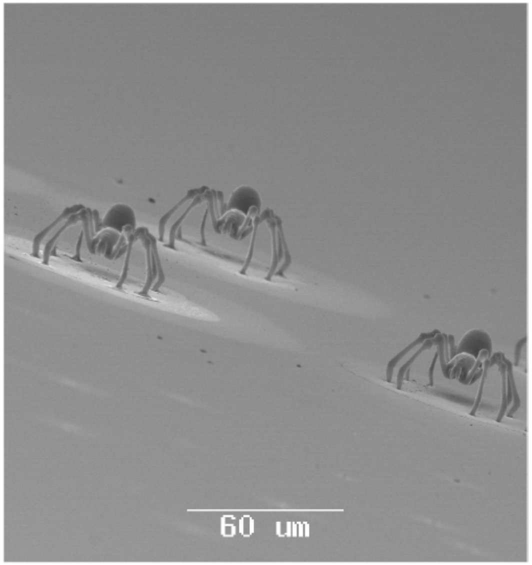
Empa
Materials Science and Technology

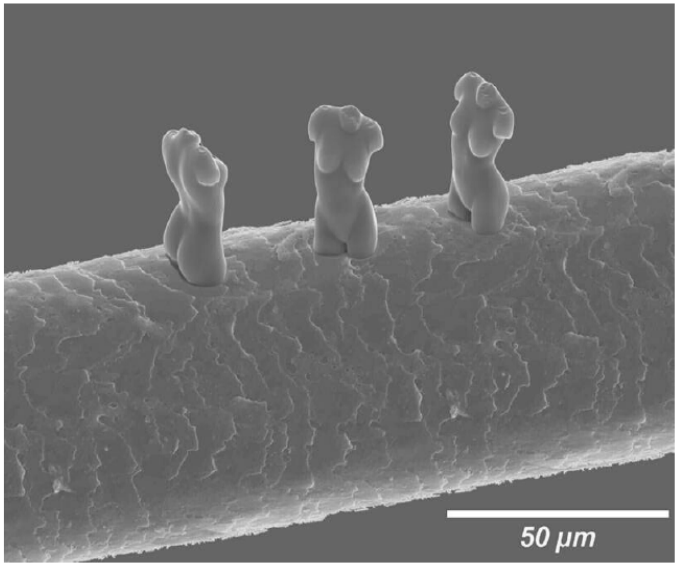
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

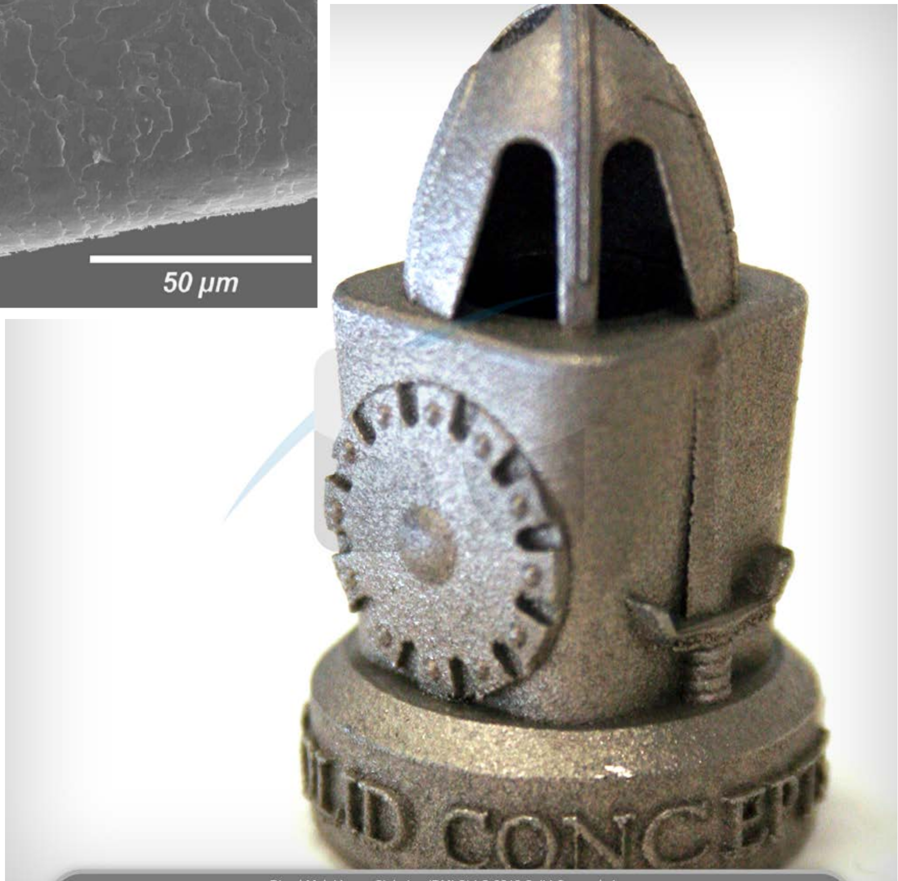
Laser Processing of Materials

Generating Techniques

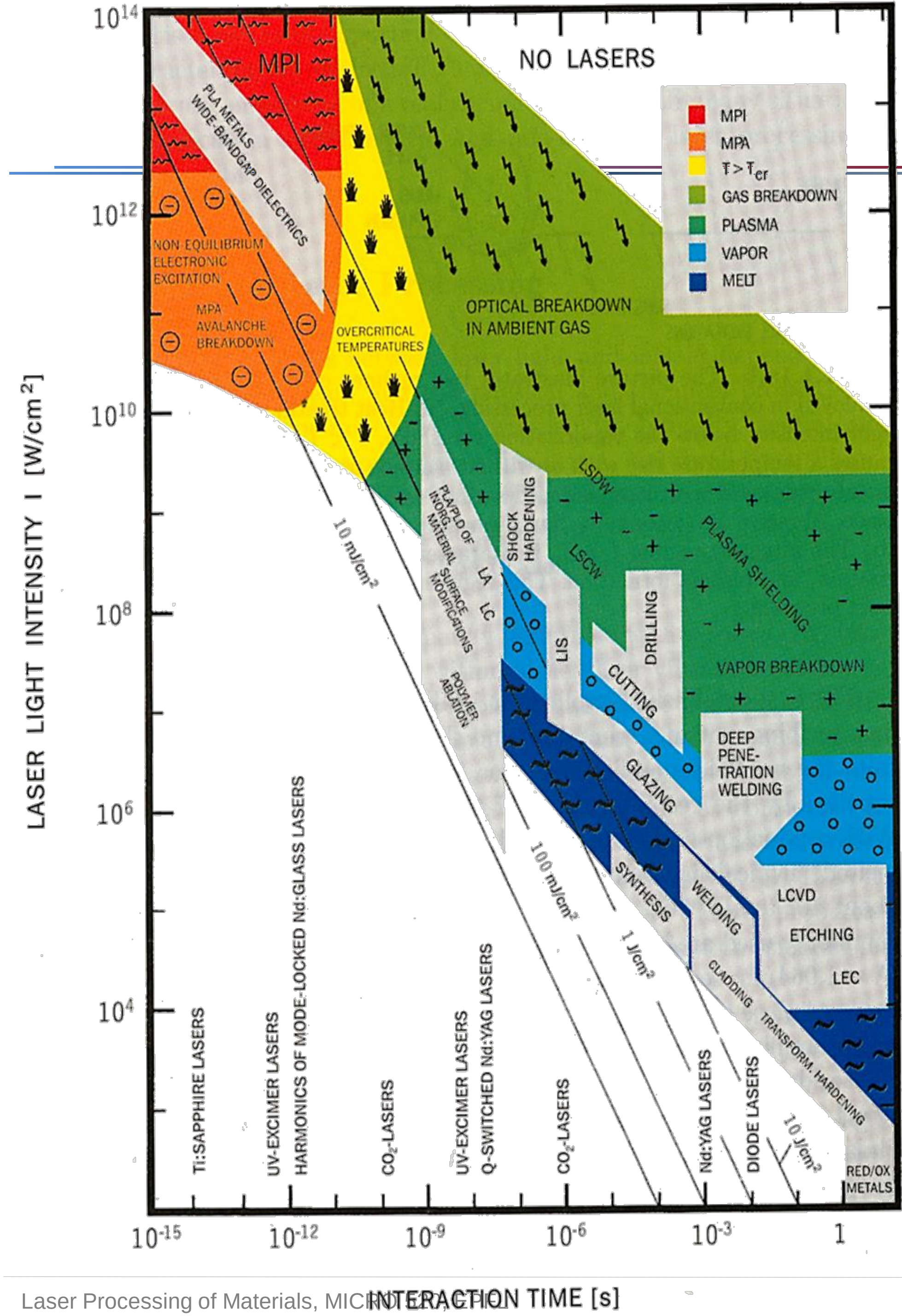
Patrik Hoffmann







Direct Metal Laser Sintering (DMLS) | © 2012 Solid Concepts Inc.



D. Bäuerle;
Laser Processing and Chemistry, 3rd ed.
Springer, Berlin, 2000

What kind of laser do you propose for bending / welding?

