Comment on the article of A. Maurel et al. "Interaction of a surface wave with a dislocation", Phys. Rev. B 75, 224112 (2007).

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We would like to make a comment to the recent paper of A. Maurel et al. [1], which, as is stated by the authors in the abstract and introduction, at least partially, is aimed at simulating the results of our experiments [2]. In paper [2], we reported on direct visualization of the interaction between surface acoustic waves (SAW) and dislocations in $LiNbO_3$ crystals. It was done by the aid of the specially developed fast stroboscopic x-ray diffraction topography at synchrotron beam line. By using this technique we were able to visualize in the same image the SAW traveling across the crystal, the dislocations beneath the crystal surface, and, what is most important, the interaction between acoustic waves (phonons) and dislocations.

As was thoroughly studied in classical works of Granato and Lücke [3], the main outcome of this interaction, is the phonon-induced vibrations of the dislocation strings. By analyzing the obtained images we directly determine the amplitudes of the vibrating dislocation segments, their velocities and, on this basis, deduce on dislocation viscosity coefficients in brittle ceramic crystals of $LiNbO_3$. It is important to mention that our analysis gave high dislocation velocities, V, (in significant parts of shear sound velocity) and, correspondingly, very low coefficients, B, of dislocation viscosity, being about two orders of magnitude lower than the values previously measured in ductile materials by the internal friction and similar techniques. A review of the dislocation viscosity issue, including our and early results together with the comprehensive list of relevant references, can be found in our review paper [4].

When comparing their simulations with our experimental results, the authors of [1] have made some contradictory statements. For example, at the end of abstract they speak about "satisfactory agreement". In section C, when describing the key picture (given below as Fig. 1a), which is the quintessence of their simulations to be compared with our experimental image also given below as Fig. 1b, they say that "both pictures are qualitatively in good agreement". Further in section C1, which in a whole is devoted to the analysis of our paper [2], they say that our analysis "certainly captures the essence of the interaction between the incident wave and the dislocation …". When comparing expressions (3.16) in [1] and (2) in [2], they say that "…. we deduce that two approaches indeed focus on the same mechanism. Actually calculations of Ref. 13 (*our paper cited in this comment as [2]*) can be recovered from our calculation". At the same time, at the end of section C1 they claim: "We conclude

that the unexpectedly high value of the dislocation velocity and the unusual low value of the drag coefficient B announced in Ref. 13 are artifacts of the approximations in the model herein."

In light of this, we would like to say that neither positive nor negative conclusions with respect to our paper [2], claimed in [1], are not justified. This follows from the fact that the papers [1] and [2] are focused on different aspects of phonon interaction with dislocations and, hence, not too much overlap.

In brief, by using stroboscopic x-ray diffraction topography we take instant snapshot of the deformation field related to the dislocation string which is under forced vibration induced by resonant interaction with SAW having wavelength, λ. The main effect observed is the periodic modulation of the shape of dislocation string, clearly visible in the x-ray diffraction images (see Fig. 1b). The vibration amplitude, ξ, and, closely related to it, the strength of interaction ξ/λ, are directly determined by us from the collected images. After that, the maximum velocity of the vibrating dislocation segments is found as $V = \omega\xi$, where ω stands for the SAW frequency. Hence, high dislocation velocities are the result of large amplitudes of dislocation vibrations (up to $\xi/\lambda \approx 0.1$), which are experimentally observed, practically with no modeling. The latter is only used for better understanding of the visible contrast modifications (for details see [2]). After extracting high dislocation velocities, we automatically receive low viscosity coefficients B, since $B \sim 1/V$ (certainly if we are not too close to the velocity of sound and B is the main factor limiting the dislocation velocity). The lowest value found by us was $B = 5 \cdot 10^{-6}$ Poise or $5 \cdot 10^{-7}$ Pa·s (the latter units were used in Ref. [1]).

On the contrary to our approach, the paper [1] is focused on calculating the amplitude of the secondary elastic waves emitted by the vibrating dislocation string and then simulating the resulting interference pattern. Not going deeply into simulation details, we stress that these simulations require the knowledge of the dislocation viscosity coefficient, B, a single important parameter not known *a priori* since it depends on details of phonon-phonon and phonon-electron interactions. Physically, larger B-values imply stronger interactions and higher amplitudes of the emitting wave. In their calculations, the authors of [1] arbitrary set $B = 10^{-5}$ Pa·s, i.e. 20 times larger than we received experimentally in [2]. In order to do this, they postulate that B-value is more or less the same in all materials, which is not true as we show below. As justification, they apply certain expression of B well above the Debye temperature and estimate several physical parameters of interest. Since we use identical equations for dislocation motion, it is easy to conclude that setting a 20 times larger B-value means 20 times smaller dislocation velocity that is indeed calculated in [1]. This is also the basis of their conclusion that they "observed" (i.e. calculated) dislocation velocities equal a few percents of the velocity of sound. Correspondingly, their calculated amplitudes of dislocation vibrations are 20 times smaller than we measured experimentally (25 nm instead about 500 nm that we obtained).

Generally, the simulations performed in [1] (see an example in Fig. 1a) do not capture the most important experimental feature – strong wave-front distortions in close vicinity to dislocation lines (see Fig. 1b). As we show in [2], these distortions reveal the phonon-induced dislocation vibrations and are well reproduced when calculating the quasi-static deformation field of such wavy dislocation line. In contrast,

calculations in [1] miss this main effect because the dislocation velocity is very much underestimated as a result of large B-value. At the same time, the simulations in [1] greatly overestimate the strength of the secondary acoustic waves far away from dislocation lines (see Fig. 1a), which hardly appear in experimental images (Fig. 1b).

