Final Design and Implementation of the KAGRA green lock system

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1 Overview

1.1 Overview of this document

This document summarizes the design and current implementation of the green lock (GRE) system or ALS (Arm Length Stabilization) system as a snapshot as of April 2021. For historical reasons, we refer this particular system either ALS system or green lock system.

1.2 Scope of this document

The scope of this document covers the following items.

- Design concept and associated considerations
- Final design and actual implementation
- Lessons learned

The performance of the implemented system is not described in this document. Those who are interested in the performance are encouraged to read [1, 2] and references therein.

2 Related documents and design history

2.1 Related documents

[1] Y. Enmoto *et al.,* journal paper in preparation (2019)

[2] K. Yokogawa, “Arm length stabilization system in KAGRA,” (in Japanese) master thesis, Univ. of Toyama (2019) Link to JGW-P1909919

[3] K. Yokoagaw and Y. Moriwaki, “Material for the review about green laser (2018.Mar.28),’ JGW-T180103-v3 (2018 Link to JGW-T180103

[4] K. Doi *et al.,* “ALS meeting material (2017.Nov.13),” JGW-E1707416-v1 (2017) Link to JGW-E1707416

[5] Y. Michimura, “Arm length stabilization conceptual design,” JGW-T1605353-v12 (2016)
JGW-T1605353

[6] D. Tatsumi *et al.,* “Servo designs for green lock, ” in Japanese, JGW-T1200788-v1 (2011)
JGW-T1200877

[7] K. Izumi, “Landing point for the messenger wire for pulling the GRE fibers,” (2018)
JGW-G1808535-v1

2.2 Brief design history

The conceptual design was initiated in 2011 by Tatsumi [6] with input from K. Arai. Several main features were already introduced, such as the use of Prometheus lasers, injection of the green light from the corner volume and the use of an AOM to lock green light to an arm cavity. Further study had been carried out at the University of Toyama, including experimental studies, fiber selection and circuit designs.

Later in 2017, the team proceeded with the implementation designs as well as procurement where the design of the optical layouts and hardware parts began being consolidated. In August 2017 and March, 2018, the team underwent review processes where the installation route of the fibers and the fiber selection were identified as main concerns.

3 Conceptual Deisgns

3.1 Role of the green lock system

3.2 Requirements

The ALS system is

3.3 Difference in comparison to LIGO

4 Final design and Implementation

4.1 Test mass coatings

The coatings of the test masses are designed such that high reflectivity is achieved at both 532 and 1064 nm. The specification calls for the values shown in table **??**

4.2 Lasers

The two lasers are both *Prometheus-532-100-CP* from Coherent Inc. The output power for the 532 nm light is 100 mW.

The lasers have to be able to produce a stable second harmonic generation of the 1064 nm light. In order not to use significant amount of the optical power out of the main laser, we chose to use independent lasers which emit 1064 nm laser light at the cost of introducing phase-locked loop systems.

4.3 Fibers

4.3.1 Specifications

Two kinds of fiber bundles are laid. The one for 532 nm and the other for 1064 nm. Although the current design does not use the 1064 nm, we took this opportunity to

4.3.2 Implementation

4.4 Fiber route

The routing external to the PSL booth was proposed in this document [7].

4.5 Voltage controlled oscillator

4.6 Phase Frequency discriminator

4.7 AOM

4.8 EOM

4.9 Mirror holders

4.10 Small optics

4.11 Photodetectors

4.12 Phase-Frequency Discriminator

4.13 Picomotors

4.14 Realtime digital system

5 Lessons learned

- Fiber vibration noise
- AC100V power supply
- VCO offset