Current Status of TAMA300

Shigeo Nagano
and
TAMA Collaboration

Outline

1. Overview of TAMA300
2. Power-recycling experiment
3. Data taking 7
4. Summary

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TAMA300 Gravitational wave detector

Laser interferometer with arm length of 300m

Site: National Astronomical Observatory of Japan
(Mitaka, Tokyo)

Aims of the project

Development of a detector capable to detect GW events in nearby galaxies.

Establishment of techniques for a future km-class interferometer

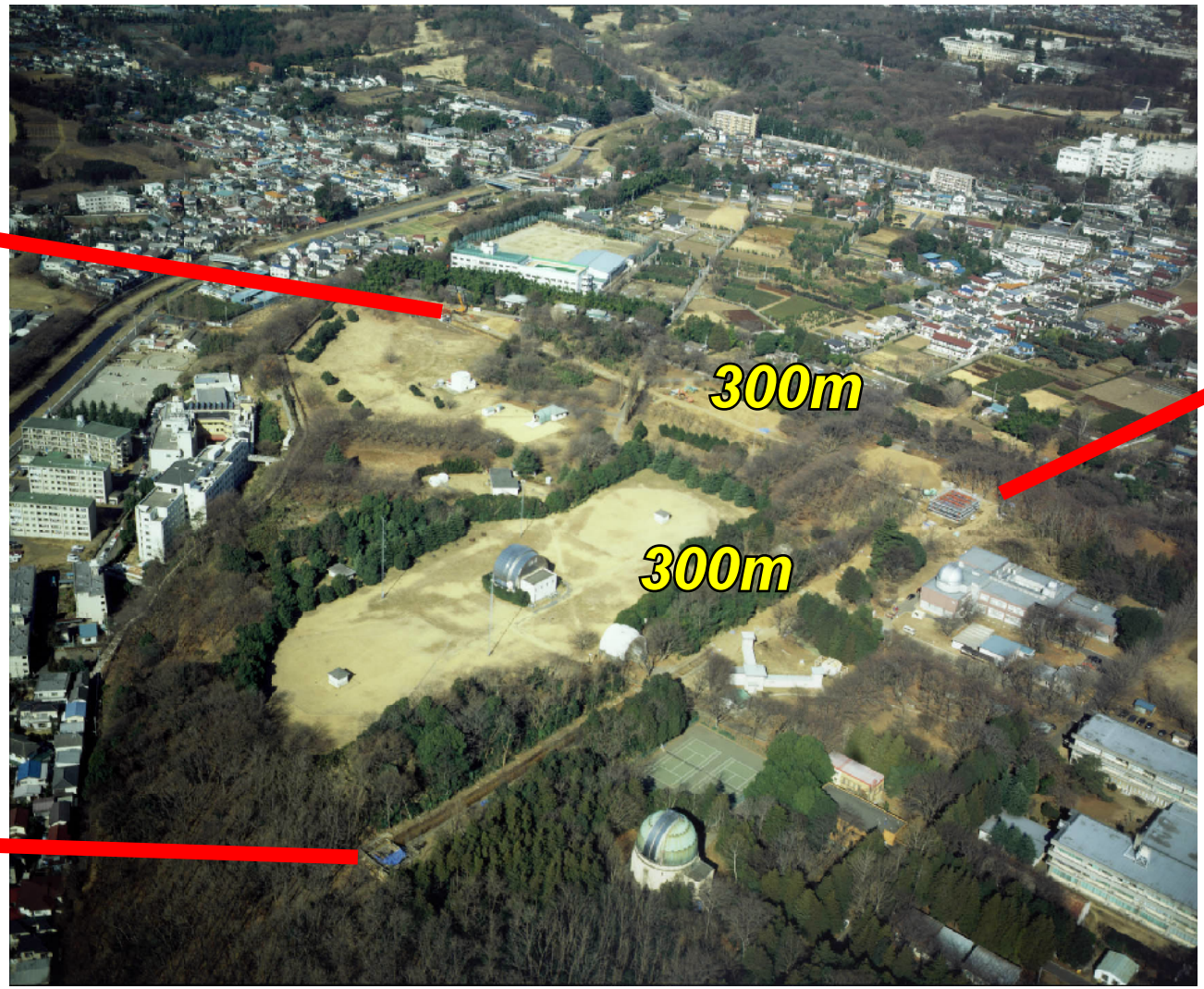
Designed sensitivity

$h = 1.7 \times 10^{-22}$ /sqrtHz (@150~450Hz)

