Summary of the 2014 LANR Colloquium at MIT

Thomas J. Dolan, University of Illinois

The Colloquium on Lattice Assisted Nuclear Reactions (LANR) at MIT March 21-23, 2014, was attended by about 90 people. Professors Mitchell Swartz and Peter Hagelstein organized the meeting, with contributions by JET Energy, Inc.

The main ideas of most speakers are summarized below. (A few presentations were not directly related to LANR, so they are omitted from this summary.) The following abbreviations are used here:

H = ordinary hydrogen
D = deuterium
P_{in} = input electrical power
P_{out} = output thermal power.
LANR = lattice assisted nuclear reactions
LENR = low energy nuclear reactions

Arik El-Boher, University of Missouri
Progress toward understanding anomalous heat

The Sidney Kimmel Institute for Nuclear Renaissance (SKINR) is conducting research on ultrasound stimulation, closed cell and open cell electrolysis experiments, glow discharges, and D_2 gas loading in Ti; and intending to investigate magnetic field effects, and to detect ^{4}He.

They have performed more than 1000 experiments with a Pd cathode and Pt anode. With electrolysis the reproducibility was on average about 20%. On the most successful run at P_{inet} = 0.71 W, the average $P_{out} \approx$ 21 W with power gain of 25. During electrolysis, when excess heat appears the voltage increases and fluctuates, the voltage in Experiment #64 increases from 3.5 V to 15 V, and several MJ of excess energy were measured.

They varied the Pd grain size from 10-140 μm and found that 20-80 μm grains work best for loading. They analyzed the cathodes morphology prior to electrolysis, using atomic force microscope. The data was analyzed by Power Spectral Density Function method (PSDF). Cathode which showed the typical double peaks in the range of (at k ≈ 1 μm^{-1} to 4 μm^{-1}), showed higher probability for excess heat to occur.

These experimental results suggest that resonant coupling to THz phonons on the surface may be occurring.

D+ ion bombardment sputters Pd(100) in a glow discharge, and pyramid-shape morphology appears on the surface. Ultrasound activation achieves high D/Pd loading at relatively very low current densities and reduces D desorption, giving good, long lasting reproducible excess heat results. "SuperWaves" combined with ultrasound excitation showed high reproducibility rates of excess heat, in the most successful set of experiments up to 70%. Deloading of D can be reduced by plastic deformation on the surface (pitted morphology, defects, dislocation and deep traps in the bulk lattice).

They conducted experiments with C nanotubes deposited on Pd substrates, topped by thin layers of Pd. The voltage rose from 2.7 V to 10 V during excess heat in the first burst; in the second burst the voltage rose from 2.7 V to 7.5 V, and then collapsed when they touched the power supply poles for measuring the voltage with a voltmeter.

They are beginning experiments with magnetic fields. RF emissions were measured during excess heat, indicative of inductive resonances.

"Local high intensity electric-fields at the phase boundary between Pd and non-conducting inclusions cause intense local mass transfer and local temperature increase, growth of secondary crystals and formation of highly-defective zones. Apparently, the initiation of low-temperature nuclear processes is possible just in these areas."

Mitchell Swartz, JET Energy and Nanortech
1) Excess power gain on both sides of an avalanche through a PdNi nanostructured cold fusion component
2) Successful applications of the deuteron flux equation in cold fusion

Successful LANR involves a flow of D or H, which may be induced by a concentration gradient or electric field. Swartz's deuteron flux equation predicts that electrolysis can quench LANR. Bubbles should be avoided, because they prevent gas from entering the metal. Codeposition (such as plating Pd from a Pd salt) results in faster hydrogenic loading of the cathode, with improved repeatability and control.

It is desirable to operate electrolytic cells at high impedance, such as by using ultra-pure water with no salts added. From operation at many different input powers, the "optimal operating point" may be found, where the excess heat generated is maximized for many types of LANR systems (electrolysis, He production, Pd/D, Ni/H, Pd black, …). This point occurs at low P_{in} for tritium production, at medium P_{in} for ^{4}He production, and at higher power for nanomaterial systems.

JET Energy has operated many "Phusor®" cells with Ni cathodes, Pt anodes, H_2O, and energy gains of 2-4. Adding D_2O to the H_2O increased the output under certain limited conditions involving concentration and electrical current. Outside of that region, the addition of D_2O damaged the Ni, and killed the reactions. The cathode shape was optimized by 2D calculation of the electric field distribution. They demonstrated heat production by operating fans with Stirling engines powered by excess heat for many hours.

They have studied many materials, including ZrO_2 and nanomaterials. Grain size is critical for optimum performance. Deuterium (D) loadings up to 3 have been attained in shallow traps.

The "Nanor®" devices have nanoparticles containing ZrO_2-PdNiD, loaded with D and hermetically sealed. Reactions may be activated by electric fields, by magnetic fields, by lasers, by ultrasound, or by high loading of D. The resistance increases during loading. One should match the power supply impedance to the nanor input impedance for optimum energy transfer. Energy gains of 3 have been attained at 1.5 W input power, and gains over 20

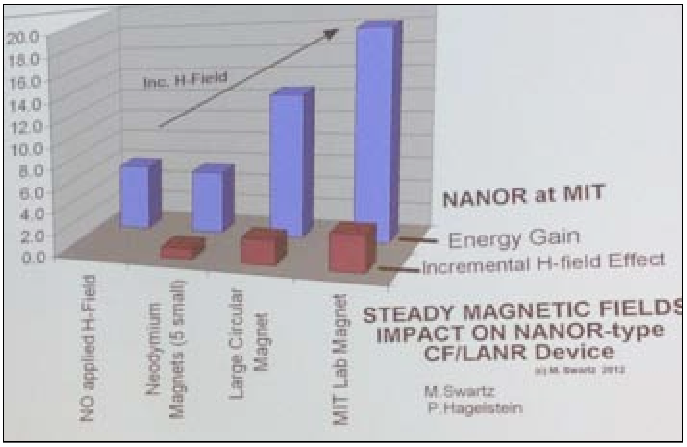

Figure 1. Increase of energy gain by applied magnetic fields.

were achieved at the open demonstration at the IAP Course at MIT in January 2012 through May 2012. Tardive thermal power (also called, when integrated over time, "heat after death") occurs when reactions continue to generate heat after Pin is switched off. Figure 1 shows how the energy gain is increased by steady magnetic fields.

