Documentation of the ISA Micro Computed Tomography System

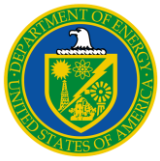
William D. Brown and Jerel A. Smith

Lawrence Livermore National Laboratory
Livermore, CA 94551

Work performed on the
Science & Technology Directorate of the
Department of Homeland Security
Statement of Work
PR RSEN-08-00066

December 18, 2013
Version 1.0
LLNL-TR-649122

IM# 768047



This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Table of Contents

Documentation of the ISA Micro Computed Tomography System

Executive Summary:

This document is intended to provide information on the ISA Micro Computed Tomography (MicroCT) system that will be installed in Yavne, Israel. X-ray source, detector, and motion control hardware are specified as well as specimen platforms, containers, and reference material types. Most of the details on the system are derived from Reference 1 and 2.

Acronyms:

cm	Centimeter
CT	Computed Tomography
EDS	Explosive Detection System
HME	Homemade Explosive
kV	Kilovolt
kW	Kilowatts
LLNL	Lawrence Livermore National Laboratory
LAC	Linear Attenuation Coefficient
LDPE	Low Density Polyethelene
PET	Polyethylene Terephthalate
ISA	Israel Security Agency

Introduction:

Objectives:

This document is intended to provide information on a high spatial-resolution computed tomography (MicroCT) scanner. The documentation is intended as a reference to inform users of the MicroCT with those details that are needed to understand and evaluate the system. The documentation will address the hardware components, their physical and functional relationships, the assembly of those components as an imaging system, and the parameters of their usage.

Overview:

The MicroCT scanner is designed to measure and compare the physical properties of samples in the context of CT imaging. The scanner includes a high-voltage DC x-ray source, an area detector, a positioning system that provides rotation and translation of the sample, a sample-support stage and carousel, and a double-slit collimator.

Samples are supported in a carousel and imaged in two different planes. The upper plane images a single specimen which is the material to be characterized and its container, as needed. The lower plane images a number of known “references” which are used for

calibration. In both planes, a strip of copper sheet provides a reference for monitoring the stability and consistency of the imaging system. The two-slit collimator projects two multiple slice x-ray fan beams, one through each plane, while minimizing the x-ray scatter from objects not essential to imaging the portion of the samples transected by those fans. The measured fan-beam transmission data are reconstructed as 2-D images.

Images are also made with the upper slit-collimator removed. These images are used either as 2-D radiographs, or reconstructed as 3-D (cone-beam) images.

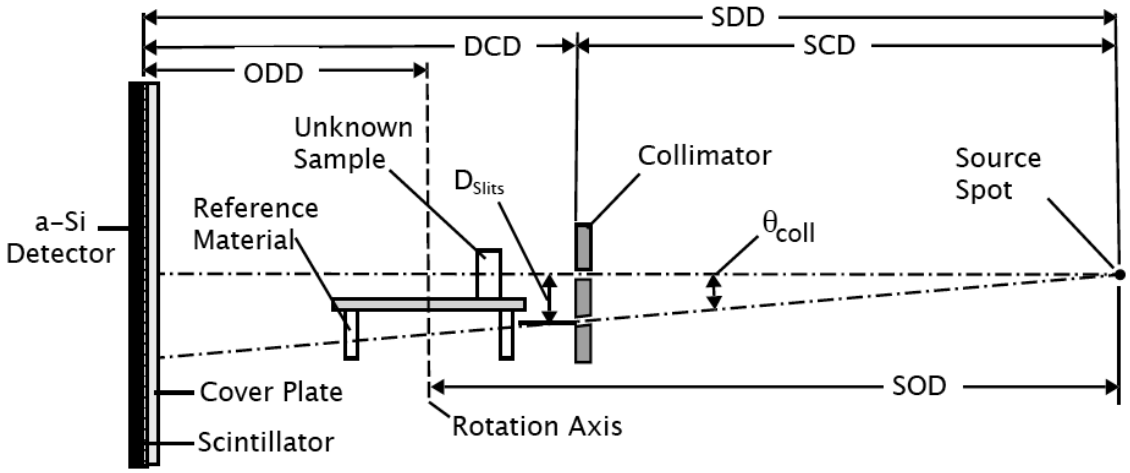


Figure 1. MicroCT System Geometry*: Measurements are from the center of the source-spot, the detector side of the collimator, the rotational center of the table and the active surface of the scintillator.*