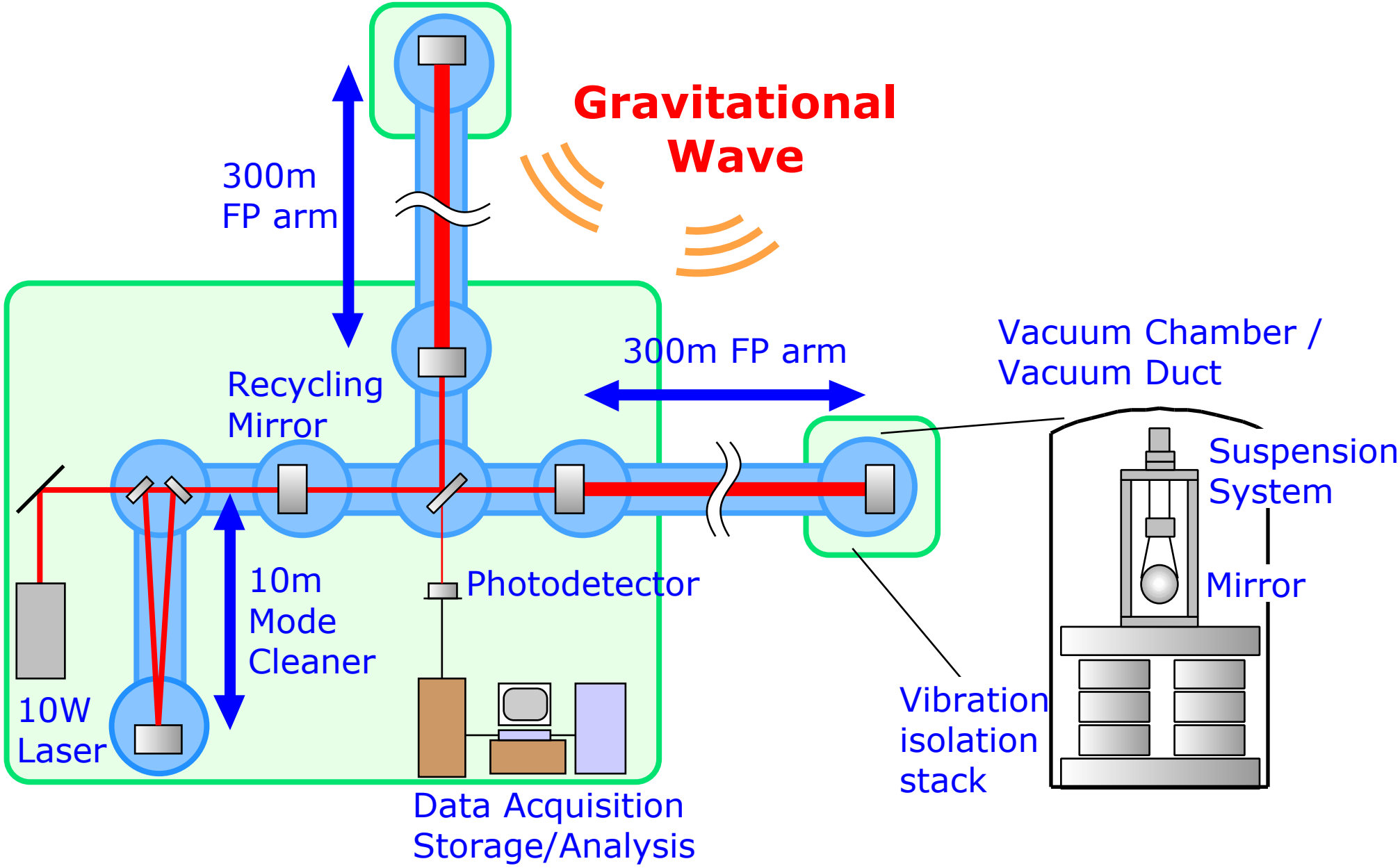
Bird's-eye view of TAMA300

National Astronomical Observatory of Japan

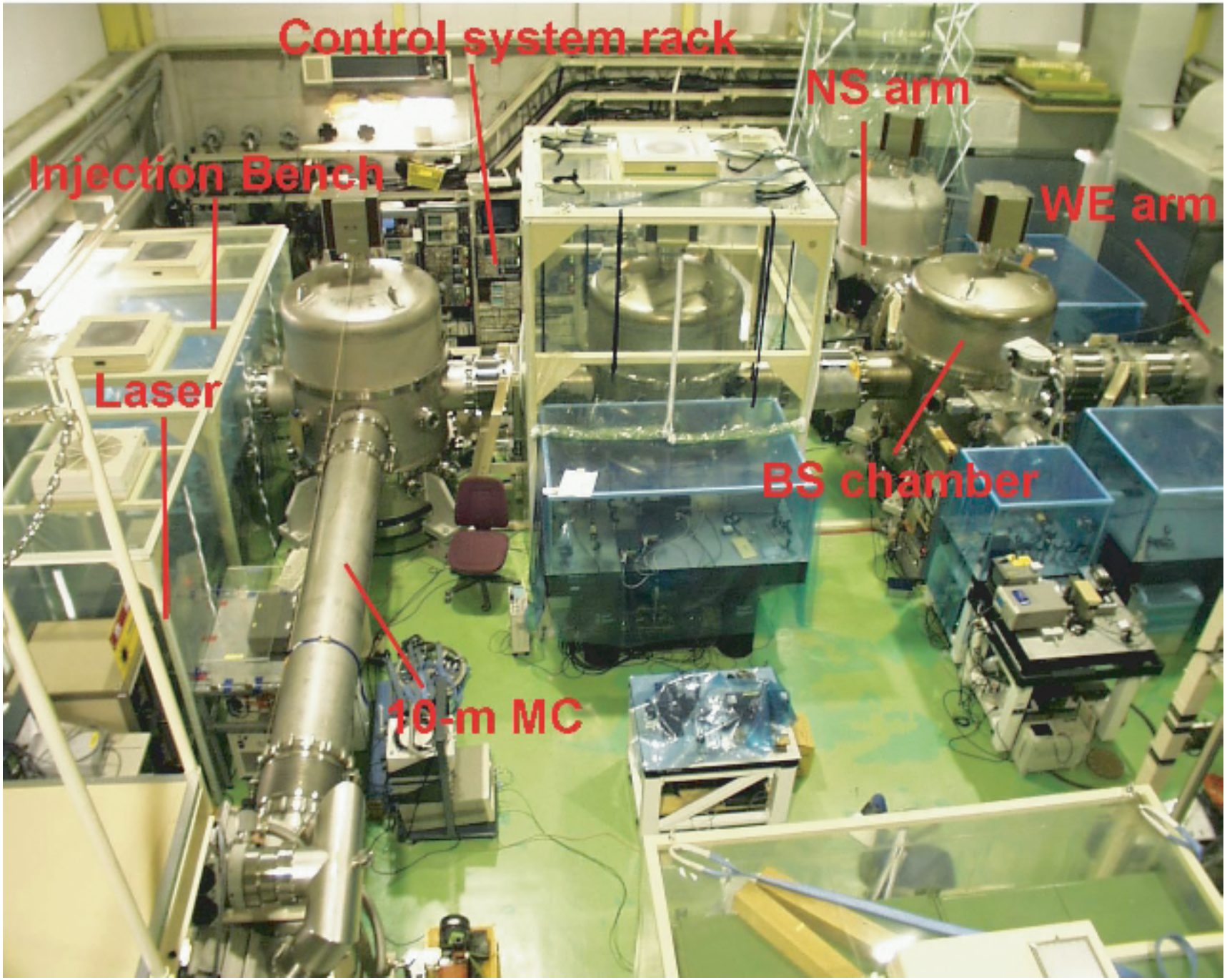
Tokyo, Mitaka Campus (E139.32.21 N35.40.25)



