Study of copper melting by laser for additive manufacturing processes

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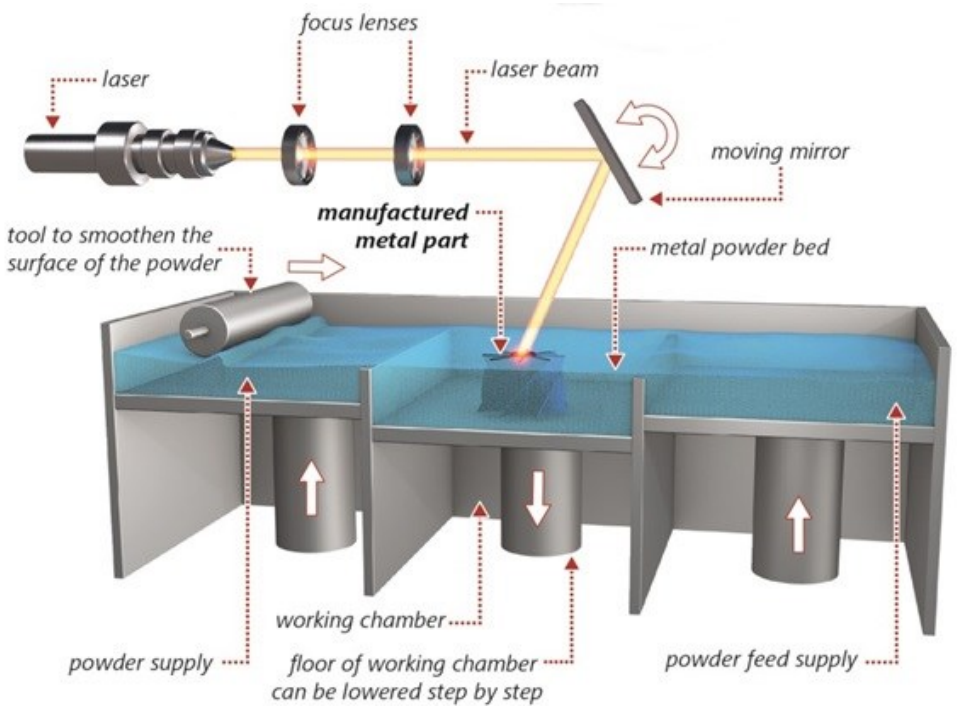
AddUp

AddUp is a 50/50 joint venture between **Fives** et **Michelin**
Established at Clermont-Ferrand in 2016

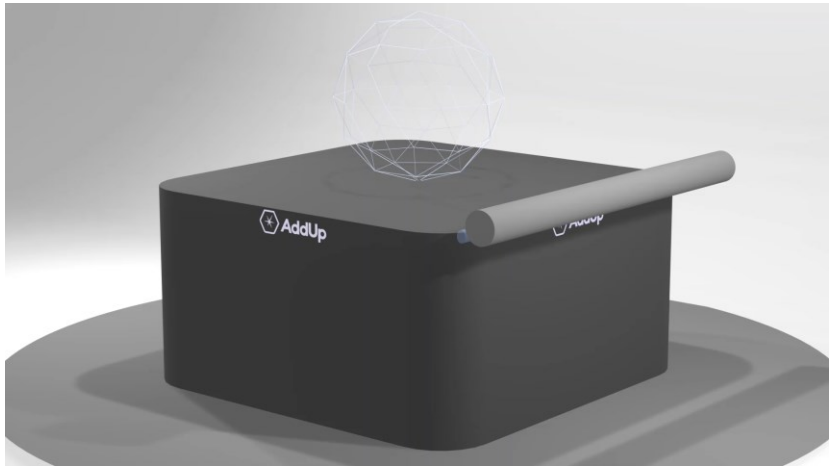
AddUp offers its customers **complete industrial metal 3D printing solutions** : (Machine design and production, Solutions HSE, Customer assistance and advice)

Additive manufacturing : LBM process

Laser Beam Melting (LBM)
Selective Laser Melting (SLM)