So, to our opinion the source of the major discrepancy between papers [1] and [2] is postulating in [1] that $B = 10^{-5}$ Pa·s in most materials. This assumption is definitely incorrect and, in fact, the B-values may strongly differ for metals and ceramics. In this relation we mention two important facts. First, in insulating ceramics, as compared to metals, there is practically no phonon-electron interaction. If so, the B-value in ceramics should be generally smaller than in metals. More important, that Debye temperatures, Θ_D, in ceramics can be two-three times higher than those for typical ductile metals in which the dislocation viscosity has been measured by internal friction technique. For example, at room temperature, Θ_D = 95 K, 225 K, 316 K, and 395 K for Pb [5] Ag [6], Cu [7], and Al [8], respectively. In contrast, for $LiNbO_3$ Θ_D = 560 K [9], and definitely high-temperature approximation for B-value used in [1] in order to estimate the B-value in this material at room temperature is not valid. As another illustration of possible diversity between materials, we indicate that the μb^3-value (the measure of dislocation energy, where μ is the shear module and b is the length of the Burgers vector) stated arbitrary as "1 eV for most of materials" in [1], for $LiNbO_3$ equals 62 eV (taking μ = 60 GPa and b = 0.55 nm [3]).

However, for us the most direct evidence of the potential large-scale diversity in the B-values in different materials is given by the fact that sound attenuation, α, at the same frequency, ω, strongly differs in metals and ceramics. For example, at room temperature the attenuation for longitudinal sound wave in Al and Cu at 1 GHz are α = 7500 dB/m [10] and α = 27000 dB/m [10], respectively, while α = 45 dB/m for $LiNbO_3$ [11] at the same conditions. Since sound attenuation, α, and dislocation viscosity, B, are originated in the same general crystal viscosity phenomenon (i.e. phonon-phonon and phonon-electron interactions), it is clear that B-values in ceramics and metals may differ by orders of magnitude, in contrast with the erroneous postulation in paper [1].

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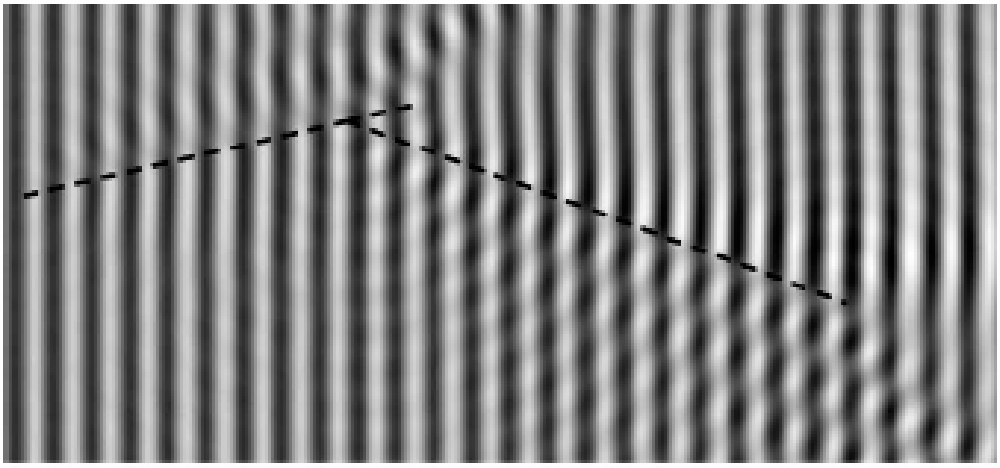
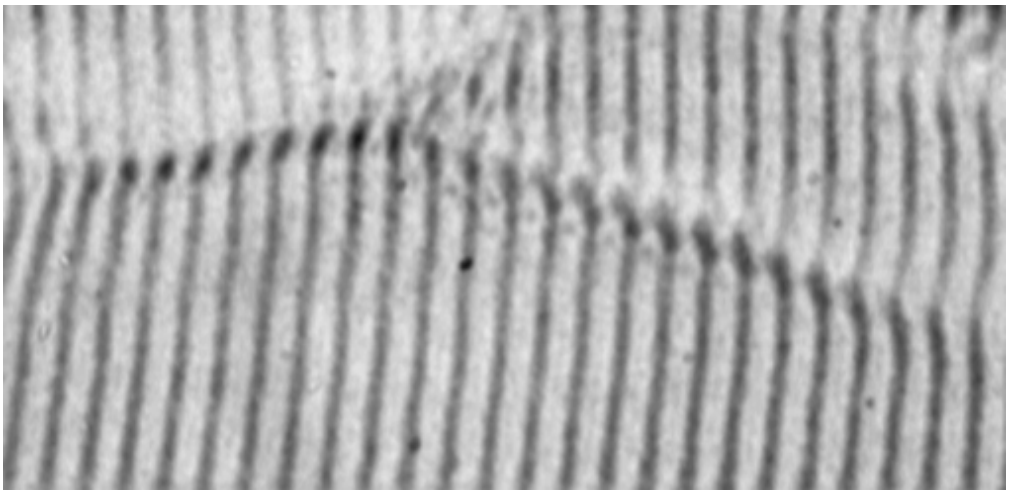


(a)



(b)

Figure 1. A comparison between the dynamic deformation fields resulted from the phonon interaction with dislocations: a) – simulated in [1]; b) - measured by stroboscopic x-ray topography [2]. Alternating dark and light vertical lines are acoustic wave fronts, while intersecting inclined lines (dashed lines in (a)) are linear dislocations.