Swartz suggests that the first optimum operating point may be induced by phonons, and the second (at higher power in metamaterials treated by very high magnetic fields), by magnons.

Electron avalanches can occur, damaging the cathode and ending the excess heat effects, so they must be avoided.

Peter Hagelstein, MIT

1) Controlled Karabut experiment at SRI

2) Model for fractionation and inverse fractionation

3) Anomalies associated with fracture experiments

In the experiments of Karabut, lattice vibrational energy may have led to the collimated 1-2 keV X-ray emission. At higher applied voltages (2.6 up to 4.2 kV) the X-ray peak shifts upwards.

How could phase coherence be achieved? Intense X-rays appear 1 ms after current termination, which is possible with vibrations. Nuclear transitions near 1 keV are not expected in elements like Ni and Pd. One possibility is a ^{201}Hg impurity, which has an energy level at 1.565 keV.

To test the hypothesis that multiple phonons contribute to excite this level, Tanzella and coworkers at SRI did an experiment using capacitive coupling to drive a 73 μm Cu foil at about 15 MHz, looking for internal conversion electron emission and X-rays. Large amounts of electron emission were observed when the foil was driven on resonance. This effect occurs at much too high a level to be internal conversion of Hg, and was found to be uncorrelated with Hg on the surface. A strong response was seen in the X-ray detector with Hg present, and not with pure Cu. Preliminary indications were that this might be the 1.5 keV line, appearing at the highest energy at the T2 resonance near 14.7 MHz drive frequency. Subsequent work carried out after the meeting (involving a recalibration of the energy scale) suggests that the large signals in the X-ray detector are more likely noise due to ionized electrons in air, probably produced by lower energy X-rays. Weaker signals are present in some of the data near 1.5 keV, which are of interest for further study.

The hypothesis is that vibrations are up-converted to produce nuclear excitation, with the maximum inverse fractionation energy determined by the frequency of the vibrations, and the size of the sample. Electron emission would be explained through off-resonant phonon exchange with the conduction electrons in the Cu, and are expected to have a maximum energy similar to the maximum X-ray energies observed at a given drive voltage and frequency.

Hagelstein presented two theoretical results relevant to this and other anomalies in LENR research. One is a simple model (the lossy spin-boson model) which shows efficient coherent energy exchange under conditions of fractionation. This model has been analyzed in weak, intermediate, and in strong coupling regimes, and has been published. The motivation for the development of the model was to account for the absence of energetic nuclear particles in the Fleischmann-Pons experiment when energy is produced. Determining whether the model applies is problematic, since the microscopic physics is "hidden", due to the absence of energetic products that might otherwise show what is going on. Because of this Hagelstein was motivated to seek other experiments in which fractionation effects could be observed more readily. This led Hagelstein to focus on the problem of up-converting vibrational energy to produce nuclear excitation. The idea was to pick the stable nucleus that had the lowest excitation energy from the ground state (Hg-201); if this level could be excited by the up-conversion of vibrational energy, it would be easy to tell (by detecting electron emission from internal conversion and X-ray emission). In essence, by studying vibrational excitation of the 1565 eV level in Hg-201 much can be learned about how nuclear energy is down-converted to vibrational energy in the Fleischmann-Pons experiment.

The other theoretical result discussed was a new fundamental Hamiltonian for condensed matter, in which a relativistic description is used for the nuclei. In this case there is a coupling between vibrations and the internal nuclear degrees of freedom that appears naturally. Under normal conditions, this coupling can be rotated out, leading to textbook physics; however, in the presence of strong loss and a highly-excited vibrational mode it is possible for coherent dynamics to occur, based on the relativistic interaction. A reduction of this new fundamental Hamiltonian to a lossy spin-boson model was presented, and solutions were described. According to this model, the inverse fractionation energy for a particular experiment based on a Nb cathode in the Karabut experiment, vibrated at the fundamental at 100 MHz, would be predicted to be about 5 keV for a sample containing about 10^{20} atoms (with about half assumed to be moving to connect with the idealized model); where in the experiment collimated X-rays were seen up to about 4 keV.

In fracture experiments of Carpinteri, Cardone, Lucidogna and coworkers acoustic emissions, electromagnetic emissions, neutrons, alphas, and elemental anomalies were reported. Hagelstein drew attention to this in connection with the very large amplitude and high frequency vibrations produced in experiments showing catastrophic failure of (large) granite test samples with increased load. Elemental anomalies show a reduction of iron and an increase in aluminum on the surface of the fracture plane, which prompted the Torino group to conjecture about a lattice-induced fission reaction

$$^{26}\text{Fe} + 42\text{ MeV} \rightarrow 2\ ^{27}\text{Al} + 2\text{n}$$

The Torino group suggested that this reaction might account for aluminum mines being located in fracture zones, as well a reduction in iron and a corresponding increase in aluminum on geological time scales.

People have proposed models to account for elemental anomalies in LENR experiments (Mizuno, Miley, Piantelli, and others). Some models are closely connected with fission models in the literature, which provided motivation to consider results from fission experiments. Photodisintegration in the 10-30 MeV range is dominated by the giant dipole resonance, and leads to n, p, and alpha emission (but not nearly-equal fission fragment yields). Hagelstein showed that to split Fe into near equal mass daughters requires electron or gamma energies > 1 GeV, that it was much more probable to have highly unequal mass products, and that fission was highly nonselective. In essence, there is no way that an incoherent fission mechanism could be consistent with the elemental anomalies in the fracture experiments, or in the LENR experiments.

