Progress in Excess Power Production by Laser Triggering

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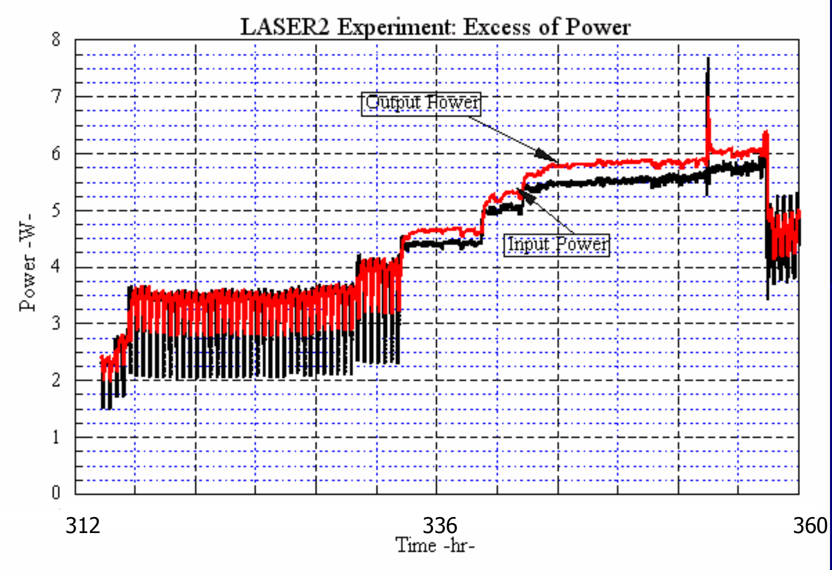
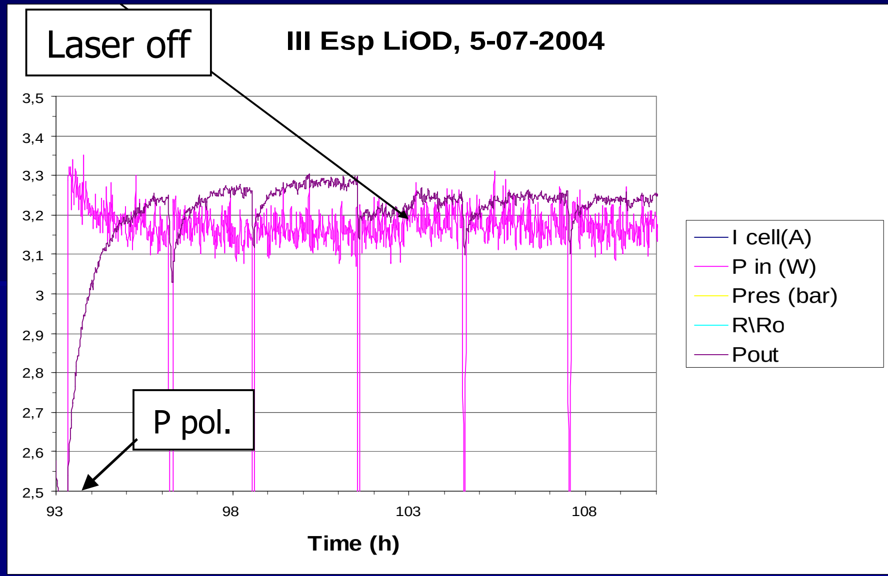
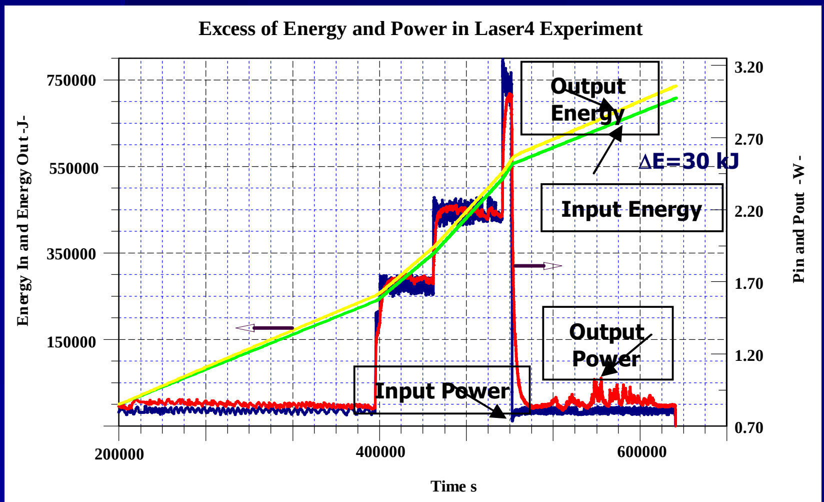
Previous Results



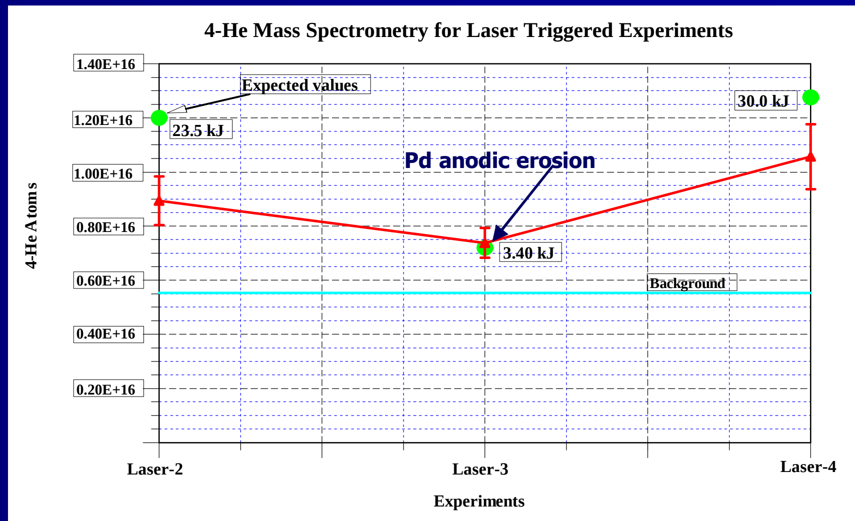


Evolution of the input and output power, last 300 hr under laser irradiation (P-polarization)

