Review of Recent Work at ENEA

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Topics

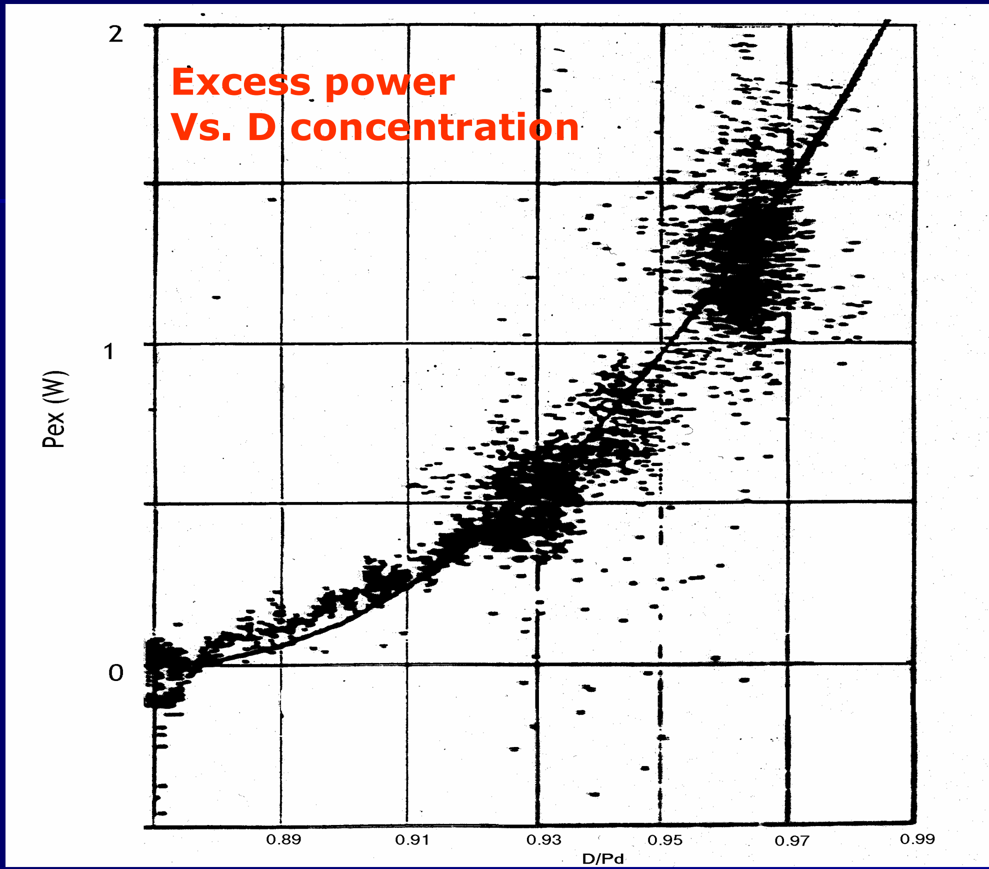
1)Materal Science & Reproducibility

2)Calorimetry

3) Laser Triggering of Excess Power

4) ^{4}He Measurements

Excess Power is a Threshold Effect



Excess power vs. D concentration: milestone in the history of CMNS.
1992: McKubre (SRI, USA), Kunimatzu (IMRA, Japan).

Excess power reproducibility requires reproducibility of high loading of deuterium.

High Loading Reproducibility and then Excess Power Production within Deuterated Metals are Controlled by Equilibrium and not Equilibrium Phenomena

$$\mu_H = \frac{1}{2}\mu_{H_2}$$

Equilibrium condition

Chemical potential of hydrogen in the metal lattice is strongly affected by the force fields that modify the free energy of the system like stress:

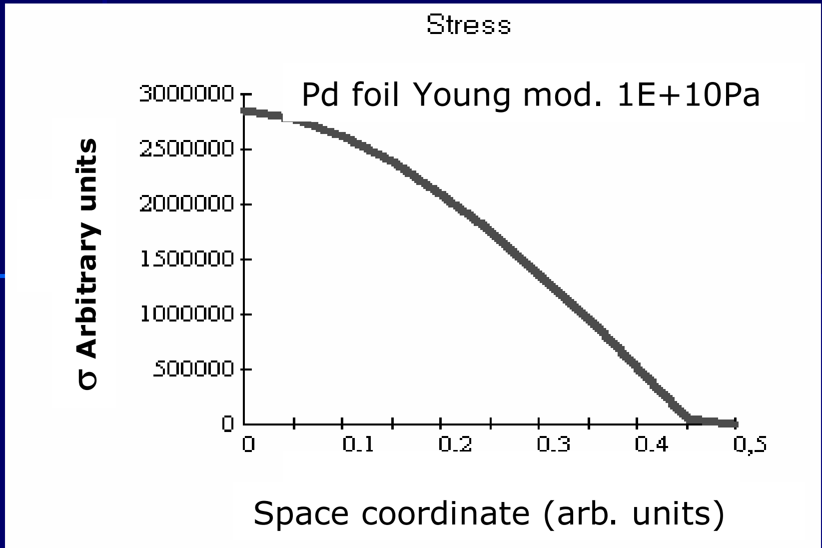
$$\mu_H^* = \mu_H - \overline{V}\, tr\overline{\overline{\sigma}}_h$$

Absorption of hydrogen isotopes inside a metal lattice is also a not - equilibrium problem because of the diffusive process produced by a chemical potential gradient. In presence of stress mass transfer is described by:

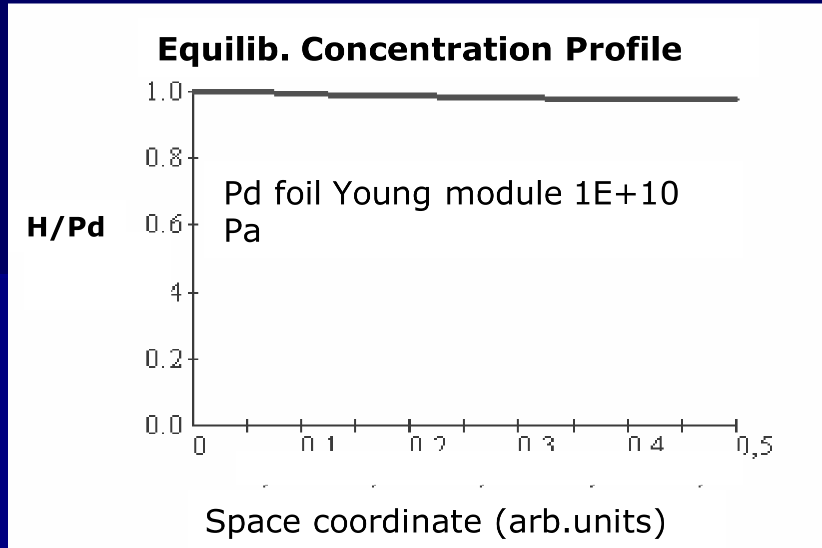
$$\frac{\partial \overline{c}}{\partial \tau} = \frac{\partial^2 \overline{c}}{\partial \overline{x}^2} - (1-\eta) b \frac{\overline{V}E}{RT}\left(\frac{\partial \overline{c}}{\partial \overline{x}}\right)^2 - (1-\eta) b \frac{\overline{V}E}{RT}\overline{c}\frac{\partial^2 \overline{c}}{\partial \overline{x}^2} - b\frac{\overline{V}E}{RT}\frac{\partial \eta}{\partial \overline{x}}\overline{c}\left(\frac{\partial \overline{c}}{\partial \overline{x}}\right)$$

(η=% of relaxed stress)

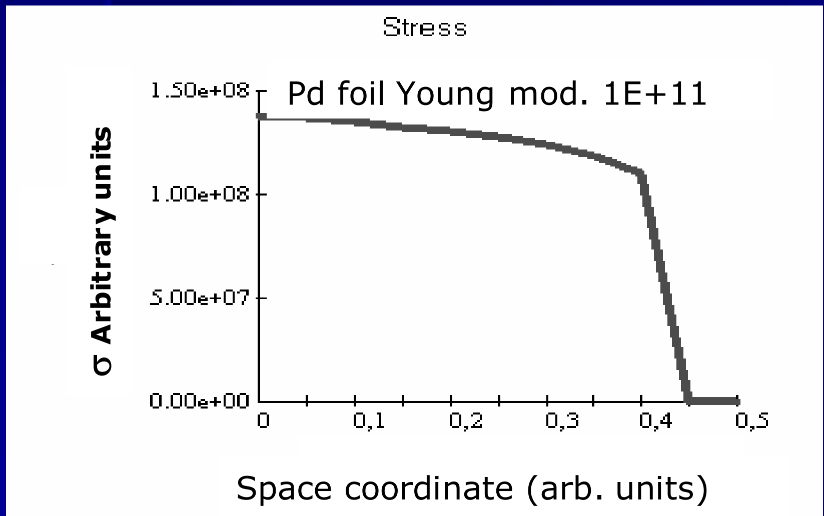
Calculations Results



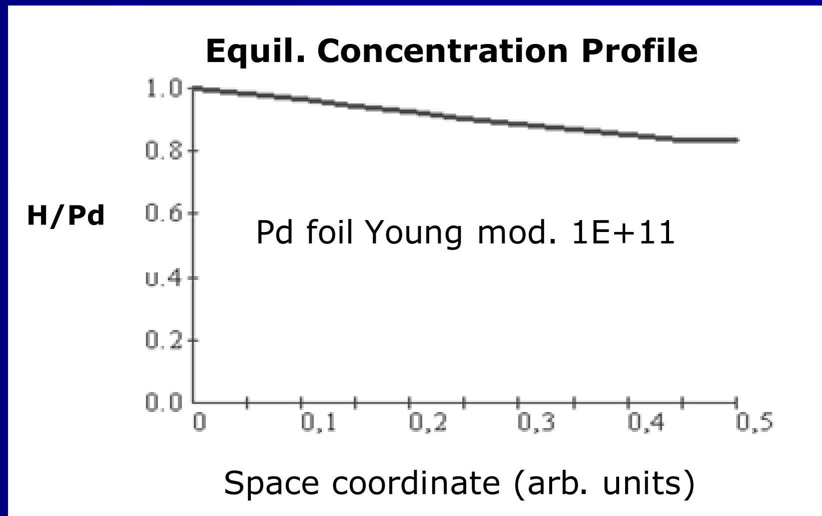
Equilibrium stress profile for high H solubility in Pd.



Equilibrium conc. profile for high H solubility in Pd.



Equilibrium stress profile for low H solubility in Pd.

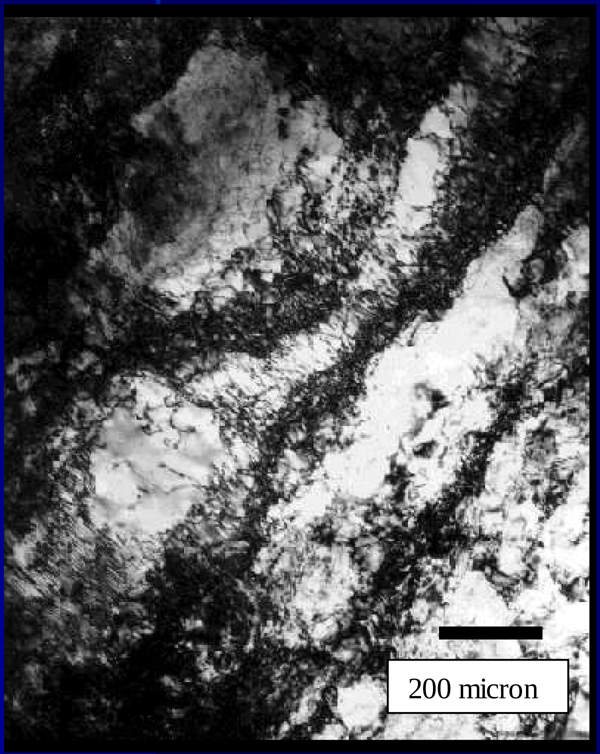


Equilibrium conc. profile for low H solubility in Pd.

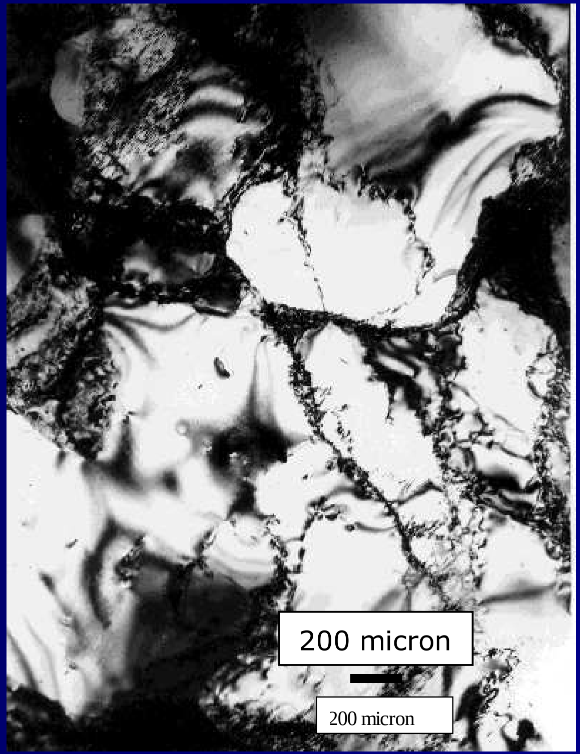
Metallurgy and Loading

Theory showed that self induced stress, created by concentration gradients, reduce hydrogen solubility in metals.

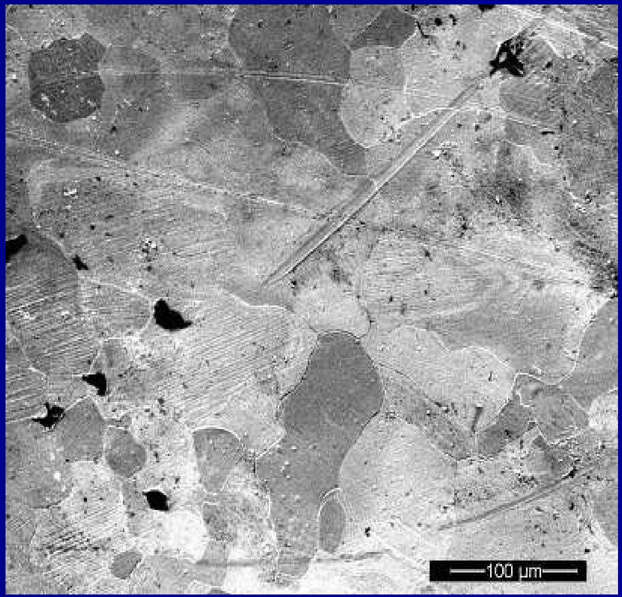
Metallurgical treatments have been studied to reduce the above mentioned effects.



Cold worked Pd foil.

