# Single-atom lasing in normal-superconductor quantum dots

Michele Governale[1] and Gianluca Rastelli[2]

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *Universität Konstanz and Zukunftskolleg, Konstanz, Germany*

Nanostructures coupled to quantum resonators have recently attracted a large theoretical [1,2] and experimental interest [3,4]. Quantum dots, due to their tunability and the availability of highly advanced fabrication and characterisation techniques, are an ideal platform to explore single-atom lasing [5]. The possibility of inducing superconducting correlations in the dot opens up new routes to achieve lasing in these nanoscale systems. We study a single-level quantum dot strongly coupled to a superconducting lead and tunnel coupled to a normal electrode, which can exchange energy with a single-mode resonator. This device can be experimentally realised either as an electromechanical system or as a photon cavity. By means of the Linblad-equation formalism, we present a theory for lasing in this hybrid nanostructure. We find that the semiclassical mean-field equations differ from the text-book result. We derive the threshold coupling and the saturation occupation of the resonator mode, as well as the full Fock-state occupation distribution. The onset of lasing is clearly identifiable in the transport characteristics of the quantum dot.

[1] M. Mantovani, A. D. Armour, W. Belzig, and G. Rastelli, Phys. Rev. B 99 (2019) 045442.

[2] A. Cottet, M.C.Dartiailh, M. M. Desjardins, T. Cubaynes, L.C. Contamin, M. Delbecq, J.J. Viennot, L.E. Bruhat, B. Douçot, T. Kontos, Journal of Physics: Condensed Matter 29 (2017) 433002.

[3] Y.-Y. Liu, J. Stehlik, C. Eichler, X. Mi, T. R. Hartke, M. J. Gullans, J. M. Taylor, and J. R. Petta, Phys. Rev. Lett. 119 (2017) 097702.

[4] A. Stockklauser, P. Scarlino, J. V. Koski, S. Gasparinetti, C. K. Andersen, C. Reichl, W. Wegscheider, T. Ihn, K. Ensslin, and A. Wallraff, Phys. Rev. X 7 (2017) 011030.

[5] P.-Q. Jin, M. Marthaler, J.H.Cole, A. Shnirman, and G. Schön, Phys. Rev. B 84 (2011) 035322.