Laser on-off effect



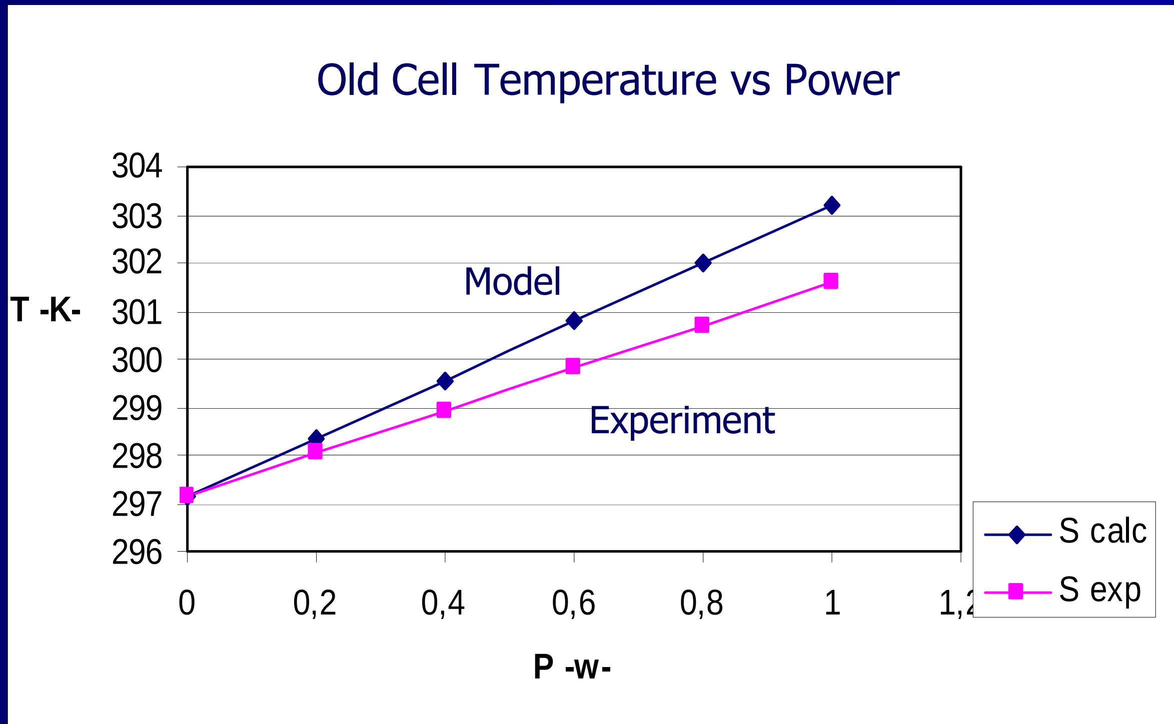
Laser 4 experiment



^{4}He Production

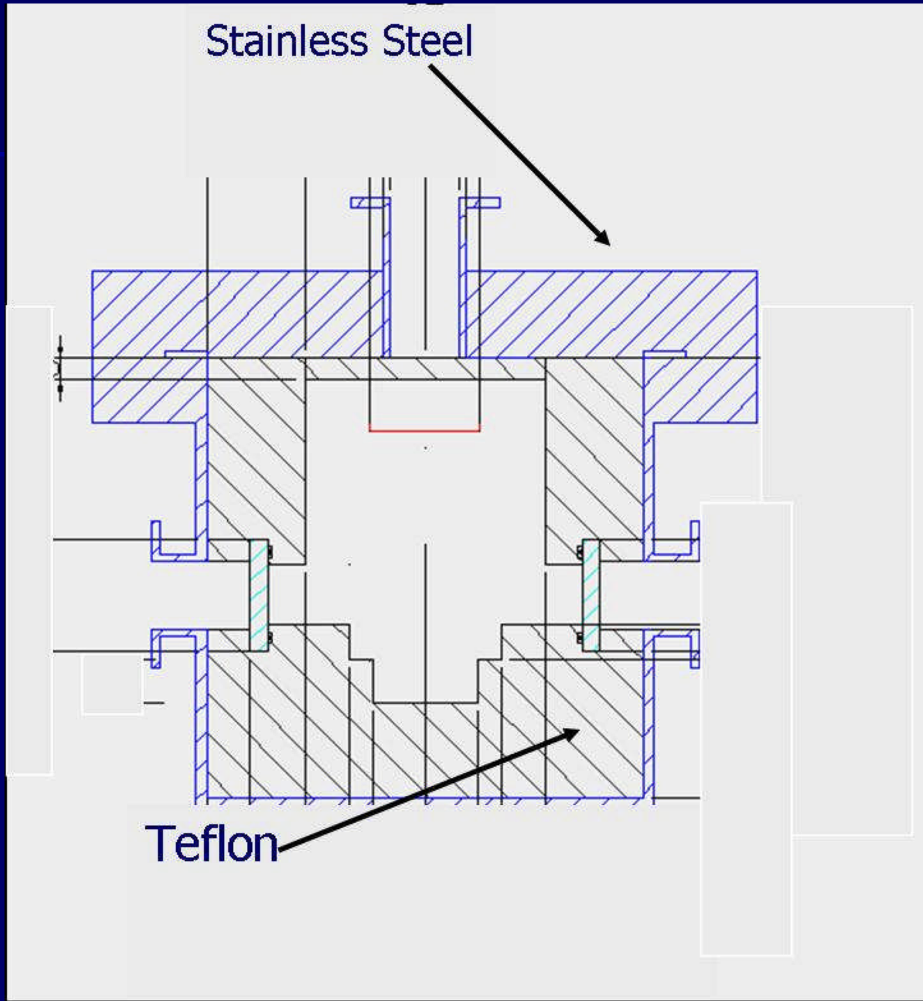
Improvement of the Cell

Old cell



Average temperature of the electrolyte vs power

Double Structure New Cell for Laser Experiments



New double structure cell

Thermal Analysis

Heat transfer equation

$$div\left(K\,grad(T)\right)+Q=\rho c_p\frac{\partial T}{\partial t}+\rho c_p\left(V_x\frac{\partial T}{\partial x}+V_y\frac{\partial T}{\partial y}+V_z\frac{\partial T}{\partial z}\right)$$

Boundary conditions

$$-K\frac{\partial T}{\partial n}=h\left(T-T_a\right)$$

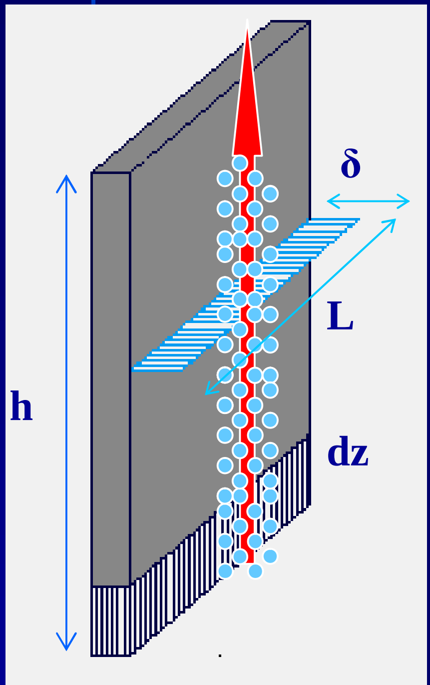
(convective heat exchange mechanism)

Assumptions:

- **3D transient**
- **isotropic (Kx=Ky=Kz)**
- **Steady state boundary conditions (thermostatic box) T_{amb} = cost.(t)**
- **Radiative heat exchange negligible**

