High Resolution Imaging for Inspection of Laser Beam Melting Systems

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Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control

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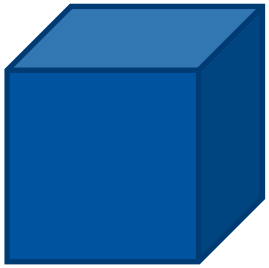
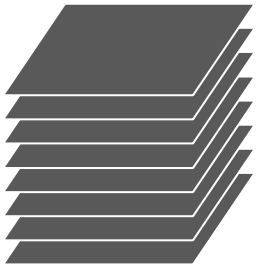
What is Laser Beam Melting? An Introduction

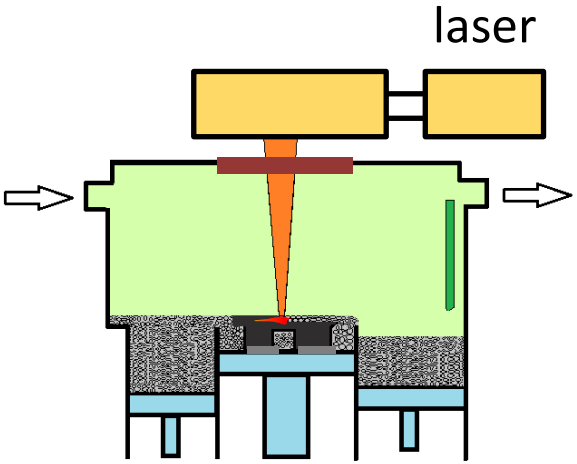
- "3D printing"
- Layer-based, iterative (additive manufacturing)



Design (3D)



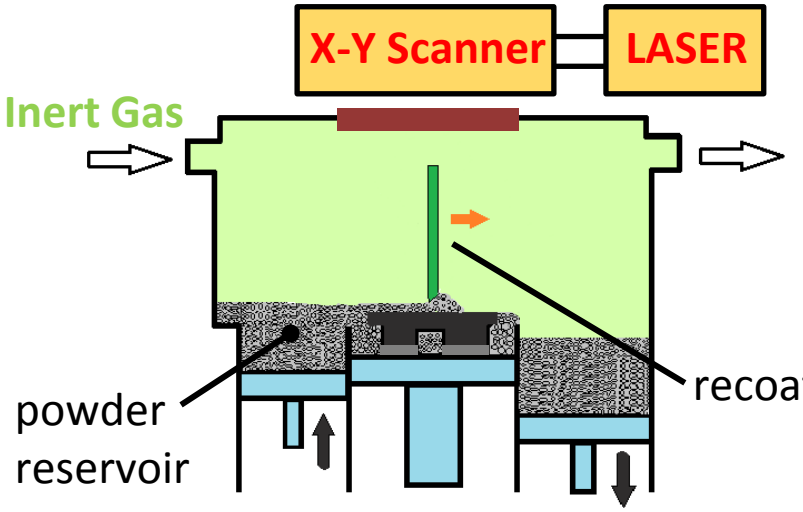
Slice (2D)



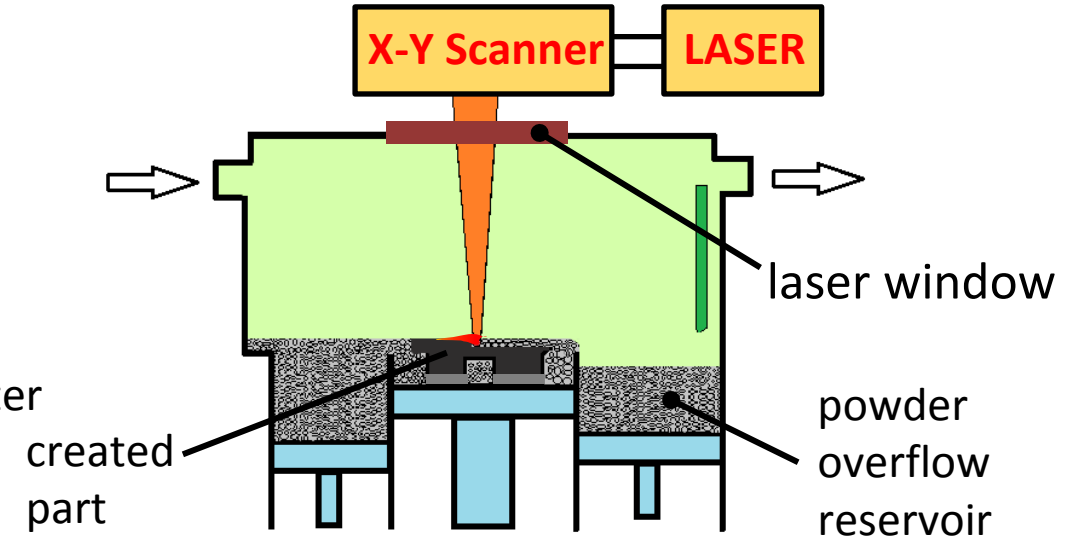
Build

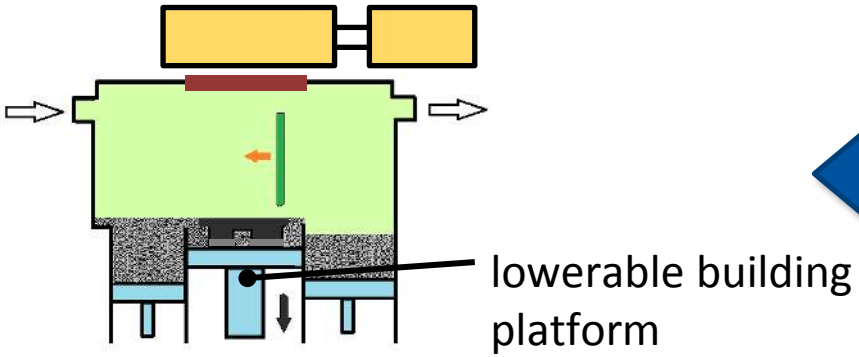
What is Laser Beam Melting? Build Process

