

High Resolution Imaging for Inspection of Laser Beam Melting Systems



Joschka zur Jacobsmühlen^{a)}, Stefan Kleszczynski^{b)},
Dorian Schneider^{a)}, and Gerd Witt^{b)}

a) Institute of Imaging and Computer Vision
RWTH Aachen University
Aachen, Germany

b) Institute for Product Engineering
University of Duisburg-Essen
Duisburg, Germany

Outline

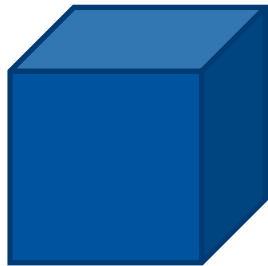
- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control

Outline

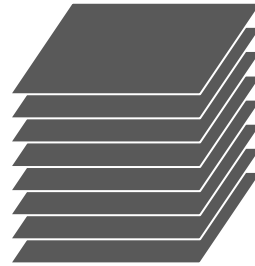
- What is Laser Beam Melting? An Introduction
- Our Imaging System
- Sample Build Images
- Applications in Quality Control

What is Laser Beam Melting? An Introduction

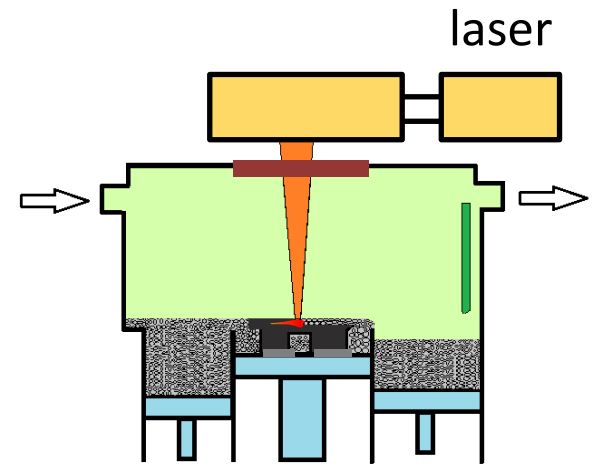
- "3D printing"
- Layer-based, iterative (additive manufacturing)



Design (3D)



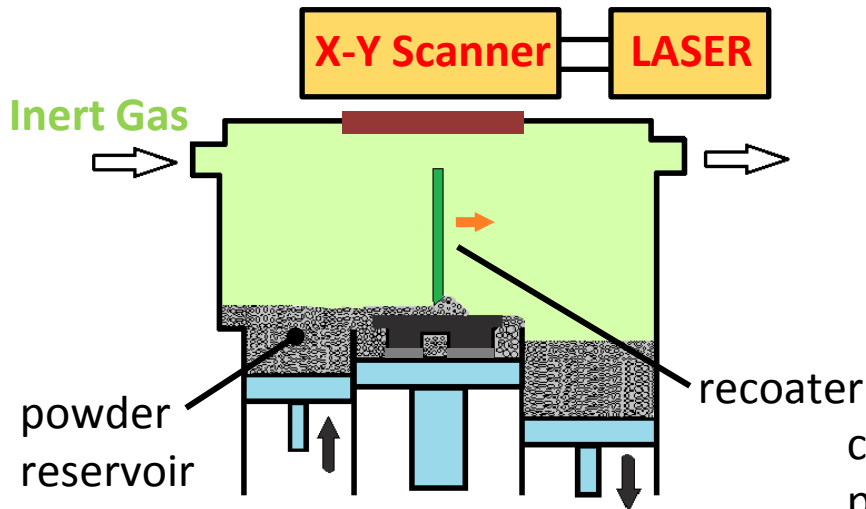
Slice (2D)