TAMA300 detector ~ overview

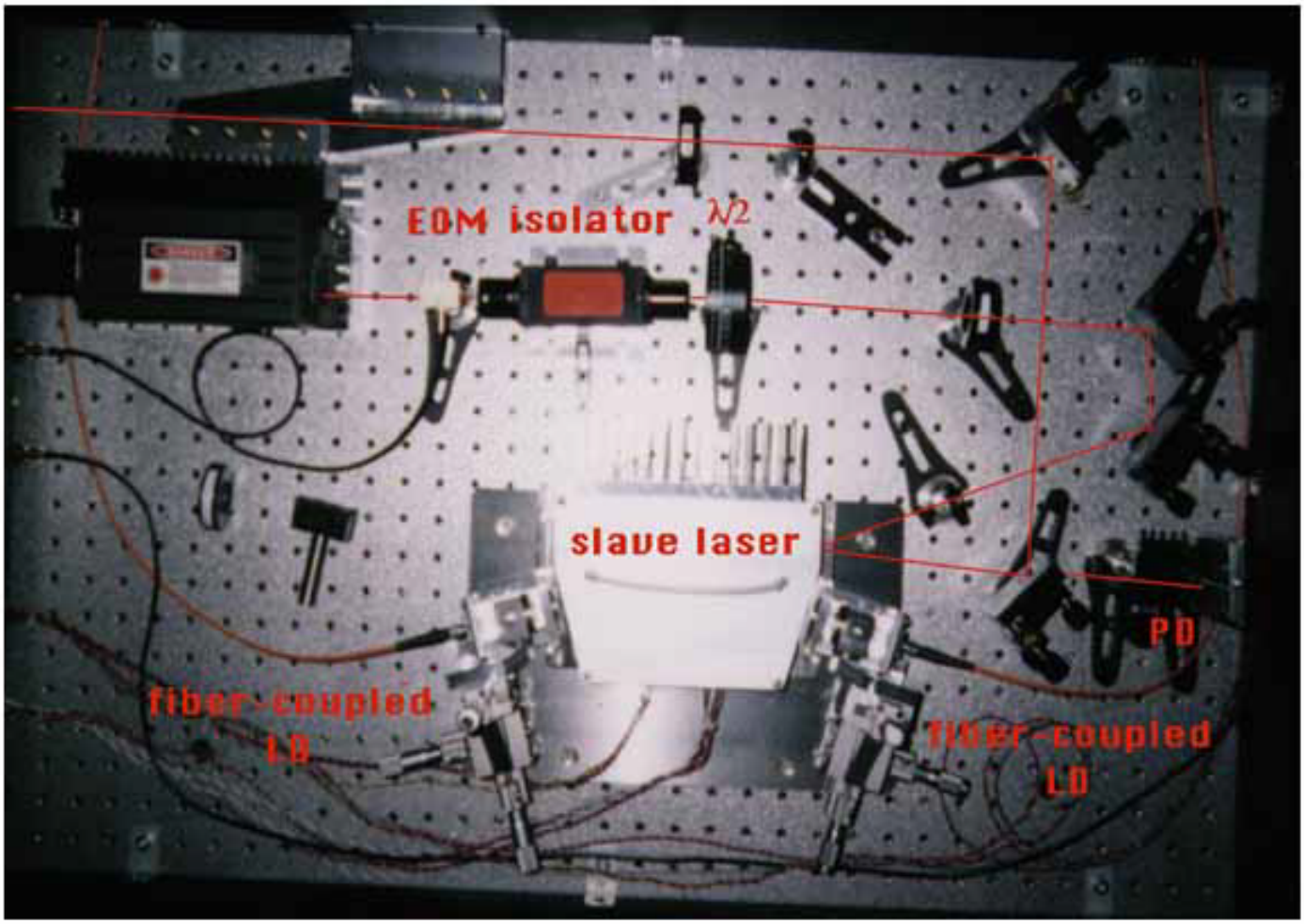


Center Room Building of TAMA300



300m vacuum tube

10-W Injection-Locked LD-pumped Nd:YAG Laser



Output power 9.5W, when pumping power is 24W

Slope efficiency 44 %

Wavelength 1064nm

Single frequency oscillation

TEM_{00}-mode M^2 value < 1.2

End-pumping scheme

Developed by SONY corporation

10-m Ring-type Mode Cleaner

Round trip length 19.7m

Finesse 1860

Cavity linewidth 8.2kHz

Vibration Isolation

Stack + double pendulum

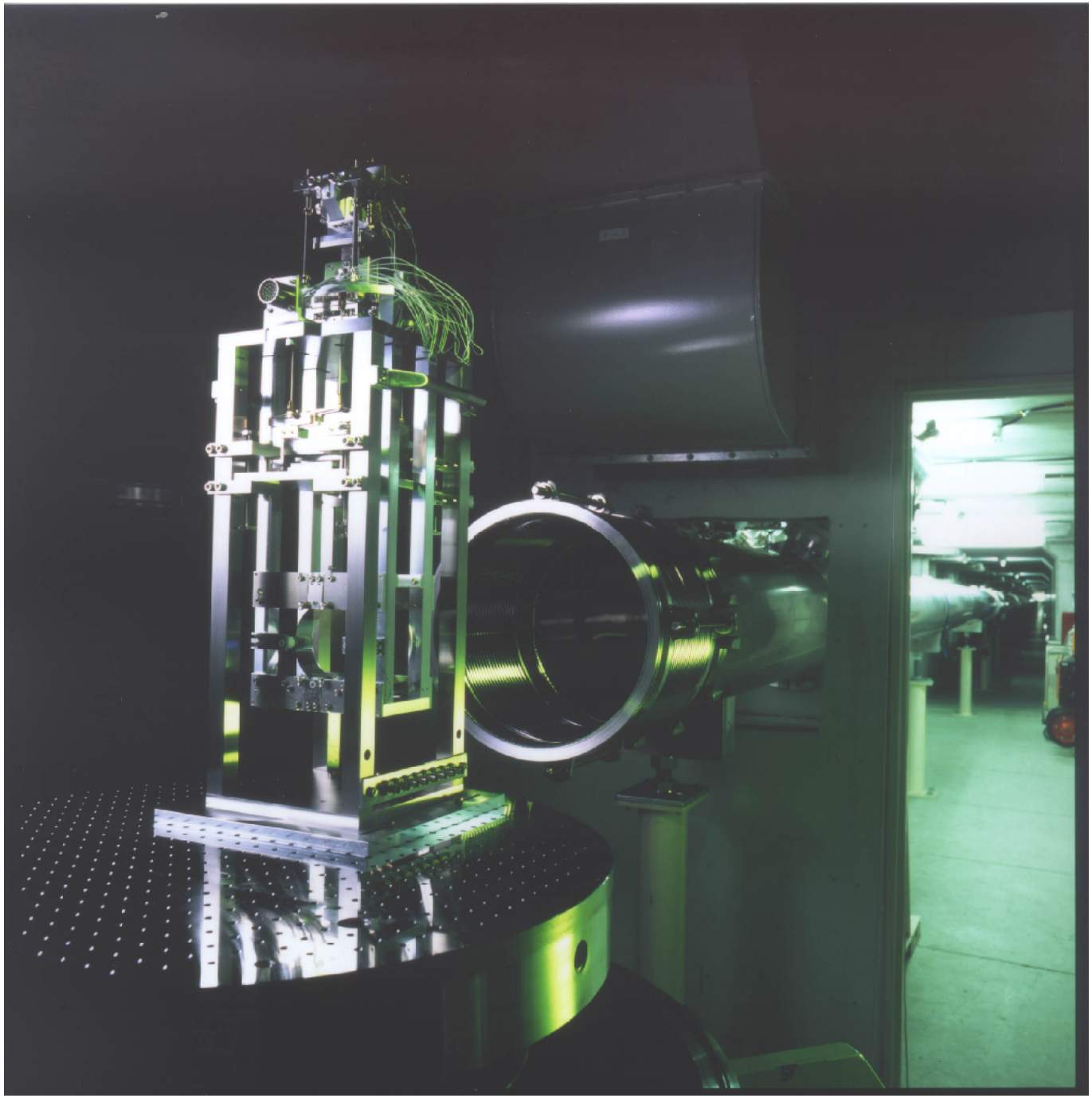
Pressure 10^{-5} Pa

Dielectric multi-layer coarting

(JAE corporation)

Mirror substrate fused silica

Vibration Isolation System



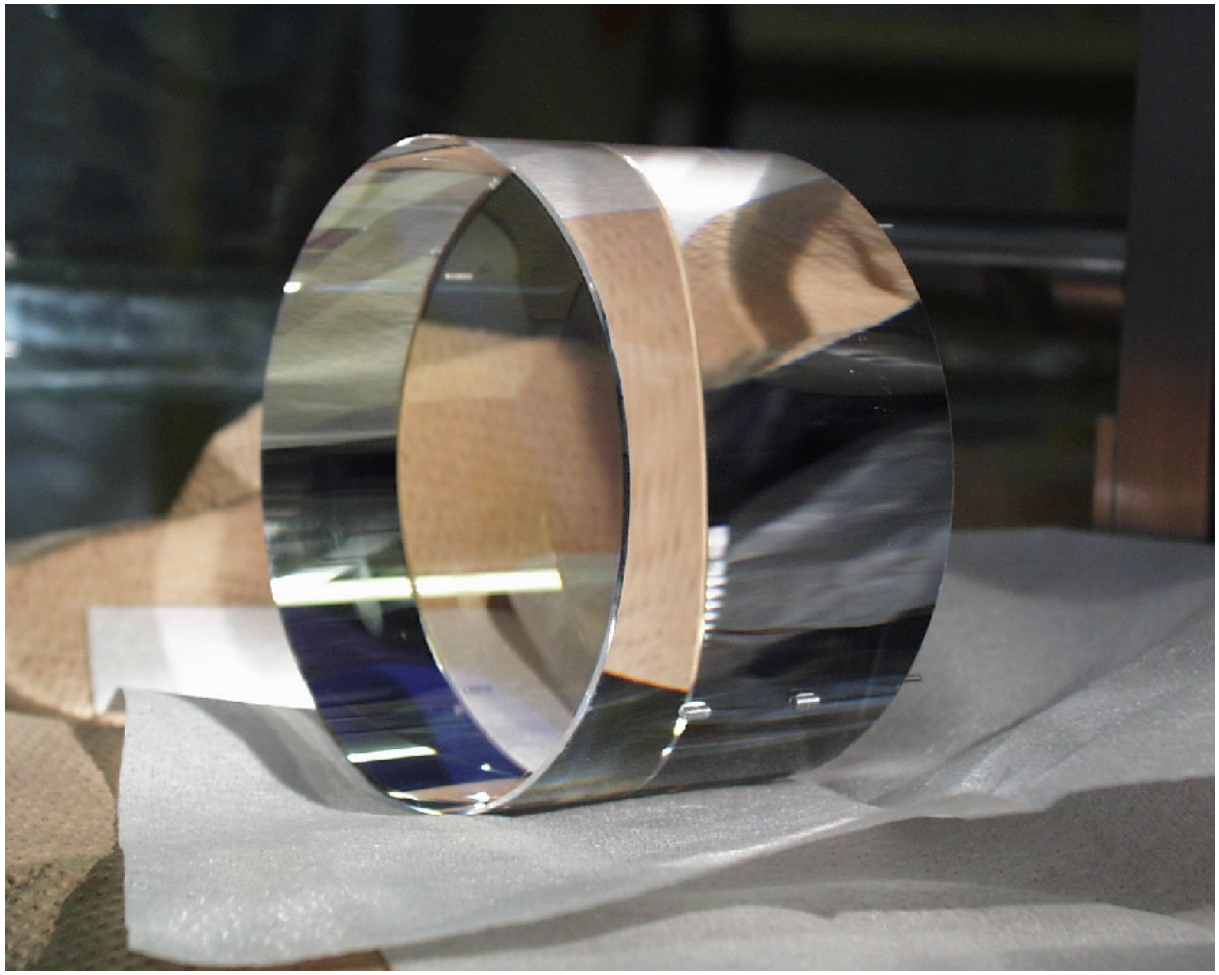
- **3 layer system**

Actively-controlled
air spring
+
Stack
(Sandwitches of rubbers
and metal blocks)
+
Double pendulum
suspension

Achieved performance
~ better than 10^{-8}
at 150Hz

Mirror

- **Fused silica (SiO_2) ϕ *100mm x 60mm***



High mechanical quality

~ to suppress thermal vibration in the observation band

High optical quality

~ ultra low loss (~30ppm) in reflection.