1. Powder Deposition



2. Layer Creation

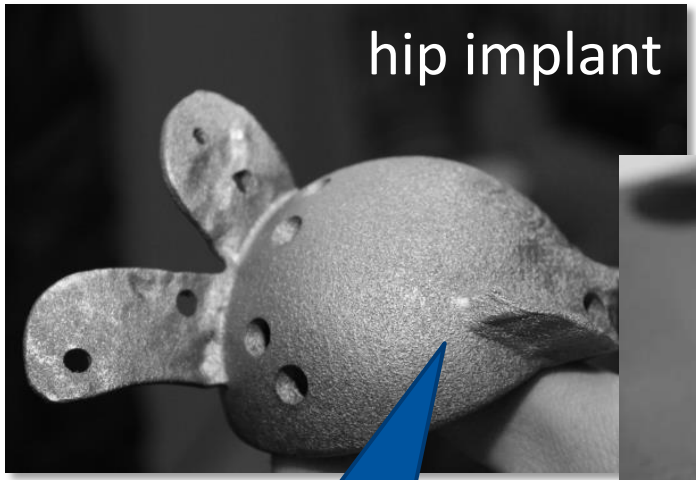


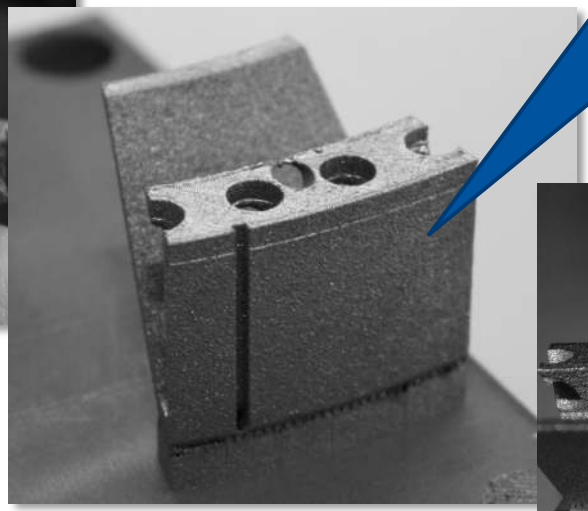


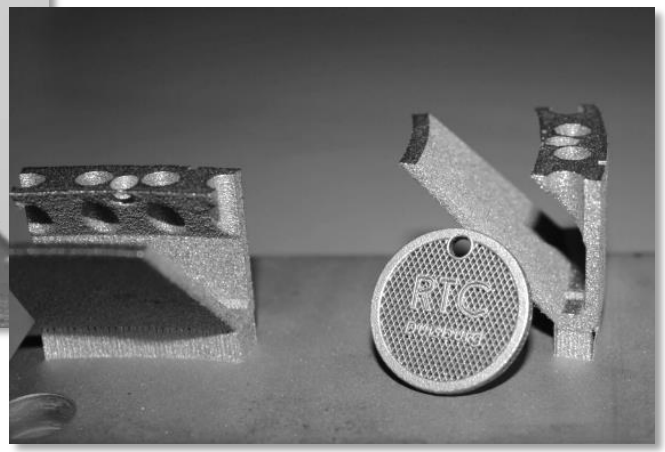
3. Lowering

What is Laser Beam Melting? Parts

High density metal parts with excellent mechanical properties







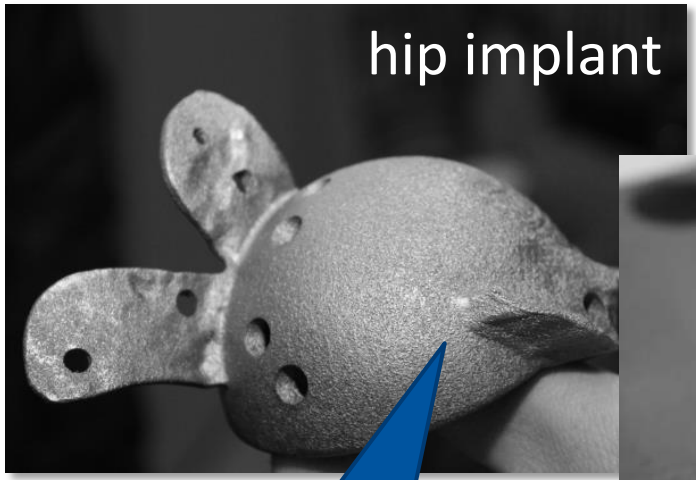
Quality?

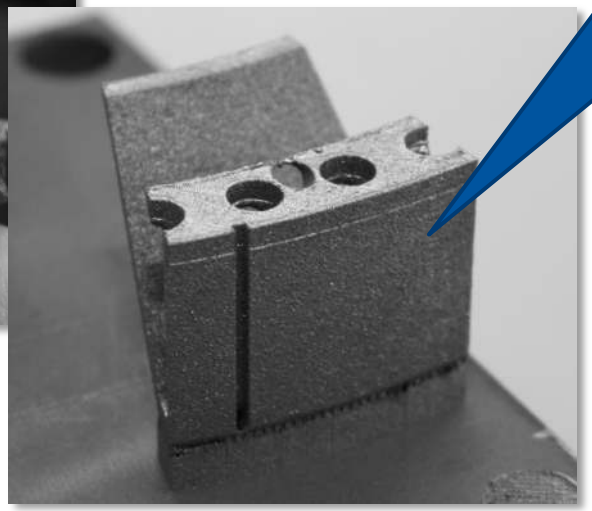
Flawless?

Quality Control for Laser Beam Melting Processes

Non-destructive inspection difficult

Can't X-ray thick metal parts!



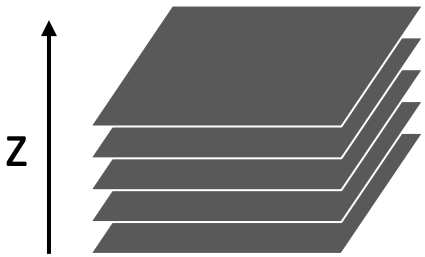


Quality?

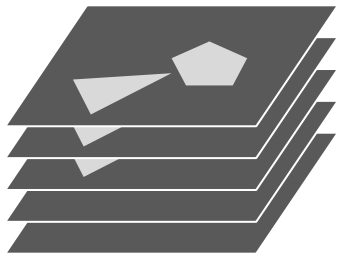
Flawless?

Inspect each layer after creation

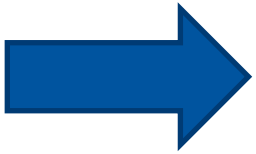
Quality Control for LBM Processes: the Idea



powder images



melt result images



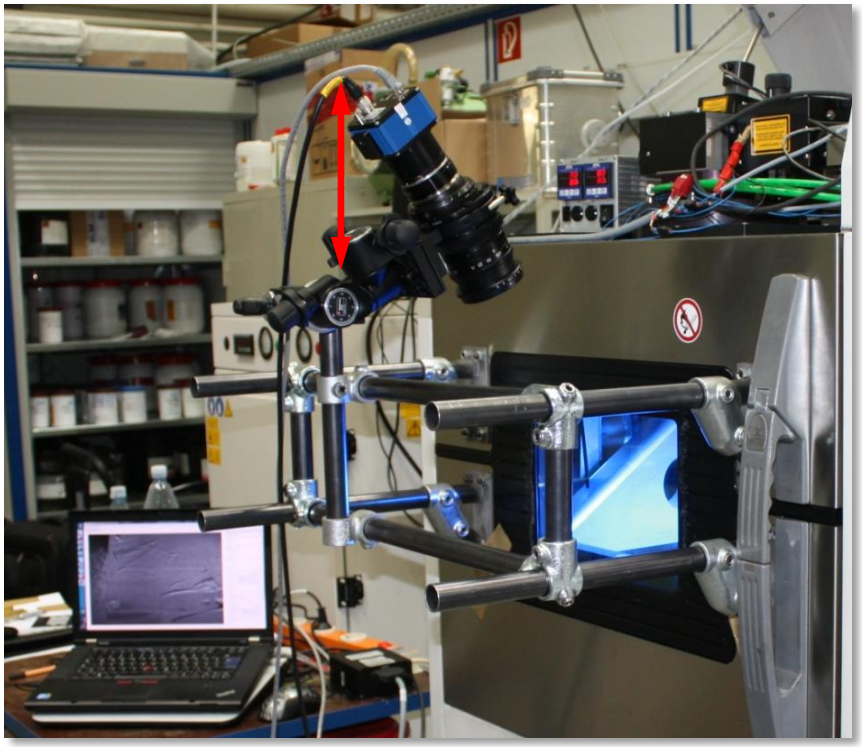
all layers correct?