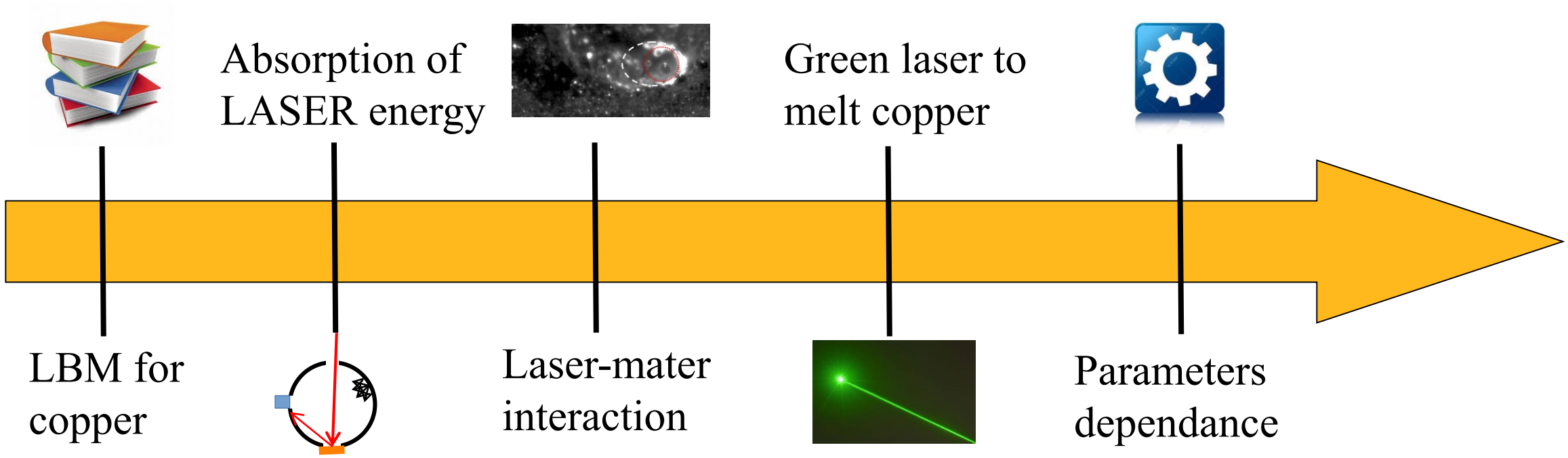


https://www.empa.ch/web/coating-competence-center/selective-laser-melting



SLM process parameters	Usual values on SLM printer
Laser emission wavelength	Infrared :1030 µm
Focalisation diameter	70 – 100 µm
Laser power	400 – 1000 W
Scan Speed	1 – 10 m/s
Powder layer thickness	20 – 100 µm
Scan strategy	
Powder composition	Maranging steel – Titanium …
Final part density	>99%

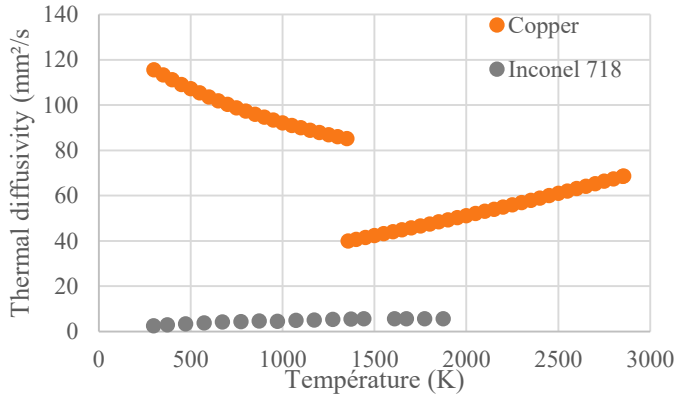
Contents


Absorption of LASER energy
Green laser to melt copper
LBM for copper
Laser-mater interaction
Parameters dependance

Bibliographic results on the SLM of copper

Welded copper line

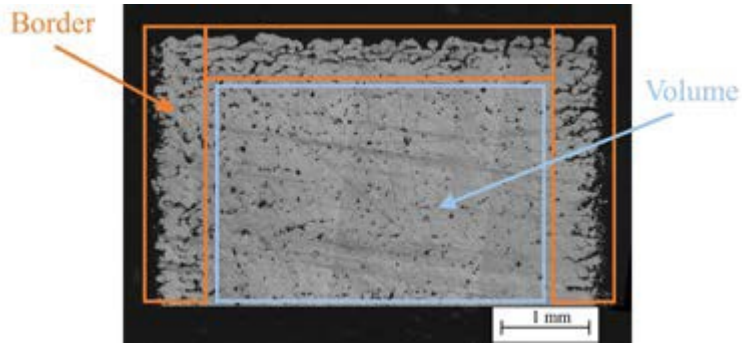
Heider A & al, Proceedings of ICALEO, 2012



- Low infrared absorption
- High thermal dffusivity $K/(\rho C_p)$
- Many projections of melting copper

Mills K., "*Recommended values of thermophysical properties for selected commercial alloys*", 2002
Cagran C., Diploma Thesis, 2000

SLM copper part



Colopi M., & al, Procedia CIRP 74 (2018) 59–63, 2018
Ikeshoji T& al, The Minerals, Metals & Materials Society, 2017

