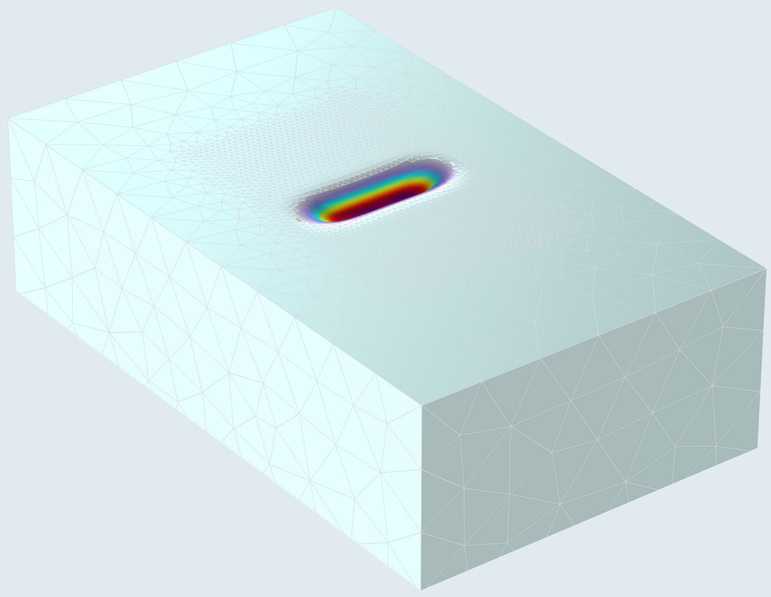


Simulation of Bone Ablation by a 355 nm Nanosecond Laser

Coupled simulation of transient thermal fields and continuous groove formation during laser scanning.

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Abstract

A three-dimensional thermal–deformed geometry model based on the arbitrary Lagrangian–Eulerian formulation was developed to visualize groove formation during 355nm nanosecond laser scanning of bone tissue. A moving Gaussian heat source describes laser energy input, while a prescribed normal mesh velocity updates the recessed surface. The model captures localized heating near the scanning front and continuous groove formation behind it, providing a basis for subsequent experimental calibration and quantitative ablation modeling.

Introduction

Laser bone ablation enables precise material removal, but heat accumulation may lead to unwanted thermal damage. During continuous scanning, thermal diffusion occurs together with progressive surface recession, which cannot be fully represented by fixed-geometry models. Therefore, a coupled thermal–geometric description is needed to better characterize the evolving laser–tissue interaction.

Modeling Methodology

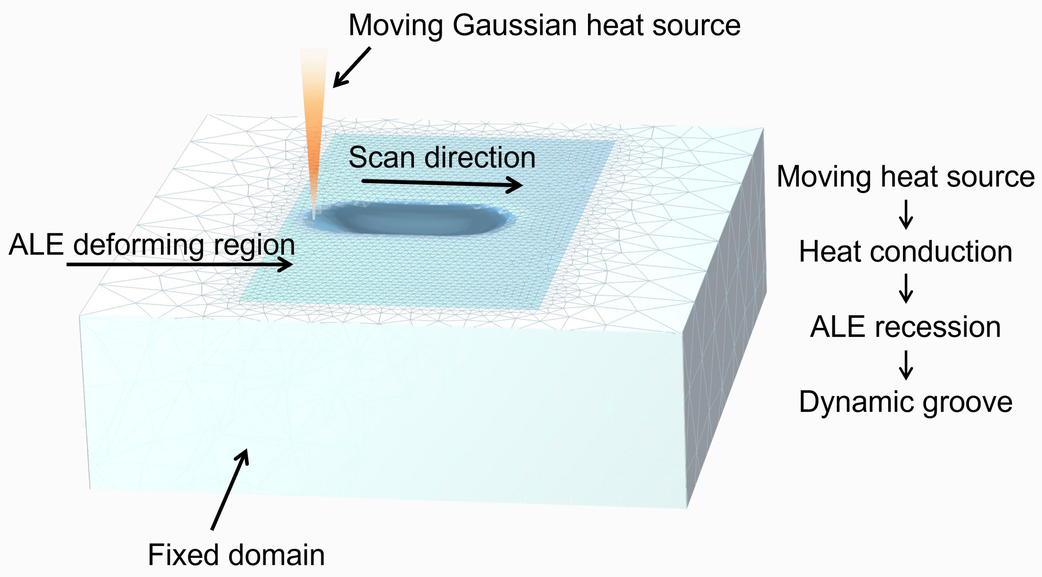


Fig. 1. Thermal and deformed-geometry modeling framework for moving laser scanning and dynamic surface recession.

$$q_{laser} = \eta_{heat} \frac{2P}{\pi \omega_0^2} \exp\left(-\frac{2r^2}{\omega_0^2}\right) g(t)$$

$$\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-\mathrm{k} \nabla T) = Q$$

Deformed geometry: prescribed normal mesh velocity updates the scanning surface.

