Comment on "Relativistic Positron Creation Using Ultraintense Short Pulse Lasers"

Recently Chen *et al.* reported the remarkable production of large numbers of relativistic positrons following the interaction of ultraintense laser pulses with gold targets [1]. The authors state that this resulted in the highest positron density ever created (10^{16} cm^{-3}) and speculate that this methodology may be suitable for the realization of Bose-Einstein condensed positronium (Ps) [2]. We would like to point out that the production of higher positron densities is implicit in previous experiments [3], and that the suggestion that the methodology described by the authors may be applicable to the production of Ps drastically underestimates the difficulties associated with thermalizing high energy positrons.

The experimental production of a high density of positrons, and then of Ps, has been the focus of our research efforts for a number of years [4]. Using a relatively low intensity dc beam and a positron trap [5] we routinely produce positron bunches with areal densities of up to 5×10^{10} cm^{-2} [6] which are implanted into either thin silica films [7] or metal targets [3]. Reference [3] describes experiments in which pulses of areal density 3.5×10^{10} cm^{-2} are implanted into an Al (111) target at a mean depth of ~25 nm. A substantial fraction of these positrons will diffuse back to the surface [8] and become trapped there, weakly bound in a surface state over almost the same radial extent as the initial beam, and spilling out from the surface by ~0.5 nm [3]. This cloud will have an areal density of at least 1×10^{10} cm^{-2}. Using these numbers we may estimate the positron density in the bulk metal just after implantation (n_b) and also at the surface following diffusion (n_s); we obtain $n_b \sim 1.5 \times 10^{16}$ cm^{-3} and $n_s = 2 \times 10^{17}$ cm^{-3}. In both cases the positrons are essentially thermal, and are thus well suited to Ps production.

Chen *et al.* do not discuss possible methods to reduce the energy of laser induced positrons to the thermal levels needed to create Ps, but do mention that the overall efficiency of thermalization and Ps formation would be "much less than unity." Fast positron thermalization has been intensively studied for over 50 years with the goal of producing Ps and monoenergetic positron beams by reducing the energy spread of positrons emitted from energetic sources [8–15]. One robust material that might be suitable as a moderator for intense laser generated positrons is tungsten [16]. When used with a ^{22}Na source the highest efficiencies obtained with this material are $\sim 1 \times 10^{-3}$, and with 6 MeV energy positrons would be less than 1×10^{-4}. This means that in the best case scenario, and assuming 100% positron-Ps conversion, an initial laser induced positron density of 10^{16} cm^{-3} would translate to a Ps density of less than 10^{12} cm^{-3}, for which the Ps Bose-Einstein condensation transition temperature T_c would be 1.5 mK. In order to achieve a Ps density of 5×10^{17} cm^{-3} (corresponding to $T_c = 9.4$ K) would therefore require an increase in the laser pulse energy of at least 5 orders of magnitude.

While the formation of large bursts of positrons using intense lasers is certainly interesting, the utility of such techniques for producing Ps is not clear. Any methods used to moderate laser generated pulses would likely be just as applicable to electron accelerators, which can also generate large bursts of MeV positrons [17], and we are led to conclude that positrons produced via intense laser pulses are really only unique in terms of the very short time widths that may be obtained; in this area other methods probably cannot compete. With a higher laser repetition rate this could be useful, for example, in creating a positron "gun" for a high energy accelerator injector [18], especially if the positron polarization can be controlled via the primary laser pulse.

This work was supported in part by the National Science Foundation under Grants No. PHY 0537431 and No. PHY 0555701.

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Received 15 June 2009; published 19 October 2009
DOI: 10.1103/PhysRevLett.103.179501
PACS numbers: 52.38.Ph, 52.59.−f

[1] H. Chen *et al.*, Phys. Rev. Lett. **102**, 105001 (2009).
[2] P. M. Platzman and A. P. Mills, Phys. Rev. B **49**, 454 (1994).
[3] D. B. Cassidy, S. H. M. Deng, and A. P. Mills, Phys. Rev. A **76**, 062511 (2007).
[4] D. B. Cassidy *et al.*, Phys. Rev. Lett. **95**, 195006 (2005).
[5] C. M. Surko and R. G. Greaves, Phys. Plasmas **11**, 2333 (2004).
[6] D. B. Cassidy, S. H. M. Deng, R. G. Greaves, and A. P. Mills, Jr., Rev. Sci. Instrum. **77**, 073106 (2006).
[7] D. B. Cassidy and A. P. Mills, Phys. Rev. Lett. **100**, 013401 (2008).
[8] P. J. Schultz and K. G. Lynn, Rev. Mod. Phys. **60**, 701 (1988).
[9] L. Madansky and F. Rasetti, Phys. Rev. **79**, 397 (1950).
[10] M. Deutsch, Phys. Rev. **82**, 455 (1951).
[11] W. Cherry, Ph.D. Dissertation, Princeton University, 1958.
[12] D. G. Costello *et al.*, Phys. Rev. B **5**, 1433 (1972).
[13] K. F. Canter *et al.*, J. Phys. B **5**, L167 (1972).
[14] K. F. Canter, A. P. Mills, and S. Berko, Phys. Rev. Lett. **33**, 7 (1974).
[15] A. P. Mills, Jr. and E. M. Gullikson, Appl. Phys. Lett. **49**, 1121 (1986).
[16] J. M. Dale *et al.*, Surf. Interface Anal. **2**, 199 (1980).
[17] E.g., R. H. Howell, R. A. Alverez, and M. Stanek, Appl. Phys. Lett. **40**, 751 (1982).
[18] E.g., K. Sinclair *et al.*, Phys. Rev. ST Accel. Beams **10**, 023501 (2007).