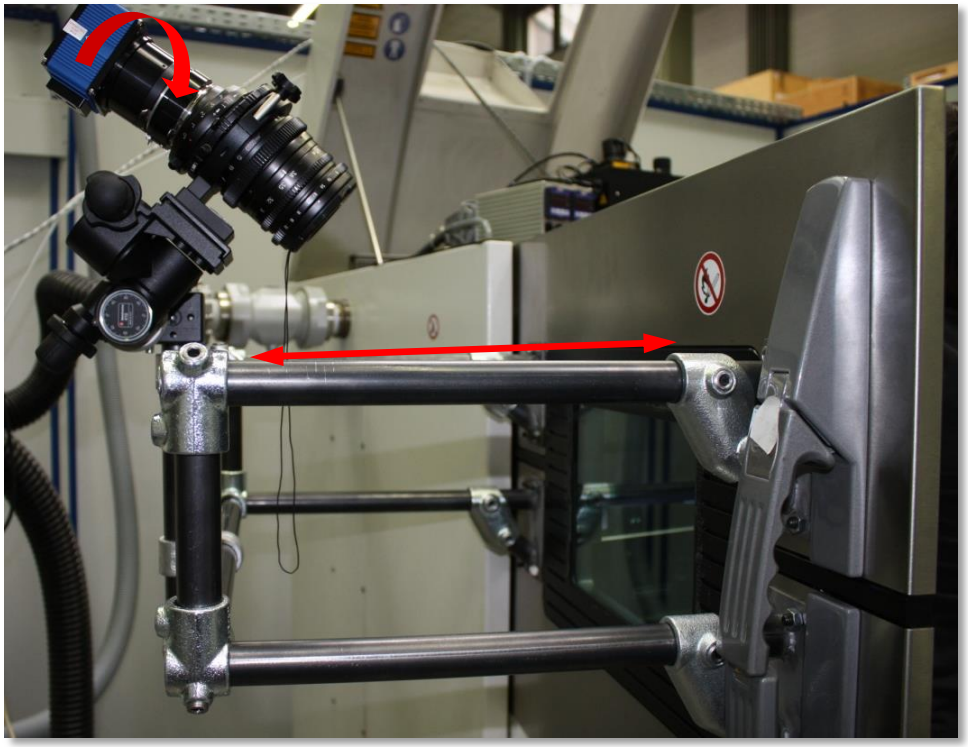
Inspect each layer after creation

Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
  - Setup
  - Resolution Measurement
- Sample Build Images
- Applications in Quality Control

Image Acquisition Setup





LBM machine: EOS EOSINT M 270

Camera

- 29 megapixels, large sensor (36 mm x 24 mm)
  - Usable pixels
- Tilt and shift lens to reduce perspective distortion

Hartblei Macro 4/120
TS Superrotator

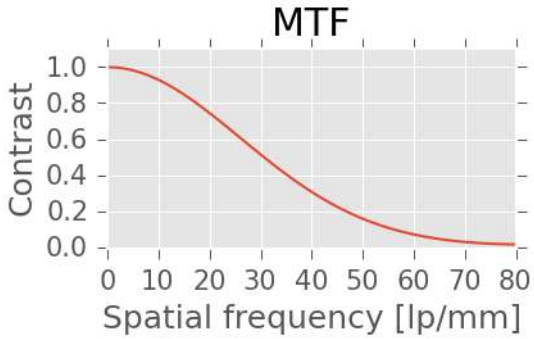
SVS-VISTEK
SVCam-hr29050

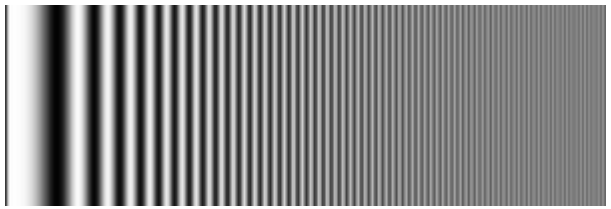
Resolution Measurement

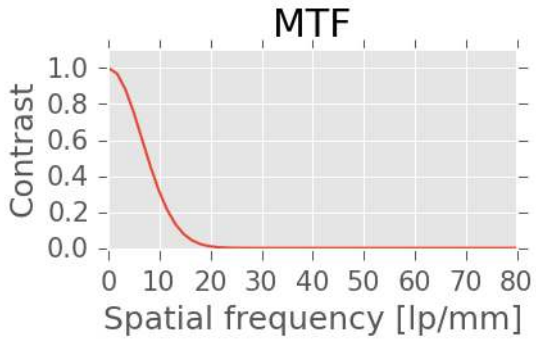
Assess properties of optical system

Resolution sufficient for small details?

- Use modulation transfer function (MTF): resulting contrast for spatial frequency







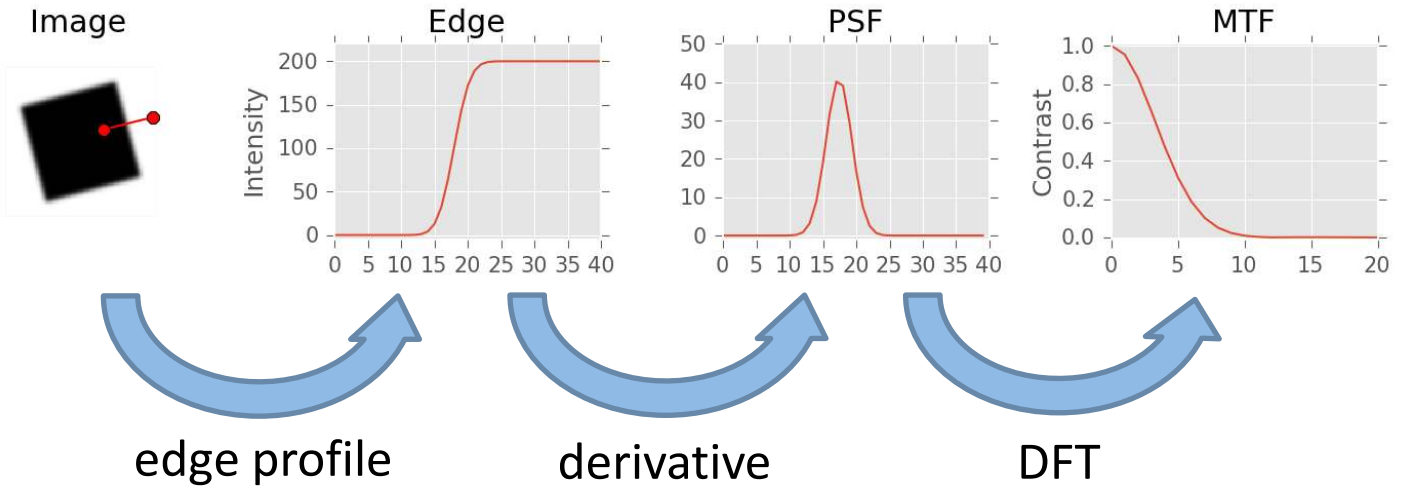
Modulation Transfer Function

Magnitude of complex optical transfer function (OTF)