MicroCT System Specifications

Geometry (These are nominal values acquired in April 2013. The values may change slightly after movement of the system, preventative maintenance, and re-alignment of the system)

SDD	1413.4 mm
ODD	310.9 mm
SOD	1102.5
SCD	950 mm
θcoll	1.51 deg.
D_{Slits}	25 mm
Object Magnification	1.30
OSD	44.45 mm Center of rotation to center of specimen
ORD	82.55 mm Center of rotation to center of references

Image-Pixel Dimensions

Inherent Detector Pixel size	0.200 mm X 0.200 mm
Image Pixel (at center of rotation)	0.156 mm X 0.156 mm

X-ray Shielded Cabinet

Shielded Cabinet Drawings:	[D1]
Shielded Cabinet Wiring Schematic:	[D2]
X-ray Interlock Wiring:	[D3]

Figure 2: ISA X-ray Shielded System. Front view showing electric door.

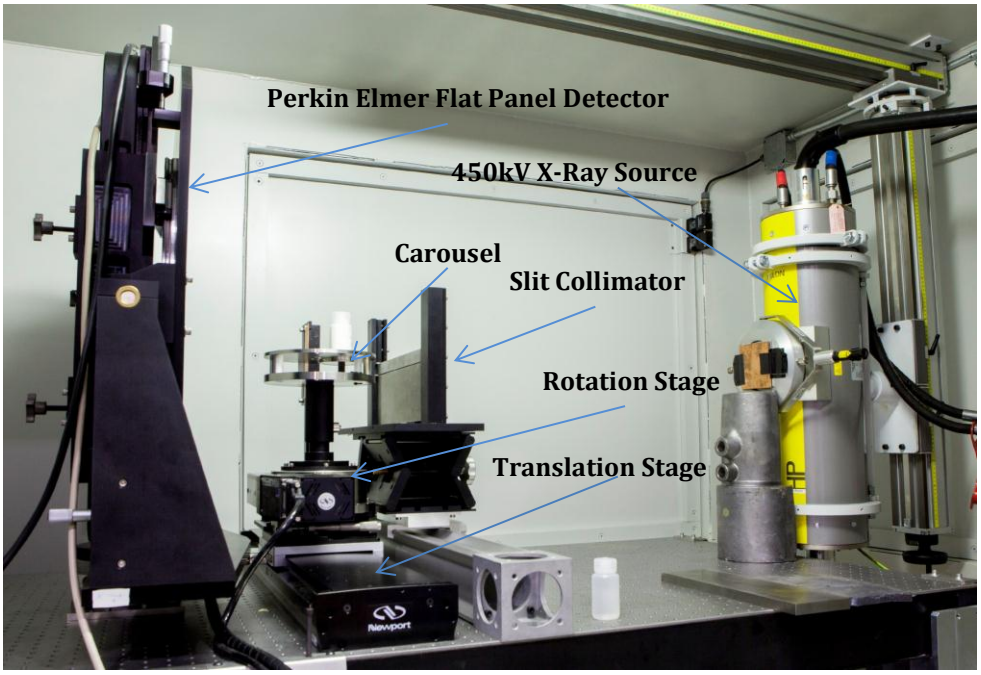


Figure 3: ISA System internal components

Functional Component Documents and Critical Specifications

X-ray Source Tubehead:

Make:	YXLON
Model:	Y.TU 450-D11
Serial No:	298251
Tube type:	Metal Ceramic
Focal Spot (EN 12543):	0.4 mm / 1.0 mm
Target Material:	Tungsten
Takeoff Angle:	11 degrees; Appendix 1
Anode-Cathode Axis: LLNL	Vertical: Anode on top
X-ray Window:	5-mm Be
HV Potential Range:	20–450 kV
Power (Max):	0.7 kW (0.4-mm) / 1.5 kW (1.0)
User Manual and Specs:	[M1]