Application of lasers in materials processing:
Intensity-Time Diagram

PLA/PLD – pulsed laser ablation/ deposition

LA – laser annealing

LC – laser cleaning

LIS – laser induced isotope separation/IR – laser photochemistry

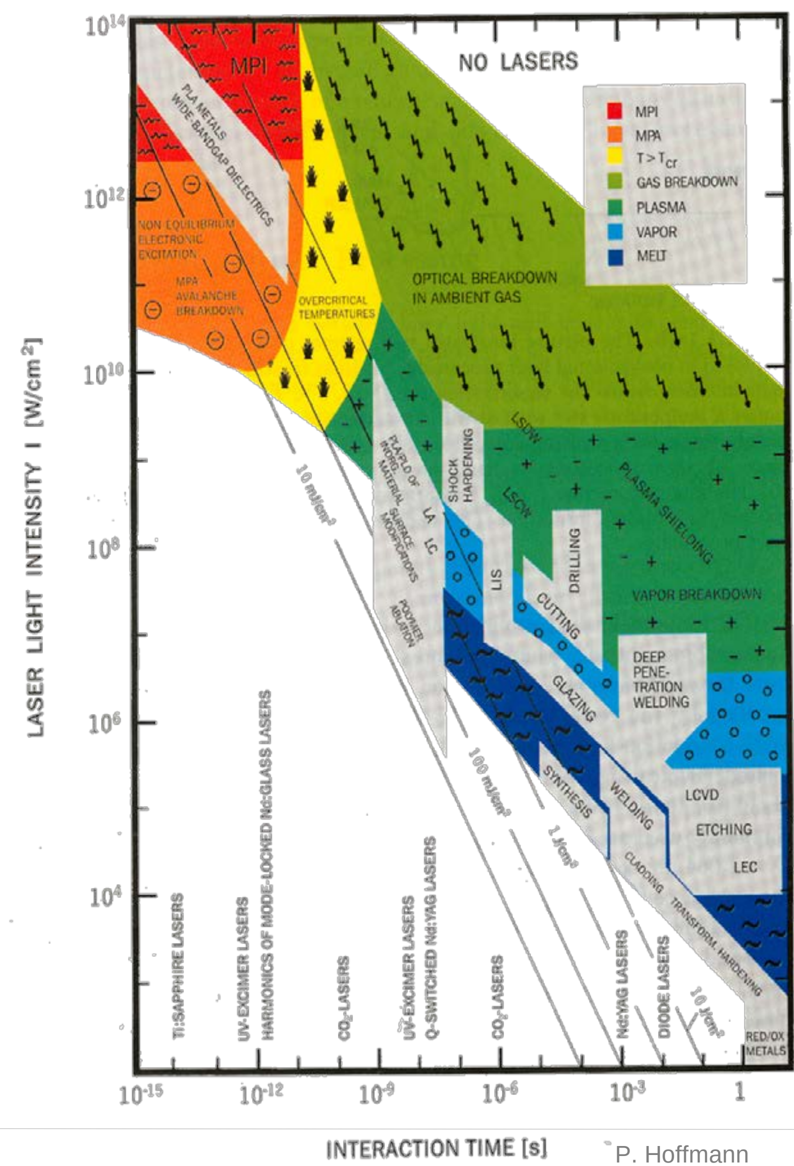
MPA/MPI – multiphoton absorption ionization

LSDW/LSCW – laser supported detonation/combustion waves

LCVD – laser induced chemical vapour deposition

LEC – laser induced electrochemical plating/etching

RED/OX – long pulse or cw CO_2-laser induced reduction/oxidation



D. Bäuerle; Laser Processing and Chemistry, 3rd ed. Springer, Berlin, 2000

Laser Types: Pulsed & CW

Type of laser	Pulse length determined by	Typical pulse length	Characteristic pulse peak power
Continuous wave (cw)	-	∞	Ws – kWs
Free running laser	Pump pulse length (flash lamp)	100 µs – 1ms	kWs
Q-switched laser	Time constants of active material and modulating element	1 ns – 100 ns	MWs
Mode-locked laser	Number of coupled modes, pulse compression	10 fs – 10 ps	GWs

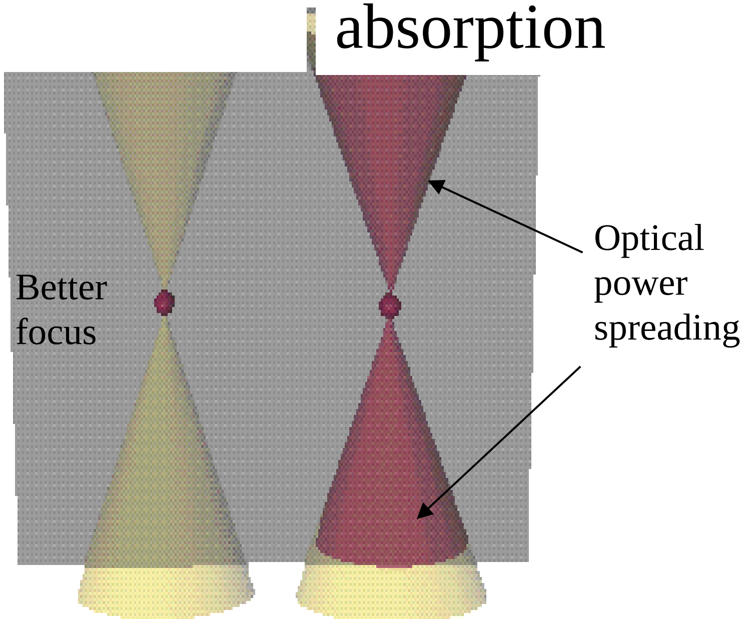
Content

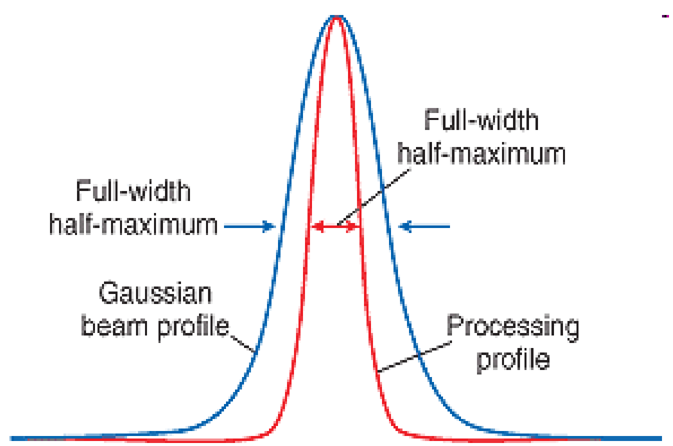
- Generating technologies
  - Laser powder sintering / melting
  - Micro-stereolithography