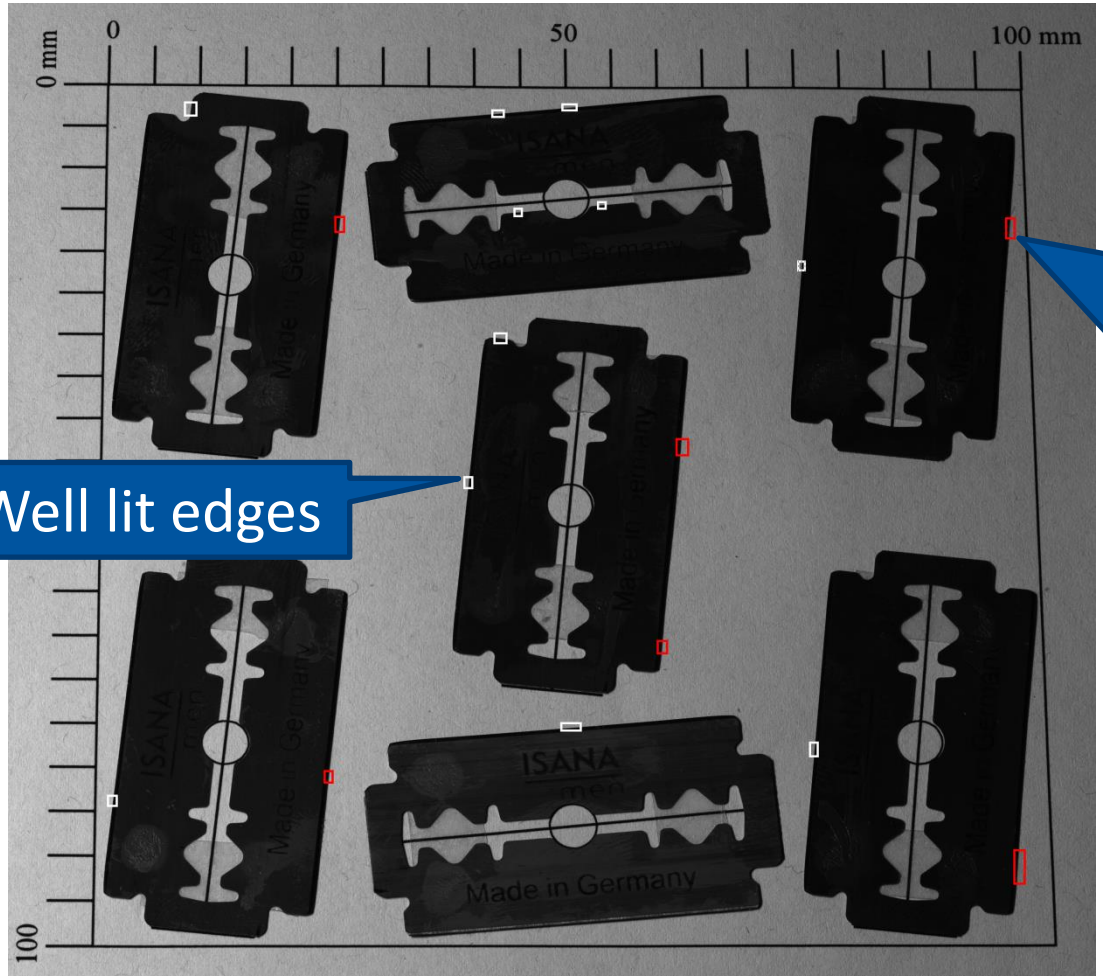
$$\mathrm{psf}(\mathbf{x}) \xrightarrow{\mathrm{DFT}} \mathrm{OTF}(\boldsymbol{f}) = \mathrm{MTF}(\boldsymbol{f}) \cdot \theta(\boldsymbol{f})$$

(point spread function)

Compute by slanted-edge method [Burns2000, ISO12233]

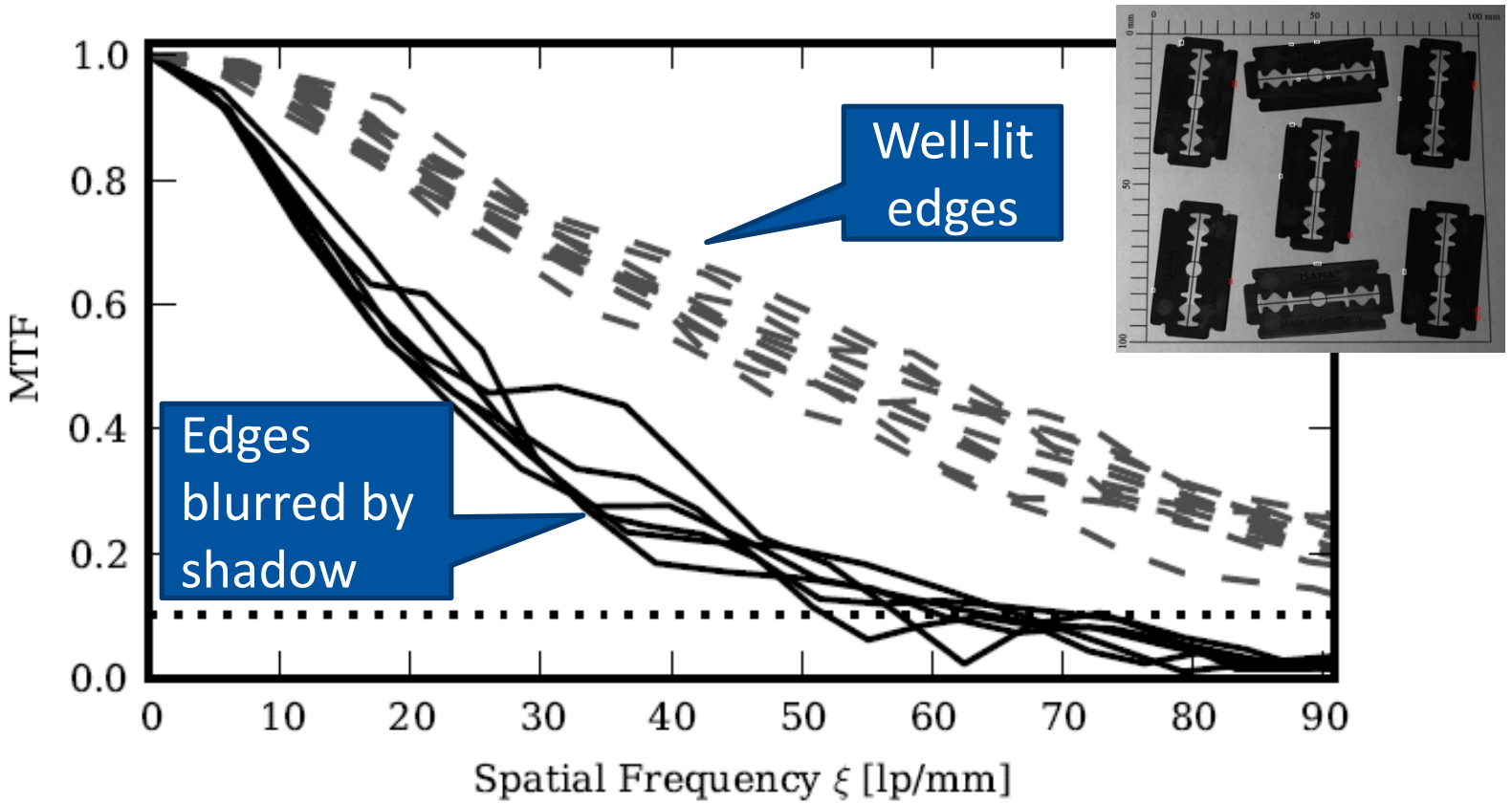


Resolution Measurement: Target



(neither dark nor bright regions are saturated in full-scale image.)