X-ray Source Controller, Power Supply, Generators and Oil Cooler :

Make:	YXLON
Controller Model / SN:	MGC41 / 310392
Power Supply / SN:	MGP41 / 309772
Generator (-) Model / SN	MGG46 / 307769
Generator (+) Model / SN	MGG47 / 306397
Potential (min/max):	20 / 450 kV
Accuracy:	± 1 % of demand value ± 0.2 kV
Current (min/max):	0.5 / 15 mA
Accuracy:	± 0.2 % of demand value ± 0.01 mA
Max Power:	1.5 kW
Oil Cooler Model / SN	OL-4502 / 2009569002
Manufacturers Specs:	[M1], [M2]

Collimator:

Material:	l5.9 mm thick tungsten
Slit Separation (D_{slits})	25.0 mm (center to center, source side)
Slit Width	2.0 mm (set by shim)
Slit Length:	330.2 mm
Collimator Drawings:	[D4]

Sample-Position Controller and Stages:

Make:	Newport
Controller Model / SN:	XPS / 12 154 031
Controller User Manual:	[M3]
Trans Stage Model/SN:	IMS600LM/B12 1619
Trans Stage User Manual:	[M4]
Rotary Stage Model/SN:	RV160PP/B11 10038
Rotary Stage User Manual:	[M5]

Detector:

Make:	Perkin Elmer
Type:	Flat Panel AmSi 2D Array
Model No:	XRD 1620 AN14 CS
Serial No:	380-6286
Front Panel:	0.75 mm Al and 0.52 mm Graphite
Scintillator:	DRZ Plus (Gd_2O_2S:Tb)
Detector User Manual:	[M6]

	Protective Layer	Phosphor Layer	Suppoprting Layer
DRZ-Plus	PET 6 µm	208 µm, 100mg/cm^2	Plastic Base 250 µm

Table 1: Scintillator components and thicknesses.

Energy Monitoring Cu Strip: 99.9+% Copper;
25.4 mm X 101.5 mm X 1.25 mm Thick

Data Acquisition Computer:

Make:	Dell
Model:	D09M
Serial No:	58RD8V1
Operating System:	Windows™ 7

Image Processing and Reconstruction Computer:

Make:	Dell
Model:	D09M
Serial No:	58SF8V1
Operating System:	Windows™ 7

12.7 mm Diameter Carousel References (Purity/Density g/cm^3)

Delrin	100 NC010/1.404
Teflon	60x Series/2.173
Graphite	99.99+%/1.804
Magnesium	99.95+%/1.734
Water	> 99.9999%
Silicon	99.999%/2.330

Container for Water Reference

Material:	Polypropylene
OD/ID:	14.0 mm/10.8 mm

Sample Container

Manufacturer:	Fisher Scientific – www.Fishersci.com
Part No:	02-896-1B
Material:	LDPE
Capacity:	60 ml

Sample/Material Positions:	Appendix 2
Sample Carousel Design:	[D5]
Filters (Type/Thickness/Purity):	Aluminum/ 2.0mm/ 99.99% Copper/2.0 mm/99.9+%

CT Techniques:

System Information	
Data Acquistion Date	Monday, April 22, 2013
System	ISA 450kV
Archive Directory	C:\ISA System\CT Data\QA_Acq
Source	
X-ray Source	Yxlon 450kV D11
Effective Spot Size (mm)	Small 0.4
Energy (kV)	160
Tube Current (mA)	4.35
Geometric Unsharpness (mm)	0.113
Filter (Type/Thickness mm)	Al/2.0 Cu/2.0
Detector	
Detector Type	Amorphous Silicon Perkin Elmer
Source-Detector-Distance (SDD) (mm)	1413.4
Source-Object-Distance (SOD) (mm)	1102.52
Object-Detector-Distance (ODD) (mm)	310.88
X-Offset (Pixels)	309
X-Size (Pixels)	1698
Y-Offset (Pixels)	1040
Y-Size (Pixels)	235
Magnification	1.282
Frame Average(s)	6
Integration Knob-Thales Only	N/A
Integration Time per Frame(sec)	1.15
Raw Pixel Size (mm)	0.2
Global Resampling	1
Effective Pixel size at Detector (mm)	0.2
Effective Pixel size at Object (mm)	0.156
CT Parameters	
Numbers of Views	401
Angular Range	200.5
Angular Step (Degrees)	0.5
Estimated PxCenterFull Panel (Pixel)	1022.7
Estimated PzCenterFull Panel (Pixel)	1061.7

Table 2: CT Technique for 160 kV 2 Slit (exp1) Data

System Information	
Data Acquistion Date	Monday, April 22, 2013
System	ISA 450kV
Archive Directory	C:\ISA System\CT Data\QA_Acq
Source	
X-ray Source	Yxlon 450kV D11
Effective Spot Size (mm)	Small 0.4
Energy (kV)	100
Tube Current (mA)	7
Geometric Unsharpness (mm)	0.113
Filter (Type/Thickness mm)	Al/2.0
Detector	
Detector Type	Amorphous Silicon Perkin Elmer
Source-Detector-Distance (SDD) (mm)	1413.4
Source-Object-Distance (SOD) (mm)	1102.52
Object-Detector-Distance (ODD) (mm)	310.88
X-Offset (Pixels)	309
X-Size (Pixels)	1698
Y-Offset (Pixels)	1040
Y-Size (Pixels)	235
Magnification	1.282
Frame Average(s)	6
Integration Knob-Thales Only	N/A
Integration Time per Frame(sec)	0.267
Raw Pixel Size (mm)	0.2
Global Resampling	1
Effective Pixel size at Detector (mm)	0.2
Effective Pixel size at Object (mm)	0.156
CT Parameters	
Numbers of Views	401
Angular Range	200.5
Angular Step (Degrees)	0.5
Estimated PxCenterFull Panel (Pixel)	1022.7
Estimated PzCenterFull Panel (Pixel)	1061.7

Table 3: CT Technique for 100 kV 2 Slit (exp2) Data

System Information	
Data Acquistion Date	Monday, April 22, 2013
System	ISA 450kV
Archive Directory	C:\ISA System\CT Data\QA Acq
Source	
X-ray Source	Yxlon 450kV D11
Effective Spot Size (mm)	Small 0.4
Energy (kV)	160
Tube Curren t (mA)	4.35
Geometric Unsharpness (mm)	0.113
Filter (Type/Thickness mm)	Al/2.0 Cu/2.0
Detector	
Detector Type	Amorphous Silicon Perkin Elmer
Source-Detector-Distance (SDD) (mm)	1413.4
Source-Object-Distance (SOD) (mm)	1102.52
Object-Detector-Distance (ODD) (mm)	312.4
X-Offset (Pixels)	309
X-Size (Pixels)	1698
Y-Offset (Pixels)	606
Y-Size (Pixels)	669
Magnification	1.282
Frame Average(s)	6
Integration Knob-Thales Only	N/A
Integration Time per Projection(sec)	0.267
Raw Pixel Size (mm)	0.2
Global Resampling	1
Effective Pixel size at Detector (mm)	0.2
Effective Pixel size at Object (mm)	0.156
CT Parameters	
Numbers of Views	401
Angular Range	200.5
Angular Step (Degrees)	0.5
Estimated PxCenterFull Panel (Pixel)	1022.7
Estimated PzCenterFull Panel (Pixel)	1061.7

Table 4: CT Technique for 160 kV 1 Slit (exp1_Open) Data

Procedures

System Alignment

Alignment of the detector panel to the tube head and determination of the beam center are described in Reference [S0].

X-ray Source Warm-up

X-ray source warm-up procedures follow the directions in the x-ray source user manual [M1].

