## Laser Enhancement of Nuclear $\beta$ Decay

A recent paper by Becker *et al.*[1] claims to show that the application of a very intense laser field will lead to a large enhancement of the $\beta$ decay of a nucleus which has a small decay energy in the absence of the field. Their work contains an internal inconsistency which, when corrected, leads to the result being unobservable. Even more important, the authors use an analytical approximation which overstates the result by many orders of magnitude.

Becker *et al.* state that, if ample phase space is available without the laser, then they do not find significant enhancement due to the laser field. This is physically plausible. Most of the work in Ref. 1 relates to the $^3$H example, which has $\epsilon_0 = 1.036$, and thus meets the requirement for low decay energy. However, the only discussion of experimental possibilities in the paper is for $^{18}$F, which is an energetic decay with $\epsilon_0 = 3.240$, which should show no enhancement. If one examines experimental conditions for $^3$H, the small size of the focal spot, the brief duration of the laser pulse, and the long half-life of the decay (even when enhanced) all combine to produce only about $5 \times 10^{-3}$ decays per 300-psec laser pulse. This low probability, aggravated by the fact that the pulse is orders of magnitude shorter than resolution times of nuclear detectors, makes the effect unobservable. This will be true for any low-energy $\beta$ decay. Detection possibilities for $^{18}$F come about only because of the improper use of an energetic (and thus short half-life) example.

In order to obtain numerical results from their theory, Becker *et al.* employ the approximation $n_0 = 0$. For low-energy decays, $n_0$ is given by $n_0 \approx (m/\omega)(\nu^2/2\Delta\epsilon)$. Since $m \approx 5 \times 10^5$ eV and $\omega \approx 2$ eV, then a value $\nu^2 = 1$ gives $n_0 = O(10^4)$ or $O(10^5)$, which is greatly different from zero. To illustrate the consequences of this very bad $n_0 = 0$ approximation, consider the single term $\epsilon J_n^2$ in $L_n(\epsilon_0, \epsilon, \theta)$. This term is simple and very important, since it is the term which accounts for the entire result in the field-free limit. [There is a typo in Eq. (5b) of Ref. 1. The expression $\epsilon - n\omega/m$ should be enclosed in parentheses.] The complete sum over $n$ involving this term of $L_n$ has the form

$$S = \sum_{n_0}^{\infty} (n - n_0)^2 J_n^2(z) = \sum_{0}^{\infty} n^2 J_{n+n_0}^2(z).$$

With the author's assumption that $n_0 = 0$, this series is readily summed to give $S_0 = \frac{1}{4}z^2$, where $S_0$ is $S$ with $n_0 = 0$. When $n_0 \gg 1$, as is in fact the case, a closed-form sum is not achievable, but any set of assumptions about relative magnitudes of $n_0$ and $z$ gives a result very much smaller than $S_0$. For example, suppose $n_0 > z$. [This is in conflict with Eq. (7) of Ref. 1. However, Eq. (7) is a purely *ad hoc* assumption made for algebraic expediency. The opposite assumption includes a broader range of angles for $\beta$ emission, although it also leads to the unphysical constraint on field intensity given in Eq. (8). The field intensity is an external parameter, and real solutions exist for all values of $\nu^2$. Equation (8) arises only because of the artificial condition, Eq. (7). Physical conclusions drawn from Eq. (8) are meaningless.] Under this assumption, $S$ can be evaluated approximately to give $S \approx \frac{1}{4}z^2 J_{n_0}^2(z)$. The difference between this outcome and $S_0$ is simply $J_{n_0}^2(z)$. Since $n_0 \gtrsim 10^4$, this correction factor is an extremely small number. The other terms in $L_n(\epsilon_0, \epsilon, \theta)$ have similar character to the term considered. Estimates for the relative magnitudes of $n_0$ and $z$ other than the one used here still lead to the same conclusion. The essential conclusion is that the authors have overestimated their result by many orders of magnitude by their approximation that $n_0 = 0$, in place of the actual $n_0 \gtrsim 10^4$.

In summary, even if the author's algebraic results are accepted as valid, laser enhancement of nuclear $\beta$ decay is unobservable because of the combination of low decay energy (and hence long half-life even when enhanced), small focal volume, and short laser pulse length. This negative conclusion is compounded by the fact that Becker *et al.* have used an approximation in their work which overestimates the results by many orders of magnitude.

Howard R. Reiss
Arizona Research Laboratory
University of Arizona, Tucson, Arizona 85721
and
Physics Department
The American University, Washington, D. C. 20016

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[1] W. Becker *et al.*, Phys. Rev. Lett. 47, 1262 (1981).

 