NUMERICAL SIMULATION OF USP LASER ABLATION OF ALUMINIUM

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- We have created a new MATLAB code that solves the TTM equations using finite difference methods, in order to simulate ultrashort laser pulses on aluminium.

TTM equations

$$\begin{cases} C_e \dfrac{\partial T_e}{dt} = \nabla(k_e \nabla T_e) - g(T_e - T_l) + S(r,t) \\ C_l \dfrac{\partial T_l}{dt} = g(T_e - T_l) \end{cases}$$

$S(r,t)$ → Laser source term

- Ablation has been modelled via a normal mesh velocity:

$$v_n = h_0 \frac{(T_l - T_a)}{\rho L_v}$$

→ Removes material once lattice temperature reaches an ablation temperature T_a

T_a was set at 0.9 times the critical temperature → Phase explosion condition

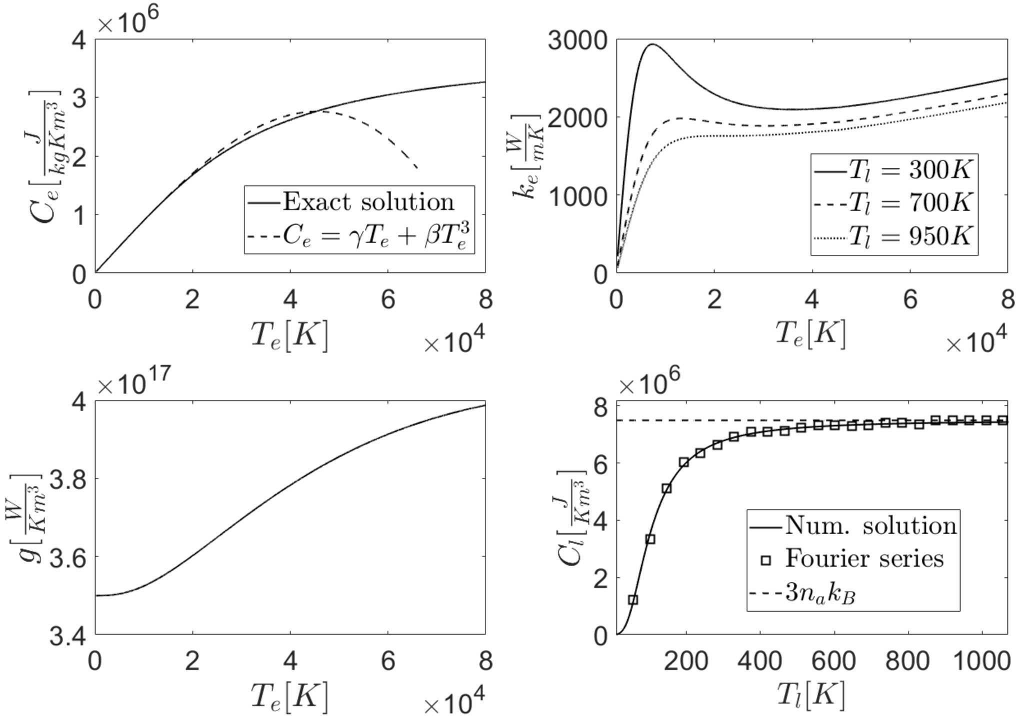
- All temperature dependencies of thermal and optical parameters have been considered

MODELLING OF THERMAL AND OPTICAL PARAMETERS

THERMAL PARAMETERS

Electron heat capacity $C_e(T_e)$ →we have developed a new analytical solution for s-band metals:

$$C_e(T_e) = 3\pi\sqrt{\pi}\left(\frac{2m_e}{h^2}\right)^{\frac{3}{2}} k_B^{\frac{5}{2}}\left[\frac{3}{2}\frac{T_0^3}{T_e^{\frac{3}{2}}}\frac{1}{Li_{\frac{1}{2}}\left(Li_{\frac{3}{2}}^{-1}\left(-\frac{T_0^{\frac{3}{2}}}{T_e^{\frac{3}{2}}}\right)\right)} - \frac{5}{2}T_e^{\frac{3}{2}}Li_{\frac{5}{2}}\left(Li_{\frac{3}{2}}^{-1}\left(-\frac{T_0^{\frac{3}{2}}}{T_e^{\frac{3}{2}}}\right)\right)\right]$$