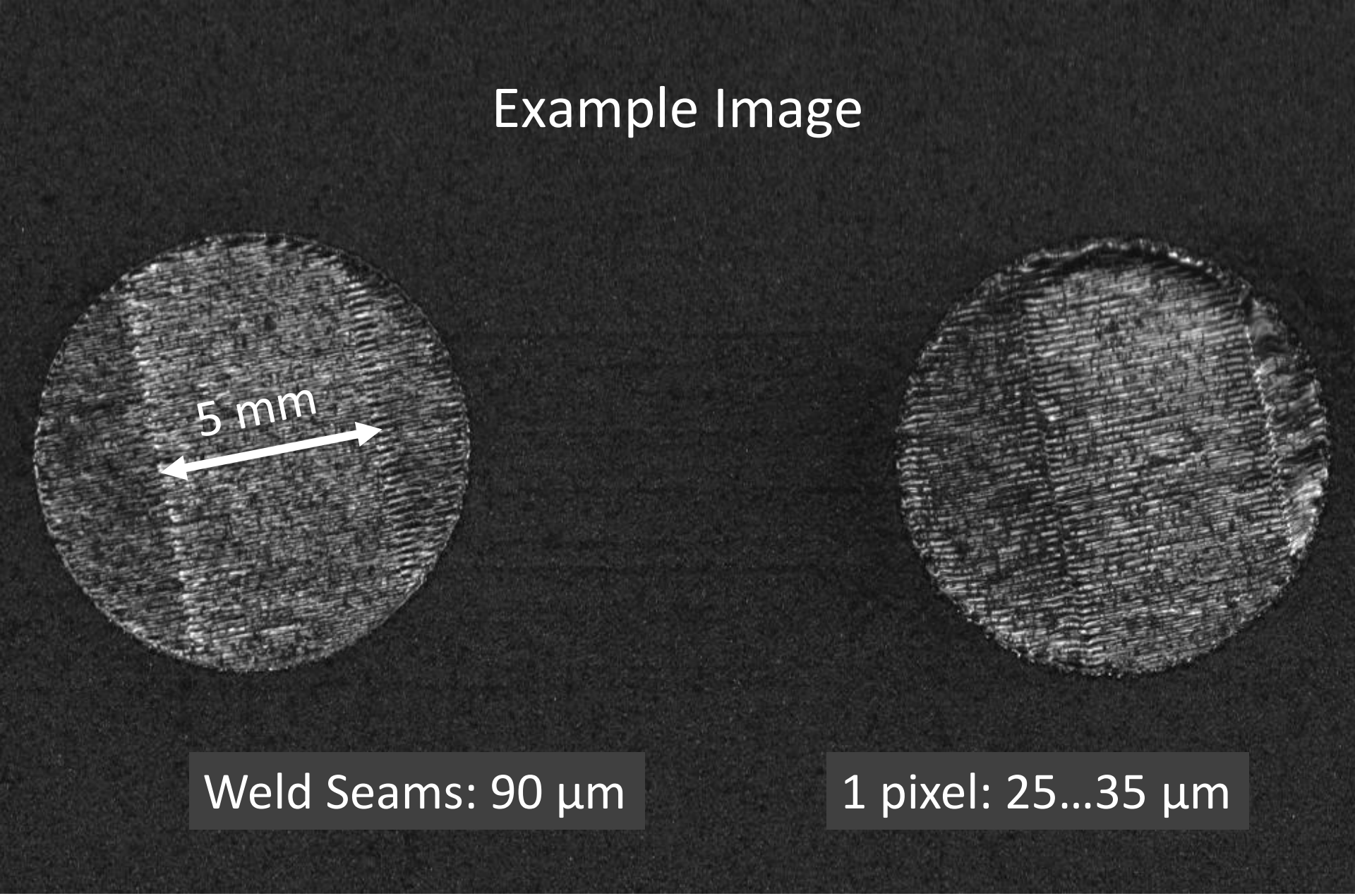
Resolution Measurement: Result



limiting resolution at least $\xi_0 = 50$ lp/mm [90 lp/mm] (on sensor)

for FOV 180 mm x 120 mm able to resolve details of 50 µm [28 µm]

Example Image



Weld Seams: 90 µm

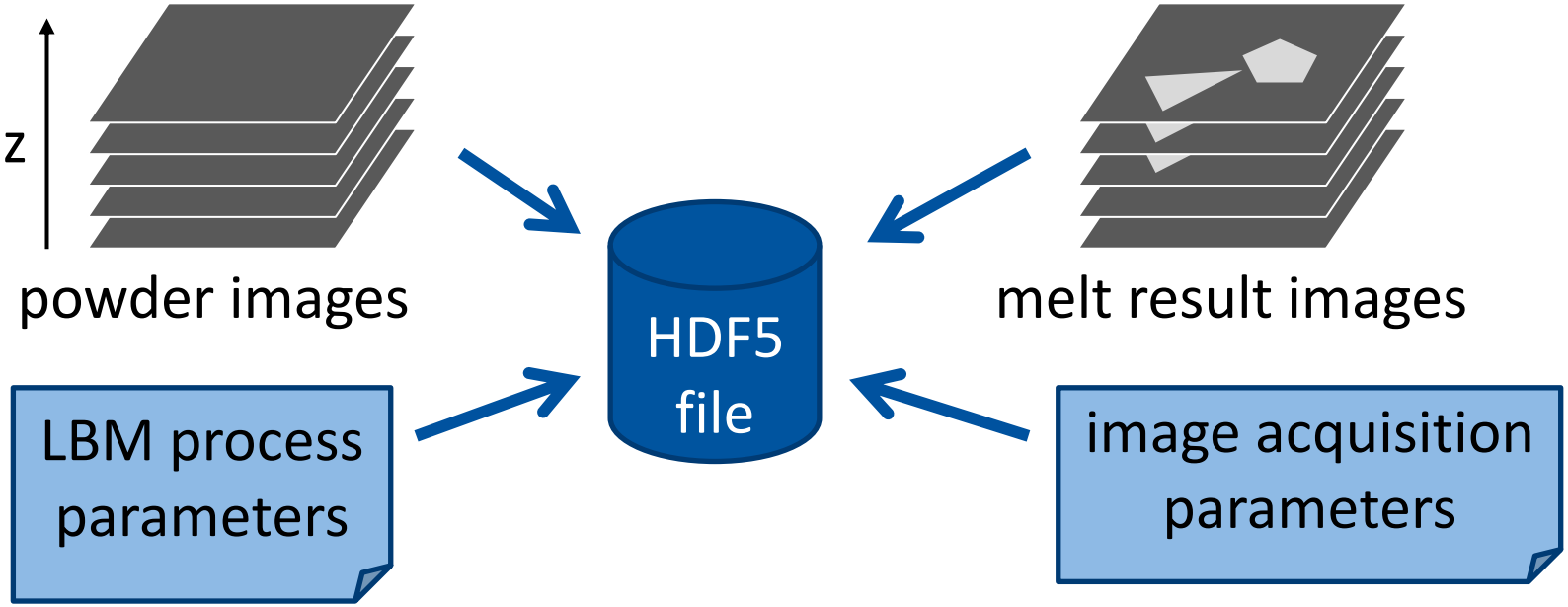
1 pixel: 25…35 µm

Outline

- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
  - Documentation Format
  - Images
- Applications in Quality Control

