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Comment on "Inverse Doppler shift and control field as coherence generators for the stability in superluminal light"

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In their study of inverse Doppler shift and superluminal light [Ghafoor *et al.*, Phys. Rev. A **91**, 053807 (2015)], Ghafoor *et al.* consider a three-level atomic arrangement with transitions in the optical domain. In fact, the values they give to the parameters lead to a probe wavelength lying in the decimeter band. We point out that the Doppler shifts are then negligible and remark that the simulations performed by Ghafoor *et al.* do not evidence any superluminal effect.

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In their study of inverse Doppler shift and superluminal light [1], Ghafoor *et al.* consider a three-level atomic arrangement with transitions in the optical domain, referring in particular to the sodium D_2 line at 586 .9 nm. On the other hand, they specify in the caption of their Fig. 2 that all the (angular) frequencies are given in units of $\Gamma = (2\pi) \times 1$ MHz and that the frequency of the probe transition $\omega_{ac} = 1000\,\Gamma$. The corresponding wavelength is thus $\lambda = 30$ cm (in the decimeter band).

The first consequence of the large value of the probe wavelength is that the Doppler broadening V_D is very small, in the order of $(2\pi) \times 1$ kHz. The consideration of V_D going from 2 to 12 MHz as made in Ref. [1] is meaningless and the so-called inverse Doppler shift, claimed as the novelty of the article, is in fact negligible.

A second point is that the calculations developed in Ref. [1] lead to fully unrealistic values of the atomic number density N. As correctly given in the article, the electric susceptibility for the probe reads, in SI units,

$$\chi = \frac{2N|\wp_{ac}|^2\rho_{ac}}{\varepsilon_0\hbar\Omega_p}, \tag{1}$$

where a (c) is the upper (lower) level of the probe transition, $\wp_{ac}$ (ρ_{ac}) is the corresponding matrix element of the dipole moment (of the density operator), and Ω_p is the Rabi (angular) frequency of the probe. From the involved discussion following this equation, it results that

$$\Gamma = \frac{|\wp_{ac}|^2\omega_{ac}^3}{\varepsilon_0\hbar c^3} = O\left(\frac{N|\wp_{ac}|^2}{\varepsilon_0\hbar}\right), \tag{2}$$

and that

$$N = O(8\pi^3/\lambda^3). \tag{3}$$

For $\lambda = 30$ cm, we get an atomic number density in the order of $10^{-2}\,\text{cm}^{-3}$, which is 12 orders of magnitude lower than those attainable in the best vacuum devices.

As a third point, we remark that, contrary to the claim made in the article title, the simulations made in Ref. [1] do not evidence any superluminal effect, namely, an advance of the intensity profile of the transmitted pulse on that of the incident one (see Fig. 5). The calculation itself raises some questions. The transmitted field is actually the inverse Fourier transform of $S_{in}(\omega)H(\omega)$, where $S_{in}(\omega)$ and $H(\omega)$ are, respectively, the Fourier transform of the incident field and the transfer function of the medium. Insofar as $S_{in}(\omega)$ is Gaussian and $H(\omega)$ is the exponential of a polynomial of degree 3, the result cannot be that given by Eq. (15) in Ref. [1] but necessarily involves an Airy function. We also note that the transfer function $H(\omega)$ considered by Ghafoor *et al.* neglects the frequency dependence of the medium transmission that can considerably affect the profile of the transmitted pulse [2].

For completeness, we mention that some equations in Ref. [1] seem to be dimensionally inhomogeneous, that the Einstein's coefficient given below Eq. (4) is erroneous (see [3] for its exact value in SI units), and that Eqs. (1) and (8) mix results that hold, respectively, in SI and in electrostatic units (the corresponding susceptibilities differ by a factor of 4π).

We finally point out that the atomic number density given by Eq. (3), anomalously weak in the conditions considered in Ref. [1], raises on the contrary to values $N = O(10^{15}\,\text{cm}^{-3})$ which are too large when the probe wavelength λ is that of the sodium D_2 line. On the other hand, the fixed ratio $\omega_{ac}/\Gamma = 1000$ leads then to lifetimes of the excited atomic states which are fully unrealistic (in the subpicosecond range).

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