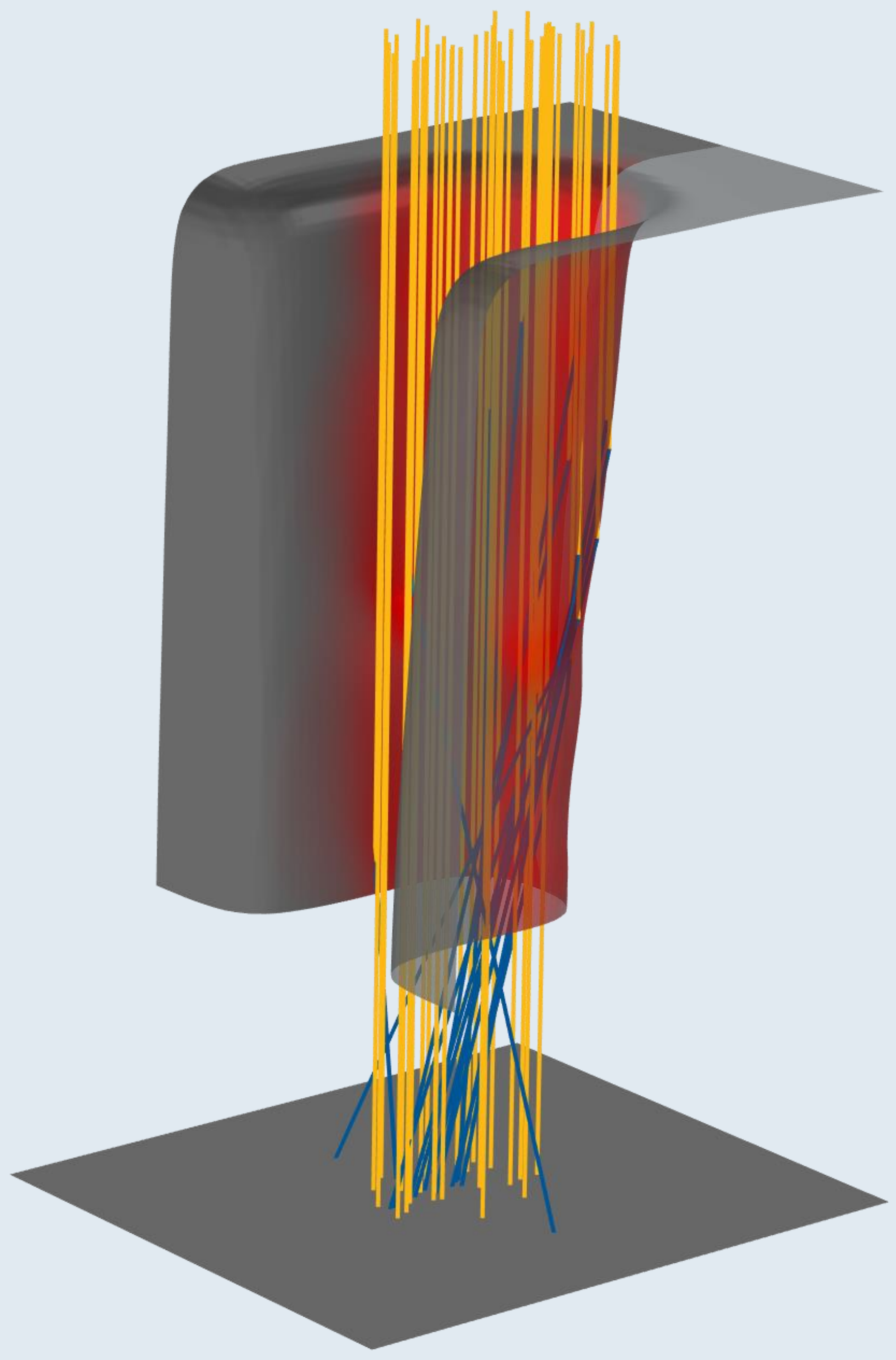

Residual Laser Energy During Laser Cutting Process

Prediction of laser propagation and residual impact during laser cutting of high-thickness stainless steel for nuclear facilities dismantling application. A hybrid Level Set – ALE approach