Instead, Hagelstein argued that if the elemental anomalies were due to transmutation, then the only theoretical possibility had to be fission as a coherent process (for the examples where the products were lower mass than the host isotope mass), since such a process could be selective. Based on the earlier discussion of models, there was a basis for coupling and energy exchange by inverse fractionation to excite the nuclei; however one needs long-lived states to accumulate significant excitation probability. In general, the states one would need to model this in detail theoretically are not known at present. However, in recent experiments by Rudolph and coworkers high spin nuclei have been studied in the mass 60 range. The states at the bottom of the band edge do not have gamma decay paths, and are reasonably long lived. It was proposed that one possibility for coherent fission was sequential coherent excitation of such long-lived states with increasing angular momentum. When the nuclei have been spun up sufficiently, then decay to near equal mass daughters might be expected, providing for the required selectivity.

Hagelstein also pointed out that inverse fractionation also had the potential to produce incoherent disintegration, and that this was most likely the mechanism responsible for low-level fast protons, fast neutrons, and fast alphas (all above 10 MeV) in Lipson's experiment and in the SPAWAR experiment. The idea is that inverse fractionation would favor excitation in the giant dipole resonance regime, producing an excited compound state that would decay giving energetic n, p, and alphas; and from the spectra and relative yields in the codeposition experiments, one had the possibility of determining consistency with this mechanism. Either coherent or incoherent excitation of the host metal nuclei would require strong excitation of THz acoustic phonons. The strongest coupling with optical phonon modes is to internal nuclear degrees of freedom in protons and deuterons, and from experiment these (both protons and deuterons) seem to be reasonably inert against this kind of decay.

Vladimir Vysotskii, Kiev National Shevchenko University

1) Review of cavitation x-ray emission

2) Observations of biophysical effects from cold fusion

3) Application of coherent correlated states of interacting particles for cold fusion optimization

This report presents a comparative analysis of two processes - generation of soft X-ray radiation during liquid cavitation and generation of such radiation in LENR experiments.

Soft X-rays (1-3 keV) have been observed in many LENR experiments involving electrolysis, gas discharges, bubble cavitation, and other processes. High pressure liquids (such as oil or water) flowing at high speed through a 1 mm orifice lead to bubble cavitation downstream. At 90 atm a bright, directed luminous beam appears, which is not due to normal sonoluminescence. The radiation is also not due to Cherenkov radiation emitted by fast electrons. Soft X-rays (1-2 keV) are observed outside the tube where the bright plume appears, and the X-ray peak shifts to higher energies as the fluid pressure is increased. The peak intensity is seen to be near the outside of the tube, not at the bright plume. Acoustic pulses are measured at the tube surface.

As the liquid flows downstream from the orifice small cavitation bubbles grow large, then collapse, sending out acoustic waves, which develop into shock waves and reflect from the outside of the tube. The reflecting shock waves energize electrons in the outer surface, which generate the X-rays. At high pressures the inward reflected shock waves also excite atoms at the surface of the plume, generating optical radiation and X-rays there. With a steel pipe the X-ray peak is at 1-1.5 keV. With a Pb coating, the peak shifts to about 4.5 keV.

Formation of micro-cracks in the lattice can also generate acoustic pulses during electrolysis, gas discharges, or thermocycling.

There is a high probability that X-ray phenomena observed during explosion of cavitation bubbles (and connected with the interaction of cavitation induced shock waves with outer surface of working chamber or distant screen) are similar to X-ray phenomena observed near outer surfaces of LENR installations. Instead of being related to LENR processes, they can take place during generation of similar shock waves at formation of numerous micro-cracks at loading and interaction of hydrogen or deuterium with metallic matrices during electrolysis, gas discharge or thermocycling.

Vysotskii also discussed nuclear transmutations in biological systems. For example, a solution of D_2O, sugar, $MnSO_4$, and bacteria Saccharomyces cerevisiae gradually developed ^{57}Fe, which was measured by Mossbauer spectroscopy. If the $MnSO_4$ were not present, or if H_2O were used instead of D_2O, then no iron was formed. Mass spectrometric data showed the same conclusion. Another experiment appeared to produce ^{54}Fe from a solution containing water, sugar, ^{23}Na, ^{31}P and Escherichia coli. Results may vary, due factors such as temperature, pH, nutrients, bacteria, and trace elements. In one experiment a transmutation rate of 10^{-6} (^{57}Fe atoms)/(^{55}Mn atom-s) was attained. Thermal Ion Mass Spectrometry measurements indicated a decrease of ^{55}Mn atoms and an increase of ^{57}Fe atoms.

A microbial catalyst-transmutator (MCT) might be developed to perform useful conversions, such as transmutation of radioactive ^{90}Sr and ^{137}Cs into stable elements for remediation of radioactive wastes and contamination. They compared decay rates of normal fission reactor water with the decay rates of (fission reactor water plus MCT materials) and found that the MCT solution reduced the activity faster than ordinary decay. In another experiment the decay half-life of ^{137}Cs was reduced from 30 years to < 500 days. (Accelerated decrease of radioactivity has also been observed in some regions in the Chernobyl accident zone, but this may have been due to rainfall washing it away.)

A theoretical model of low energy nuclear transmutation in biological objects was also discussed. It was shown that the most probable mechanism for suppression of Coulomb barrier action and optimization of LENR in biological systems is associated with the self-formation of coherent correlated states during monotonous changing of nano-wells in different growing biological macromolecules and their ensembles.

Vysotskii described a theory of such transmutations, based on the Schrödinger-Robertson uncertainty relation. As a microscopic crack width increases, the potential well depth increases, and the oscillator frequency changes. In some cases the crack width may oscillate due to lattice vibrations, affecting the oscillations and the cross-correlation coefficient r. When the cross-correlation coefficient $r \rightarrow 1$, the effective value of the Planck constant becomes very large, δp and δq become large; and the tunneling probability becomes significant. It was shown that in real nuclear-physical systems at $1-|r|=10^{-5}-10^{-6}$ very sharp growth (up to a factor of 10^{50} -10^{500} and more!) of Coulomb barrier penetrability at very low energy of interacting particles is possible. This process could be stimulated by ultrasound or by THz laser radiation. In the Letts, Cravens, and Hagelstein experiment (irradiating a surface at the beat frequency of two laser beams) the fundamental optical phonon resonances in PdD are about 8 and 10.5 THz. Additional, higher peaks are seen at about twice these frequencies due to parametric resonances. The coherent oscillations make $r \to 1$, and the quantum effects facilitate penetration of the Coulomb barrier.