Hydrogen Bubbles at the Cathode

Gas velocity V_{H2} is calculated by means of the current density



Pd foil

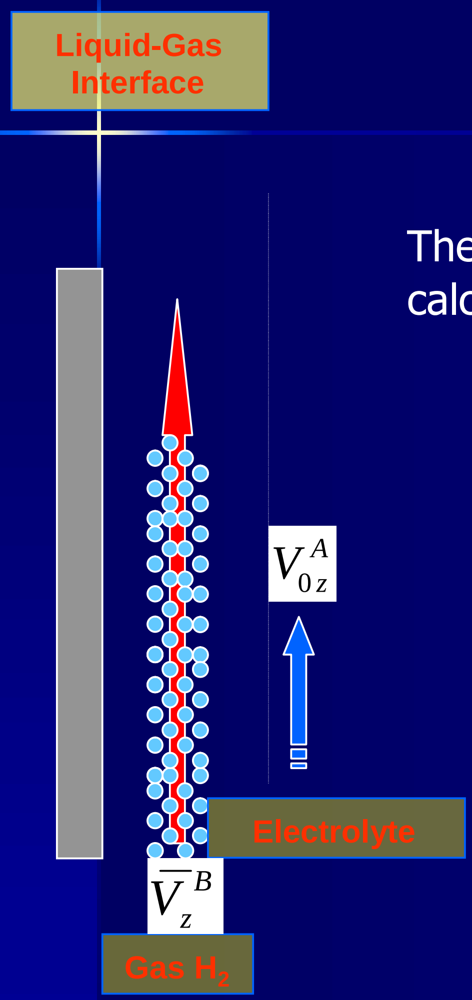
Gas flow rate for unit area $$K = \frac{J \cdot 22{,}4 \cdot 1000}{nF} \quad (cm/s)$$

Total gas flow rate $$W = \int_0^z L \cdot K \cdot dz = L \cdot K \cdot z \quad (cm^3/s)$$

Gas velocity $$V_{gas}(z) = \frac{W}{A} = \frac{W}{L \cdot \delta} = \frac{K \cdot z}{\delta} \quad (cm/s)$$

Liquid-Gas Interface Velocity

One fluid is moved by the other having different density and viscosity

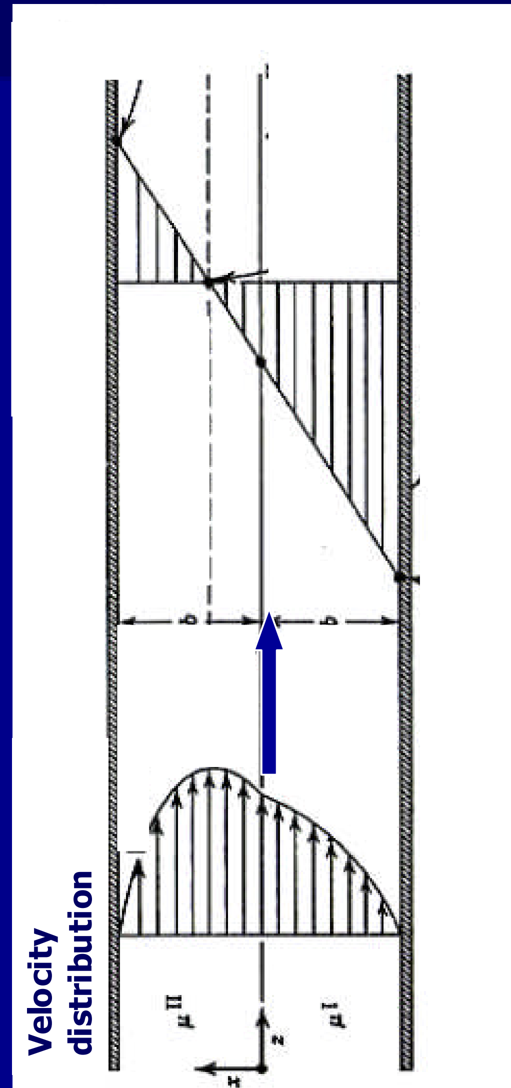


The electrolyte interface velocity is calculated by the average gas velocity

$$\left.\frac{V_z^A}{V_z^B}\right|_{x=0} = \frac{\frac{1}{\mu^A}\left(\frac{2\mu^A}{\mu^A+\mu^B}\right)}{\frac{1}{\mu^B}\left(\frac{2\mu^B}{\mu^A+\mu^B}\right)} = 1$$

$$\frac{V_{0z}^A}{\overline{V}_z^B} = \frac{12\mu^B}{\mu^A+7\mu^B} = 0.093$$

$$V_{H_2Oz}^A = 0{,}093\cdot\overline{V}_{H_2z}^B$$



Equations

$$\frac{1}{r}\cdot\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)=0$$

Motion Equation

$$\frac{1}{r}v_r+\frac{\partial v_r}{\partial r}+\frac{\partial v_z}{\partial z}=0$$

Continuity equation

Assumptions

axial symmetry

density and viscosity are constant

steady state

negligible effect of pressure and mass

Iterative procedure for velocity field calculation

step1: Equation of motion

solving the equation of motion with the boundary conditions

$v_z=V_{0z}$ r=a ; $v_z=0$ r=R

$$v_z = -\ln R \cdot \frac{V_o}{\ln\left(\frac{a}{R}\right)} + \frac{V_o \cdot \ln r}{\ln\left(\frac{a}{R}\right)}$$

Step 2: Continuity equation

by replacing the v_z calculated at step 1 and by solving the continuity equation **with the condition of zero flow rate** in the radial direction

$$v_r(r) = \frac{C_{1R}}{r} - \frac{K \cdot r \cdot \left[2\ln\left(r/R\right) - 1\right]}{4 \cdot \delta \cdot \ln\left(a/R\right)}$$

$$C_{1R} = -\frac{1}{4}\frac{K}{\delta} \cdot \frac{a^2 - R^2 + a^2 \ln\left(R/a\right)}{\left[\ln(R/a)\right]^2}$$

