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Stephane Gounand, Dihya Mezi, Guilhem Roux, Jean-Paul Garandet, Hicham
Maskrot

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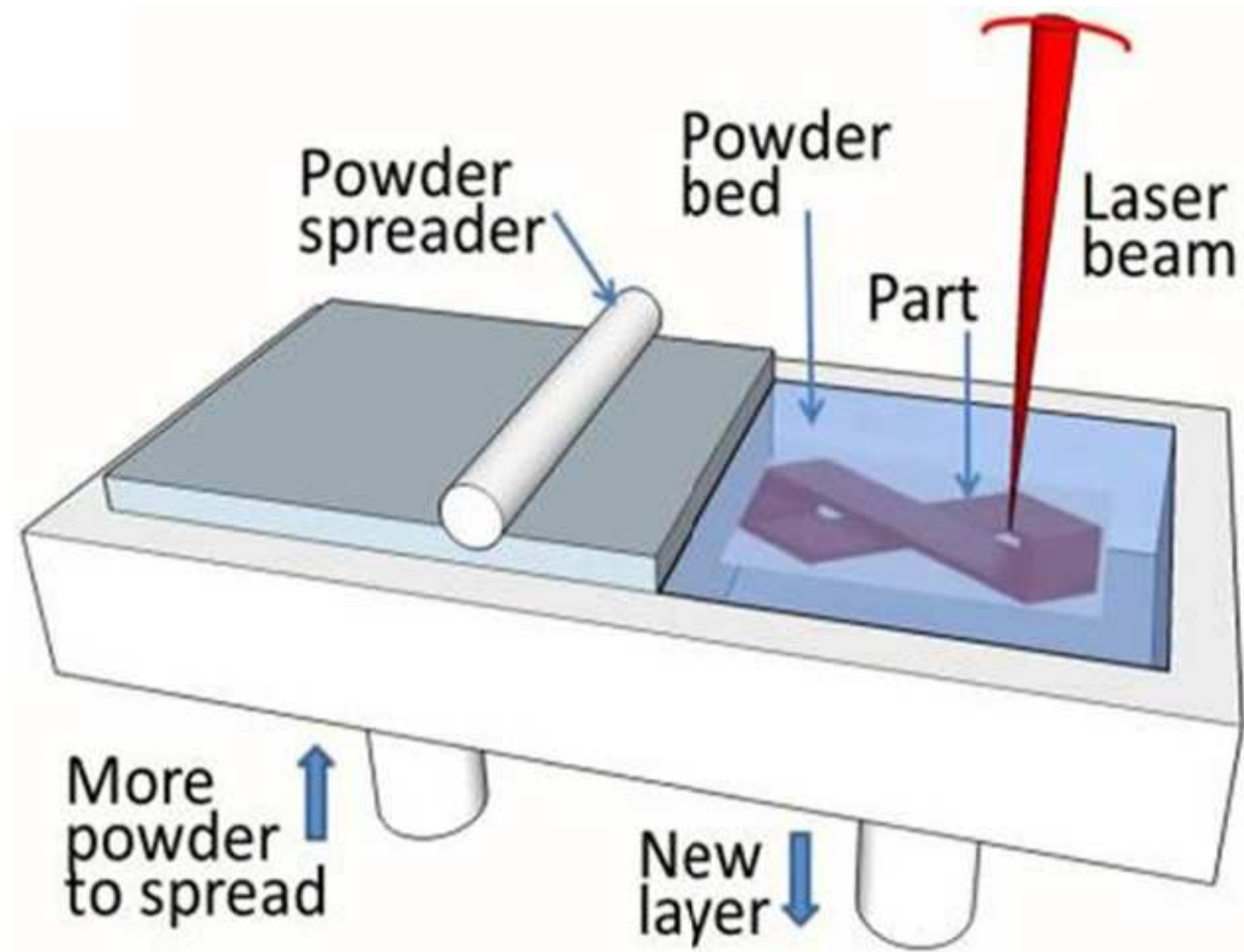
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Melt Pool Modelling for Additive Manufacturing (MOBAFA)