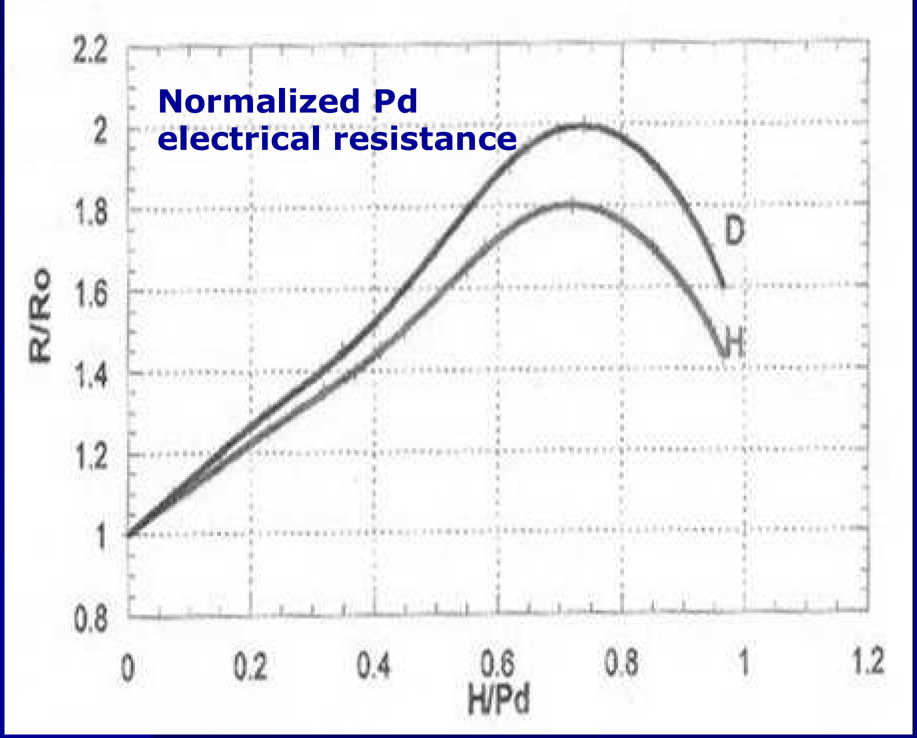


Cold worked and annealed at 1100 °C for 5 hr Pd foil.

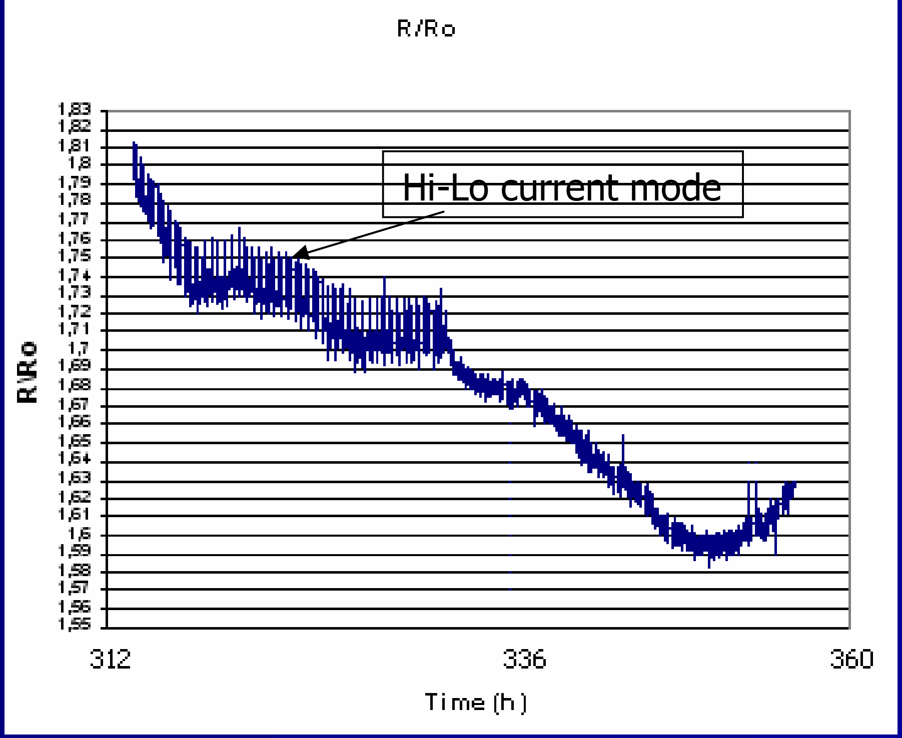


Cold worked and annealed at 850 °C for 1 hr.

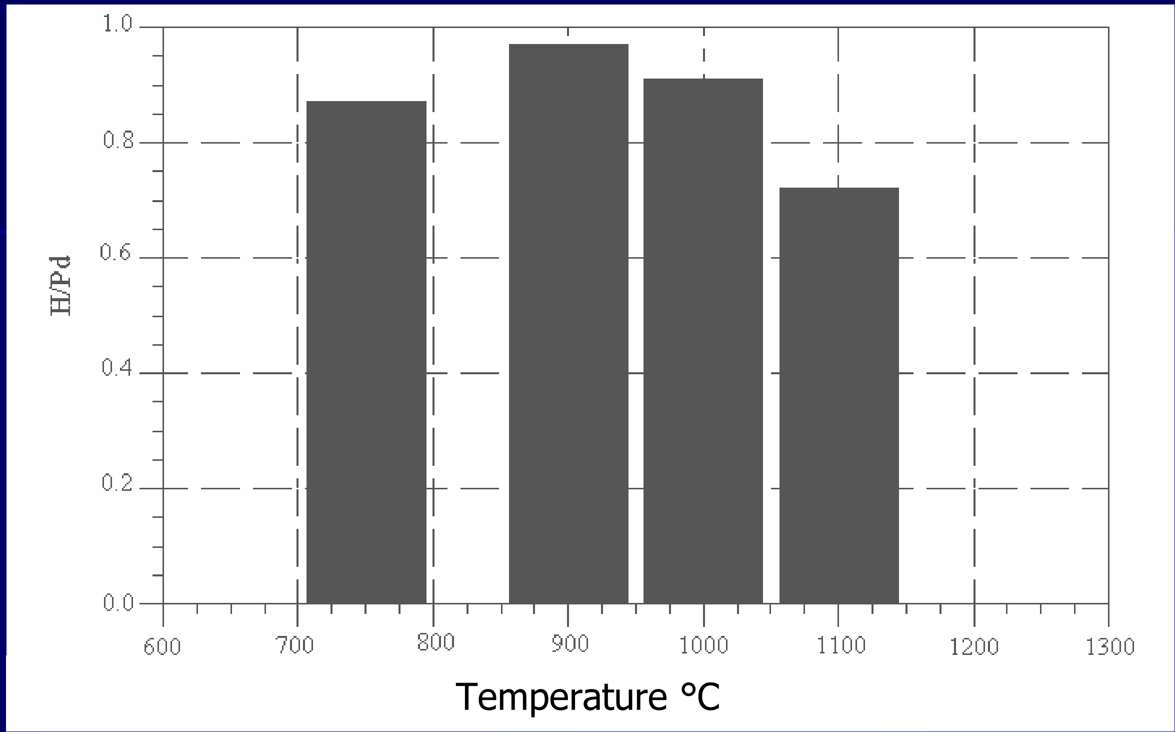
D/H Concentration Measurement as Resistance Measurement



Baranowsky curves.



Loading evolution into a treated Pd sample.



Annealing temperature effect on H loading in Pd.

Self induced stress, created by very steep concentration gradients, makes impossible to achieve the concentration threshold D/Pd > 0.95 giving excess power production.

A Proper microstructure of Pd due to metallurgical treatment allows high D loading.

References

A.De Ninno, V. Violante et Al., Consequences of Lattice Expansive Strain Gradients on Hydrogen Loading in Palladium. Phys. Rev. B, Vol. 56, N. 5 (1997) 2417-2420.

A. Adrover, V. Violante et Al. Stress induced diffusion of hydrogen in metallic membranes, Cylindrical vs. planar formulations I, J. Of Alloys and Compounds I(2003).

A. Adrover, V. Violante et Al. Stress induced diffusion of hydrogen in metallic membranes, Cylindrical vs. planar formulations II, J. Of Alloys and Compounds I(2003).

A. Adrover V. Violante et Al. Effects of self-stress on hydrogen diffusion in Pd membranes in the coexistence of α and β phases. J. of Alloys and Compounds II (2003).

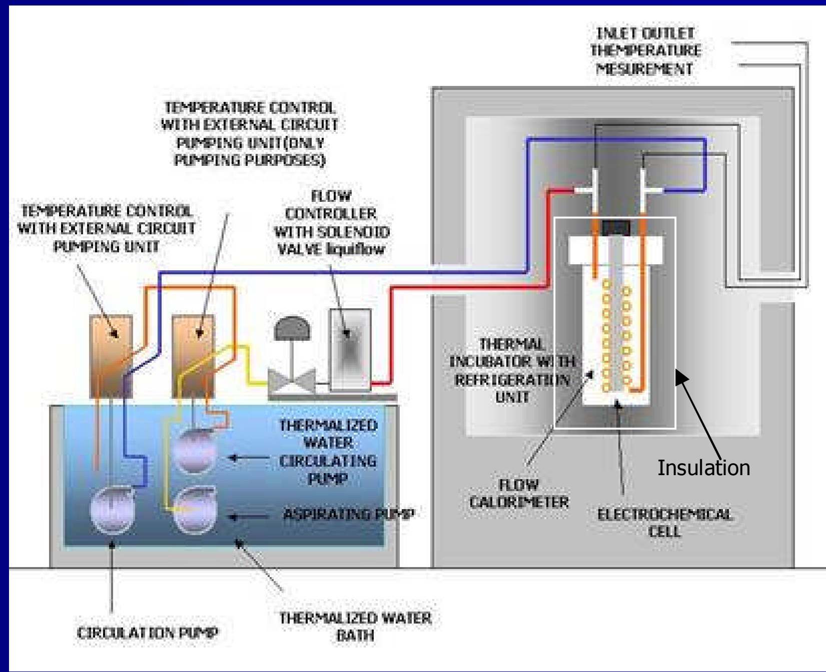
Flow Calorimetry on Closed Cells with Recombiner

$$P_{In} = V\,I$$

$$P_{Out} = W c_p \left(T_{Out} - T_{In} \right)$$

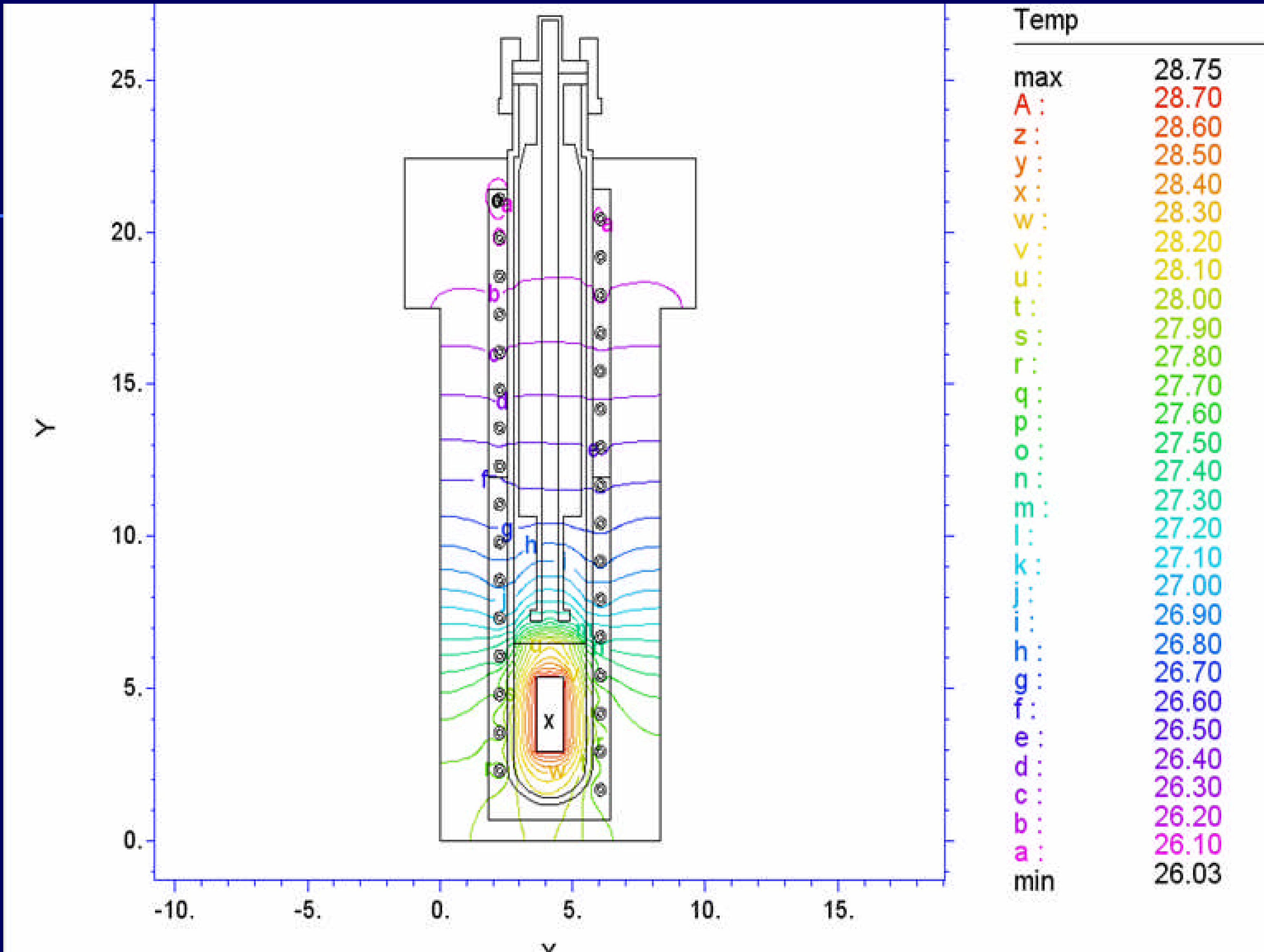
W = coolant mass flow rate

ENEA Flow Calorimeter

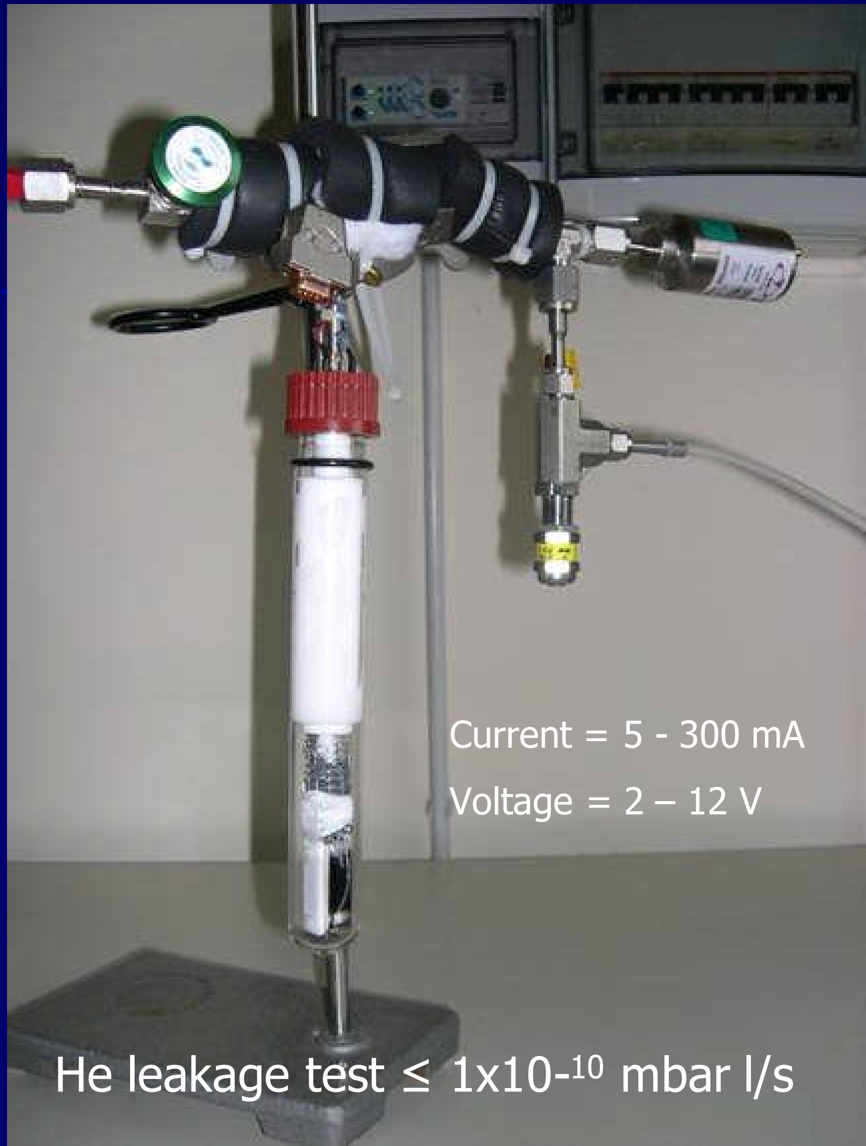


Memmert Calorimetric box (±0.05°C) + Haake thermostatic bath +Bronkhorst high precision mass flow meter + HP-4263 LCR Meter. Measure limit: 50 ± 15 mW