Detector Calibration

Detector calibration procedures follow the manufacturer's instructions provided in the detector user manual [M6].

Data Acquisition

The data acquisition procedures are laid out in Reference 1. The detailed steps used for LLNL micro-CT scans are documented in Reference [S1].

References

Published Documents

1. Brown, WD, *TPXX – Data Collection and Image Reconstruction using the ISA MicroCT System*, LLNL-TR-XXXXXX, December 18, 2013.
2. Smith, JA, D. Schneberk, J. Kallman, H. Martz, Jr., D. Hoey, R. Krauss, R. Klueg, *Documentation of the LLNL, TAFB and TSL Micro-Computed-Tomography Systems*, LLNL-TR-421377 Revision 1, November 30, 2011

Standard Operating Procedures

S0 Divin, CJ, *MicroCT: Procedure for Alignment*, Lawrence Livermore National Laboratory, LEDP-MCT-SOP-010, March 14, 2013

S1 Pincus, C, *MicroCT Data Acquisition Checklist*, Lawrence Livermore National Laboratory, LLNL-TR-XXXXXX, May 1, 2013

Manuals (Manuals can be located in the ISA MicroCT Manual)

M1: UM_MG103_452 10IG15.pdf

M2: OL 4502 Yxlon New.pdf

M3: Newport XPS-C6 Users Manual.pdf

M4: Newport IMS-LM Series Linear Motor Stages_08-11.pdf

M5: Newport RV Users Manual

M6: Perkin Elmer Flat Panel Users Manual

Drawings (Drawings can be located in the ISA MicroCT Manual)

D1: Shielded Cabinet Drawings

D2: Shielded Cabinet Wiring Schematic

D3: X-ray Interlock Wiring Schematic

D4: Slit Collimator Drawings

D5: MicroCT Universal Carousel System.pdf

Appendices

Appendix 1: X-ray Anode Geometry

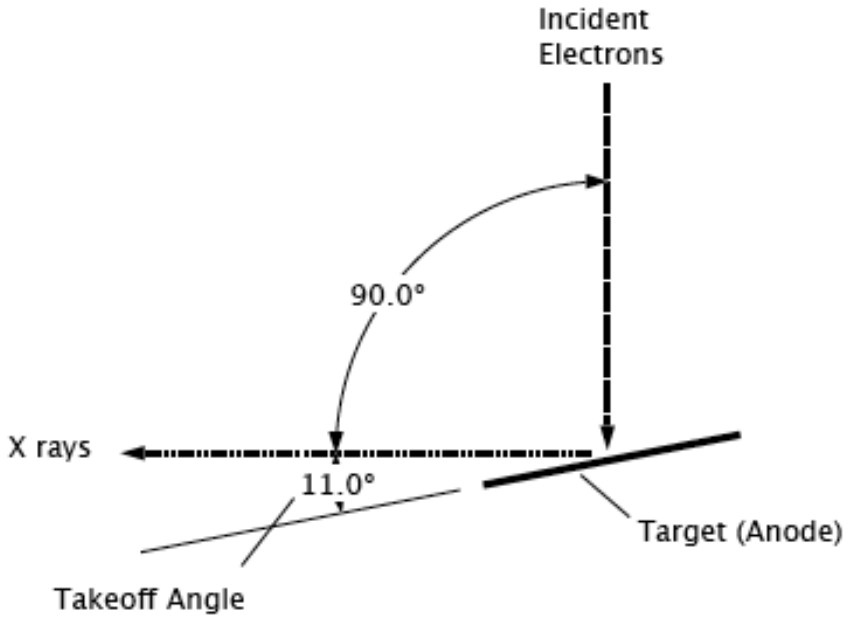


Figure 1A. The geometry of the x-ray target and the definition of "Takeoff Angle" are shown. The vector marking the exit path of the x rays, defines the "central ray" of the CT system. System alignment sets this ray normal to the surface of the detector and locates the position (row and column) of incidence.