Stéphane Gounand¹, Dihya Mezi, Guilhem Roux, Jean-Paul Garandet, Hicham Maskrot

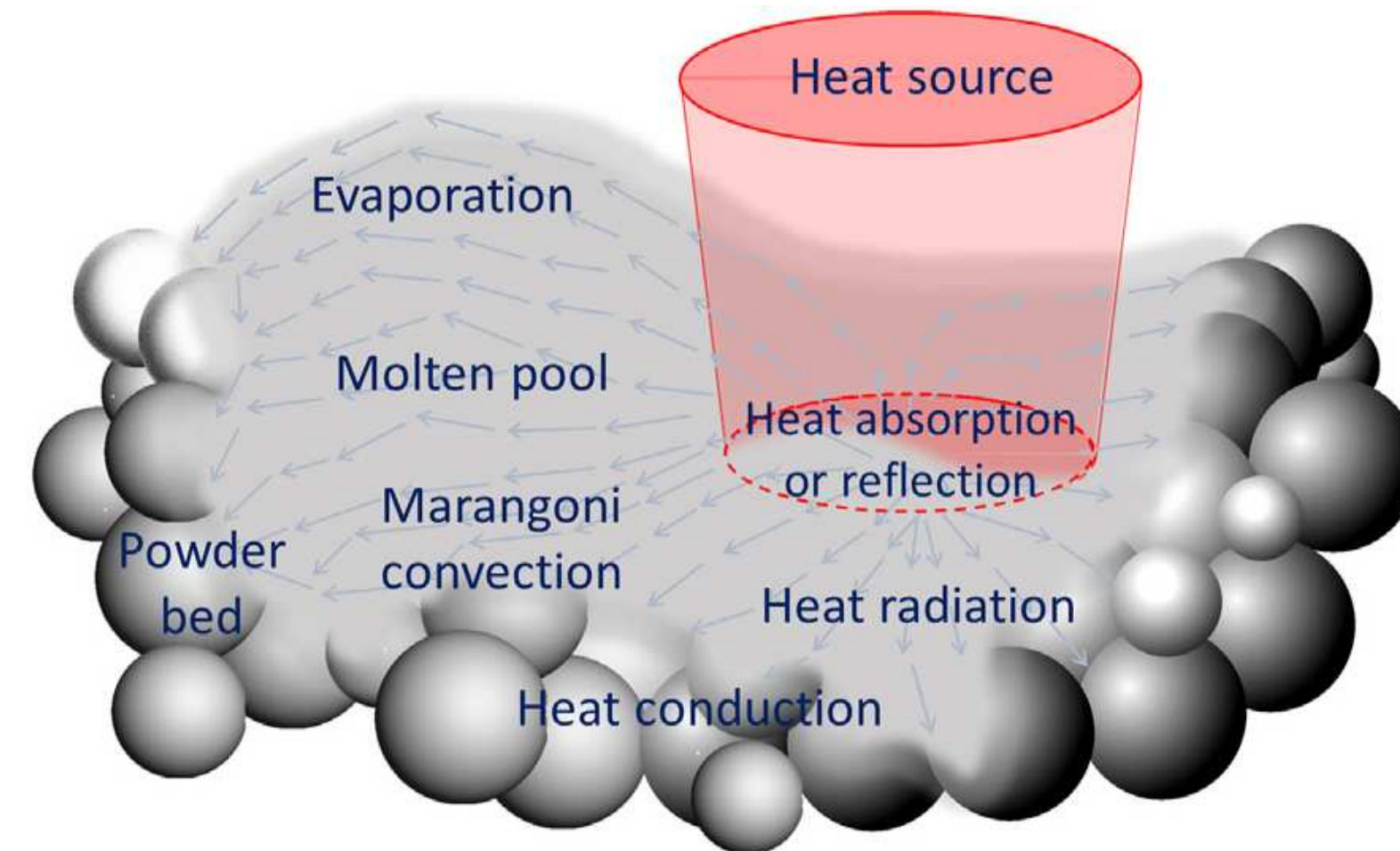
¹ stephane.gounand@cea.fr – <https://cv.hal.science/stephane-gounand>
Des-Service de recherche en matériaux et procédés avancés (SRMA)
CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