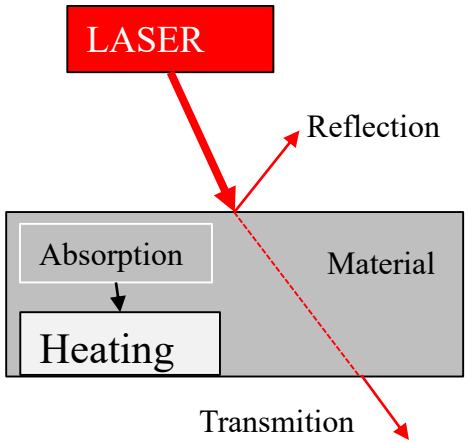
➢ Colopi, 2018

- d = 78µm
- P = 1kW
- V =1 m/s
- Substrat : 316L Steel
- **Max density: 97%**

➢ Ikeshoji, 2017 :

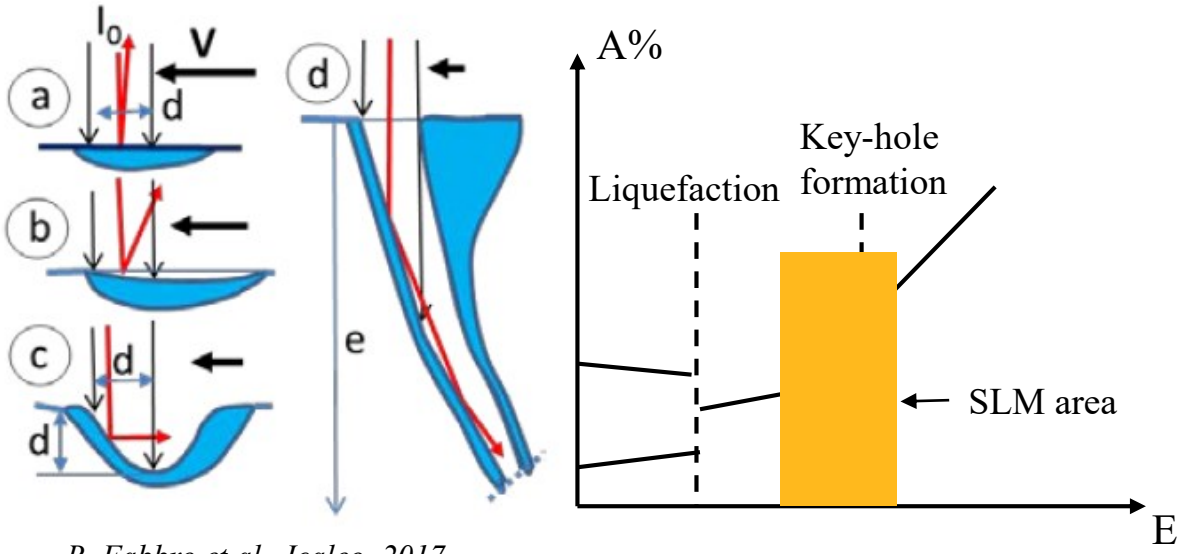
- d = 100 µm
- P = 800 W
- V = 0.3 m/s
- Substrat : pur copper
- **Max density : 97%**

