To The SciPost Team.

Thank you for your message of January 10, regarding our manuscript submitted to SciPost Physics, scipost_202408_00023v1, entitled "Coherent deflection of atomic samples and positional mesoscopic superpositions", authored by L. F. Alves da Silva, L. M. R. Rocha, and M. H. Y. Moussa. We also thank the referee (Report #1) for the criticisms raised, which helped us to greatly improve the presentation of the manuscript, including the introduction of a new figure with “a schematic view of the experimental system under study”. Below we present our answers to the questions raised in Report #1.

1) First of all, as suggested by the referee, we performed a spellcheck of the manuscript (which we regrettably failed to do before submission). We believe this problem has now been resolved in the new version of the manuscript.

2) We have also defined all the physical quantities introduced in the manuscript. In fact, in the submitted manuscript we also failed to define properly all the parameters involved in our theoretical approach to the coherent deflection of an atomic sample. The changes made in the new version of the manuscript are listed below:

i) We have defined the parameters involved in Hamiltonian (1).

ii) We have also defined the Lewis and Riesenfeld phases $\Phi_{+}^{a}(t)$ and $\Phi_{-}^{a}(t)$ which appear in Eq. 6(a and b) of the new version of the manuscript, noting that in the first version we had forgotten to insert these phases into the general superposition of the atomic state $|\psi_a(t)\rangle = c_+ e^{i\Phi_{+}^{a}(t)} |+, t\rangle + c_- e^{i\Phi_{-}^{a}(t)} |-, t\rangle$ appearing right above Eq. 6.

iii) In the paragraph below Eq. (10), we have now correctly defined the initial state of the atomic sample, replacing ϕ by ϕ_0, thus obtaining: $|\psi_a(0)\rangle = \cos[\theta_0/2]\,|e\rangle + e^{i\phi_0}\sin[\theta_0/2]\,|g\rangle$.

iv) We have now designate ϵ as the coherence parameter, which helps us better understand Figs. 2 to 5. On this regard, bellow Eq. (12) we have stressed that: “As expected, greater coherence of the sample deflection results from greater atom-field couplings and smaller samples and atomic decay factors.”

The referee also suggested that "a schematic view of the experimental system under study might clarify" the measurable quantities introduced in the manuscript. Considering the referee’s suggestion, in the new version of the manuscript we have introduced Fig. 1, in which we present a schematic drawing of the experimental realization of the coherent deflection of an atomic sample.

3) The referee also suggested us to "Add practical, experimental numerical estimation of realizable systems to check in which conditions different effects/regimes (damped, underdamped, ...) might be experimentally observable."

The referee here raises an important point, asking us to provide typical values for the parameters used in the experimental implementation of the protocol presented in the manuscript. To better address this question from the referee, in the new version of the manuscript we decided to modify the presentation of Figs. 2 to 4. Essentially, instead of defining the overdamped, damped and underdamped regimes by fixing the number of atoms and varying their relaxation rates, as we did previously, in the new version we did the opposite: we fixed the relaxation rate of the atoms and varied the number of atoms in the sample. This procedure seems more suitable for the purposes of defining the parameters to be used in a cavity QED experiment; in fact, the relaxation rate of the atoms is defined a priori, by the choice of the atomic states, while the number of atoms can be modified through trapping techniques. Based on this fact, in the new version of the manuscript we modified the paragraphs, below Eq. (28), where we present figures 2, 3 and 4. We have now written:

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For the implementation of the overdamped, damped, and underdamped regimes, we consider $\omega = 10^5 g$ and $\gamma = 5 \times 10^{-3} g$, in order to contemplate both microwave [24] and optical [25] cavity QED regimes, simultaneously. In fact, depending on the value of the Rabi frequency, $g \approx 10^5 Hz$ or $\approx 10^9 Hz$, we are in the microwave or optical regime, respectively. Starting with the overdamped regime, considering a sample with $N = 10^8$ atoms, such that $\epsilon \approx 0.1$, in Fig. 2(a, b and c) we set $\alpha_0 = 0.1$, $\theta_0 = 2/N$, and $\phi_0 = \pi/2$, to draw the curves for the numerical and analytical solutions for $\theta(t)$, $|\alpha(t)|$, $\mathcal{I}_a$, and $\mathcal{I}_f$, respectively. Whereas the circles and squares represent the numerical solutions, the full and dotted lines represent the analytical ones. As we observe, the analytical solutions match very well for the overdamped regime where we basically observe, in Fig. 2(c), an atomic superradiant pulse with intensity of about $10^{18} g^2$ and delay time $\tau_D \approx 2.65 \times 10^{-4} g^{-1}$, in perfect agreement with the analytical value coming from Eq. (15). The field superabsorption, presenting negative intensity [14], is inhibited by the small coherence parameter ϵ. In Fig. 3(a, b, and c), we plot the same functions as in Fig. 2 for the damped regime, with $N = 10^6$ such that $\epsilon \approx 1$, and all other parameters equal to those in Fig. 2. As anticipated above, our overdamped solutions apply with much less accuracy to the damped regime. We now observe a superradiant-superabsorption cycle, although the superabsorption occurs slightly less intensely than the superradiance ($10^{14}g^2$). Moreover, the delay time for superabsorption is slightly greater than that for the superradiance, the latter being around $\tau_D \approx 1.55 \times 10^{-3}g^{-1}$.

In Fig. 4(a, b, and c), we again plot the same functions as in Fig. 2, considering the underdamped regime for $N = 10^4$ such that $\epsilon \approx 10$. We again consider all other parameters equal to those in Fig. 2, except for $\theta_0 = \pi/2$ due to the linearization procedure. Now, we observe around 4 superradiant-superabsorption cycles, with intensities starting at around $10^{10}g^2$, as the strong coherence parameter leads to a slow damping of the initial atomic excitation. The number of superradiance-superabsorption cycles can be controlled by Stark shifting the sample out of resonance with the field. From Ref. [14] it follows that the time interval for a superradiant-superabsorption cycle is around two times the characteristic emission time $2/\sqrt{N}g$, which is in excellent agreement with Fig. 4(c).

From Fig. 4(c) it follows that the time required for the 4 superradiance-superabsorption cycles is around $10/\sqrt{N}g$, resulting in the values $10^{-6}s$ and $10^{-10}s$, for the microwave and optical cavity QED regimes, respectively. In the microwave regime the decay time of a high-finesse cavity is around a thousand times greater than $10^{-6}s$, while in the optical regime it is around 10 times greater than $10^{-10}s$, making it possible to carry out the experiment in both regimes, with advantage for microwave cavities.

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4) Finally, as weaknesses of the manuscript, the referee listed two points:

1- A simple, conceptual design of the system being studied is missing, only references to other papers are given.

2- No numerical example based on a realizable atomic system is given

We believe that the weakness listed in the first point —the lack of a conceptual design of the system being studied— was overcome through the introduction of Fig. 1, which was suggested by the referee himself. And the weakness listed in the second point —numerical examples based on a realizable atomic system— was also overcome through the discussion introduced in the new version of the physical parameters involved in the realization of coherent deflection in the microwave and optical regimes in cavity QED.

We believe that all the criticisms and suggestions made by the referee were observed in the preparation of the new version of the manuscript, which certainly made it clearer, more precise and complete.

Best regards,

L. F. Alves da Silva, L. M. R. Rocha, and M. H. Y. Moussa.