Appendix 2: MicroCT Carousel Layout

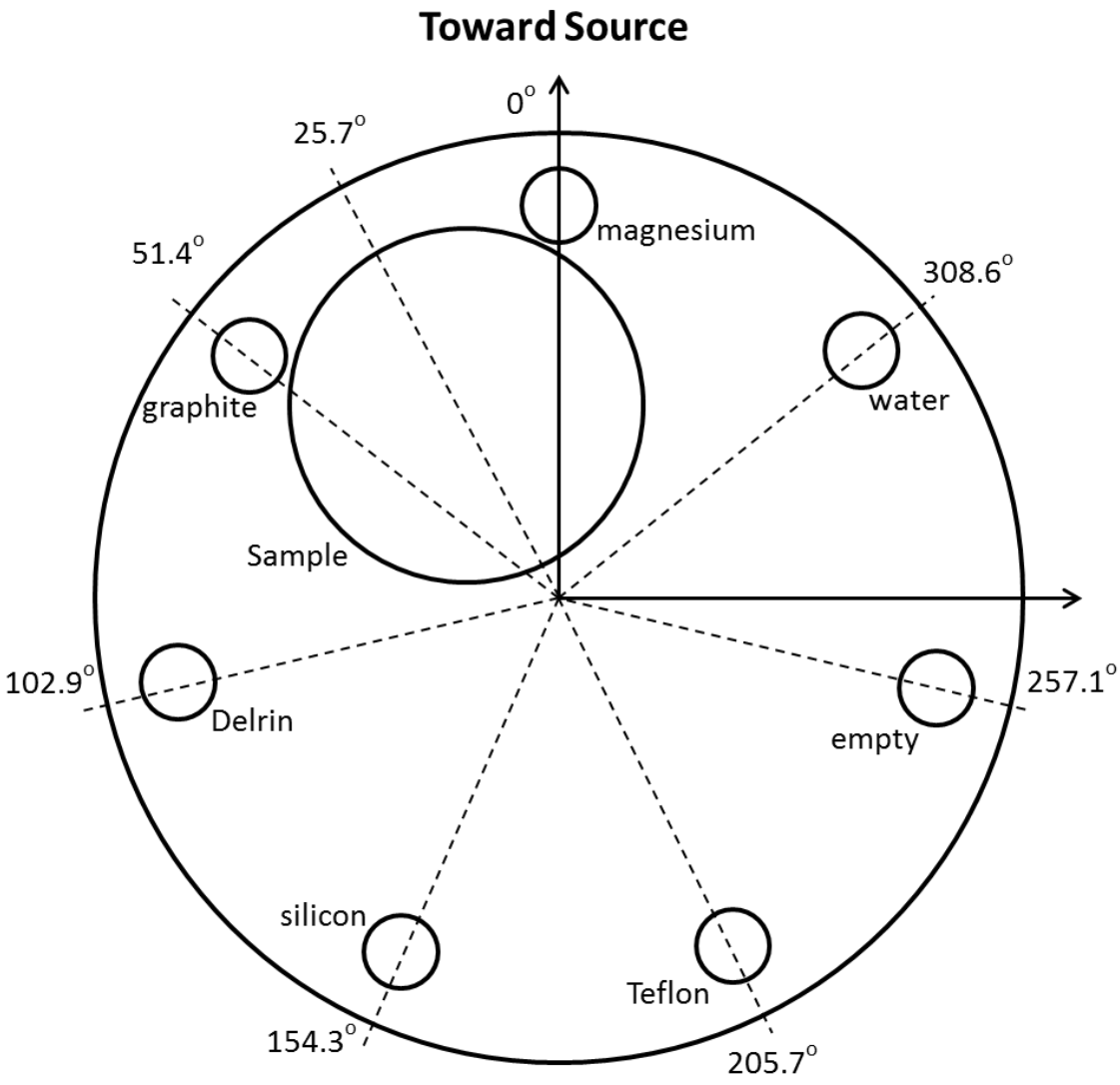


Figure 2A. Sample carousel. The carousel is viewed from above in the initial position and rotates clockwise