Laser energy absorption

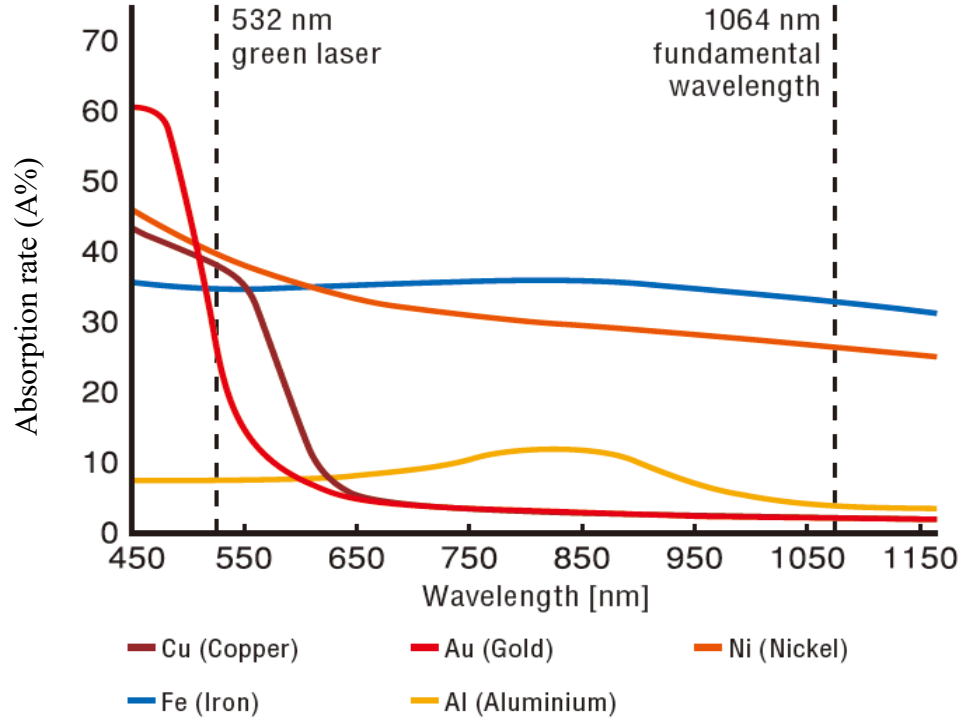


$$1 = A + R + T$$

For metal : T = 0



R. Fabbro et al., Icaleo, 2017

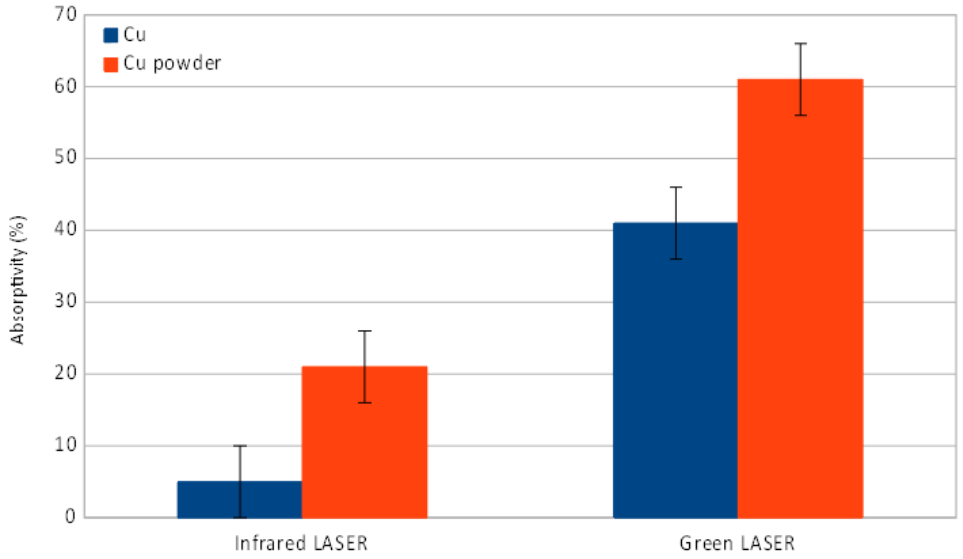


Laser energy absorption is lower for noble metal in IR mode

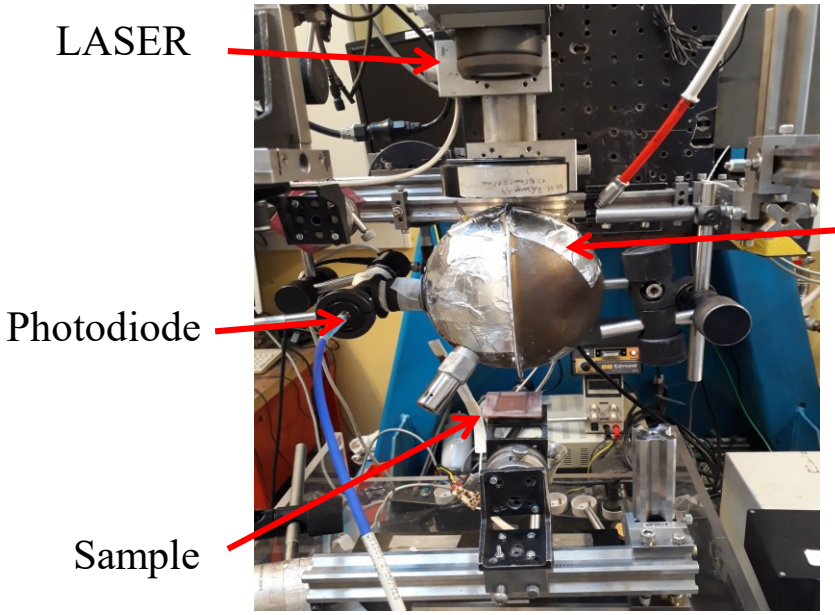
Usual SLM welding regime are near to the key-hole formation : more energy is absorbed due to a laser trap

