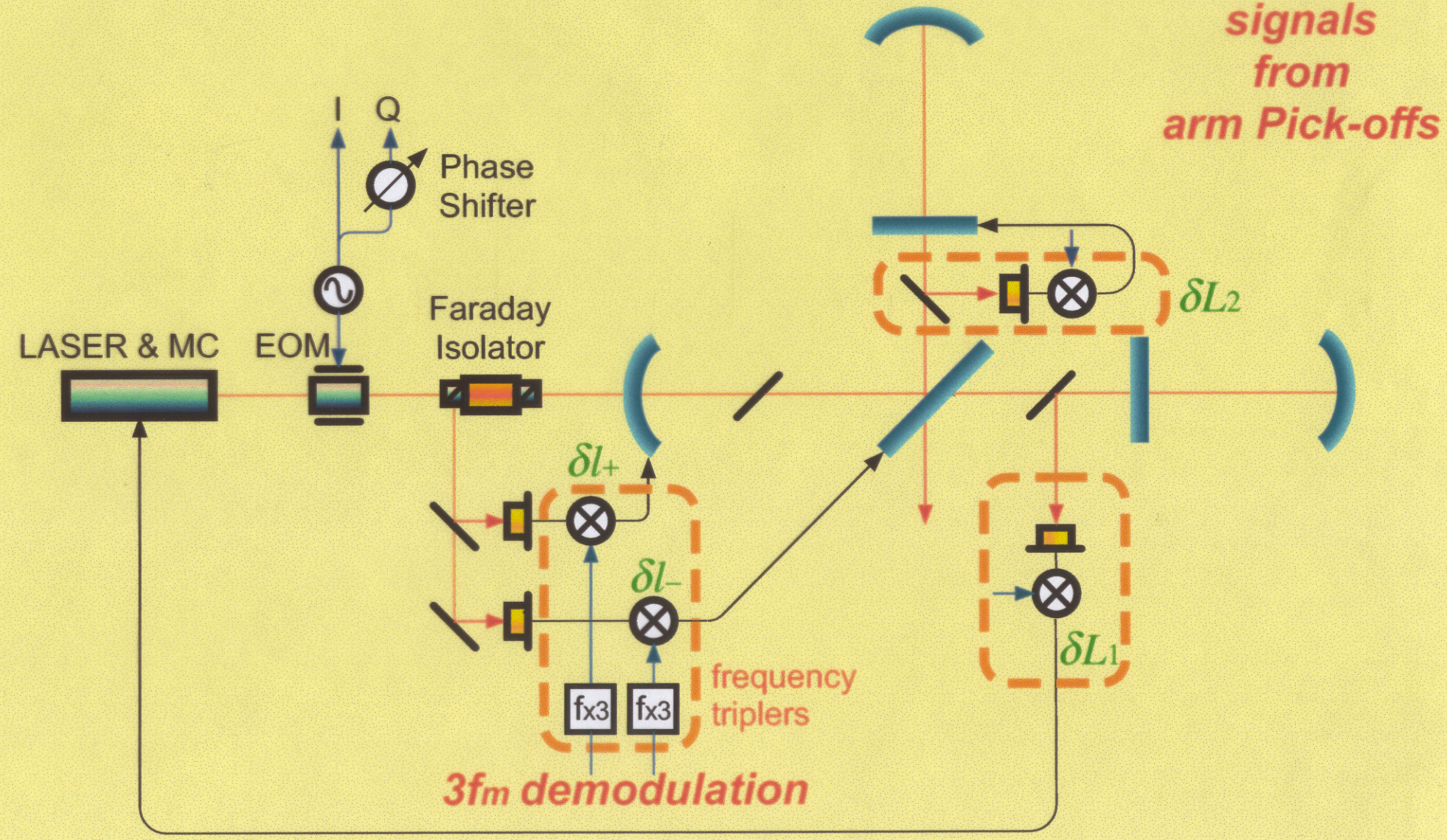
- Lock acquisition procedure



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

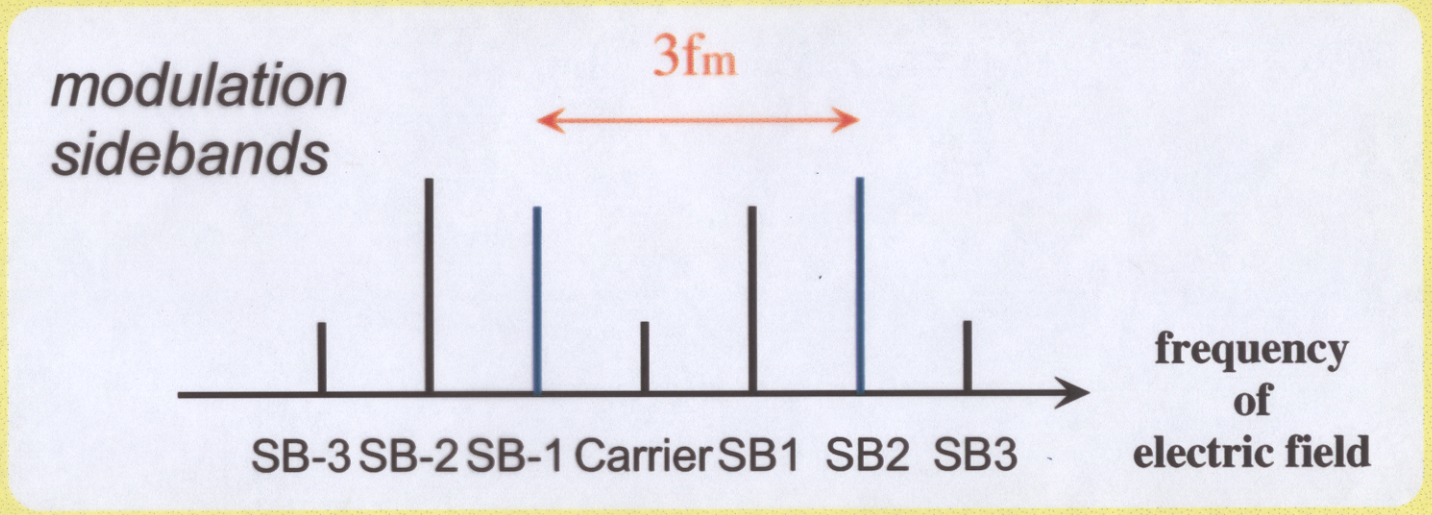
