Stabilized Laser for TAMA300

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and TAMA Collaboration

OUTLINE

1. Introduction

   Requirements for the light source;
   Power, Beam Quality, Laser Stability

2. 10-m Ring-type Mode Cleaner with 10-W Injection-Locked Laser

   Relative Frequency Noise, Excess Noise

3. Frequency Stabilization

   Multistage Stabilization, δL_+ Error Signal

4. Intensity Stabilization

   Intensity Noise after Mode Clenaer

5. Summary

Requirement of Light Source for TAMA300

Goal

Strain Sensitivity

$\tilde{h}=2\times10^{-22}[1/Hz^{1/2}]$ (Phase2)
with Power Recycring

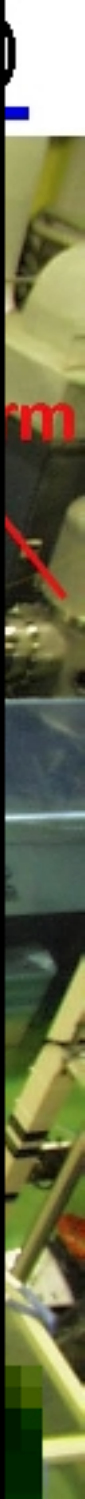
$\tilde{h}=2\times10^{-21}[1/Hz^{1/2}]$ (Phase1)
without Power Recycring

Laser Power	10W	
Beam Quality	Single Frequency, TEM_{00}, Linear Polarization	
Laser Stabilities	Phase1	Phase2
Frequency Noise $\delta\nu$ [Hz/sqrtHz]	5×10^{-6} (CMRR 40dB)	5×10^{-7}
Intensity Noise $\delta I/I$ [1/sqrtHz]	1×10^{-8} ($dL_{rms}=5\times10^{-11}$ m)	1×10^{-9}(?)