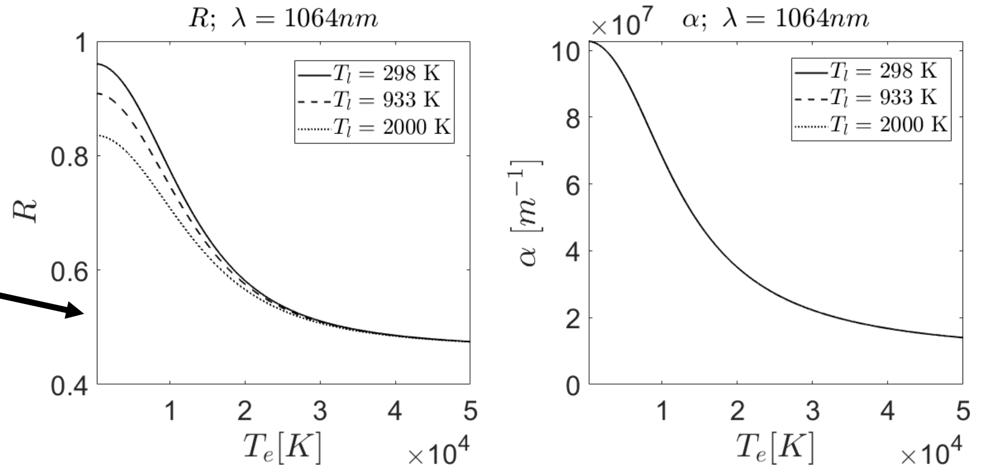


For temperatures bellow $5 \cdot 10^4$K, cubic approximation from this function is valid → $C_e = \gamma T_e + \beta T_e^3$