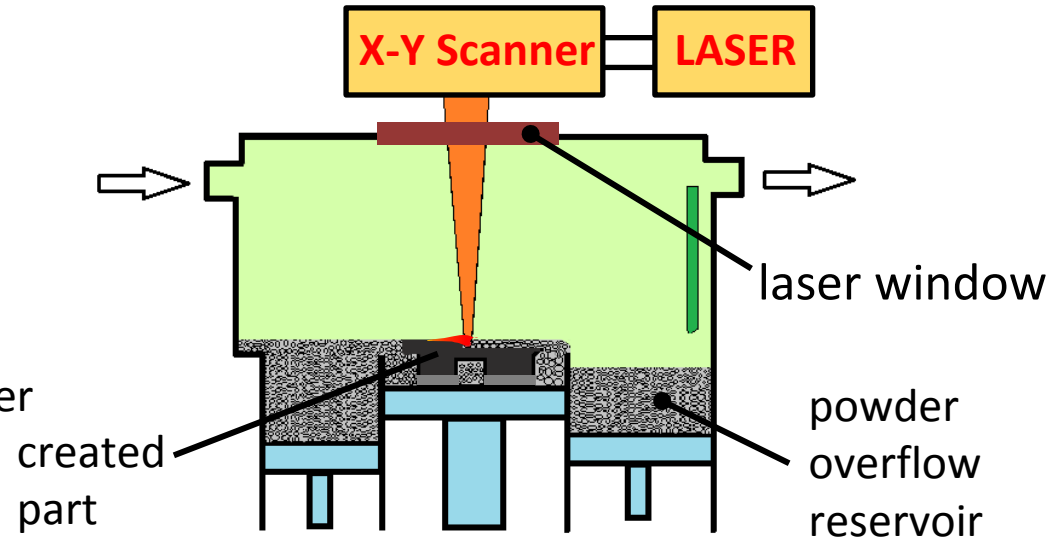
Build

What is Laser Beam Melting? Build Process

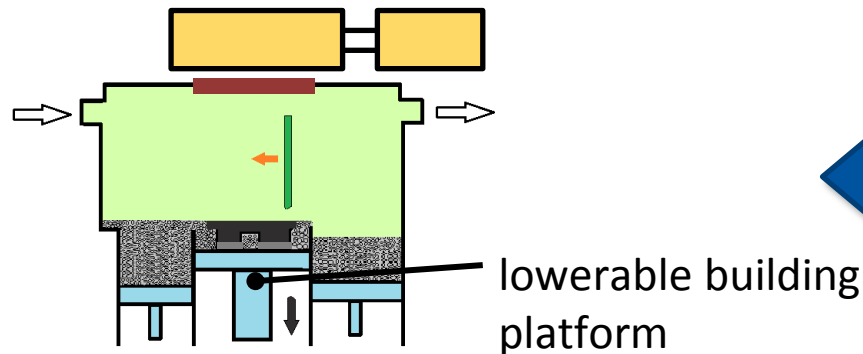
1. Powder Deposition



2. Layer Creation



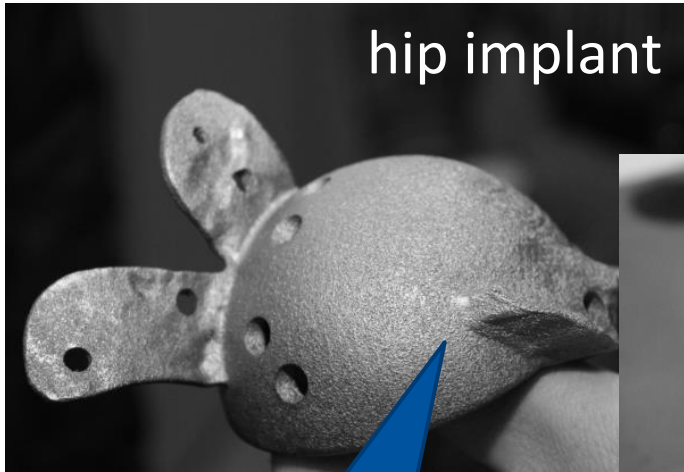
3. Lowering



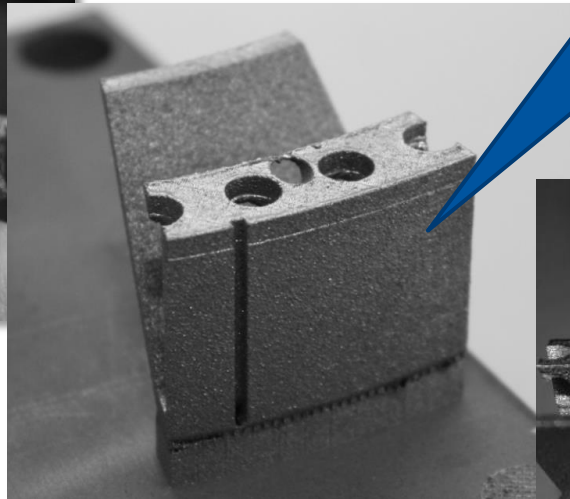
What is Laser Beam Melting? Parts

High density metal parts with excellent mechanical properties

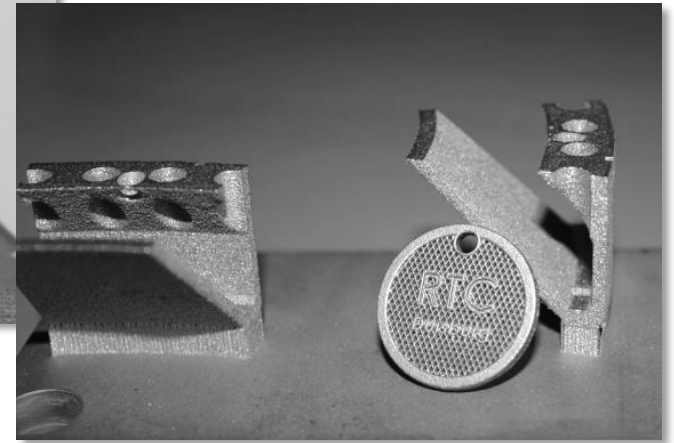
hip implant



Quality?



Flawless?

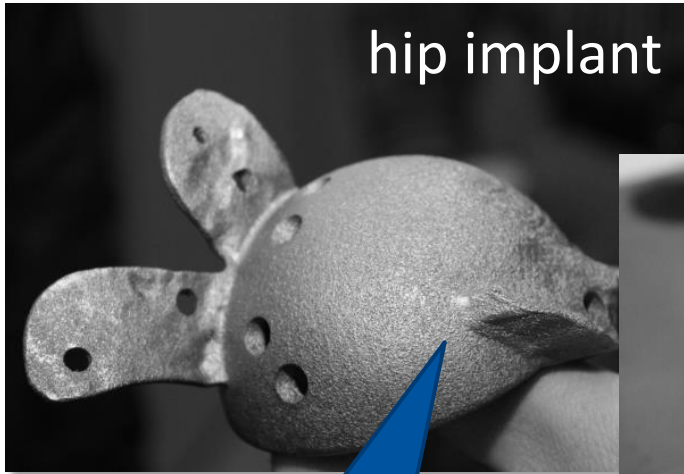


Quality Control for Laser Beam Melting Processes

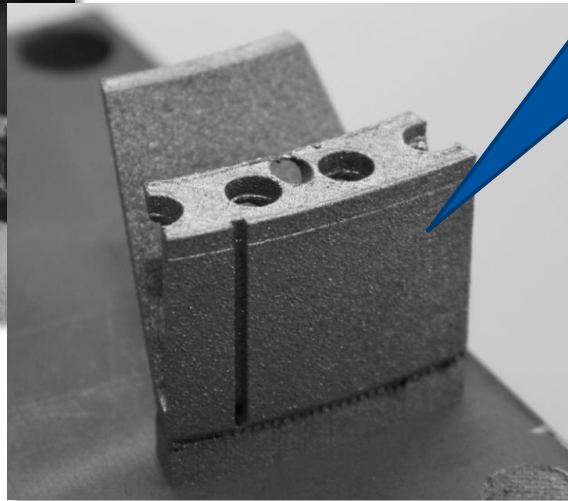
Non-destructive inspection difficult

Can't X-ray thick metal parts!

hip implant



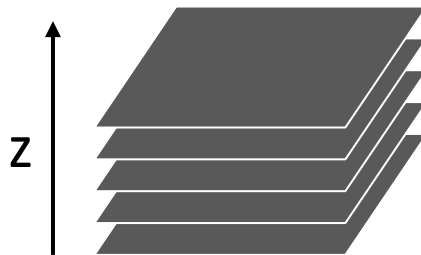
Flawless?



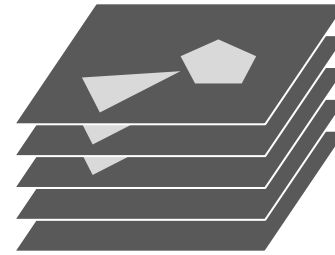
Quality?

