Comment on "Test of the Isotropy of the Speed of Light Using Fast-Beam Laser Spectroscopy"

In a recent Letter, Riis *et al.*[1] reported ". . . on a novel experiment sensitive to the anisotropy of the one-way speed of light. The frequency of a two-photon transition in a fast atomic beam is compared to the frequency of a stationary absorber while the direction of the fast beam is rotated relative to the fixed stars. The experiment yields an improved upper limit for the anisotropy: $\Delta c/c \leq 3\times 10^{-9}$."

The purpose of this Comment is to point out that from the constancy of the laser frequency found by the authors no conclusion can be drawn concerning the one-way speed of light or any anisotropy of it.

The authors base their conclusions on the "test theory" of Mansouri and Sexl[2] which assumes a slow transport synchrony defined by $\epsilon_T = 2\alpha v/c^2$ which may differ from the value $\epsilon = -v/c^2$, $\alpha = -\frac{1}{2}$ used in the special theory of relativity (STR) where it is called "standard synchronization." The synchrony adopted in STR results in isotropy of the one-way speed of light in the moving system.

If $\alpha \neq -\frac{1}{2}$, the one-way speed of light, measured at that synchrony, is anisotropic by the amount $c(\theta) = c - v(1+2\alpha)\cos\theta$, where θ is the angle between the velocity **v** of the moving system and the direction of light propagation.

Mansouri and Sexl[2] do not analyze the two-photon absorption (TPA) in their test theory, but the authors claim that because of a possible anisotropy in the one-way propagation speed of light a shift in the laser frequency of $\Delta\nu/\nu_0 = (1+2\alpha)uv/c^2\cos\theta$ can be predicted.

This prediction is erroneous because values of all kinds of speeds, measured in a moving system, depend on the synchrony accepted for that system. Thus, not only the speed of light propagation but mechanical speeds, and consequently also the time dilatation function for the moving atoms, are important for the resonant absorption: all depend on the synchrony assumed for the moving system and have to be taken into account.

If the calculations are extended to all synchrony dependent quantities, the result is that the *laser frequency* in the TPA experiment is *independent of the synchrony* introduced to the moving system by slow clock transport or by some other hypothesis. Thus instead of the above erroneous formula, $\Delta\nu/\nu_0 = 0$ should be predicted.

For illustration we cite two rather extreme examples.

(1) Accepting the standard synchrony of STR, there is no anisotropy in the moving system (laboratory). Here, of course, $\Delta\nu/\nu_0 = 0$ is predicted.

(2) If, on the other hand, synchrony in the moving system is taken to be the same as in the rest system ("absolute simultaneity"), the transformation is closest to the classical (Galilean) case, except that an experimentally accurately verified Lorentz contraction and time dilatation have to be included in the transformation (Ref. 2, p. 503). The theory in this case (called "relativity without relativity" by Mansouri and Sexl) is *very* different from STR with respect to light propagation, since $\epsilon = 0$ and the one-way speed of light in the moving system is in this case $c(\theta) = c - v\cos\theta$. This certainly is a large anisotropy (larger by more than 5 orders of magnitude than the upper limit claimed by the above authors if the velocity of the Earth is 300 km/sec). But still, *even that large anisotropy would not cause any diurnal variation in the TPA* laser frequency, since the large change of the Doppler frequency shifts proportional to $uv/c^2\cos\theta$ would be compensated by the same change of opposite sign of the eigenfrequencies of atoms moving with **u** (owing to the time dilatation). This was already pointed out in an early paper by Cedarholm and Townes.[3] Thus even in this theory, not equivalent to STR, $\Delta\nu/\nu_0 = 0$ can be predicted.

The two examples show that over the range of 5 orders of magnitude there is no correlation between the anisotropy of the one-way velocity of light and a possible diurnal modulation of the TPA laser frequency.

Therefore the reported TPA experiment is not "sensitive to the anisotropy of the one-way speed of light," and cannot be used to set an upper limit for it.

One final remark. The authors state that the high sensitivity of their experiment represents a tenfold improvement. It yields $\alpha = -\frac{1}{2} \pm 1.4\times 10^{-6}$ for time dilatation in the theory of Mansouri and Sexl. They do not mention that earlier Mössbauer rotor experiments of Isaak,[4] interpreted by Mansouri and Sexl as "first-order experiments," give $\alpha = -\frac{1}{2} \pm 10^{-7}$ (Ref. 2, p. 522) which is better by more than 1 order of magnitude than the figure of the authors.

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Received 24 May 1988
PACS numbers: 03.30.+p

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