



Melt pool modelling for additive manufacturing (MOBAFA)

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Melt Pool Modelling for Additive Manufacturing (MOBAFA)



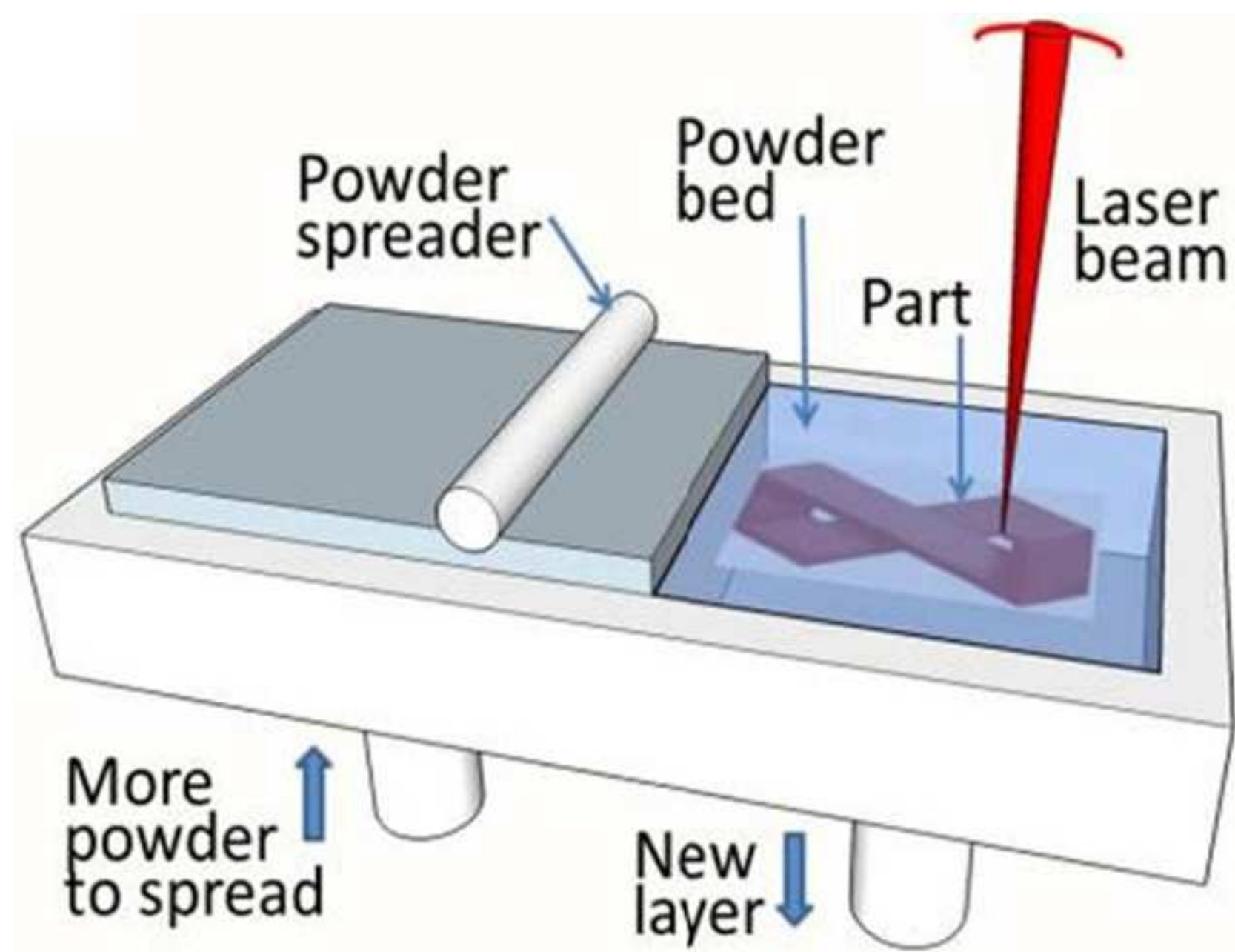
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Des-Service de recherche en matériaux et procédés avancés (SRMA)