An applied magnetic field affects the ion resonant frequencies, enhancing coherence. A coherent correlated particle state can be achieved by:

* monotonic decrease or increase of the harmonic oscillator frequency of a particle in a parabolic field (as by changing a crack width)
* periodic variation of the parabolic potential well width or depth.

Frank Gordon, SPAWAR Systems Center (retired)
Observations of a variety of codeposition protocols used to prepare cold fusion cathodes

The Naval SPAWAR Systems Center has pioneered the development of codeposition electrolysis, whereby Pd is deposited from a solution such as $PdCl_2$ or LiCl. They took photos showing many small hot spots, and a PZT transducer detected bursts of sound.

It is desirable to begin at low current density and gradually increase it. They achieved high loading ratios in seconds, and D/Pd loading ratios > 1.1 may be attainable. The "Galileo Protocol" was followed by several labs, using CR-39 detectors to measure charged particles. They did plating 2 weeks and loading 1 week, then saw particle tracks. SRI, Berkeley, and Prof. Oriani all saw tracks.

One interesting possibility is that super-abundant vacancies (SAV), produced during codeposition with $PdCl_2$, are associated with heat generation. The lattice contracts. The F-P experiment may have been effectively a codeposition experiment.

Larry Forsley, JWK International Corporation
1) Neutron and charged particle spectroscopy
2) Enhanced Tc superconductivity and anomalous nuclear emissions in YBCO and palladium

Larry Forsley described many diagnostic techniques to measure neutrons and charged particles. ^{3}He detectors moderated with polyethylene can measure neutrons well, but do not give neutron energy spectra. Liquid scintillators are sensitive to alphas, betas, gammas, and neutrons, but need to be in close proximity to sources of alphas and betas.

A time-of-flight system with two scintillators can measure the neutron energy spectrum.

A high purity germanium (HPGe) detector gives excellent gamma energy resolution from 5 keV to 3 MeV, but is expensive and must be cryogenically cooled. One damaged by neutrons cost $5k to repair.

CR-39 nuclear track detectors have been successful at measuring approximate energies of protons, alphas, and neutrons. The microscopic tracks can be etched and examined to determine particle type and energy. An automated scanner can analyze a 1x2 mm area to measure 10^5 images in minutes. Tracks are seen on the back side of Pd and Au. Triple tracks give evidence of high energy neutrons from $^{12}C + n \to 3(^4He) + n'$.

About 10000 people are working on high temperature superconductivity (HTSC), and several G$ have been spent on it. PdH_x exhibits superconductive behavior when T < 9 K, and also at high loading when x > 1 and T < 77 K.

Ferromagnetic Ni suppresses nuclear tracks from PdD codeposition, but Au, Ag, Pt do not.

YBCODx exhibits nuclear reaction effects, such as energetic particle emission. Celani saw neutron emission only during superconducting transition in YBCO in LN2 at 80-100 K. If YBCO/D is loaded next to a weak neutron source, it increases neutron flux. Hirsch claims quench of large superconductors produces 511 keV annihilation lines. Both PdD and YBCOD produce >14 MeV charged particles and 2.5 and 14 MeV neutrons. Ti also has strange effects.

Tom Claytor, LANL
Recent tritium production from electrically pulsed wires and foils

Tom Claytor discussed the surface effects of codeposition. Pure Pd is desired, but most Pd contains C impurities from the drawing process. They measured ^{3}H evolution from wires and foils. Plasma cells yield ~ 500 pCi/hr-g(Pd). Ni foils yield ~ 25 pCi/hr-g(Ni). Pulse rise time and current density affect the surface morphology. Grains form with about 100 μm size. The surface sometimes looks like tiny cauliflowers. They looked for Rn, but saw none. Sometimes the radiation persists for hours after the current is turned off.

It appears that super-abundant vacancies (SAV) can help facilitate excess heat generation. Up to 6 H atoms may be strongly trapped per vacancy. The lattice parameter shrank by about 1.5%. Codeposition can deposit Pd, H, and vacancies simultaneously.

Yasuhiro Iwamura, Mitsubishi Heavy Industries
Deuterium permeation induced transmutation experiments using nano-structured Pd/CaO/Pd multilayer thin film

Iwamura's group has studied D_2 gas permeation through thin films of Pd-CaO and observed the following transmutations:

$$^{133}Cs \to ^{141}Pr$$
$$^{88}Sr \to ^{96}Mo$$
$$^{135}Ba \to ^{149}Sm$$
$$^{44}Ca \to ^{48}Ti$$
$$^{182}W \to ^{190}Pt$$

which correspond to addition of 2, 4, or 6 D entering the nuclei. They see no transmutations of Cs with H, only with D. They did not perform calorimetry.

There is much more Pr generated than could be expected from accidental contamination. Hioki *et al.* (Toyota Laboratories) independently confirmed the production of Pr, though at lower levels. Iwamura typically found about 10^{-8} g (products) per cm^2, which has recently been increased to 10^{-6} g (products)/cm^2 using electrochemical permeation. In the past they used batch processing, but now they are developing consecutive processing, passing Cs solutions multiple times in a flow loop through an electrolytic reaction cell. High pressure (~200 kPa) and temperature (~80 C) increase the Pr yield, but T > 100 C reduces the D/Pd loading to < 0.1. Consecutive processing at 0.1-0.2 mA/cm^2 can achieve reaction yields > 1 μg/cm^2-week, about an order of magnitude greater than batch processing yields. Batch processing deposits the products on a thin film, but consecutive processing leaves the products in the solution for easier separation.

X-ray photoelectron spectroscopy shows clear peaks due to Pr levels near 931 and 952 keV. They have measured several gamma peaks using an HPGe detector. An unidentified peak at about 1445 keV may be due to a minor short-lived impurity.

