



Fraunhofer Entwicklungszentrum
Röntgentechnik

**The EZRT is a joint department of the
Fraunhofer-Institutes IIS Erlangen
and IZFP Saarbrücken/Dresden**

Dr. Theobald Fuchs, Dr. Thomas Wenzel, Ingo Bauscher

International Workshop on Imaging NDE
April 25 – 28, 2007, Kalpakkam, India

Fraunhofer EZRT @ INDE 2007

Status of Computed Tomography

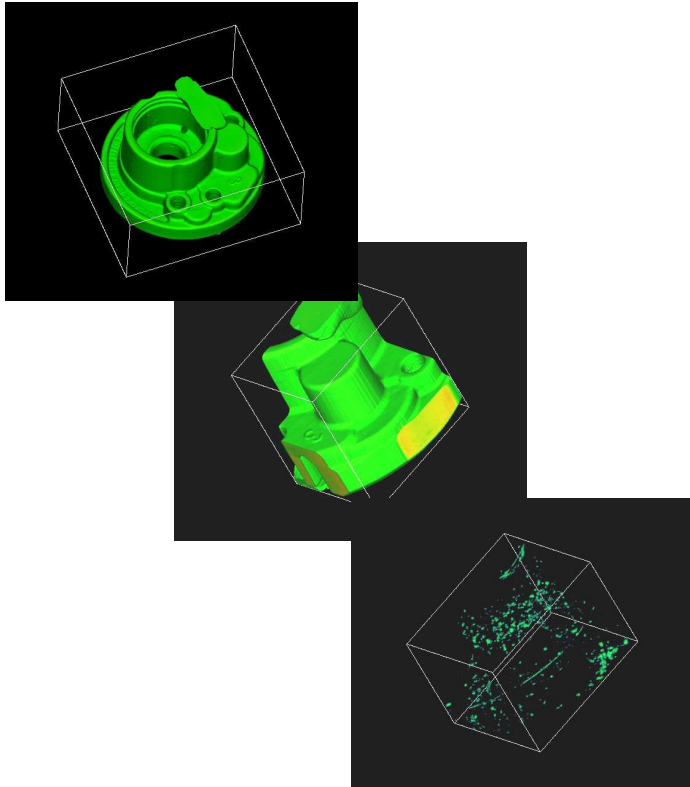
Fast Inline CT

Automated Defect Recognition and CT

Dimensional Measurement with CT

Fast Inline Computed Tomography

Motivation



- No quantitative information on defects possible by transmission radioscopy
- 3D CT can provide complex spatial information about a component and contained unwanted elements therein
- Evaluation based on 3D methods is less prone to artifacts than 2D methods
- Fast computers and algorithms allow for pace keeping reconstruction and analysis
- Relatively low resolutions necessary for NDT tasks

