Virtual Laser Laboratory: Online Simulation of Laser Experiments

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Outline

- Motivation
- Conception of virtual laser laboratory
- Basic features of the model
- User interface and examples
- Conclusions and outlook

Motivation

- Simulation and interpretation of laser experiments are problems of today
- There are complex wide-range models that give reliable results
- But how to give an access to these models?

⇩

Web interface + code = Virtual Laser Lab

Conception of Virtual Laser Laboratory

Virtual Laser Laboratory

Purpose: Expert system for simulation of laser experiments

Principles
- open
- user-friendly

Tools
- wide-range physical models
- simulation module
- user web interface
- visualization

Benefits
- experiment cost reduction
- interpretation of experimental findings
- education

Two-Temperature Hydrodynamic Model

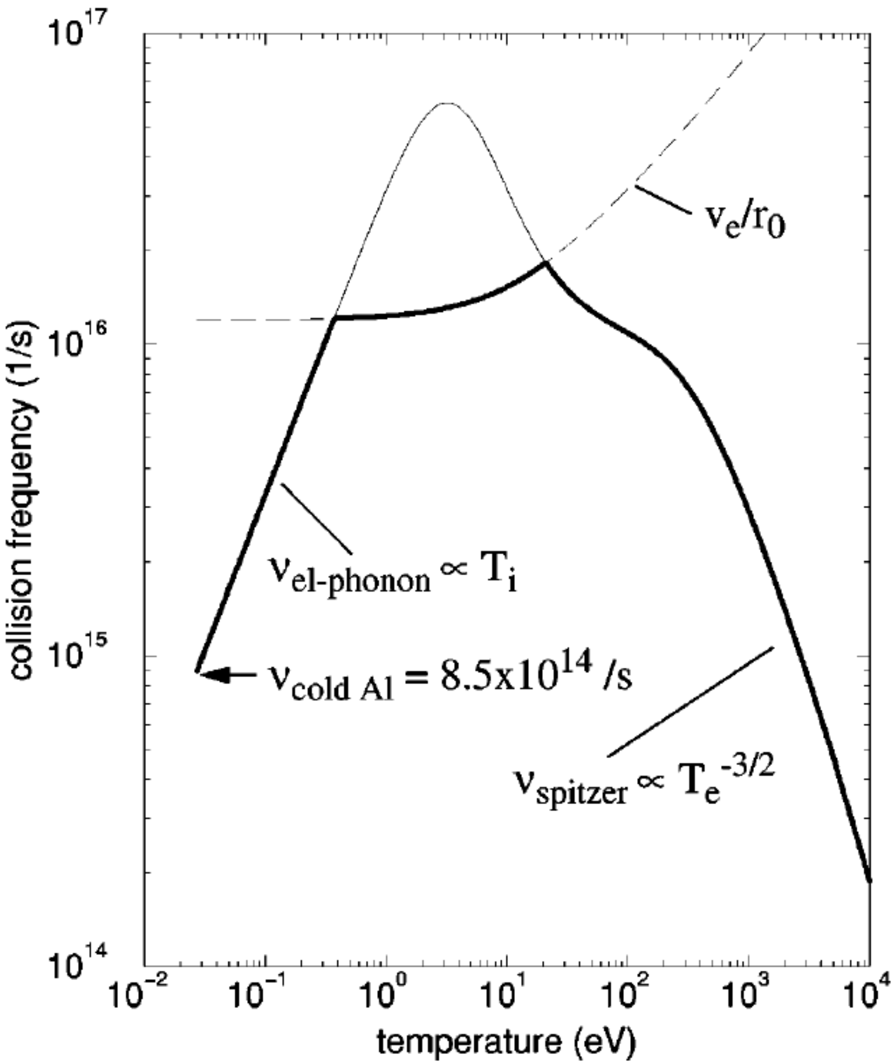
$$\frac{\partial(1/\rho)}{\partial t} - \frac{\partial u}{\partial m} = 0, \tag{1}$$

$$\frac{\partial u}{\partial t} + \frac{\partial(P_i + P_e)}{\partial m} = 0, \tag{2}$$

$$\frac{\partial e_e}{\partial t} + P_e \frac{\partial u}{\partial m} = -\gamma_{ei}(T_e - T_i)/\rho + + Q_L/\rho + \frac{\partial}{\partial m}\left(\rho \kappa_e \frac{\partial T_e}{\partial m}\right), \tag{3}$$

$$\frac{\partial e_i}{\partial t} + P_i \frac{\partial u}{\partial m} = \gamma_{ei}(T_e - T_i)/\rho. \tag{4}$$

Collision frequency



Eidmann et al. PRE 62 (2000)

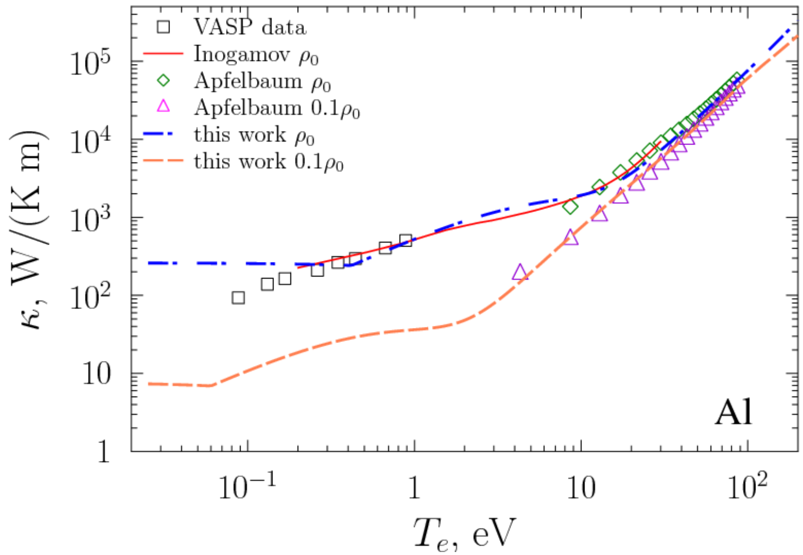
Pump-probe for ν_{cold}

[30] Elsayed et al. PRL **58**, 1212 (1987)