Inspect each layer after creation

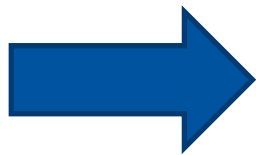
Quality Control for LBM Processes: the Idea



powder images



melt result images



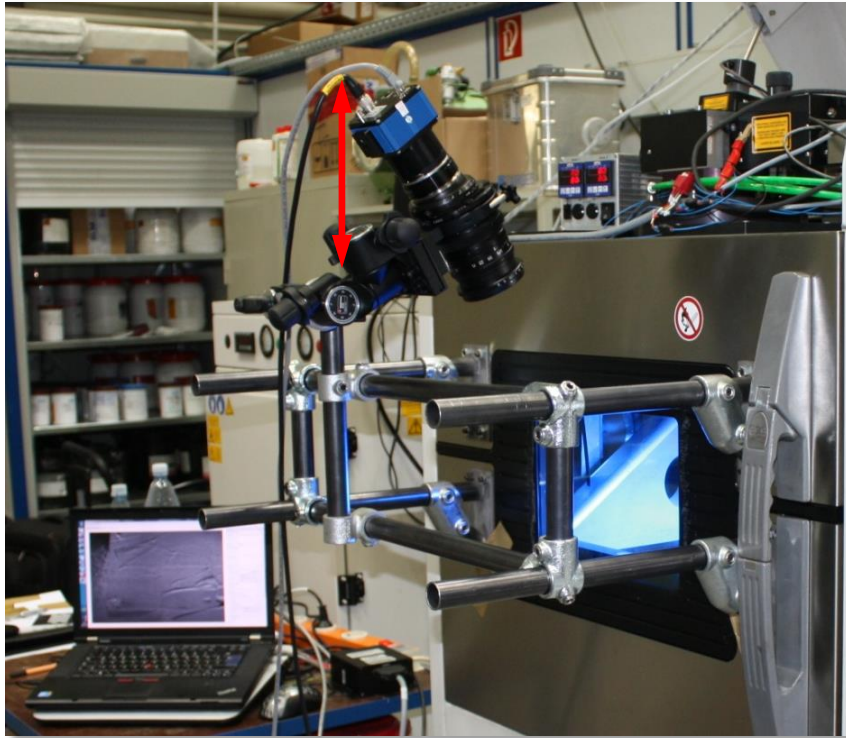
all layers correct?

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



SVS-VISTEK
SVCam-hr29050

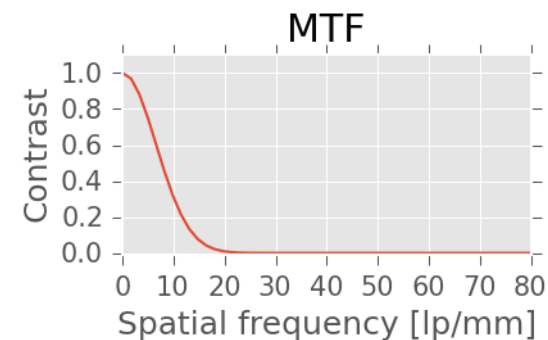
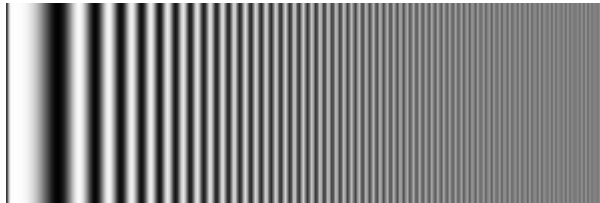
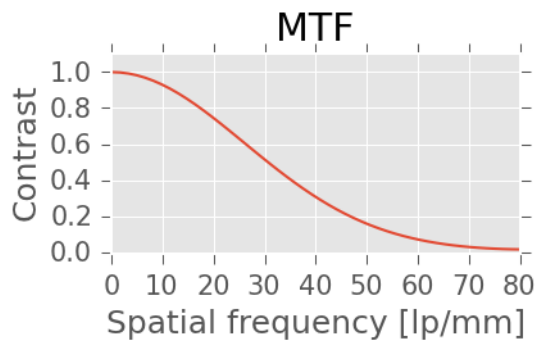
Hartblei Macro 4/120
TS Superrotator

Resolution Measurement

Assess properties of optical system

Resolution sufficient for small details?

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



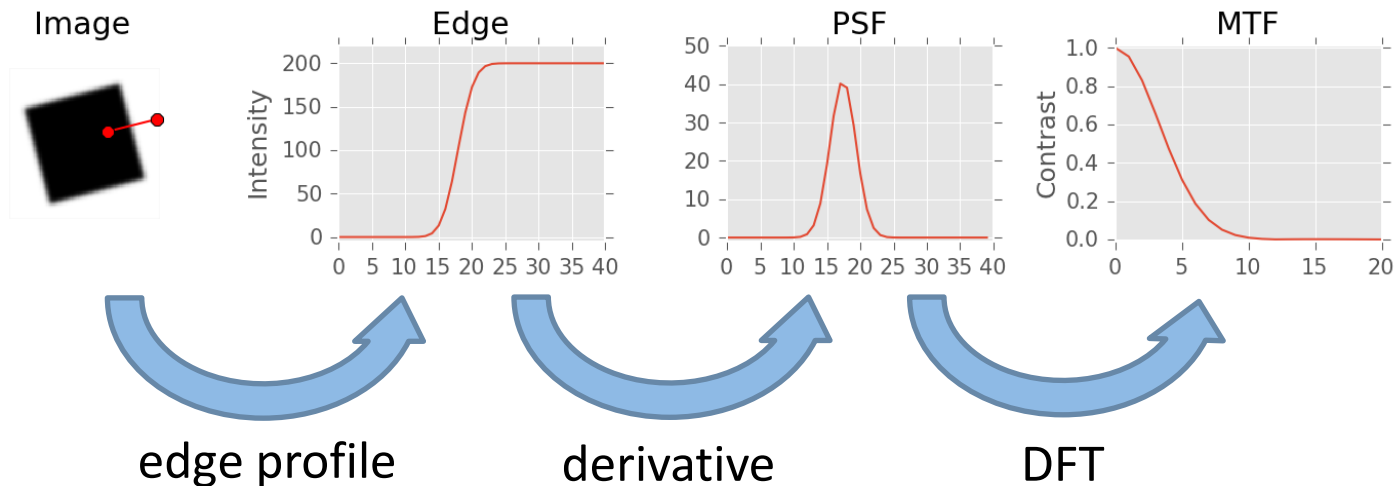
Modulation Transfer Function

Magnitude of complex optical transfer function (OTF)