Fast Inline Computed Tomography

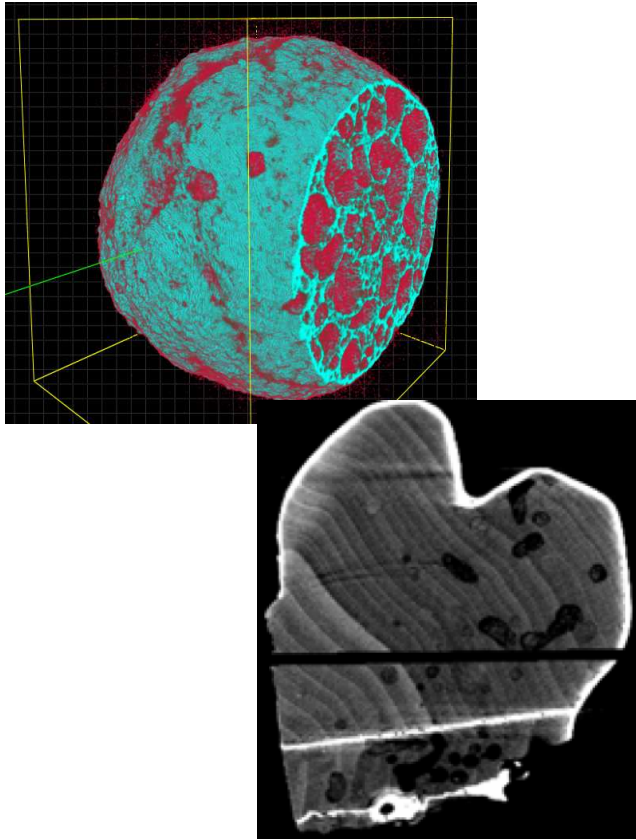
Goals

- A fast CT System for inline 3D-inspection in industrial production of casting parts
- Time of measurement and reconstruction below 40 seconds
- Evaluation of the 3D volume in less than 15 seconds
- Sufficient quality of reconstructed data from less than 200 projection images, probably by utilizing a-priori information
- Development and implementation of a dedicated radiation-hard Fraunhofer detector system
Long-term: detector area up to 1 m x 1 m



Fast Inline Computed Tomography

Fields of Application



Automated defect recognition for cast parts

- Blow holes, defects, pores, inclusions
- Metals, plastics, ceramics

Characterization of foam

- Foams with open and closed bubbles
- Sandwich-structures
- Pore distribution and properties, search for leakage

Characterization of fiber reinforced plastics

- CFC, GFC
- Fiber distribution, orientation and volume fraction

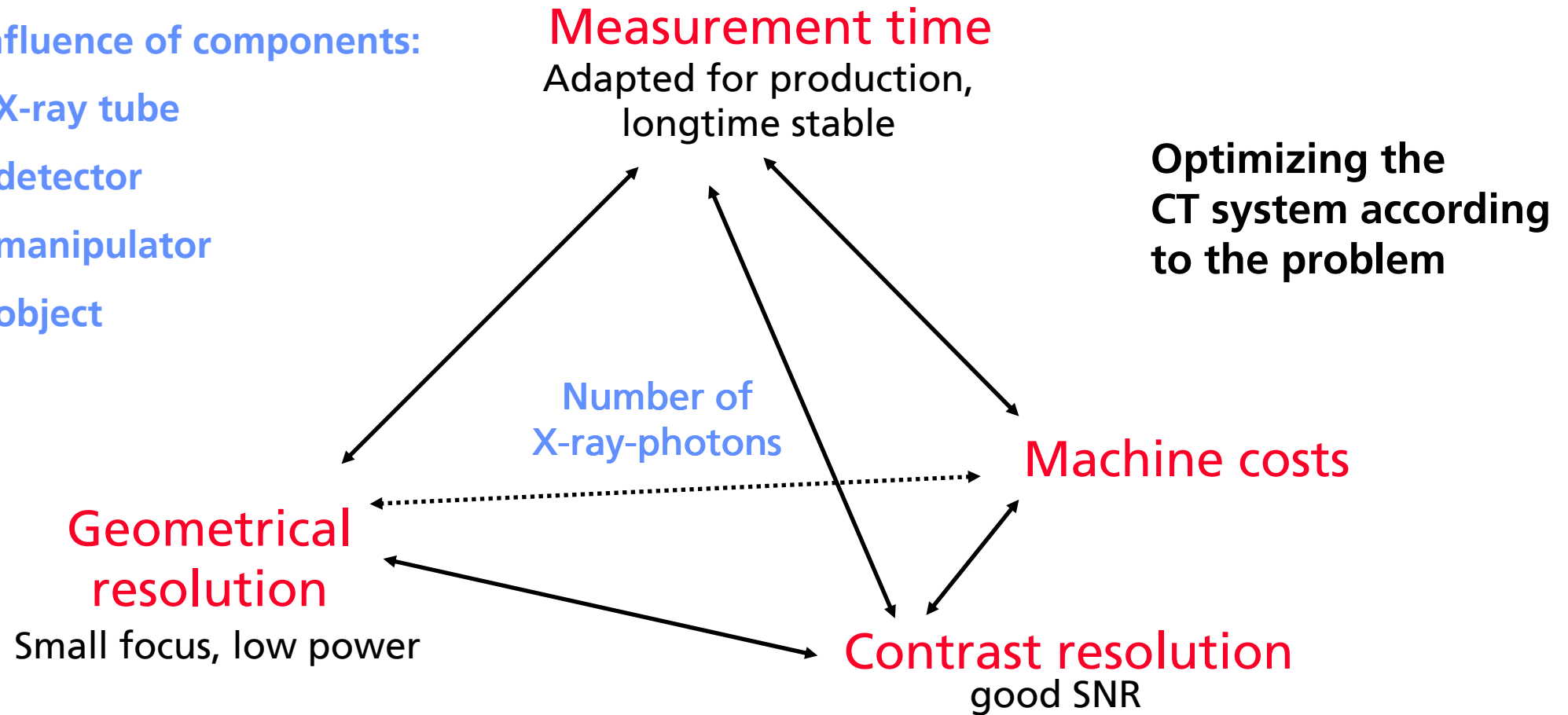
Characterization of biological materials and products