[31] Groeneveld et al. PRL **64**, 784 (1990)

[32] Schoenlein et al. PRL **58**, 1680 (1987)

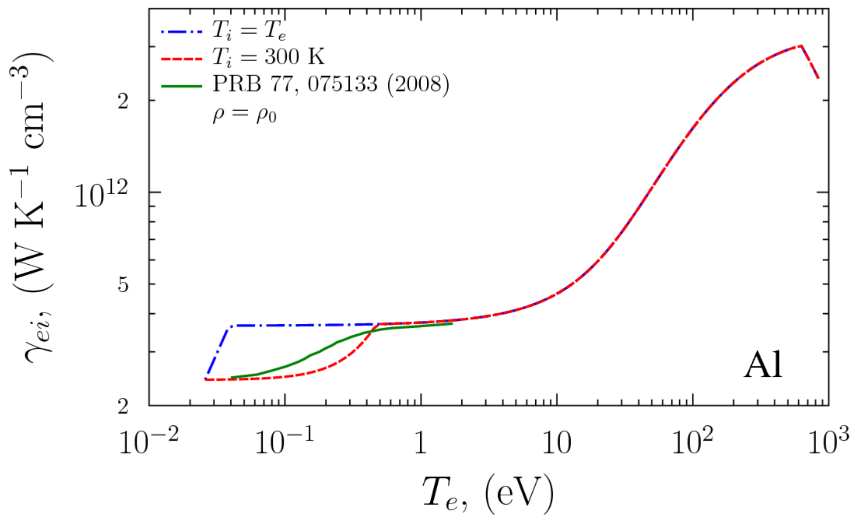
Thermal conductivity and electron-ion coupling



$$\kappa = \kappa_{\text{pl}} + (\kappa_{\text{met}} - \kappa_{\text{pl}})e^{-A_4^t T_e/T_F}$$

$$\kappa_{\text{met}} = \frac{\pi^2 k_B^2 n_e}{3 m_e \nu_{\text{eff},t}} T_e \qquad T_e << T_F$$

$$\kappa_{\text{pl}} = \frac{16\sqrt{2} k_B (k_B T_e)^{5/2}}{\pi^{3/2} Z e^4 \sqrt{m_e} \Lambda} \qquad T_e >> T_F$$



$$\gamma_{ei} = \frac{3 k_B m_e}{m_i} n_e \nu_{\text{eff}}$$

Equations of EM field

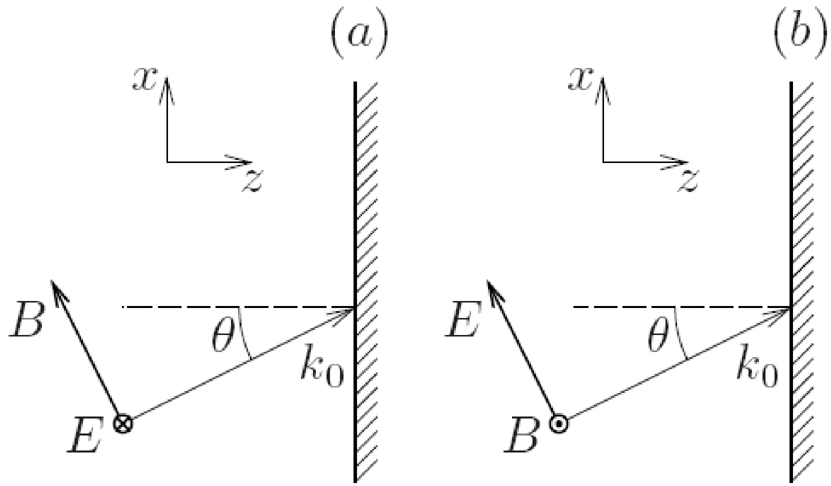


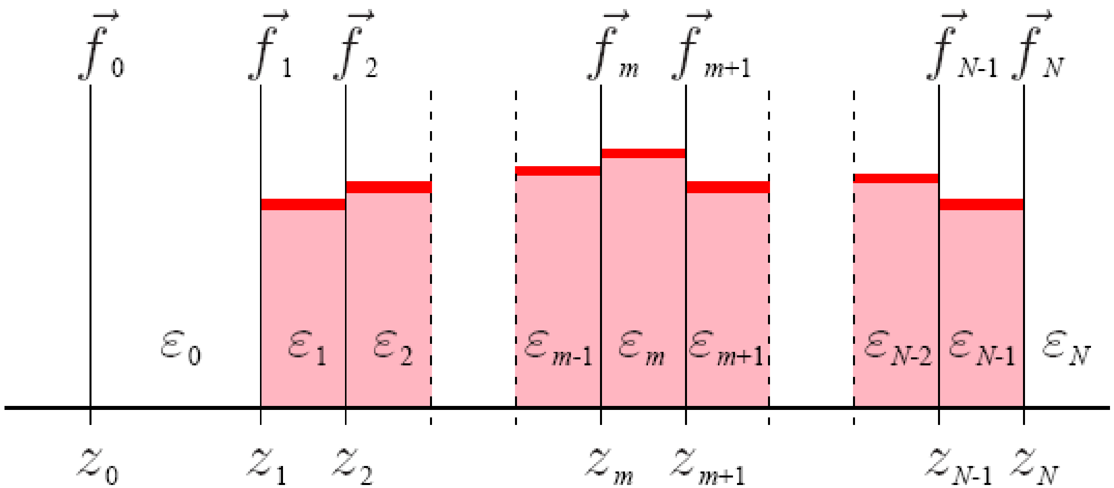
Figure 3. Polarization of laser light: (a)—s; (b)—p.