Additive Manufacturing

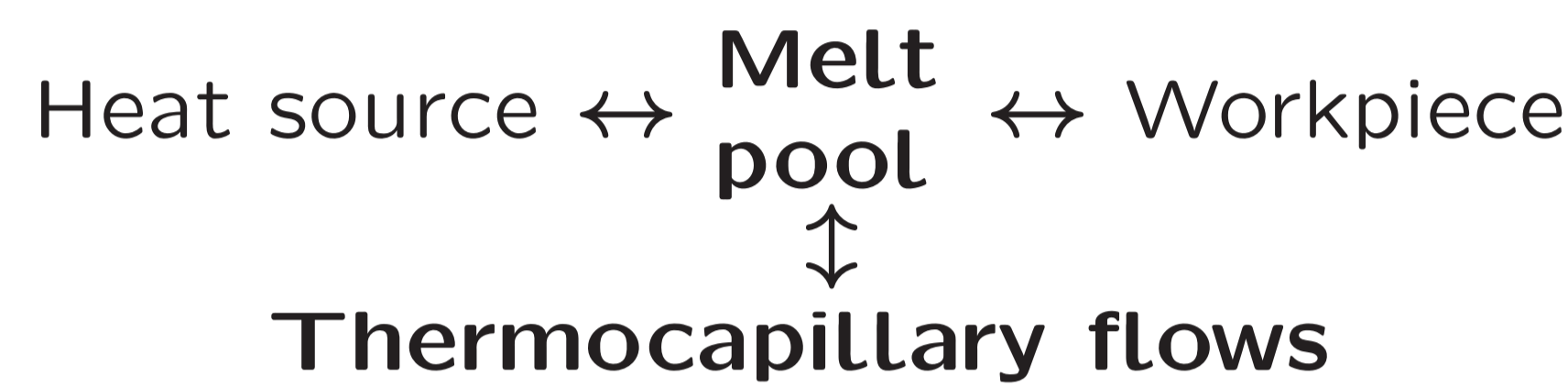


3D metal printing. Laser-Powder Bed Fusion (L-PBF) process [1]