- First grade wood products, quality control of seeds

The X-ray Pyramid

Influence of components:

- X-ray tube
- detector
- manipulator
- object



Fast Inline Computed Tomography

Design of an Inline-CT System (1)

- Detector
 - low integration and transfer time to achieve high throughput
 - long life time (radiation hardness)
 - high sensitivity → large pixel area
- X-ray source
 - highest intensity → rotating anode
 - long-term stability
- Radiation safety and mechanical set-up
 - Housing for the X-ray source
 - “Open” cabinet to enable quick exchange of parts
 - Low number of axis, simple mechanical set-up



Fast Inline Computed Tomography

Design of an Inline-CT System (2)

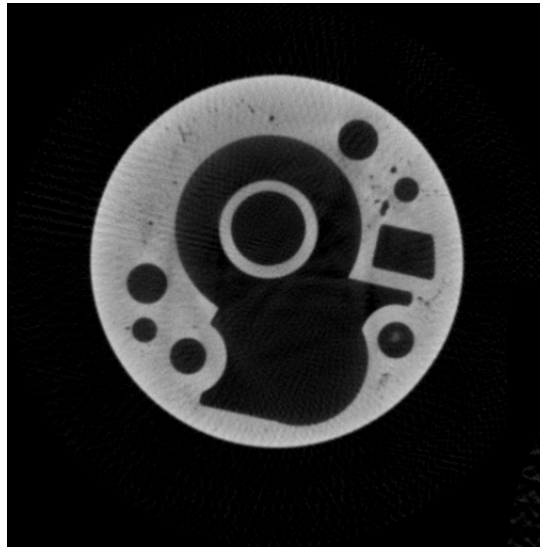
- Reconstruction method
 - Small number of projections
 - Small amount of transferred data
 - Reduced angular range ($180^\circ + \text{opening angle}$)
 - Utilization of a-priori knowledge
 - CAD-data or models
 - Reconstruction quality „as good as necessary“
- Evaluation
 - True 3D-evaluation → generation of attributes in 3D
 - Evaluation in real time synchronously with the reconstruction



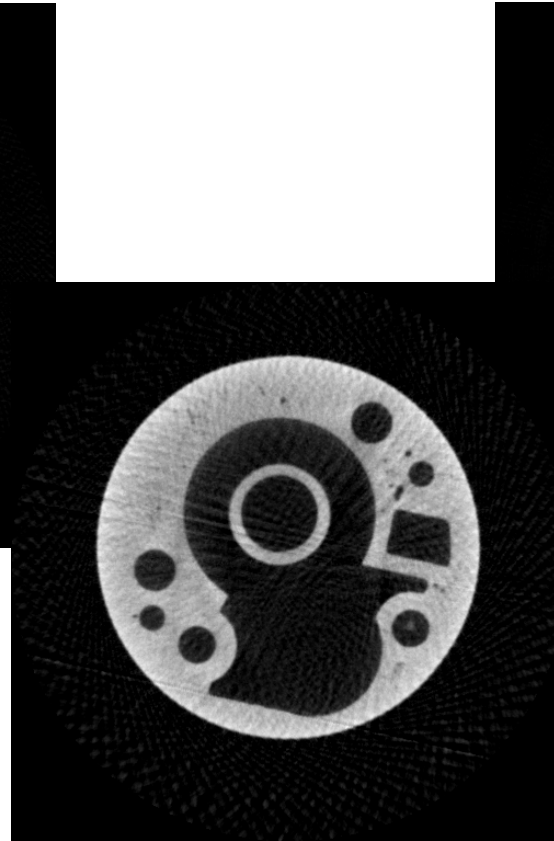
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Reconstruction with reduced number of projections

