Superradiant lasing in inhomogeneously broadened ensembles

A. Bychek[*1], **C. Hotter** [1], **D. Plankensteiner** [1], **H. Ritsch** [1]

1. Institute for Theoretical Physics, University of Innsbruck, Technikerstraße 21, 6020 Innsbruck, Austria

Theoretical studies of superradiant lasing on optical clock transitions predict a superb frequency accuracy and precision closely tied to the bare atomic linewidth [1]. Such a superradiant laser is also robust against cavity fluctuations when operated in a bad-cavity regime. Recent predictions suggest that this unique feature persists even for a hot and thus strongly broadened ensemble, provided the effective atom number is large enough. Here we use a second-order cumulant expansion approach to study the power, linewidth and lineshifts of such a superradiant laser as a function of the inhomogeneous width of the ensemble. We show how sufficiently large numbers of atoms subject to strong optical pumping can induce synchronization of the atomic dipoles over a large bandwidth. This generates collective stimulated emission of light into the cavity mode leading to narrow-band laser emission at the average of the atomic frequency distribution. The linewidth is orders of magnitudes smaller than that of the cavity as well as the inhomogeneous gain broadening and exhibits reduced sensitivity to cavity frequency noise [2].

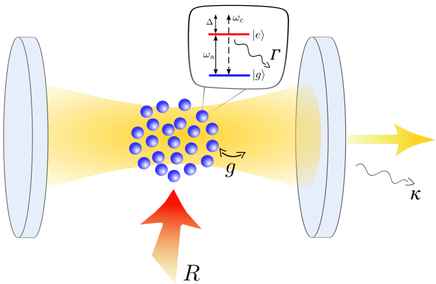

Fig. 1: Schematic illustration of the system. The atomic medium is placed inside the optical resonator and is subject to strong inhomogeneous broadening of atomic frequencies. The lasing transition couples to the cavity mode (g) as well as the environment (Γ). Additionally, the atoms are incoherently driven from the side (R) such that they can provide gain to the cavity mode.

References

[1] D. Meiser, J. Ye, D. R. Carlson, M. J. Holland, Phys. Rev. Let. **102**(16) 163601 (2009).

[2] A. Bychek, C. Hotter, D. Plankensteiner, H. Ritsch, Open Research Europe **1:73** (2021).

*Corresponding author: Anna.Bychek@uibk.ac.at