Liquid melt pool

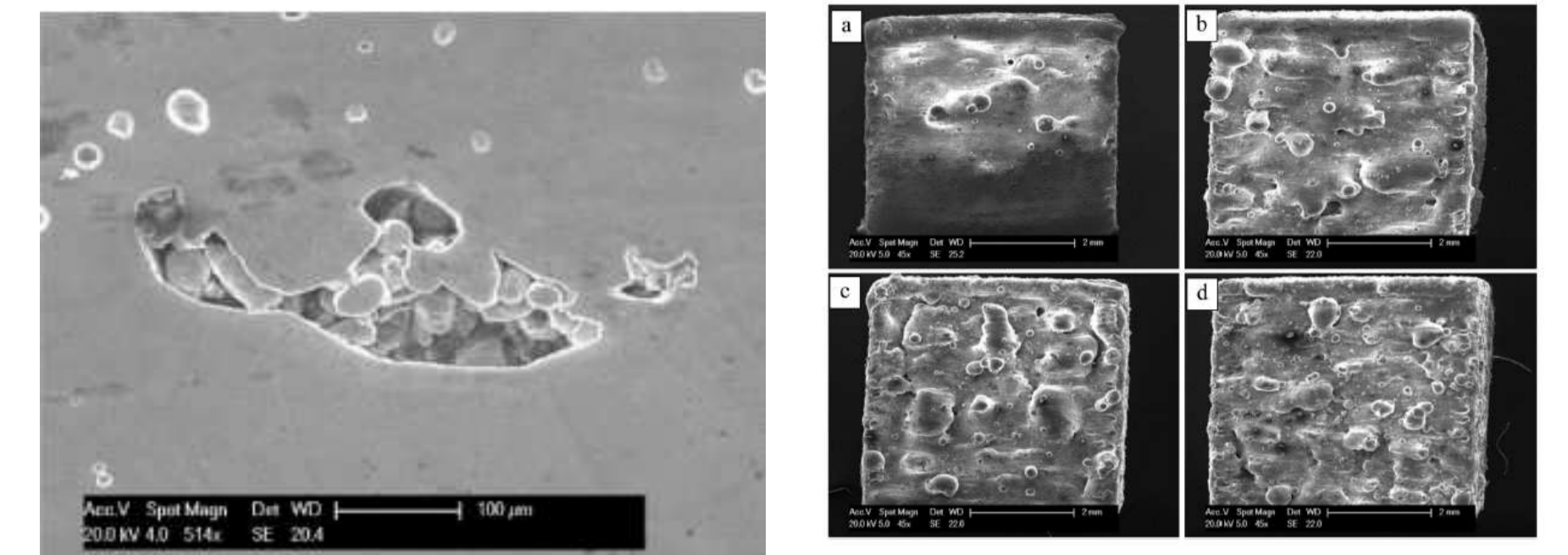


Melt pool physical