Lock acquisition (2)

- 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

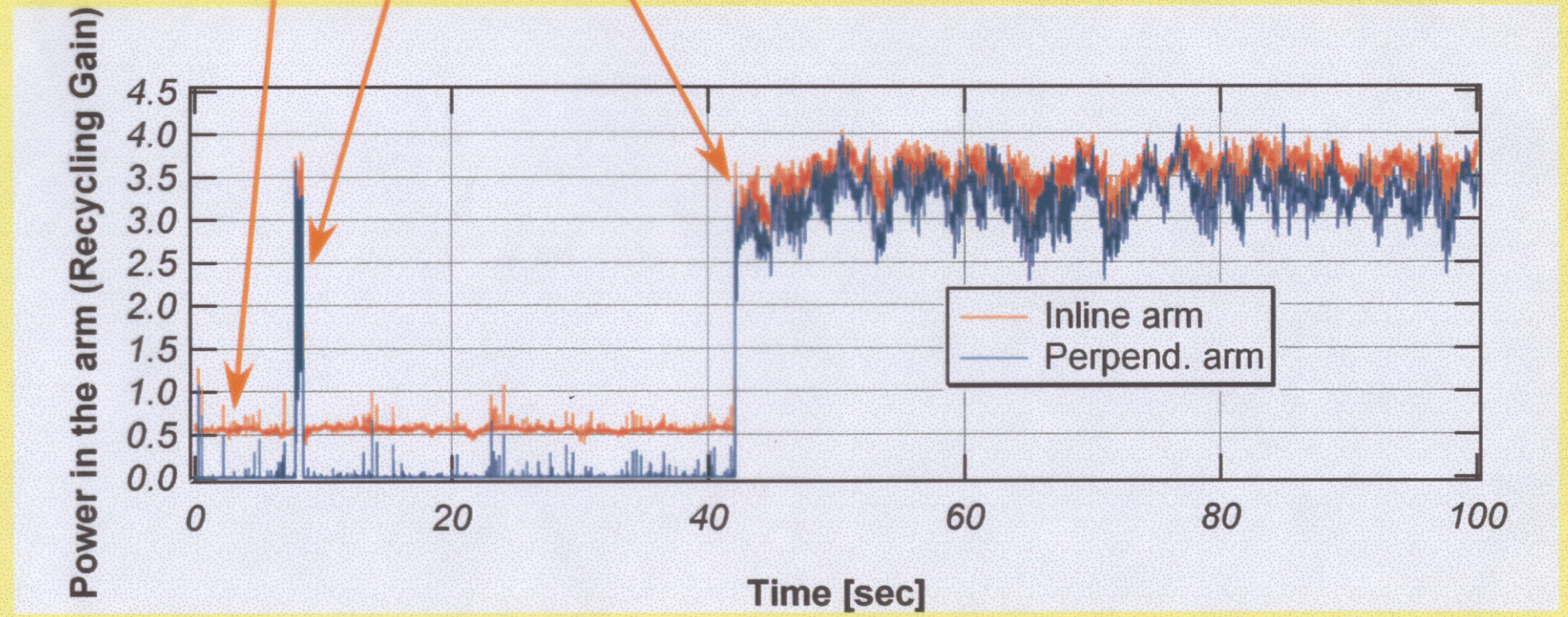
Lock acquisition (4)