Olga Dmitriyeva, Coolescence
Using numerical simulations to better understand the cold fusion environment

In order to study how a chemical environment can facilitate cold fusion, Olga Dmitriyeva is using Density Functional Theory (DFT), which is used for numerical simulations of nuclear interactions.

The Schrödinger Equation would describe problems by trying to solve the wave equation in 3 dimensions, but it cannot be solved for many bodies. DFT uses equations for single non-interacting particles in effective potential wells, and solves for the electron density. The ground state properties of a many-electron system are uniquely determined by an electron density n(r), which defines the potential, which governs the Schrödinger Equation solution for the wave function ψ(r). The electron density that minimizes the overall functional energy is the true electron density. One example of a functional is a definite integral operator. An "exchange-correlation functional" is used to link DFT to the many-body Schrödinger Equation. A Local Density Approximation and a Generalized Gradient Approximation are used to simplify the equations. To simplify the equations at small radii (below a cutoff radius) a pseudo-potential replaces the all-electron potential, eliminating core states; and pseudo-wave functions with fewer nodes replace the valence electrons.

DFT can predict electron density, total energy, lattice constant, bond lengths, and vibrational frequencies, but it cannot predict excited state energies, wave functions, superconductivity, excitons, or electronic transport. With other methods and approximations DFT can estimate band structure, the Fermi surface, densities of states, and electronic transport.

Using DFT Dmitriyeva has estimated the binding energy and separation distance of H_2 and PdH, which are within about 10% and 2% of the reference values, respectively. The calculated lattice parameters of Pd, PdH, Ni, and NiH are close to experimental values, and the H adsorption energies are within 0.2 eV for Pd, Pt, Cu, and Ni.

DFT is used to study screening potential, adsorption energy, and transport properties at high H/Pd loading ratios; effects of cracks and crystallographic planes; and effects of etches and impurities. They find that H adsorbs preferentially on the (100) and (111) planes, while halogens adsorb on (100) and (110). Thus, wet etching can change the surface morphology, and halogens may compete with H for adsorption sites.

DFT facilitates understanding of adsorption, desorption, surface morphology, cracks, vacancies, and other material properties. .

David Nagel, NUCAT Energy, LLC and George Washington University

Scientific and practical questions about cold fusion

There are some significant questions about LENR that are not receiving adequate attention, so David Nagel has compiled a list of research questions, some of which point towards new experiments. Some example questions are:

Is there more than one mechanism to explain experimental results? This could be addressed by using the same materials in both electrochemical and gas loading experiments.

Is the process due both nuclear and chemical reactions, or entirely nuclear?

Do the reactions occur at the surface, in the bulk, in vacancies, or elsewhere?

What roles are played by electrical, mechanical, chemical, or nuclear resonances?

What roles are played by electrical fields, magnetic fields, electromagnetic waves, and ultrasound?

What role is played by sudden temperature changes?

Nagel plans to publish articles on these and other issues under three categories: "Mechanisms and Materials", "Experiments, Theories, and Computations", and "Engineering and Applications".

Brian Ahern

Nanomagnetism for energy production

Takahashi did not see results at particle sizes ~ 20 nm, but saw results later at 5-10 nm. At 5-10 nm nuclei have large, slow oscillations. Ahern saw 80 W in, 85 W out with 5 nm Ni-Pd in ZrO_2 powder. Each grain has about one million atoms.

Arthur Manelas was interested in high voltage pulses through magnetic nanopowders and did experiments. He developed a "Solectria" automobile, in which the power source involves $SrFe_{12}O_9$ nanograins. The ferrite core operated below ambient temperature, and appeared to power a 60 W light bulb for 20 months. Ferrites at 3-12 nm may have cooperative oscillations and magnetic vortices, but the energy source is not understood. In one experiment at home the powder exploded in a heated dewar.

Manelas is now incapacitated by a medical problem, and he left no clear circuit diagram of his apparatus.

Francesco Celani, Italian National Institute of Nuclear Physics

Glass surface co-factors in the generation of anomalous effects under H_2 gas at high temperatures

Since 2002 Celani's group at INFN-LNF (Italy) has done several experiments with 100cm long, 50-100 µm diameter wires of Pd, Pd-Y, Ni, loaded with H or D at high temperature and mild pressures (2-20 bar), and coated with hundreds of thin (2-50 nm) layers of very diluted, soluble salts (usually nitrates) of elements like Sr, B, Th, P, C, and Si, Pd, and Ni at nanometric sizes. The multi-coating was inspired by Y. Iwamura's procedures since 2000, and the nanomaterials, by Y. Arata since 1996.

Recently new experiments have been performed using special surface treatments of 200µm Constantan (Cu-Ni-Mn alloy) wires. The rationale behind this choice is the high catalytic activity for hydrogen molecule splitting predicted by S. Romanowski-Poland (1999) for this alloy. The main aim of surface treatments is the creation of micro/nanostructures on wire surfaces, a requirement for the "Energy Localization" effect (found, by change, by E. Fermi-Italy on 1954). Recently it was well described by B. Ahern (USA). The INFN-LNF group considers the presence of monatomic hydrogen and energy localization in nanostructures two important "boundary conditions" for anomalous heat generation due to local non-equilibrium conditions.

In some of the experiments two Constantan wires (one with ~500 thin layers), were inserted in 1 mm diameter flexible glass sheaths (hundreds of 3-10 µm fibers) and braided with a 100 µm Pt wire.

The experiments seem to indicate the possibility of an active role played by H adsorbed on glass fibers for apparent excess heat generation, *i.e.* the glass could be a co-factor.

Each glass sheath has a total surface area of ~ 1 m^2, containing ~ 10^{19} H atoms, according to old (1927) measurement made by I. Langmuir-USA.

In one of the experiments reported, they applied power to the Pt wire, and the Constantan wire was thus indirectly heated.