Multiphoton absorption

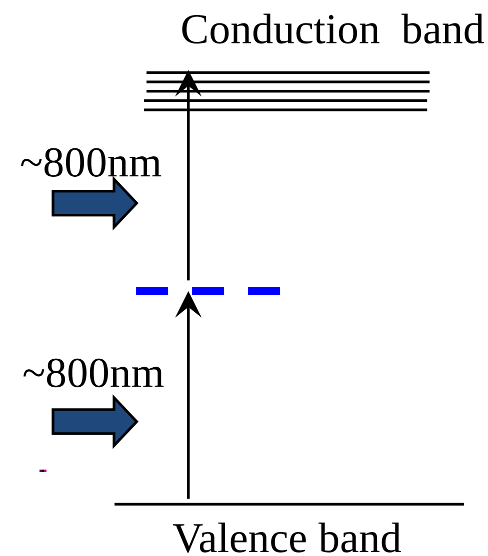
Multiphoton absorption

Single photon absorption

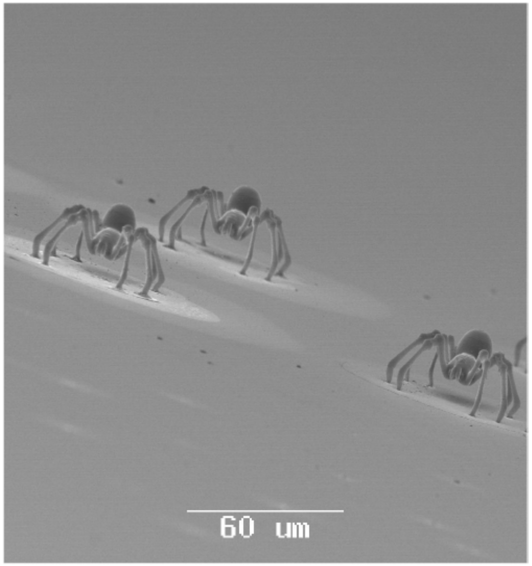


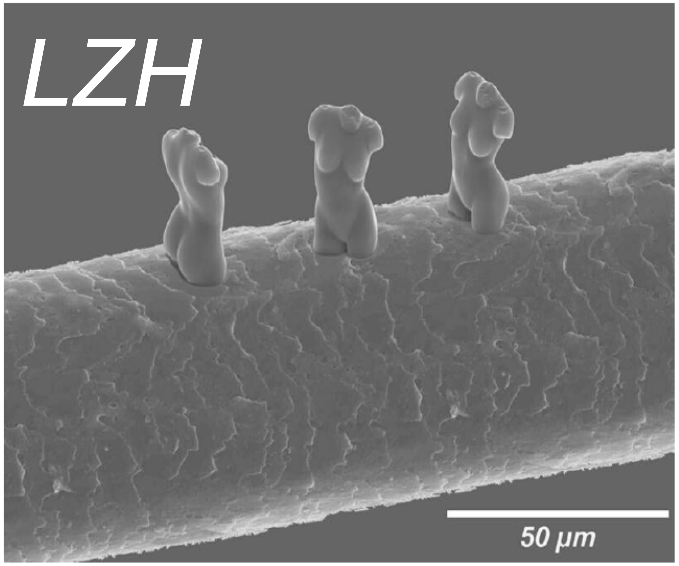


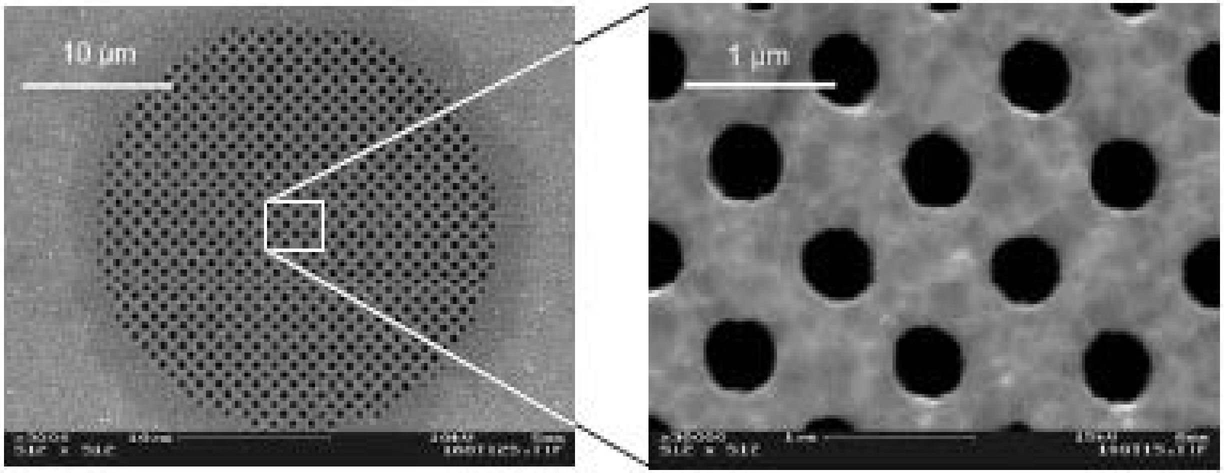
Two photon absorption



3D Polymerization (Multiphoton)

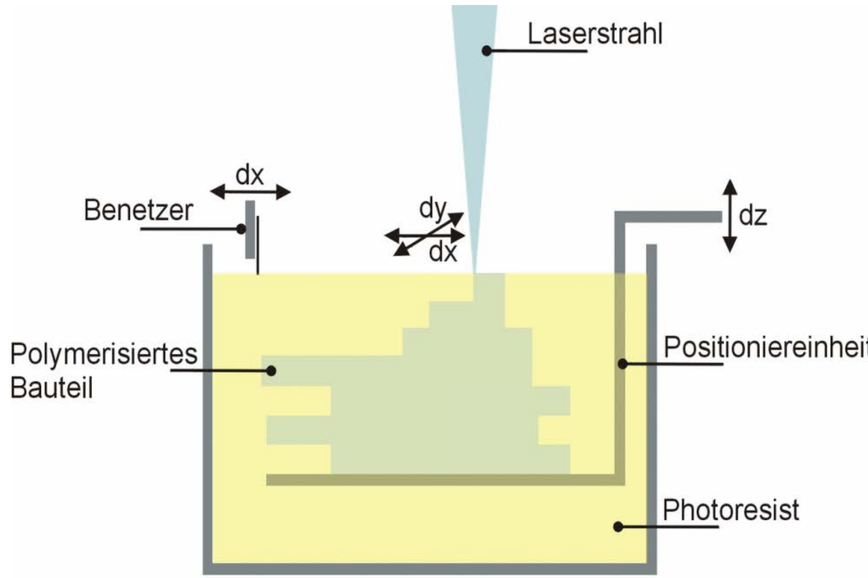


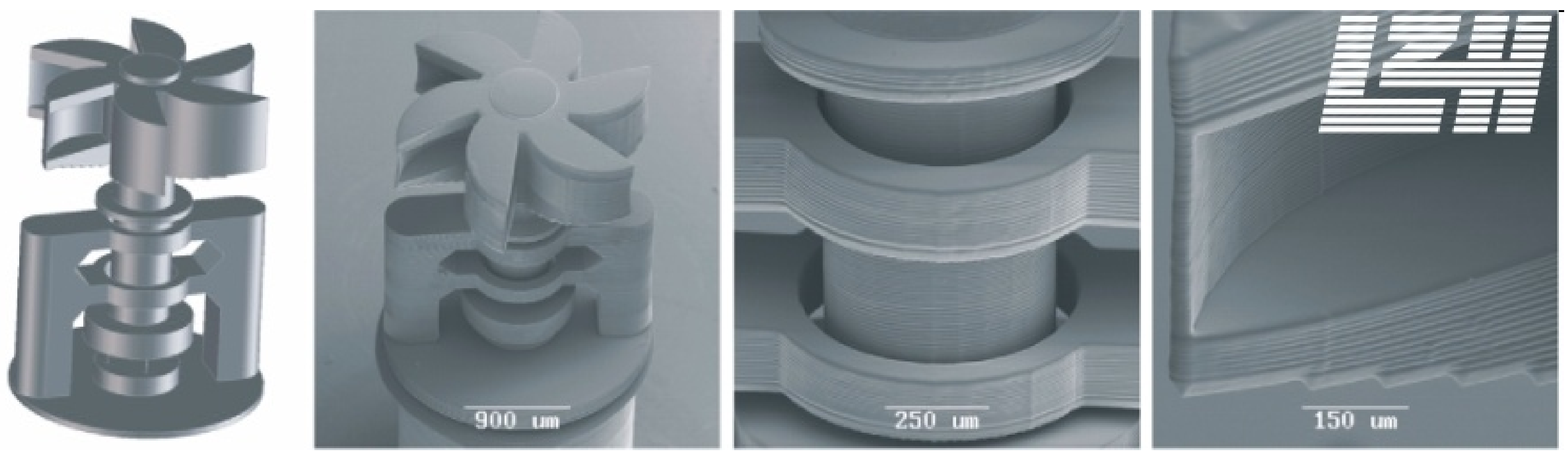




Klein-Wiele, J.H.; Bekesi, J.; Simon, P. *Appl. Phys. A* 79 (2004) 775.

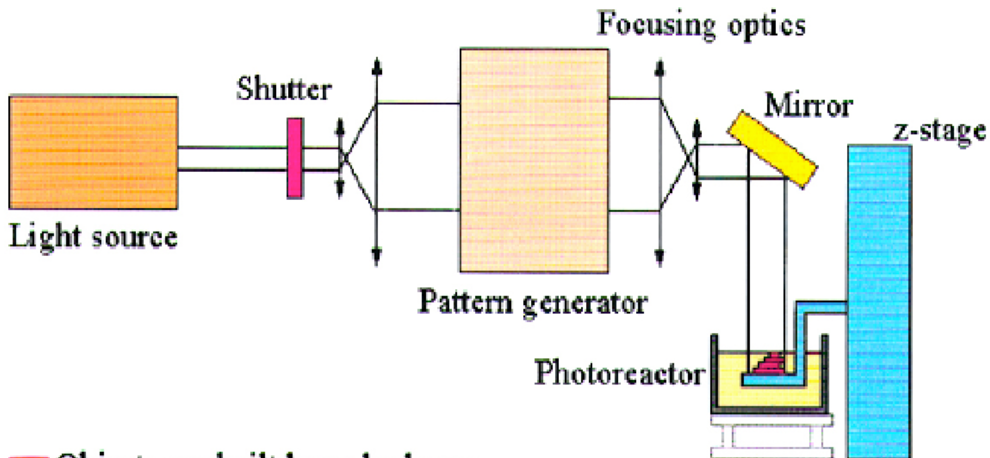
Quasi 3D Polymerization





Stereo lithography

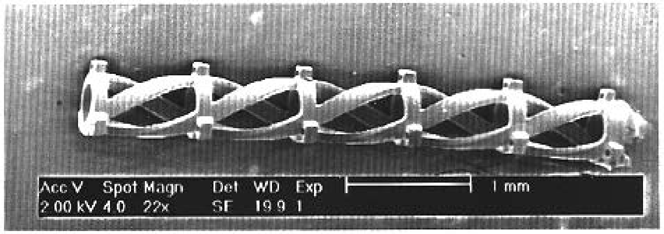
Principle of an integral microstereolithography apparatus



