

A+ and AdV+ Selection Process for O5 Test Mass Coatings

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[LIGO-M2100135](#)

[VIR-0938A-21](#)

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REVISION HISTORY

<i>version</i>	<i>date</i>	<i>by</i>	<i>Source file</i>	<i>notes</i>
-v0	7/28/21	mez	https://docs.google.com/document/d/1EtlKVwPS4Soq2xDvT3XHCUW9ISuz9prQVDdFUBYINOs/edit#	Working draft (not in DCC)
-v1	8/2/21	mez	"	uploaded as -v1
-v2	8/3/21	mez	"	add virgo TDS link; revise panel
-v3	9/8/21	gb		Update presentation and report dates

Scope and context

R&D underway in multiple worldwide laboratories seeks a practical new coating material for LIGO and Virgo test masses in O5. This will afford reduced coating thermal noise (CTN), which currently limits midband detector sensitivity, without compromising optical performance. At least two promising candidates have emerged. From these A+ and AdV+ will select a common solution, in order to optimize network sensitivity for coincident observations in O5¹.

While continuing improvement is expected, industrial coaters must adopt and focus on a single formulation in time to scale the process to LIGO and Virgo aperture, and to refine it to a point where defect-free, uniform and predictable coatings are essentially routine. They must then coat production ITM and ETM optics for all three interferometers (12 mirrors plus spares and test articles), a time-consuming sequential process. To avoid delaying O5, these optics should be fully characterized and ready to commence installation immediately after the O4 observing run, planned to complete in late summer of 2023.

¹ Kagra will also participate in observations, but uses incompatible technology.

Based on prior coating pathfinder and production efforts for Initial and Advanced LIGO and Virgo, these steps are expected to require about 2 years. Therefore it is expedient to adopt a baseline coating prescription now.

To do this in the most transparent and accessible manner, we invite proposals from the major low-CTN coating R&D centers. We then ask an expert panel to evaluate these against A+ and AdV+ requirements, consider their technical and programmatic merits, and formulate a recommendation. A+ and AdV+ Project leadership will study this recommendation and issue a joint decision.

By nature, implementation of a novel process, even one strongly supported by research, carries risk. Additional breakthroughs are also possible, and O5 is only an intermediate performance horizon. Selecting the O5 baseline should not, by itself, form a reason to curtail R&D on alternatives and further improvements. Continued investigations are justified both as risk reduction, and as investments in subsequent upgrades. It is also likely that industrial pathfinding and production may redirect or seed new R&D.

Proposal invitation

Representatives of each coating R&D collaboration are invited to present (via teleconference) a summary of modeling projections and experimental results, at a date and time to be agreed.

An initial presentation of 40 minutes duration or less is requested from each group, with an additional 20 minutes reserved for questions and discussion.

A follow-up meeting may be requested by the evaluation panel, to be arranged as needed.

Presentations will be open to LVK membership; therefore no privileged or proprietary information should be disclosed.

Links should be furnished to a draft of the presentation slides and to all supporting publications and internal reports, at least 3 working days prior to the scheduled meeting.

Presentations

Each presentation is asked to address the following elements:

- Specific proposed design of the coating system, along with any variants or parametric choices that remain to be determined
- Projected CTN performance of the design in ITM and ETM multilayer stack configurations, and in overall displacement spectral density as deployed for A+/AdV+

- Projected conformance with other Advanced LIGO and Advanced Virgo core optic specifications, such as uniformity over aperture, scatter loss, absorption, defect density, etc. (see Appendix A below)
- Experimental evidence and modeling to support the above
- Similarities and differences of proposed process with respect to established core optic coatings, related, e.g., to manufacturability, coating chamber time, matching or repeatability, defect vulnerability, quality assurance, etc.
- Remaining risks and unknowns, presuming this technology is selected now
- Plan and timeline for addressing these risks and unknowns.

Evaluation

An expert panel will be appointed. Membership will be jointly agreed by A+ and AdV+ leadership, who will also join the panel *ex officio*. The panelists may convene in closed session before and after presentations as needed. They may request additional meetings, clarifications or data from the R&D teams or from LIGO and Virgo collaborations, in support of fulfilling their charge.

Evaluation Panel

The following panelists are proposed, subject to availability:

- Sheila Rowan, co-chair
- Helios Vocca, co-chair
- Peter Fritschel
- Laurent Pinard
- Raffaele Flaminio, AdV+ (ex-officio)
- GariLynn Billingsley, A+ (ex-officio)

Panel Charge

1. Evaluate and compare proposed coating solutions for projected CTN strain spectral density in AdV+/A+ deployment, and for expected optical conformance with LIGO and Virgo core optic requirements (Appendix A).
2. Consider the relative maturity and completeness of the experimental data, modeling and reference literature underpinning these projections.
3. Evaluate comparative readiness of each proposed solution for scaling to full aperture, and also for achieving the necessary uniformity, predictability, and quality to support production coating on ITM/ETM substrates.
4. Highlight any unproven performance requirements or other future risks associated with each approach, as well as the feasibility of addressing these risks in parallel with industrialization.

- Summarize your findings in a report addressed to AdV+ and A+ leadership. A consensus report is requested. Dissenting opinions will also be welcomed, if a panel consensus is not forthcoming.

Decision process timetable

Subject to member schedule constraints, we propose the following timeline. For reasons discussed above, all things being equal, we will prioritize meeting the announcement date and, where necessary, adjust durations to suit.

event	responsible	week	date (TBR)
Invite presentations	AdV/A+ leaders	-10	8/6
Convene panelists	Panel chair	-5	9/8
Proposal presentations	R&D teams	-4	9/14 and 9/17
Panel deliberation	Panel chair	-3 to -2	9/20 to 10/1
Deliver panel report	Panel chair	-1	10/8/21
Announce decision	AdV+/A+ leaders	0	10/15/21

Appendix A: A+ and AdV+ Coating Requirements

AdV+ and A+ coatings are expected to conform with aLIGO and Advanced Virgo ITM and ETM requirements ([E0900041](#), [E0900068](#), and [VIR-0128A-12](#)) *except in the following respects:*

- Coating material
- Coating thermal noise performance
- Coated aperture (AdV+ ETM only)

Where feasible, interferometer performance impacts of possible or expected deviations from these specifications should be estimated.

These requirements are preliminary. Final specifications will continue to evolve through the Pathfinder production development program.

References

- [VIR-0932A-21](#) AdV+ timeline
- [M1800270](#) A+ schedule
- [M1800262](#) LIGO Lab Project Schedule FY19-23
- [VIR-0128A-12](#) Advanced Virgo Technical Design Report
- [E0900041](#) Advanced LIGO ITM coating specification
- [E0900068](#) Advanced LIGO ETM coating specification