- Time-series data of a lock acquisition

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

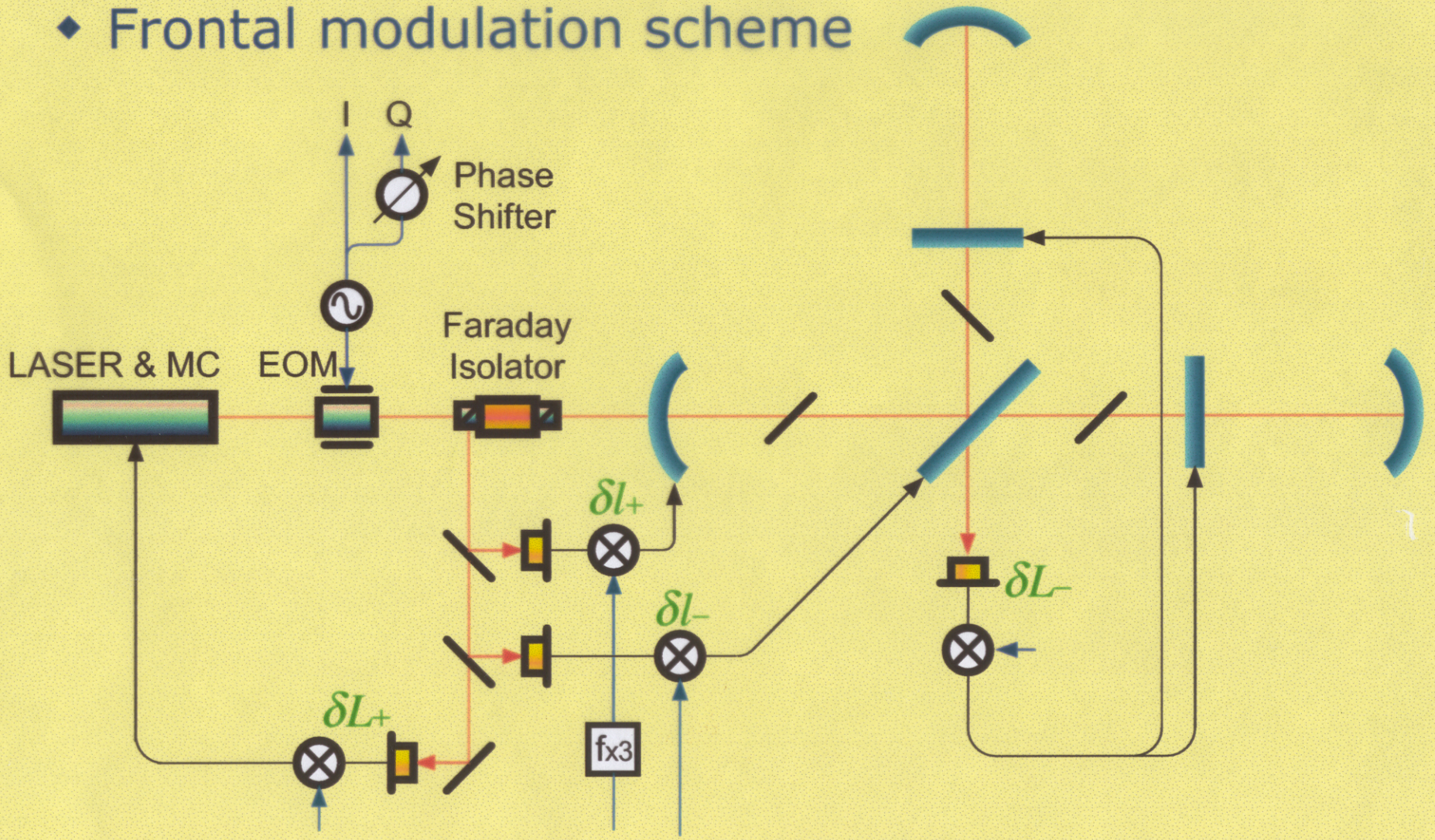
Lock attempt failed

Locked!