$$\frac{\partial^2 E}{\partial z^2} + k_0^2[\varepsilon(z) - \sin^2\theta]E = 0.$$

$$\frac{\partial^2 B}{\partial z^2} + k_0^2[\varepsilon(z) - \sin^2\theta]B - \frac{\ln\varepsilon(z)}{\partial z}\frac{\partial B}{\partial z} = 0.$$

Transfer-matrix method (optics)

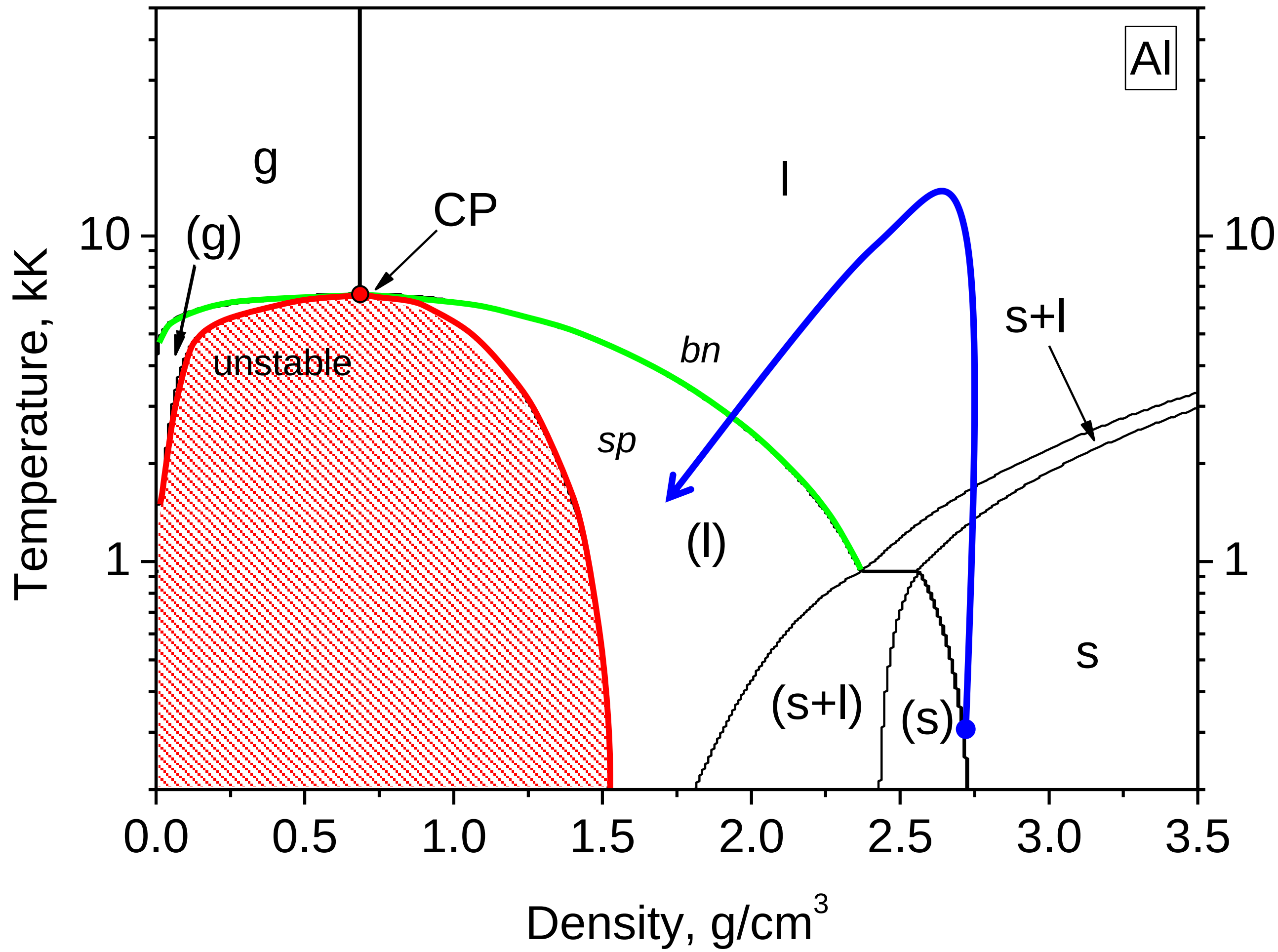
Born, M.; Wolf, E., Oxford, Pergamon Press, 1964.



$$F_m(z) = f_m^{(+)} e^{ik_m(z-z_m)} + f_m^{(-)} e^{-ik_m(z-z_m)} \qquad z_m \leqslant z \leqslant z_{m+1}$$

$$\begin{aligned} F_m(z_{m+1}) &= F_{m+1}(z_{m+1}), \\ (\partial F_m/\partial z)|_{z_{m+1}} &= D_m\,(\partial F_{m+1}/\partial z)|_{z_{m+1}}, \end{aligned} \qquad D_m = \begin{cases} 1, & \text{if s-polarized,} \\ \varepsilon_m/\varepsilon_{m+1}, & \text{if p-polarized.} \end{cases}$$