Flow Calorimeter FEM Analysis

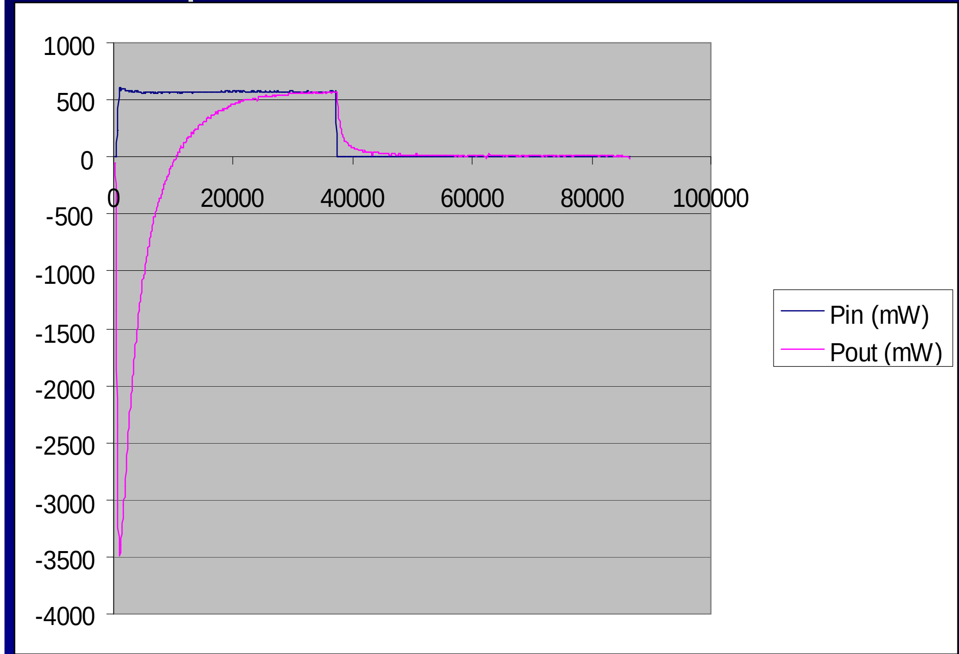


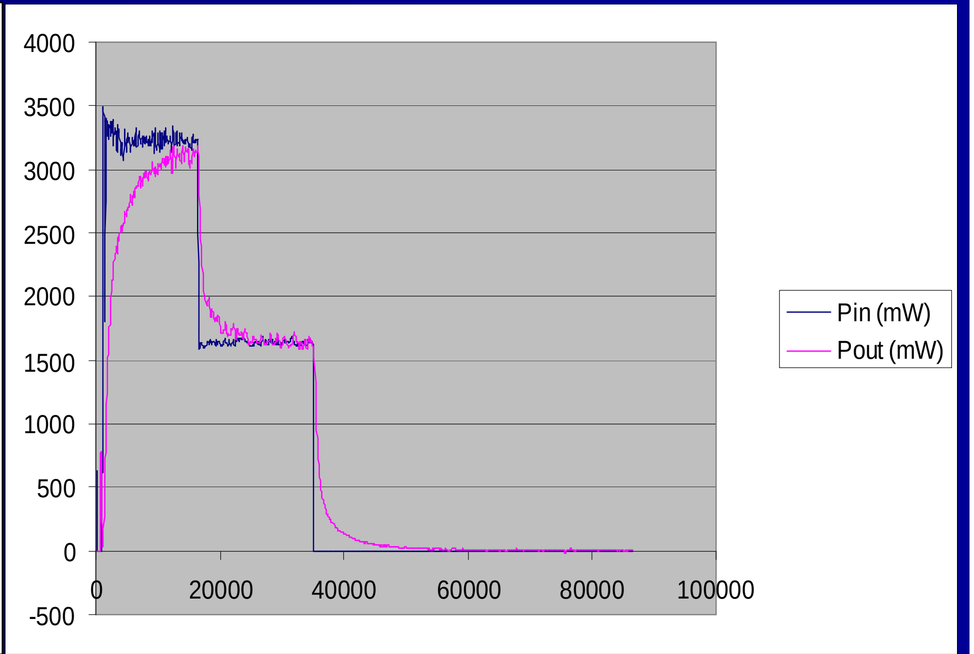
Finite element modelling has applied to design the calorimetric system



Symmetric eelectrochemical cell :Pt-foil/Pd-foil/Pt-foil (20x10mmx50μm Pd).

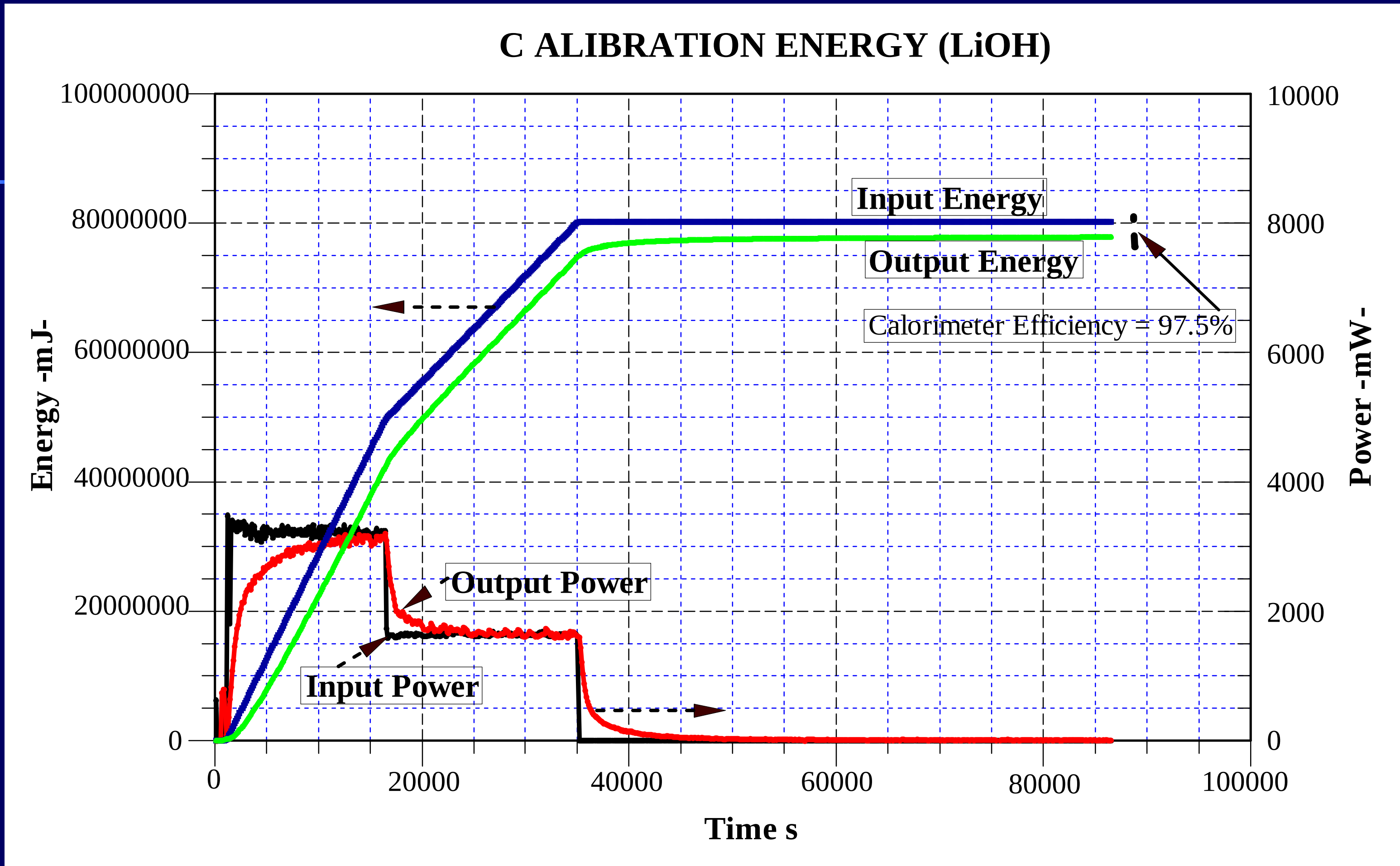
Reference Experiments with Hydrogen at ENEA





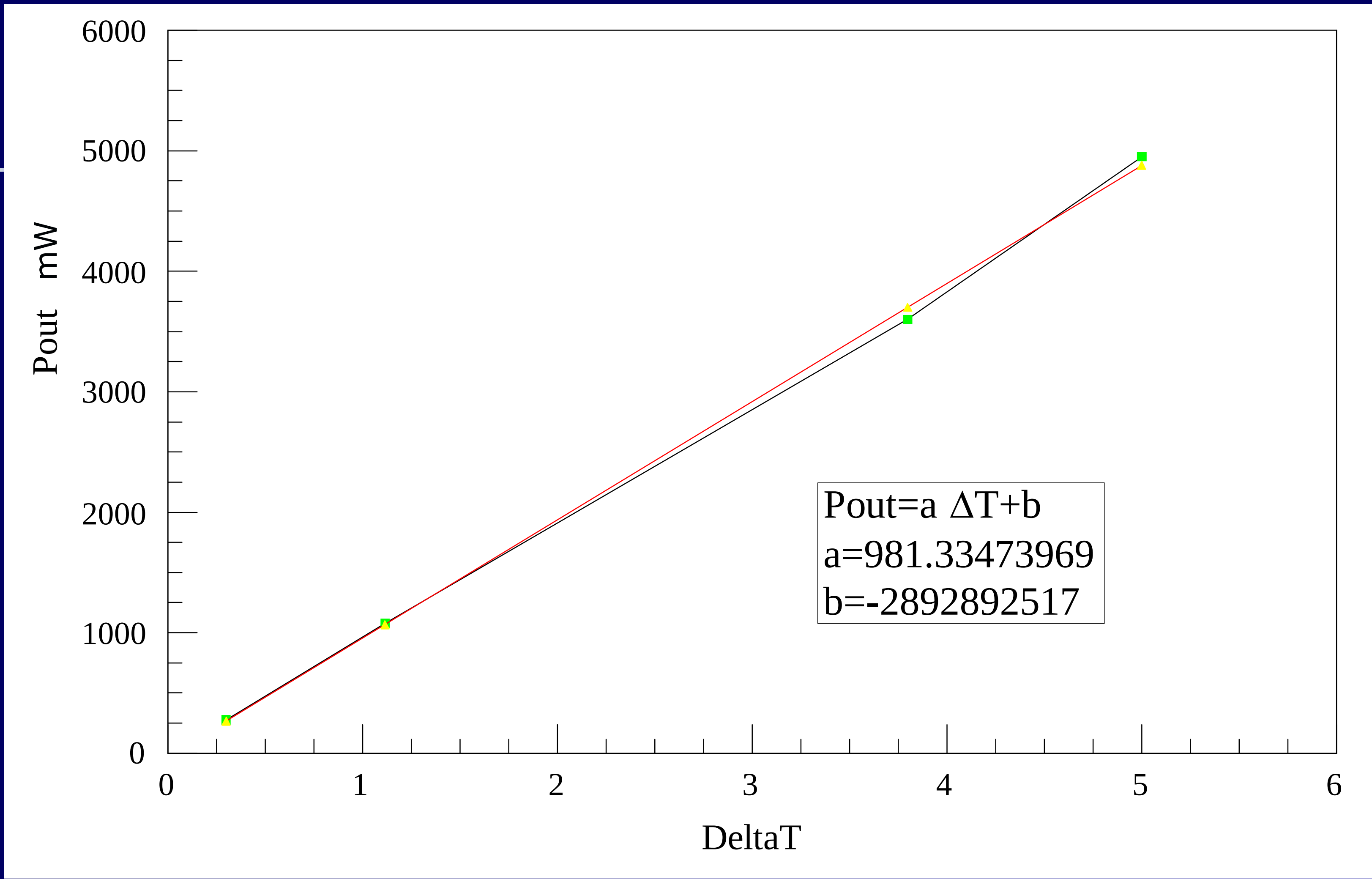
Input and output of power during electrochemical loading of hydrogen into Pd foils. Calorimeter efficiency = 97.5%.

Energy & power (input and output) during calibration with H2O 0.1 M LiOH



Plot of energy & power (input and output) for calibration with H_2O 0.1 M LiOH.