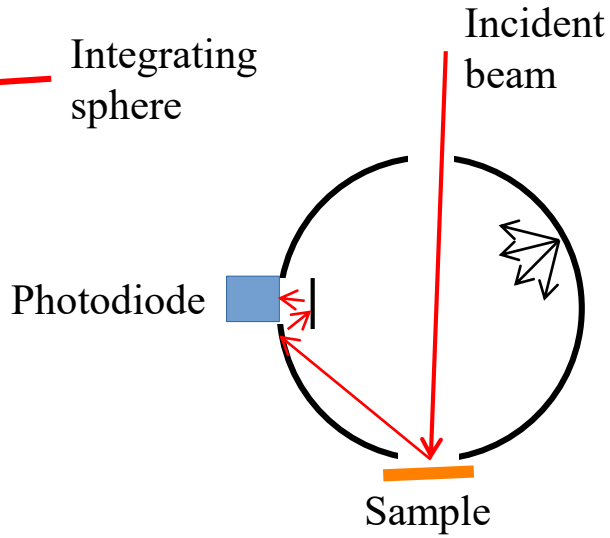
Measuring copper absorptivity

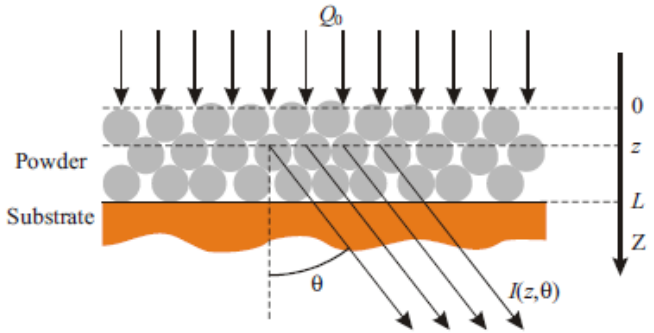
Laser used :
- Infrared laser (λ = 1030nm)
- Green laser (λ = 530nm)



Absorption rate increase for powder bed both green and IR laser.



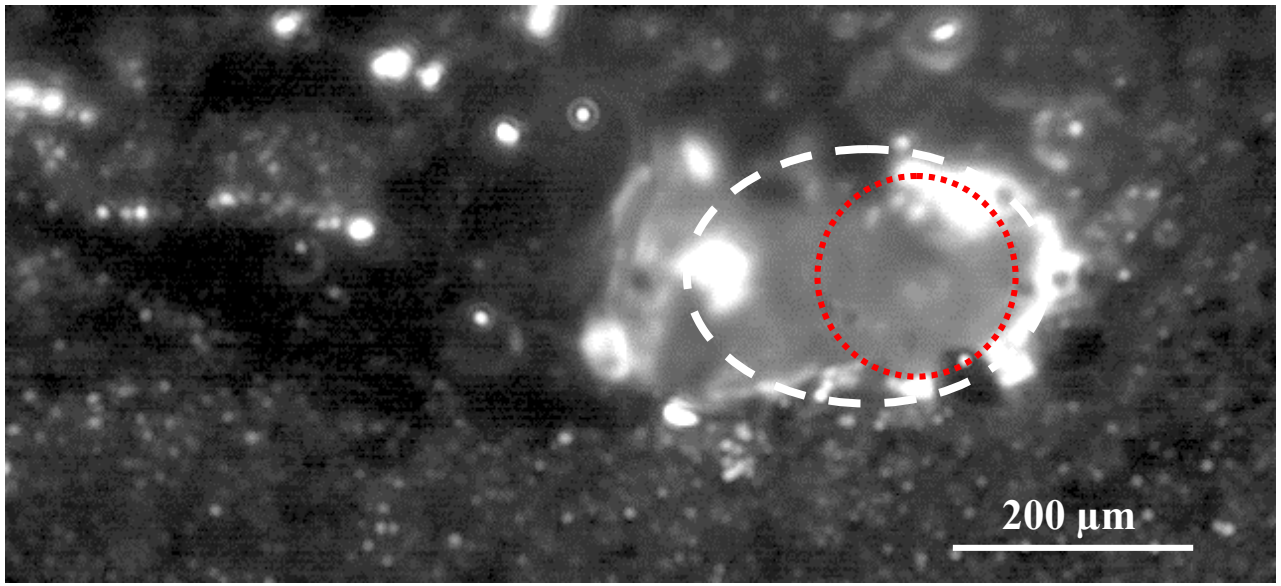




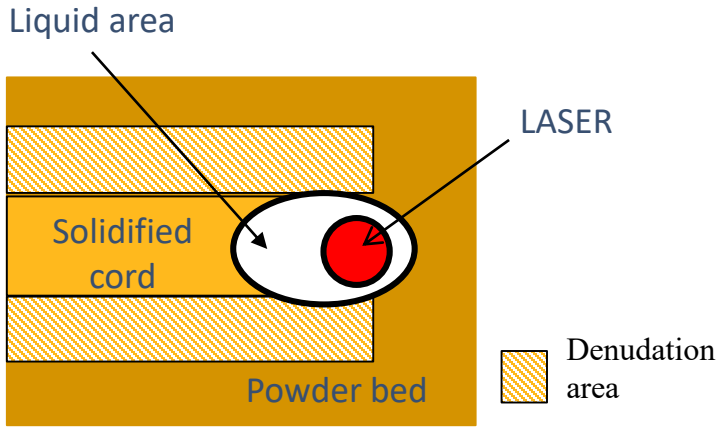
Calculated absorptivity for a Cu bed powder at λ = 1030nm (Gusarov, 2010) :