With an even larger total glass area (up to about 50 m^2) and the addition of 10 m long, 200 µm diameter W, the internal temperature rose from 300°C to 410°C as the pressure was reduced from 2.5 bar to 0.2 bar: remarkably larger than a previous long during experiment where the total glass surface was about 8 m^2. Also the external temperatures of glass test tube were larger when the amount of glass sheaths was increased.

The glass fibers appear to improve the anomalous heat effect, as if there were nanostructures coated with hydrogen mono-layers. A possible hypothesis is that irregular (non-crystalline) distributions of atoms in glasses may contribute to the "energy localization

Pamela Mosier-Boss, Visiting Scientist, MIT
CR-39 detecting emission during Pd/D codeposition cold fusion

CR-39 nuclear track detectors are used to measure proton, alpha, and neutron emission from Pd/D codeposition electrolysis cells. Some detectors have a 60 μm polyethylene film, which blocks 7 MeV alphas and 1.8 MeV protons. Pd metal did not penetrate the film. The pits were etched and then machine-scanned to tabulate the track parameters.

12.6-17.5 MeV protons appear as 3.4-14 MeV tracks after passing through Pd, water, and the plastic film. Researchers expected a continuum of energies, but found a trough at 11 MeV. Perhaps 11 MeV protons are consumed by nuclear reactions. Proton capture by Pd to produce Ag and Cd could explain the loss of these protons. Ag and Cd have been observed by John Dash.

Three methods of analysis yielded similar results, indicating the emission of 2.5-12 MeV neutrons, 2.5-15 MeV protons, and energetic alphas.

CR-39 front side tracks were due to 7-15 MeV alphas, 2.6-3.4 MeV protons ($d+D \rightarrow p+t$), and 12.6-17.5 MeV protons ($D+{}^3He \rightarrow {}^4He+n$). The DD reaction branching ratio was estimated to be

$$n/p = \text{rate}(D+D \rightarrow {}^3He+n) / \text{rate}(d+D \rightarrow p+t) = 8.3$$
(protons are undercounted, due to attenuation)

In previous work Lipson estimated $n/p = 4.75$.

Some tracks on the back side of the CR-39 were from energetic neutrons. The reaction

$$n + C \rightarrow 3 \text{ alpha}$$

produces triple tracks, which were detected.

The appearance of new elements and the emission of 7-16 MeV alphas suggest fission of some Pd atoms. The new elements concentrations vary widely from one spot on the cathode to another.

John Dash, Eugene Mallove Research Laboratory
SEM and energy dispersive spectrometer studies of metal surfaces interacting with hydrogen isotopes

John Dash presented data from Pd closed-cell electrolysis experiments using H_2SO_4 in the electrolyte and a recombination catalyst to avoid H_2 and O_2 accumulation. A control cell used a Pt cathode, instead of Pd. One Pd cathode buckled from reactions. They studied the cathodes' surfaces with a scanning electron microscope and with energy dispersive X-ray spectroscopy. After operation the surface had many small craters (10s of μm). A dark crater had substantial concentrations of Ag and Cd. The radioactivity of some uranium components decreased after exposure to hydrogen plasmas.

Takahiko Mizuno, Hokkaido University
Replicable model for controlled nuclear reaction using metal nanoparticles

Mizuno's group tested 73 combinations of metals and gases, at T = 200 C and p = 100-300 Pa. With Ni nanopowders and D_2 gas about 75 W excess heat was generated for over one month with a coefficient of performance (P_{out}/P_{in}) = 1.9, yielding 108 MJ of excess energy. They cleaned the metal, then used a cycle of (1) heating in vacuum, (2) exposure to plasma discharges, (3) heating in H_2 or D_2 to load it, returning to step (1) each cycle, finally cooling in vacuum. To generate excess heat they activated the Ni with this cycle, heated the Ni to >200 C, and then supplied H_2 or D_2 at 100-300 Pa.

The electrode temperature rose from 230°C to 380°C as the D_2 gas pressure was elevated from 150 kPa to 360 kPa over a period of about an hour, and the reactor temperature rose from 56 C to 71 C during the same period. At P_{in} = 80 W, Pout rose to about 155 W.

For one 37-day run P_{in} = 81 W and P_{out} = 115 W, so P_{ex} = 34 W, which would yield 108 MJ of excess energy over the 37 days. Assuming that the mass-3 gases measured by a mass spectrometer were ^3H and ^3He, they estimate the energy released by DD reactions to be 78 MJ, which is comparable to the thermal analysis value of 108 MJ. owever, the amount of mass-2 gases appeared to increase during the experiment, instead of decreasing as expected.

They have a 1 kW reactor (Scarlett) and a 10 kW reactor (Catherine) under preparation and testing.

John Wallace
Relativistic quantum mechanics of cold fusion

As a metallurgist John Wallace is interested in ferromagnetic effects. He has studied propagation of electromagnetic waves at 1 kHz - 3 MHz in an iron bar, from which a dispersion relation can be measured. The result indicated an anomalously low effective electron mass $m^* \sim 10^{-9}\ m_o$ (rest mass), which is not understood, but may be relevant to LANR, where ferromagnetic effects are probably significant.

Wallace did a quantum mechanical analysis with a 3-dimensional spherical potential, with a "dimension of randomization" parameter $\varepsilon = \hbar/mc$. He assumed a 3D spherical potential, then studied the limiting case where the potential $V \rightarrow 0$ to see the resulting quantum numbers.

A high-energy electron may go into a D nucleus, resulting in a zero spin state boson, which may lead to reactions.

George Miley, University of Illinois
Ultradense clusters in nanoparticles and thin films for both hot and cold fusion

Ultradense clusters of H or D in nanoparticles and in thin Pd films can promote LANR. They do loading and unloading by cyclically cathodizing and anodizing the Pd film, which creates dislocation loops and cluster formation, Figure 2.