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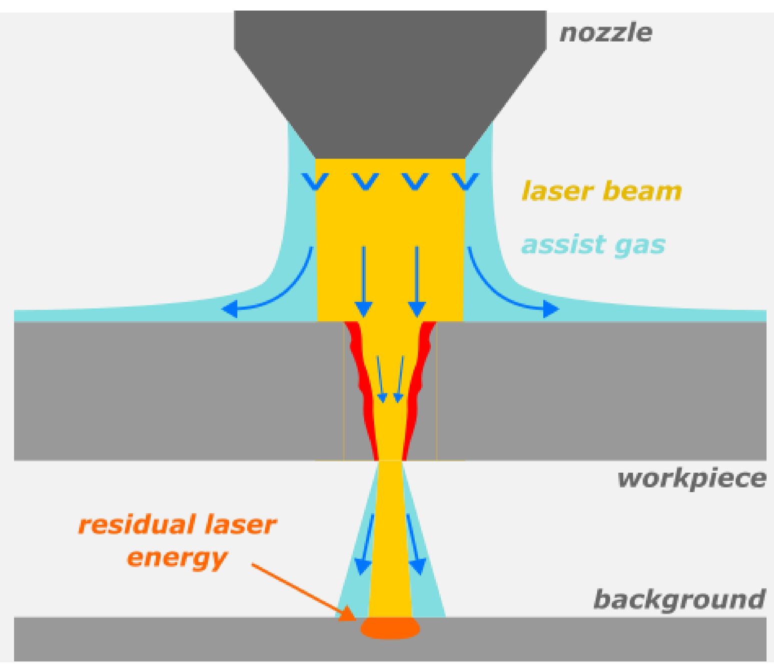
Introduction

The laser cutting is applied to dismantle nuclear facilities and uses a laser beam to locally melt a workpiece and an assist gas ejects the melted metal. The laser beam splits into two parts, where one part is consumed to melt the target metal and the non-interacting remainder attains the background. This transmitted remainder, named the residual laser energy, reaches background structures and could thermally and mechanically affect these structures (tightness problem and mechanical strength) and must be predicted and calculated.