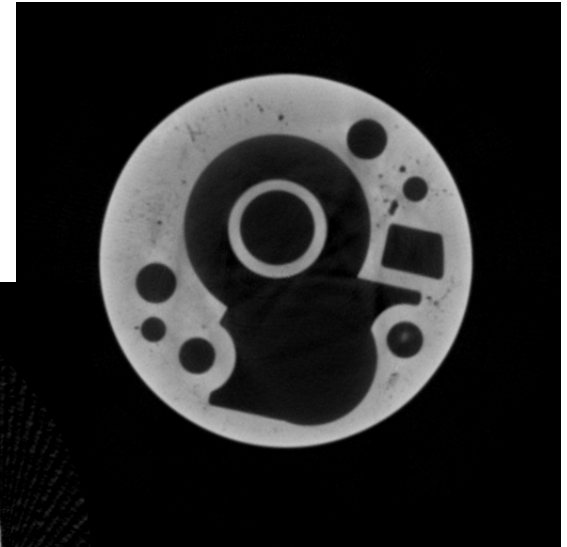
reconstruction from
200 projection angles



reconstruction from
100 projection angles



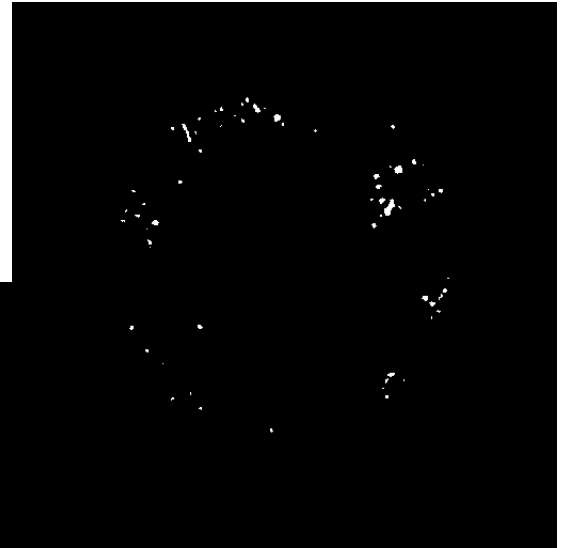
reconstruction from
400 projection angles