Documentation Format

Many images and associated metadata

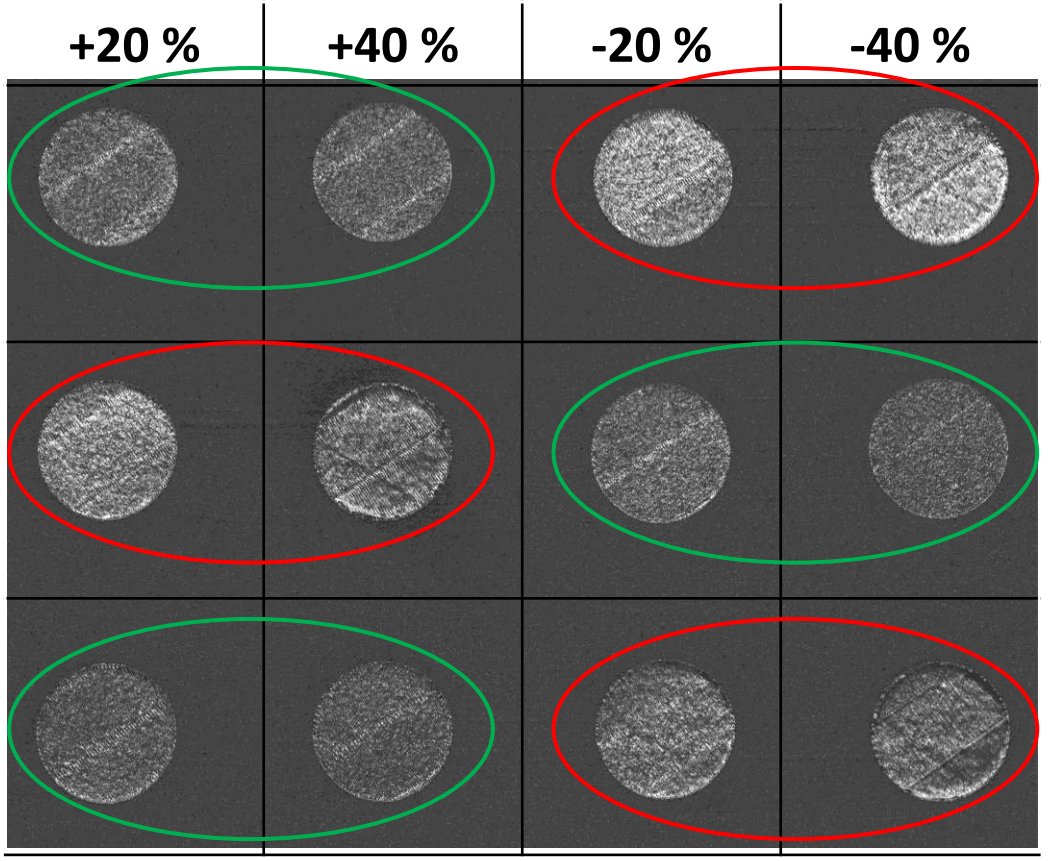


Hierarchical Data Format (HDF5)

- Documentation of entire process in one file

[www.hdfgroup.org]

Sample Build

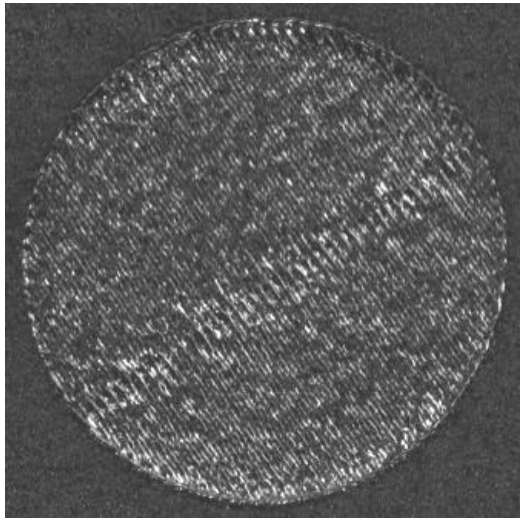


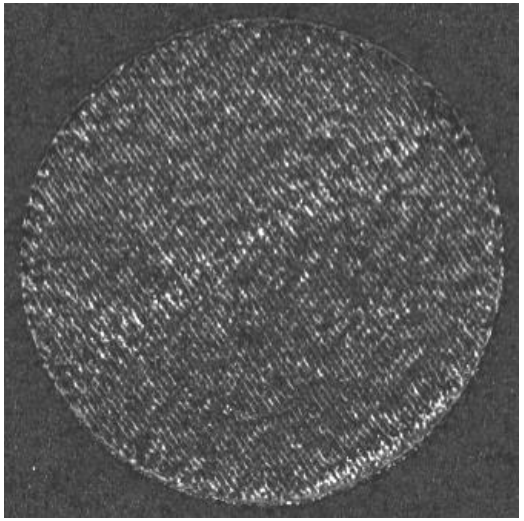
: Increased energy input

: Decreased energy input

Sample Build: Hatch Distance

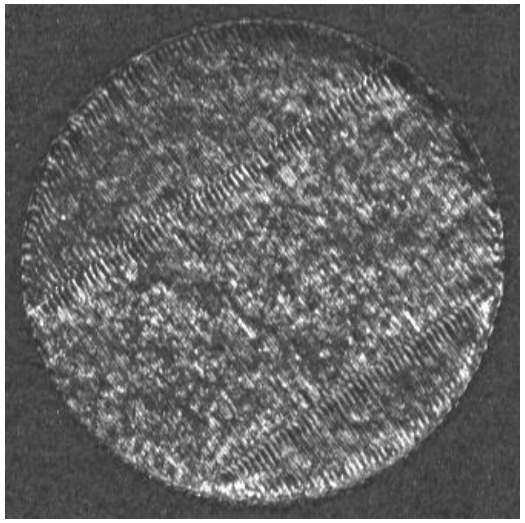
+20 %

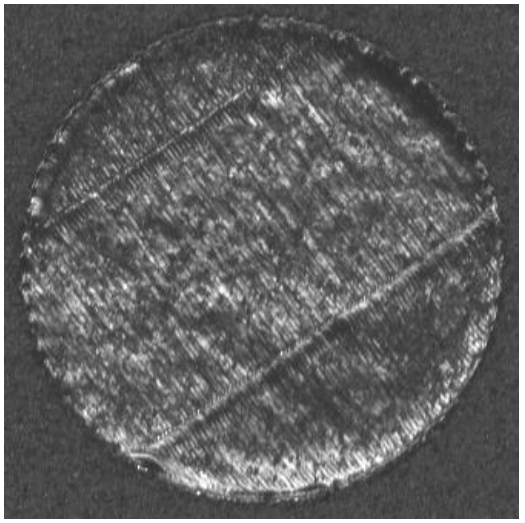




+40 %

-20 %

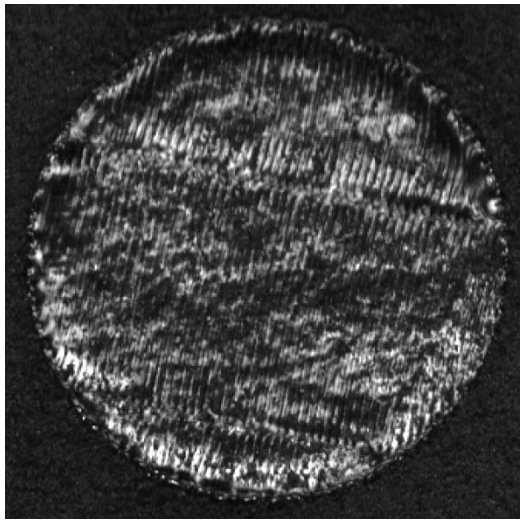


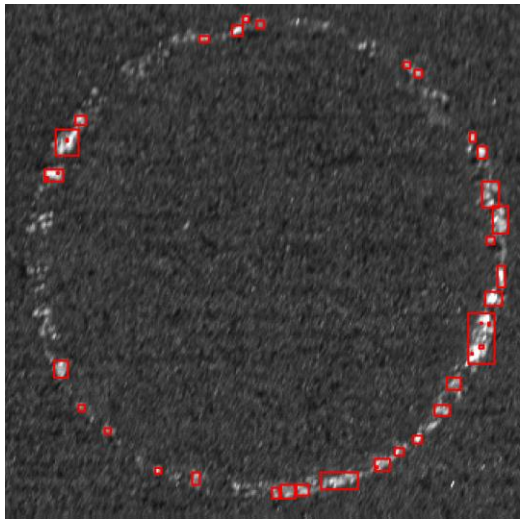


-40 %

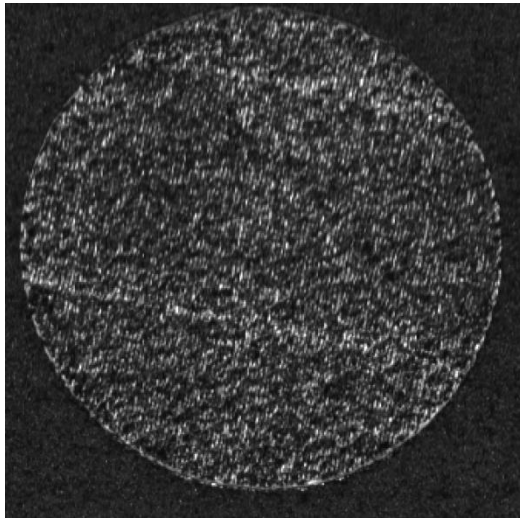
Sample Build: Elevation of Contour Regions