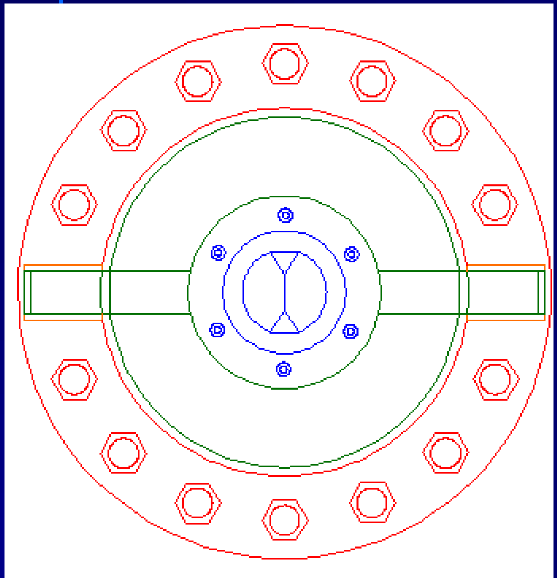
Step 3: Continuity equation

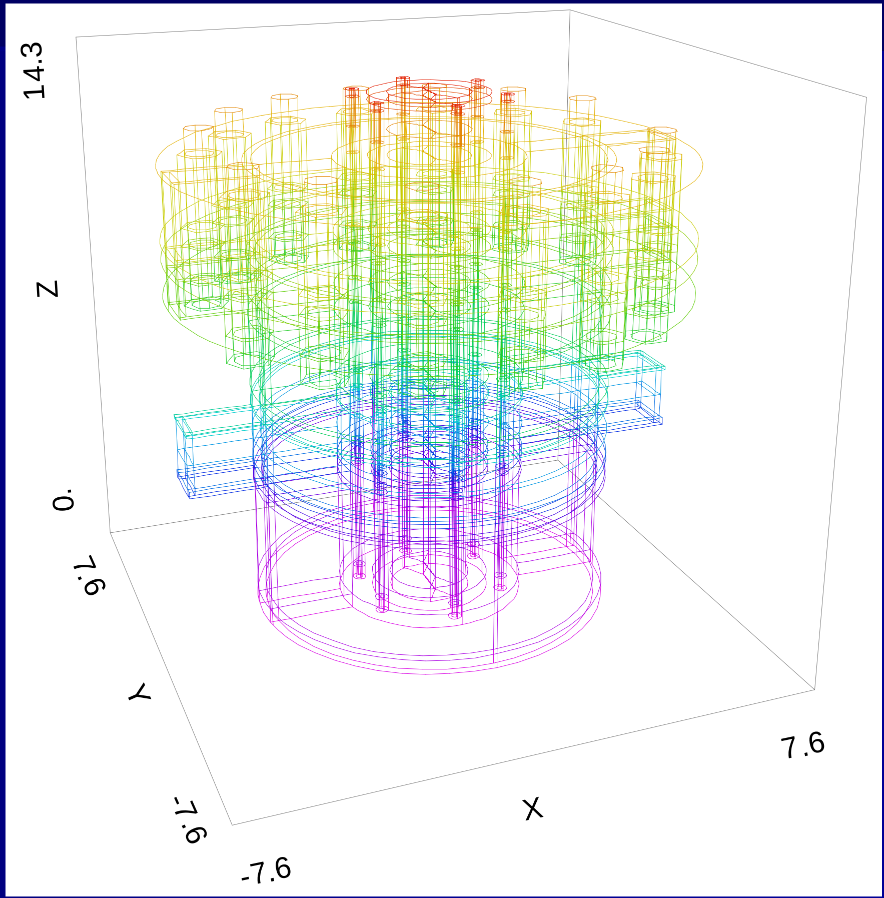
By replacing v_r calculated at step 2 and by solving the continuity equation with the condition of zero flow rate in axial direction

$$VV_z(r,z) = -z \cdot K_2 \cdot \ln\left(\frac{r}{R}\right) + C_{1z}$$

$$C_{1z} = \frac{1}{2} K_2 \cdot z \frac{\left(a^2 - R^2 + 2\ln R/a\right)}{a^2 - R}$$