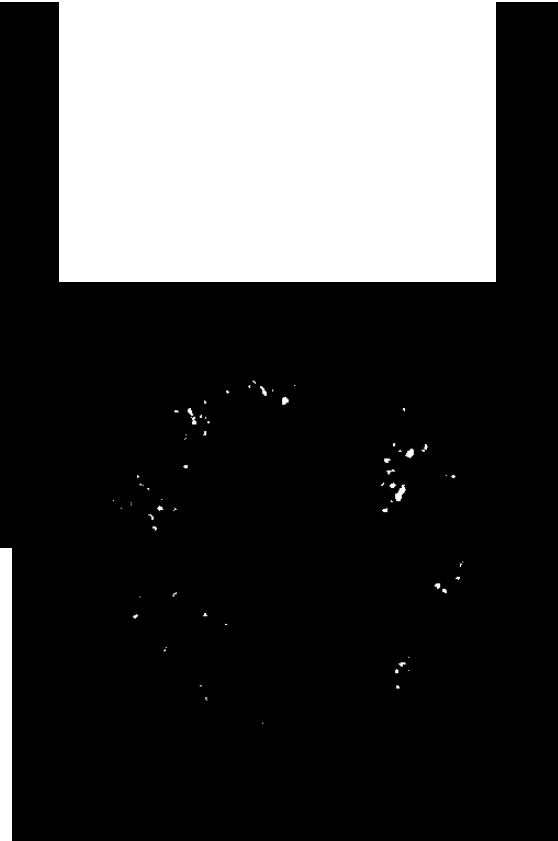
Fast Inline Computed Tomography

Automatic evaluation on reduced volume data sets

defect recognition in 3D
with 200 projection angles



defect recognition in 3D
with 100 projection angles

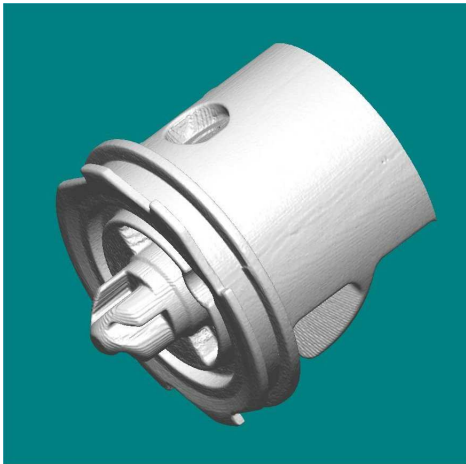


defect recognition in
3D with 400
projection angles



Fast Inline Computed Tomography

Making use of a-prior knowledge



- Account for CAD data to define the reconstructed volume
- Substitution of views missing due to insufficient image quality by simulated projections
- Making use of the a-priori knowledge on the inspection issue (what? & where?)
- Adapt scan geometry to shape and size of the object
- Adapt image acquisition time dynamically to current projection angle

Fast Inline Computed Tomography

Two Approaches



Continuous Rotation

- Permanent detector image acquisition
- Short integration times
- Online reconstruction and evaluation

Stop-and-go

- Axis of rotation triggers the detector
- Integration of several frames if necessary
- Online reconstruction and evaluation

Fast Inline Computed Tomography

Continuous Rotation

Advantages

- very short times of measurement achievable (< 20 sec)
- simple to realize
- heavy parts are handled more easily due to absence of acceleration and deceleration
- “free running” image acquisition modus, no need for synchronization if constant speed of rotation given



Fast Inline Computed Tomography

Continuous Rotation

Disadvantages

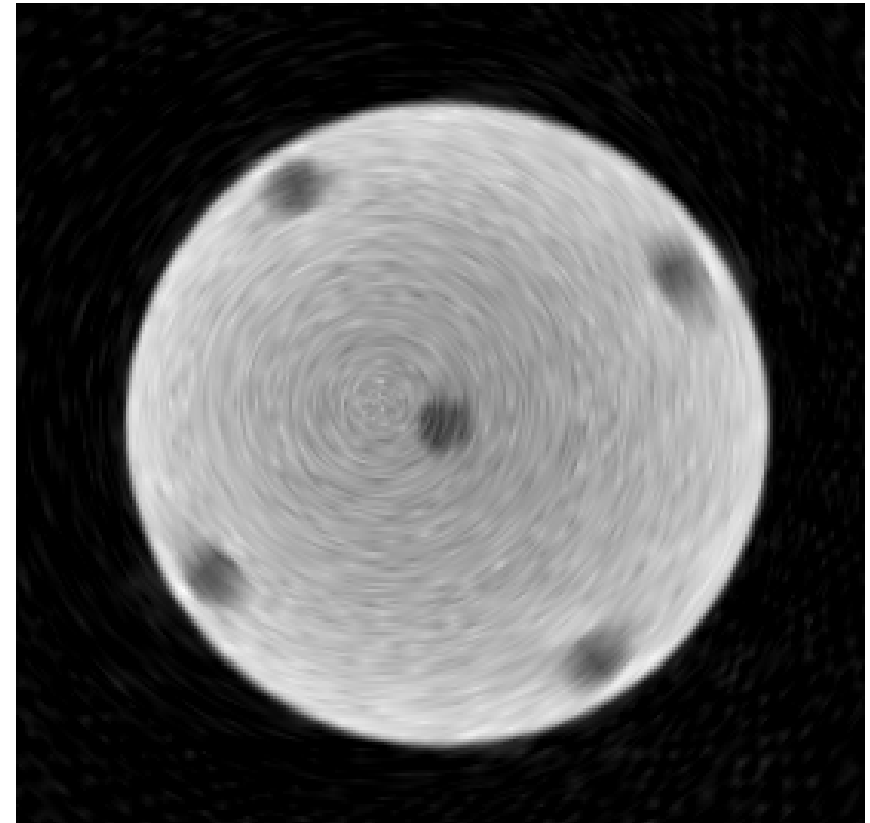
- loss of spatial resolution with increasing distance from the center of rotation due to movement of the object
- need for highly constant angular speed of the axis of rotation
- need for constant temporal distance of detector frame read-out