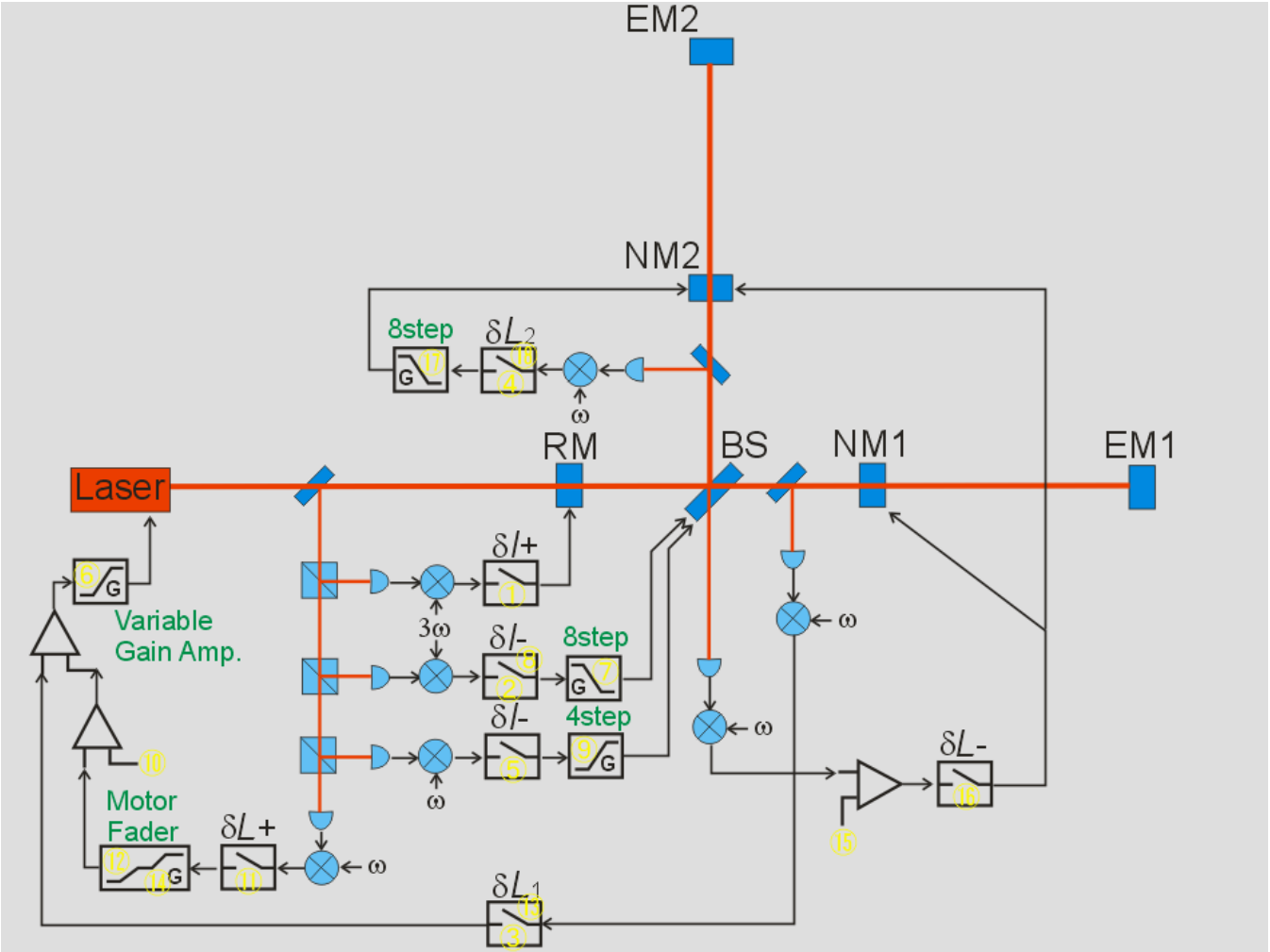
Control electronics

Automation of detector operation

Hardware: PC + PCI board (National Instruments 6025E, 6711)

Digital switch: 24ch, Digital I/O: 16ch, A/D: 8ch, D/A: 6ch

Software: National Instruments LabVIEW



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Power recycling for TAMA300

Recycling experiment began in October, 2001.

Purpose

To improve SNR to NS binaries

To integrate the technical achievement of the R&Ds.

Present Status

Full lock has been achieved.

Recycling gain ~ 4 (design: 4.6)

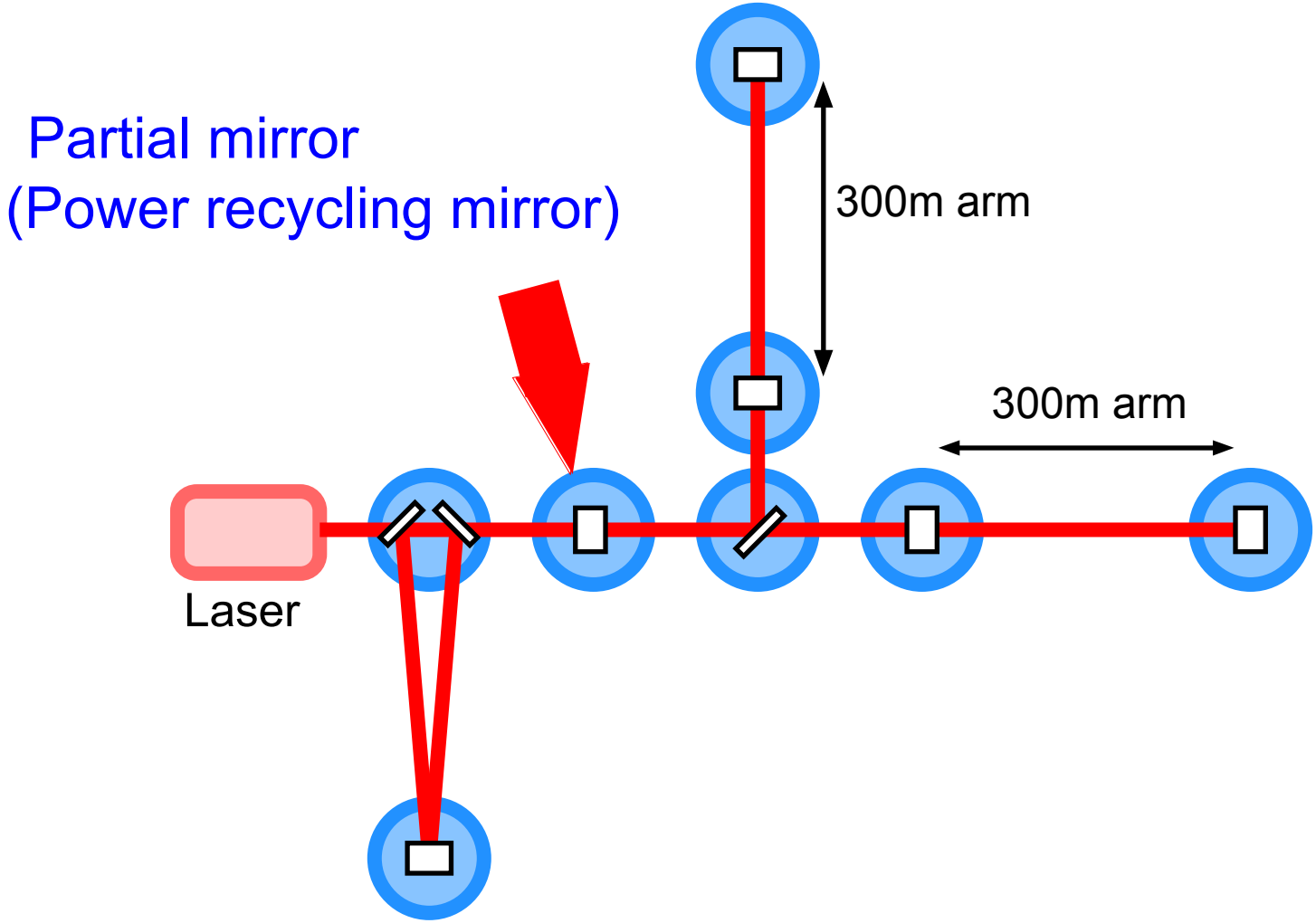
Continuous lock more than 8 hours

Length control with the frontal modulation scheme

Alignment control for the test masses

Power recycling technique

Enhancing light power in the interferometer



->Shot noise level can be decreased.