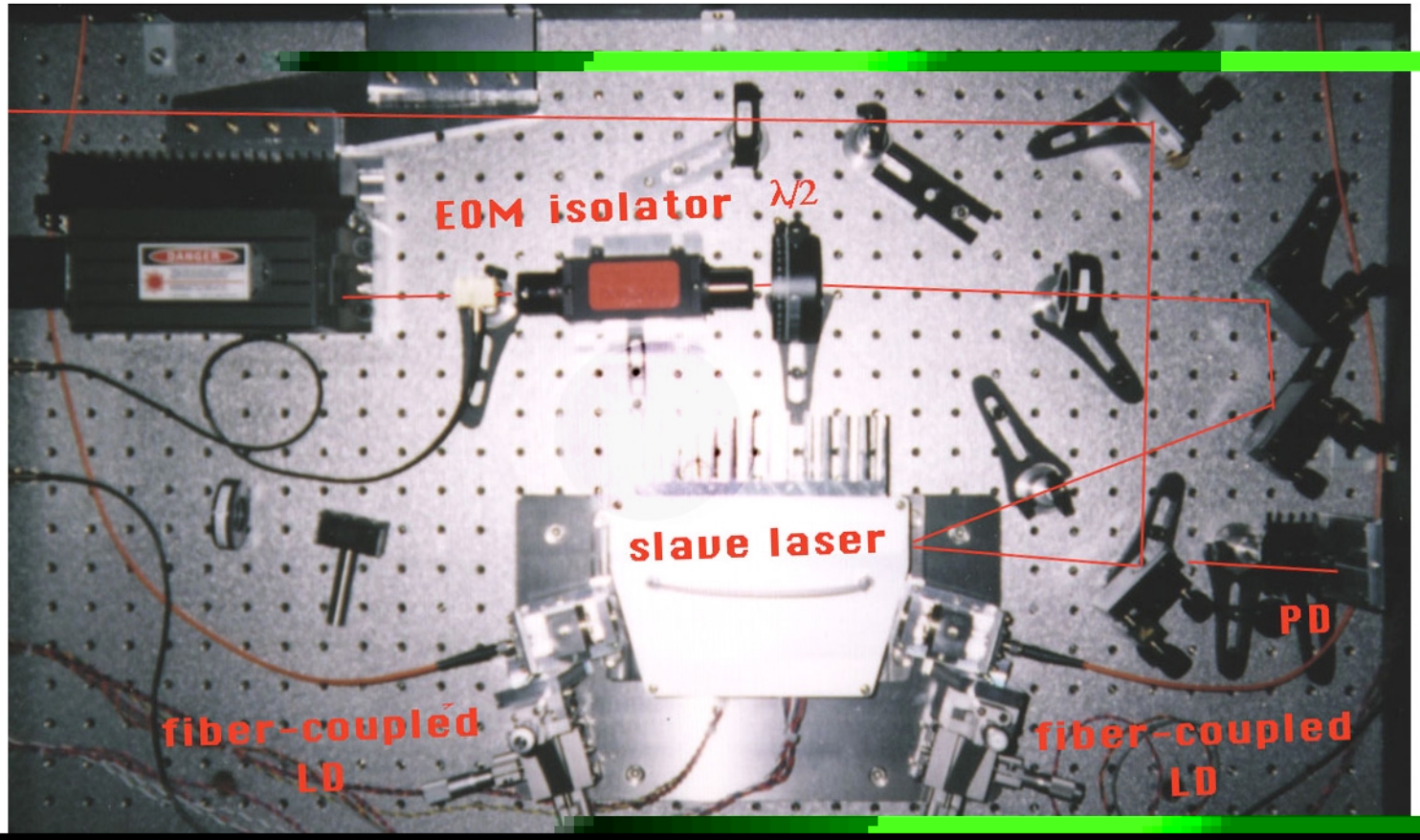
Solution

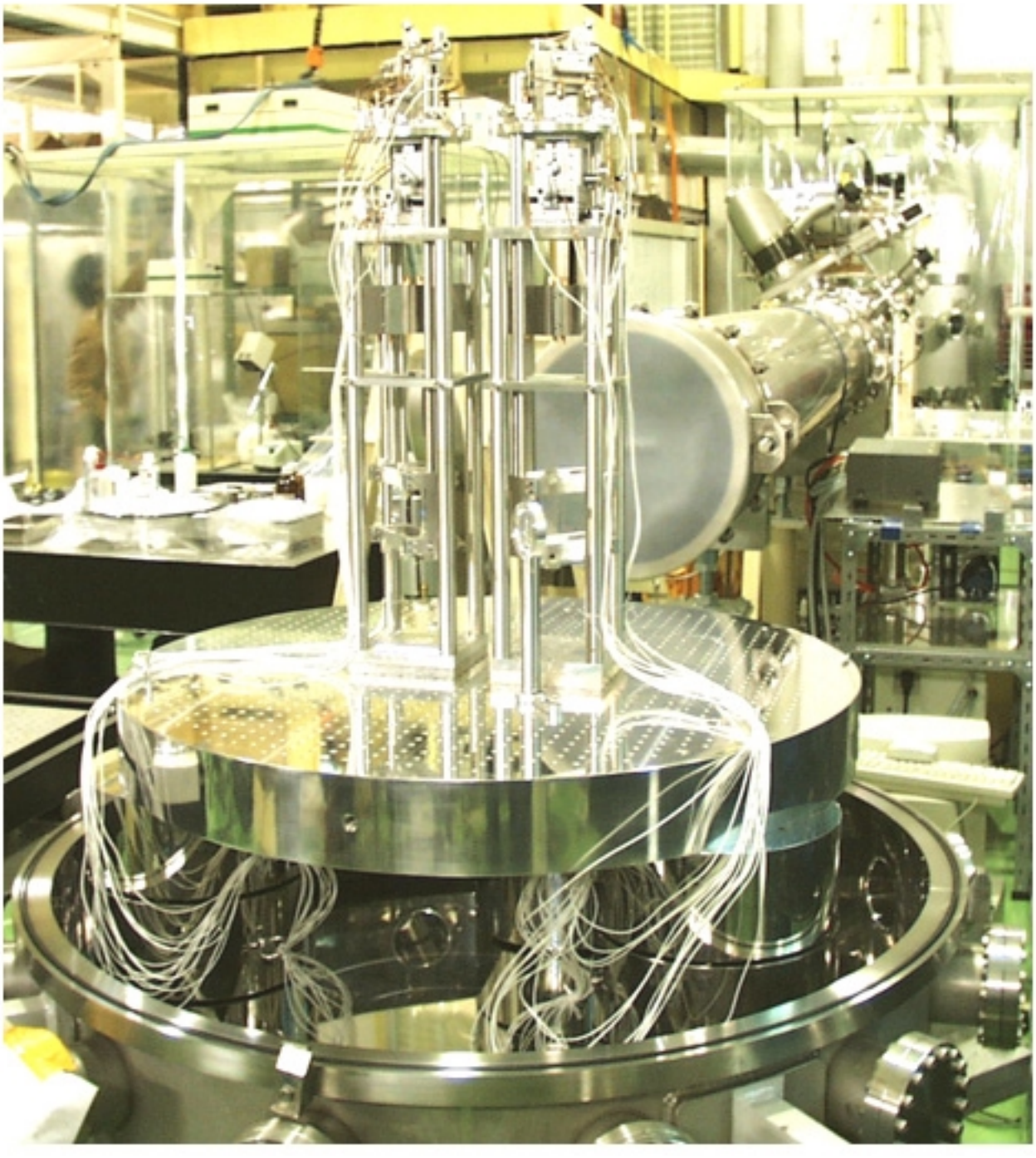
10-W Injection-Locked Nd:YAG Laser
and
10-m Ring-type Mode Cleaner