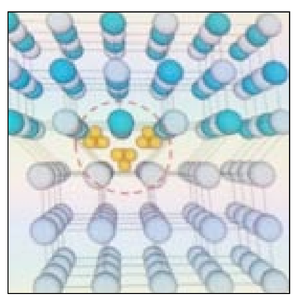
Figure 2. Sketch of H/D clusters (yellow) in a dislocation loop. (Courtesy of George Miley)

The magnetic moment of H_2-cycled in Pd/PdO:H_x samples at $2 \le T < 70$ K is much lower than that of the original uncycled Pd/PdO:H_x.

They have considered a conceptual design of an LENR power source, based on present power density limits, assuming good control and long run times are achievable. LENR units could have power/mass ratios ~ 1 kW/kg, similar to those of ^{238}Pu radioisotope generators used for space applications. The reactor could be a long cylinder containing nanopowder reacting with flowing H_2 gas at high temperature, with the H_2 pressure cycling up and down. The outside fins would have thermoelectric generators cooled by flowing water. Two such reactors would be coupled so that one is generating while the other is regenerating (pausing in the sinusoidal temperature variation). They estimate a capital cost of about \$2/W installed. The nanopowders would cost about \$500 to replace every 6 months, and other components should be reliable. They estimate a cost of electricity ~ 7 cents/kWh. Such power units would have great market potential. Nanopowder lifetimes are a major uncertainty, and coagulation must be avoided. Sintering can be reduced by using a thick oxide layer, optimizing composition, embedding the particles on a substrate, and by avoiding hot spots.

Gas-loaded nanoparticles have more surface area than thin films and higher excess power. The particles might be Pd-Zr, Pd-Zr-N (high Pd), or Pd-Zr-Ni (low Pd). The alloy should be baked to promote oxidation, then ball milled in Ar to achieve particle sizes ≤ 50 μm. During absorption chemical energy yields 690 J, but the total measured energy is about twice as large, due to LENR effects. During endothermic desorption energy should be supplied to the powder, lowering the temperature, but the temperature actually rises, due to LENR effects.

One experiment yielded 4769 J from 23 g of nanopowder in about 4 hours, of which only 690 J were from chemical energy. High temperatures achieve better yields, but can damage the nanopowders. They are working on vacuum chamber design to control heat flow.

Miley also presented some slides about ignition of inertial confinement fusion targets by deuterium beam injection into a D-cluster foil. The idea is that CF reactions in the foil would provide high power to ignite the target. A Trident deuteron acceleration experiment is considered at LANL.

The crucial dimension for success is the size of the defects (nm), not of the particles (μm size)

Nikita Alexandrov, Permanetix Corporation

Advanced analytic and highly parallel cold fusion experimentation

Nikita Alexandrov, President of Permanetix Corporation, presented his view of the way forward in understanding and engineering the LENR effect. Alexandrov compared this scientific problem to the human genome project, a huge scientific problem that will be solved by lowering the cost of data and developing new tools and experimentation methods. Over $250 Billion a year is spent on alternative energy research and the cold fusion field needs to be ready to adapt to utilize these resources.

The combinatorial material discovery technique is already being used in other fields to identify materials, which are hard to predict. Sputtering of thin films is one technique which is scalable, familiar to industry, and very repeatable. By combining a combinatorial material discovery process with new real-time analytical tools, we can drastically lower the cost of data and accelerate the understanding of this complex effect.

He discussed the benefits of real-time analytic tools, like an insitu soft radiation detector that his company has developed for this field. By examining soft radiation that would otherwise never be detected outside of the experiment, more can be understood about LENR; and single nuclear events can be detected, as well as individual molecules of tritium. He believes that low cost helium isotope analysis needs to be developed for the field, and proposed a low-cost residual gas analyzer coupled with a custom sample processing system that Permanetix is exploring.

Twenty-five year old Nikita Alexandrov issued a sort of call to action to other young scientists: For a generation whose famous technical advances include facebook and phone apps involving birds, this is an amazing opportunity to use that aggressive innovation, flexibility and forward vision to build a valuable technology and change the world.

Charles Beaudette

Post Missouri priorities for cold fusion

Charles Beaudette discussed the relation of the CF group with the scientific community and with society. At the 1989 APS meeting Caltech people opposed CF, citing "bad calorimetry", but some technical papers in the Journal of Electroanalytical Chemistry should have been recognized as good. The MIT physics staff stated, "theoretically impossible".

Little credibility was accorded to positive results. Most science reporters do not have a science background. They ingratiate themselves with a few scientists, and treat the controversy like a horse race – "Who is winning?"

In one instance Miles explained about importance of gas loading, but reporter ignored the point and could not judge without the advice of Lewis, who opposed CF. The good 1998 report in *Wired* was an exception.

Reporters chasing claims of power production gave prominence to Rossi E-Cat demos, but not to Piantelli.

The Sidney Kimmel Institute for Nuclear Renaissance is doing good work.

Fortunately, some countries like Japan take CF seriously

Nathan Cohen, Fractal Antenna Systems, Inc.

The tortuous path of innovation and implications for cold fusion in the next decade

Most things in universe are fractals, which must have some degree of self-similarity. Fractal-shaped antennas have several resonances, which improves their operation.

Paradigm shifts may take years, until the opponents retire or die. Cohen cited the example of Alfred Wegner, so proposed tectonic plate theory.

Adoption of innovations is usually not controlled by the end users, but by competitors, media, investors, and government regulations. "Patent napping" refers to filing a patent application, getting a patent, and then waiting for it to bring success.

John Fisher

Polyneutron theory and its application to excess power generation in three types of devices

John Fisher's son Mark Fisher provided information about John's impressive career, then introduced John's talk.

After initial skepticism about CF, experimental data from Oriani and Miles convinced Fisher that CF is real, and he developed polyneutron theory to explain the phenomenon. Polyneutron theory assumes that neutrons may bind in clusters An, where A ≥ 6 is the integer number of neutrons in the cluster. Clusters can grow via reactions like

$$^{A}n + D \rightarrow {}^{A+1}n + H$$

And they can decay by beta or alpha emission. Four growth reactions from D can be followed by two beta decays and one alpha decay with release of 21 MeV:

$$4D \rightarrow 4H + {}^{4}He + 21\ MeV + 2\ beta$$

There should be one alpha and four protons for each 21 MeV. After the current shuts off the beta and alpha decays continue as the polyneutron population decreases, providing tardive thermal power ("heat after death") for a few hours.