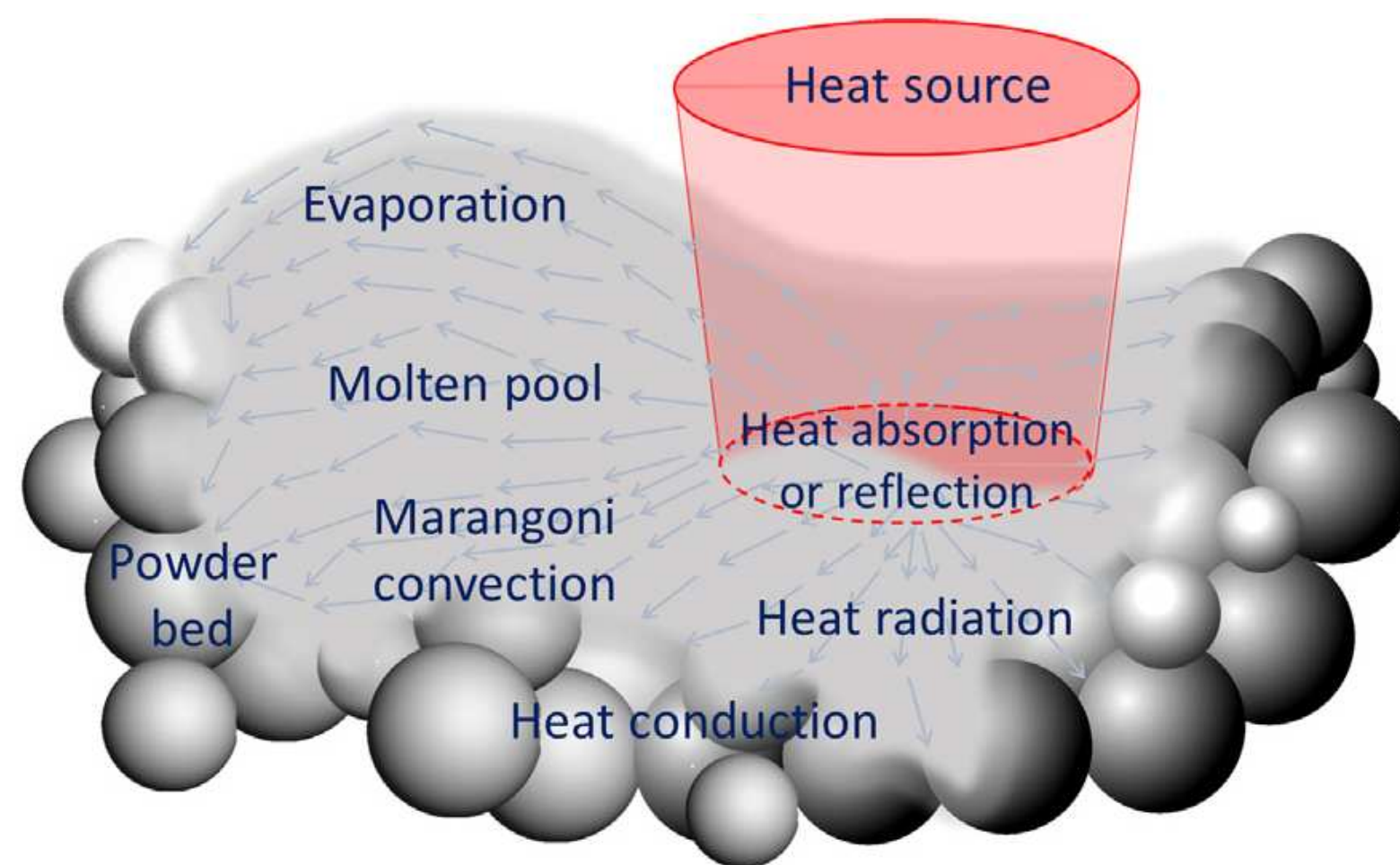
CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France