Bird's-eye view of TAMA300

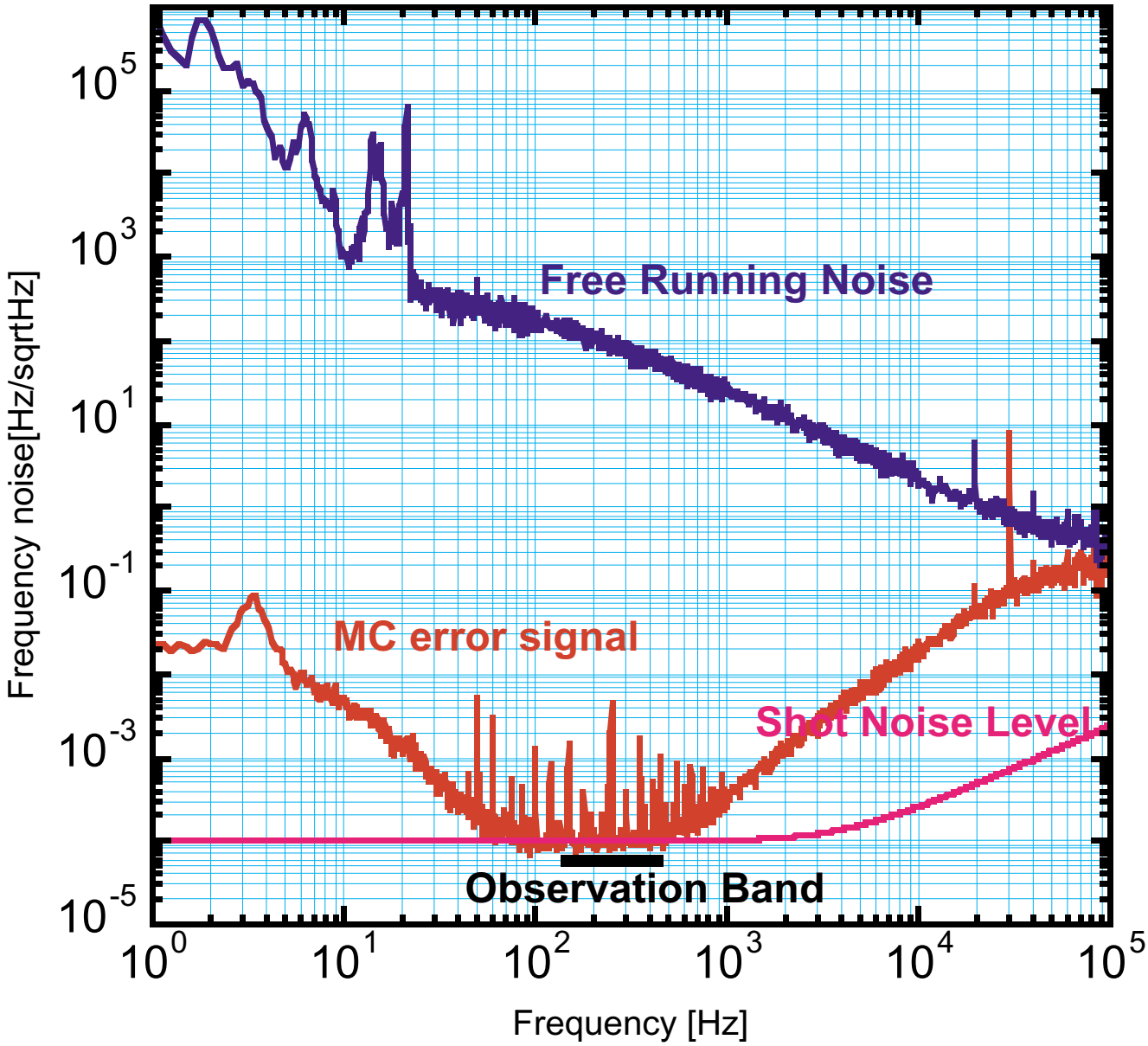


10-W Injection-Locked LD-Pumped Nd:YAG Laser





MC Error Signal



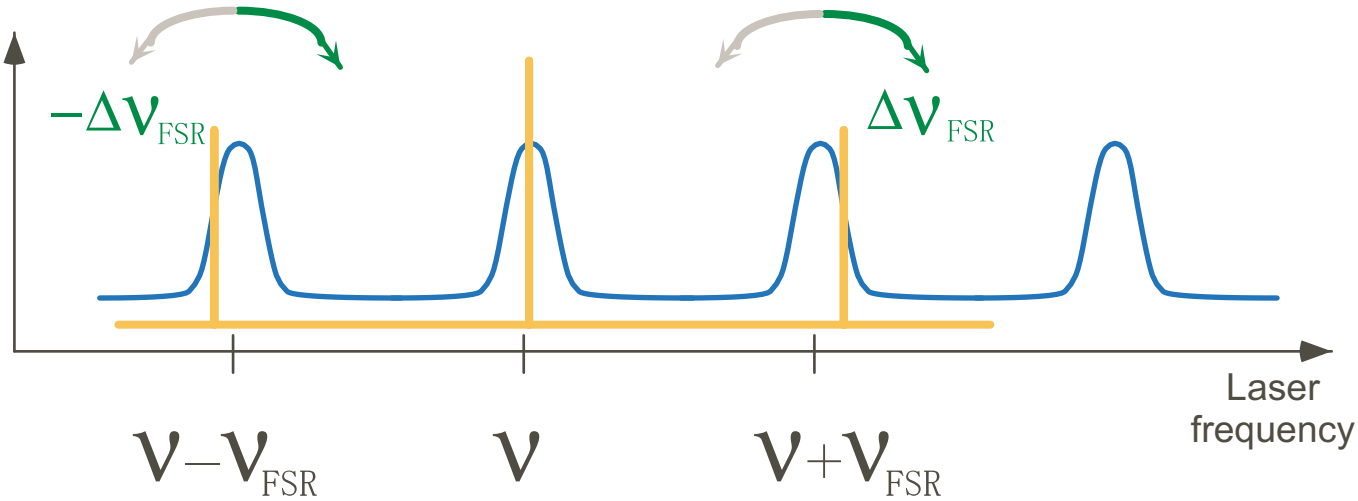
☺ Stabilized frequency noise level is 1×10^{-4}[Hz/sqrtHz].