FEM Domain

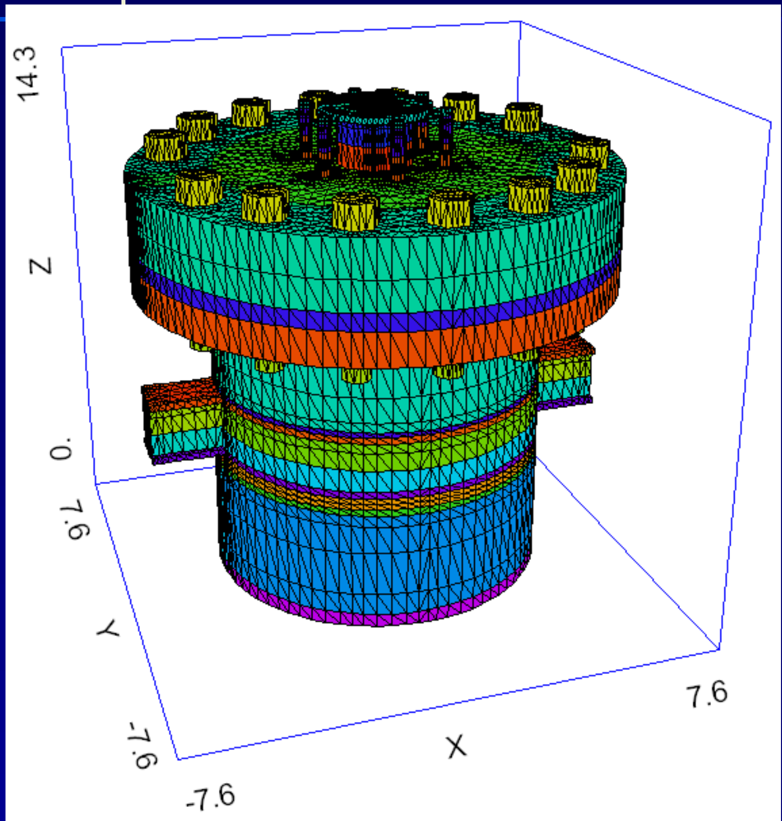




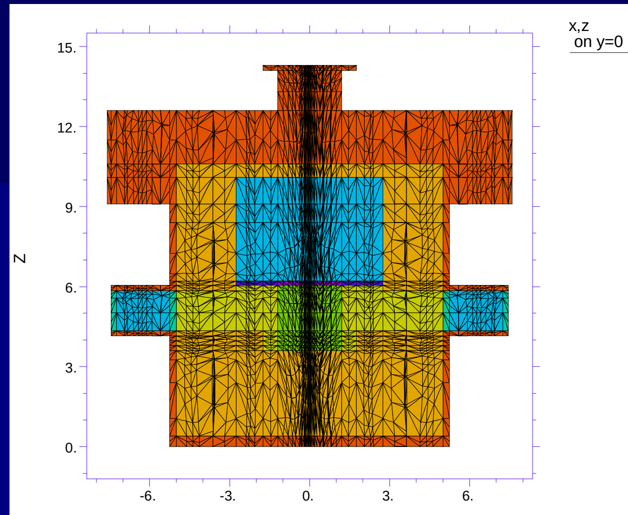
CAD 2D

Domain estrusion

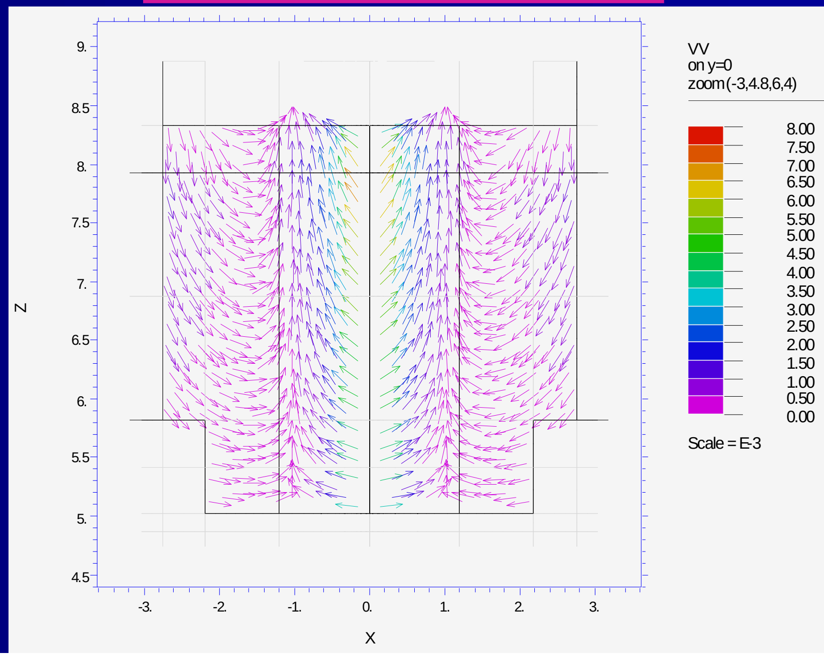
Mesh and Velocity Field



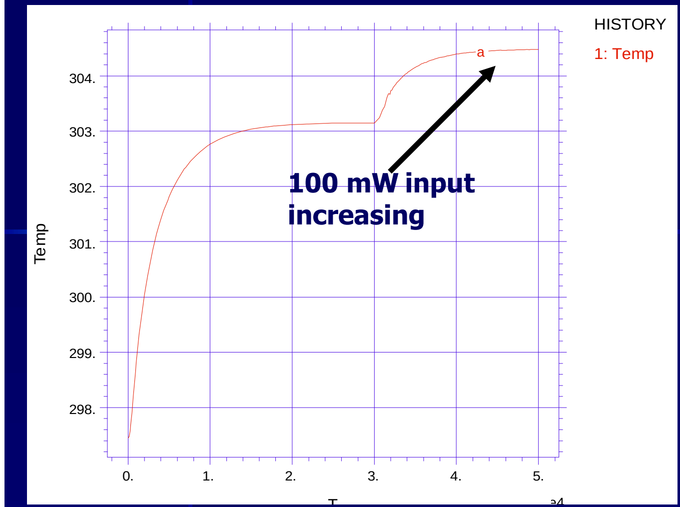
Mesh 3D



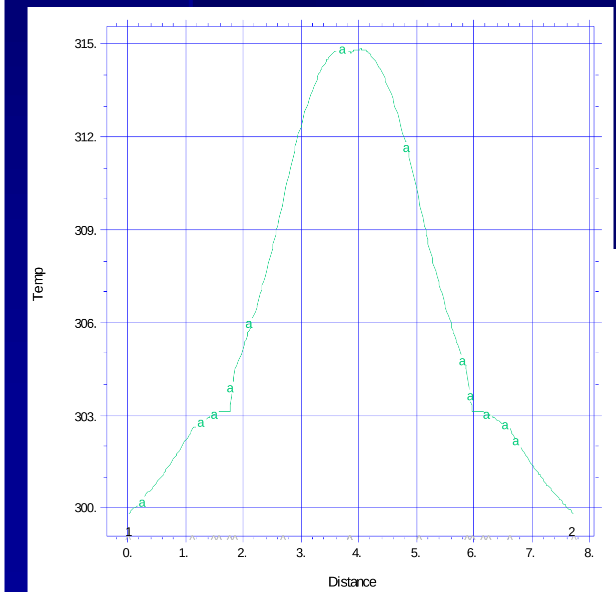
Velocity field due to bubbles



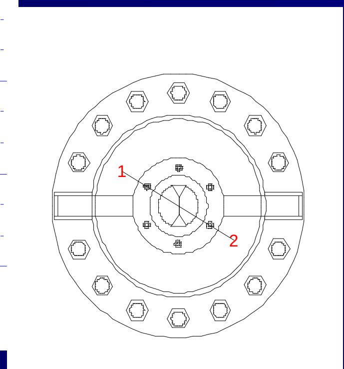
Thermal Analysis

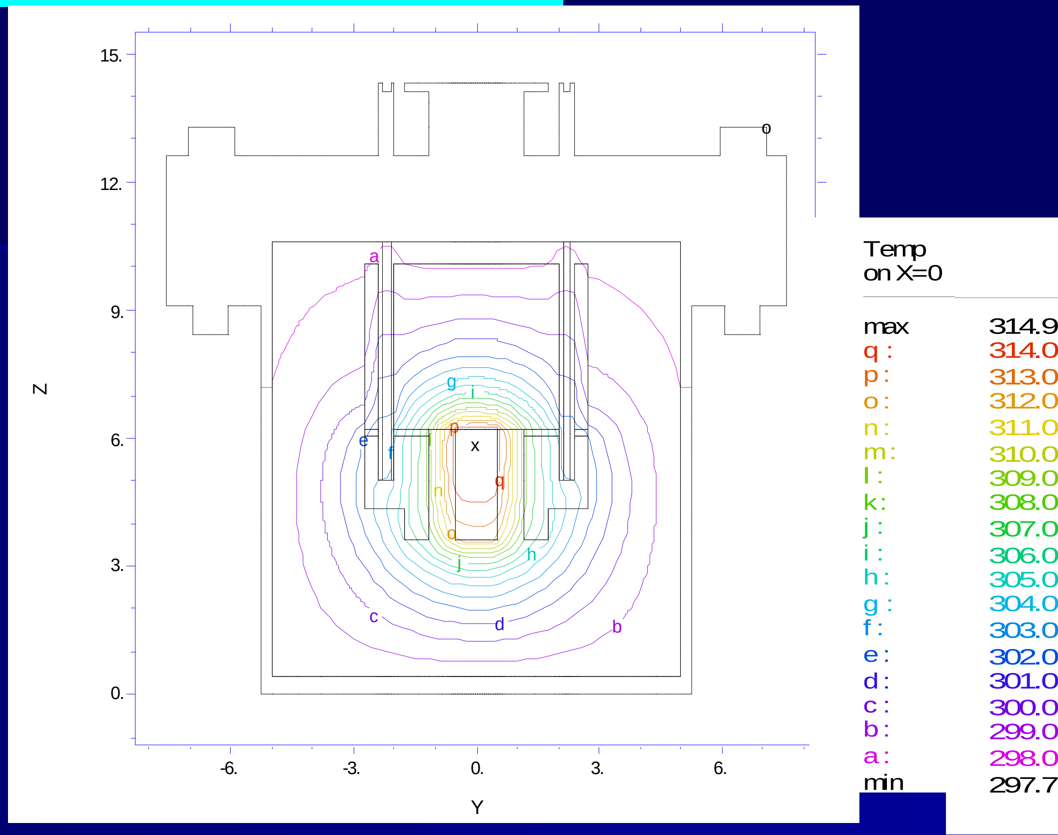