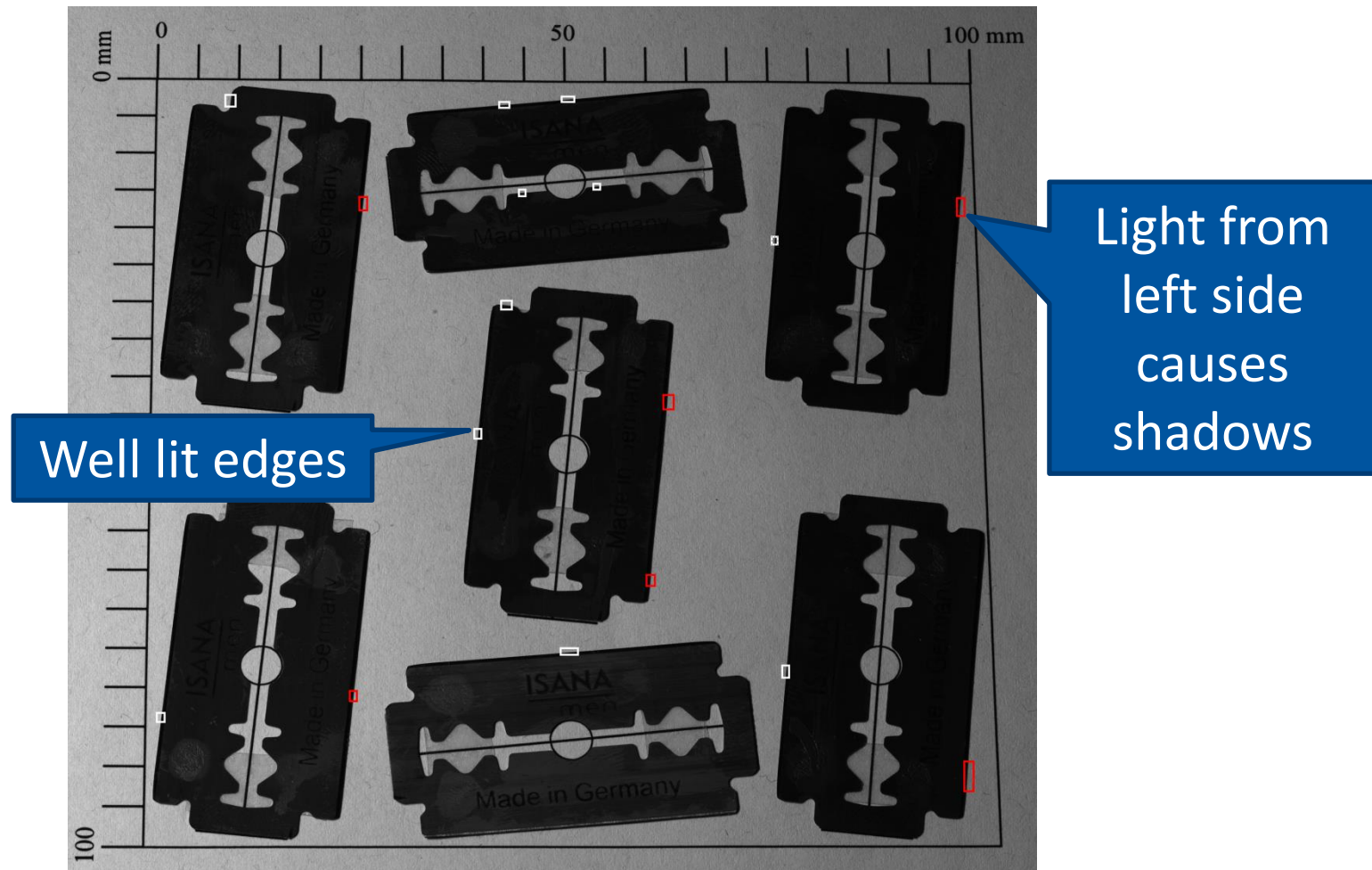
$$\text{psf}(\mathbf{x}) \xrightarrow{\text{DFT}} \text{OTF}(\mathbf{f}) = \text{MTF}(\mathbf{f}) \cdot \theta(\mathbf{f})$$

(point spread function)

Compute by slanted-edge method [Burns2000, ISO12233]