Additive Manufacturing



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

Liquid melt pool

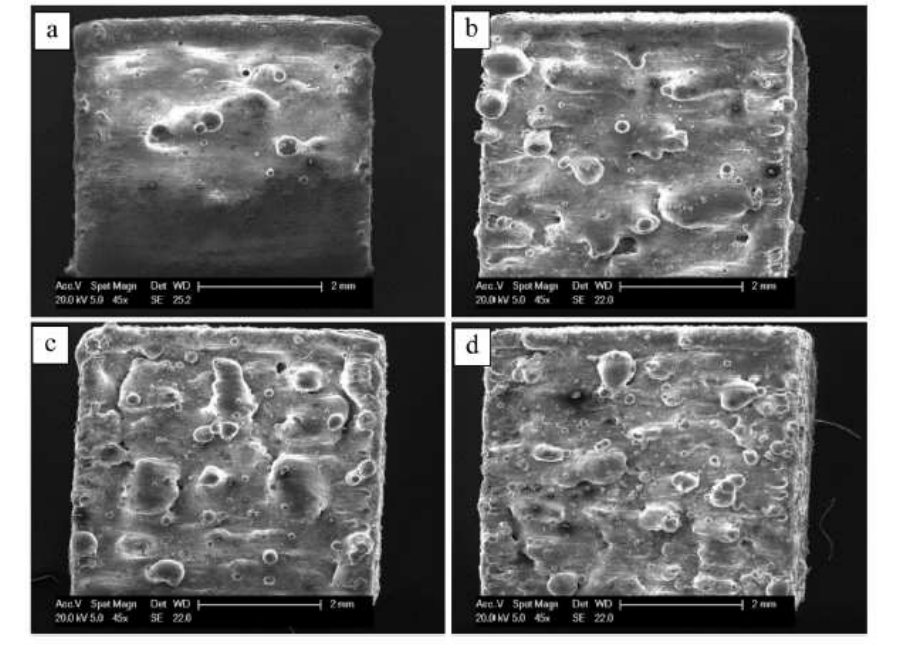
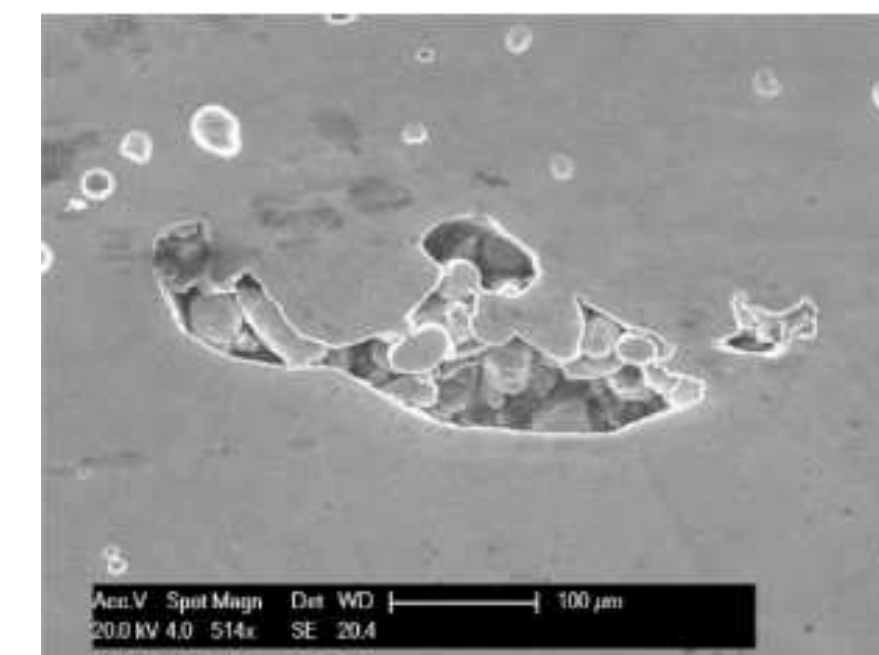


Melt pool physical phenomena [1]