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Purpose

Scientific motivation

To perform observation with improved SNR to NS binaries

1st step: Low gain recycling (RRM~48%, G~4.6)

Goal: Faster realisation of the full locking

Earlier full operation and observations.

Feeding back the information to the design of high gain recycling.

Establishing techniques for diagnoses and analysis.

2nd step: High gain recycling (RRM~90%, G~10)

Goal: Optimizing the detector performance

Power recycling R&Ds in Japan

3m Prototype in Tokyo Univ. (Gachieved: 2.9~5.5)

Demonstration of recycling with suspended FPMI [*1]

Investigation of the length sensing & control scheme

Sideband elimination technique [*2,3]

3rd harmonic demodulation technique [*4]

20m Prototype in NAO (Gachieved: 8~12)

Evaluation of the TAMA optics [*5]

Investigation of the length sensing & control scheme 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

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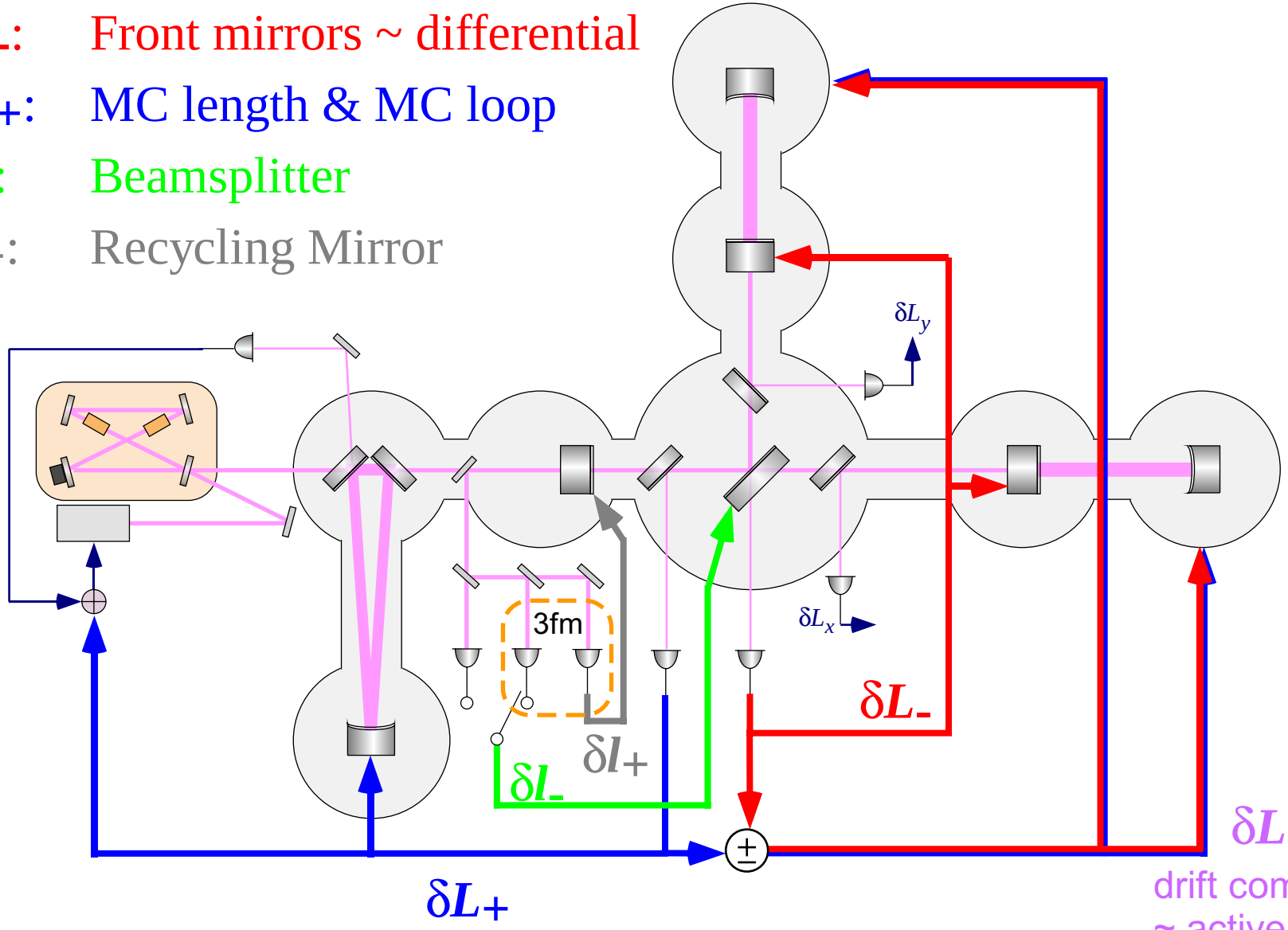
Control topology