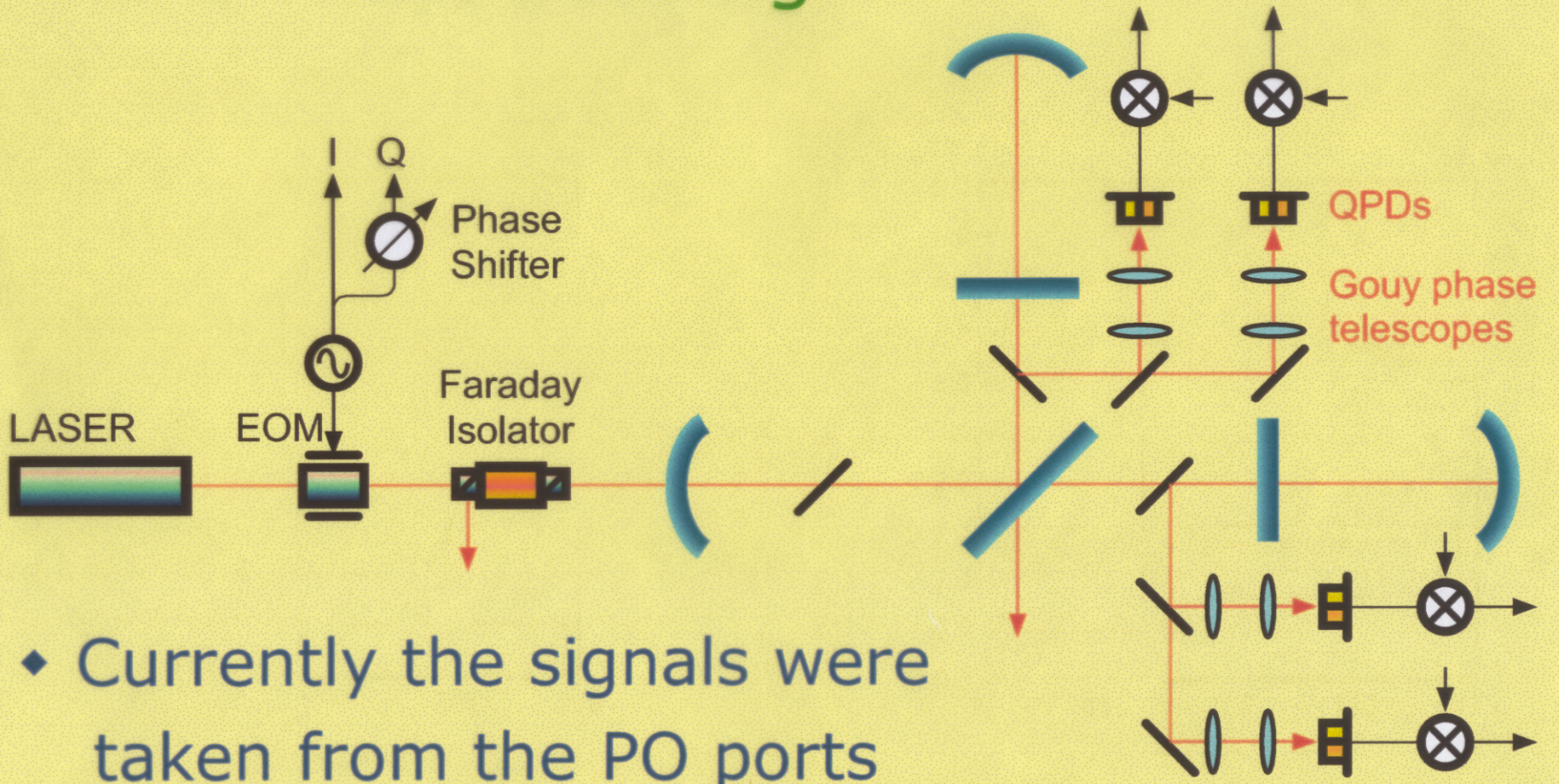
Operation mode

- Length sensing for the operation
  - Frontal modulation scheme



Alignment control (1)