phenomena [1]



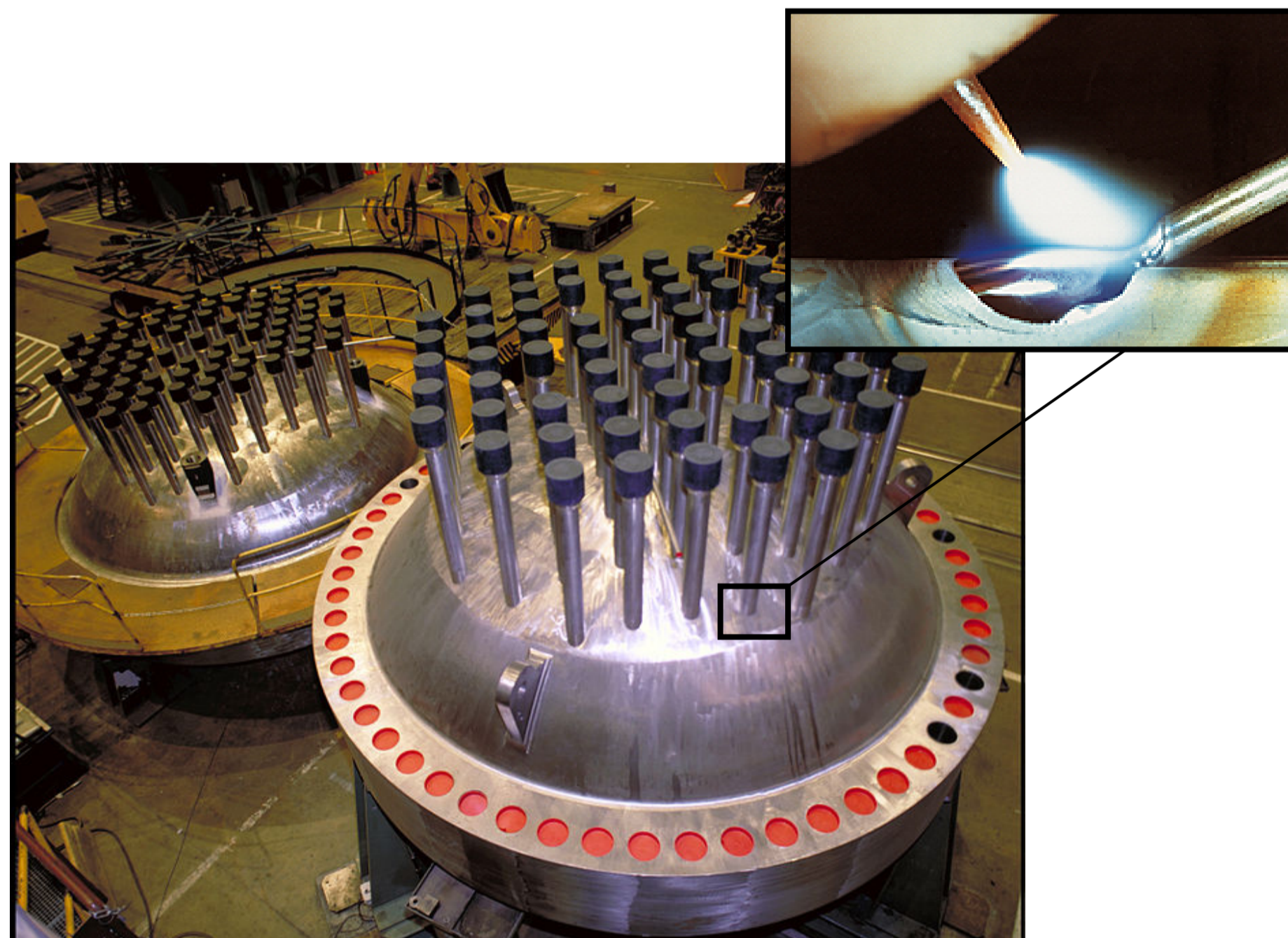
Simulation goals ?

