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Quantum synchronization of many coupled atoms for an ultranarrow linewidth laser PEIRU HE, MINGHUI XU, DAVID TIERI, BIHUI ZHU, ANA MARIA REY, KADEN HAZZARD, MURRAY HOLLAND, JILA, National Institute of Standards and Technology and Department of Physics, University of Colorado, Boulder — We theoretically investigate the effect of quantum synchronization on many coupled two-level atoms acting as high quality oscillators. We show that quantum synchronization – the spontaneous alignment of the phase (of the two-level superposition) between different atoms – provides a potential approach to produce robust atomic coherences and coherent light with ultranarrow linewidth and extreme phase stability. The atoms may be coupled either through their direct dipole-dipole interactions or, as in a superradiant laser, through an optical cavity. We develop a variety of analytic and computational approaches for this problem, including exact open quantum system methods for small systems, semiclassical theories, and approaches that make use of the permutation symmetry of identically coupled ensembles. We investigate the first and second order coherence properties of both the optical and atomic degrees of freedom. We study synchronization in both the steady-state, as well as during the dynamically applied pulse sequences of Rabi and Ramsey interferometry. This work was supported by the DARPA QuASAR program, the NSF, and NIST.

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