☺ Shot noise level is calculated to be 1×10^{-4}[Hz/sqrtHz].

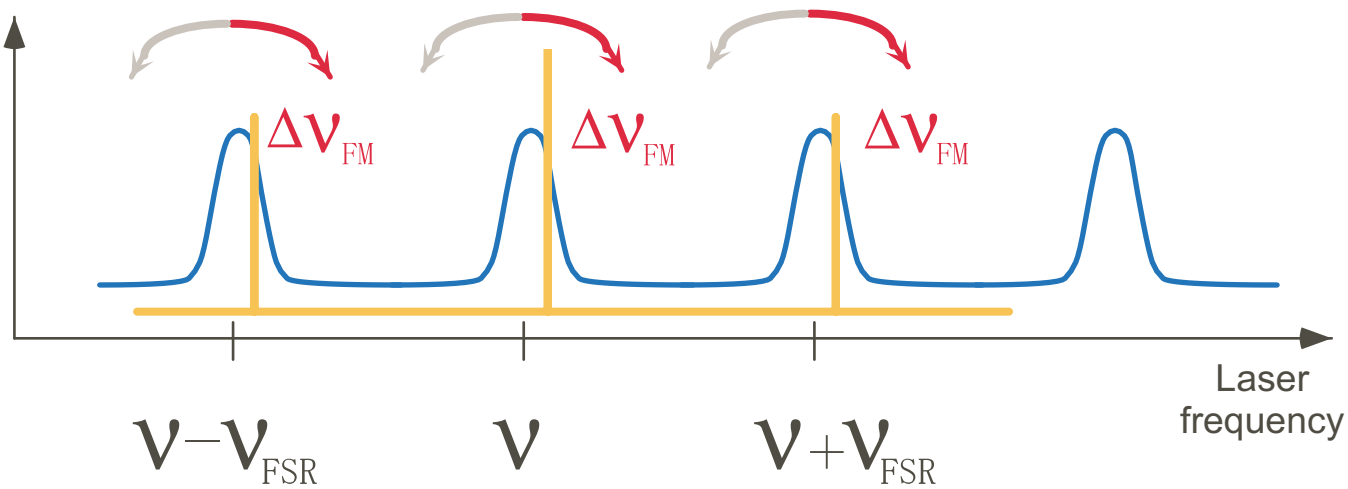
Mechanism of Excess Noise (FM-AM Conversion Noise)

Difference between the FSR and modulation frequency.

$$\Delta\nu_{FSR} = \nu_m - \nu_{FSR}$$



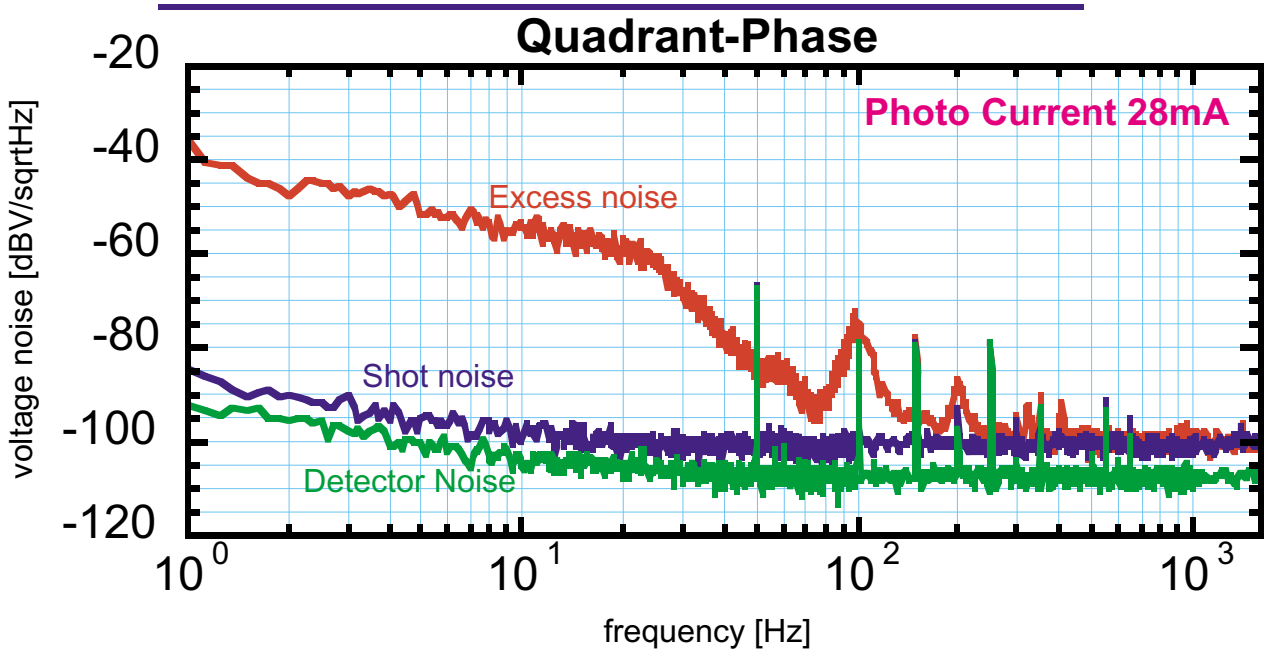
FM noise of laser and resonat point of cavity