C_l, k_e, g → various preexisting models from literature were employed

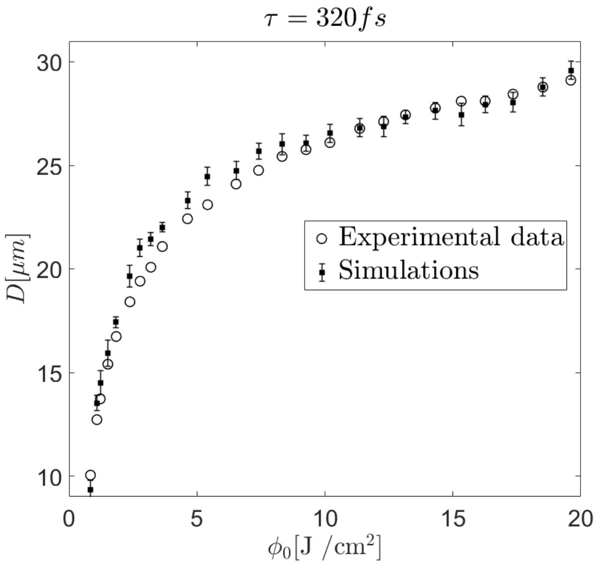
OPTICAL PARAMETERS

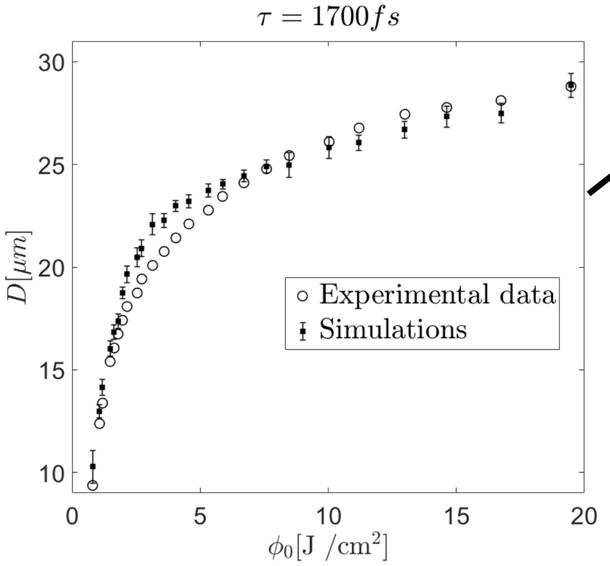
Drude+Critical points (CP) model for the electrical permittivity → Determines the reflectivity and absorption coefficient



RESULTS

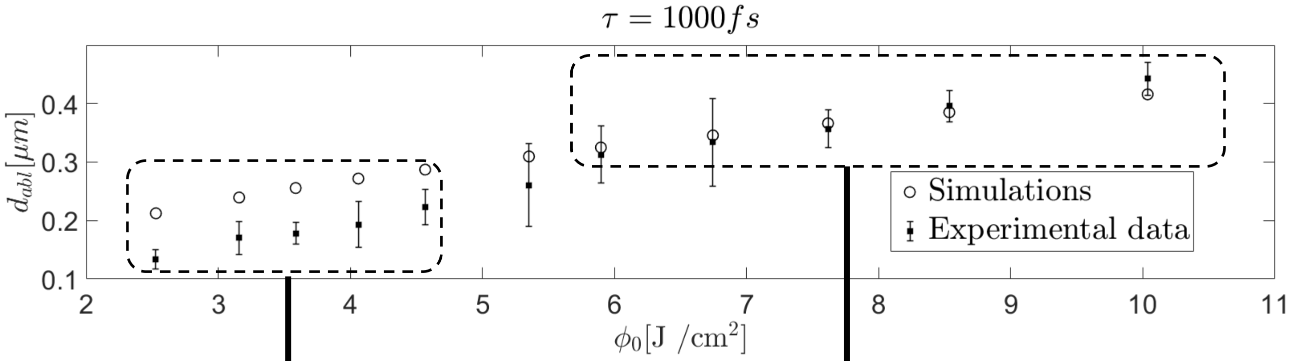
COMPARISON WITH EXPERIMENTAL DIAMETERS





Good agreement between experiments and simulations

DEPTHS



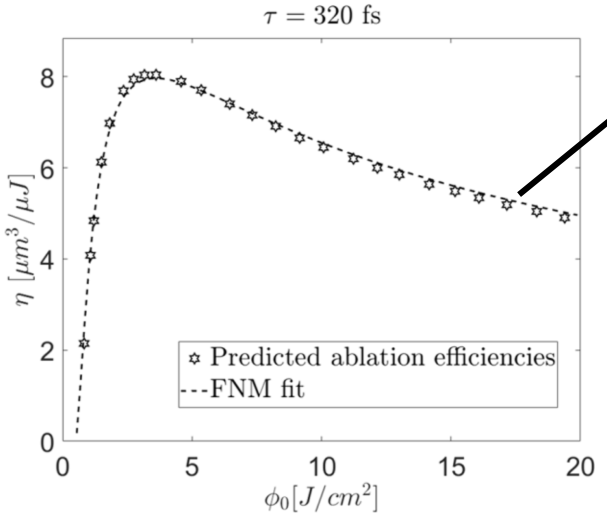
Worse agreement (spallation)

Better agreement (phase explosion)

ABLATION EFFICIENCY PREDICTION

Given by: $\eta = \frac{V}{E_P}$ — V → Crater volume; E_P → Pulse energy

- Predicted crater volumes → found by radial integration of the resulting shapes



FNM equation

$$\eta = \frac{1}{2}\frac{\delta}{\phi_0}\left(ln\left(\frac{\phi_0}{\phi_{\mathrm{thr}}}\right)\right)^2$$

Fitted to predictions