Temperature evolution



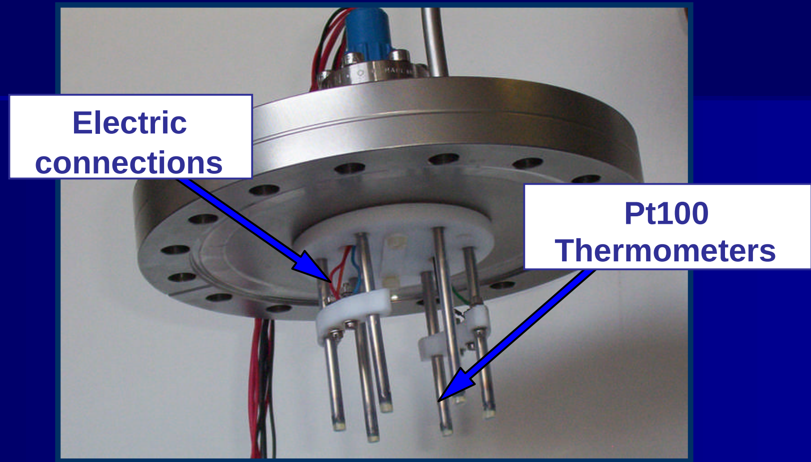
Temperature profile along 1-2



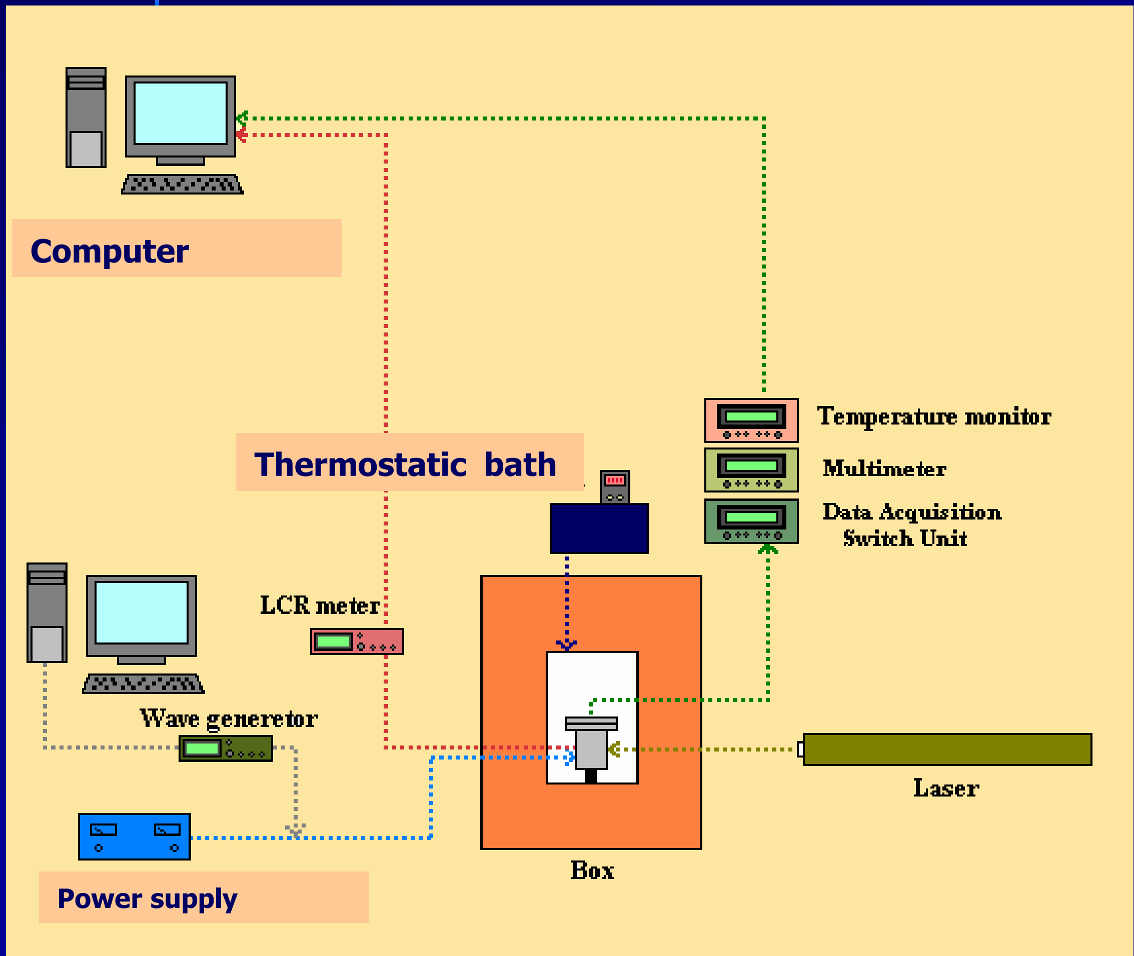


Isotherms axial plane

Cell



Experimental System Set up



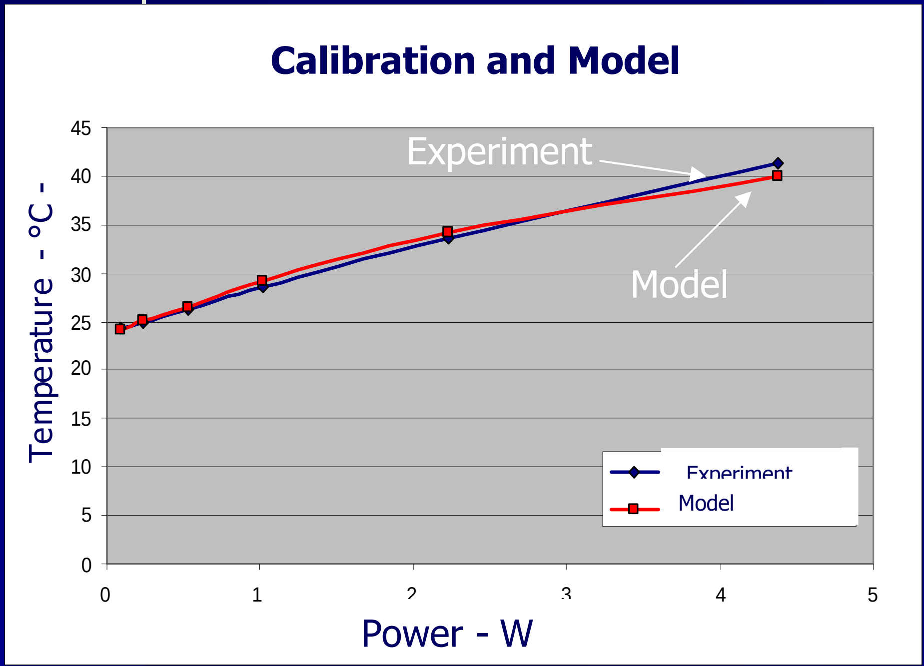
Thermostatic bath

Measurement instruments

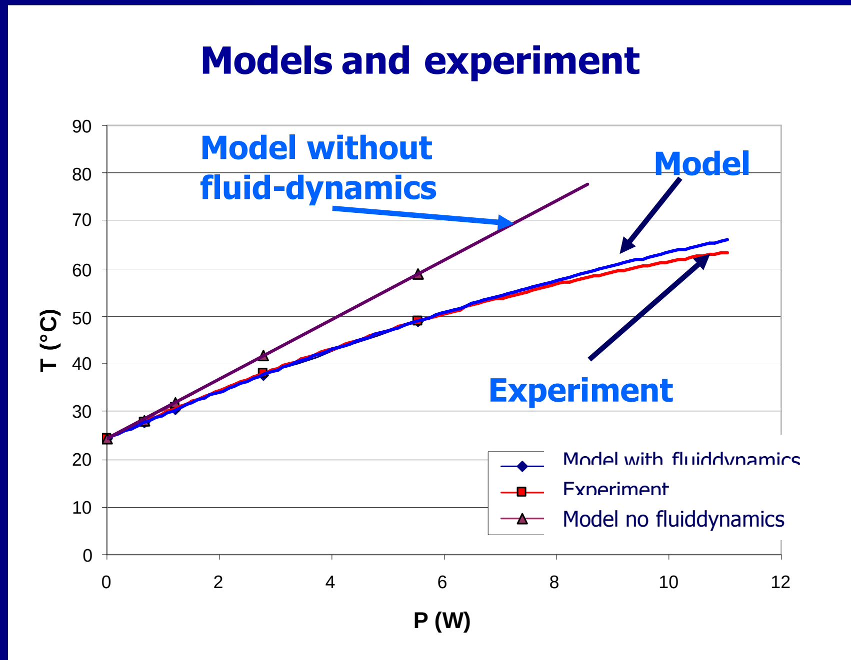
Thermostatic box

Thermostatic System

Comparison between Experimental Data and Model

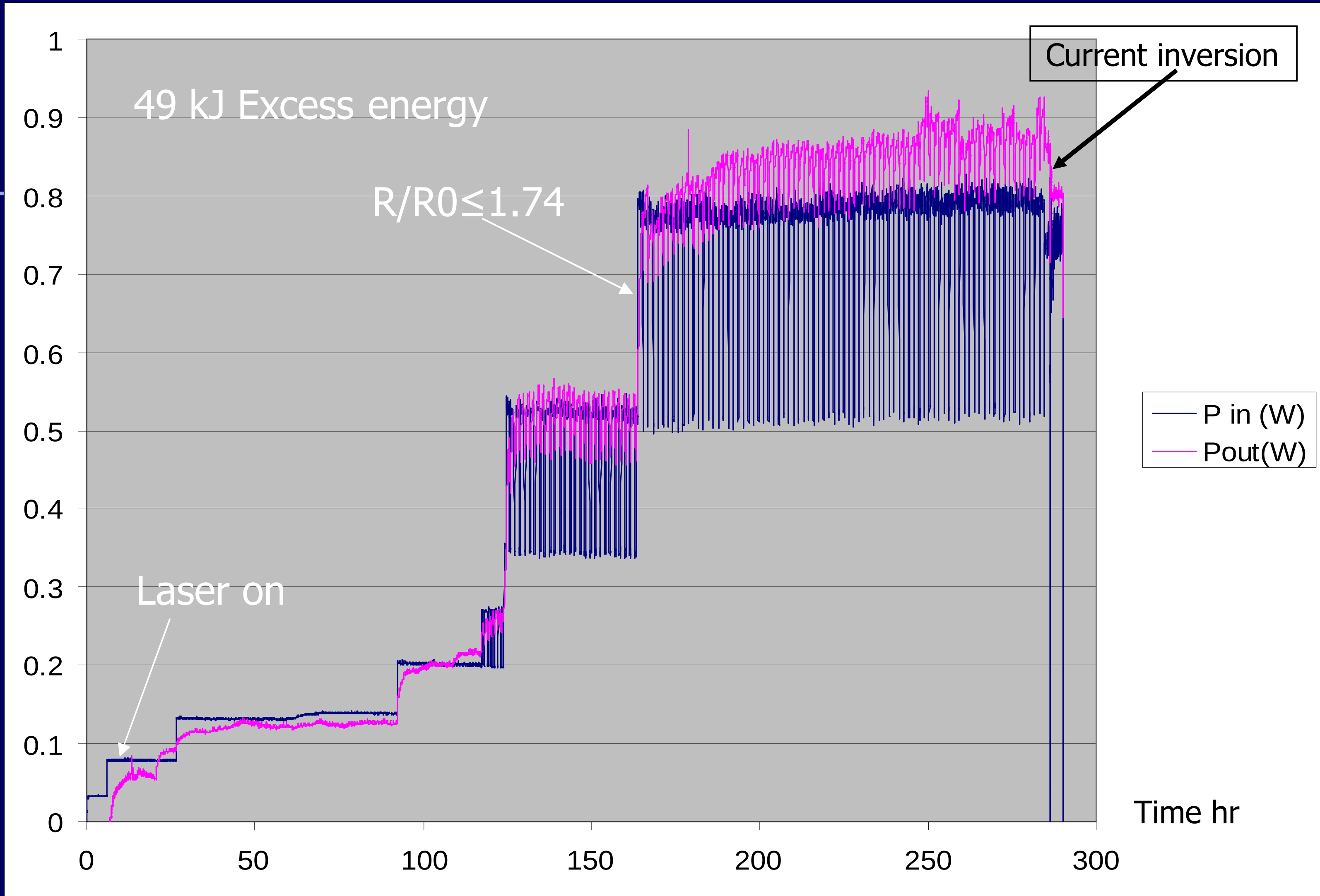