A= 38 %

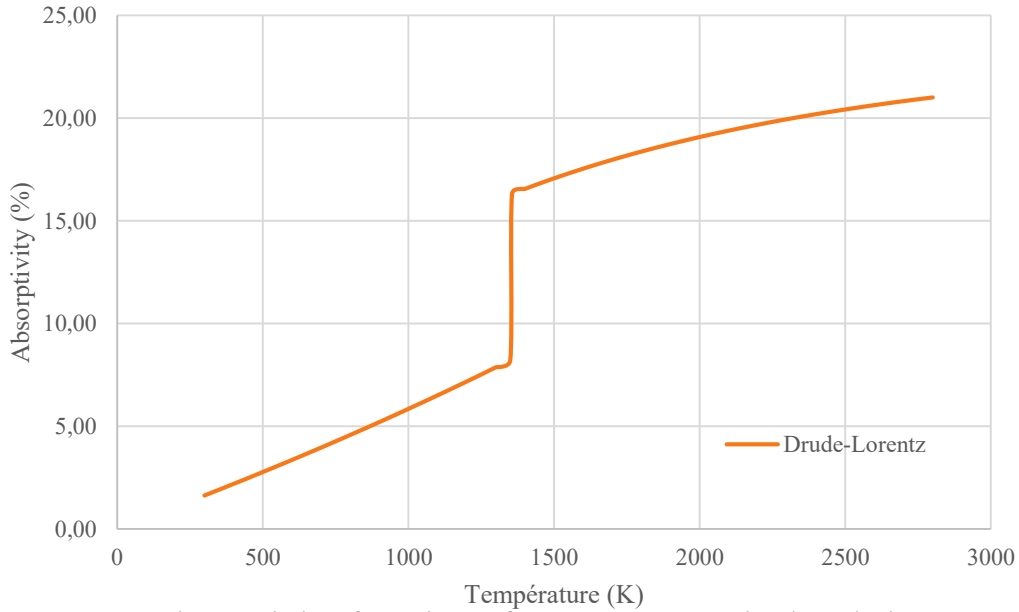
Laser-mater interaction at infrared wavelength



