Using polarons for sub-nK quantum non-demolition thermometry in a Bose-Einstein condensate

M. Mehboudi[a], A. Lampo[a], C. Charalambous[a], L.A. Correa[b], M.Á. García-March[a], and M. Lewenstein[a,c]

[a]ICFO—Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain
[b]School of Mathematical Sciences The University of Nottingham, University Park, Nottingham NG7 2RD, United Kingdom
[c]ICREA, Lluís Companys 23, E-08010 Barcelona, Spain

We introduce a novel minimally-disturbing method for sub-nanoKelvin thermometry in a Bose-Einstein condensate (BEC). Our technique is based on the Bose-polaron model; namely, an impurity embedded in the BEC acts as the thermometer. We propose to detect temperature fluctuations from measurements of the position and momentum of the impurity. Crucially, these cause minimal back-action on the BEC and hence, realize a non-demolition temperature measurement. Following the paradigm of the emerging field of *quantum thermometry*, we combine tools from quantum parameter estimation and the theory of open quantum systems to solve the problem in full generality. We thus avoid *any* simplification, such as demanding thermalization of the impurity atoms, or imposing weak dissipative interactions with the BEC. Our method is illustrated with realistic experimental parameters common in many labs, thus showing that it can compete with state-of-the-art *destructive* techniques, even when the estimates are built from the outcomes of accessible (sub-optimal) quadrature measurements.