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Comment on "Ultrafast polarization switching in ferroelectrics"

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The mechanisms of ultrafast switching of ferroelectric polarization are of great interest and importance currently both from the fundamental and from the practical points of view. One such mechanism, harnessing feedback from the resonator field, was recently proposed by Yukalov and Yukalova [Phys. Rev. Research **1**, 033136 (2019)]. The Ising model in a transverse field that is used there is the standard to order-disorder ferroelectrics. However, I note that the assumption of a nonzero transverse electric dipole moment associated with a transverse pseudospin, essential for the proposed mechanism, does not hold for the most common order-disorder ferroelectrics mentioned there for reasons of symmetry. Therefore, care should be taken when choosing the material to which the mechanism can be applied.

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Yukalov and Yukalova [1] have suggested a new mechanism of ultrafast switching of ferroelectric polarization, based on the interaction of a ferroelectric sample with the feedback field of a resonator in which the sample is inserted.

To consider a realistic ferroelectric model, the Hamiltonian in the pseudospin representation, Eq. (1) in Ref. [1], was taken

$$\hat{H} = -\Omega \sum_j S_j^x - \frac{1}{2} \sum_{i \neq j} J_{ij} S_i^z S_j^z - \sum_j \mathbf{E}_{\text{tot}} \cdot \mathbf{P}_j, \qquad (1)$$

where S_j^α is an α component of the $S = 1/2$ spin operator characterizing an electric dipole at site j, Ω is the tunneling frequency, and $J_{ij} = J_{ji} > 0$ describes the strength of dipolar interactions. The total electric field acting on dipoles consists of two terms $\mathbf{E}_{\text{tot}} = E\mathbf{e}_x + E_0\mathbf{e}_z$. The first term is the field of the resonator cavity in which the sample is inserted, and the second term is the external constant electric field. The dipolar operator was assumed to be proportional to the pseudospin operator $\mathbf{P}_j = d_0\mathbf{S}_j$.

I note that the Hamiltonian (1) is, indeed, the standard Hamiltonian for order-disorder ferroelectrics, in particular, with hydrogen bonds [2,3]. In the latter case, for example, protons are located in one of two minima of the double-well potential along the hydrogen bond (Fig. 1). In the pseudospin formalism, these are the eigenstates of the quantum operator S^z with eigenvalues $\langle S^z \rangle = \pm 1/2$. The action of the operator S^x on these states corresponds to the tunneling of protons from one minimum to another with a frequency Ω. Thus, the electric dipole moment associated with the hydrogen bond is determined only by the location of the proton along it $P^z = d_0 S^z$ and has a zero value in the perpendicular direction $P^x = 0$, in contrast to the assumption used in Ref. [1] and mentioned above. In the most general case, including proton tunneling, $P^x = 0$ always when the proton wave function has an axial symmetry around the axis connecting two proton minima. Since the electric field of the resonator is directed along the x axis and, therefore, is coupled to P^x in Ref. [1], the ferroelectric polarization switching mechanism proposed in Ref. [1] in its current form cannot be applied to, at least, the hydrogen-bonded ferroelectrics [4] mentioned in Ref. [1].

Of course, it would be interesting to find the ferroelectrics described by the Hamiltonian (1) with $P^x \neq 0$ and see in the experiment the switching of polarization through the mechanism proposed in Ref. [1]. However, I also note that, in this case, the dipole-dipole interaction in (1) is likely to additionally include the coupling $S_i^x S_j^x$. Nevertheless, in the

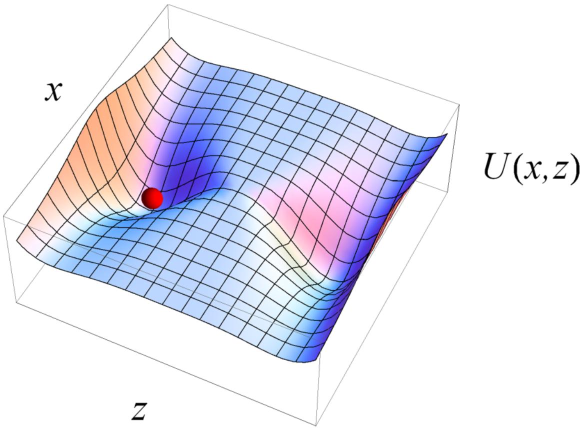

FIG. 1. Double-well potential $U(x, z)$ for protons in hydrogen-bonded ferroelectrics. A proton (red sphere) can be in one of two wells along the z axis, which determines the electric dipole moment P^z of the bond, or tunnel between them with a frequency Ω. The proton position along the x axis is constant, which means $P^x = 0$.

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dipolar-coupled Ising ferromagnet $LiHoF_4$, described by the same Hamiltonian (1), transverse and longitudinal g factors were found to be equal to $g_\perp = 0.74$ and $g_\parallel = 13.8$ [5]. This means that, in principle, the mechanism proposed in Ref. [1] with changing electric fields to magnetic can be tested there to switch the magnetization in the sample.

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