- Physical insights;
- Defect control: cracks, porosity, ejecta, bead stability. . .
- Process optimization: quality, speed. . .

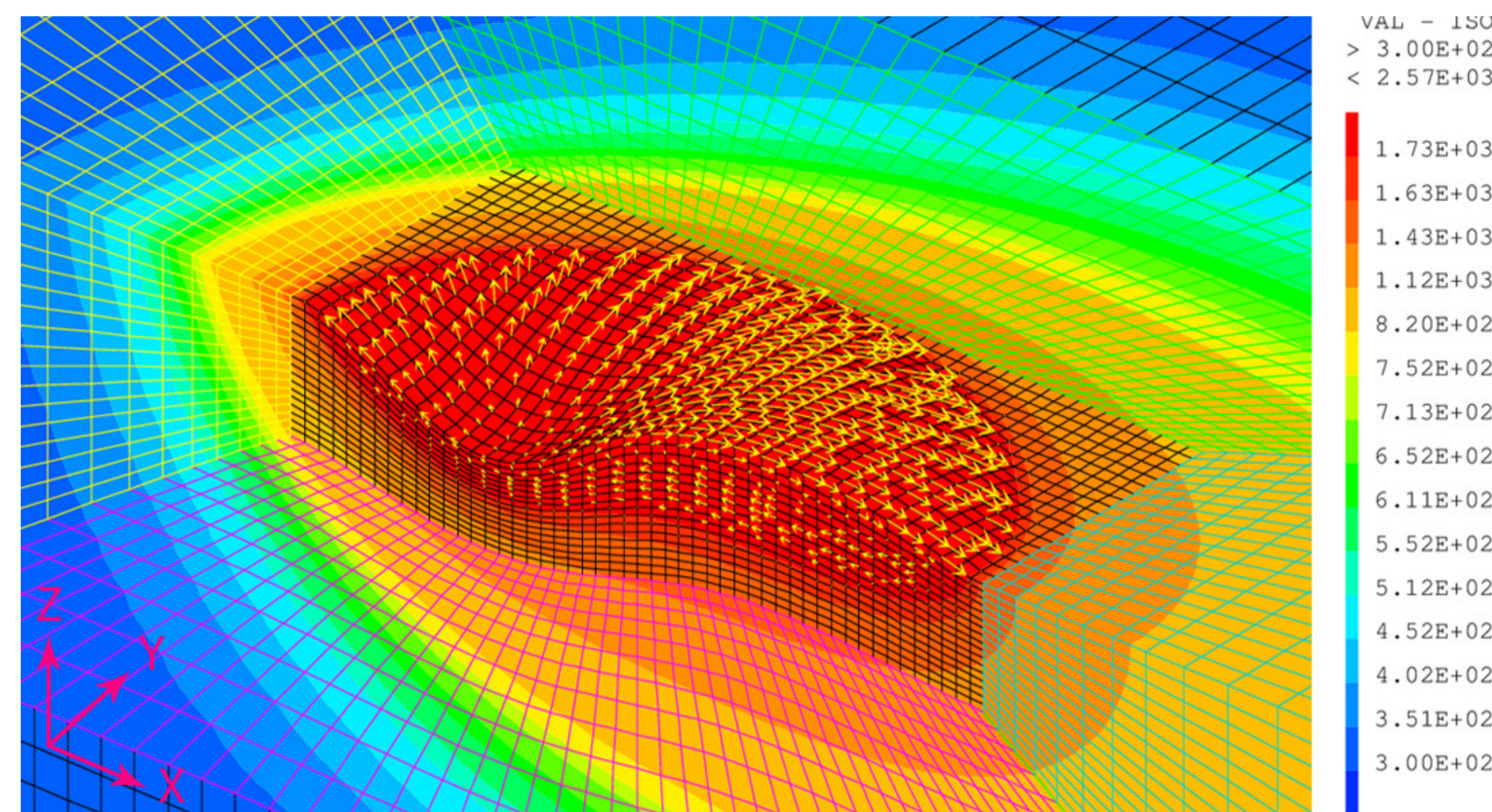


Porosity and projections

From multi-physics welding simulation. . .



PWR vessel head ©NRC



Melt pool velocity and temperature [2]

Finite Element toolbox Cast3M [3]

$$\rho_0 \frac{\partial \mathbf{u}}{\partial t} + \rho_0 (\nabla \mathbf{u}) \cdot \mathbf{u} \stackrel{\Omega}{=} -\nabla p^* + \nabla \cdot \boldsymbol{\tau} + \mathbf{f}_{\text{Bou}} + \mathbf{f}_{\text{Ext}}$$

$$\nabla \cdot \mathbf{u} \stackrel{\Omega}{=} 0$$

$$\mathbf{u} \stackrel{\partial \Omega \setminus \Gamma}{=} \mathbf{u}_0$$

$$\mathbf{u} \cdot \mathbf{n} \stackrel{\Gamma}{=} \frac{\partial \mathbf{x}_\Gamma}{\partial t} \cdot \mathbf{n} - \frac{\dot{m}}{\rho_0}$$

$$-p^* + (\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{n} + \rho_0 g z \stackrel{\Gamma}{=} \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right) + s$$

$$(\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{t} \stackrel{\Gamma}{=} \frac{\partial \gamma}{\partial T} \nabla_s \gamma + s$$

$$\theta \stackrel{\partial \Gamma}{=} \theta_0 \text{ ou } \mathbf{x}_\Gamma \stackrel{\partial \Gamma}{=} \mathbf{x}_0$$

$$\rho_0 \frac{\partial h}{\partial t} + \rho_0 \mathbf{u} \cdot \nabla h \stackrel{\Omega}{=} \nabla \cdot \lambda \nabla T + s$$