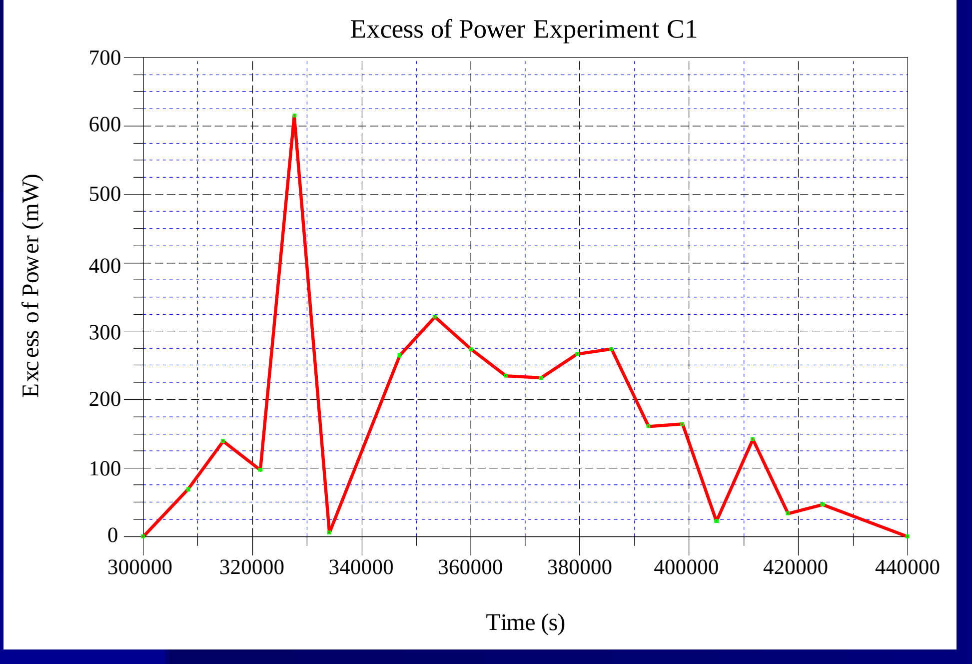
Flow Calorimeter Calibration Curve



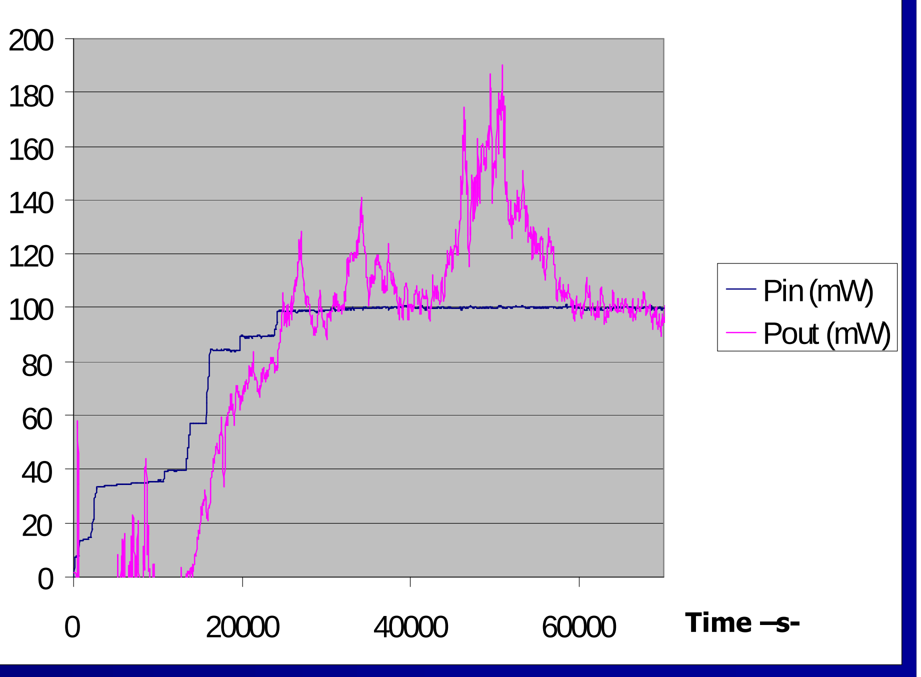
In principle flow calorimetry doesn't require calibration

Excess Power

C1 and C3 Experiments

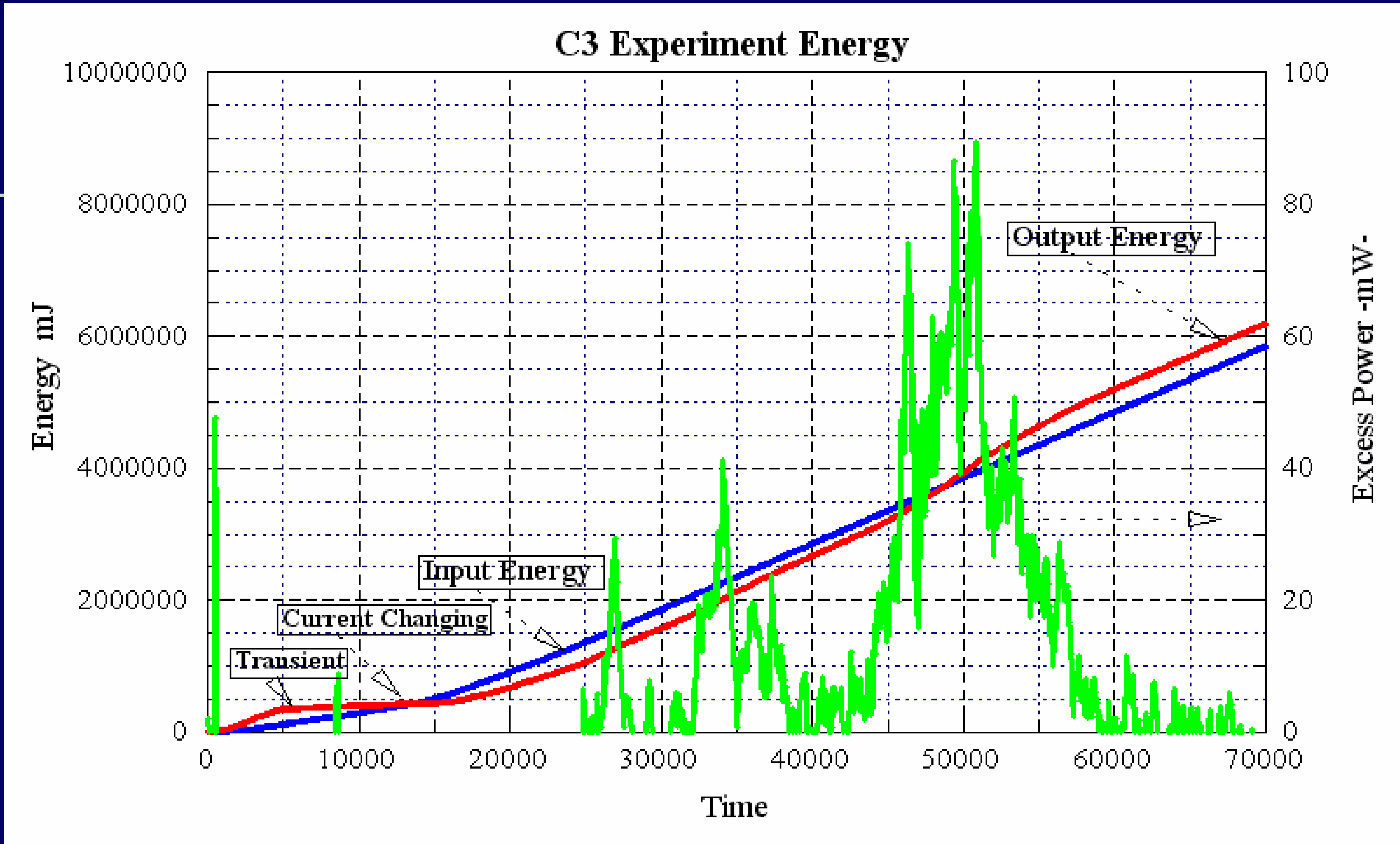


Experiment C1: excess power vs time (45 KJ of produced energy = 35 MJ/mol Pd)



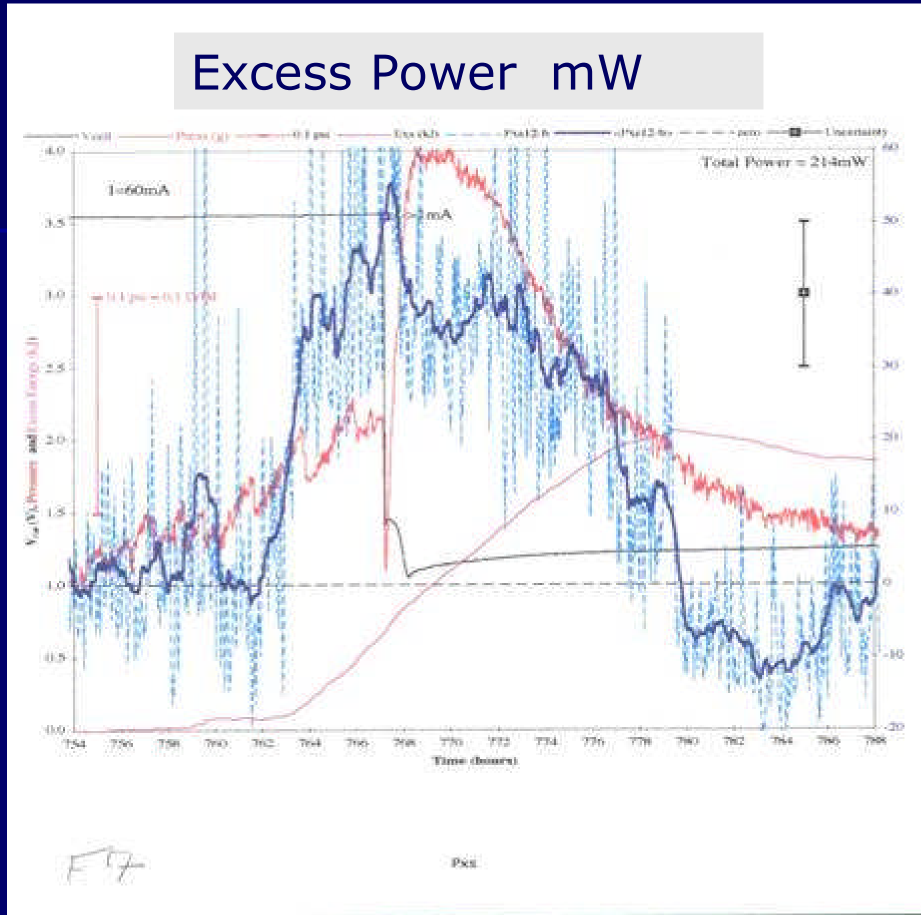
Experiment C3: excess power vs time

Excess Power and Excess Energy in C3 Experiment



C3 experiment: plot of energy & power (input and output)

Excess Power at SRI



SRI results by using a treated Pd foil.

Similar and enhanced results have been obtained by Dr. T. Zilov (Energetics Technology) by using the same materials.

Remarks

Why a trigger ?

Two excesses of power have been observed over 9 experiments although the achieved D concentration in Pd (atomic fraction) has always been larger than 0.9.

The loading threshold D/Pd > 0.9 is clearly only a ***necessary condition***.

Plasmons-Polaritons Laser Triggering

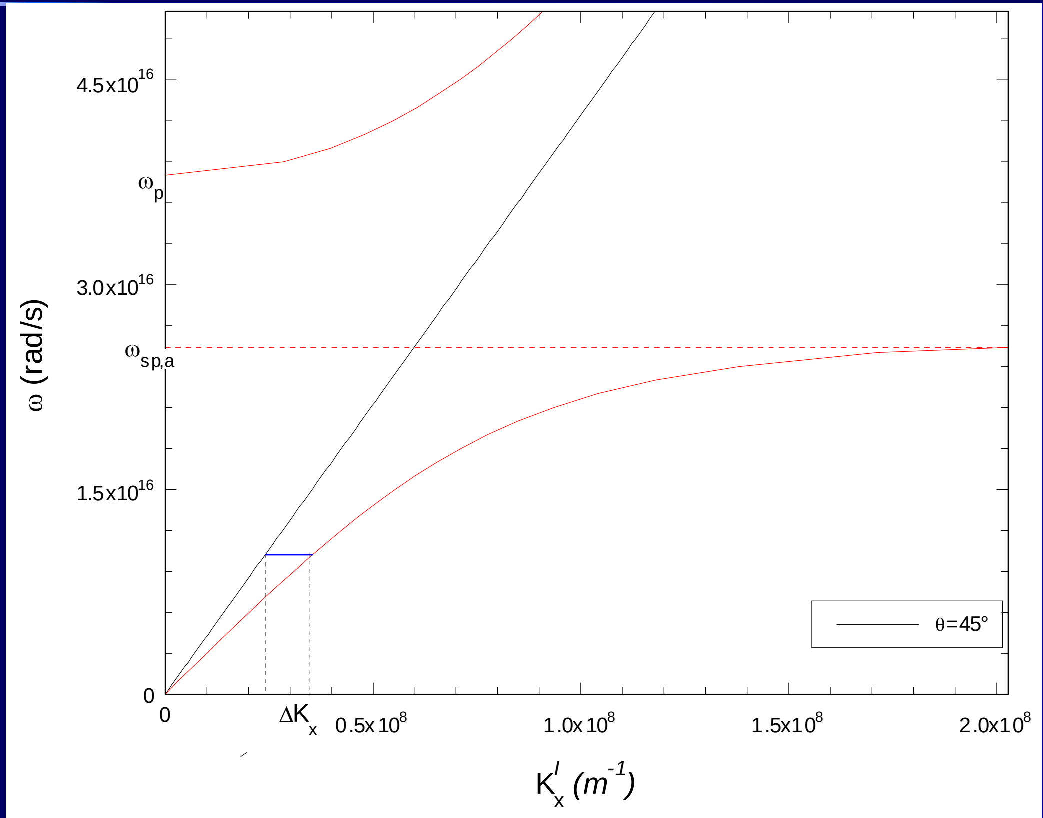
According to the idea that collective electron oscillations have a key role in LENR processes a proper trigger has been introduced to create surface plasmons (polaritons).

Surface plasmons are quantum of plasma oscillations created by the collective oscillation of electrons on a solid surface.

Surface plasmons may be generated by mechanisms able to produce charge separation between Fermi level electrons and a background of positive charges (i.e. lattice atoms):

1) Electrons beam.
2) Laser stimulation.
3) Lattice vibrations.
4) Charged particles interacting with a surface.

Coupling by Roughness



$$K_x = \frac{\omega}{c}\sin\theta \pm \Delta K_x = K_{sp}$$

Where:

$$\Delta K_x = \pm ng$$

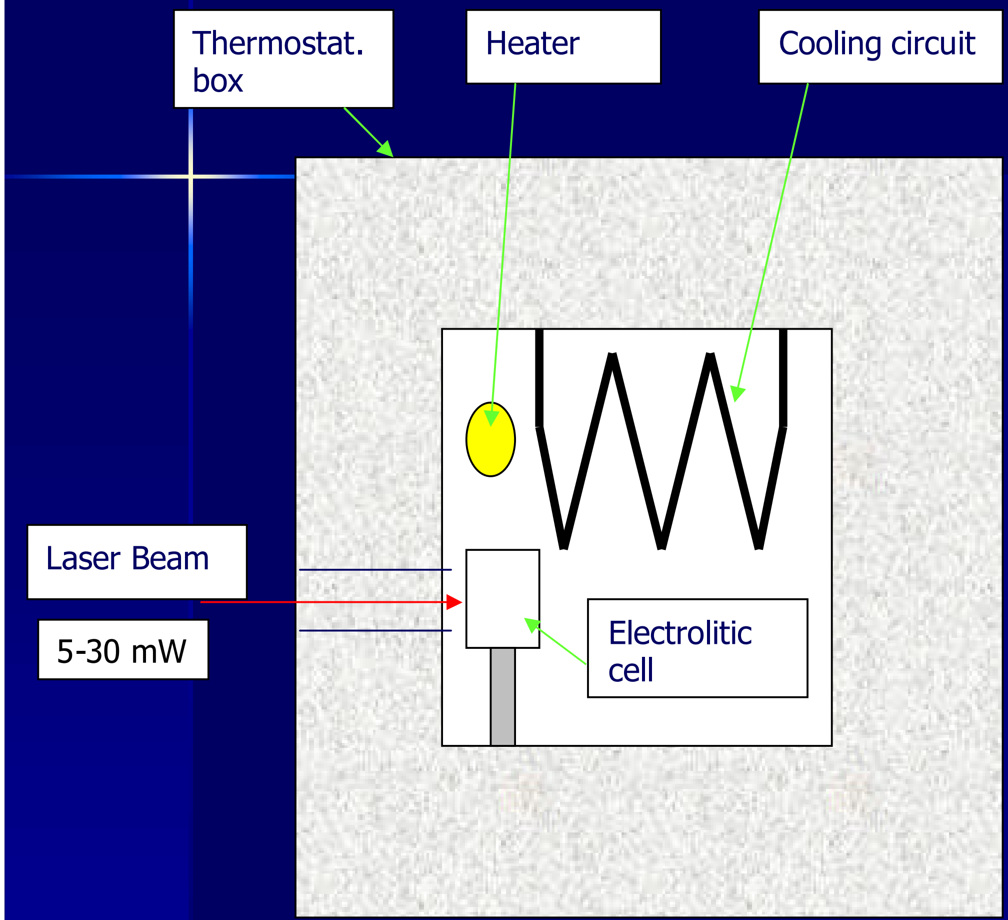
$$g = \frac{2\pi}{a}$$

n=1,2…..