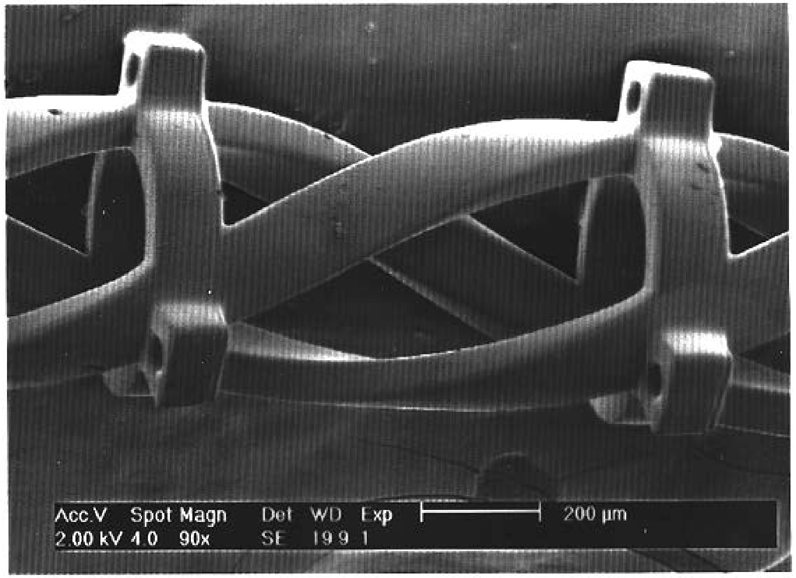
- Objects are built layer by layer
- A pattern generator is used to shape the light beam, so that it contains the image of the layer to be built
- This image is then focused and projected on the surface of a photopolymerizable resin
- A selective polymerization of the liquid resin occurs in the irradiated areas
- A shutter occults the light when a layer is solidified
- The object is then lowered in the photoreactor
- A new layer of fresh resin is spread on the surface of the already polymerized part of the object
- When the liquid surface is stabilized, the irradiation of the next layer can be started

Stereo Lithography

Imbricated springs made by microstereolithography



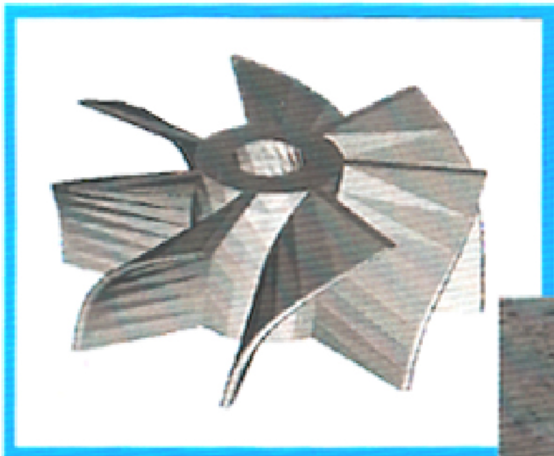
This structure is made of 1000 layers, each is 5µm thick.
Its total length is 5mm and its diameter 500µm.
The fabrication time is approximately 5 hours.



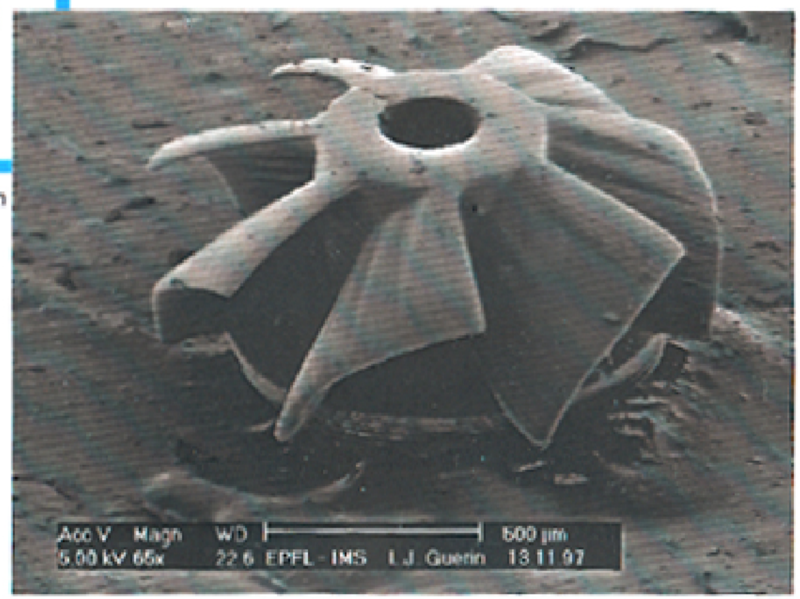
Detail of the springs: Note the smoothness of the surface.

Stereo lithography

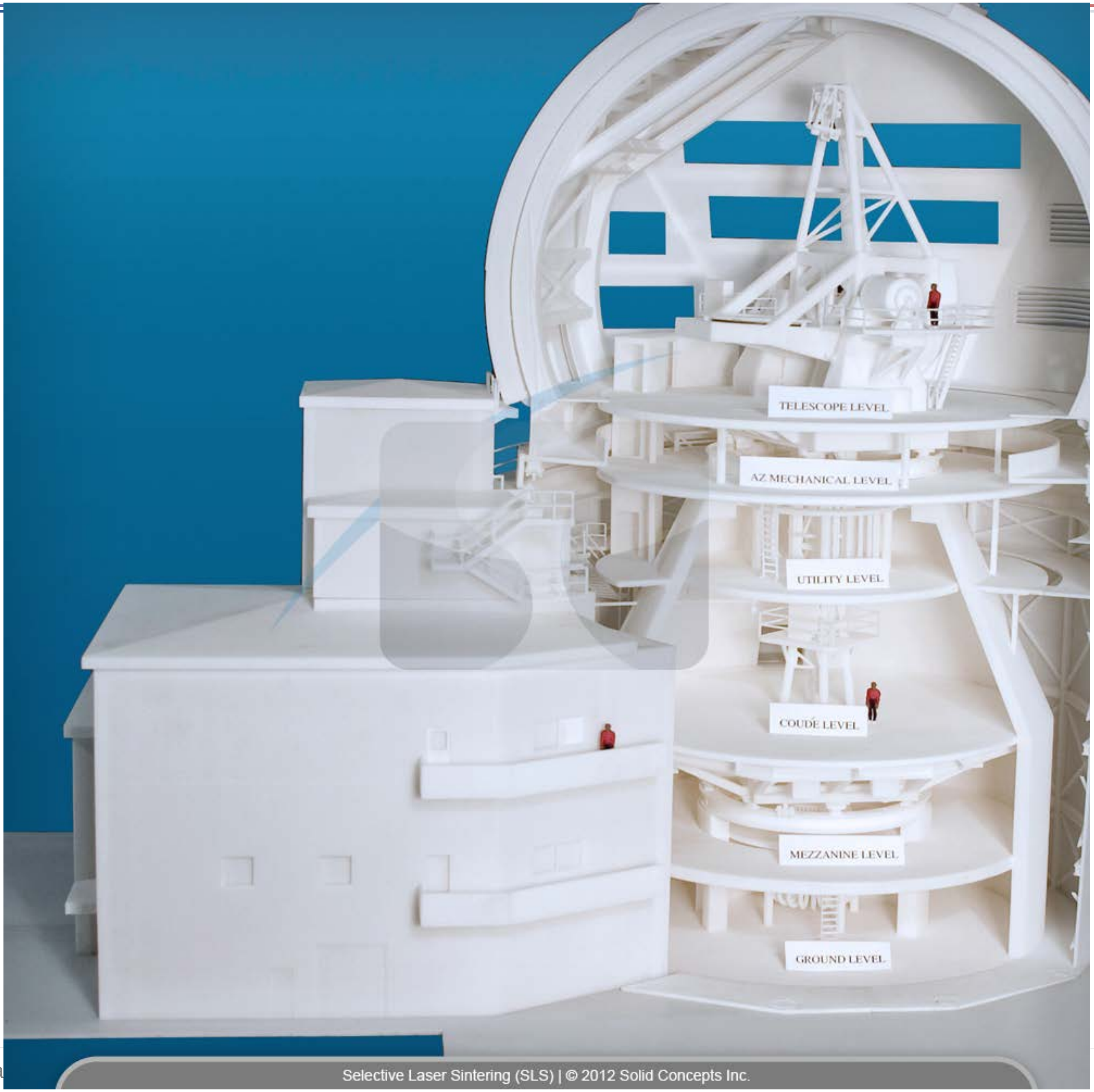
Object generated with a CAD program and built by microstereolithography

