Collectively Enhanced Inertial Sensing with Ultracold Atoms in Optical Cavities

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We consider a hybrid light-matter setup, involving ultracold bosonic atoms trapped inside a high-Q optical cavity, as an inertial sensing device. The rotating atomic ensemble works as a heterodyne mixer of photons between two degenerate modes of light, so that the rotation frequency can be read out of the oscillations of the mode populations. We demonstrate that the rotation sensitivity is enhanced by a factor 1/N with N the atom number, due to the collective dispersive coupling of cavity photons with the whole atomic cloud. This Heisenberg-like scaling with the atom number combines with a further shot-noise scaling with the photon number injected into the cavity. This scaling with the whole number of metrological resources, together with the strong atom-photon coupling, the high-density low-temperature ultracold ensemble, and the efficient photon counting out of the cavity, potentially allows for ultra-high precisions of parameter estimation.