Heat source ↔ Melt pool ↔ Workpiece
Thermocapillary flows

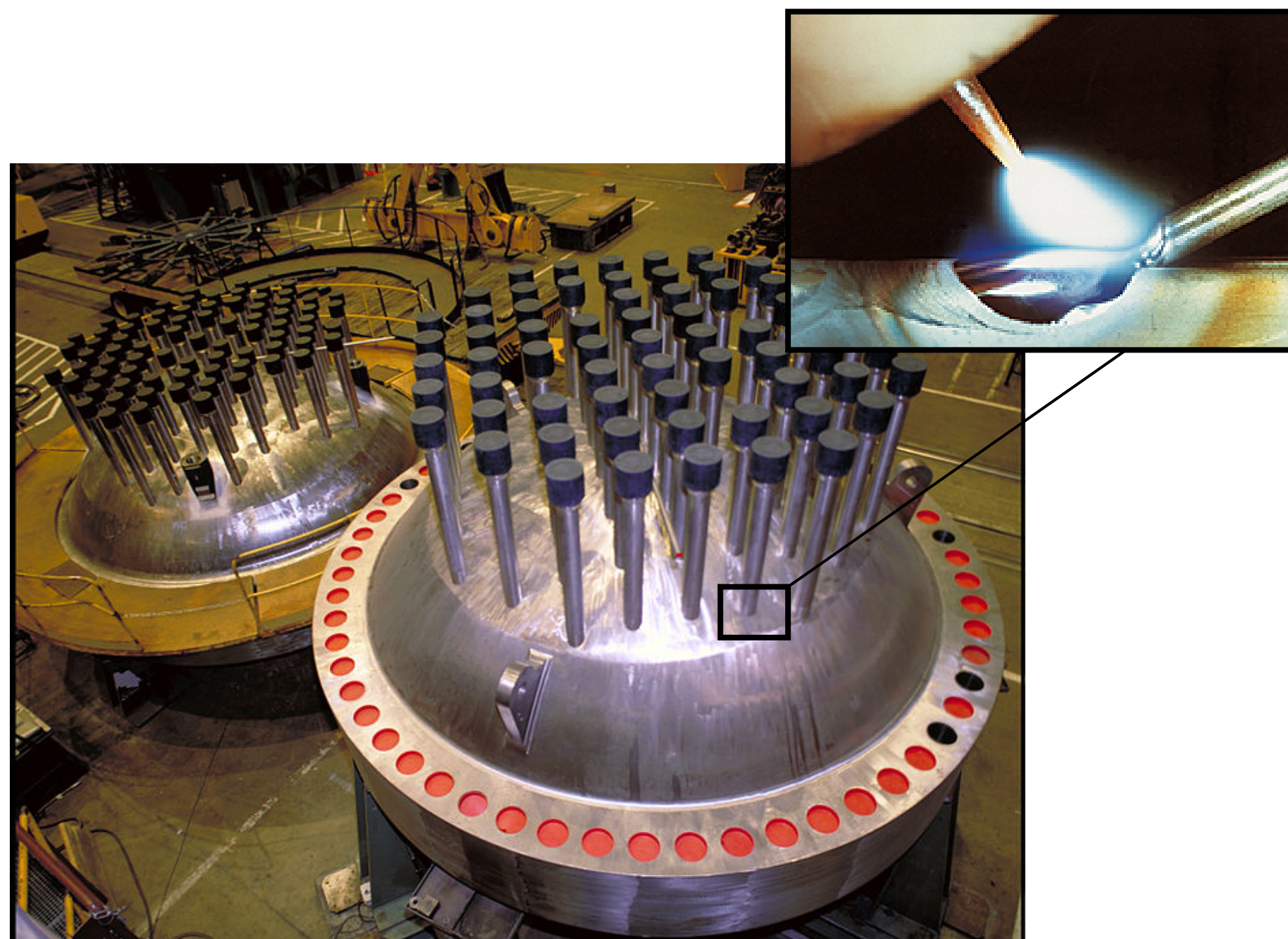
Simulation goals ?