In nature poly-n reactions might occur in stars or inside the earth, with very long lifetime decay tails of An. LENR labs might have accumulated poly-n. Part of a poly-n could attach to a heavy nucleus, such Cs, transmuting it during several beta decays. Poly-n can also cause fission of heavier element, such as Pd.

The 21 MeV would be increased by the energy released by fissions, but decreased by the energy lost to antineutrinos during beta decay. The neutrons emitted are captured locally before they can escape and be counted externally.

Bubble growth and collapse near the cathode surface cause turbulent mixing of D and poly-n, and enhanced reaction rates, which raise the temperature explosively, causing craters. Deuterium is the primary fuel for poly-n growth, and heavier elements (Ni, Pd, Ca,…) may be fuels for poly-n fission.

The reactions may be controlled by cooling water flow, external heating power reduction, radiation losses, or D fuel supply rate control.

The essential ingredients for economic power generation are D, Ca, Ni (even-A), a poly-n seed, mixing, and a control system.

Robert Smith, Oakton International Corporation
Assuring sufficient number of deuterons reside in the excited band state for cold fusion

The Coulomb repulsion can be reduced by coherent action of many deuterons in the ion band state theory of Talbot Chubb and Scott Chub. The number N_{cell} of participating deuterons should be ~ 10^5. The problem is how to lift many ions into the band state (increasing N_{cell}), where their wave functions overlap, facilitating interactions. Heat must be removed to prevent lattice overheating and melting. A cube with a fractal hole pattern could provide a large surface area for LENR and good channels for flowing gas coolant.

The reactor should have D gas at p > 1 MPa and T > 450°C, but low enough to prevent lattice melting. Impurities generated by transmutations can be removed from the flowing gas.

Curt Brown, PointSource Energy
Measurement of anomalous heat at high ambient temperatures

PointSource Energy has developed a toroidal heat-generating ampoule based on LENR. If heated to 300°C it begins emitting heat. They want to do accurate calorimetric measurements of it. If the internal temperature exceeds ambient temperature, then heat is being generated. They can make two similar devices, one with LENR, and both with electrical resistance heaters. When the resistances are adjusted to make the two temperatures differ by a fixed amount dT, then difference of the heating powers gives the LENR power. The temperature can be controlled within a few hundredths of a degree C. The system takes about 6 minutes to reach thermal equilibrium and is accurate within about 15 mW.

Clint Seward, Electron Power Systems, Inc.
Ball lightning and tokamak

Ball lightning is a self-stable plasma toroid that requires no external magnetic field for stability. It requires a high current, like a lightning bolt, to form an arc, which then develops a toroidal ring around the arc, with separate thin surfaces for ions and electrons. An experiment at 12 kPa N_2 formed the ring at 860 ms. It had a major radius of 6 mm and minor radius 2.5 mm, with an estimated $3x10^{19}$ electrons/cm^3. A similar plasma configuration is proposed for space propulsion.

David French, Patent Attorney
The role of the patent attorney in patenting cold fusion inventions

David French provided information about the patent process. A patent must be an apparatus or a process, it must work, and the description must enable others to copy it.

A patent attorney listens to your story. He must understand the process.

Do a pre-filing patent novelty search to ensure that you are not wasting your time.

You can always get a patent if you reduce what you are doing to a trivial detail, but it would not be valuable. 0.5 M applications filed every year, 0.25 M issued, but only a few are worthwhile. The attorney should try to get valid patent of the broadest scope that you deserve. Ask him "will it be worth it? Will people want to use it? Are there existing good alternatives?"

You don't require a patent to go into the marketplace. If you don't succeed, you don't need a patent. If you succeed, then you need to protect your advantage. Keep out the competition, instead of lowering your price to compete.

A patent enhances profitability, if the product succeeds. If an invention is available to public, it cannot be patented. "Obvious" is a subcategory of "available to public".

The USA has a new system for filing or public disclosure. The USPO only asks to prove your invention works if there is "doubt". Some doubted fields are Cold Fusion, invisibility cloaks, and warp drives.

"Extraordinary claims merit extraordinary evidence." Carl Sagan

Give your disclosure to a reputable institution, and have them certify that it works. The USPO did not want to hear experts' information about CF.

Patents that have been issued may be challenged by litigation. You must reply to examiner's question within 3 months (or pay extra for 6 months).

In 1879 Attorney Selden's gasoline motor patent was delayed 18 years. Henry Ford litigated against the patent, lost, then bought the patent, then required others to pay him royalties.

Patenting does not create market demand. Will my patent protect me from competition? Read your claim and ask "If I were a competitor how could I get around this patent?" Watch for a new arrangement or process that makes a difference.

Can we patent something that was described in science fiction?

The Greek hero Hercule" used flowing water to clean a barn, so this process cannot be patented now.

Get a Provisional Patent. This preliminary application protects your rights for one year. You can rewrite and improve your story during that year. Concatenate multiple provisional applications into one final application.

The Viagra patent was invalidated in Canada on grounds that they did not tell the best way to do the invention. And Claim 6 was too hard to read/

Patterson challenged the European patent of Fleischmann & Pons. The owner did not defend the suit, and the patent lapsed.

An improvement on original patent can be patented, even if it overlaps on original patent.

File a PCT to protect your rights. Mitchell Swartz started filing CF applications in 1989, but has not gotten one issued yet,

The Board of Patent Appeals only considers whether final rejection was based on the application. The "Whole file wrapper" is available to the public if a patent issues.

Other Talks

Thomas Grimshaw discussed levels of evidence that relate to public policy for funding new technologies. He cited examples of various groups working in the LANR area. **Barry Unger**, Boston University, discussed how to commercialize radical inventions. **Carl Dietrich**, Terrafugia, Inc., told about development of flying cars. **Sandra Rose Michael**, Applied Integrative Bio-Physics, described health benefits of her company's technology.