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33rd KAGRA Face-to-Face Meeting Aug 2024

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Future Strategy for KAGRA

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(Moved from Caltech in April 2024)

Future Strategy Committee

- FSC's goal is (i) to make a suggestion of a concrete plan for KAGRA+ and beyond, and (ii) to recommend technologies that are to be implemented to KAGRA
  https://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC/FSC
- Chairs changed in May 2024

  Masaki Ando (Chair)
  Sadakazu Haino (co-chair)
  Somiya Kentaro (co-chair)

  Yuta Michimura (Chair)
  Sadakazu Haino (co-chair)
  Somiya Kentaro (co-chair)
  Atsushi Nishizawa (co-chair)
- White paper writing team (chaired by S. Haino) is dissolved, but now whole FSC will take care
- Project R&D Committee (PRDC; chaired by K. Somiya) is still managed by FSC

Welcome to join FSC

- We welcome anyone interested to join FSC
  Just email me at michimura@resceu.s.u-tokyo.ac.jp
- Current members:

Masaki Ando
Rishabh Bajpai
Hong-Bo Jin
Ray-Kuang Lee
Matteo Leonardi
Ettore Majorana
Quynh Lan Nguyen
Micheal Page
Surojit Saha
Shalika Singh
Lijing Shao
Haoyu Wang
Kazuhiro Yamamoto
Takaaki Yokozawa

Instrument Science White Paper

- 2019 version (JGW-M1909590) was summarized as following papers, but we failed to update since
  Y. Michimura+, PRD 102, 022008 (2020) (instrument part)
  KAGRA Collab., PTEP 2021, 05A103 (2021) (science part)
- 2024 is a year to turn over a new leaf
- Overleaf link:
  https://www.overleaf.com/6619811679sbdjbqnrpxdm#bb456b
- We will focus on instrument, and plan to update yearly by Dec F2F
- Science part is updated yearly as LVK Observational Science White Paper

White Paper Structure

- Executive Summary (to be written by Dec 2024)
  - Summary of feasibility and relevance for each tech.
  - Summary of good upgrade candidates
- Introduction (written)
  - Background and the scope
- Survey of Current Technologies (to be written by Oct 2024)
  - Review of technologies relevant to KAGRA upgrade
  - Authors are (tentatively) assigned to most of items
  - Any ideas on **new technologies** missing and **volunteers to write** are highly welcomed
- Possible Upgrade Plans (to be written by Dec 2024)
  - Example upgrade plans that can be achieved by combining these technologies

List of Technologies for Survey

Light sources
- High power laser
- Use of different wavelengths
- Multi-carrier injection
- Frequency-independent squeezing
- Frequency-dependent squeezing

Test masses and coatings
- Birefringence reduction
- Large beam
- Large sapphire mass
- Use of different materials for test mass
- 120K Silicon
- Composite mass
- Parametric instability mitigation
- Thermal compensation system
- Use of different materials for coatings
- Non-TEM00 beam
- Non-cylindrical mass
- Khalili cavity
- Gratings

Cryogenic suspensions
- Sapphire blade spring improvement
- Use of ribbons
- Use of long fibers
- High conductivity fibers

Other optics
- Large beamsplitter
- Low-loss Faraday isolator
- Low-loss OMC
- Low-loss PD

Calibration
- Multi-color calibration

Low frequency noise reduction systems
- Seismic noise reduction
- Suspension point interferometer
- Newtonian noise cancellation
- Environmental magnetic noise sensors
- Charge noise reduction
- Instrumental baffles

Advanced classical control systems
- Phase camera
- Machine learning
- Laser induced desorption
- Quantum locking

Quantum control systems
- Homodyne readout
- Variational readout
- Optical spring
- Long-SRC
- Quantum expander
- Intracavity OPA
- White-light cavity
- PT symmetry
- Kerr amplification
- EPR squeezing
- Quantum teleportation
- Negative inertia

Alternative topologies
- Speed-meter
- Acceleration-meter
- Detuned speed-meter
- Delay line
- Local readout
- Single-photon detector
- Displacement noise free interferometer
- L resonator

Example of Survey Text

3.8.4 Long-SRC

Version history: First version in 2019 by K. Somiya; Updated in July 2024 by K. Somiya

Feasibility: 3 (Demonstrated by K. Komori in 2024)

A delay line in the signal-recycling cavity (SRC) generates a phase shift on the signal sideband and the signal response improves at around a certain frequency.