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

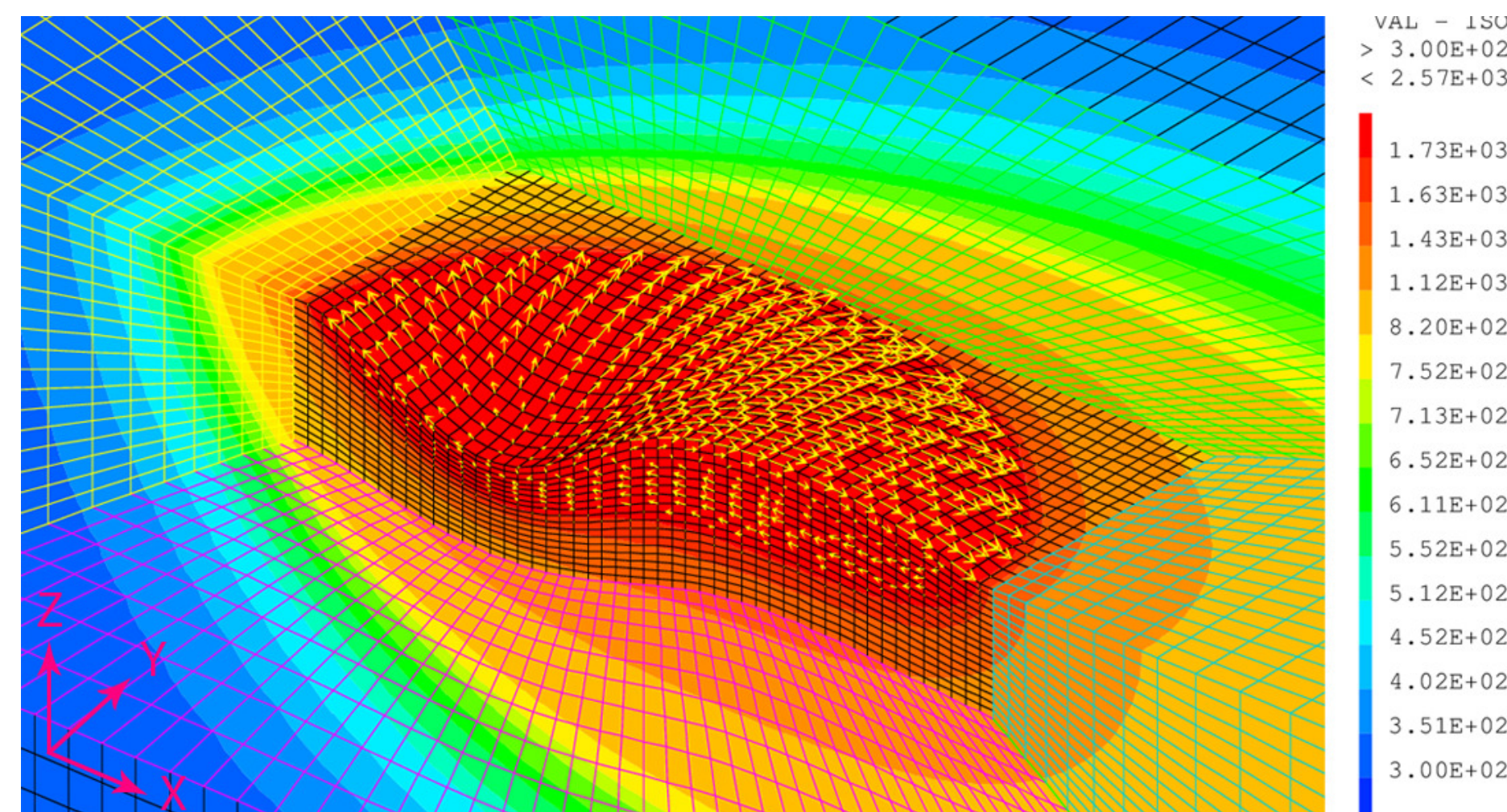


Porosity and projections

From multi-physics welding simulation...



PWR vessel head ©NRC



Melt pool velocity and temperature [2]

Finite Element toolbox Cast3M [3]

$$\begin{aligned} \rho_0 \frac{\partial \mathbf{u}}{\partial t} + \rho_0 (\nabla \mathbf{u}) \cdot \mathbf{u} &\stackrel{\Omega}{=} -\nabla p^* + \nabla \cdot \boldsymbol{\tau} + \mathbf{f}_{\text{Bou}} + \mathbf{f}_{\text{Ext}} \\ \nabla \cdot \mathbf{u} &\stackrel{\Omega}{=} 0 \\ \mathbf{u} &\stackrel{\partial \Omega \setminus \Gamma}{=} \mathbf{u}_0 \\ \mathbf{u} \cdot \mathbf{n} &\stackrel{\Gamma}{=} \frac{\partial \mathbf{x}_\Gamma}{\partial t} \cdot \mathbf{n} - \frac{m}{\rho_0} \\ -p^* + (\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{n} + \rho_0 g z &\stackrel{\Gamma}{=} \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right) + s \\ (\boldsymbol{\tau} \cdot \mathbf{n}) \cdot \mathbf{t} &\stackrel{\Gamma}{=} \frac{\partial \gamma}{\partial T} \nabla_s \gamma + s \\ \theta &\stackrel{\delta \Gamma}{=} \theta_0 \text{ ou } \mathbf{x}_\Gamma \stackrel{\delta \Gamma}{=} \mathbf{x}_0 \\ \rho_0 \frac{\partial h}{\partial t} + \rho_0 \mathbf{u} \cdot \nabla h &\stackrel{\Omega}{=} \nabla \cdot \lambda \nabla T + s \end{aligned}$$