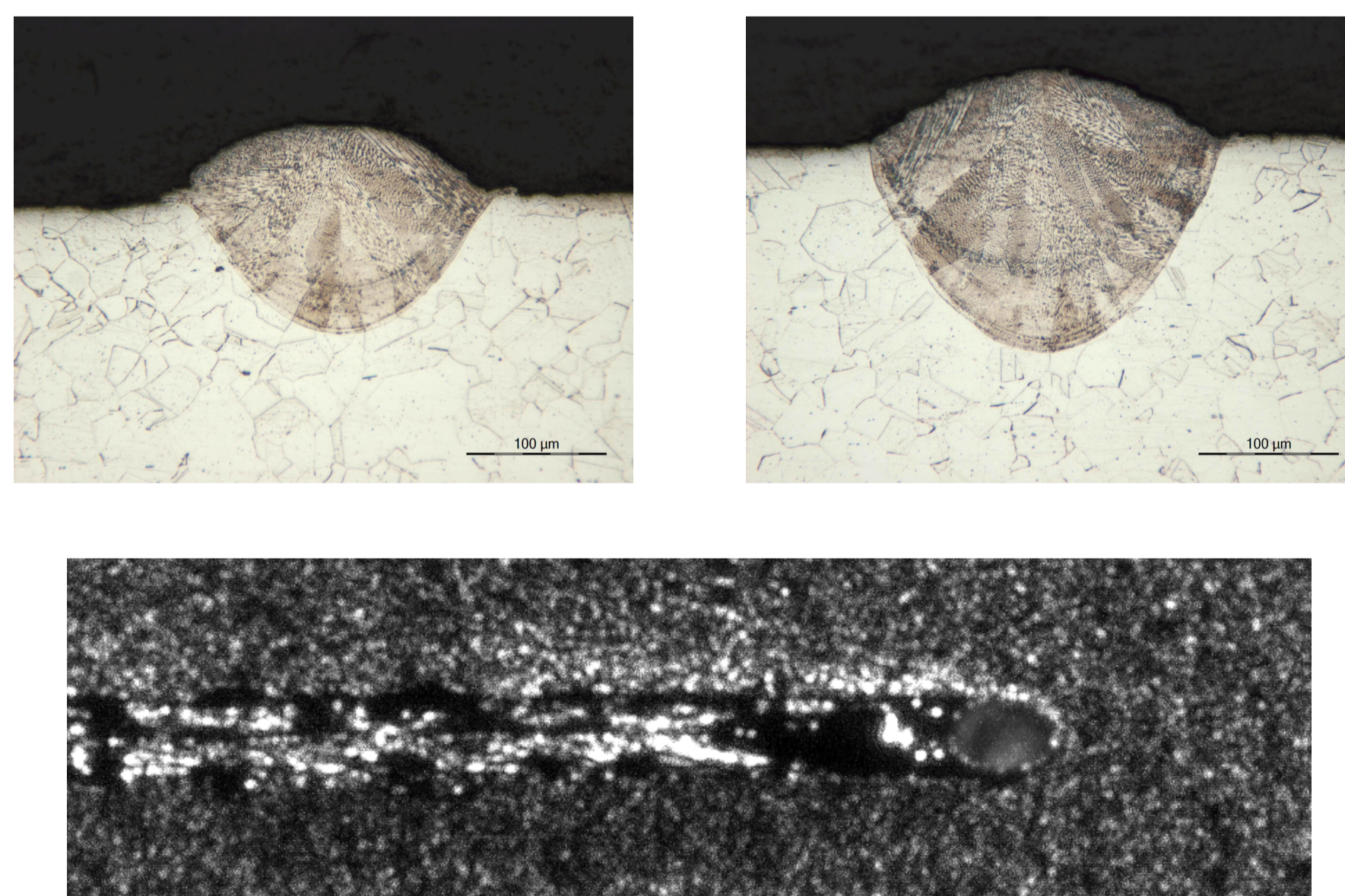
Steady free-surface laminar Navier-Stokes

. . . to multi-physics additive manufacturing simulation (AM)