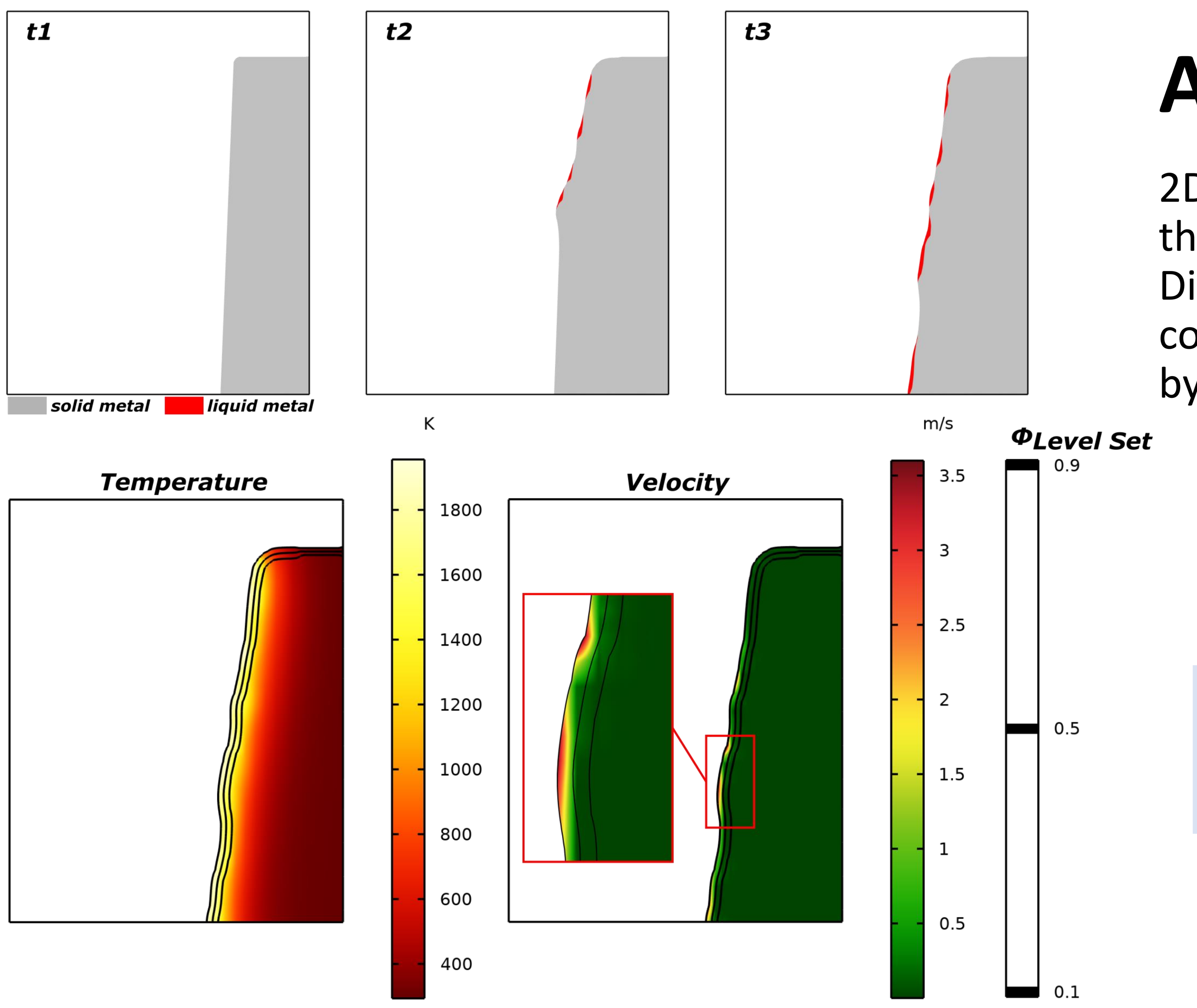


FIGURE 1. 2D simulation of $5mm$ SS304L cut with : $P_{laser} = 8\ kW$, $v_{inert\ gas} = 943\ mm.s^{-1}$, $v_d = 20\ mm.s^{-1}$

A Multiphysics Problem

2D and 3D models, considering all states (gas, liquid and solid), are developed to model the laser cutting process. Level Set module enables to track gas – metal interface. Different meshes adapted to each physic and equation group are used to reduce computational time. Physical phenomena related to the assist gas are taken into account by using dynamic pressure and friction forces exerted by the gas jet [1].

Heat Transfer

$$\rho_\phi\, cp_\phi \left[\frac{\partial T}{\partial t} + \vec{u}\cdot\vec{\nabla}T\right] = \vec{\nabla}\cdot\left(\lambda_\phi\, \vec{\nabla}\, T\right) + \left(Q_{laser} + Q_{vap} + Q_{rad}\right)\delta(\phi)$$

Level Set

$$\frac{\partial \phi}{\partial t} + \vec{u}\cdot\vec{\nabla}\phi = \gamma\cdot\vec{\nabla}\left(\epsilon_{ls}\vec{\nabla}\phi - \phi(1-\phi)\frac{\vec{\nabla}\phi}{|\vec{\nabla}\phi|}\right)$$

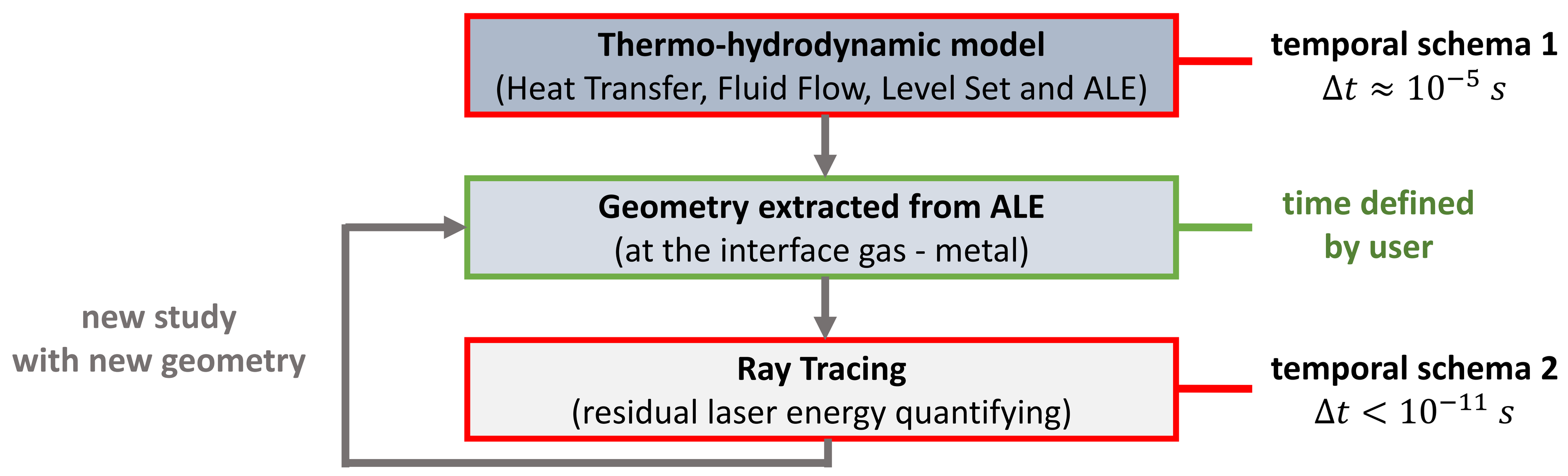
Fluid Flow

$$\rho_\phi\left[\frac{\partial \vec{u}}{\partial t} + (\vec{u}\cdot\vec{\nabla})\vec{u}\right] = \vec{\nabla}\cdot\left[-pI + \mu_\phi\left(\vec{\nabla}\vec{u} + (\vec{\nabla}\vec{u})^T\right)\right] + \vec{F_g} + +\overrightarrow{F_{Darcy}} + \left(\overrightarrow{F_{ST}} + \overrightarrow{F_{dyn\,p}} + \overrightarrow{F_{fric}}\right)\delta(\phi)$$

$$\vec{\nabla}\cdot\vec{u} = 0$$

Residual Laser Energy

Ray Tracing module is used to model laser beam propagation [2], and in this work to quantify the residual energy not absorbed. The gas – metal interface needs to be described discretely, a feature which is not considered by the Level Set approach. Therefore, to overcome this issue, a moving mesh method, namely Arbitrary Lagrangian-Eulerian (ALE), enables a discrete gas – metal interface to behave as a boundary.