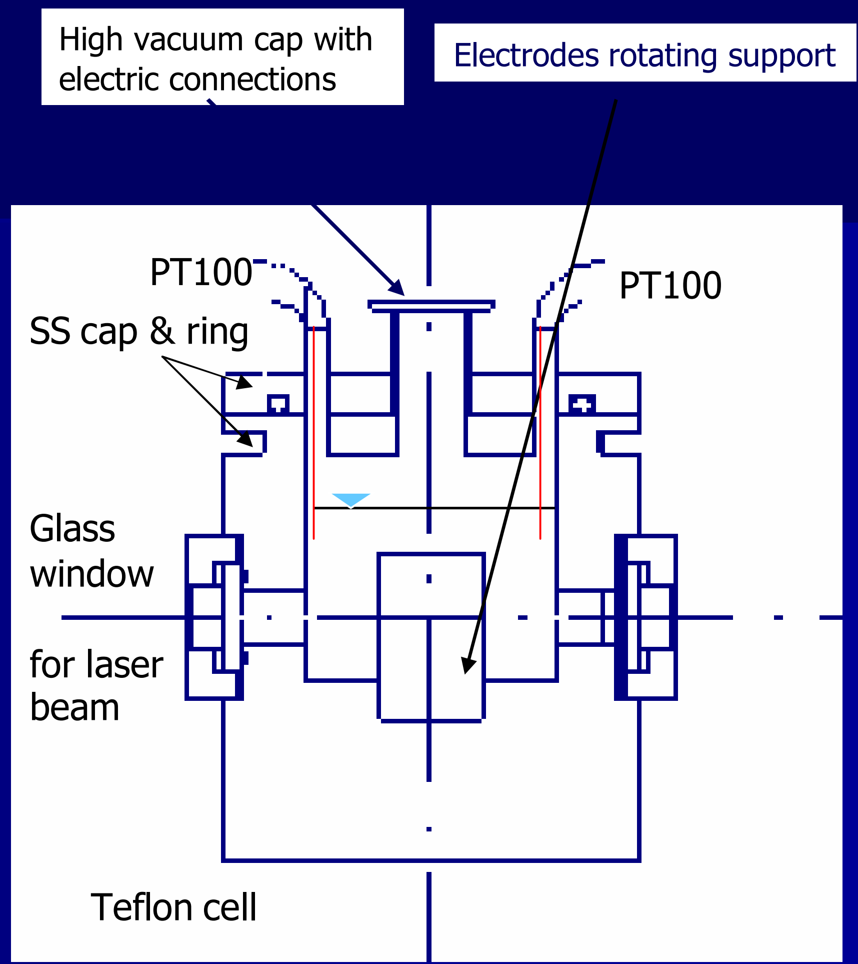
a is the surface corrugation lattice parameter.

Shift of the incident radiation wave vector produces plasmons excitation: a proper corrugation of the surface creates the required shift.

Isoperibolic Calorimetry under Laser Triggering



Calorimetric system for laser triggering experiments (T Box = Set p. ± 0.15 °C)



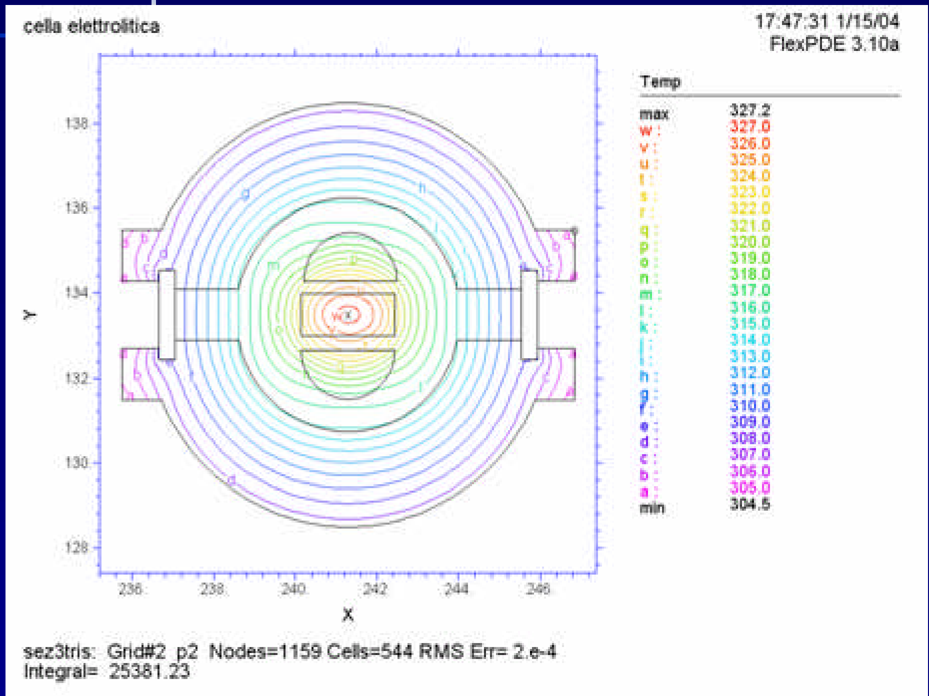
Electrochemical cell for laser triggering Experiments. He leakage ≤ 10^{-10} mbar l/s.

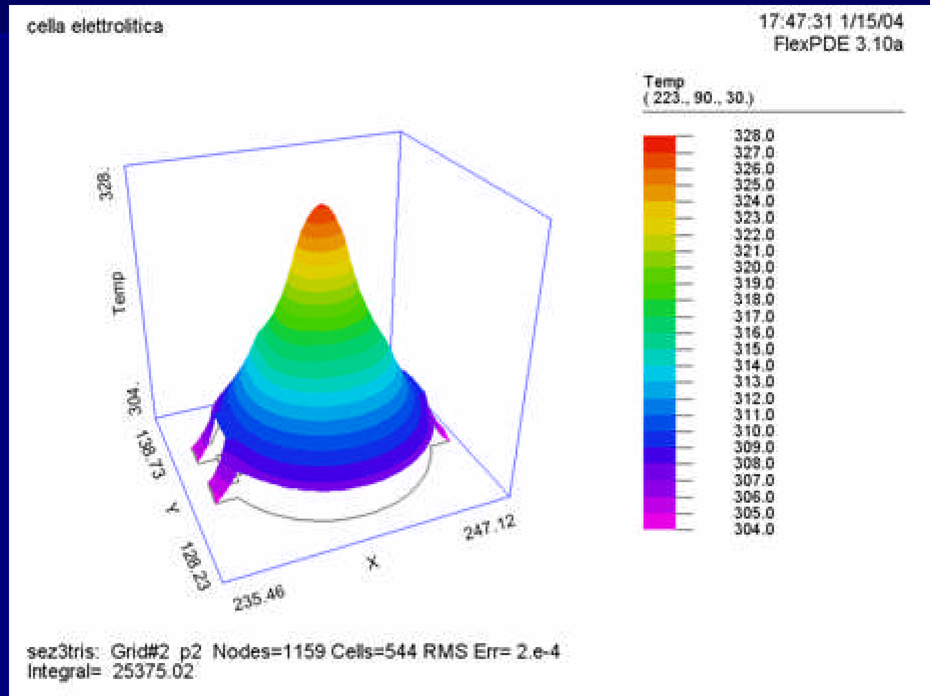
Pd foil (20x10 mm x 50 μm) cathode, spiral Pt wire anode.

Current = 5 - 400 mA

Voltage = 2 – 15 V

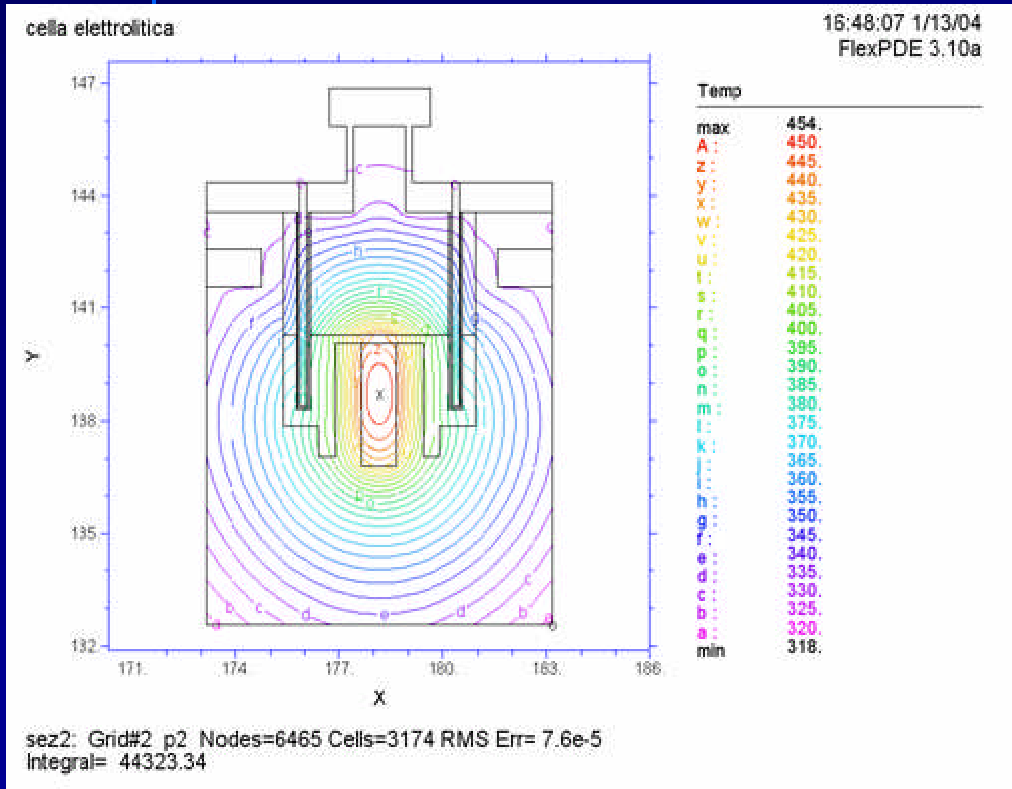
Electrochemical Cell FEM Analysis to Design the Calorimetric System





Calculated temperature profiles.

Electrochemical Cell FEM Analysis to Design and Optimize the Isoperibolic Calorimetric System for Laser Triggered Experiments



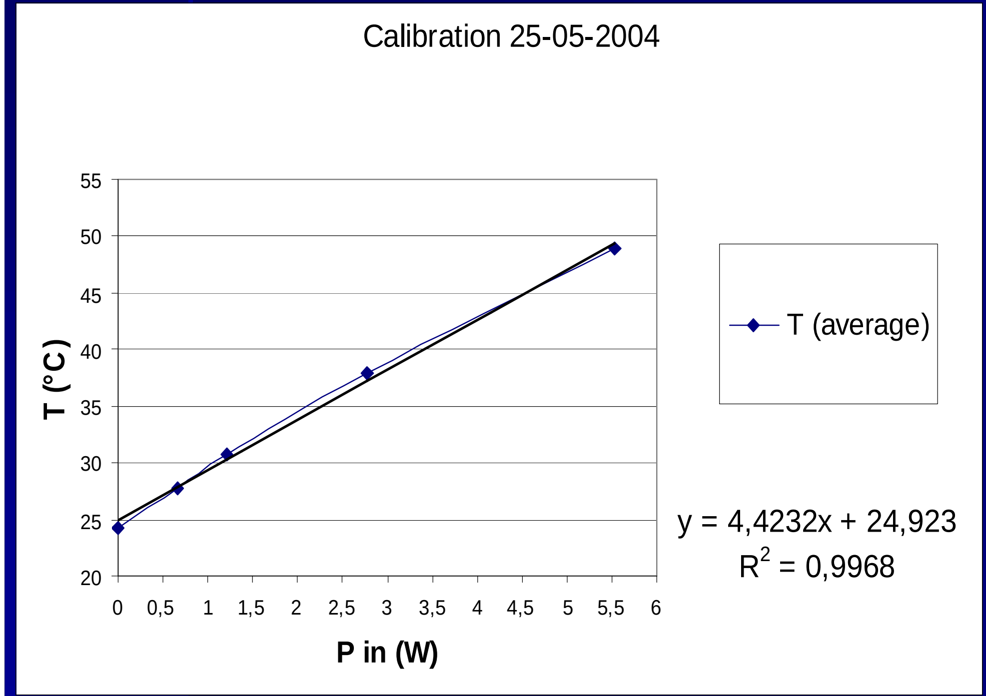
He leakage test < $1x10^{-10}$ mbar l/s

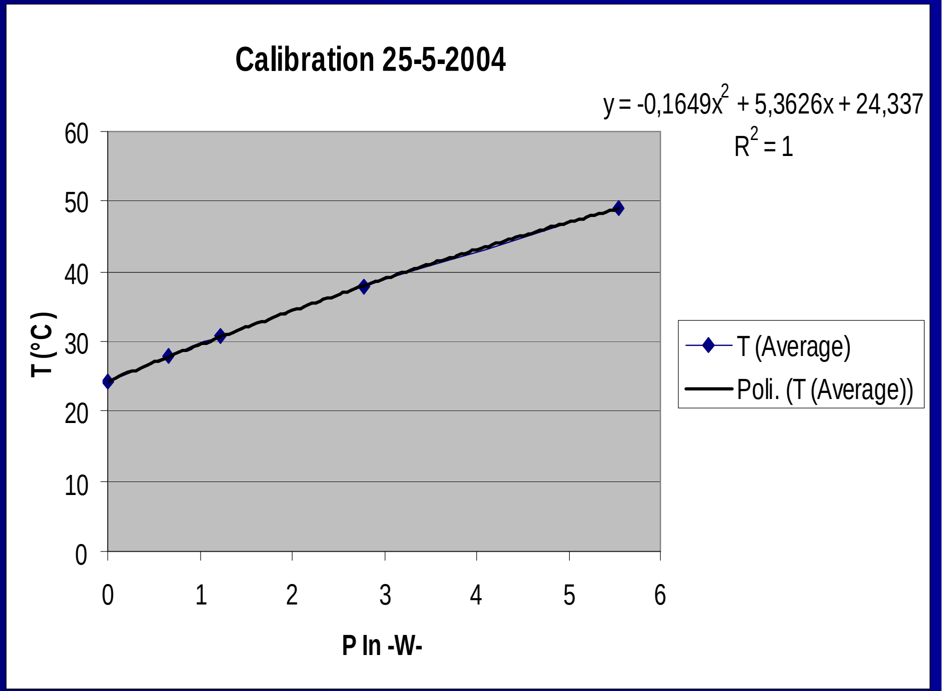
Simulated cell and experimental cell (closed cell with recombiner)

Isoperibolic Calorimetry for Laser Triggered Experiments.

Calibration is mandatory

Calibration based on the average of the 2 PT-100 temperature values obtained by means of electrolysis in LiOD.