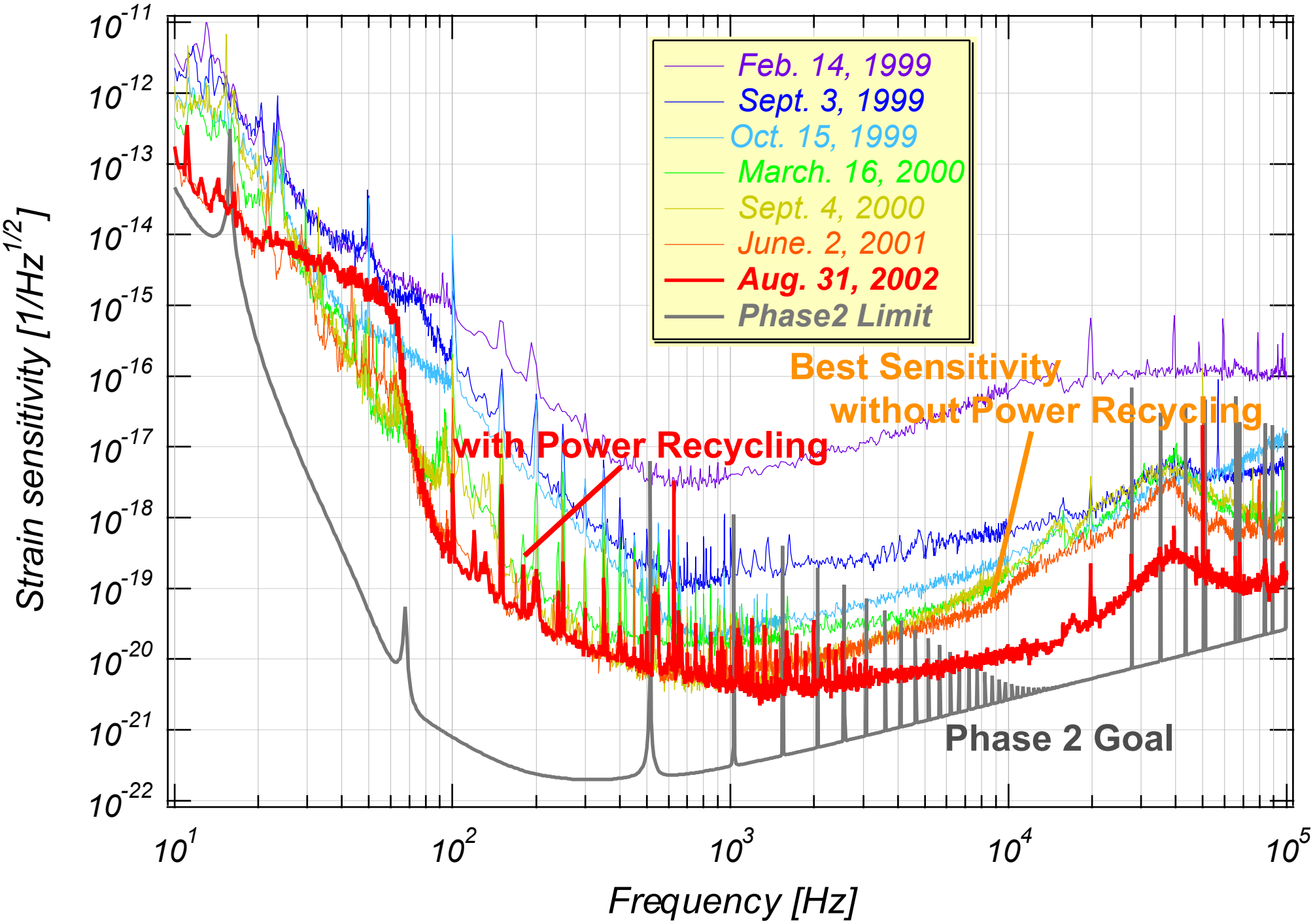
δL_-: Front mirrors ~ differential

δL_+: MC length & MC loop

δl_-: Beamsplitter

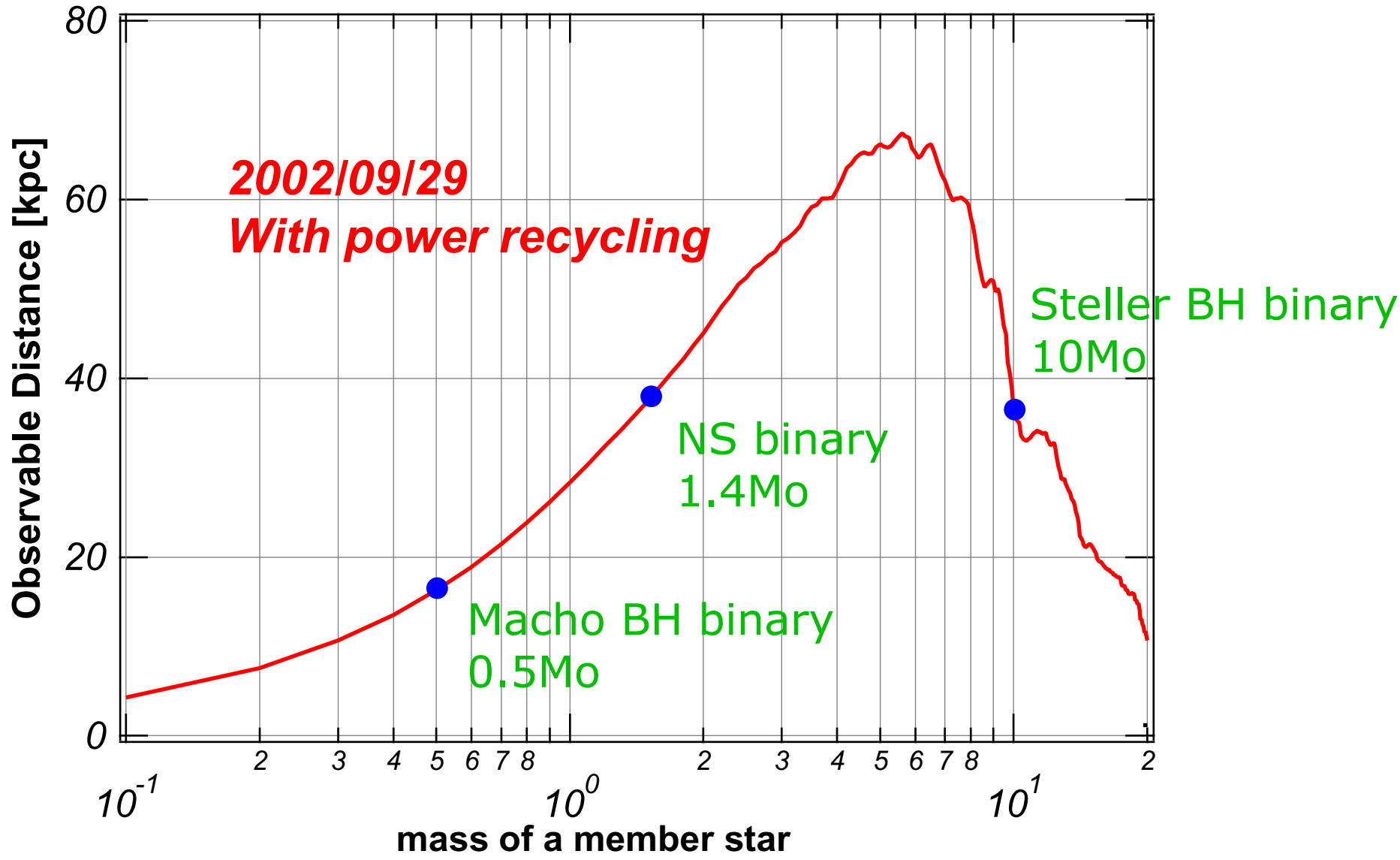
δl_+: Recycling Mirror




Feb. 14, 1999
Sept. 3, 1999
Oct. 15, 1999
March. 16, 2000
Sept. 4, 2000
June. 2, 2001
Aug. 31, 2002
Phase2 Limit
Best Sensitivity
without Power Recycling
with Power Recycling
Phase 2 Goal
Strain sensitivity [1/Hz^1/2]
Frequency [Hz]
10^-11
10^-12
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^1
10^2
10^3
10^4
10^5