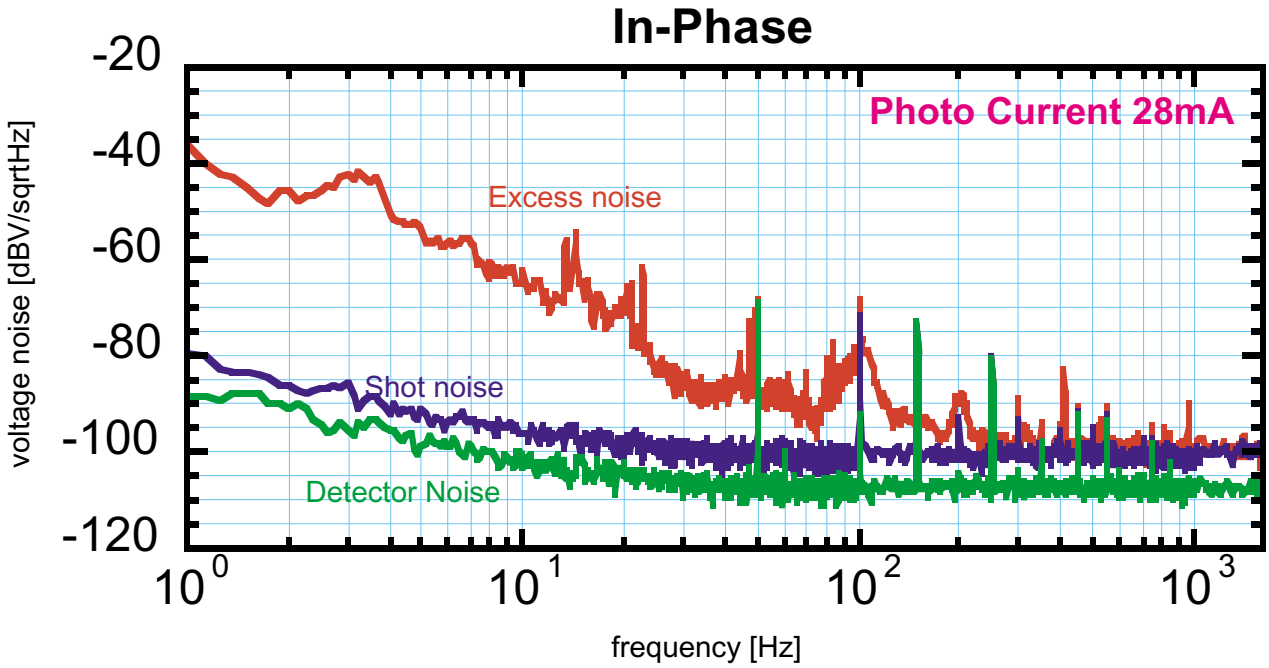


Quadra-phase $$-4m\,F^2 \frac{\Delta\nu_{FM}}{\nu_{FSR}} \frac{\Delta\nu_{FSR}}{\nu_{FSR}}$$