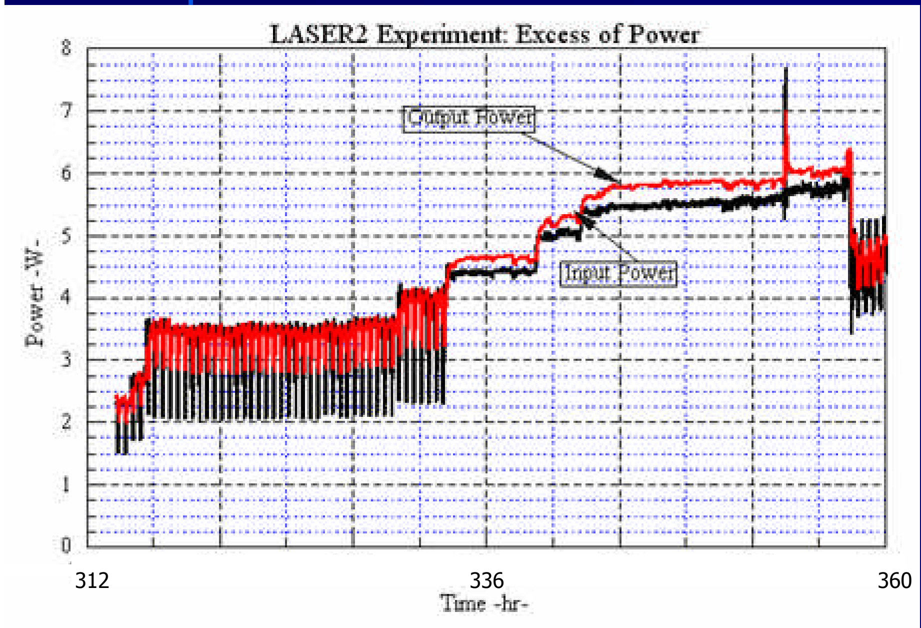


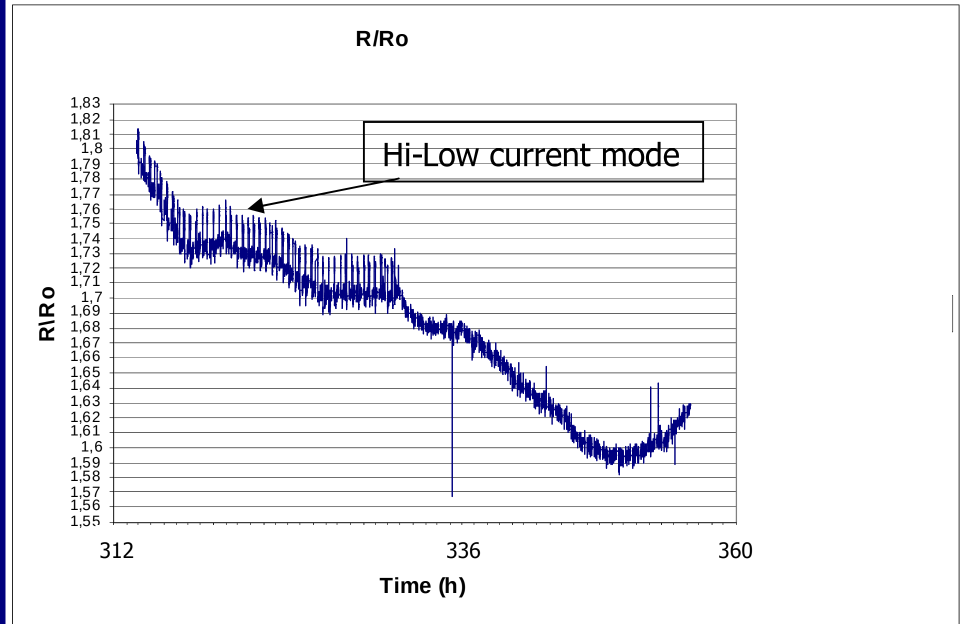


Calibration of the isoperibolic calorimeter

Laser2 Experiment

23.5 kJ of produced energy: 17.3 MJ/ mol Pd



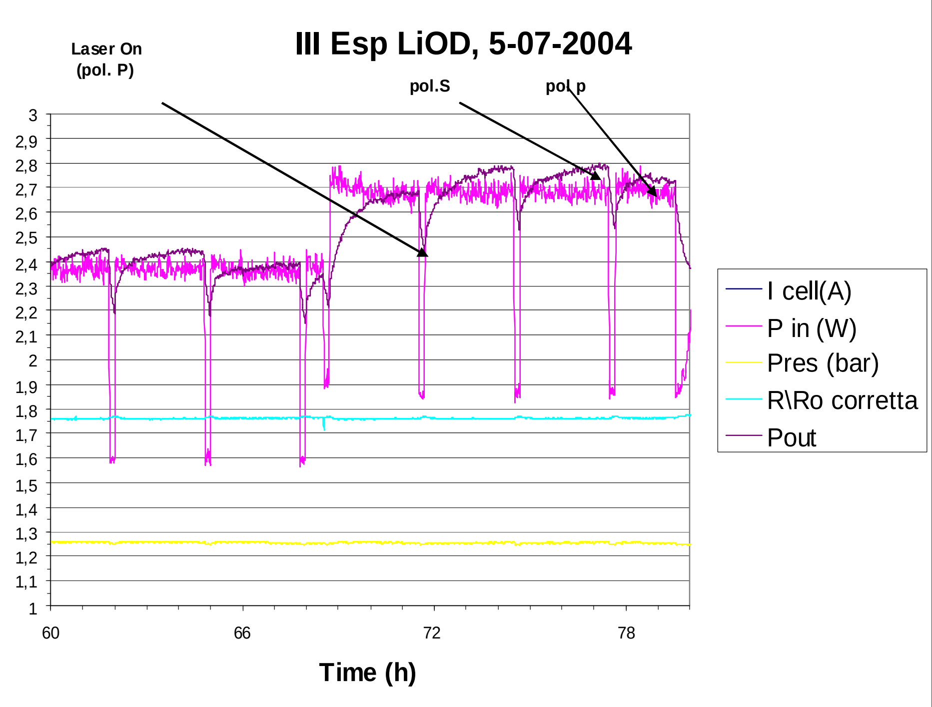


Evolution of the input and output power, last 300 hr under laser irradiation (P-polarization), 632 nm, 5 mW. ^{4}He production estimate 6.12E+15.

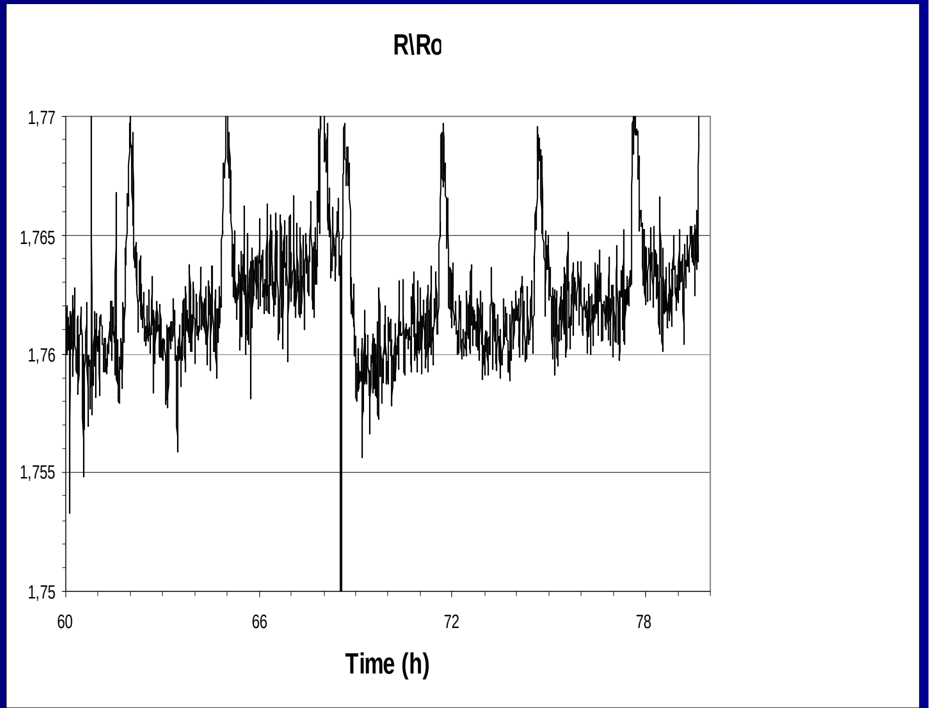
Evolution of loading (normalized resistance).

Laser3 Experiment: Calorimetric Results

3.4 kJ of produced energy: 2.5 MJ/ mol Pd



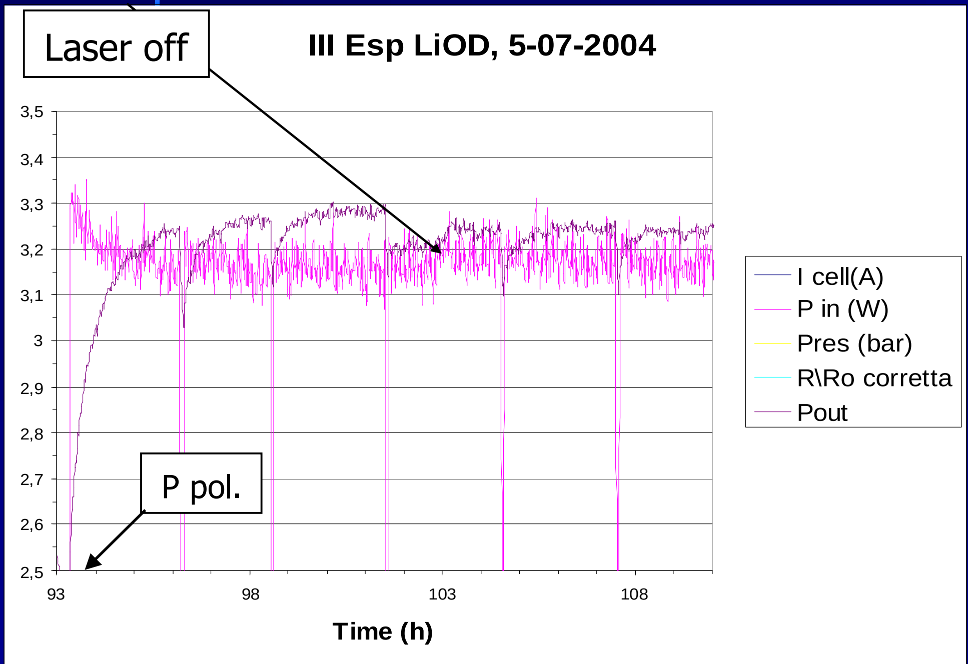
Excess power under laser triggering (P and S polarization effect). 632 nm, 33 mW Hi-Lo current mode.

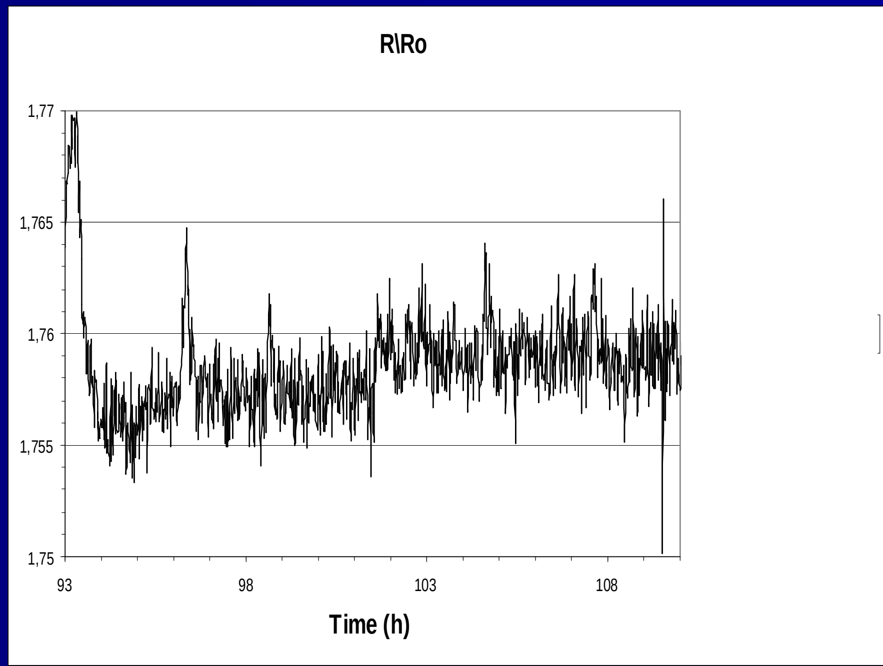


Loading evolution (normalized resistance)

Laser3 Experiment: Calorimetric Results

3.4 kJ of produced energy: 2.5 MJ/ mol Pd

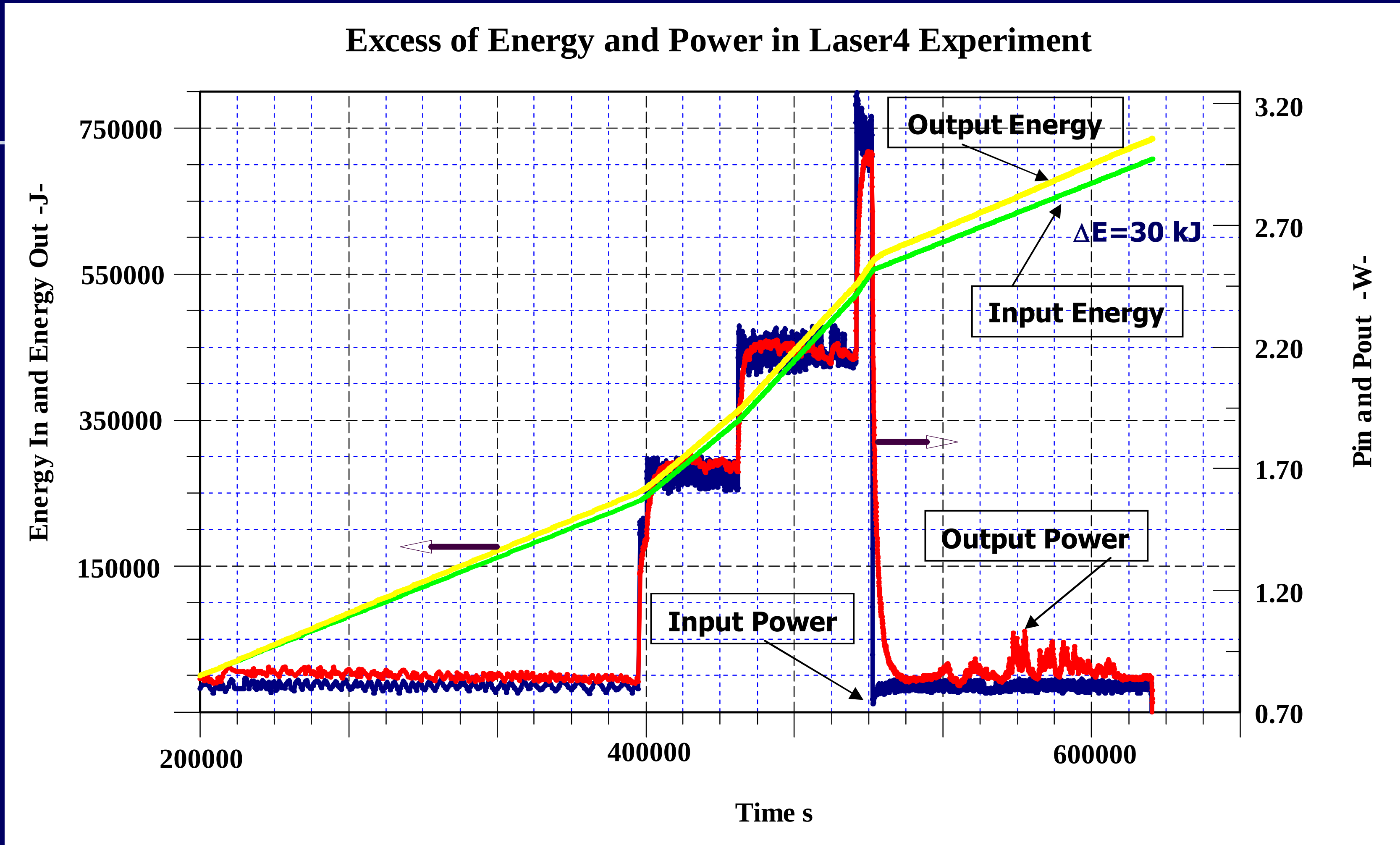




Excess power under laser triggering (laser off effect). Hi-Lo current mode.

