Optimizing your Femtosecond Laser Processes using a Numerical Simulation based Decision Support Tool

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FEMTO-SECOND LASER TEXTURING:

- Laser surface texturing (LST) is a non-contact process that shows excellent repeatability as well as the ability to achieve small-size features.
- The use of ultra-short laser pulses in LST offers the possibility to reduce significantly the amount of molten material hence increase the quality of the finishing.

FEMTO-SECOND LASER ABLATION MODELLING:

Thermal problem: the Two-Temperature Model

- Continuous model used to describe the time evolution of the temperatures of the sub-systems by coupled differential equations:

$$\rho_e C_e \frac{\partial T_e}{\partial t} = \nabla[k_e \nabla(\mathrm{T_e})] - \kappa(T_e - T_l) + S(x,t)$$

$$\rho_l C_l \frac{\partial T_l}{\partial t} = \nabla[k_l \nabla(T_l)] + \kappa(T_e - T_l)$$

Where T is the temperature of the system, subscripts e and l denotes the electrons and the lattice respectively. C, ρ and k are the specific heat capacity, mass density and thermal conductivity. κ is the electron-phonon coupling constant and $S(x,t)$ is the laser source term.

Laser ablation modelling

- Numerical convective heat flux

$$Flux_{vap} = h \cdot (T - T_{vap})$$

Where h is a numerical parameter and T_{vap} is the vaporization temperature.

- Vaporization modelling using deformed geometry with the mesh velocity set at the liquid/gas interface :

$$v_{mesh} \cdot \boldsymbol{n} = \frac{Flux_{vap}}{\rho L_v}$$

Where $\boldsymbol{n}$ is the surface normal vector and L_v is the latent heat of vaporization.

Model prediction possibilities:

- It is possible to make predictions on the shape of a single and multi-impact craters.
- Further work on the model would include the development and experimental validation of the prediction of the topography produced after hundreds of ultra-short laser impacts.

SHARK

→Developing laser surface texturing from the current trial-and-error, lab-scale concept to a highly predictable, data driven industrial approach.

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More info on www.sharkproject.eu

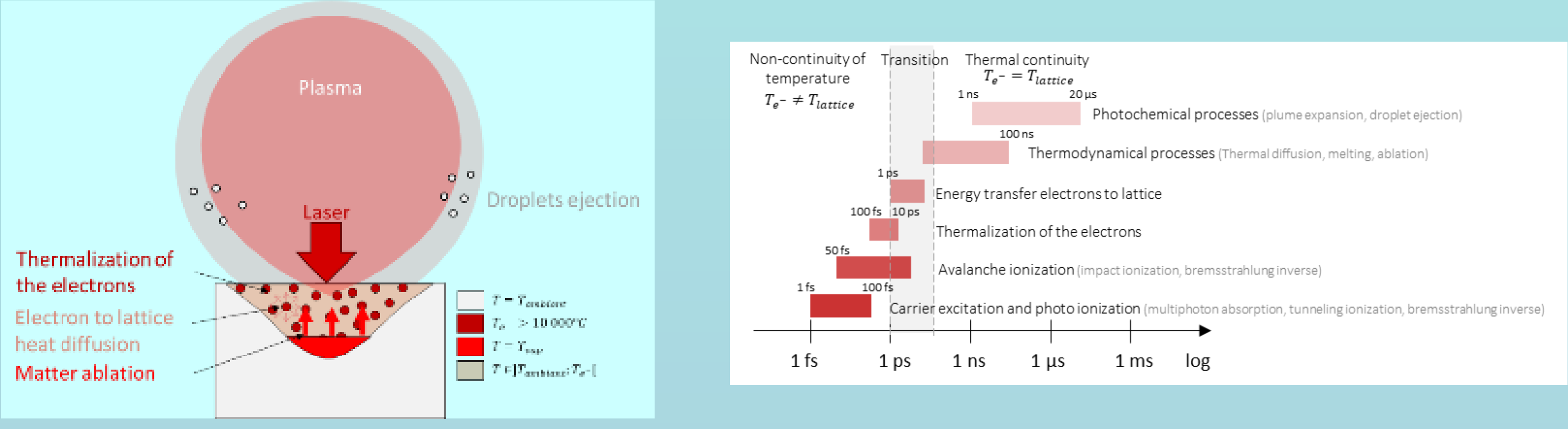

Figure 1: Physical phenomena involved in the ultrashort laser ablation. Description adapted from [2].