Comparison between calibration data and model

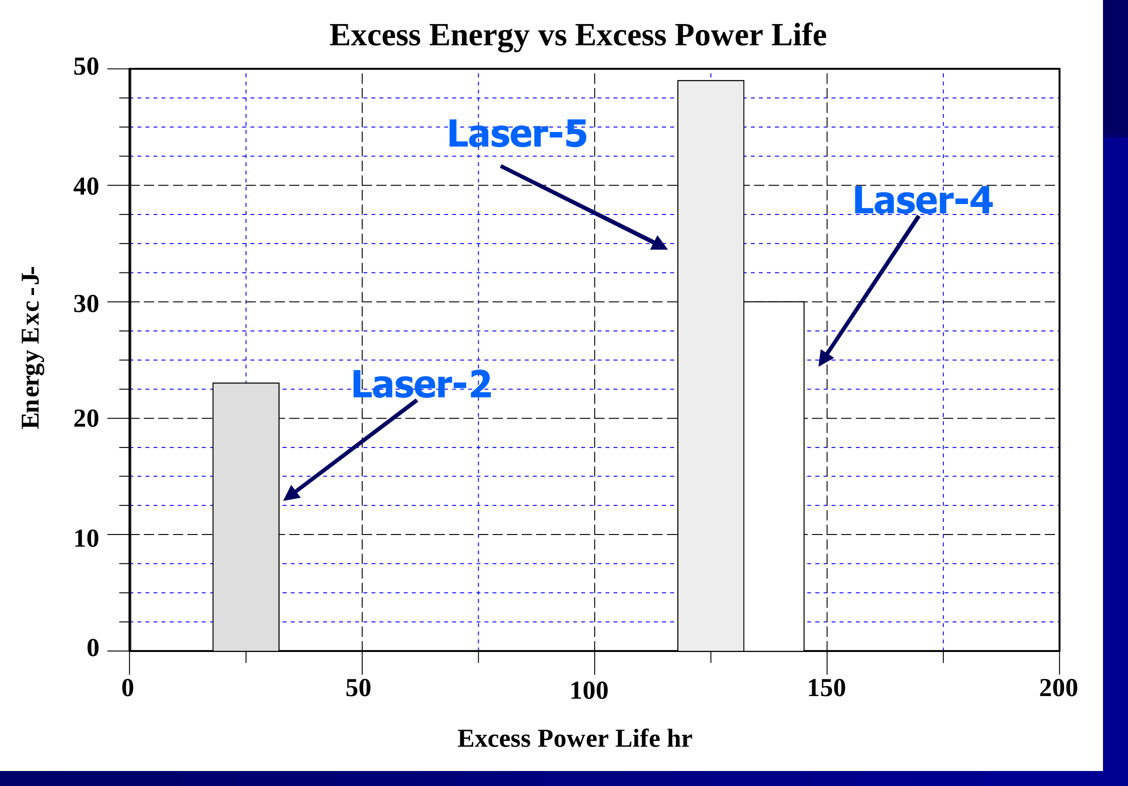


Comparison between experimental data and model, with and without fluid-dynamics

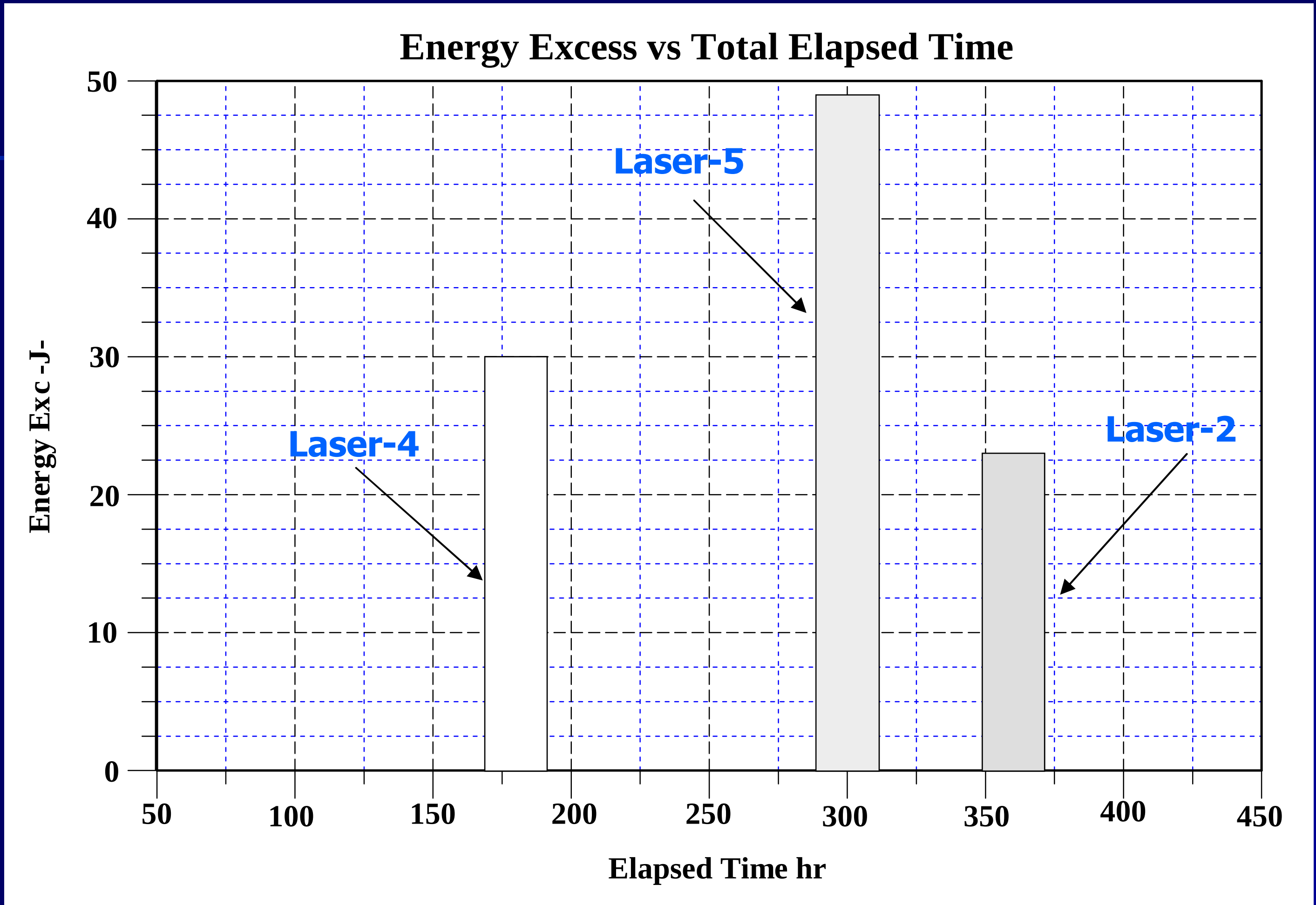
Laser 5 Experiment: Calorimetric Results



Excess power during laser triggering (HeNe laser)



Excess energy vs excess power life time



Excess energy vs experiment elapsed time

Conclusions

- The improvement of the calorimeter design allowed to obtain a satisfactory agreement between model and experiment.
- Laser trigger gave significant reproducibility:
  excess power in 4 out of 5 experiments
- The amplitude of the effect is not yet under control
  even though high loading is almost always achieved.
- Material studies are in progress to identify and control the status of the system producing enhanced values of the signal.