Loading evolution (normalized resistance)

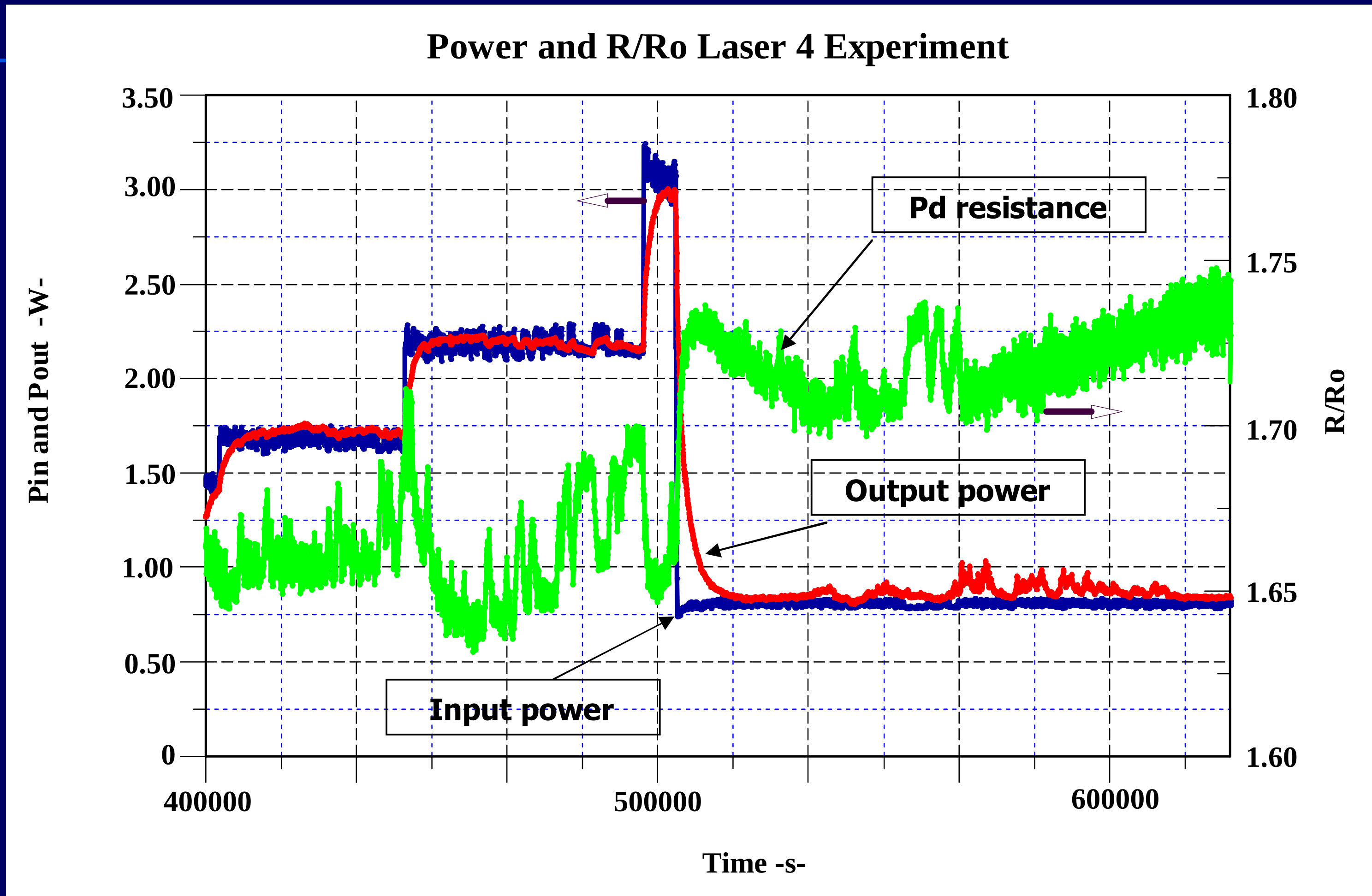
Laser4 Experiment: Calorimetric Results



Excess energy and excess power in Laser4 experiment.

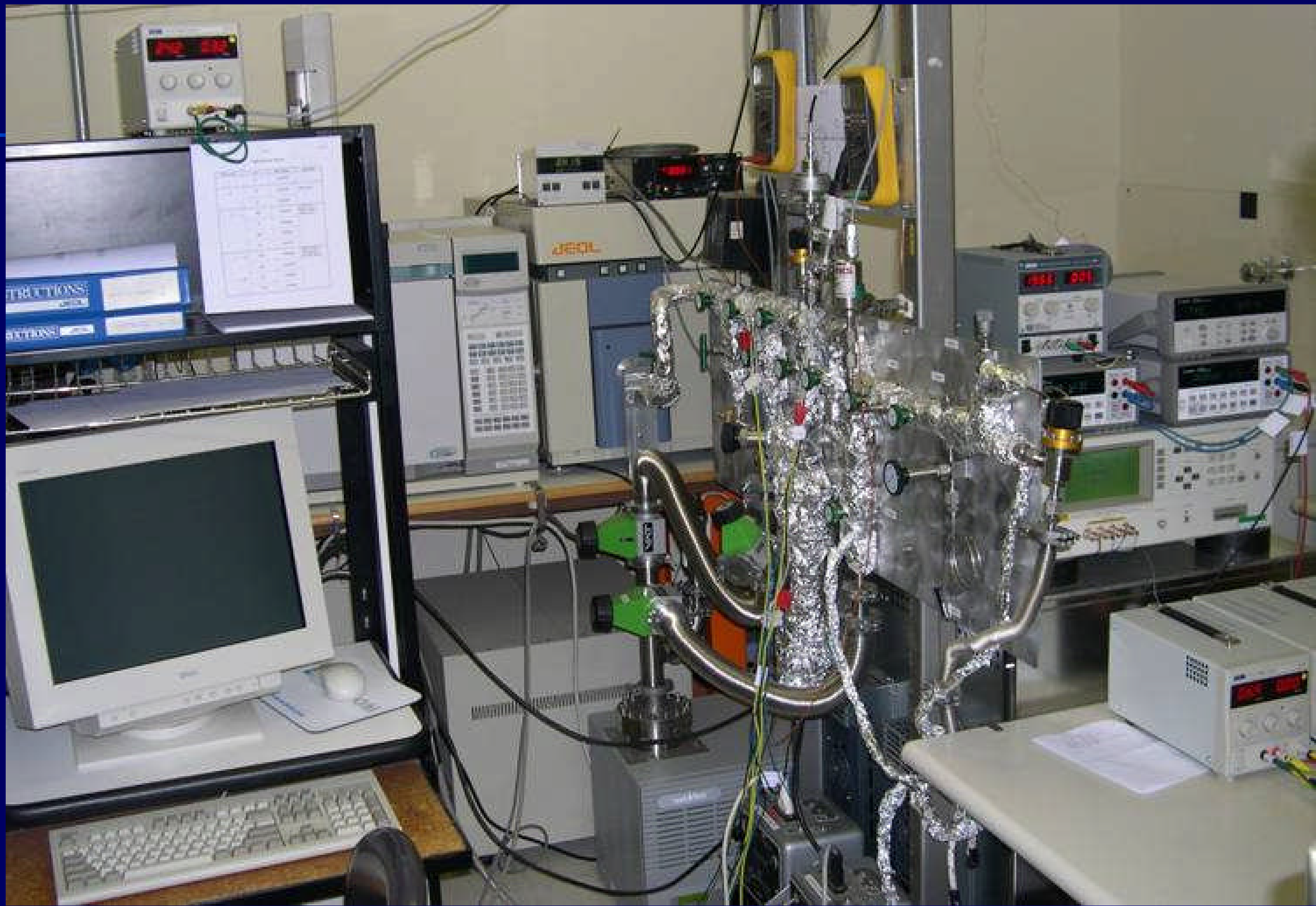
Laser4 Experiment: Calorimetric Results

30.3 kJ of produced energy: 19.4 MJ/ mol Pd



Excess power and loading evolution.

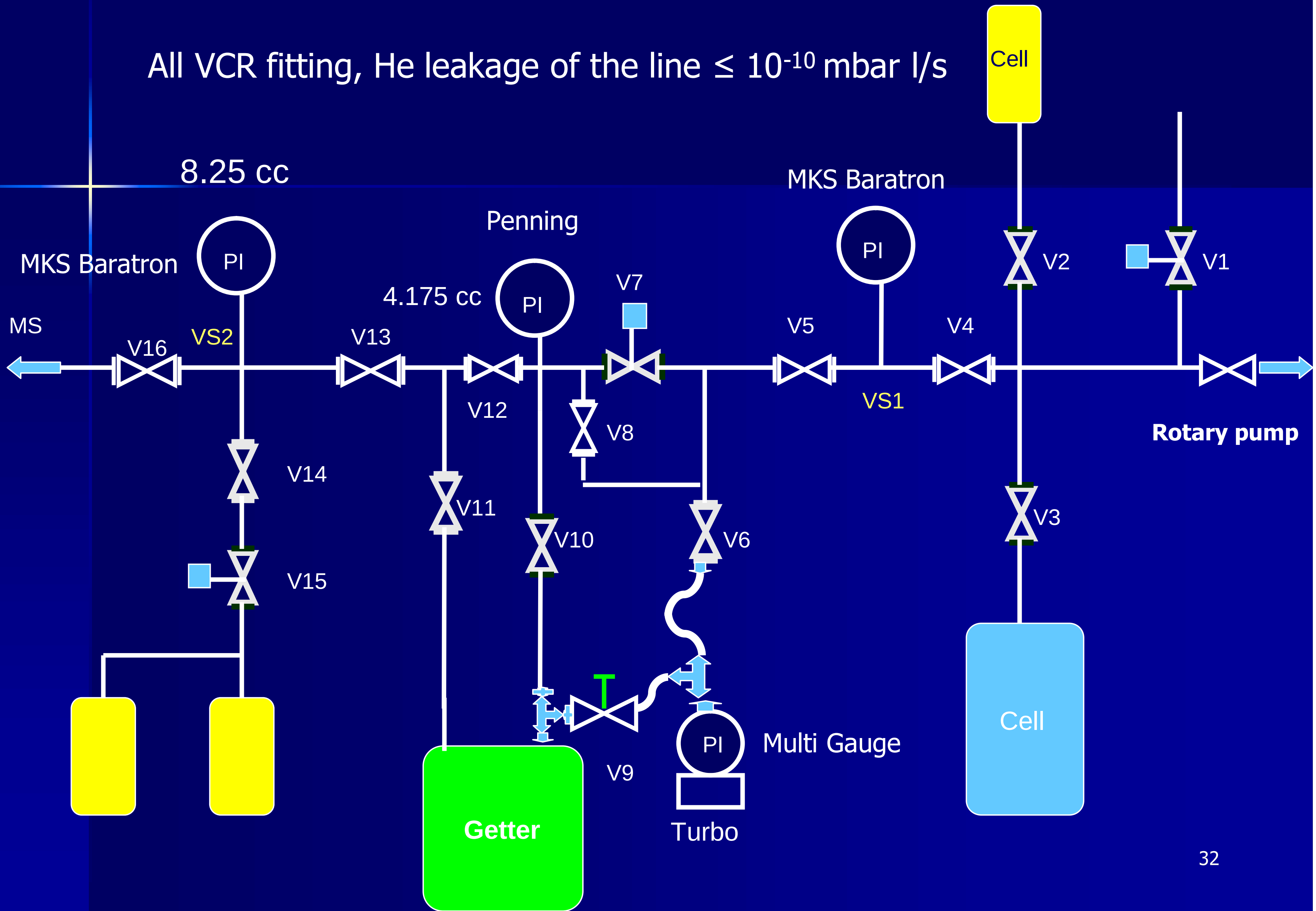
Mass Spectrometer: JEOL GC Mate



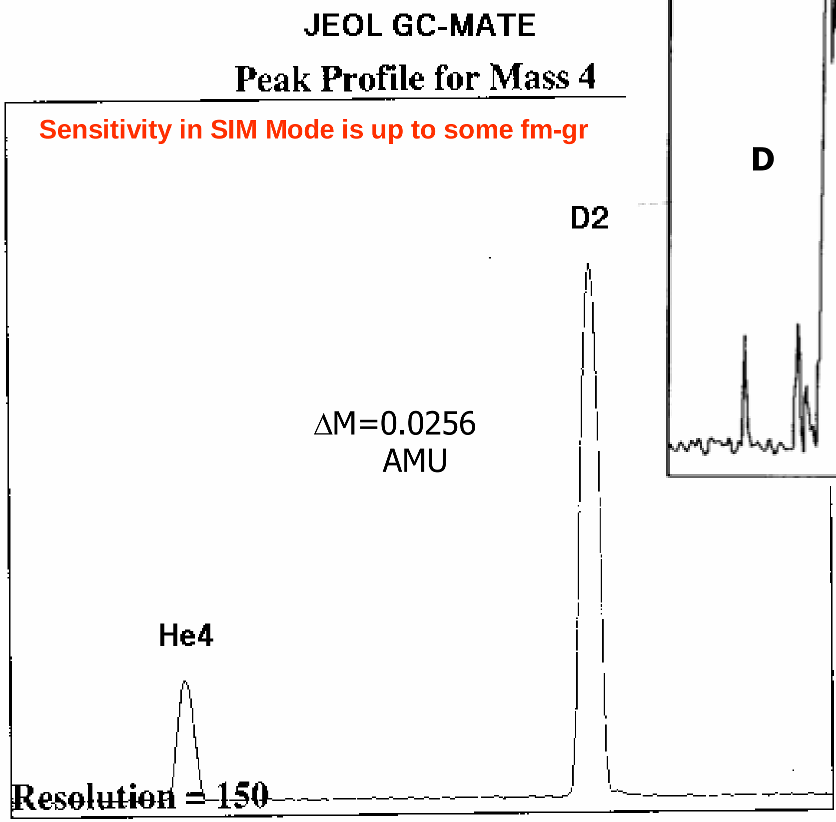
JEOL mass spectrometer and inlet system.

