Highly reproducible LENR experiments using dual laser stimulation

Dennis Letts*

12015 Ladrido Lane, Austin, TX 78727, USA

The present article reports a summary of results relating to 170 on-protocol tests performed on five deuterated palladium bulk cathodes stimulated by dual lasers at 8, 15 and 20 THz over the period March 2007 to May 2008. These frequencies were not measured but assumed to be effective based on a calculated difference beat frequency. Excess power was observed in 161 tests, giving a success rate of approximately 95%. The cathode fabrication, loading and laser application protocols are discussed.

Keywords: Cold fusion, deuterated palladium cathodes, dual laser stimulation, low energy nuclear reaction.

Introduction

THE field of low energy nuclear reactions (LENR) began on 23 March 1989 with the controversial name of cold fusion. Two electrochemists, Martin Fleischmann and Stanley Pons reported sudden increases in cell temperature when deuterated palladium cathodes were run electrochemically at high current densities for long periods of time[1]. The amount of excess energy observed was beyond that which could be explained by normal chemistry; so a nuclear interpretation was proposed.

The idea of low temperature nuclear reactions was immediately controversial, amplified by the early lack of reproducibility. In the years that followed, various researchers were able to develop protocols that increased the probability of observing the excess heat or excess power effect.

In 2002, Peter Hagelstein suggested that dual (red) lasers might be effective in triggering excess power if operated in difference mode around 8 and 15 THz. Single laser output power ranged from 1 to 25 mW. Dual laser power output ranged from 2 to 50 mW. The lower power output was realized when using one or two red laser pointers with wavelengths of approximately 650 and 670 nm. The higher laser power output was realized when using tunable diode lasers commercially available from Hitachi or Sony. The magnitude of the thermal response did not depend upon laser power between 1 and 50 mW but did seem to depend on the assumed beat frequency tuned according to Figure S1 of the Supplementary Information (see online). The idea was that PdD lattice vibrations might occur around 8 and 15 THz as marked in the density of states (DOS) plot for PdH (Figure 1). This plot was actually used to tune the lasers because at the time there was no good plot for PdD, as shown in Figure S2 of the Supplementary Information (see online). Intuitively we expected to see the peak excess power response near 12 THz, but that was not observed. The peak thermal responses were off the flanks of the DOS plot, suggesting low group velocities typically located at the edge of an optical phonon mode. In palladium deuteride, the band edges occur near 8 and 15–16 THz (Figure S2; see Supplementary Information online), similar to that shown for PdH (Figure 1). These vibrations are known to involve phonons, which might be implicated in coupling energy to the palladium lattice[2]. Five years later in 2007, the author developed a cathode fabrication and dual laser protocol to test the Hagelstein conjecture. Excess power was observed immediately at 8 and 15 THz. As higher beat frequencies were tested, a third trigger frequency appeared around 20 THz. The nature of the third frequency was unclear. It was conjectured that it might be due to the presence of H in the lattice as a contaminant. However, the 20 THz triggering frequency was equally robust as the 8 and 15 THz frequencies, which was not consistent with an effect based on a small amount of contaminant. This remains an open question.

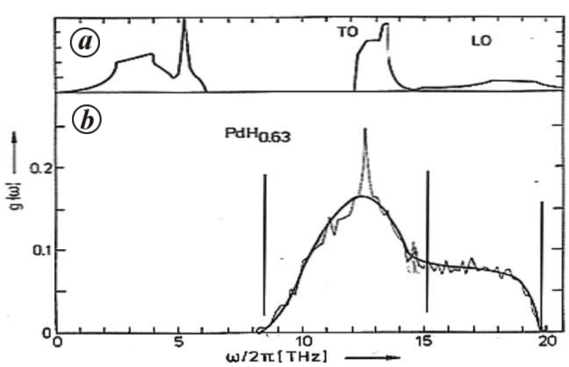

Figure 1. Density of states plot for PdH that was used to tune the dual lasers. The edge phonon frequencies are marked. It was thought that the edge frequencies of PdH would be similar to PdD. See the density of states plot for PdD in Figure S2 of the Supplementary Information (see online).

*e-mail: lettslab@sbcglobal.net

The stronger-than-expected thermal response to the 20 THz frequency might be attributed to a higher surface concentration of light hydrogen (H) compared to its concentration in the bulk. Another possibility is that the laser beat frequency is coupling with the deuterium–hydrogen bond frequency positioned on the cathode surface or in palladium vacancies. Figure 1 shows that PdH has a normal mode near 20 THz. Normal mode calculations for the deuterium–hydrogen bond reveal a normal mode frequency that ranges from 18 to 22 THz, consistent with the observed triggering frequencies which ranged over 18.56 to 22.14 THz (Figure S1; see Supplementary Information online).

Laser stimulation is likely to be restricted to the cathode surface where the PdD or PdH vibrational frequencies will likely be different than bulk vibrational frequencies, as depicted in the DOS plots shown in Figures 1 and S2 (see Supplementary Information online). However, the presence of polaritons at the interface between the gold layer and palladium substrate may alter that argument. Polaritons represent surface phonons that have coupled to light waves. Polaritons move in the interface at the speed of light and may be able to distribute laser or beat frequency energy to other parts of the cathode, perhaps even to the bulk. This is highly speculative, but might be worth considering as a way localized laser energy can be distributed to the entire cathode.

