Development of a high-performance gantry system for a new generation of optical slope measuring profilers

Lahsen Assoufid[1], Nathan Brown[2], Dan Crews[2], Joseph Sullivan[1], Mark Erdmann[1], Jun Qian[1], Valeriy V. Yashchuk[3], Nikolay A. Artemiev[3], Daniel J. Merthe[3], Wayne R. McKinney[3], Peter Z. Takacs[4], Frank Siewert[5], Thomas Zeschke[5], Pete Jemian[1]

[1]Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Il 60439, USA

[2]ALIO Industries, 11919 I-70 Frontage Road N, Unit 119, Wheat Ridge, CO 80033, USA

[3]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA

[4]Brookhaven National Laboratory, Upton, NY 11973, USA

[5] Helmholtz Zentrum Berlin / BESSY-II, Albert-Einstein-Str. 15, 12489 Berlin, GERMANY

utline

Motivation and goals

Specification development

Gantry system and motion control

Enclosure and environment control

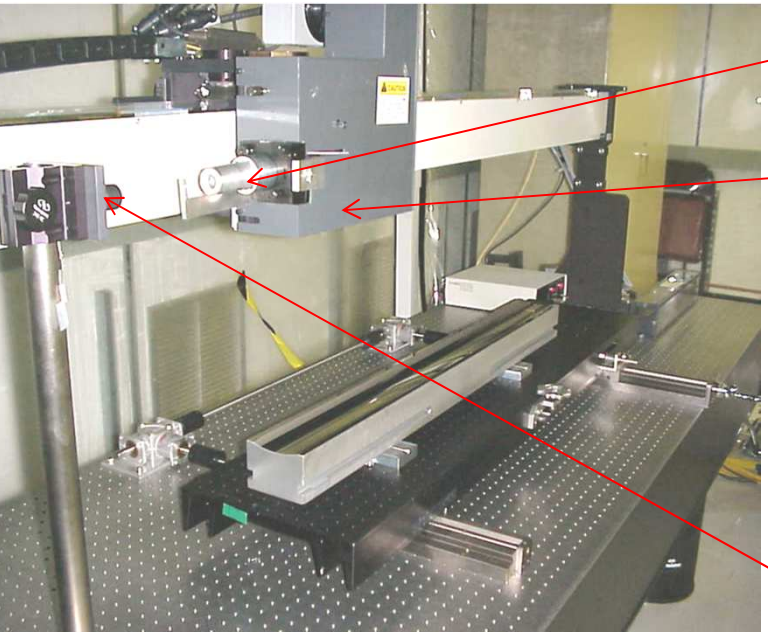
Data acquisition and analysis software

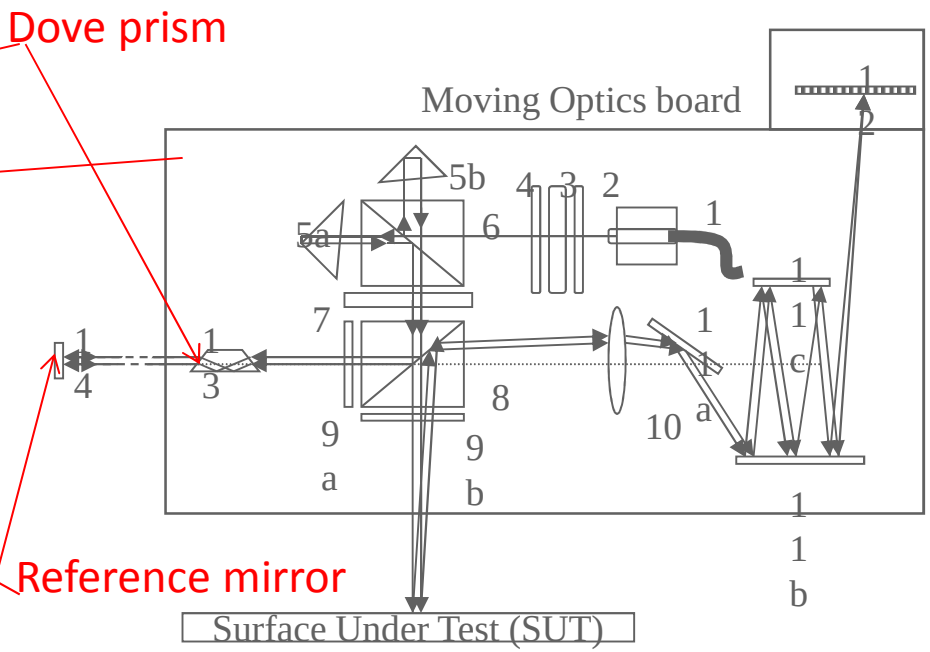
Preliminary tests and results

- Temperature survey
- Characterization of the gantry system

Summary and future work

he APS Long Trace Profiler (LTP-II)





Acquired in 1994 from Continental Optic, Inc.