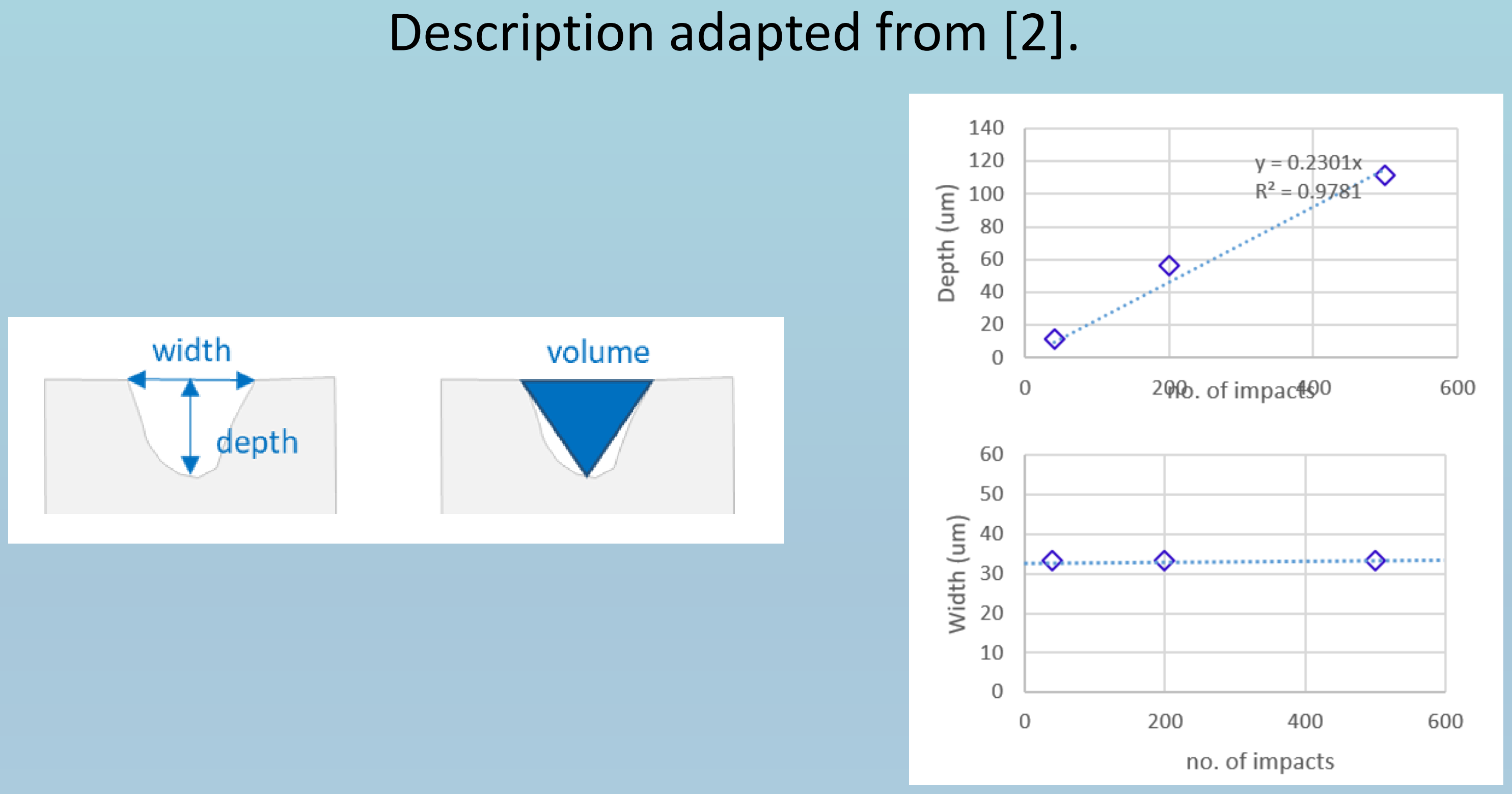

Figure 2: (left) Graphical definition of ablated craters width, depth and volume. (right) Linear interpolation of the measured width (top) and depth (bottom) of the impacts created in [1] with up to 500 pulses.