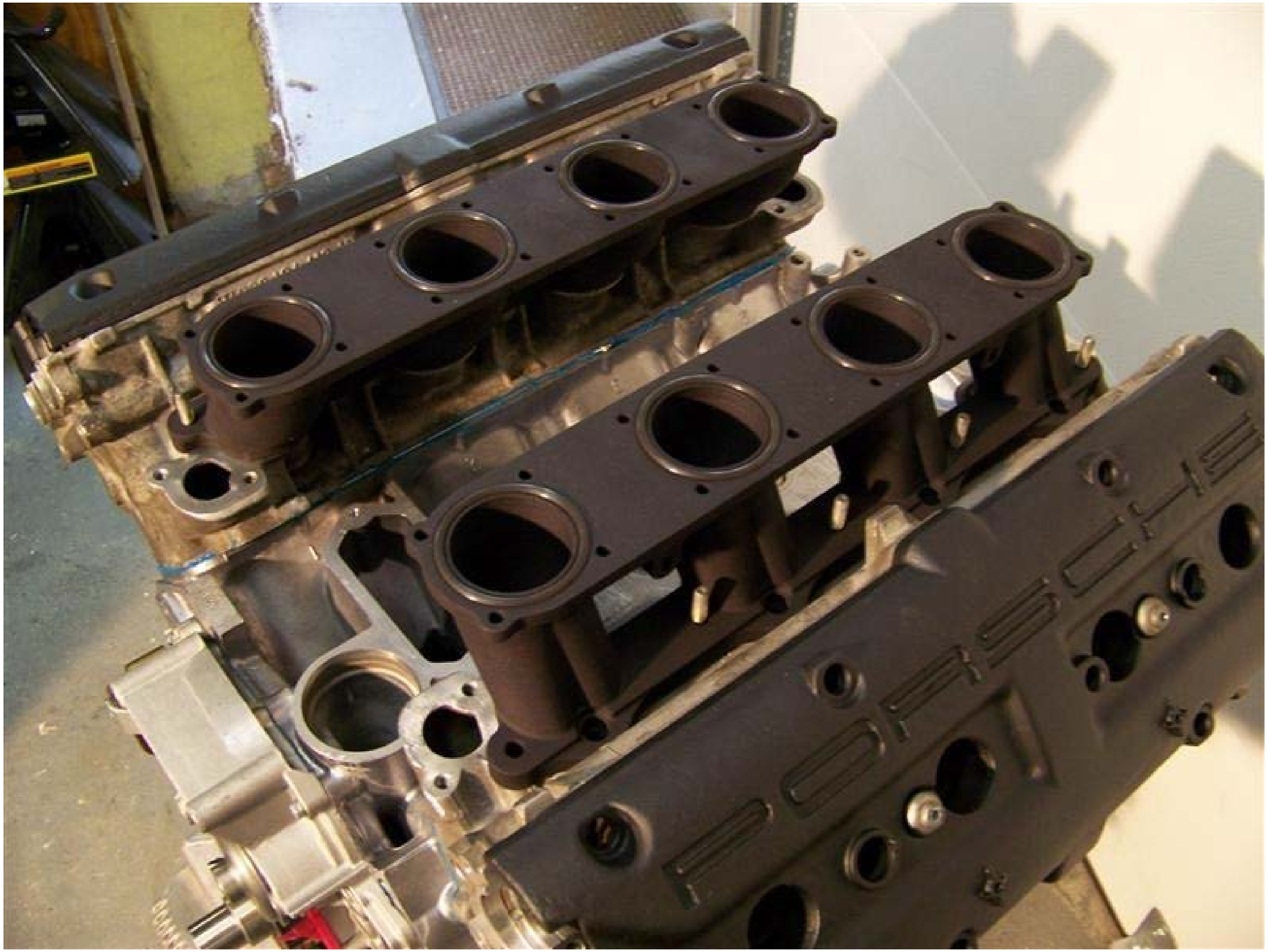


STL file of a turbine obtained with a CAD program



Micro turbine made by microstereolithography from a CAD file.
This object is 1.3mm in diameter and made of 120 layers of 5µm each


TELESCOPE LEVEL
AZ MECHANICAL LEVEL
UTILITY LEVEL
COUDÉ LEVEL
MEZZANINE LEVEL
GROUND LEVEL
Selective Laser Sintering (SLS) | © 2012 Solid Concepts Inc.


PORSCHE

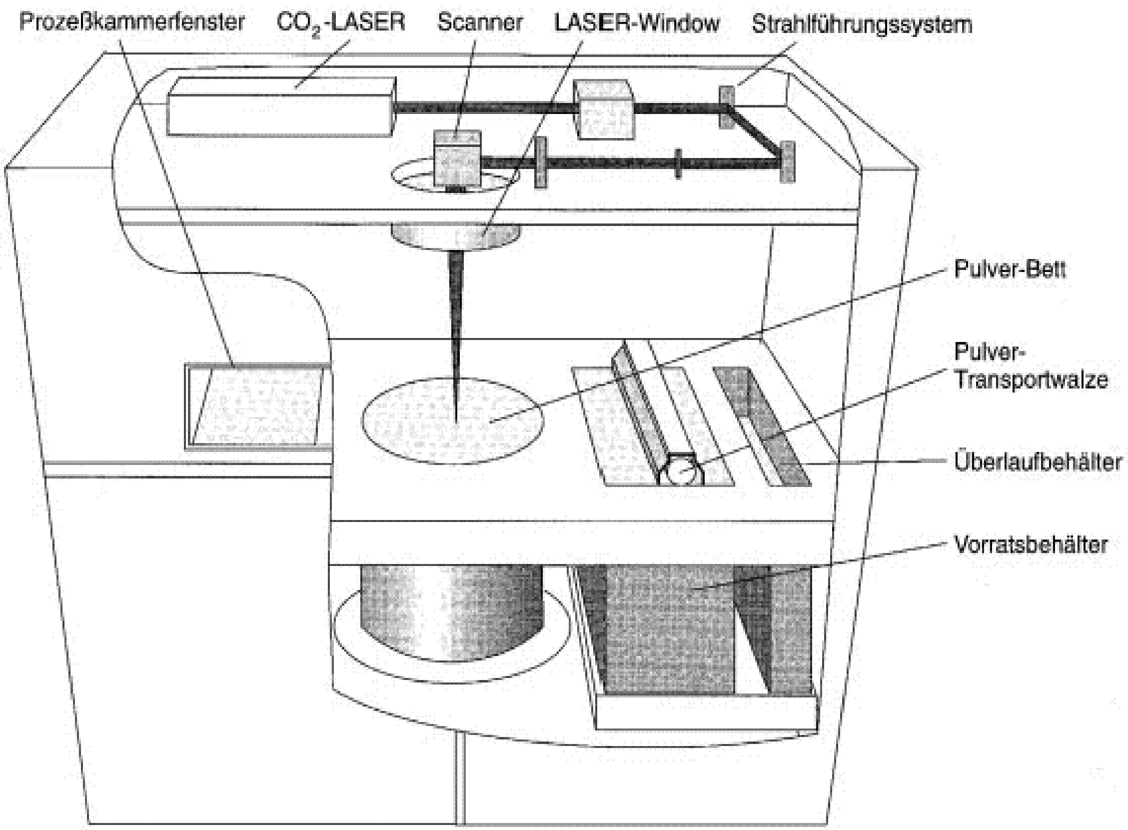
Laser Sintered copy of Browning 1911 pistol standed at least 50 shots!