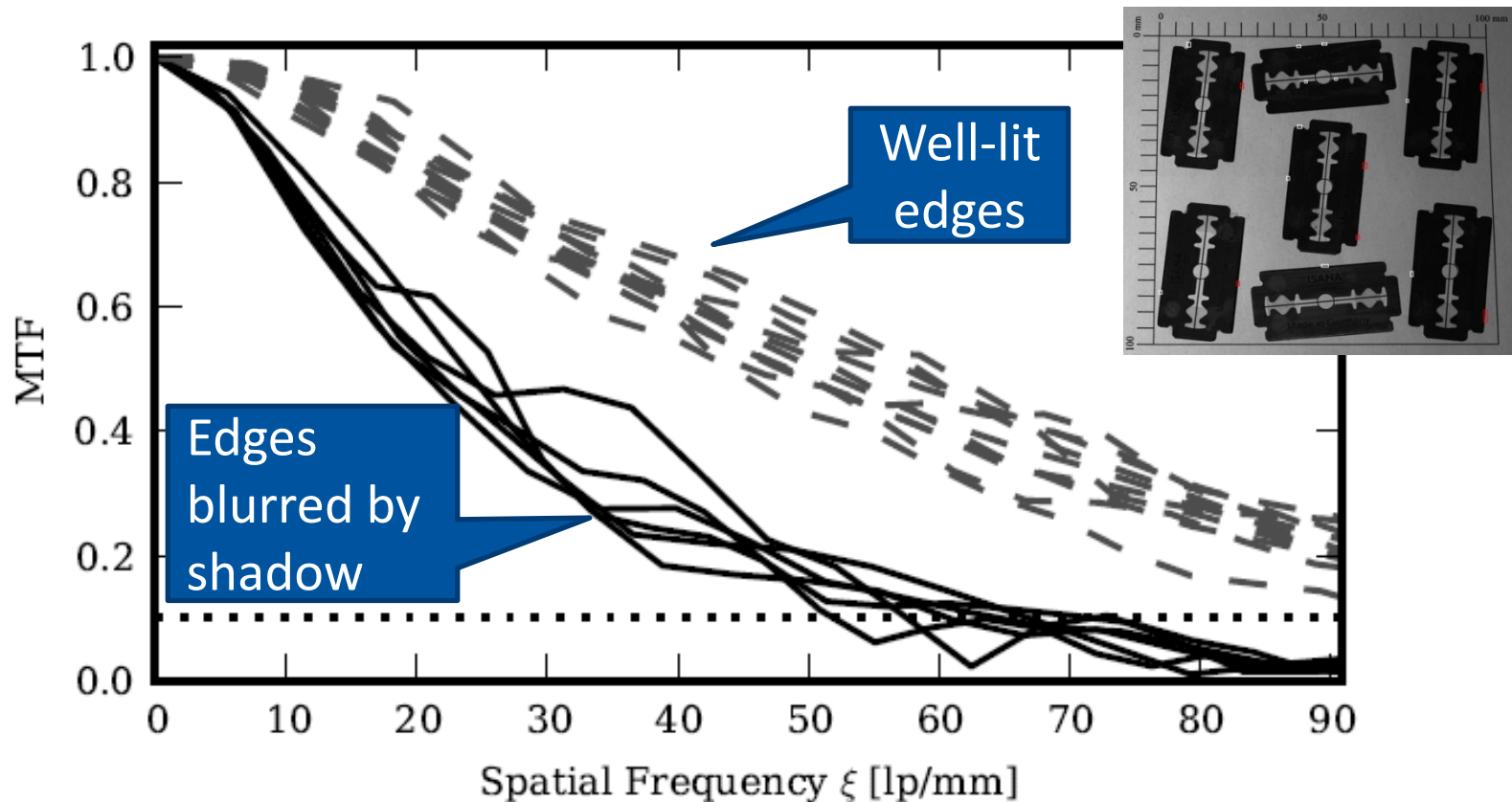


Resolution Measurement: Target



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

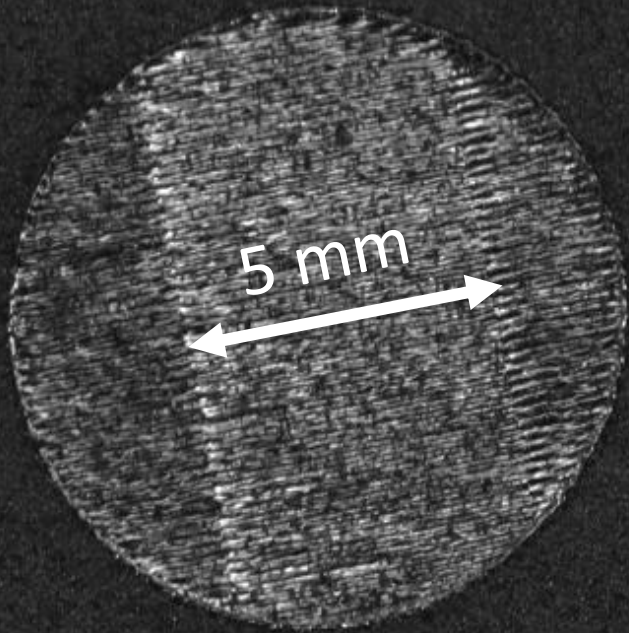
Resolution Measurement: Result



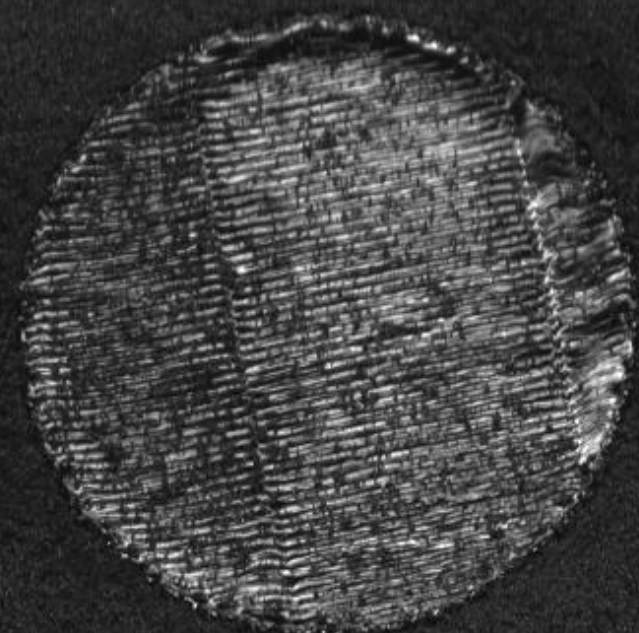
limiting resolution at least $\xi_0 = 50$ lp/mm [90 lp/mm] (on sensor)