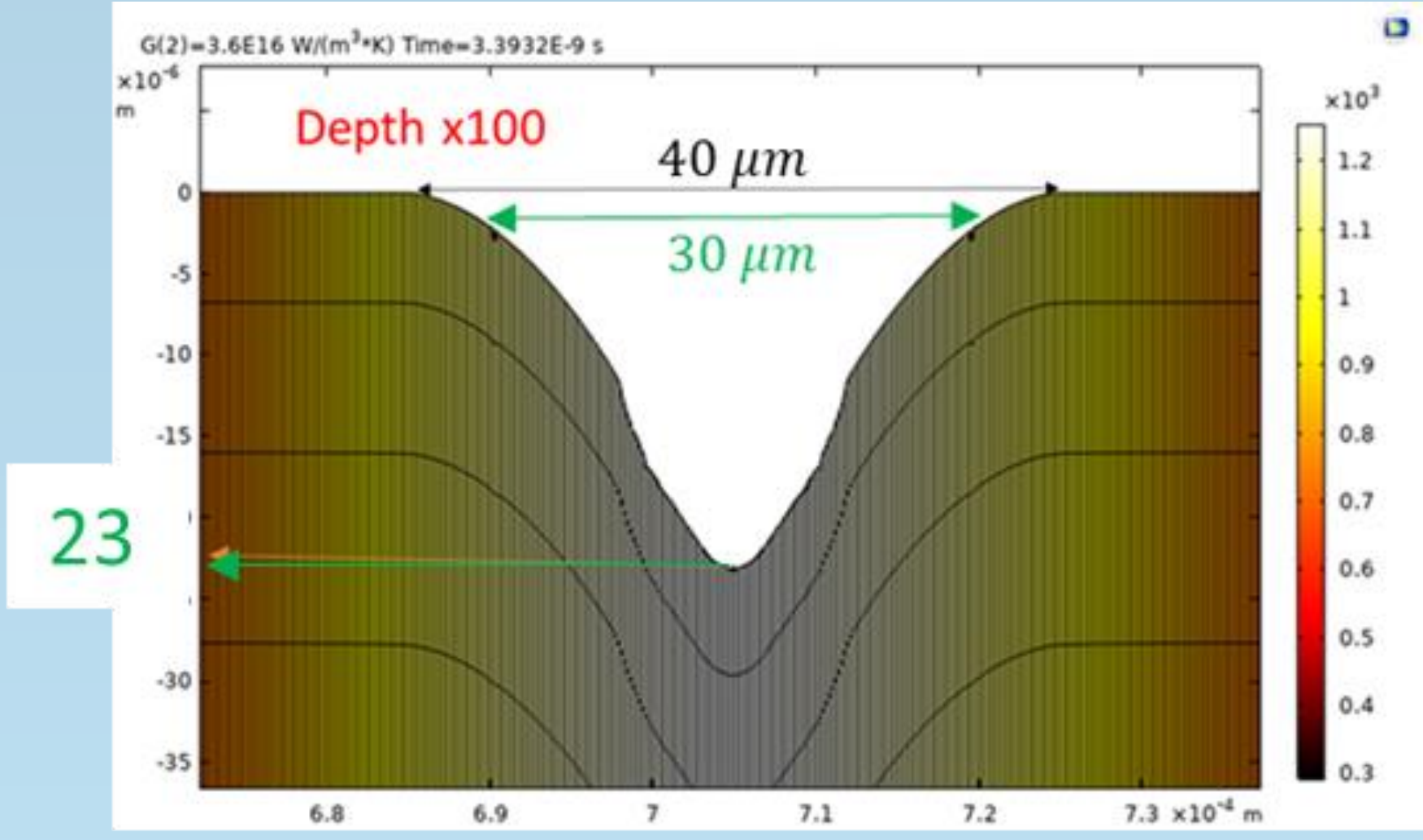

Figure 3: Crater prediction from the FE model with an electron-lattice exchange coefficient G = 3.6e16 W/m^3/K.