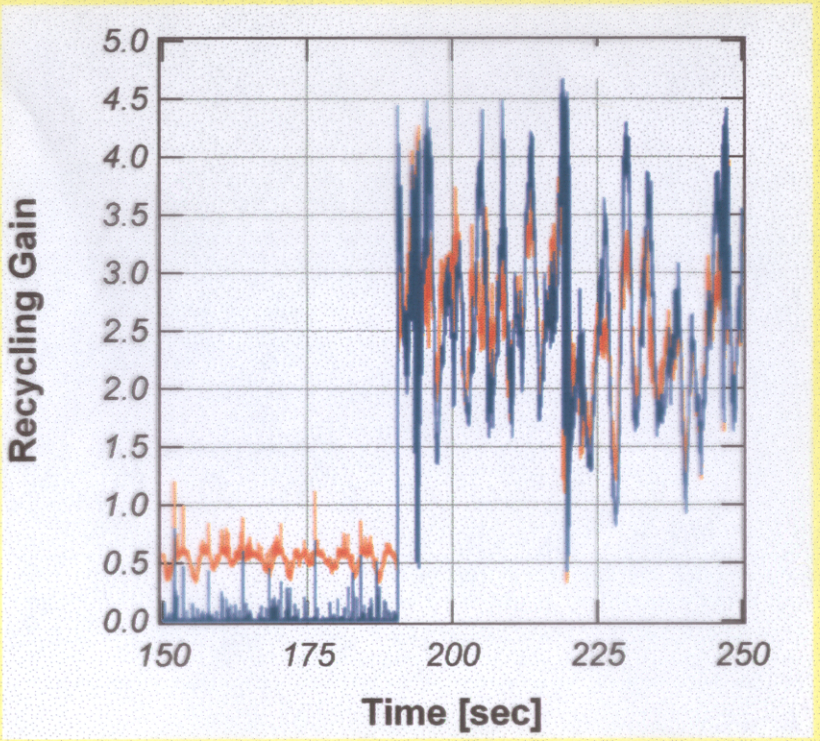
- Wave Front Sensing

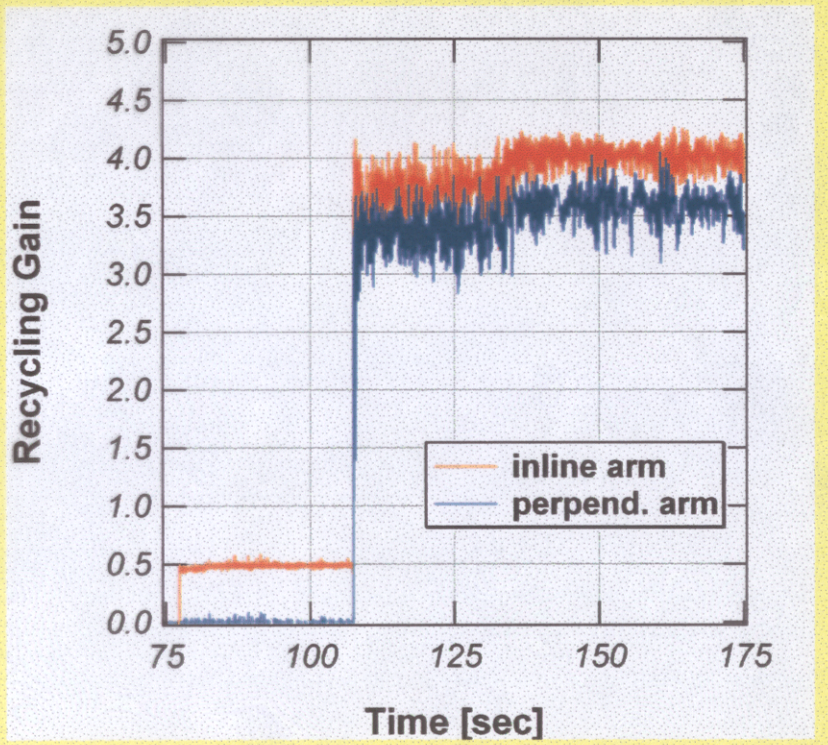


- Currently the signals were taken from the PO ports
- Eventually it will be replaced to the common differential control

Alignment control (2)

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





- The alignment servos were activated even during the lock acquisition

Future Plan

Power Recycling

- Now going (G=4)
- High gain (G=10) in 2002

Observation

- Coincidence run with LIGO in 2002
  - with GEO, VIRGO, …

Seismic Attenuation System (SAS)

- For low frequency (0.1~10Hz)
- R&D with Caltech