Laser sintered Titanium Heel

Laser Sintering

Lasertechnik II

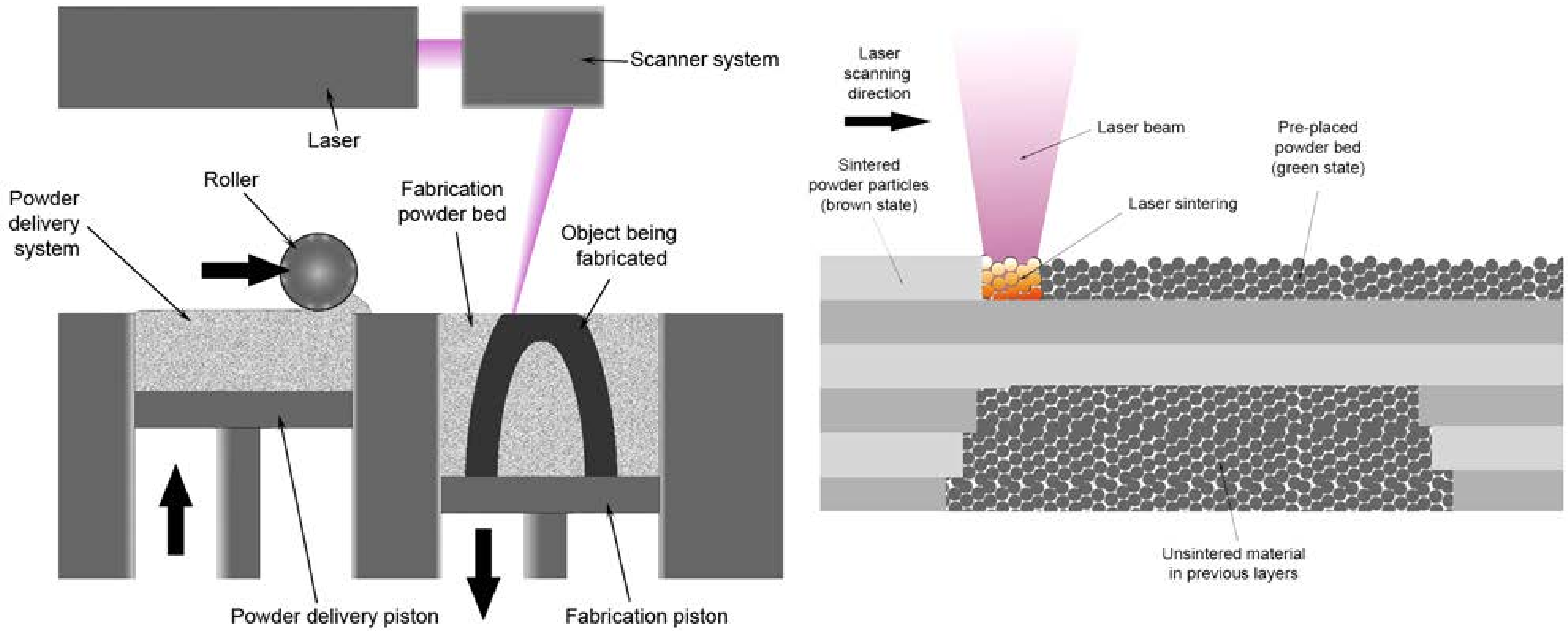
Aufbau einer Lasersinteranlage



Quelle: LBBZ und DTM

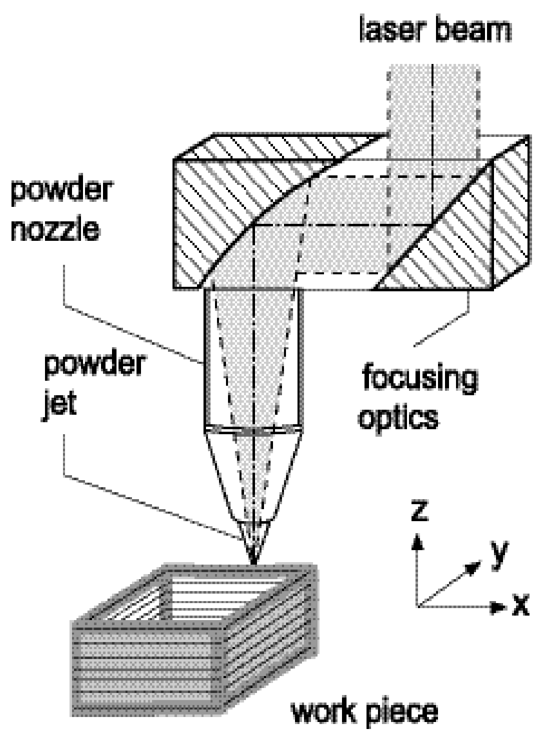
LEHRSTUHL FÜR LASERTECHNIK

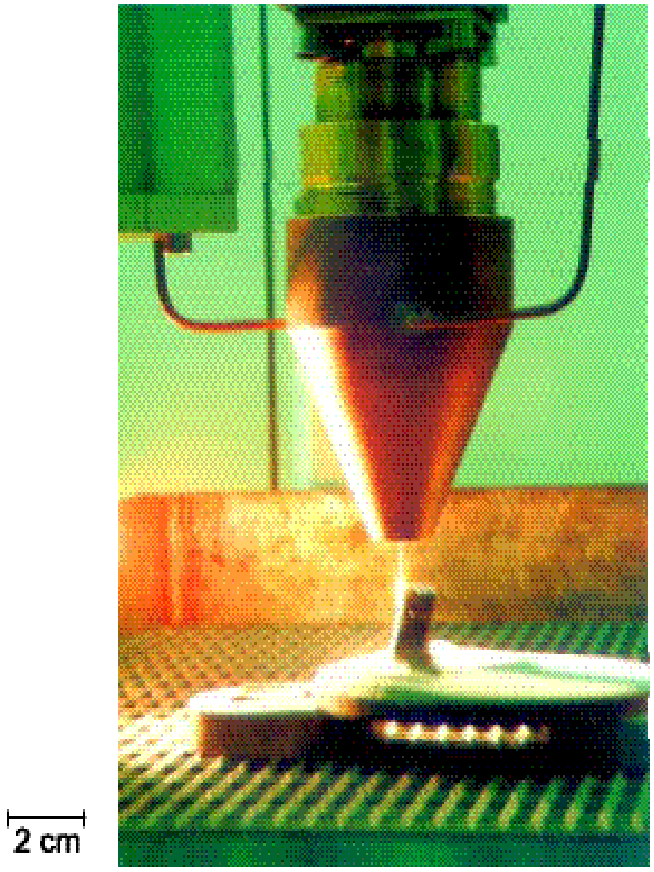
Scheme of Selective Laser Sintering Machine