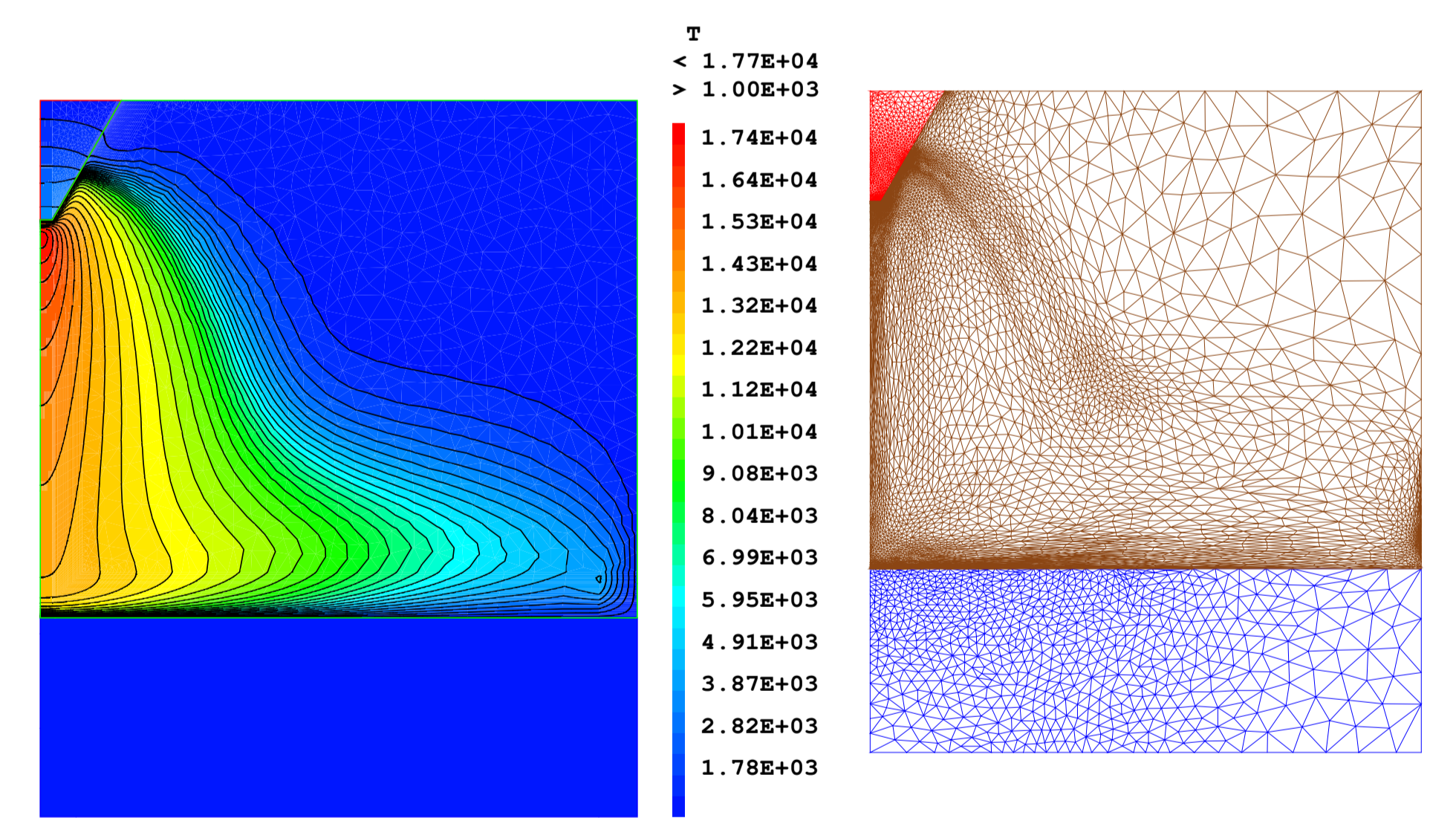
Characteristic values

	Welding	AM
P_{source} (W)	1.10^3	1.10^2
r_{source} (m)	$5,0.10^{-3}$	$5,0.10^{-5}$
$\mathbf{u}_{\text{source}}$ ($\text{m} \cdot \text{s}^{-1}$)	$1,0.10^{-3}$	1,0
Mass addition	Wire	Powder

Process parameters



Single-pass validation experiments [4]



Multiscale numerical methods

Post-doctoral work, 2022-2023 (Dihya Mezi)

- Up-to-date bibliography;
- Implementation of laser-matter interaction: evaporation and recoil pressure models;
- Comparison: numerical simulation vs Baumard's experiments [4].

Bibliographie

- [1] T. DebRoy et al. Additive manufacturing of metallic components – process, structure and properties. **Progress in Materials Science**, 92: 112 – 224, 2018.
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- [3] Cast3m. Cast3m Web site. <http://www-cast3m.cea.fr/>.
- [4] Anaïs Baumard, Danièle Ayrault, Olivier Fandeur, Cyril Bordreuil, Frédéric Deschaux-Beaume, and Anne-Laure Vetele. Numerical prediction of grain structures formation during Laser Beam Melting of Single-Track 316L Stainless Steel. **Computational Materials Science**, 2020. URL <https://www.sciencedirect.com/science/article/pii/S0264127520309709>.