Record Rate : 6400 fps



Laser-mater interaction occurs mostly on a liquid phase

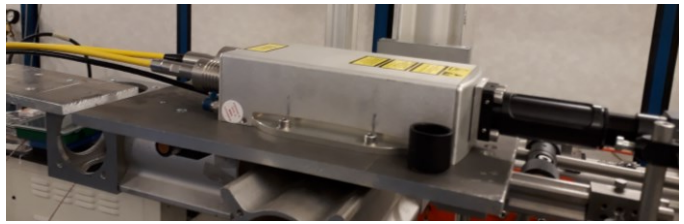


Absorptivity function of temperature calculated about a Drude-Lorentz model

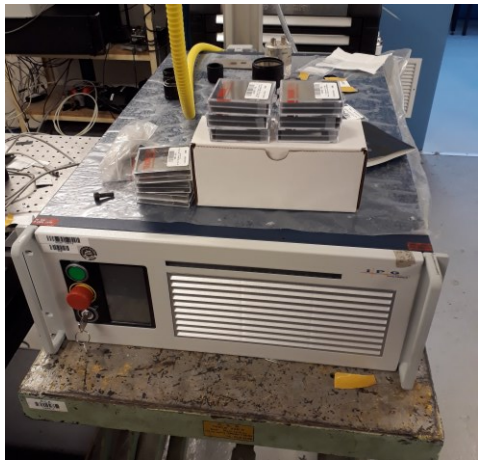
Copper fusion with a green laser

Green laser : 500 W IPG

Laser head

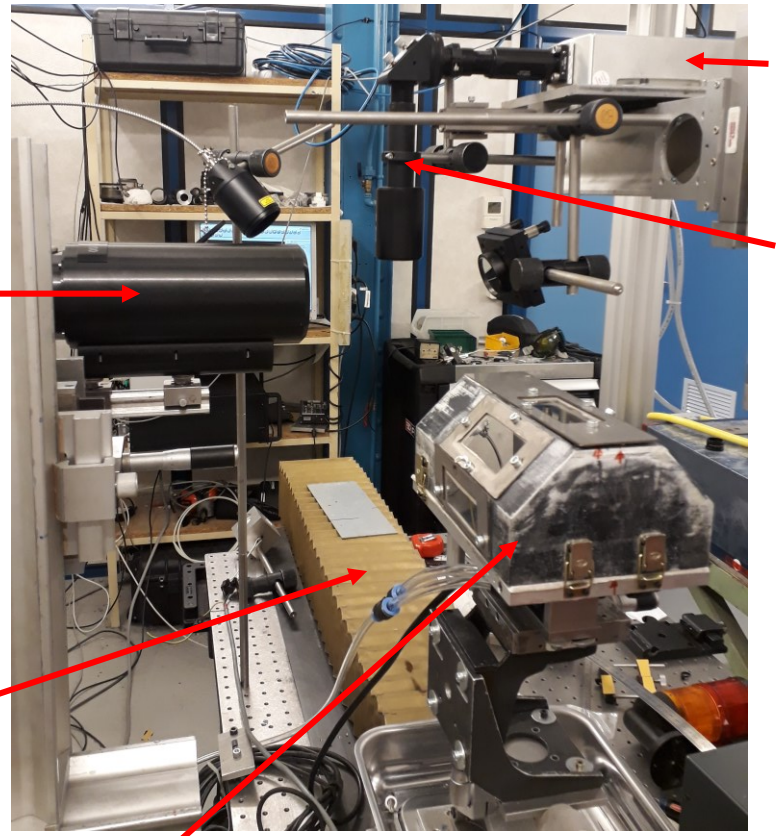


Main consol

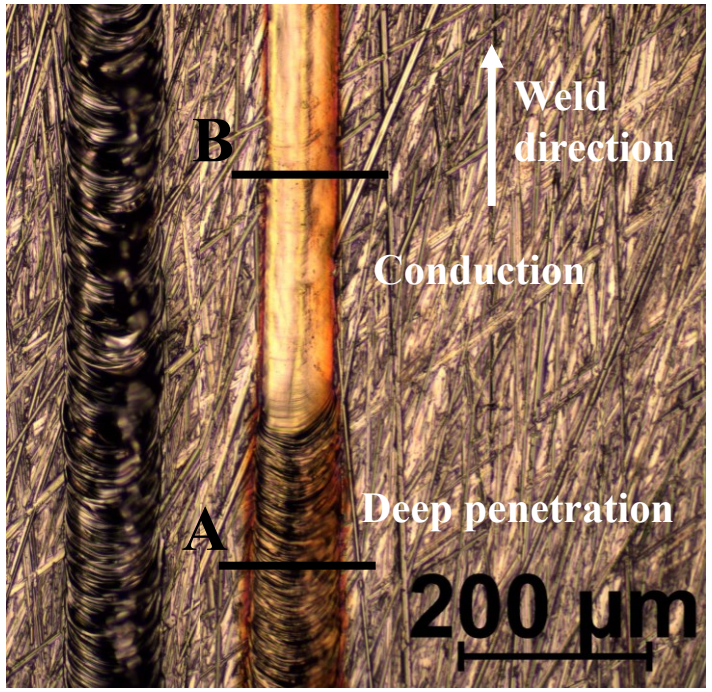


$\lambda = 532$ nm
$P_{max} = 500$ W,
$P_{pick} = 2500$ W
Frequency : 150 MHz
Pulse duration : 1,6 ns
Duty Cycle = 24 %

Experimental prototype



Influence of gas shielding on copper welding

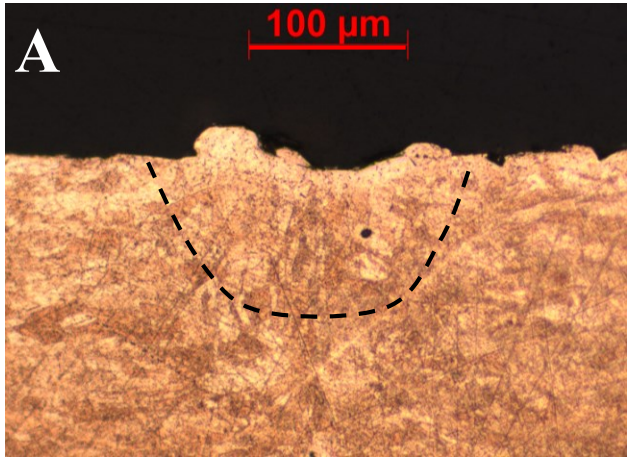


With argon

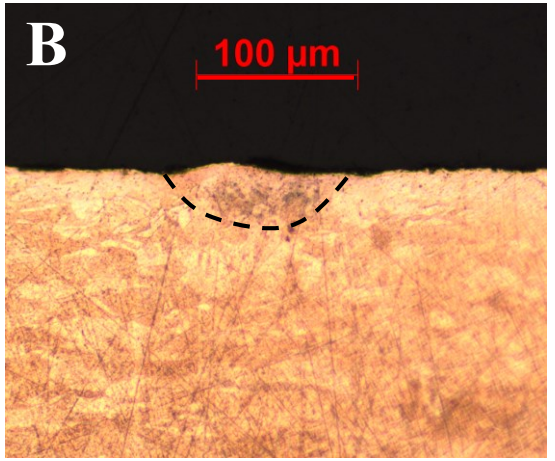
Without argon

2 welding modes :

