



Contribution ID: 127

Type: **Contributed Oral**

## Exponentially Enhanced Laser Coherence through Cascaded Cavities

*Tuesday 2 December 2025 18:00 (15 minutes)*

The pursuit of highly coherent light sources is fundamental to advancements in quantum metrology, sensing, and communication. Although the Schawlow-Townes limit, where coherence scales as the square of the number of photons in the laser cavity, has long defined the standard for laser coherence, recent work [1] established a more fundamental limit, the “Heisenberg limit”, where coherence scales as the fourth power of the photon number. This is achievable with specially engineered input-output relations.

We present a novel and more accessible architecture that exponentially surpasses the Heisenberg limit using only standard optical components. Our method involves cascading a series of standard subthreshold laser cavities, where the output of one cavity serves as the input of the next. We demonstrate analytically that a simple two-cavity cascade reproduces the Heisenberg scaling without requiring unconventional cavity designs.

In general, we show that for  $N$  cascaded cavities, coherence can scale exponentially with the total intracavity photon number. This is made possible by violating the assumption of ideal Glauber coherence statistics, upon which the Heisenberg limit is predicated. The cascaded system introduces correlations across multiple, distinct timescales corresponding to the linewidth of each cavity, allowing it to store significantly more phase information than a single cavity.

However, this exponential scaling is not without caveats. As we discuss within the paper, the practical implementation faces considerable challenges, including the utility of the resulting non-standard photon statistics and the demanding experimental conditions required. Our work therefore initiates an analysis of this fundamental trade-off, highlighting the path for future research into overcoming these limitations.

**References:** [1] Baker, Travis J., et al. “The Heisenberg limit for laser coherence.” *Nature Physics* 17.2 (2021): 179-183.\*

**Authors:** Dr PANTALEONI, Giacomo (Monash university); WISEMAN, Howard M. (Queensland Quantum and Advanced Technologies Research Institute (QUATRI)); Dr OSTROWSKI, Lucas; BERRY, Dominic

**Presenter:** Dr PANTALEONI, Giacomo (Monash university)

**Session Classification:** Quantum Science and Technology

**Track Classification:** Topical Groups: Quantum Science and Technology