$$F = \frac{c}{2L}$$

Excess Noise Spectrum of 10-W Laser





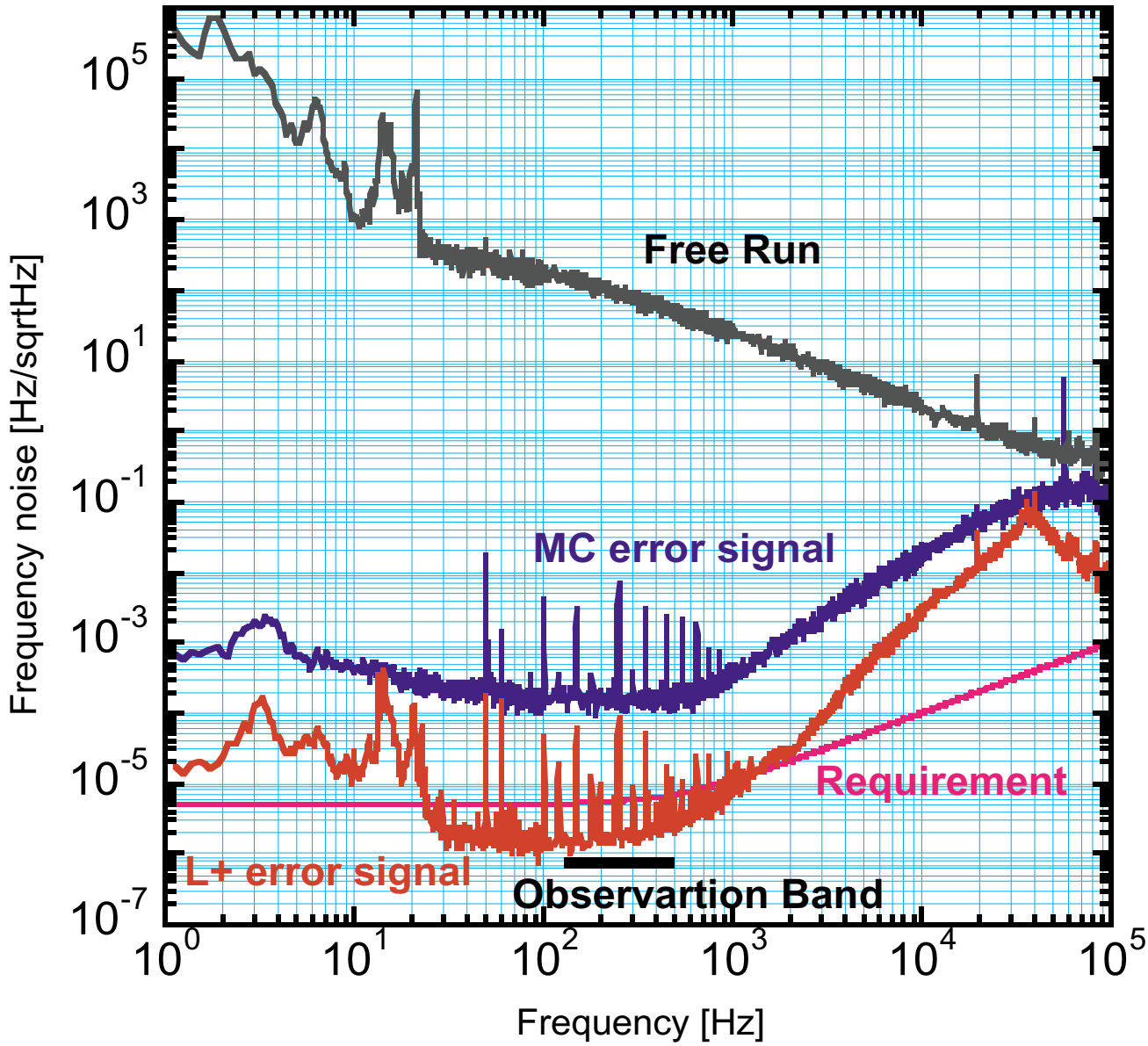
☺ Photo Current 28mA
(Requirement 30mA; We assume P=3W, C=98%.)

☺ Unity gain frequency of sideband transamissin servo is about 7Hz.

☺ Excess noise is less than shot noise above 250Hz.

😐 Low frequency Noise consists of beam pointing noise and unknown noise.

