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A superradiant laser with < 1 intracavity photon[1]

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We will describe a recently demonstrated laser-cooled Raman laser that operates deep into the superradiant or bad-cavity regime in which the gain medium (i.e. the atoms) acts as the primary reservoir of phase information [1]. The system operates with < 1 average intracavity photons and with an extremely small effective excited state decay linewidth < 1 Hz. This model system demonstrates key physics for future active optical clocks (similar to masers) that may achieve frequency linewidths approaching 1 mHz due to 3 to 5 orders of magnitude reduced sensitivity to thermal mirror noise. For scale, a 1 mHz linewidth laser would have a coherence length spanning the distance from the earth to the sun. The measured linewidth of our model system demonstrates that a superradiant laser's frequency linewidth may be below the single atom dephasing and natural linewidths, greatly relaxing experimental requirements on atomic coherence.

[1] Justin G. Bohnet, Zilong Chen, Joshua M. Weiner, Dominic Meiser, Murray J. Holland, and James K. Thompson, "A steady-state superradiant laser with less than one intracavity photon," *Nature* **484**, pp. 78-81 (2012).

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