The wave vector of the laser beams might be near zero when irradiating the cathode immersed in electrolyte. Also, the wave vector of the palladium cathode vibrational modes might be near zero, making it unclear how 8 and 15 THz frequencies could result. According to the literature[3], light and transverse optical phonons can only couple when their wave vectors are near zero, and when these conditions are met, a surface polariton is formed at the interface of a metallic overlayer and a metallic substrate. Perhaps this is the role of the gold plating in these experiments.

The set-up for the basic dual laser experiment consists of a 250 ml electrochemical cell, 100 ml of LiOD, a 5 × 10 × 0.25 mm palladium cathode cut from a larger processed billet, a small coil of platinum wire to serve as the anode, a second anode of gold that can be plated to the cathode *in situ* and a pair of lasers under computer control. An optical spectrum analyser is also used to check laser tuning as the experiment proceeds. A typical arrangement is shown in Figure 2.

A protocol was developed to fabricate cathodes that would respond to dual laser stimulation. The protocol consisted of 17 steps that involved polishing, annealing and cold rolling cathode material (see Figure S3 of the Supplementary Information online).

Prior to beginning the experiment, two permanent magnets were placed around the cells, aligned with the edges of the cathode, while the face of the cathode is perpendicular to the laser beams. If the magnetic field is not present, dual lasers will not trigger excess power, as shown in Figure S4 of the Supplementary Information (see online). Eleven of the tests in the dataset did not have magnets around the cells and without exception, significant excess power was not observed in those tests.

The cathode loading protocol requires the cathode to be loaded electrochemically with deuterium for 120 h at 0.05 amp, then increase the current to 1.25 amp for 48 h and plate the cathode with gold in 10 min increments while applying an assumed laser beat frequency at 8, 15 or 20 THz. Gold plating is continued in 10 min increments until excess power is observed. Cell power is held constant to within ± 10 mW. Excess power was never observed unless the cathode was plated with gold after loading with deuterium. The thickness of the gold plating was not measured due to equipment limitations, but an estimated minimum of 10 min at 1.25 amp was observed during several tests. The role of gold plating is not clear, although surface polaritons are known to exist in the interface between plated metals and metal substrates. The involvement of surface polariton in the laser triggering effect is suspected because surface polaritons would only couple with laser beams through the transverse optical vibrations and the triggering frequencies we observed at 8 and 15 THz are transverse optical (TO) vibrations, as shown in Figure S2 (see Supplementary Information online).

Polarization of the laser beams is also important. The E fields of the two laser beams should be on a line that passes from the upper left corner to the lower right corner of the cathode to enable triggering of excess power. When all protocol requirements were met, dual lasers triggered excess power in 95% of the experiments, as shown in Figure S5 of the Supplementary Information (see online).

A dataset was assembled and plotted to reveal how equilibrated excess power compared with the assumed

Figure 2. Cell inside a temperature enclosure designed to hold ambient temperature at 25 ± 0.03°C. A pair of permanent magnets is positioned next to the cell and provides approximately 625 gauss at the cathode. The dual lasers are shown in the foreground.

dual laser beat frequency. The data are shown in Figure S6 of the Supplementary Information (see online) and provide a spectrum for the thermal response of the cathodes to dual laser stimulation.

After the experiments were completed, two questions about the lasers arose: (i) Can the laser beams penetrate the gold over-layer to reach the palladium substrate? (ii) How can we be sure that the individual lasers are not responsible for the excess power?

The answer to question (i) is that the effect is well known and is called enhanced light transmission[4]. Question (ii) was answered by experiment 715b conducted at the request of Edmund Storms in May 2012. Figure S7 in the Supplementary Information (see online) shows that laser 1 was applied individually to a bulk palladium cathode provided by Storms for 1 h. Then laser 2 was applied individually for 1 h. Excess power was not observed. Then both lasers were applied to the same spot on the cathode and 200 mW of excess power was produced. Each laser was tuned to produce an assumed beat frequency of 20 THz and all protocols were followed.

The dual laser experiments seem to support these conclusions: (i) Three specific beat frequencies will trigger excess power in a deuterated cathode. (ii) Cathode fabrication, loading and laser application protocols enable excess power. (iii) An external magnetic field is required and its affect is linear. (iv) Polarization of the laser beams affects excess power. (v) Plating gold on the cathode surface after loading is required to produce excess power. (vi) Higher cell temperature produces larger excess power and is exponential in effect. (vii) The dual laser effect is highly reproducible when protocols are followed.

1. Pons, S. and Fleischmann, M., Electrochemically induced nuclear fusion of deuterium. *J. Electroanal. Chem.*, 1989, **261**, 301–308.
2. Letts, D. and Hagelstein, P. L., Stimulation of optical phonons in deuterated palladium. In ICCF-14 International Conference on Condensed Matter Nuclear Science, Washington, DC, 2008.
3. Fox, M., *Optical Properties of Solids*, Oxford University Press, New York, 2001, pp. 204–224.
4. Barnes, W. L., Murray, W. A., Dintinger, J., Devaux, E. and Ebbesen, T. W., Surface plasmon polaritons and their role in the enhanced transmission of light through periodic arrays of subwavelength holes in a metal film. *Phys. Rev. Lett.*, 2004, **92**(10), 107401-1–107401-4.