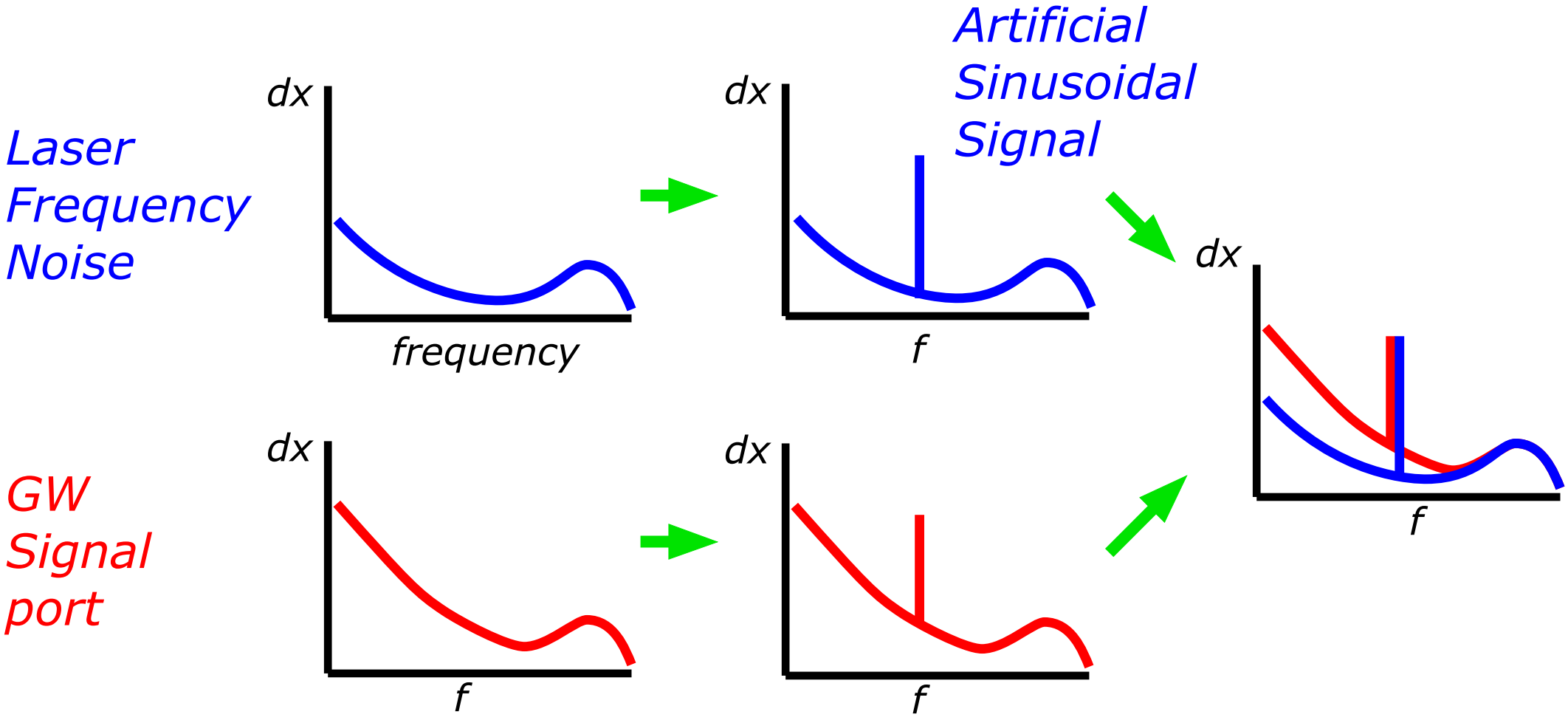
Expected SNR to inspirals

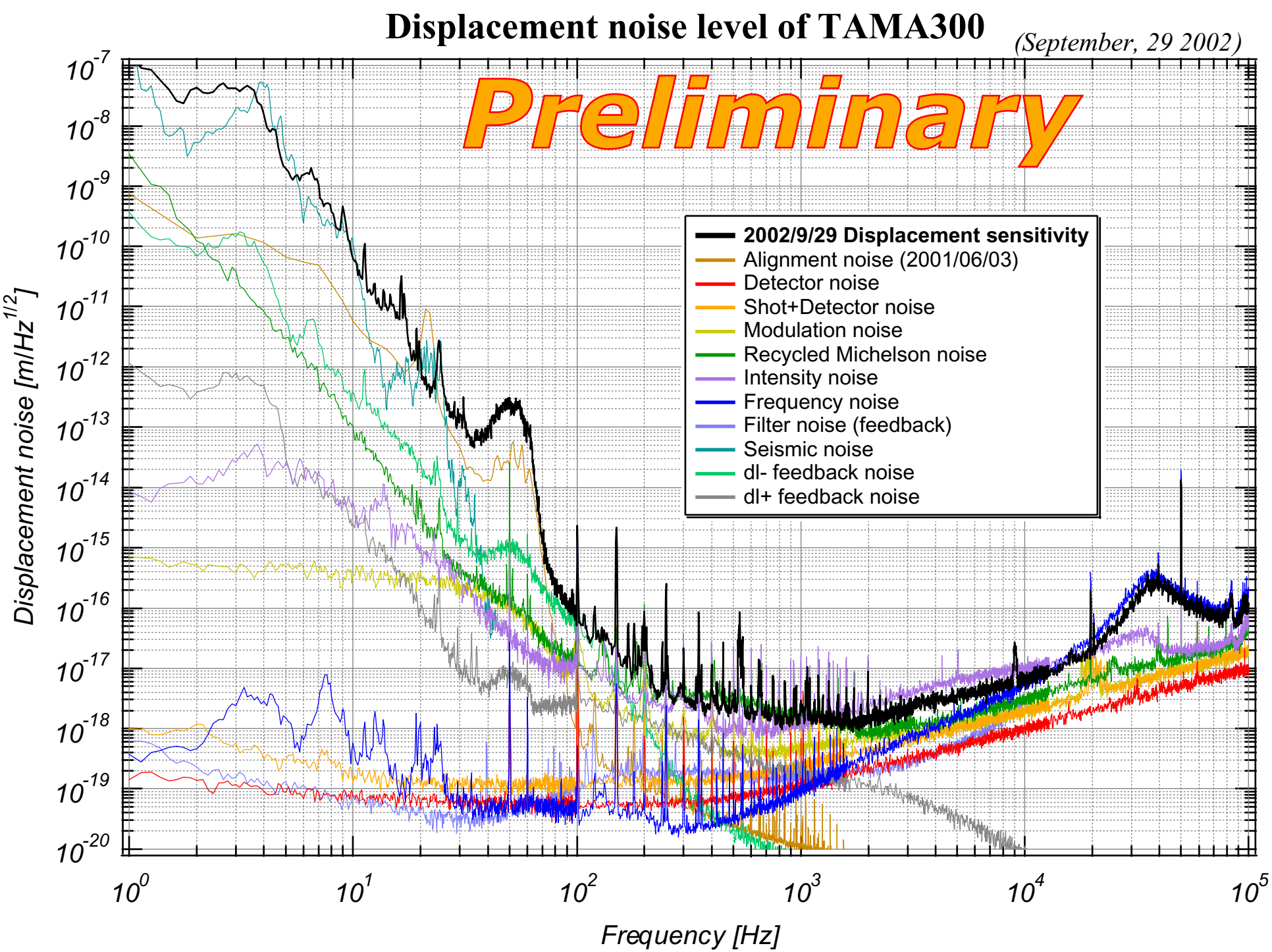
- **Observable distance with SNR=10**
  - **using matched filtering**



Estimation of noise contributions

- **Noise estimation based on signal injection**

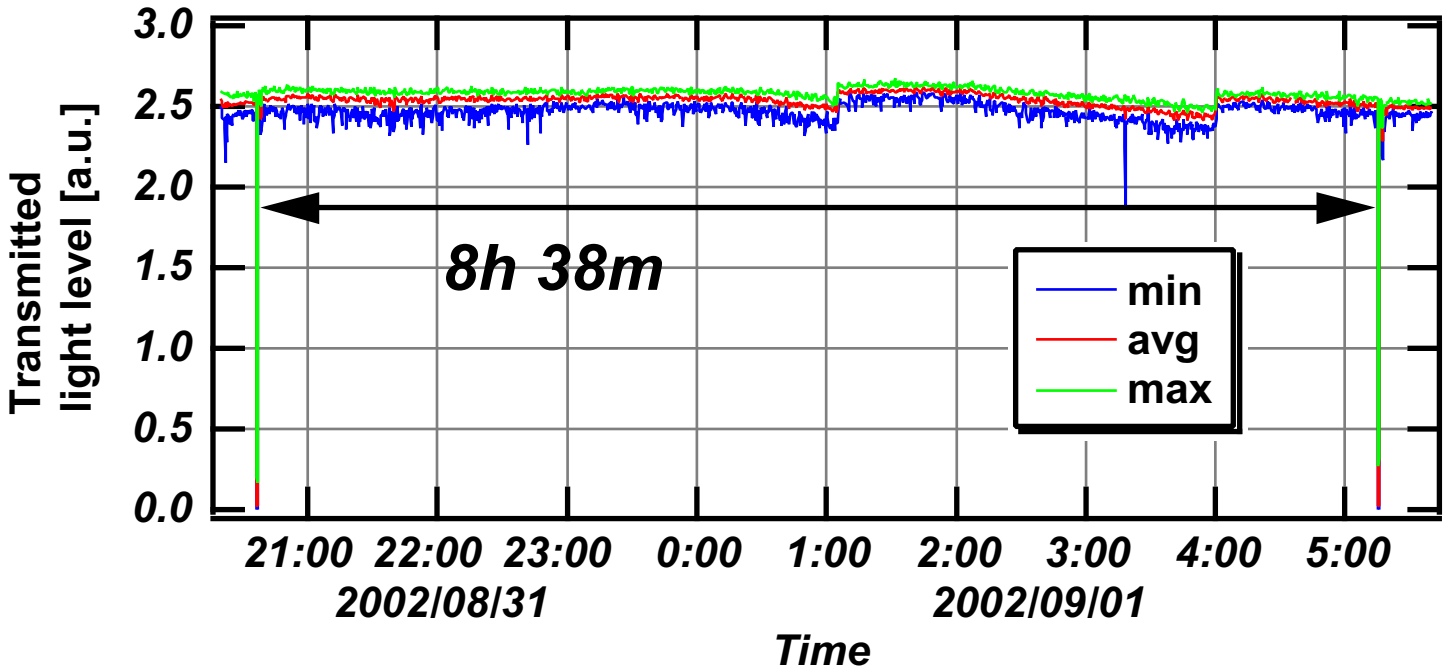



Displacement noise level of TAMA300
(September, 29 2002)
Preliminary
2002/9/29 Displacement sensitivity
Alignment noise (2001/06/03)
Detector noise
Shot+Detector noise
Modulation noise
Recycled Michelson noise
Intensity noise
Frequency noise
Filter noise (feedback)
Seismic noise
dl- feedback noise
dl+ feedback noise
Displacement noise [m/Hz^1/2]
Frequency [Hz]

Stability

- **Recycling also increases complication**
  - **of the system**

Internal power becomes sensitive to mirror motions



Longest continuous operation

- with power recycling: 8h 38m
- (without power recycling: 24h 50m)

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Data Taking 7

Period：2002/08/31~2002/09/02（32 hours）

->First observation run after installing power recycling mirror.

LIGO S1（2002/08/23~09/02）

LIGO (USA, Hanford: 4km, 2km, Livingstom: 4km)

GEO (Germany, Hannover: 600m)

->5 detectors were operated with comparable sensitivity.