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

Example Image



Weld Seams: 90 μm



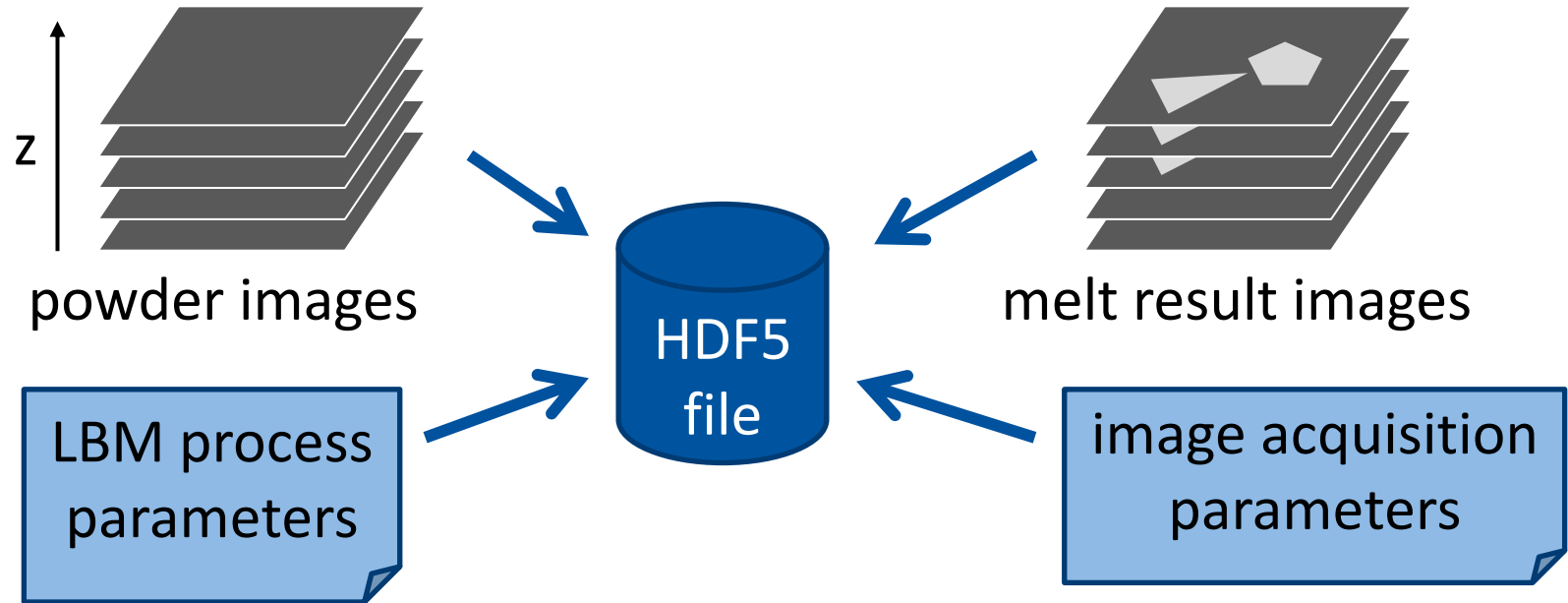
1 pixel: 25...35 μm

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

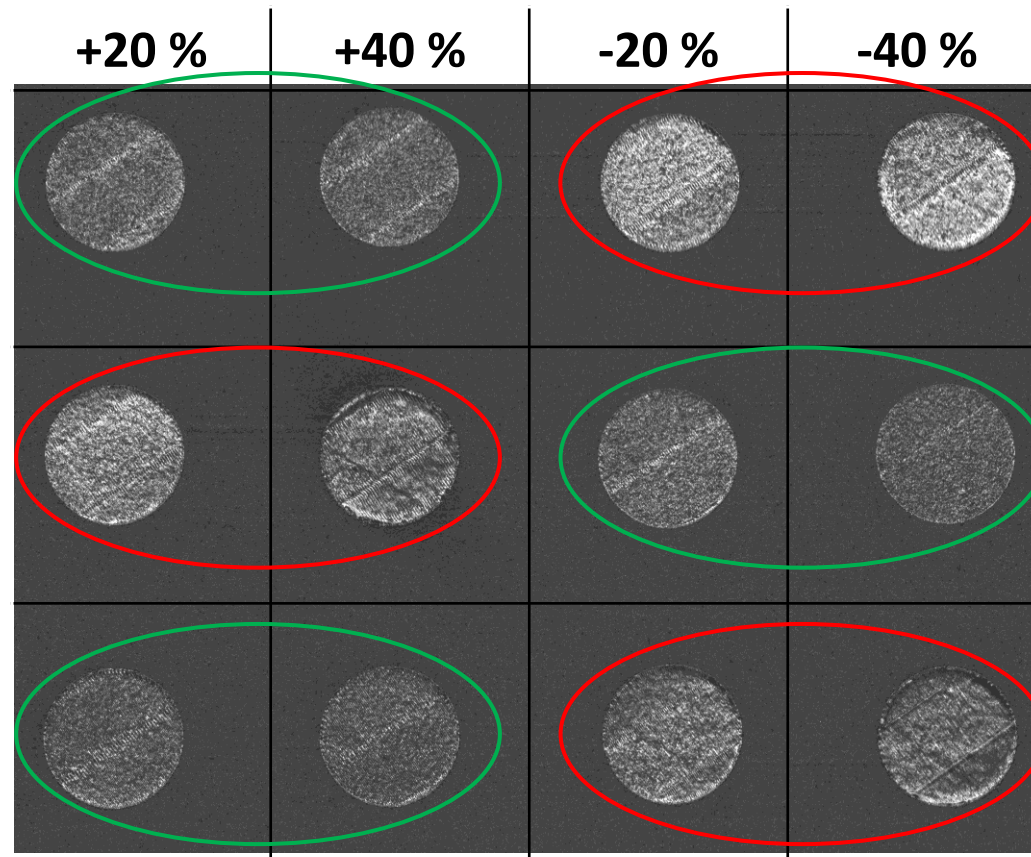
[www.hdfgroup.org]



Sample Build

Laser scan velocity

Laser power

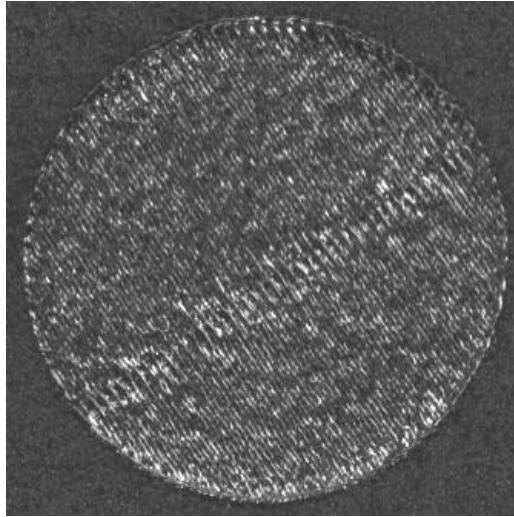
Hatch distance



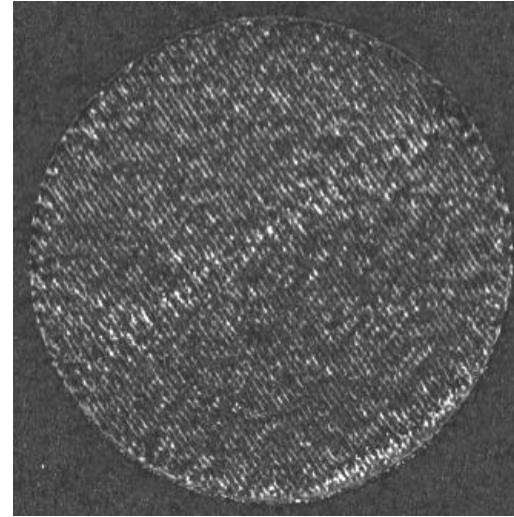
: Increased energy input
: Decreased energy input