Fast Inline Computed Tomography

Continuous Rotation - Results

Implications on spatial resolution

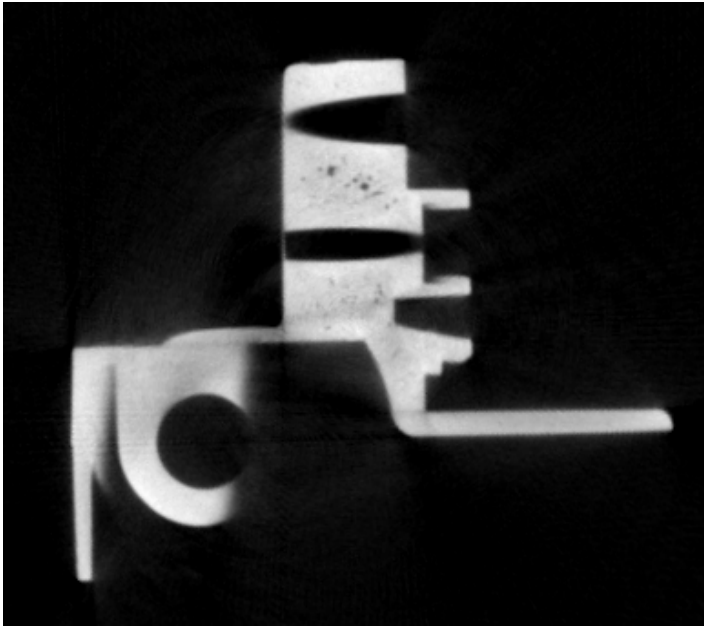


Cylindrical test object with 5
identical bore holes
(100 projections with each
400 ms integration time)



Fast Inline Computed Tomography

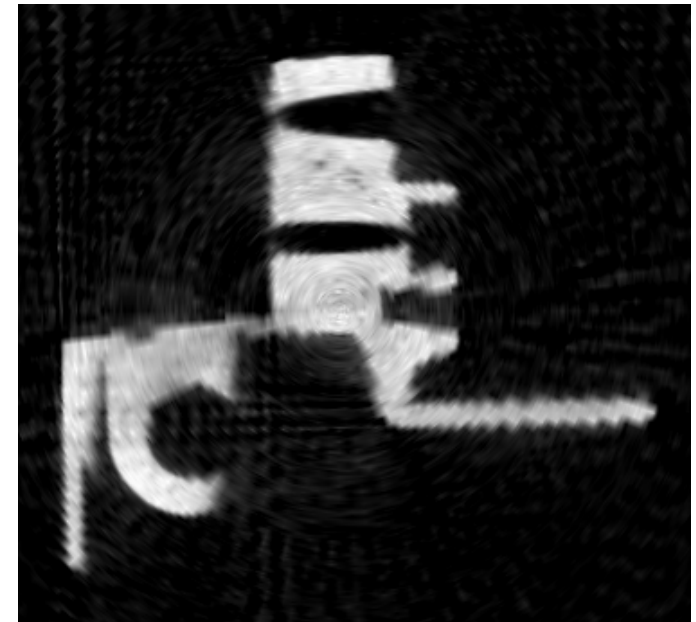
Continuous Rotation - Results



400 ms integration time

400 projection angles

160 s total time for measurement



400 ms integration time

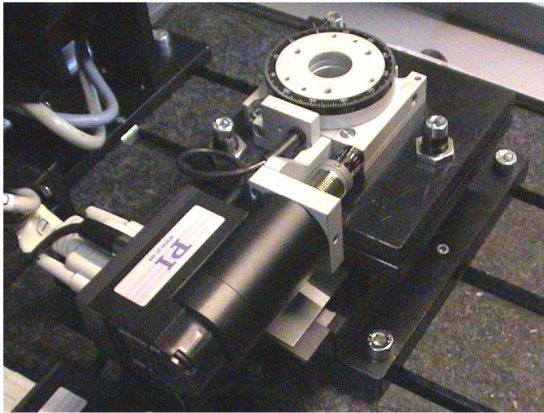
100 projection angles

40 s total time for measurement



Fast Inline Computed Tomography

Stop-and-go Technique



Advantages

- No loss of resolution due to motion
- Low-price components (conventional step motors)