Data Taking 7

Period：2002/08/31~2002/09/02（32 hours）

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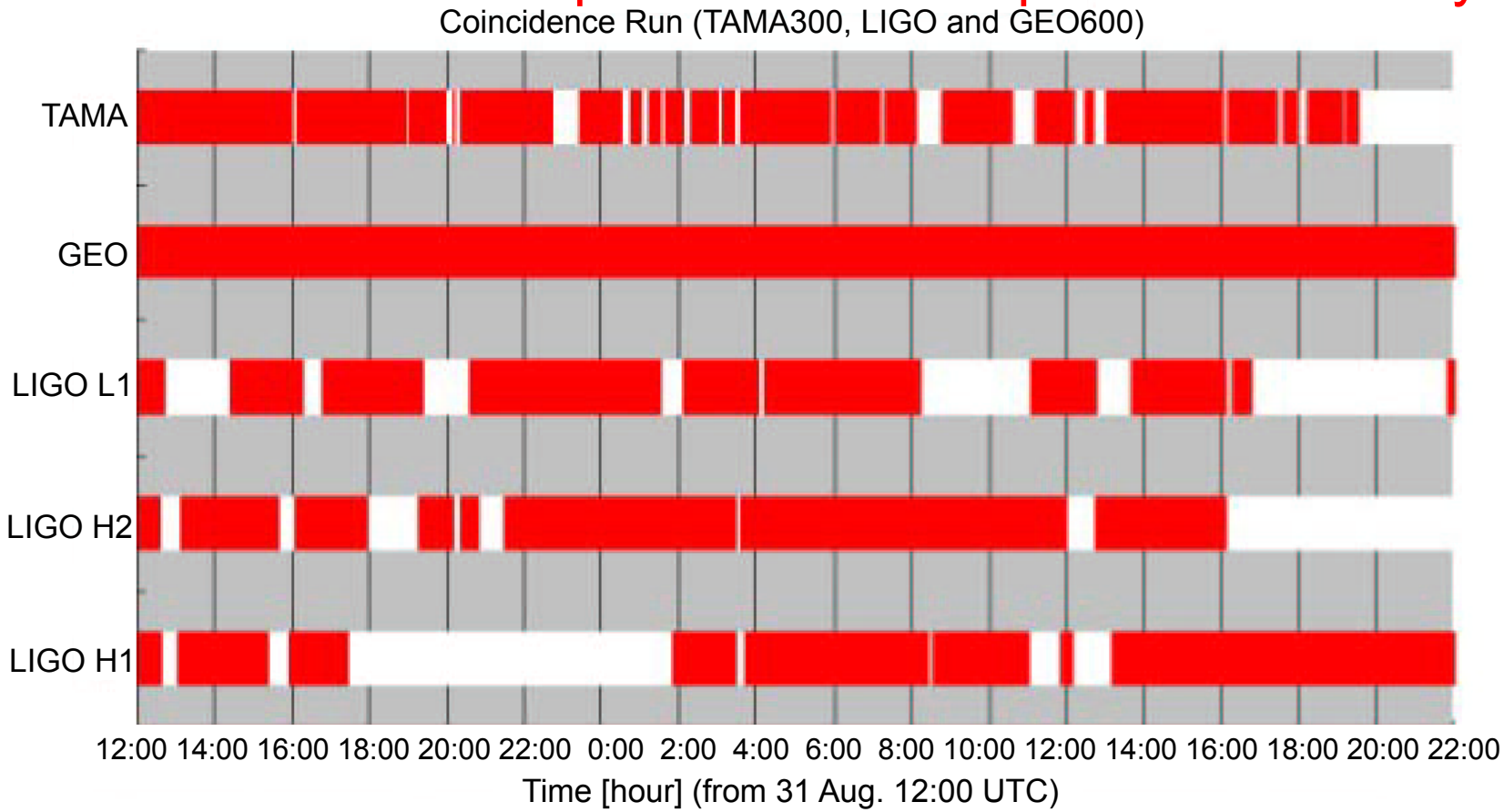
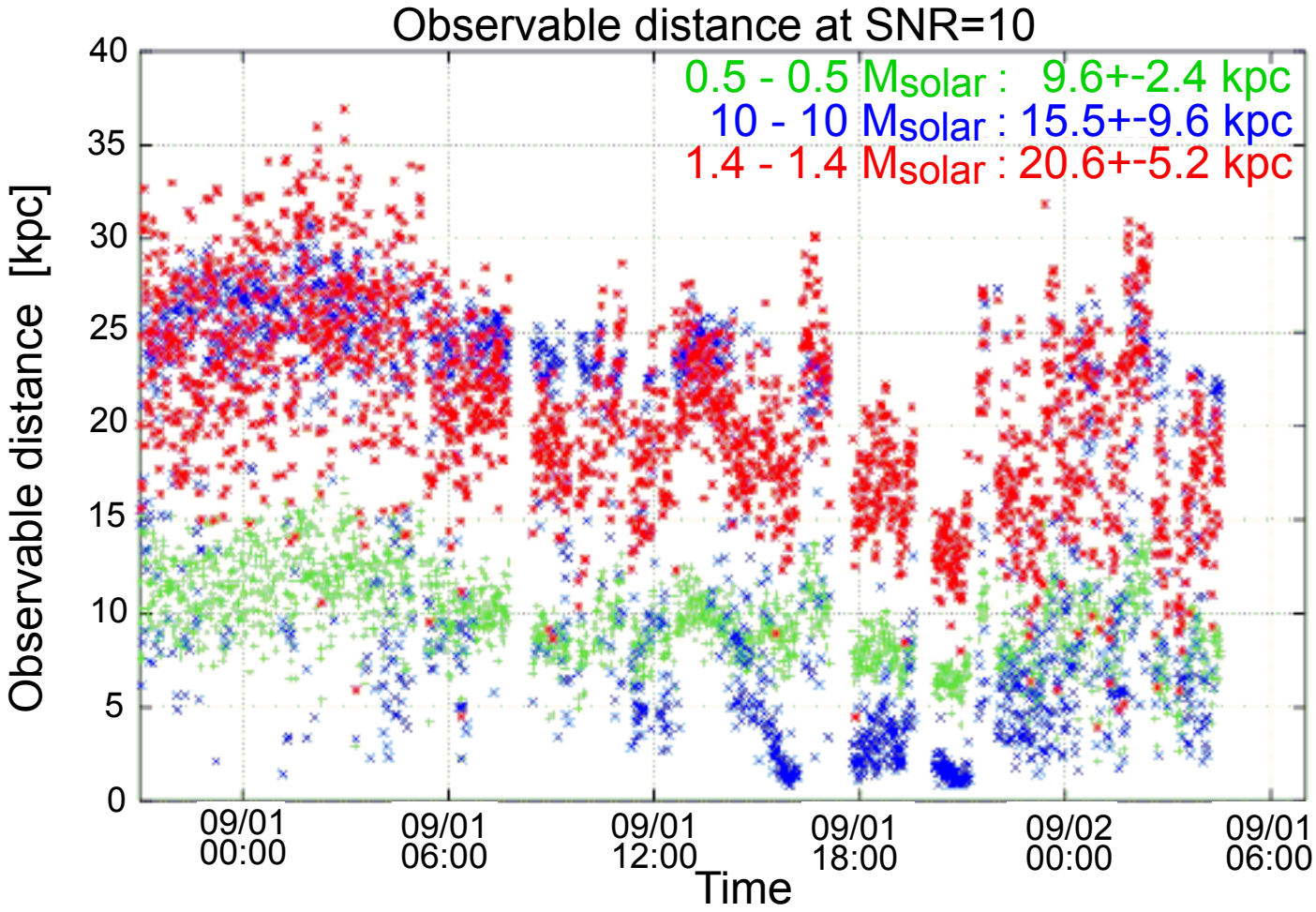


Common lock of 5 detectors: 9 hours 50 min.

Longest common lock stretch: 2 hours 24 min.

Results of Data taking 7

Period：2002/08/31~2002/09/02（32 hours）



Total observation time: 24 hours 34 min. (Duty cycle: 76.7%)

Best sensitivity: h = 3.3 x 10^{-21} /sqrtHz @1kHz

Longest locking stretch: 8 hours 38 min.

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  - ->Continuous locking: 8 hours 38 min.

Data taking 7 (2002/08/31~2002/09/02)

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  - ->Total observation time: 24 hours 34 min. (Duty cycle: 76.7%)

Coincidence run with LIGO and GEO

- 5 detectors were operated with comparable sensitivity.
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Future plan

Continue to improve the detector performance

Coincidence observation with LIGO and GEO
(2003/02/14~2003/04/14)

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