Example spectra are shown in Fig. 1. With $\ell = 100\,\mathrm{m}$, the shot noise curve is different from the one with $\ell = 10\,\mathrm{m}$, showing a gentle dip at around 3 kHz. With $\ell = 300\,\mathrm{m}$, the dip frequency comes lower to 2 kHz. Since there is no asymmetry in the upper and lower signal sidebands, the squeezing angle does not rotate at around the dip frequency. Thus, unlike the squeezing of a detuned interferometer, a simple frequency independent squeezing is good enough to obtain a gain in broadband frequencies around the dip frequency.

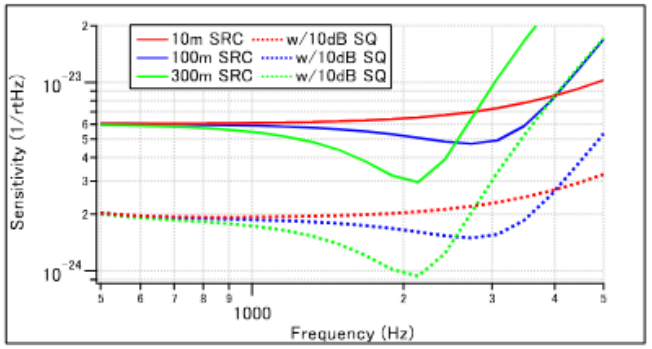


Figure 1: Sensitivity curve of KAGRA with a long signal recycling cavity and frequency-independent squeezing.

This is an attractive option for KAGRA+. One question is how to build a 300 m recycling cavity in the current facility. Actually the signal recycling cavity length in KAGRA is as long as 66 m for extending the cavity with two folding mirrors (SR2/SR3). We need to, however, use some part of the arm cavity vacuums to extend it to 300 m.

References:

- H. Miao *et al.*, Class. Quantum Grav. **31**, 165010 (2014).

Name of the technology

Version history to keep track of when/who updated the text

Feasibility score and short justification
0: Idea phase
1: Theoretically well studied
2: Demonstration experiment on going
3: Demonstrated with a table-top experiment
4: Demonstrated with a prototype experiment (e.g. TAMA)
5: Demonstrated with one of LVK detectors

Copy text from previous version (2019) and updated part will be in red. Summarize in 3-4 paragraphs.

Plot if you have (usually not necessary)

References

White Paper Writing Workshop

- Dates: October 2-3, 2024
  Venue: Hiroshima University
  https://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC/FSC/WWW2024
- Authors of white paper are invited





FWG 4th Open Meeting

- Future Working Group (FWG) is open to anyone interested in new ideas
  https://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/KSC/FSC/FWG
- You can be a member just by sending an email to kagra-fwg-ctl@icrr.u-tokyo.ac.jp with "subscribe (YOUR NAME)" in the main body

- Planning to have a FWG 4th Open Meeting in Dec 2024, as a satellite meeting of F2F

Schedule

- **Oct 2-3, 2024**: White paper Writing Workshop
- **Dec 16-18, 2024**: KAGRA F2F
  - FWG 4th Open Meeting
  - Release of White Paper 2024
- **Feb-Apr 2026**: Call for Project R&D
  - White Paper will be used to evaluate
- **Apr-June 2025**: Application for KAKENHI grants
  - Hopefully the White Paper will be useful for applying to Tokusui, Kiban S etc., with more common agreement among collaborators