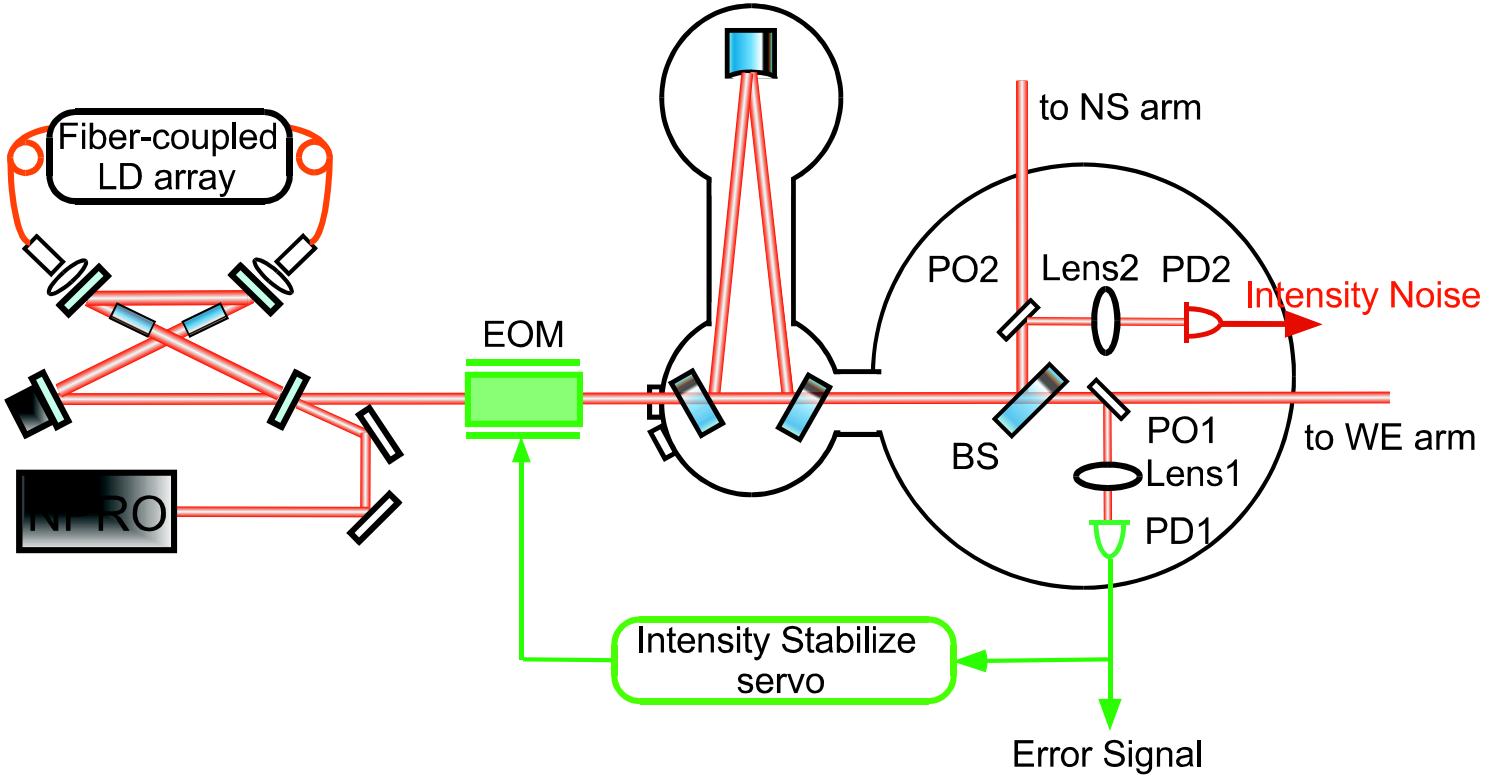
dL_+ Error Signal

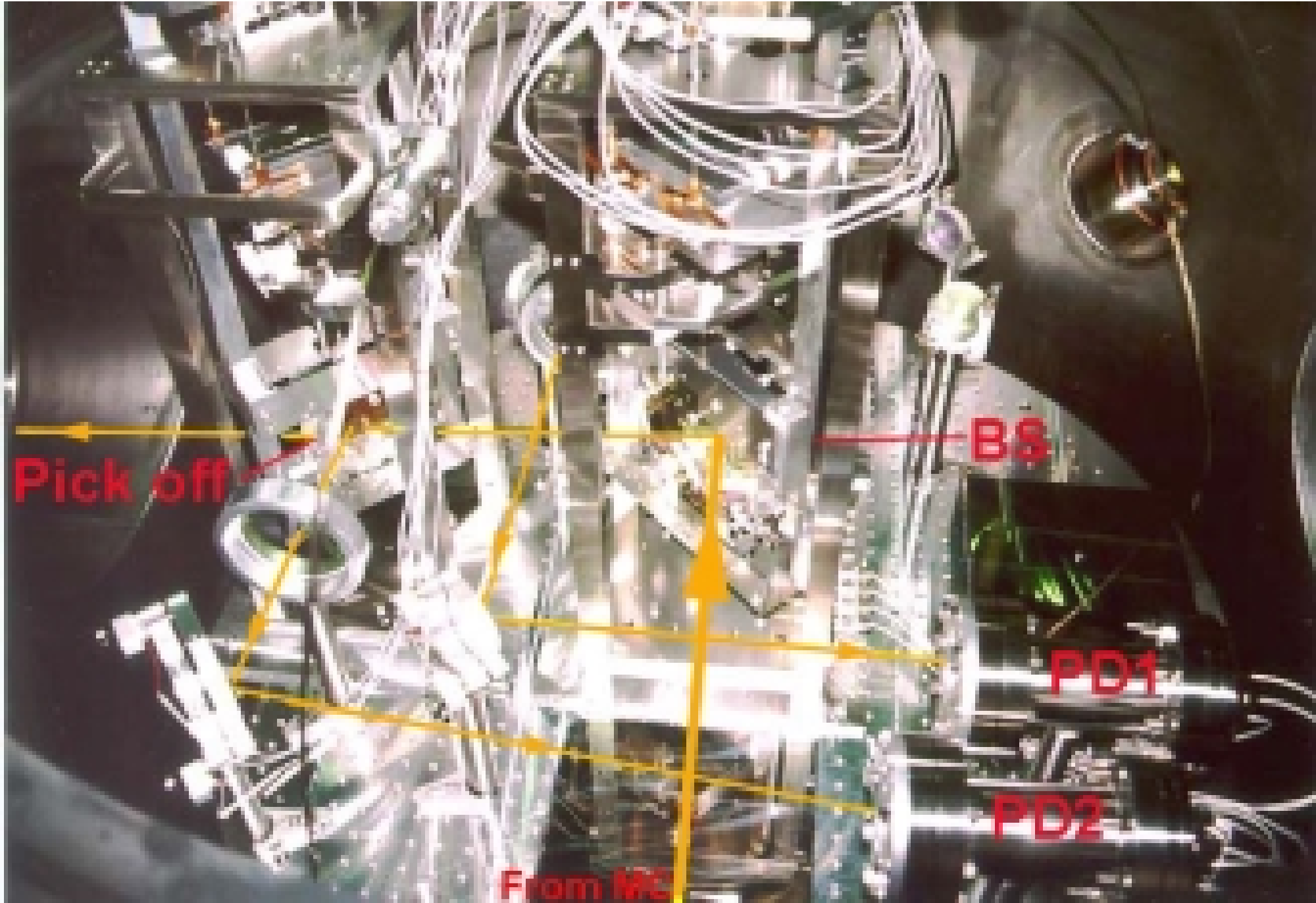


☺ L_+ error signal is 1.3×10^{-6}[Hz/Hz$^{1/2}$].