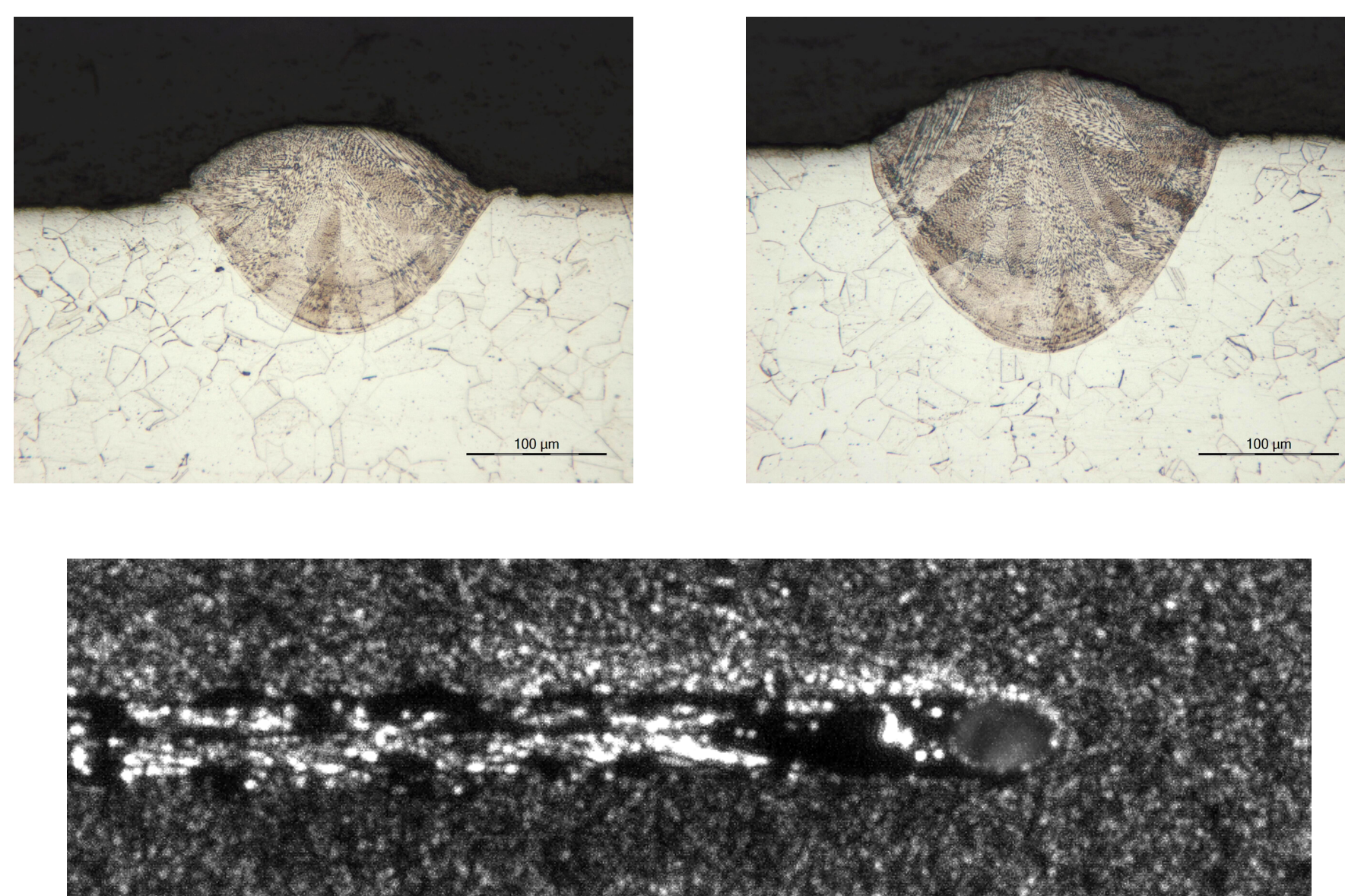
Steady free-surface laminar Navier-Stokes