Two-temperature semi-empirical EOS



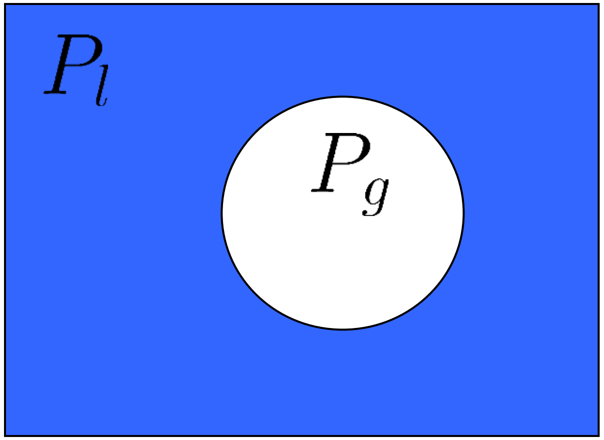
Nucleation model

$$\tau_{\text{wait}} = (CN)^{-1}\exp(W/k_BT)$$

$$C \approx 10^{10}\ s^{-1}$$

$$W = \frac{16\pi\sigma^3}{3(P_g - P_l)^2}$$

$$\tau_{\text{nucl}} = \tau_{\text{wait}} + \tau_{\text{grow}}$$



$$P_g > P_l + \frac{2\sigma}{R}$$

V. P. Skripov, Metastable Liquids. Wiley, New York, 1974.

Pump-probe technique

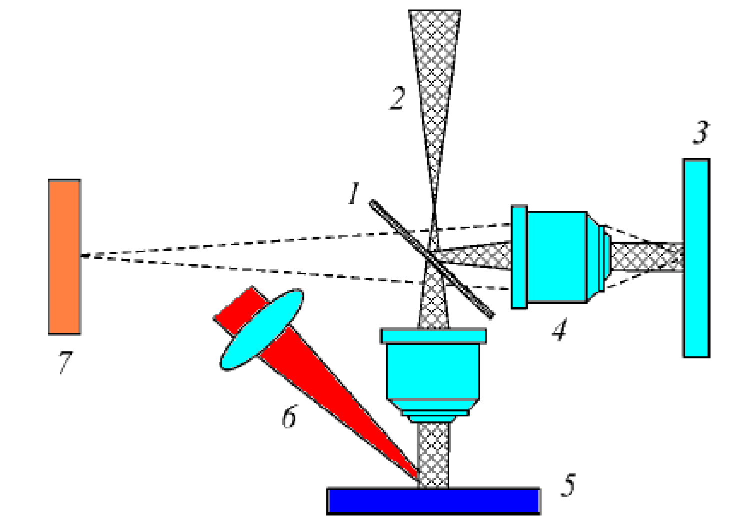
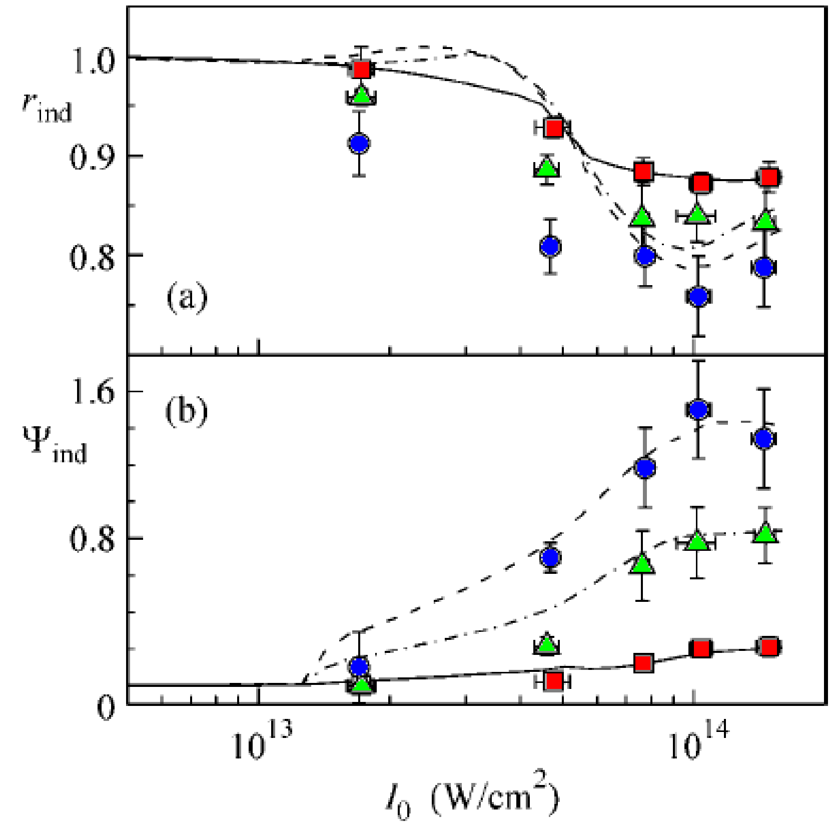