Laser assisted generating techniques

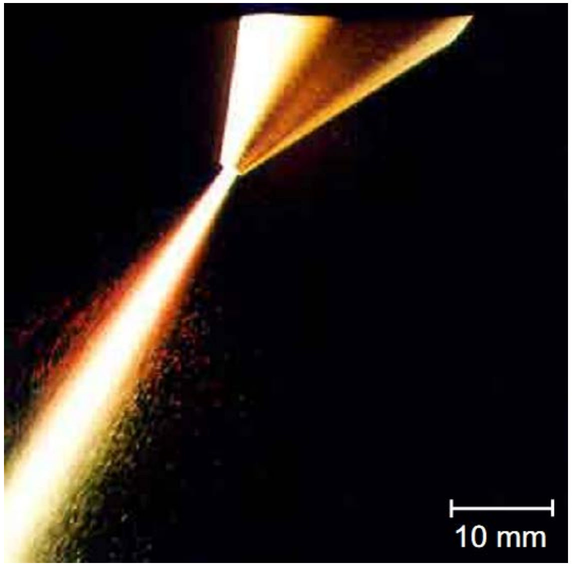
Direct production





LEHRSTUHL FÜR LASERTECHNIK

Powder Gas Nozzle



Off-axis nozzle

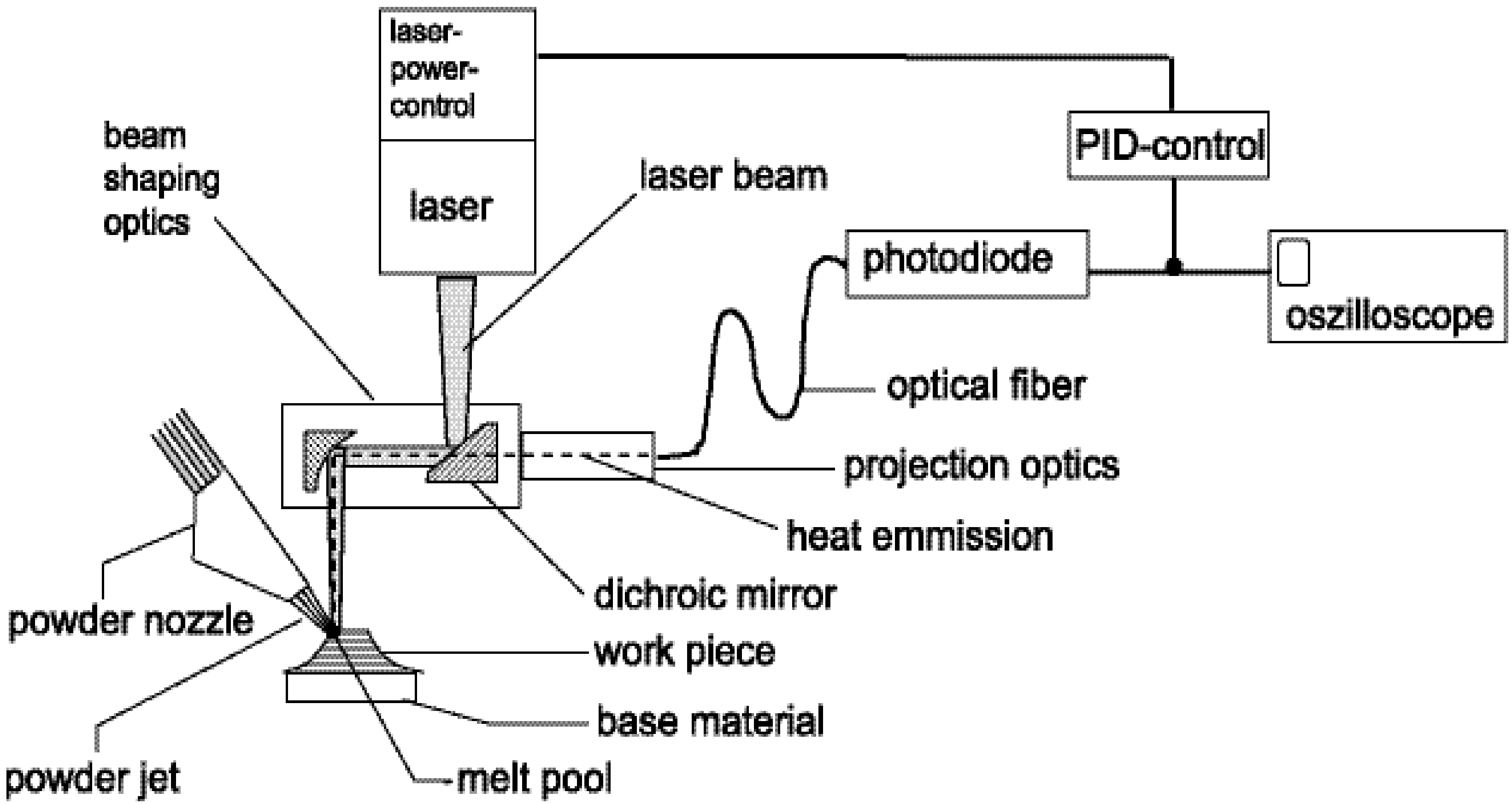
Multi beam nozzle

Coaxial nozzle

Laser assisted generating techniques

Principle of Temperatur-Control

LEHRSTUHL FÜR LASERTECHNIK



Selective Laser Sintering

Selective Laser Sintering

- **Metals - Single component**
  - Steel
  - Aluminum
  - Titanium
  - ...
- **Metals - Multi component (low + high melting point)**
  - Nickel (core) + Bronze (shell)
  - Steel (core) + Copper (shell)
  - ...
- **Metal+Non-metal**
  - Metal core + polymer shell
- **Non-metals**
  - Nylon
  - Polycarbonate
  - Polystirol
  - ...