Results and Conclusions

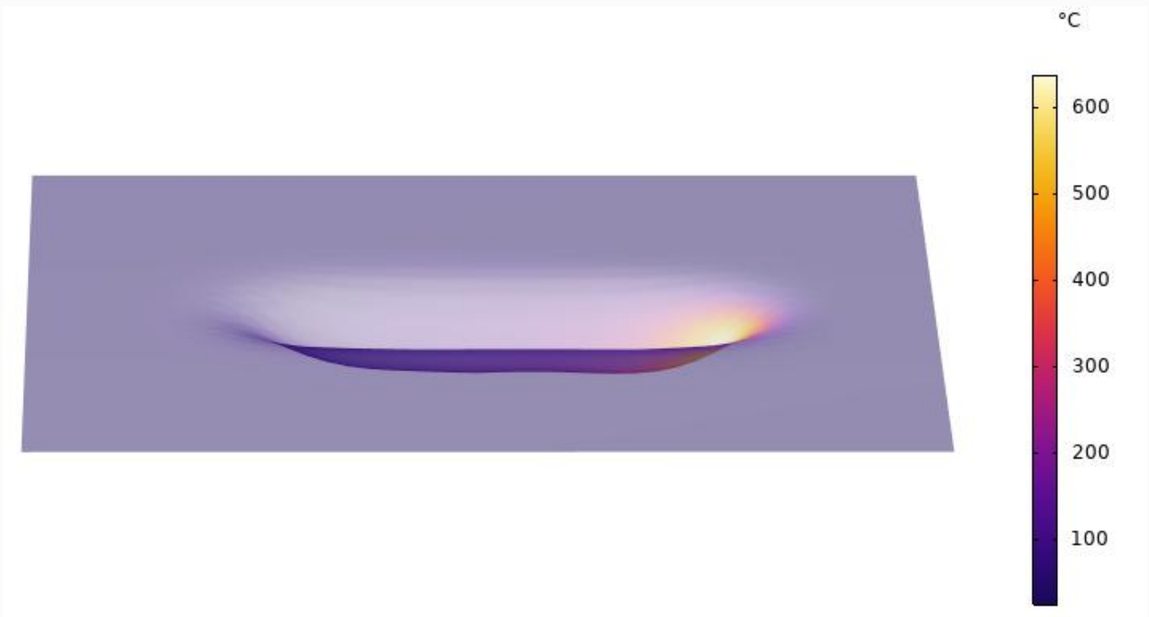


Fig. 2. Recessed groove and local thermal field during laser scanning.

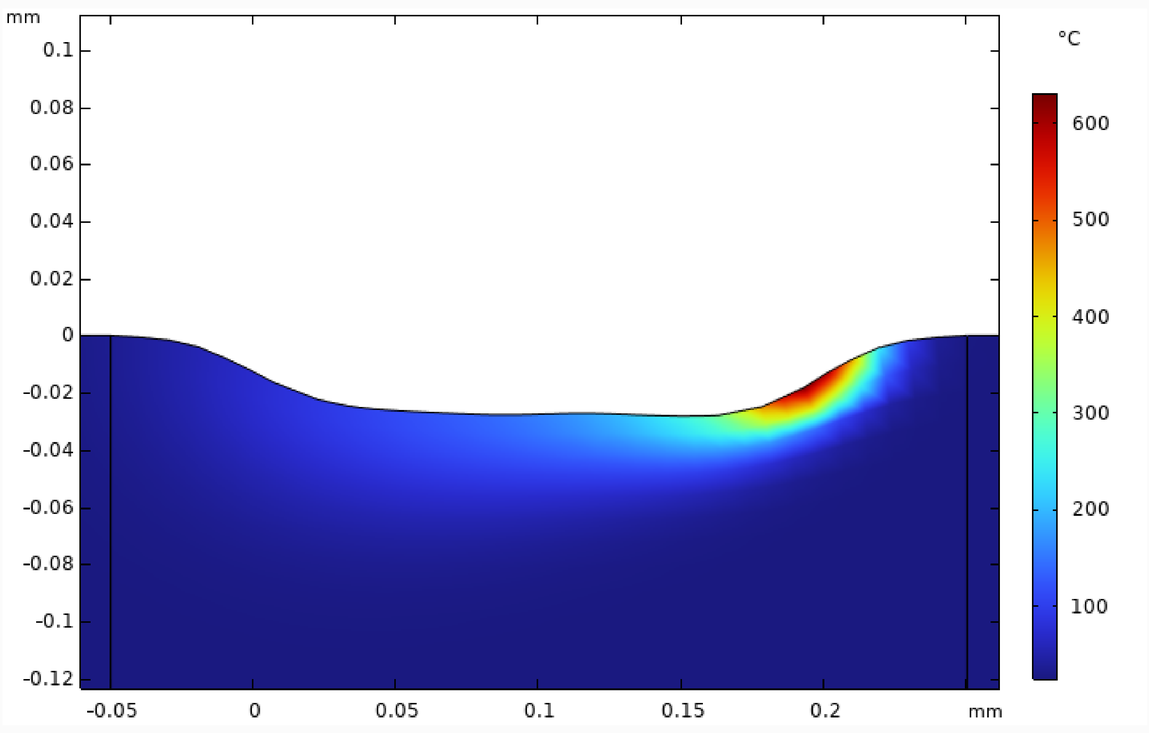


Fig. 3. Longitudinal thermal field along the groove centerline.

The model captures coupled thermal–geometric evolution during laser scanning, providing a basis for experimental calibration and subsequent quantitative prediction.