- Installation in 2004

High Power Laser

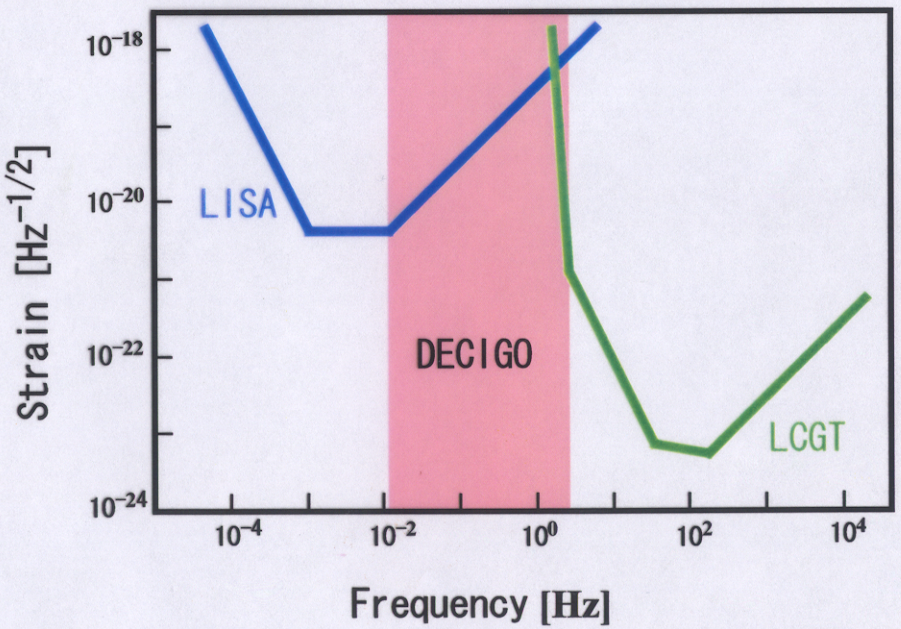
- More than 10W
- R&D with Adelaide University
- Installation in 2005

What is DECIGO？

Deci-hertz Interferometer Gravitational Wave Observatory

Aiming at the Gap between LISA and Ground-based Antenna

(Named by Nakamura in the PRL paper by Seto, Kawamura, and Nakamura)



Confusion Limiting Noise

f < 10mHz

GWs from WD binaries in our galaxy form confusion limiting noise.

f > 0.1Hz

There is no GWs from WD binaries.

The sensitivity of DECIGO could be improved in the future in accordance with the technology development.