- Conduction → Low penetration mode
- Deep penetration → High penetration mode



Deep penetration



Conduction

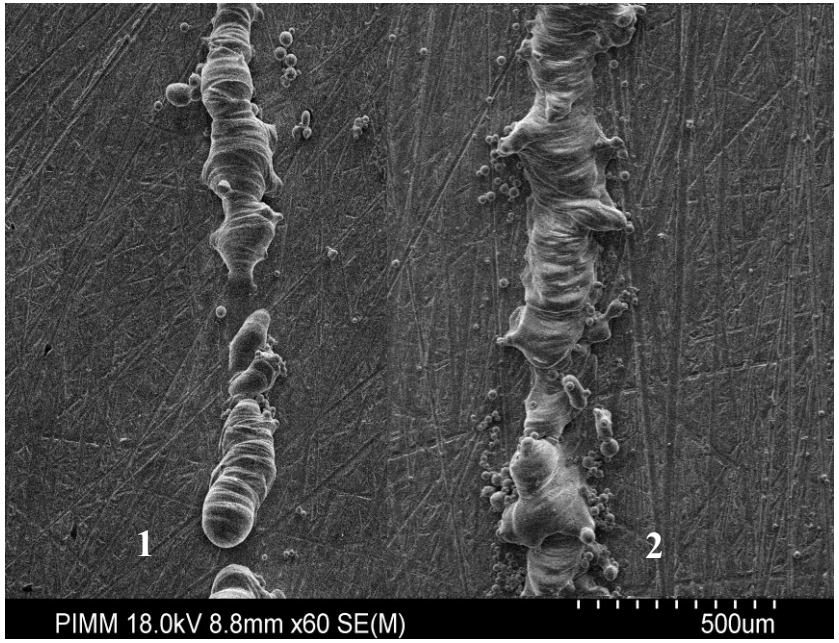
Detrimental influence of an oxygen atmosphere :
↗ variation of the two welding modes

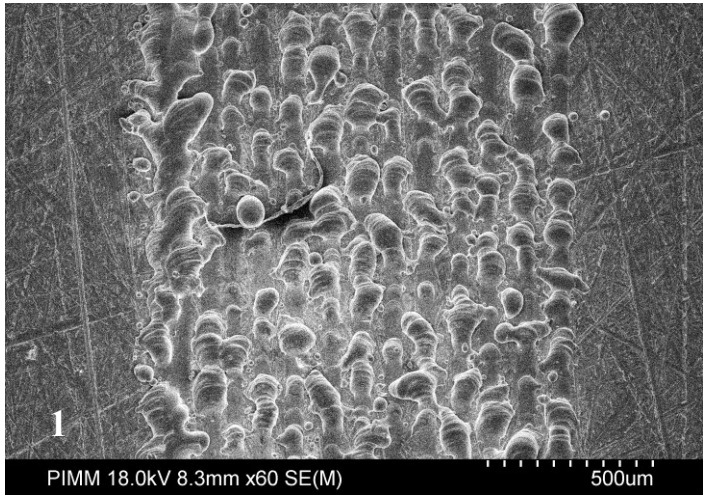
Fusion weld of a copper powder bed

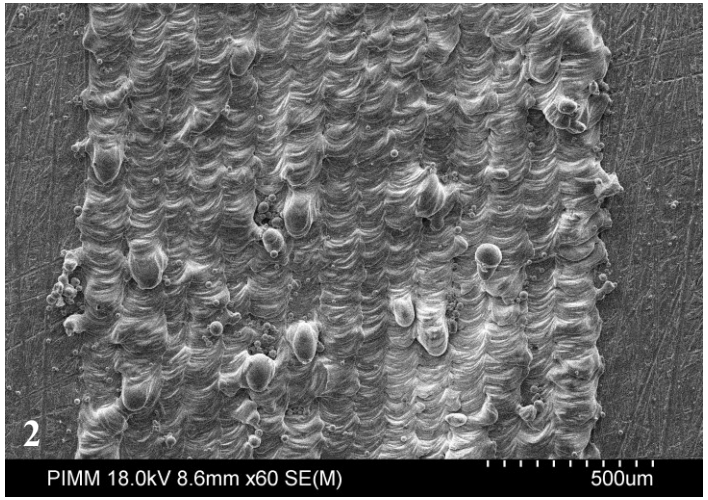
Without powder

Conduction Deep penetrattion

With powder







More stable weld for deep penetraton mode on powder

Conclusion

Green laser allows to create continuous line and surface

Possible to build small parts with a green laser in the experimental prototype

However, no industrial prototype available with green laser

For copper, using an other wavelength to improve absortivity is not sufficient to optain stable penetration

Thanks

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