Sample Build: Hatch Distance

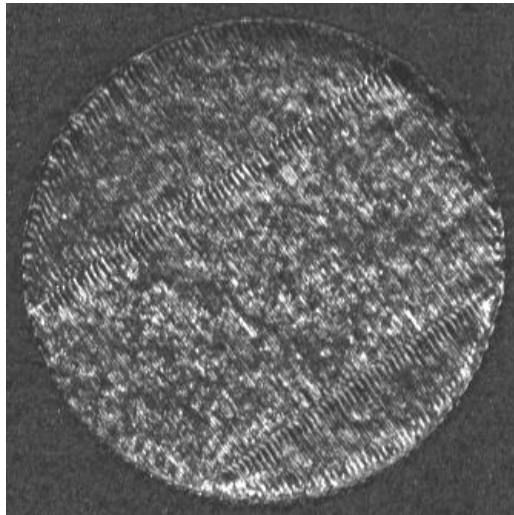
+20 %



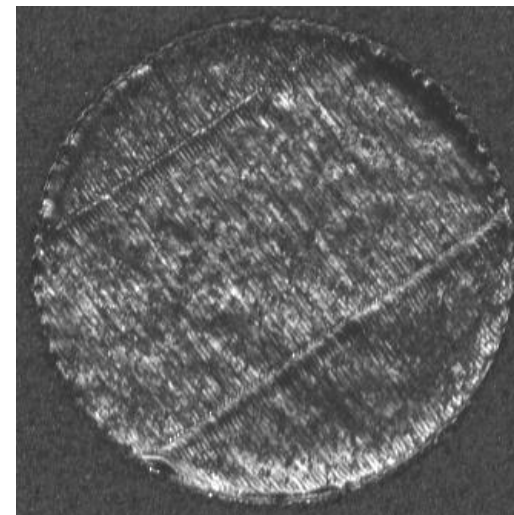
+40 %



-20 %

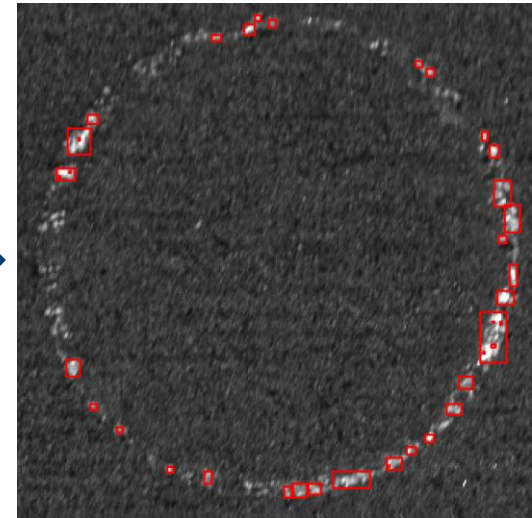
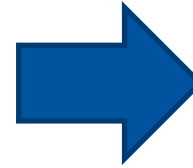
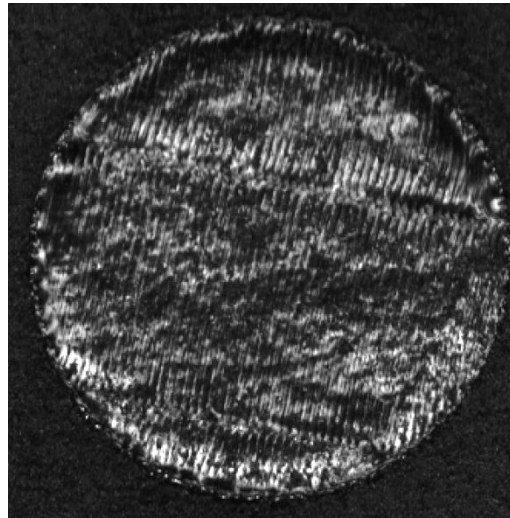


-40 %

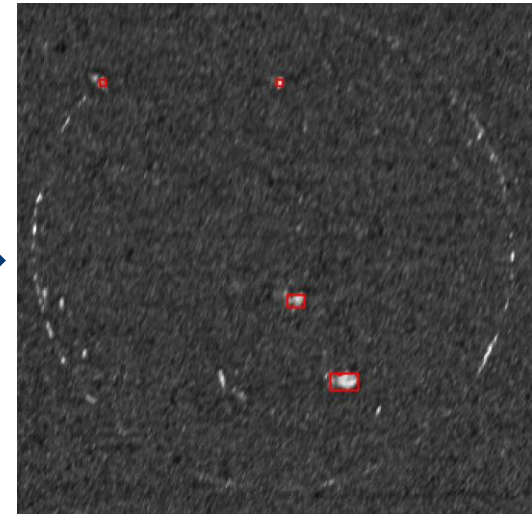
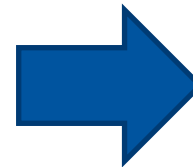
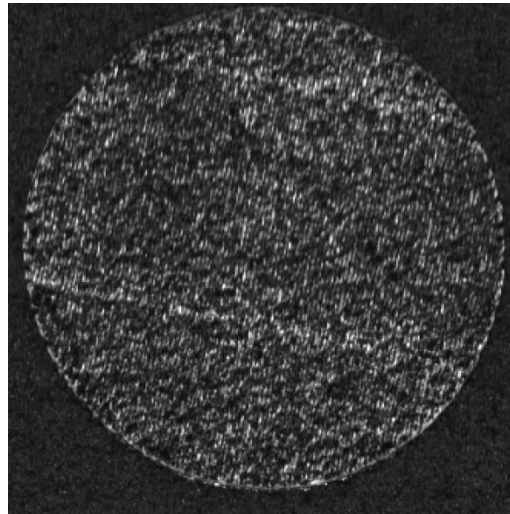


Sample Build: Elevation of Contour Regions

Power +40 %



Power -40 %

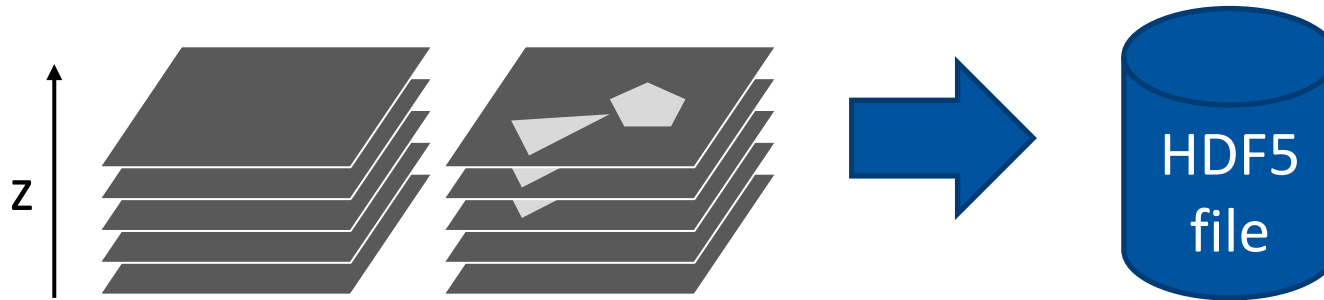


Outline

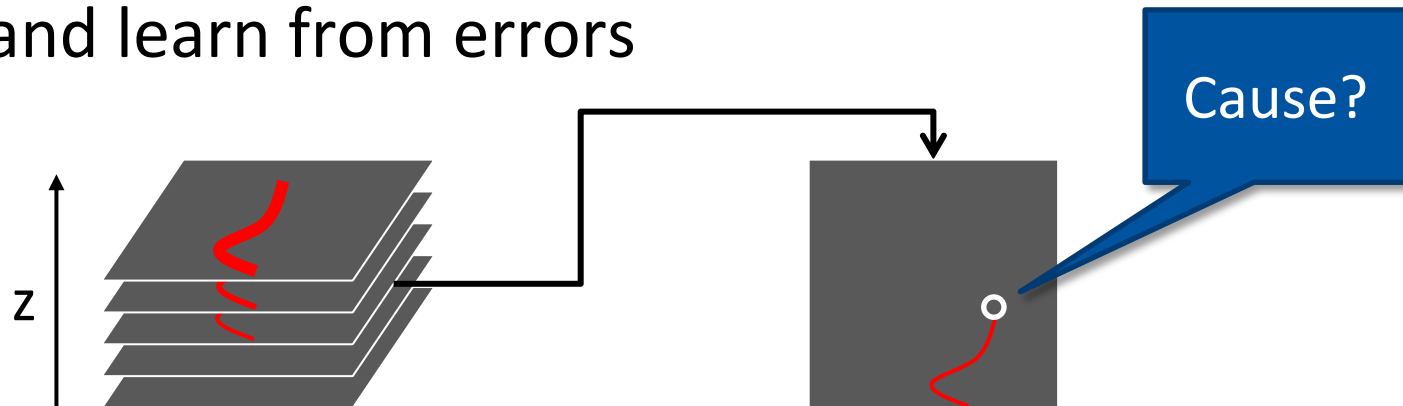
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Applications in Quality Control

