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Comment

Comment on: "Lorentz violation in high-energy ions" by Santosh Devasia

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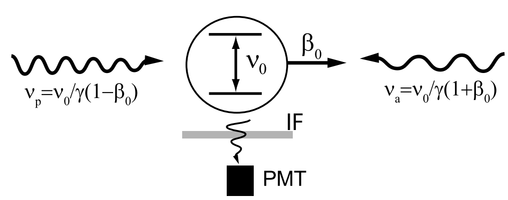
Abstract In an article "Lorentz violation in high-energy ions" by S. Devasia published in this Journal [EPJ C 69, 343 (2010)], our recent Doppler shift experiments on fast ion beams are reanalyzed. Contrary to our analysis, Devasia concludes that our results provide an "indication of Lorentz violation". We argue that this conclusion is based on a fundamental misunderstanding of our experimental scheme and reiterate that our results are in excellent agreement with Special Relativity.

We have performed experiments of the Ives-Stilwell (IS) type [1] that test time dilation of Special Relativity (SR) via the relativistic Doppler shift [2–5]. A beam of ions, which exhibit an optical transition with a frequency ν_0 in their rest frame, is stored at velocity $\beta = v/c$ in a storage ring. To resonantly excite these ions by a laser at rest in the laboratory frame, the frequency ν of the laser needs to be Doppler shifted according to $\nu = \nu_0/\gamma(1 - \beta\cos\theta)$, where θ is the angle between the laser and the ion beam, measured in the laboratory frame, and γ governs time dilation. For a parallel ($\theta_p = 0$) or an antiparallel ($\theta_a = \pi$) laser beam the frequencies required are $\nu_{p,a} = \nu_0/\gamma(1 \mp \beta)$, respectively. Multiplying these two frequencies and using $\gamma = (1 - \beta^2)^{-1/2}$ as predicted by SR results in

$$\nu_p \nu_a / \nu_0^2 = 1, \qquad (1)$$

i.e. the geometric mean of the Doppler shifted frequencies equals the rest frame frequency for all velocities β.

In one of our implementations of the IS experiment saturation spectroscopy is used by overlapping simultaneously a parallel and antiparallel laser beam with the ion beam to select a narrow velocity class β_0 within the ions' velocity distribution. The parallel laser is held fixed at the laser frequency $\nu_p = \nu_0/\gamma(1 - \beta_0)$ and is resonant with ions at β_0, while the other laser is scanned over the velocity distribution. The fluorescence yield, measured with a photomultiplier (PMT) located around 90 degree with respect to the ion beam, will exhibit a minimum (a Lamb dip)



when the antiparallel laser interacts with the same velocity class β_0, i.e. when its frequency is at $\nu_a = \nu_0/\gamma(1 + \beta_0)$. SR thus predicts the Lamb dip to occur when (1) is fulfilled, which is shown to be confirmed by our experiments to an accuracy of $< 2 \times 10^{-10}$ on Li^+ ions at $\beta_0 = 0.03$ and $\beta_0 = 0.06$ [3].

S. Devasia [6] claims that the Doppler shift of the emitted light has to be taken into account and replaces ν_0 in (1) by $\gamma\nu_0$, i.e. by the frequency of the light detected exactly at $\theta = \pi/2$. This is a misconception of our experimental measurement scheme. While it is true that the detected light is Doppler-shifted, this Doppler shift is irrelevant for the analysis. Neither do we measure the frequency

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of the emitted light nor do we intend to observe at exactly right angle. We only record the number of re-emitted photons as a function of the scanning laser frequency to monitor the Lamb dip caused by the simultaneous resonance of both lasers with the same ions. Thus the angle of detection is irrelevant but $\theta \approx \pi/2$ helps to separate fluorescence from laser stray light. In fact, stray light suppression is the only reason for using an interference filter (IF) in front of the PMT; its transmission width of 10 nm corresponds to 10 THz, about 10^6 times broader than the width of the Lamb dip, and a factor of 10 larger than the transverse Doppler shift (at $\beta = 0.064$). None of the filters employed in our experiments [2–5] to improve the signal-to-noise ratio in the fluorescence light detection are affecting the shape and position of the signal indicating the resonance of the parallel and antiparallel laser with the same velocity class β_0. The frequency ν_0 occurring in (1) has nothing to do with the frequency of the emitted light in our experiment, but is the rest frame frequency ν_0 deduced from experiments at smaller ion velocities [3, 7].

In conclusion, SR predicts (1) as the outcome of our experiments, which is confirmed with high accuracy.

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