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

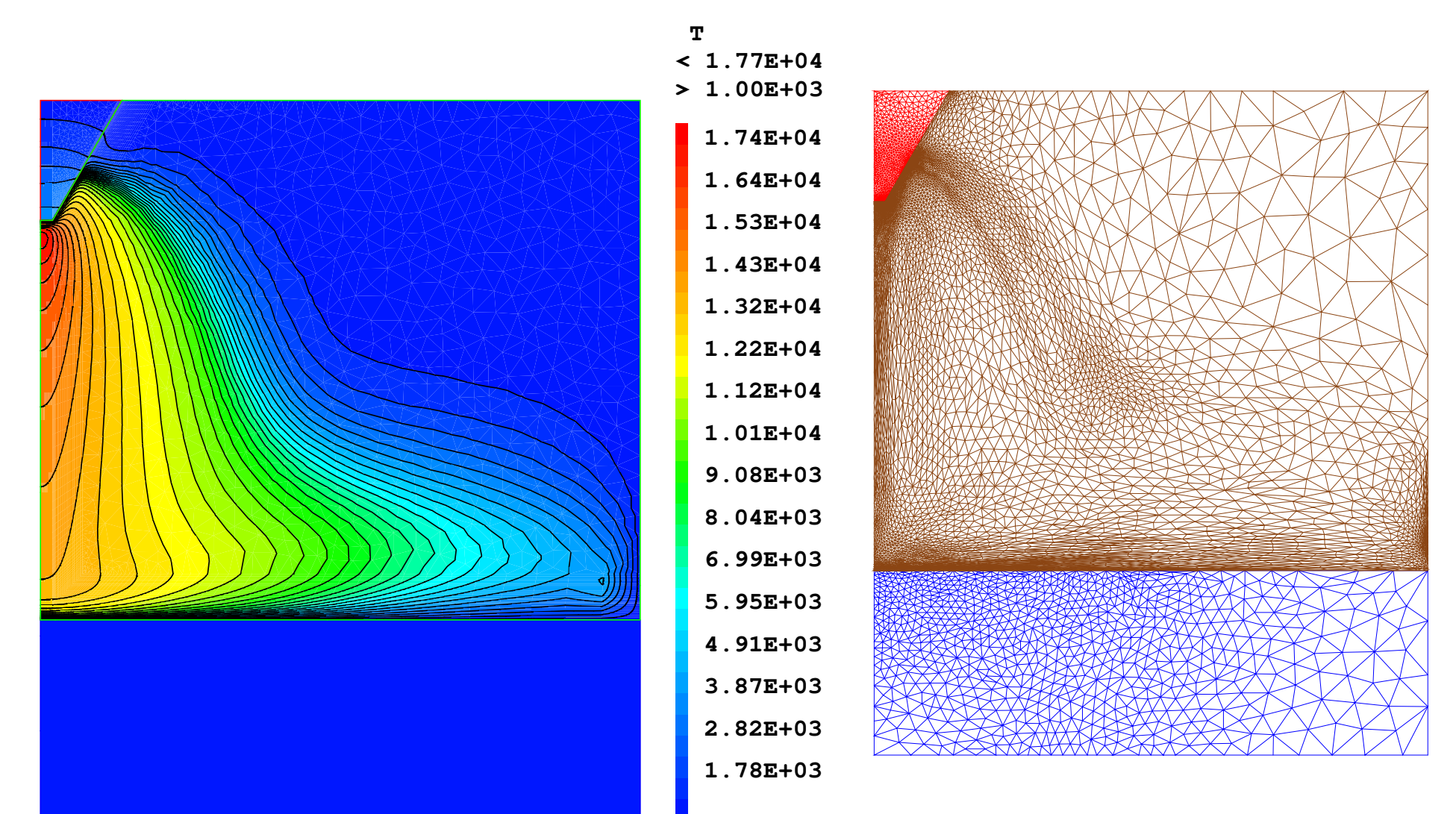
Characteristic values

	Welding	AM
P_{source} (W)	1.10^3	1.10^2
r_{source} (m)	$5.0.10^{-3}$	$5.0.10^{-5}$
$\mathbf{u}_{\text{source}}$ (m · 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.
- [2] Minh Chien Nguyen, Marc Medale, Olivier Asserin, Stéphane Gounand, and Philippe Gilles. Sensivity to welding positions in GTA welding with a 3D multiphysics numerical model. **Numerical Heat Transfer, Part A: Applications**, 71(3):233–249, 2017. URL <https://dx.doi.org/10.1080/10407782.2016.1264747>.
- [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>.