Measurement of Acceleration of the Universe by DECIGO

Seto, Kawamura, Nakamura PRL 87, 221103 (2001)

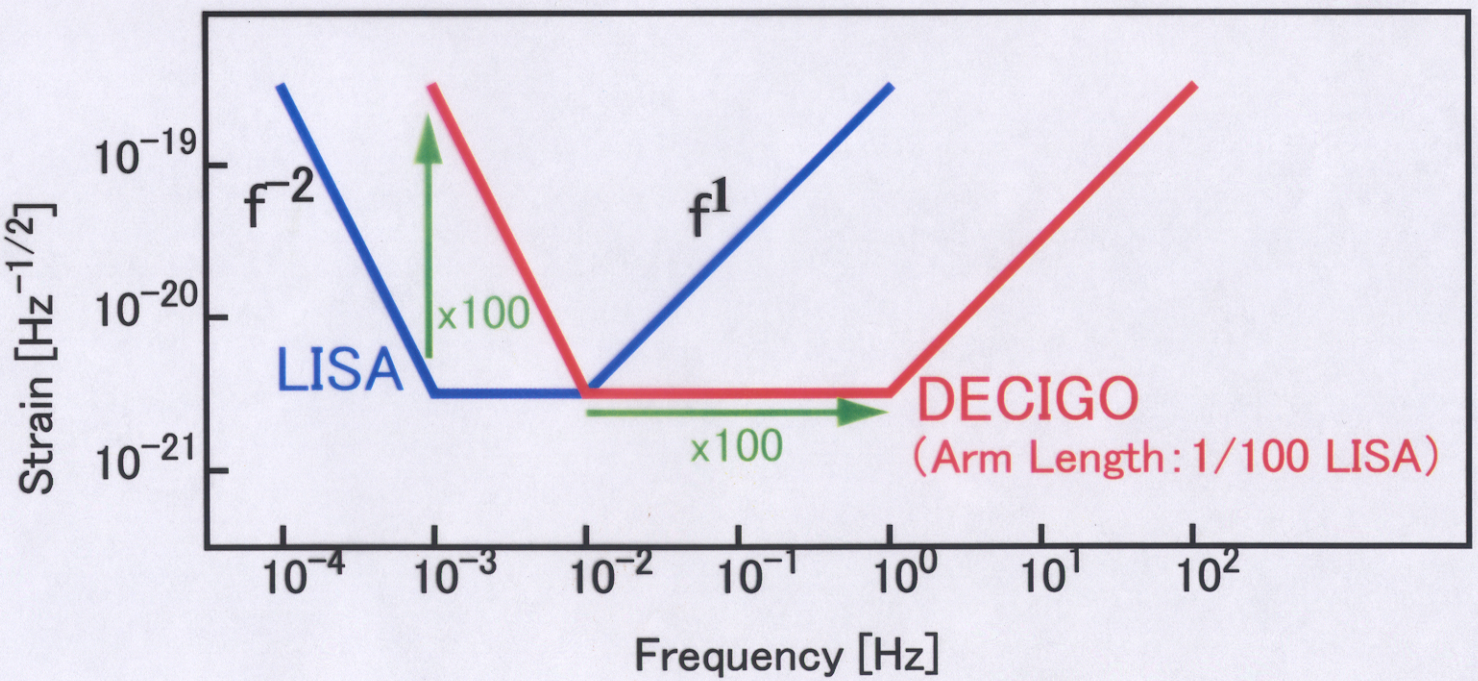
Measuring the gravitational waves around 0.1Hz coming from high-z binary neutron stars for 10 years

The effect of acceleration of expansion of the Universe on the delay of the GW signals for 10 years is about 1 sec.

The sensitivity at 0.1Hz should be better than 1×10^{-23} ($Hz^{-1/2}$).

Relationship between Sensitivity and Arm Length

- Shot-Noise starin sensitivity below fc does not depend on the arm length.
- fc is inversely proportional to the arm length.
- Force-noise strain sensitivity is inversely proportional to the arm length.



NAOJ Space GW Antenna WG

● NAOJ started investigating the future project after ALMA.
⇒ Several candidate projects convened WGs.

● Space GW Antenna WG convened in March 2002.
(70 members at present; NAOJ, ISAS, CRL, many Univs)

⇒ Scientific Goal
⇒ Feasibility
⇒ Prototype Experiment
⇒ Learn from LISA
⇒ Collaboration with LISA

Summary

1. TAMA300 achieved satisfactory sensitivity and operation stability.

2. TAMA300 is now operable with low-gain recycling.

3. We will implement high-gain recycling and SAS in TAMA300, and also take data as a coincidence run with other detectors.

4. We have started studying DECIGO. We hope that this project will be eventually approved in Japan.