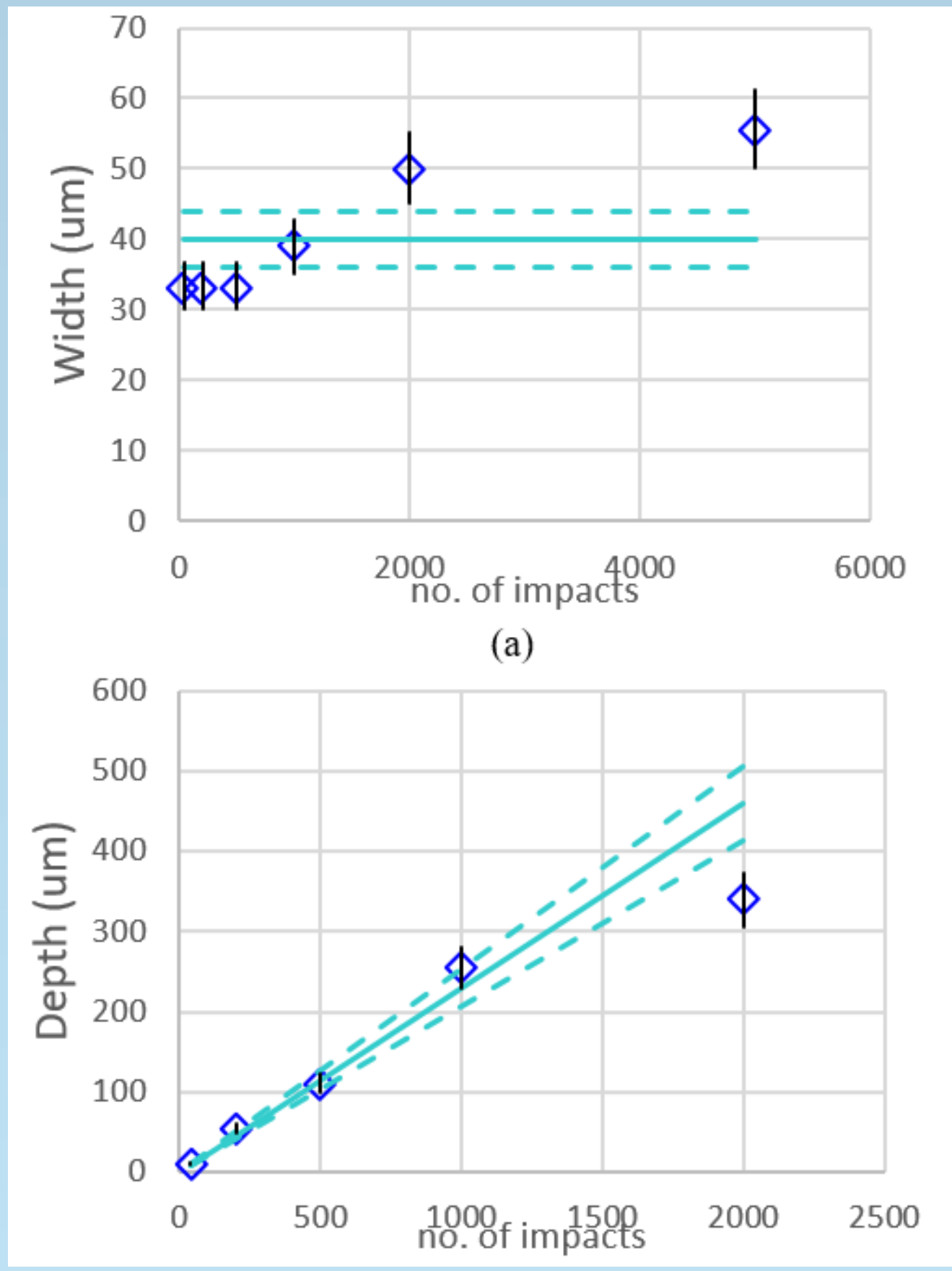

Figure 4: Linear extrapolation of the FE predictions of ultrashort laser ablation width (top), depth (bottom) crater from one pulse.

1. K.-H. Leitz, B. Redlingshöfer, Y. Reg, A. Otto and M. Schmidt, Metal Ablation with Short and Ultrashort Laser Pulses, Physics Procedia, vol. 12, pp. 230-238, (2011).

2. J. Lopez, Le micro-usinage par laser et ses applications, Photoniques 60 (2012) 46-50 (2012)