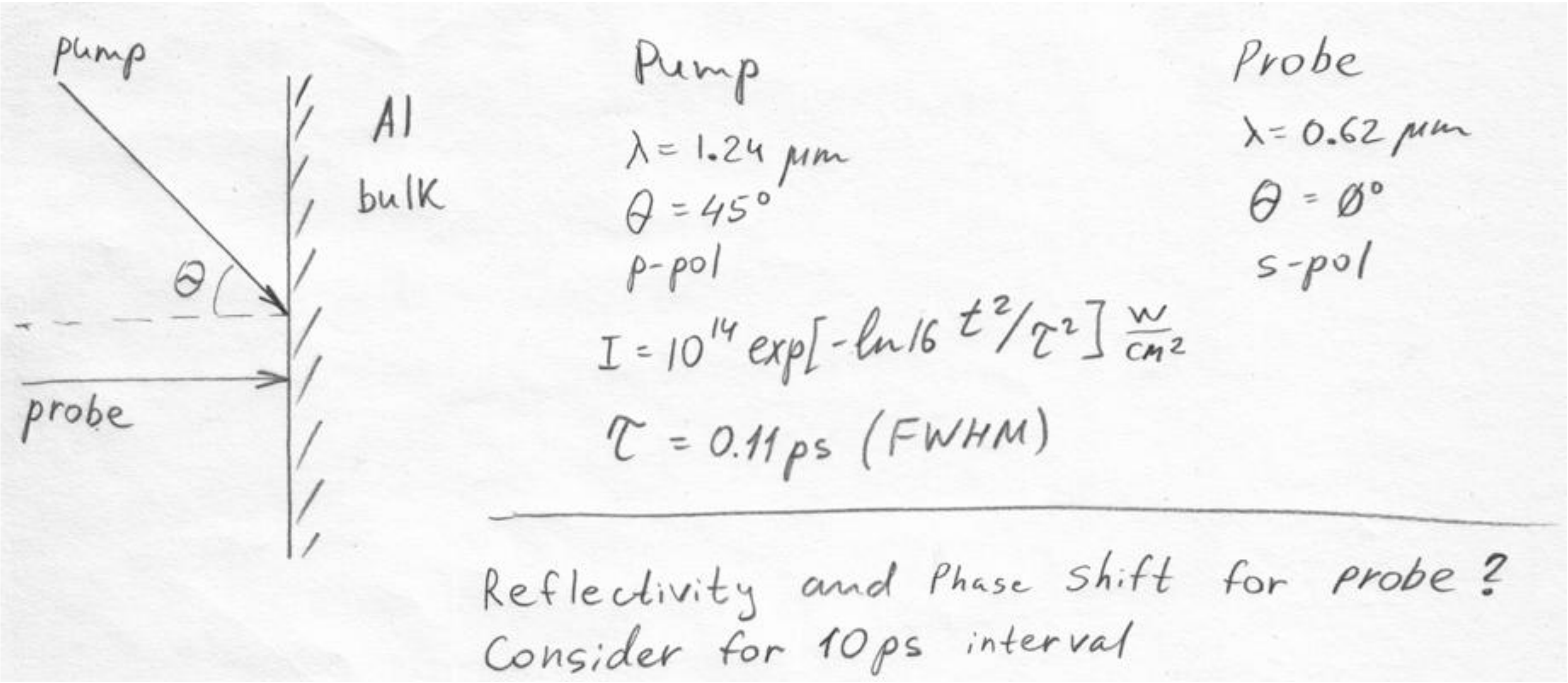
Fig. 1. Optical measurement scheme: (*1*) the beam splitter plate, (*2*) the probe pulse, (*3*) the reference mirror, (*4*) the microobjectives, (*5*) the target, (*6*) the heating pulse, and (*7*) the CCD matrix.



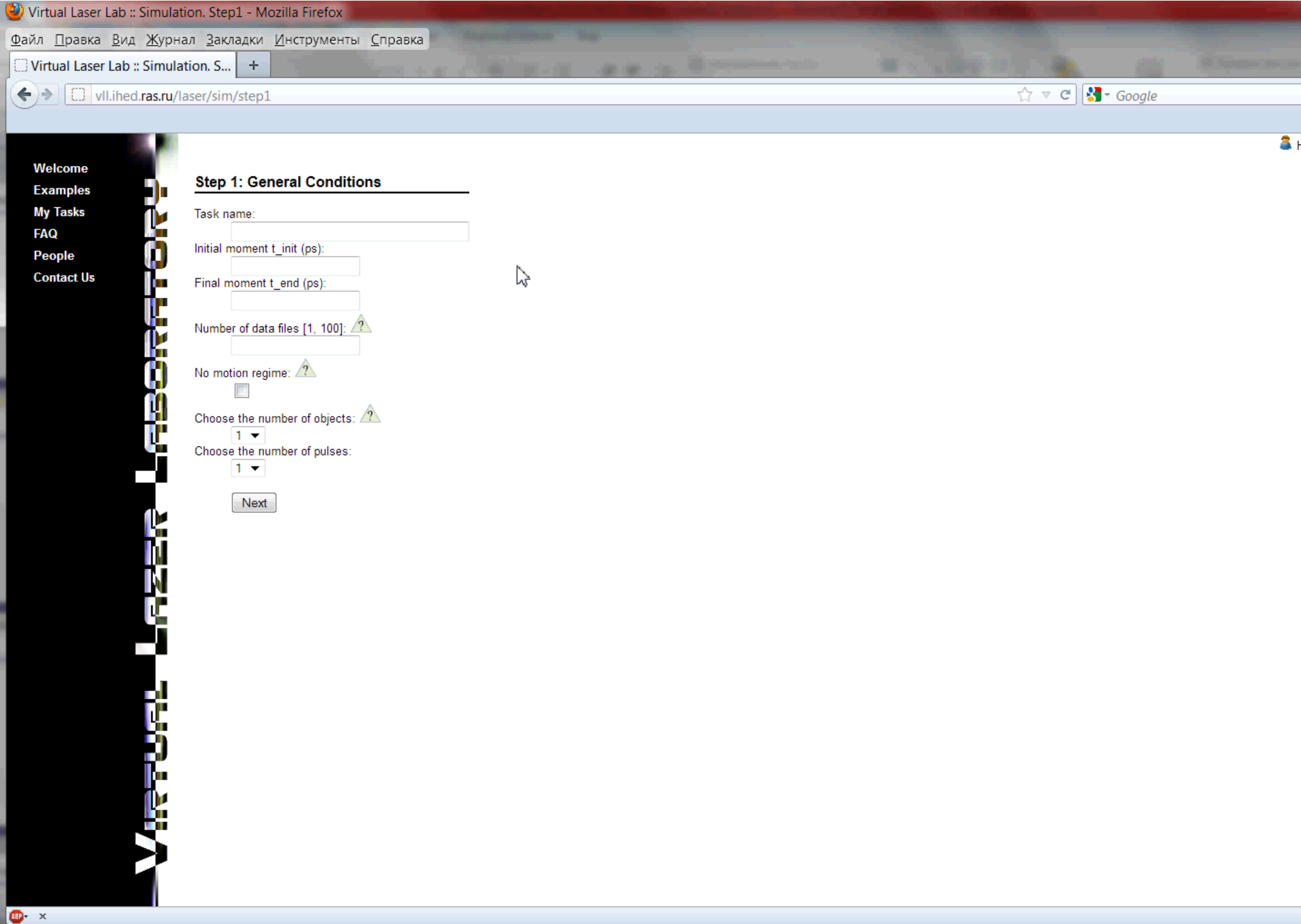
M.B. Agranat et al.
JETP Letters **85** (2007)