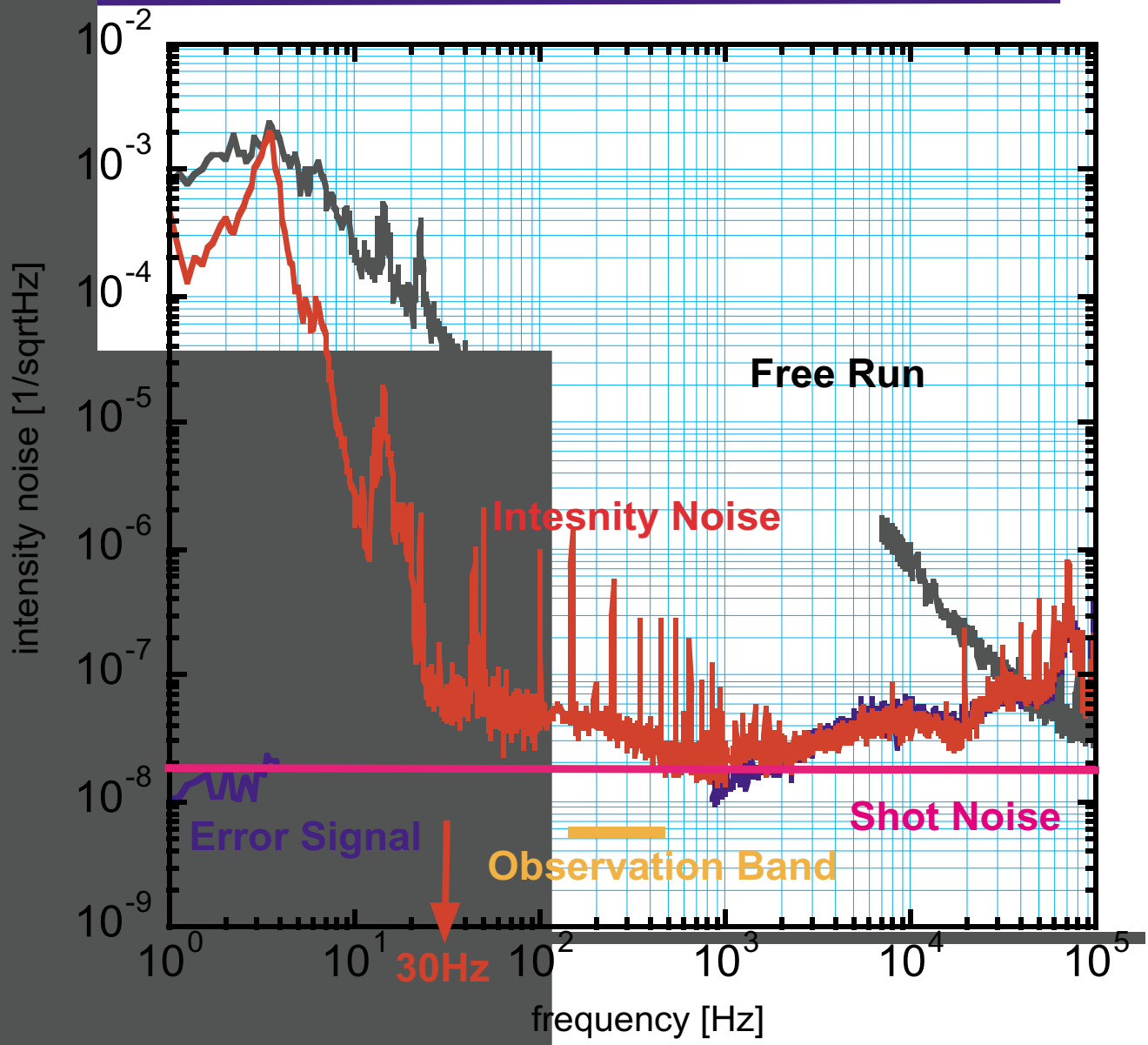
☺ **Requirement of 5×10^{-6}[Hz/Hz$^{1/2}$] is satisfied.**

Experimental Setup for Intensity Stabilization




Pick off
BS
PD1
PD2
From MC

Intensity Noise Spectrum after Mode Cleaner



used in BS vacuum chamber.

10^{-8}[1/sqrtHz].

ntensity stabilization servo

ty noise equal to error signal.

light noise
luctuation noise is limiting.

SUMMARY

1. Excess (FM-AM conversion) noise is suppressed less than shot noise of photocurrent 28mA.

   (Requirement: photocurrent 30mA)

2. Requirement of Laser Frequency Noise is Satisfied.

   ☺ Stabilized frequency noise level is 1×10^{-6}[Hz/Hz$^{1/2}$].

   (Requirement is 5×10^{-6}[Hz/Hz$^{1/2}$].)

   ☺ Continuous locking time is more than 7 hours.

3. We tried to detect the sample light for intensity stabilization in vacuum.

   😐 Stabilized intensity noise level is 3×10^{-8}[1/Hz$^{1/2}$].

   (Requirement is 1×10^{-8}[1/Hz$^{1/2}$].)