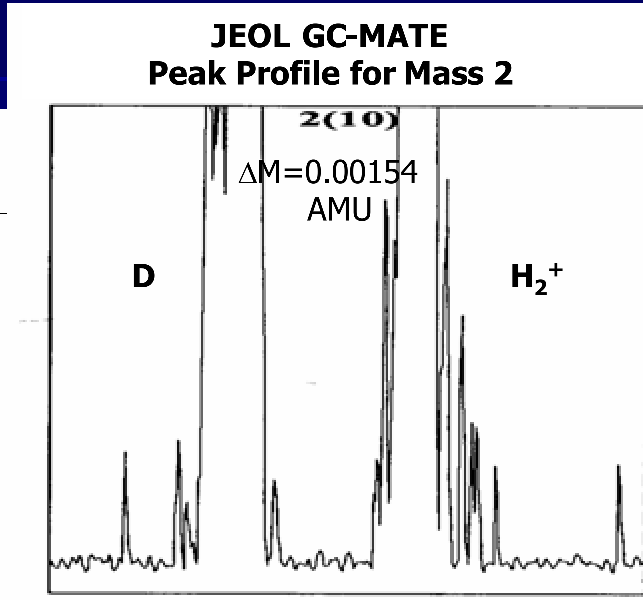
MS - Inlet Line

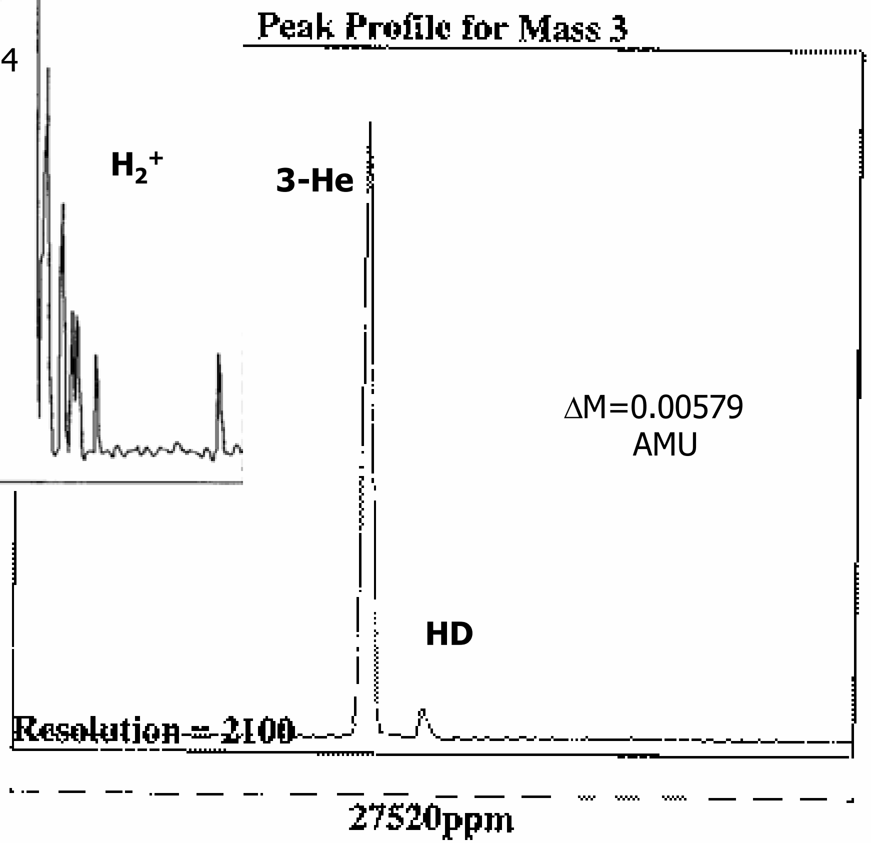
All VCR fitting, He leakage of the line ≤ 10^{-10} mbar l/s



JEOL GC-Mate Resolution and Sensitivity

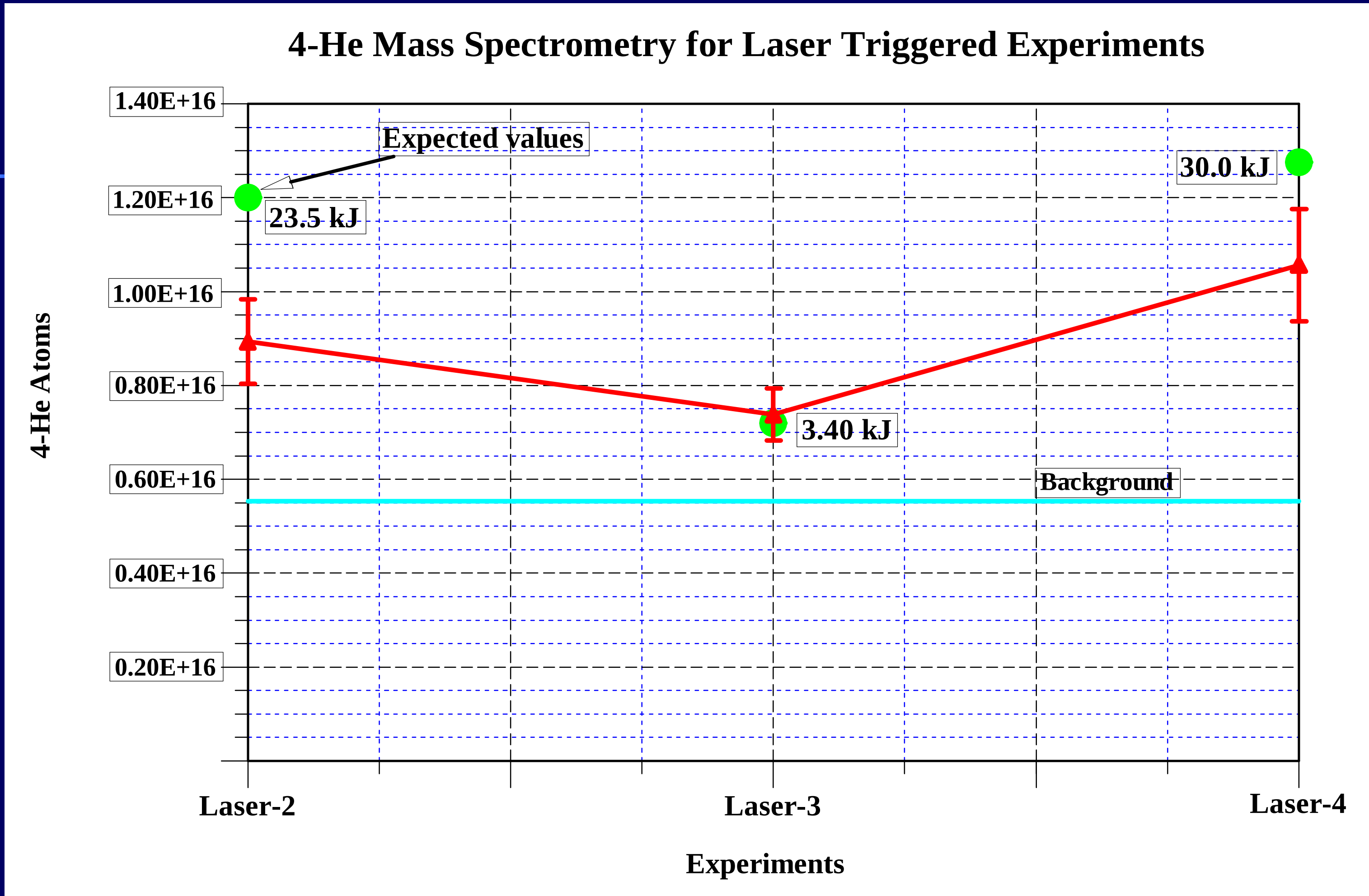






GC-Mate resolution up to 0.0001 AMU, sensitivity in SIM mode up to some Fg.

Laser Triggered Experiments: ^{4}He Results



The expected amount of increasing of ^{4}He is in accordance with the energy gain by assuming a D+D = 4He +24 MeV reaction.

Conclusions

- Heat effects are observed with D, but not with H, under similar (or more severe) conditions.

- Heat bursts exhibit an integrated energy at least 10 x greater than the sum of all possible chemical reactions within a closed cell.

- Experiments reproducibility was significantly improved as a result of material science study.

- Conditions are required to have a reproducible excess power:

1) Loading threshold D/Pd > 0.9 (*necessary condition*).
2) Suitable material to have a reproducible loading above the threshold.
3) Trigger
4) Suitable status of the material to have coupling with trigger.

Three excess power over three effective experiments have been achieved by respecting these conditions!

The accordance between revealed ^4He and produced energy seems to be a clear signature of a nuclear process occurring in condensed matter.

Acknowledgments

The authors thank:

Energetics Technology for the support given to the development of these activities.

Sued Chemie for the help received in all the aspects of the research concerning the catalysts.

JEOL for the assistance in preparing the GC-Mate mass spectrometer.

E.N.E.A. Frascati

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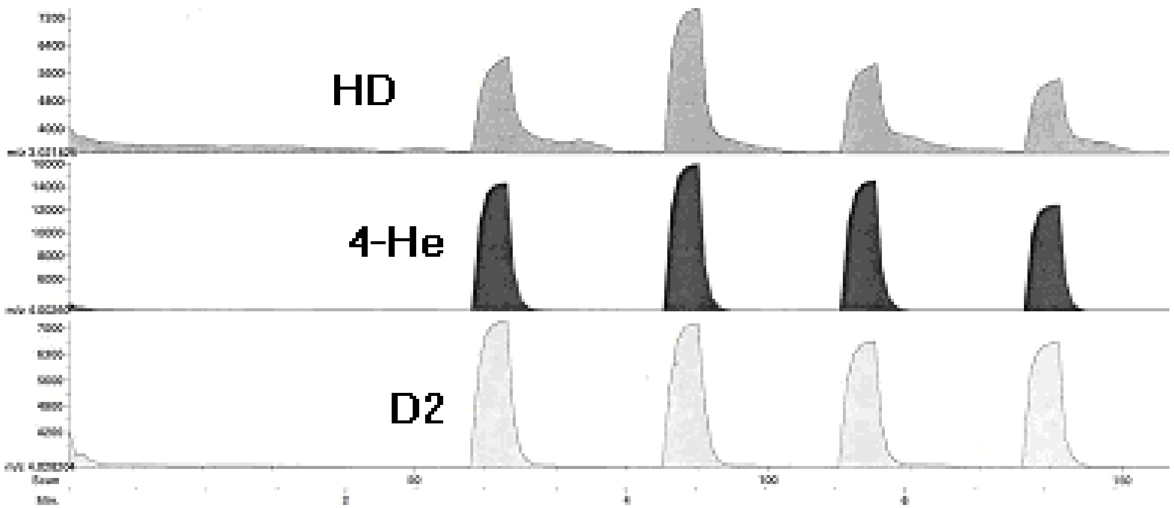
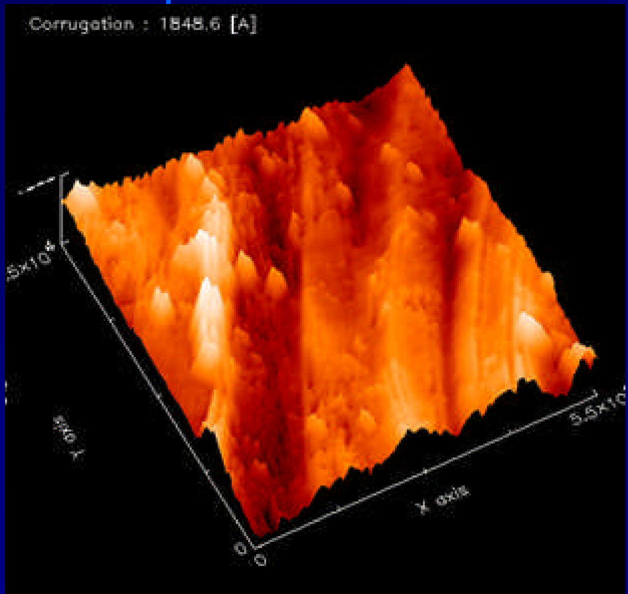
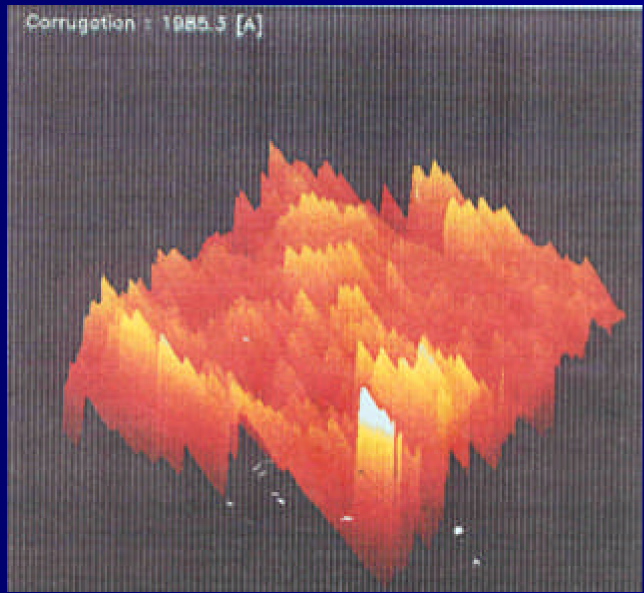
File: L41610 Date Run: 10-16-2004 Time Run: 17:31:31
Sample: Analisi gas cella Laser4 fine esperimento 16.10.04
Instrument: JEOL GCmate Run By: JEOL
Inlet: My Inlet Ionization mode: EI+ Printed by: JEOL



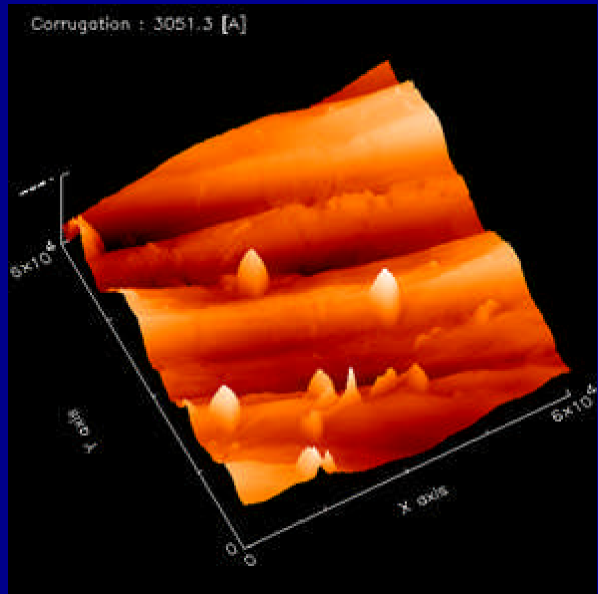
Different surface different behavior



Palladium giving excess, before electrolysis.



Palladium giving excess, (after) with Pd deposition during electrolysis.



Not working palladium

SURFACE-SOLITON FORMATION IN METAL/ELECTROLYTE INTERFACE ELECTRODYNAMICS

A. M. Brodskii

UDC 541.135.5

Attention has been aroused in recent years by the anomalous enhancement of optical effects near metal/electrolyte interfaces, e.g., the Raman scattering of adsorbed molecules, second-harmonic surface generation, and photoemission from the surface [1, 2]. After analyzing the experiments most workers believe that two effects must be realized simultaneously to explain these phenomena, viz., so-called chemical amplification (which arises, in particular, from an increase in the transition moments owing to overlap of the electronic wave functions of the molecule with state functions of the metal adatoms [3]) and electrodynamic amplification owing to the formation of surface plasmons (SP; see [4] and the literature cited there). However, much remains unexplained in the phenomena being discussed. It is obscure, in particular, why for a significant enhancement of the optical processes occurring near the surface, the two effects mentioned must combine, and also why the enhancement is observed at distances up to hundreds of angstroms from the surface, even though the influence of chemical amplification should be limited to atomic distances. The strong dependence on a number of details of surface preparation also is difficult to explain.

In the present communication we offer an explanation for anomalous enhancement which is based on the idea that solitons to which the SP combine are generated on the metal surface. For its realization, this mechanism requires roughness, without which SP will not form or decay to light, and at the same time it requires effects of the type of chemical amplification, without which sufficiently strong nonlinearities in the field equations will not arise. Also needed is a special surface organization. For a quantitative estimate, we shall start from the following expression for the effect, S, of the electromagnetic field in the medium:

$$S=S_0-iSp\ln(1+\Gamma G)=S_0+iSp\ln(1-\Gamma G_0),$$
$$G=G_0+G_0\Gamma G,\quad \Gamma=-\frac{e}{2mc}(\mathrm{Ap}+\mathrm{pA})+\frac{e^2}{2mc^2}A^2+e\varphi, \tag{1}$$

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Translated from Élektrokhimiya, Vol. 22, No. 2, pp. 270-273, February, 1986. Original article submitted December 18, 1985.

0038-5387/86/2202-0247$12.50