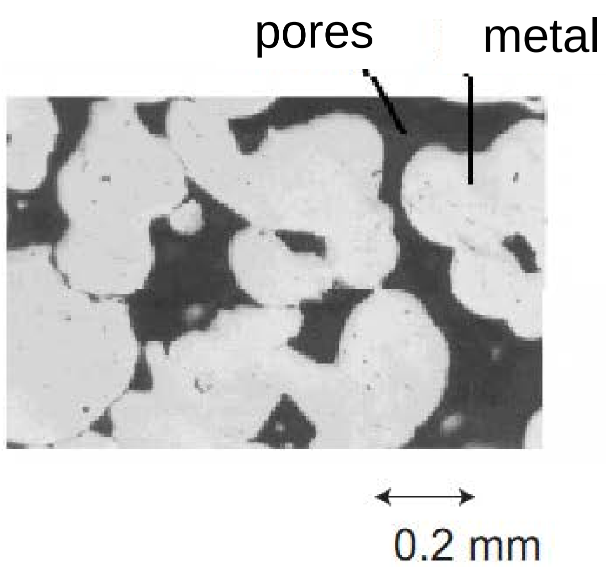
usually less post-processing required

no polymer binder

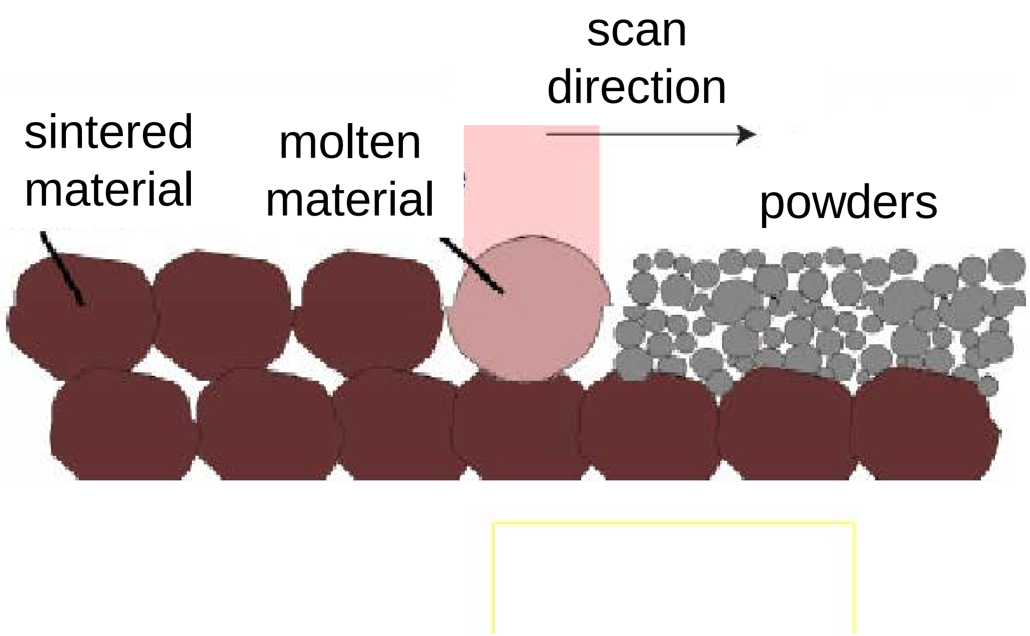
post sintering + de-binding required

Pores Formation

Cross-section

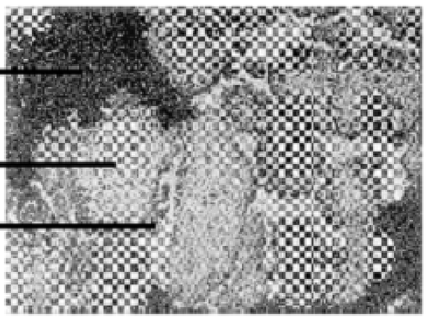


Scheme

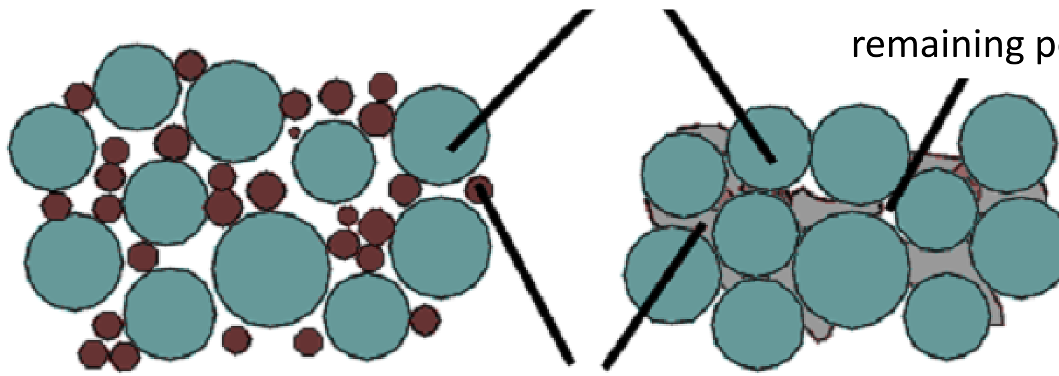


Multi Component Powder Laser Sintering

Iron-Copper powder mixture
cross-section after processing

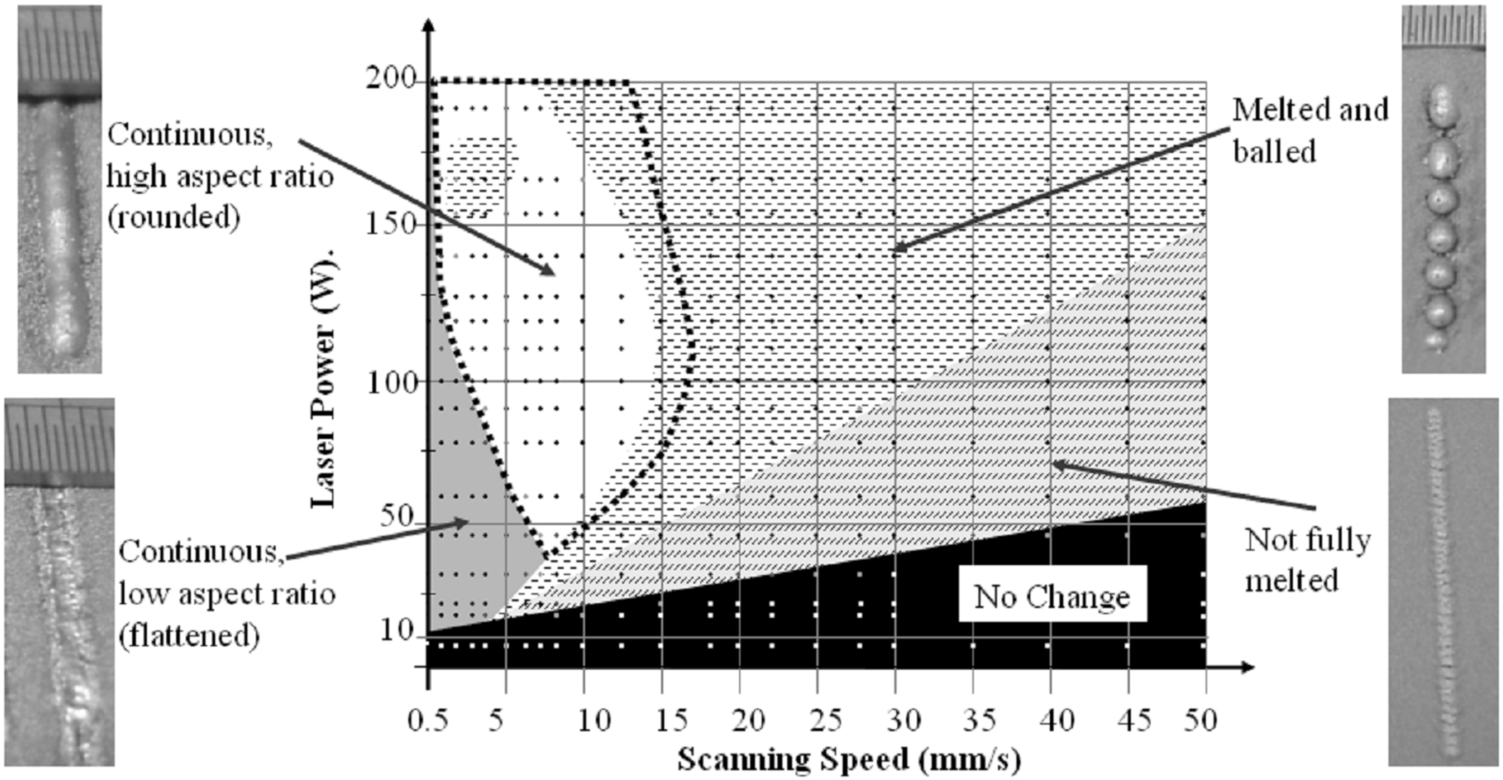


Quelle: van der Schueren, LANE '94



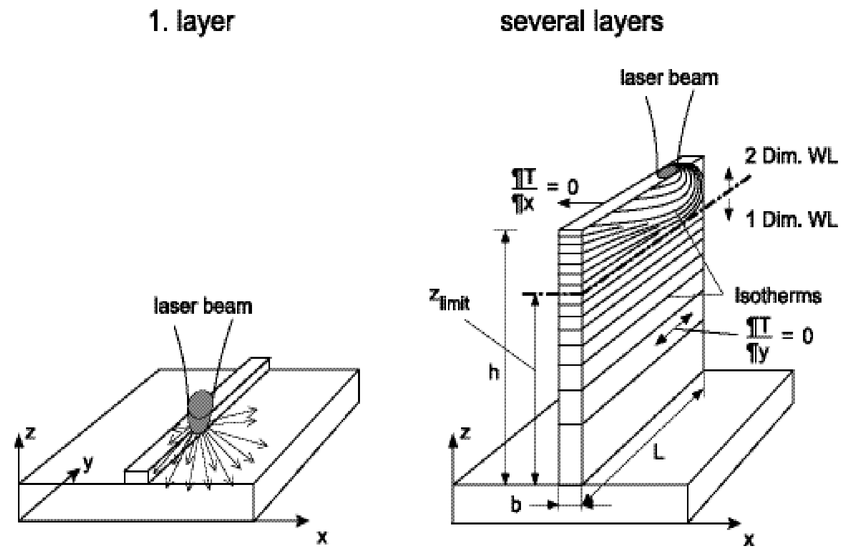
powder before sintering

powder after sintering


Continuous,
high aspect ratio
(rounded)
Continuous,
low aspect ratio
(flattened)
Melted and
balled
Not fully
melted
No Change
Laser Power (W).
200
150
100
50
10
0.5
5
10
15
20
25
30
35
40
45
50
Scanning Speed (mm/s)

Laser assisted generating techniques

heat flow

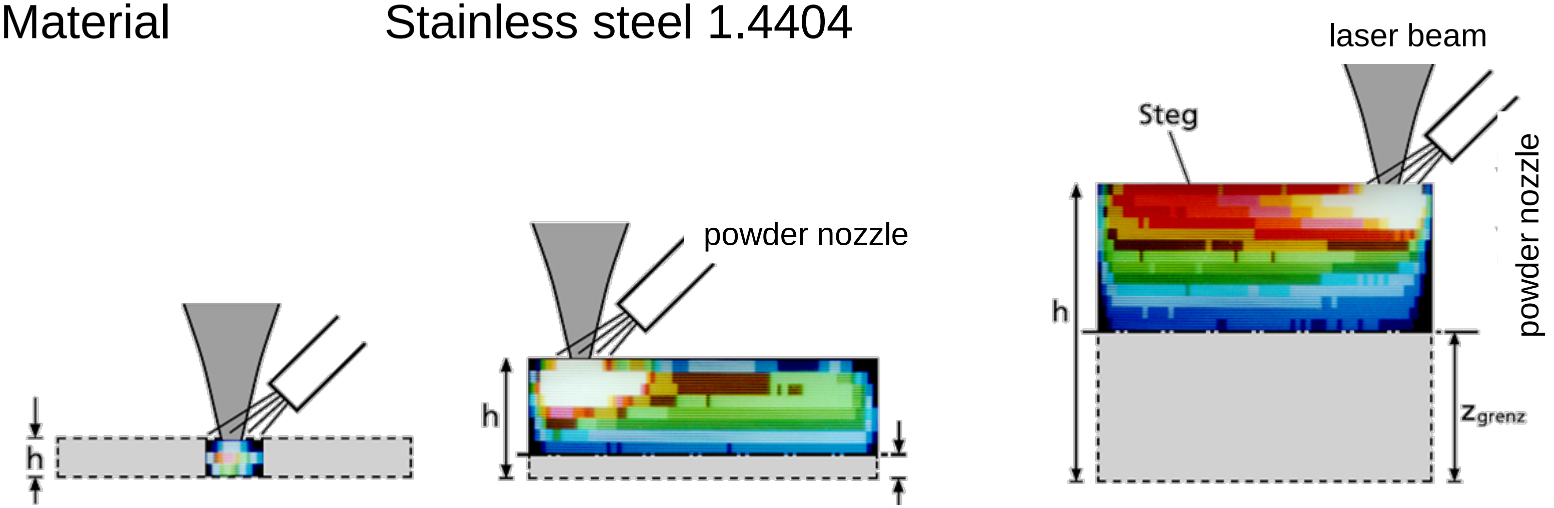


z » 0 :	z » 0 Þ ¶T/¶x = 0	
three dimensional heat conduction	z = h	z < z_{limit} Þ ¶T/¶y = 0
	two dimensional heat conduction	one dimensional heat conduction

LLT RWTH
LEHRSTUHL FÜR LASERTECHNIK

Isotherms in the deposited thin wall

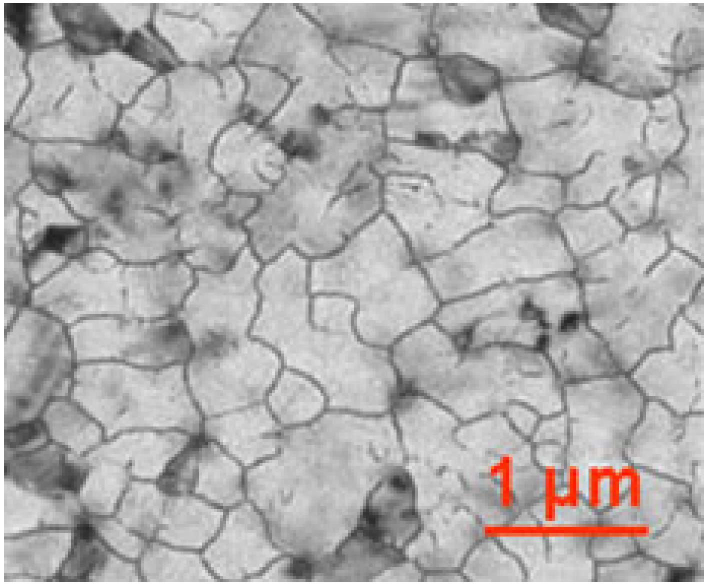
Laser power	P=1kW
Powder feed-rate	m=3.1 g/min
Scan speed	v=400 mm/min
Layer height	Dz=250 µm
Wall width	b=1.7 mm
Wall length	L=40 mm
Material	Stainless steel 1.4404

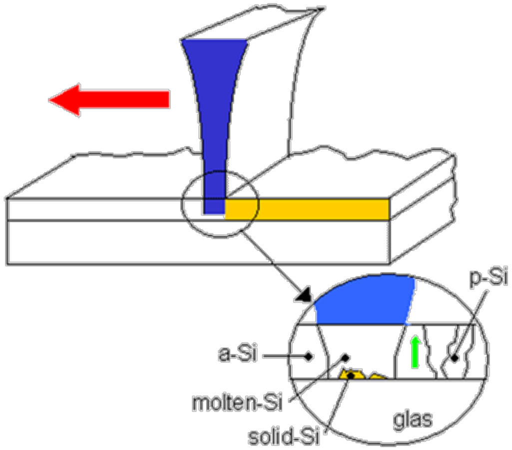


5 Layers, h=1.25 mm   51 Layers, h=1.3 mm   150 Layers, h=37.5 mm

TFT Annealing – Si Recrystalization

Excimer laser treatment with XeCl at 308 nm





Schematic view of Excimer laser annealing transforming amorphous silicon of ca. 50 nm thickness into polysilicon.