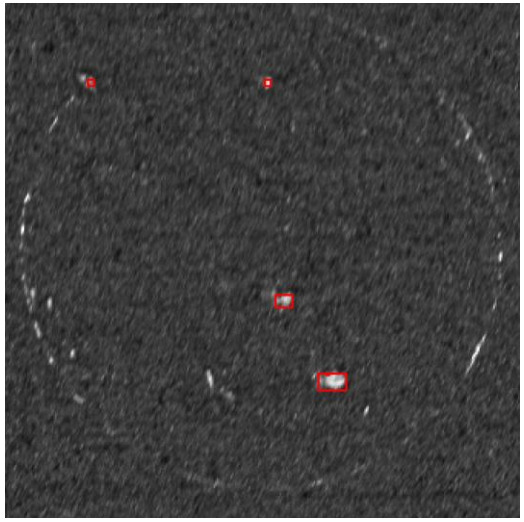
Power +40 %





Power -40 %





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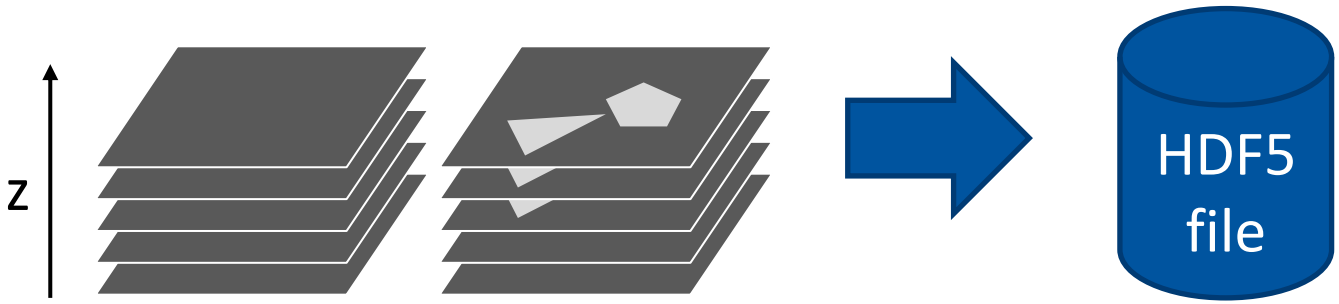
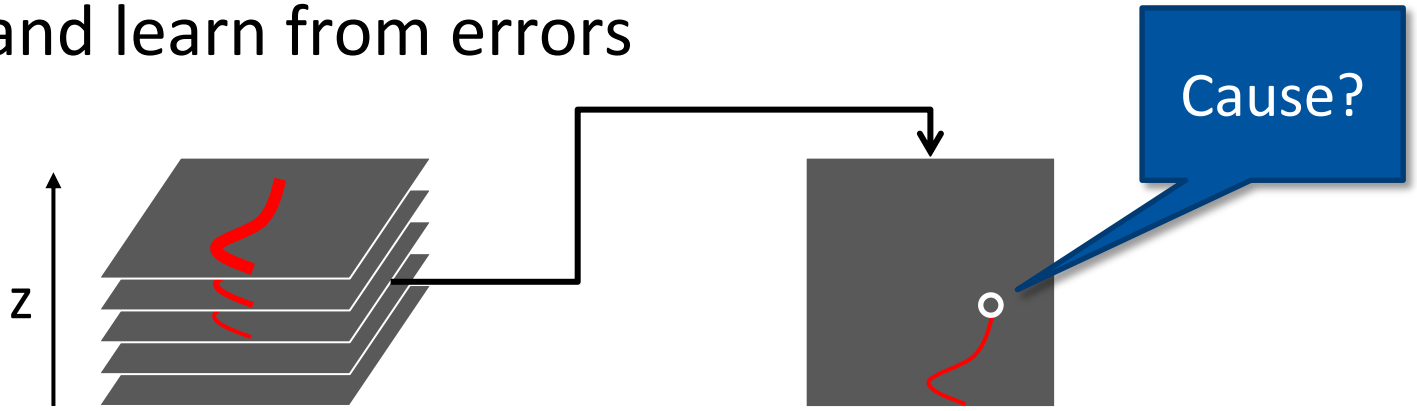
Applications in Quality Control