Pump-probe modeling

M.B. Agranat *et al.* JETP Letters **85** (2007).



http://vll.ihed.ras.ru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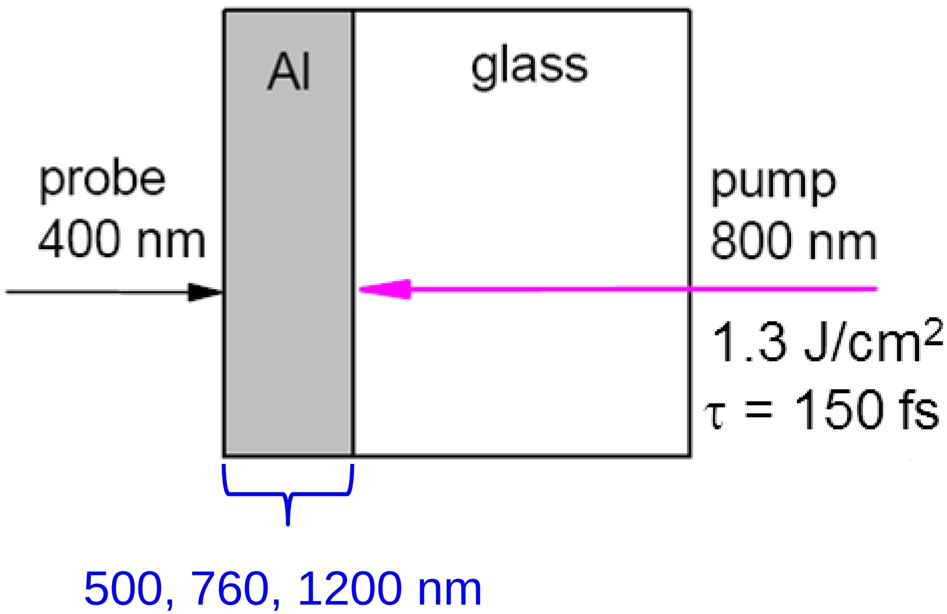
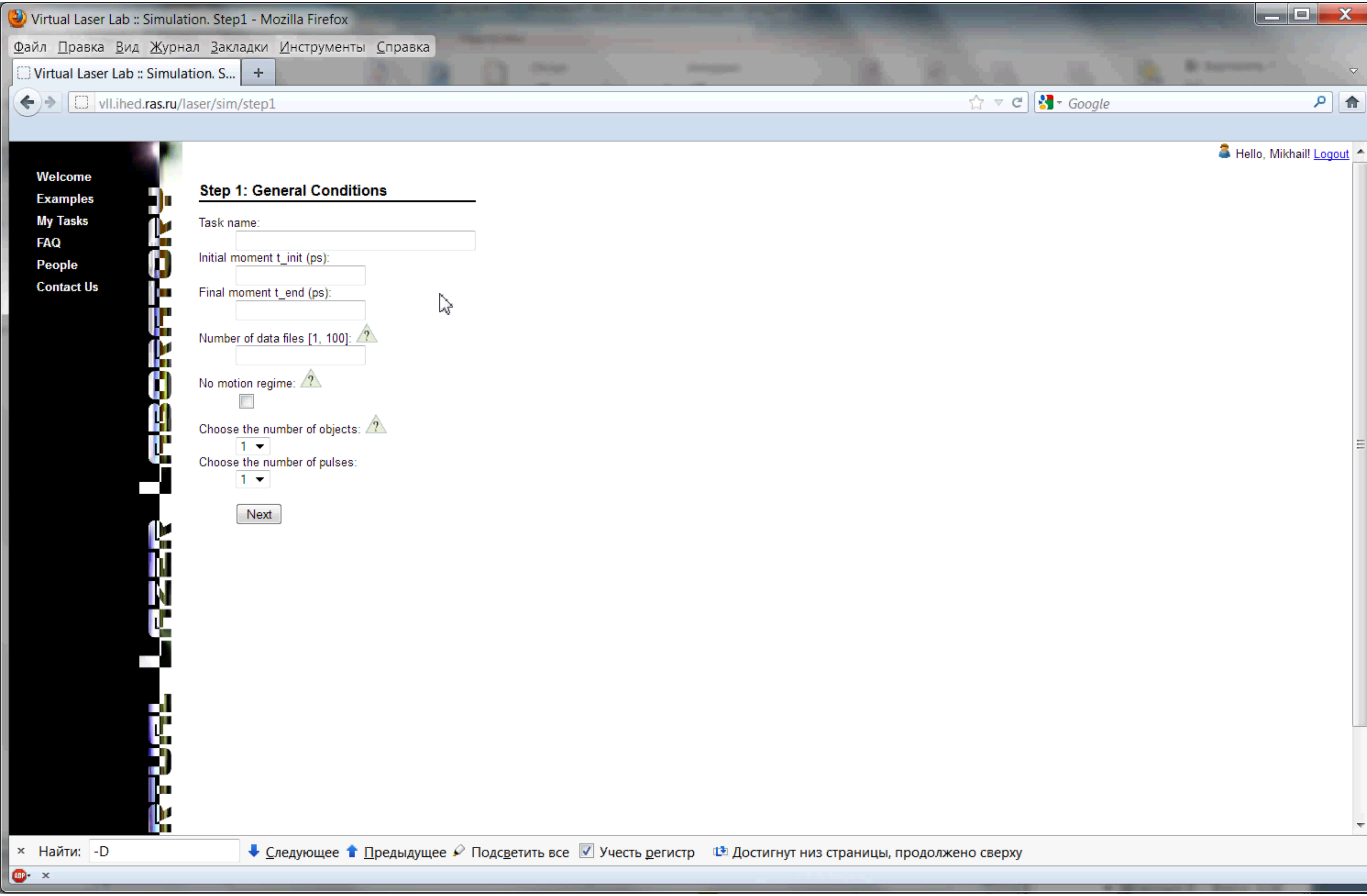
Virtual Laser Laboratory
Step 1: General Conditions
Task name:
Initial moment t_init (ps):
Final moment t_end (ps):
Number of data files [1, 100]:
No motion regime:
Choose the number of objects:
1
Choose the number of pulses:
1
Next