- **Dec 2025**: Release of White Paper 2025 …

Summary

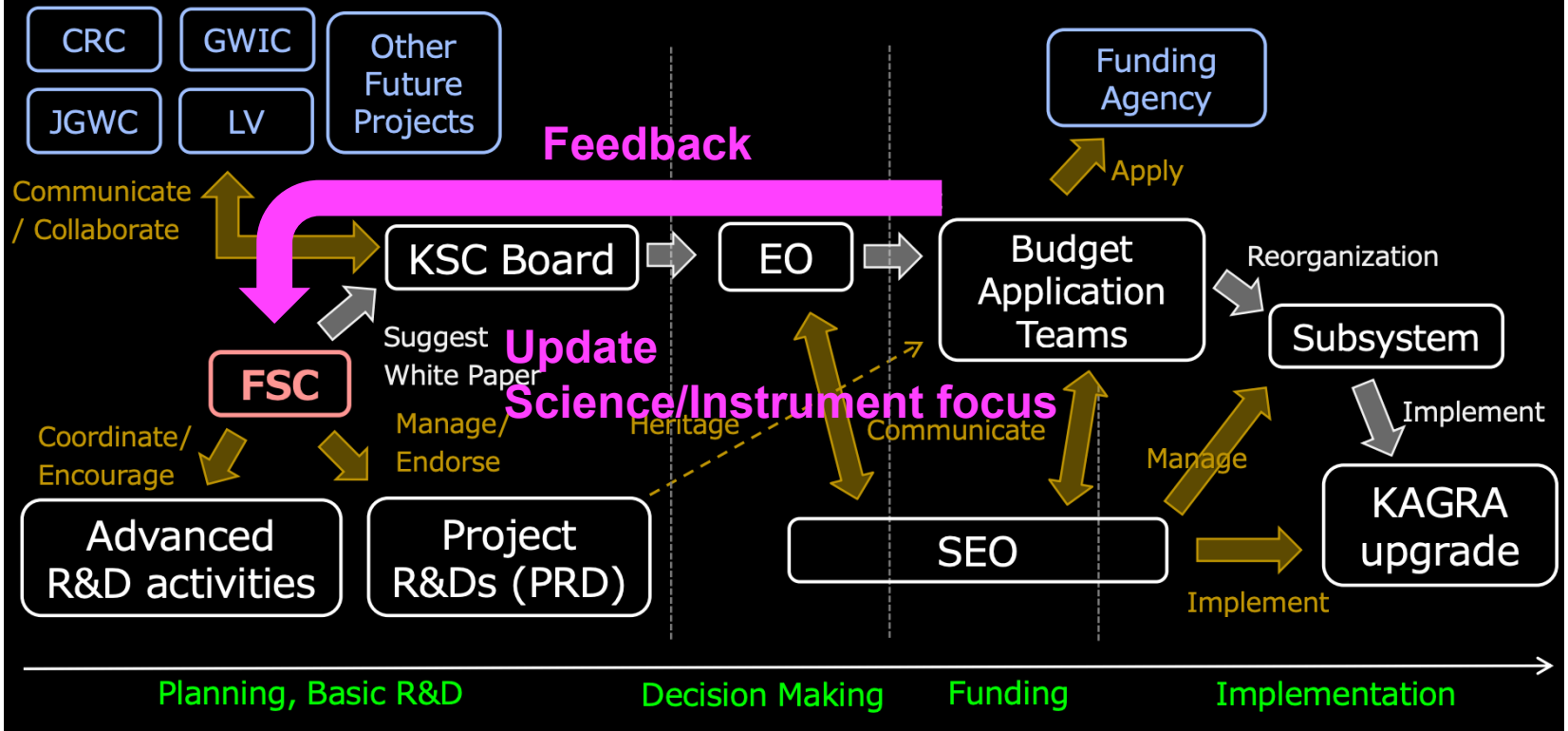
- KAGRA Instrument Science White Paper 2024 is being written
- Any comments and volunteers are welcomed
- Welcome to join FSC or FWG

Additional Slides

Scope of FSC

- White paper writing
- Organizing Project R&D and Advanced R&D
- Coordination of Future Working Group Open Meetings
- Responsible for future discussions within KAGRA
- Responsible for future discussions in JGWC, CRC meetings etc.
- Responsible for discussions of 2.5-3Gs in LVK meetings, IGWN etc.

Conceptual Flow of KAGRA Upgrade



Original figure by Y. Michimura, Updated by M. Ando

New ideas
Stimulating new ideas

Commit to the Project
Implementation

Advanced R&D

White Paper

Project R&D

FWG Open Meeting