Fast Inline Computed Tomography

Stop-and-go Technique

Disadvantages

- Need for reliable synchronization of the detector and the axis of rotation (external trigger)
- Higher times of measurement compared to continuous rotation
- High forces during acceleration and deceleration limit the mass of the object to be inspected



Fast Inline Computed Tomography

Stop-and-go Technique - Results

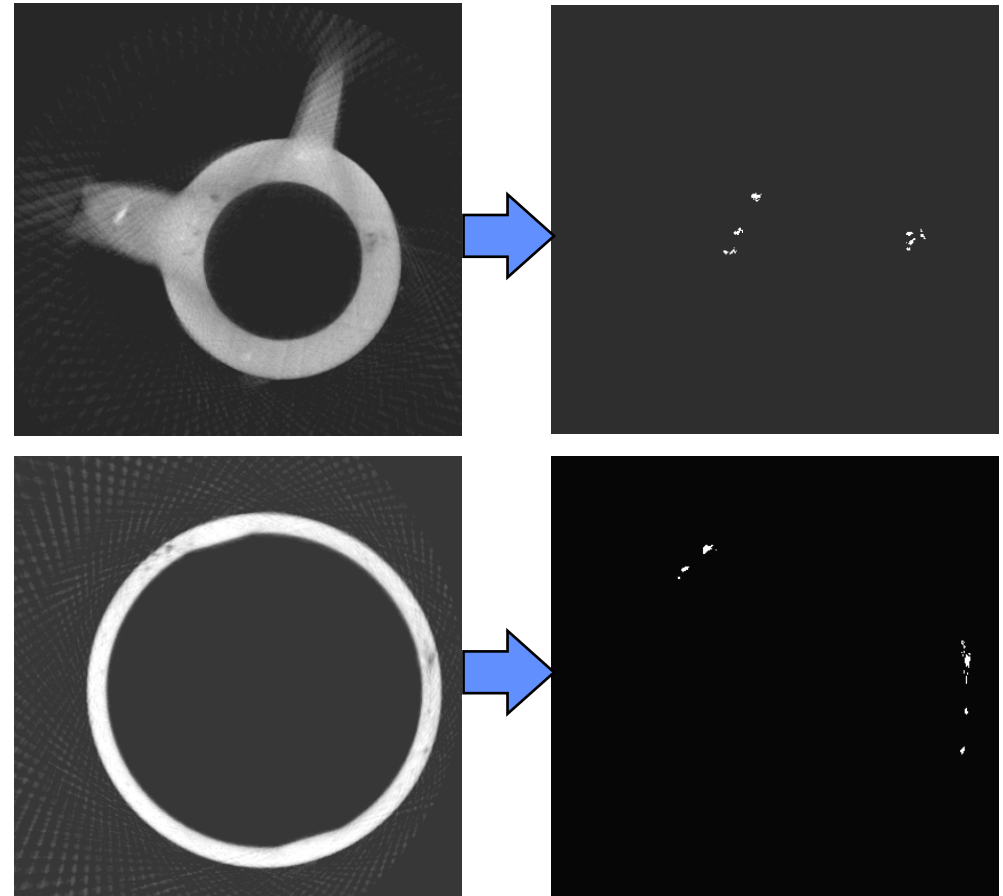
3D reconstruction based on
100 projection angles

Automatic defect recognition

134 ms integration time for
each projection

26,8 s duration of
measurement

28 s reconstruction time



Fast Inline Computed Tomography

Summary

- Measurement and evaluation of a complete object with CT is feasible within less than 30 seconds
- The 1st inline CT-system has been installed on the factory floor
- Reliable inspection is possible despite reduced image quality (100% defect detection, low false-positive rate)
- CT has the potential to replace conventional digital radiography in industrial production