Process documentation

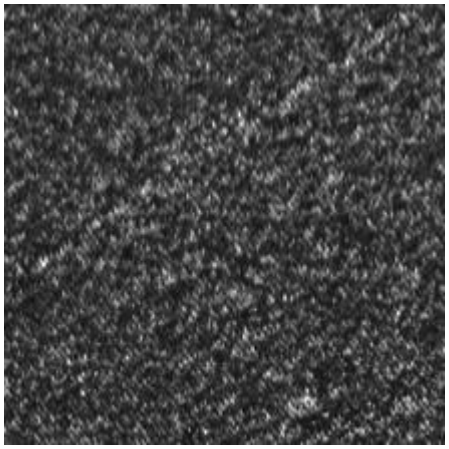


Detect and learn from errors

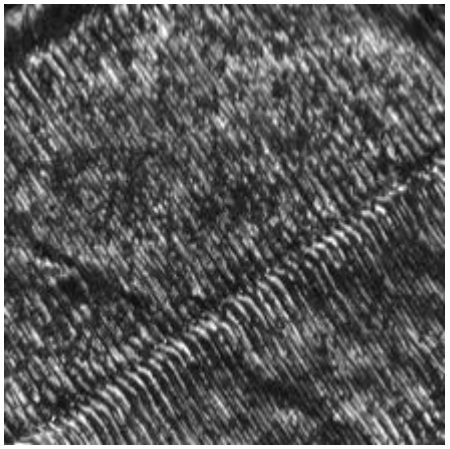


Applications in Quality Control

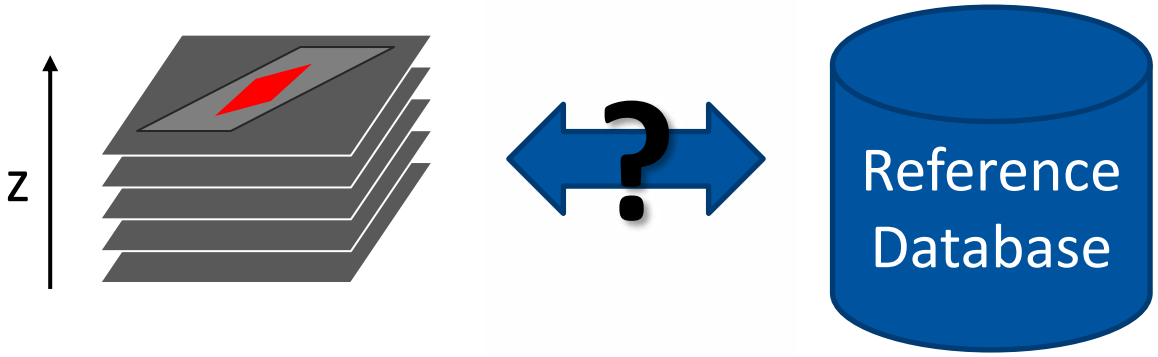
Detect non-optimal parameter values



Laser power -40 %

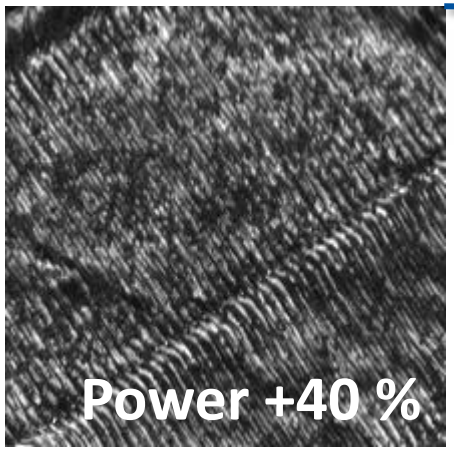


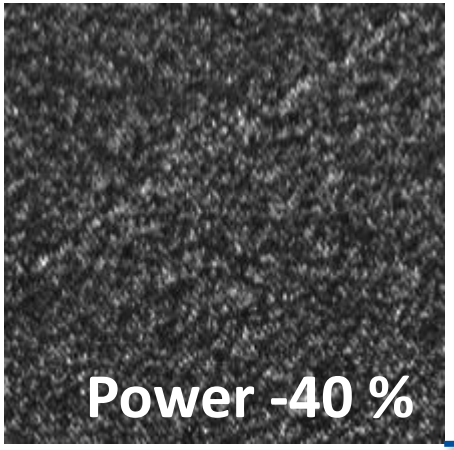
Laser power +40 %

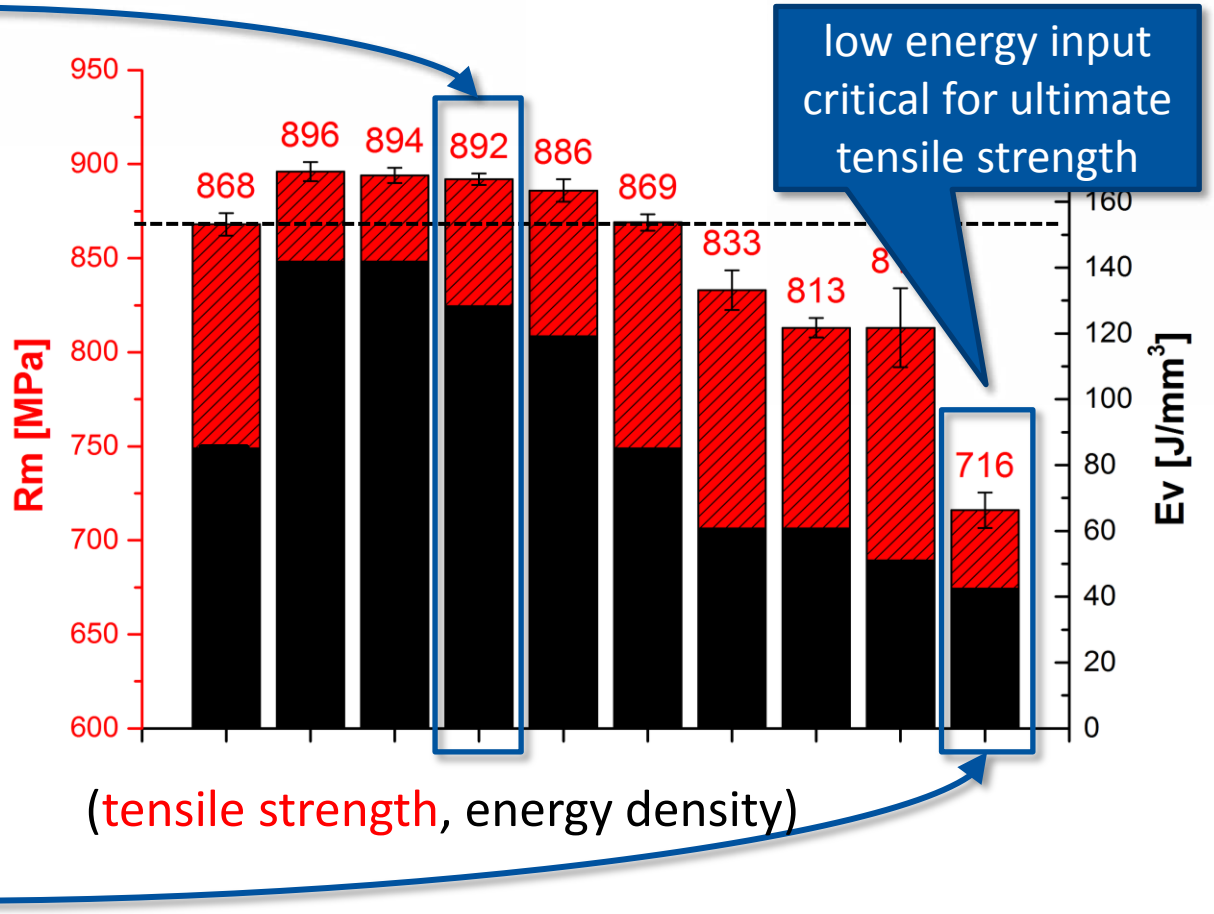


Applications in Quality Control

Link surface images to mechanical part properties







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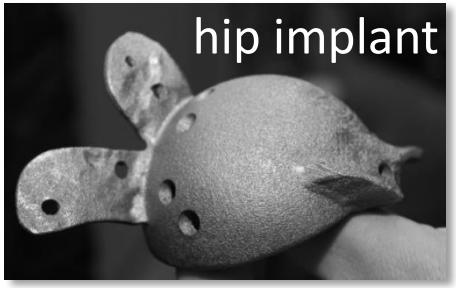
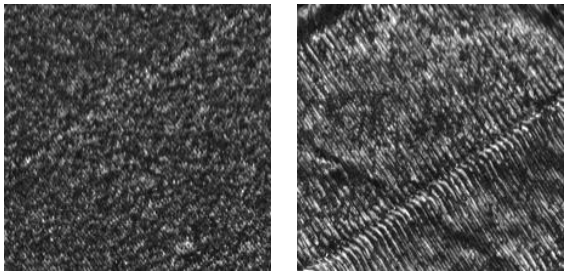
- Summary

Summary

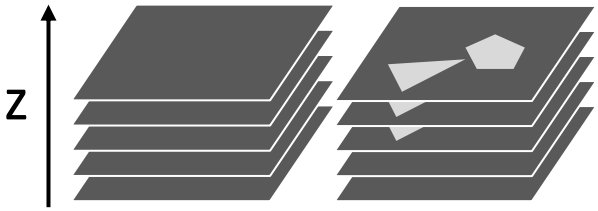
- What is Laser Beam Melting? An Introduction
  - "print" complex metal parts
  - no complete process documentation, yet



- Our Imaging System
  - MTF for resolution measurement
  - resolution at least 50 µm [28 µm]



- Sample Build Images
  - different surface quality visible in images
- Applications in Quality Control
  - documentation
  - flaw detection: energy input, elevated regions



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References

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