Thin foil spallation



S. I. Ashitkov *et al.*, JETP Letters **92**, No. 8, (2010).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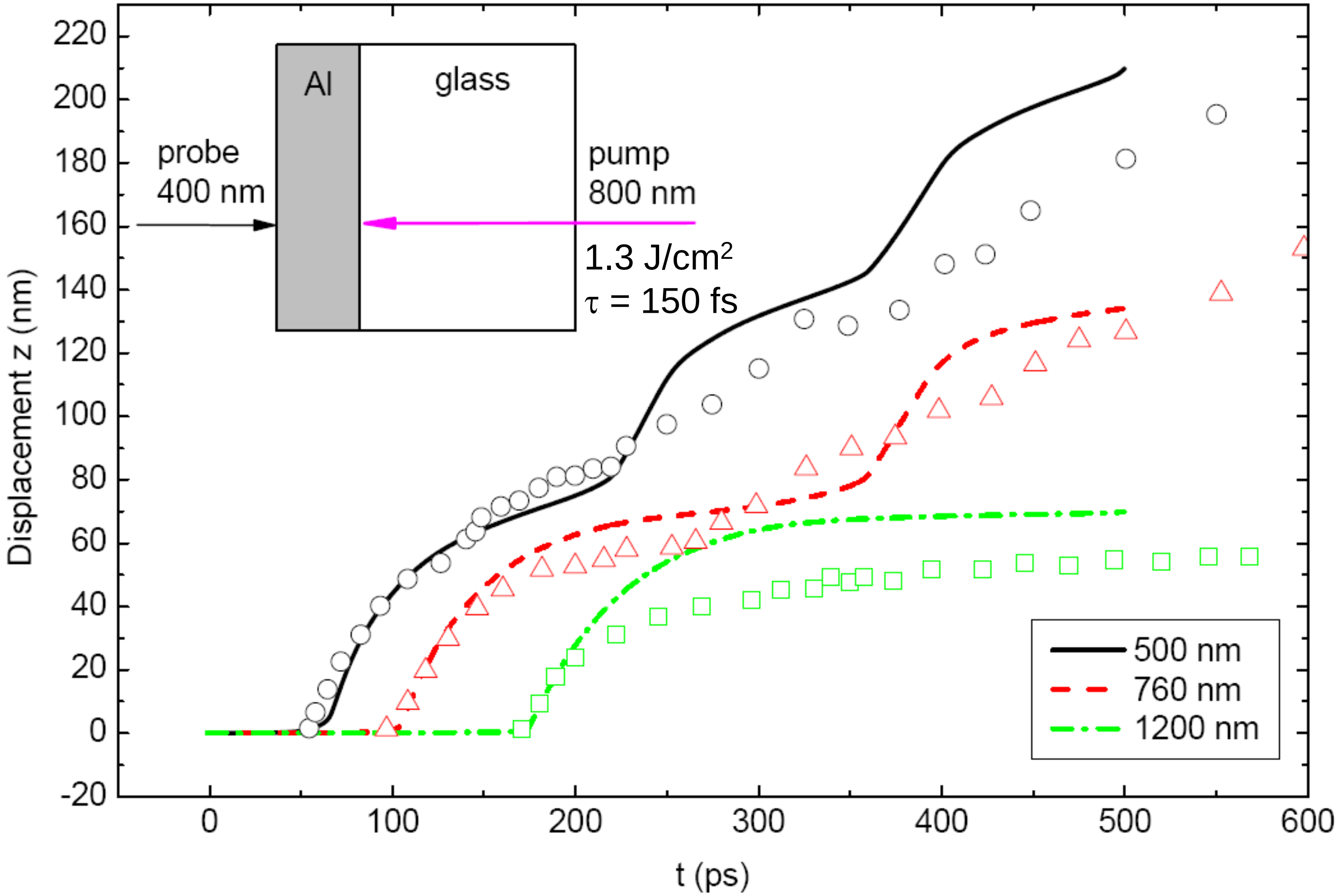
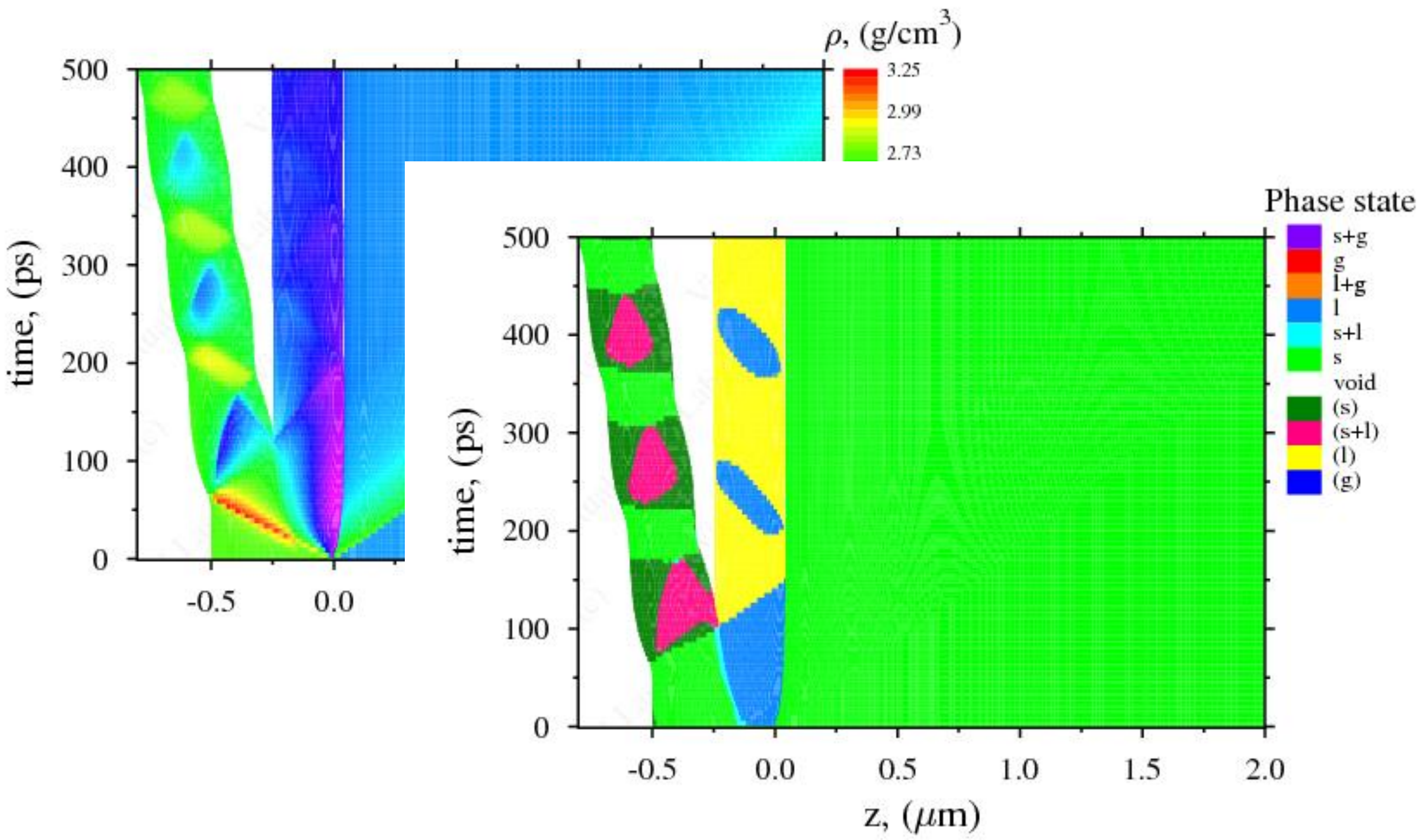
vll.ihed.ras.ru/laser/sim/step1
Google
Hello, Mikhail! Logout
Welcome
Examples
My Tasks
FAQ
People
Contact Us
Step 1: General Conditions
Task name:
Initial moment t_init (ps):
Final moment t_end (ps):
Number of data files [1, 100]:
No motion regime:
Choose the number of objects:
1
Choose the number of pulses:
1
Next
Найти: -D
Следующее
Предыдущее
Подсветить все
Учесть регистр
Достигнут низ страницы, продолжено сверху

Thin foil spallation



S. I. Ashitkov *et al.*, JETP Letters **92**, No. 8, (2010).

Thin foil spallation, 500 nm Al on substrate



Summary

- Virtual laser laboratory is online tool for 1D simulation of laser–matter interaction
- VLL can be useful for preliminary analysis of experiments and post-processing of experimental finding
- A set of wide-range models used in VLL helps to get reliable results
- Potential users are experimentalists, numerical modeling specialists, students etc.

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