Process documentation

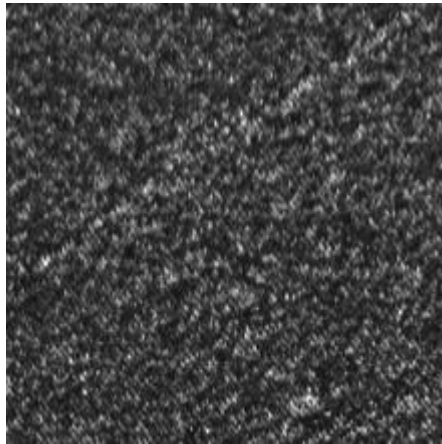


Detect and learn from errors

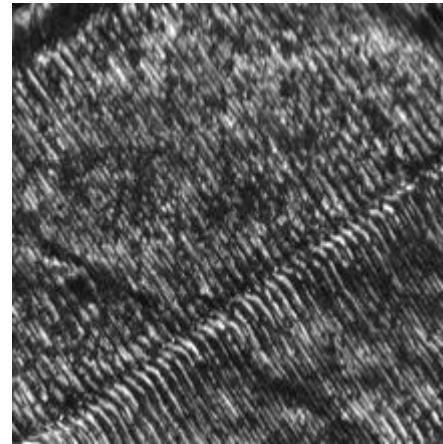


Applications in Quality Control

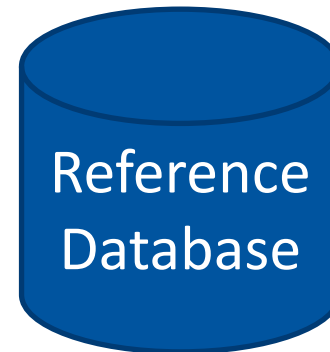
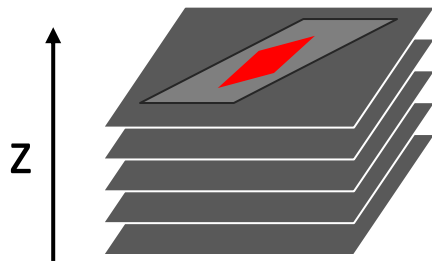
Detect non-optimal parameter values



Laser power -40 %

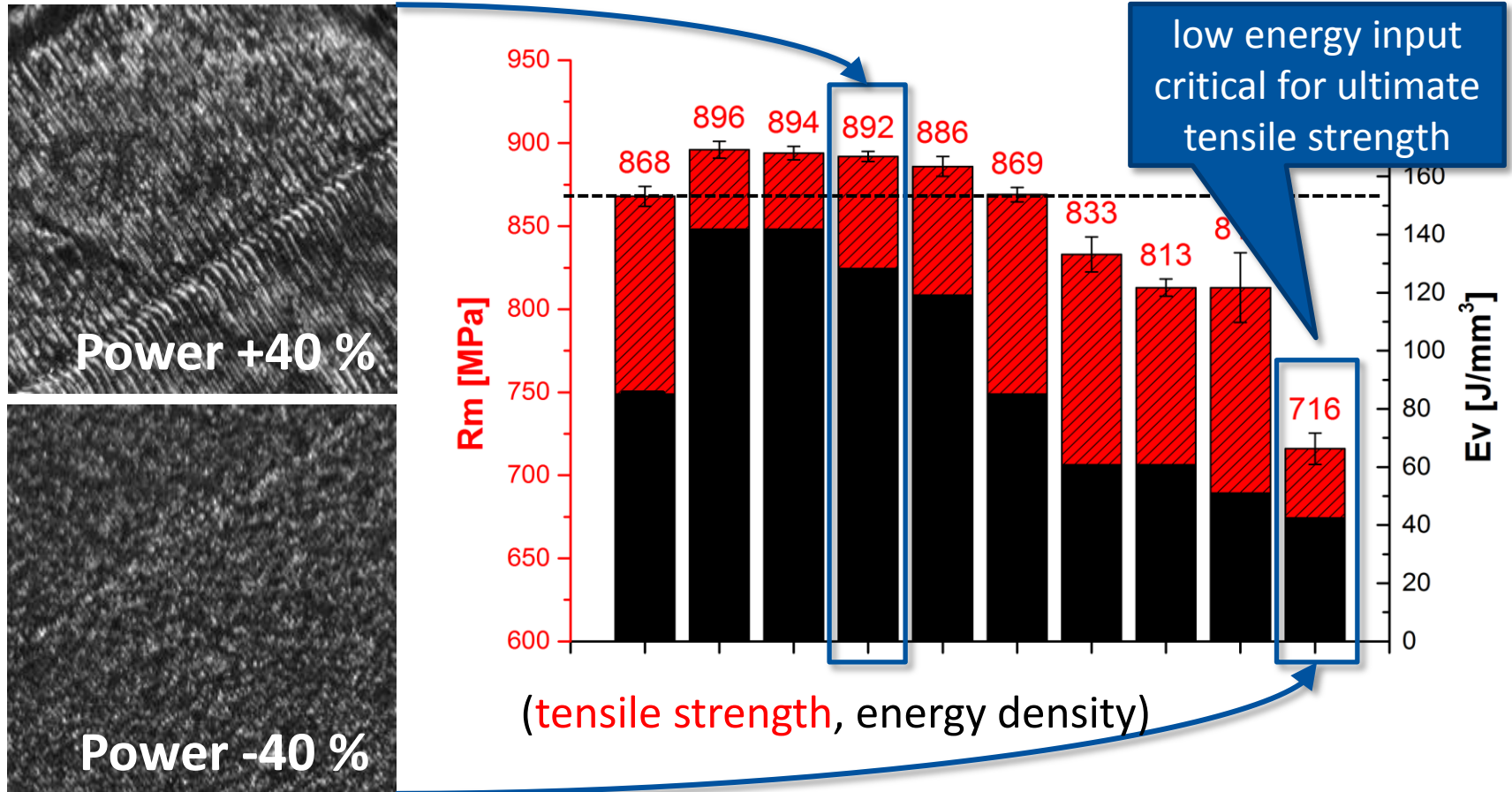


Laser power +40 %



Applications in Quality Control

Link surface images to mechanical part properties



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- Summary

Summary

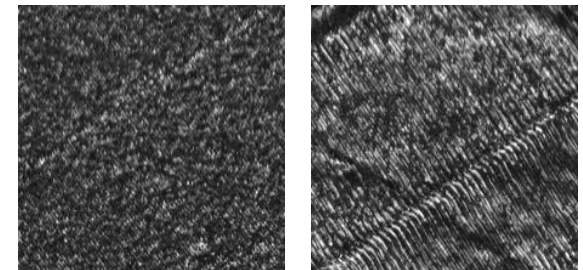
■ What is Laser Beam Melting? An Introduction

- "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





High Resolution Imaging for Inspection of Laser Beam Melting Systems



Joschka zur Jacobsmühlen¹⁾, Stefan Kleszczynski²⁾,
Dorian Schneider¹⁾, and Gerd Witt²⁾

1) Institute of Imaging and Computer Vision
RWTH Aachen University
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2) Institute for Product Engineering
University of Duisburg-Essen
Duisburg, Germany

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