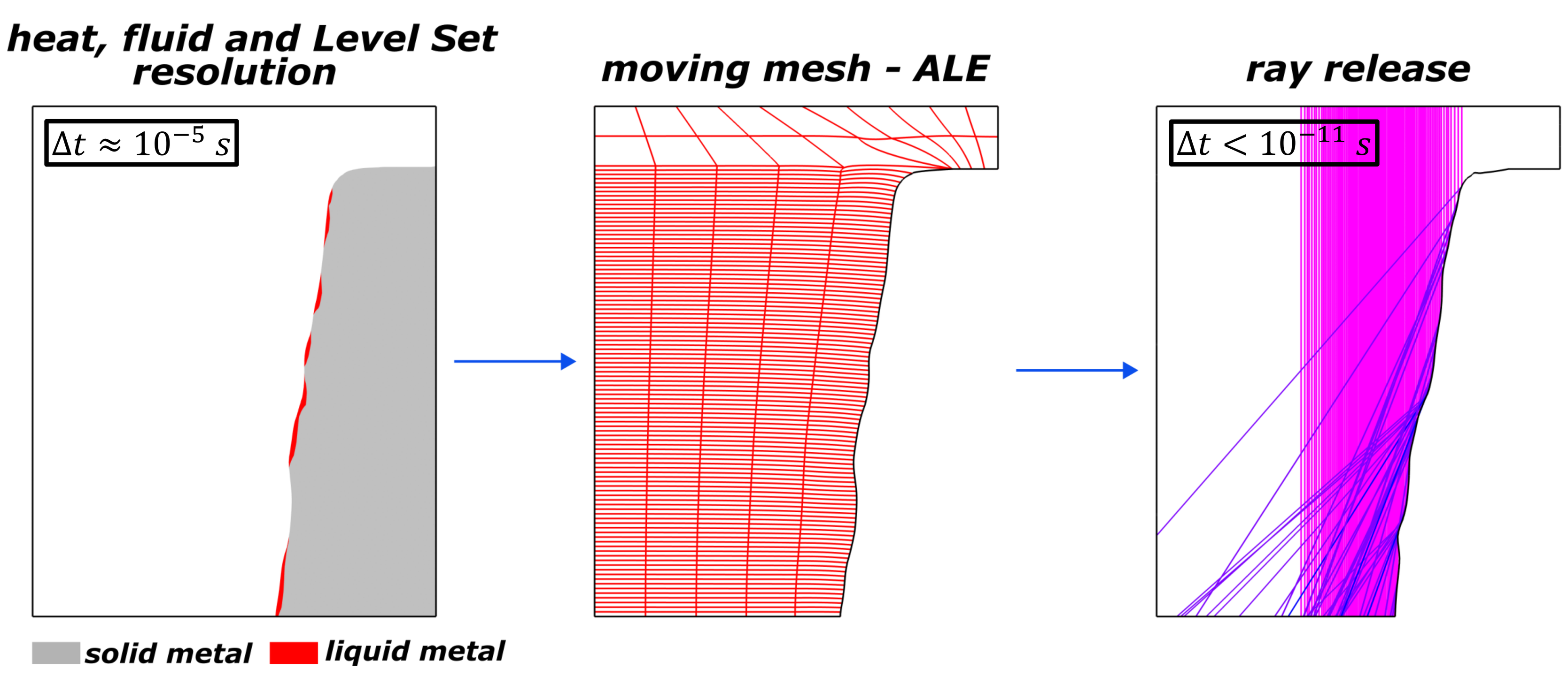


FIGURE 2. Steps to quantify residual laser energy at a time t of thermo-hydrodynamic simulation

Ray Tracing temporal schema differs from that of the thermo-hydrodynamic laser cutting model. It is therefore necessary to automate the ray release at any time chosen by a user. To do so, an algorithm is in development using *LiveLink*™ *via* the *MATLAB®* programming interface.

REFERENCES

[1] K. Kheloufi and E.H. Amara, "Numerical Investigation of the Effect of Some Parameters on Temperature Field and Kerf Width in Laser Cutting Process", *Physics Procedia*, vol. 39, pp 872-880, 2012

[2] J. Daligault & al., "Combination of Eulerian and ray-tracing approaches for copper laser welding simulation", Journal of Laser Application, 34(4), 2022