Dove prism added in the reference arm in 1996 to compensate for thermal drift

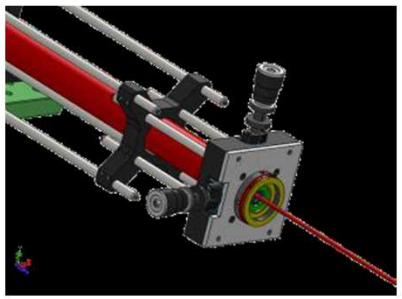
- Noise level is ≈ 0.3 urad.
- Systematic error >0.5µrad due to imperfections in the optical elements of the optics board.
- Non linearity

It is ready to retire!

step to upgrade APS LTP attempted in 2009-10 with modest budget and objective

n-Pierre Rock* and Lahsen Assoufid , APS LTP -II Upgrade Conceptual Design ort, Internal Report, Argonne National Laboratory, 2010

mmer Student 2009 and 2010, University of Maryland



Scanning Pentaprism

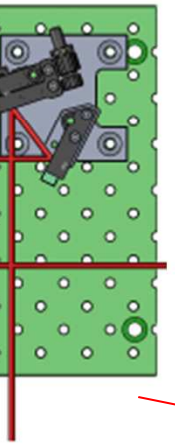


Table 2: Change in length as a function of temperature.

Δ°C	ΔL (μm)		
	Carbon steel		Granite
	min	max	
0.5	2.955	4.954	1.104
1.0	5.909	9.909	2.209

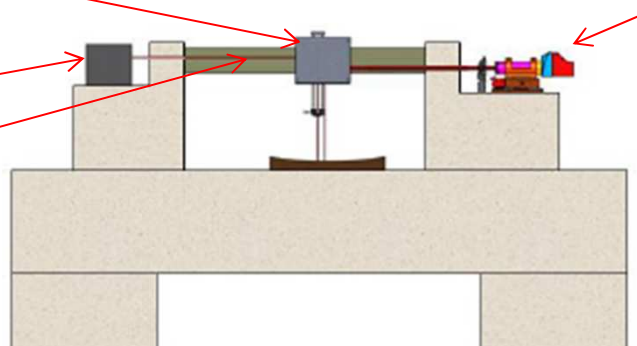
Diaphragm for the AC

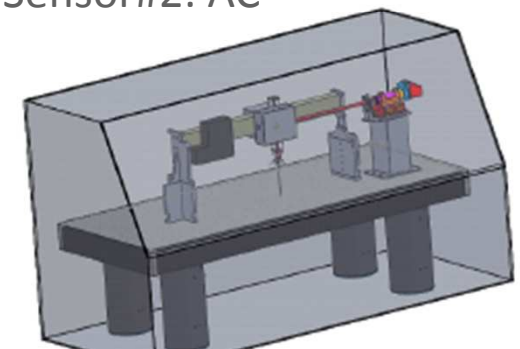
Another addition to the system could be to place a thermal enclosure for the LTP within the existing thermal enclosure of the metrology laboratory to have a more precise temperature control. An illustration of future work is shown below.

Sensor#2: AC

II Sensor#1

ng LTP-II
ic bridge





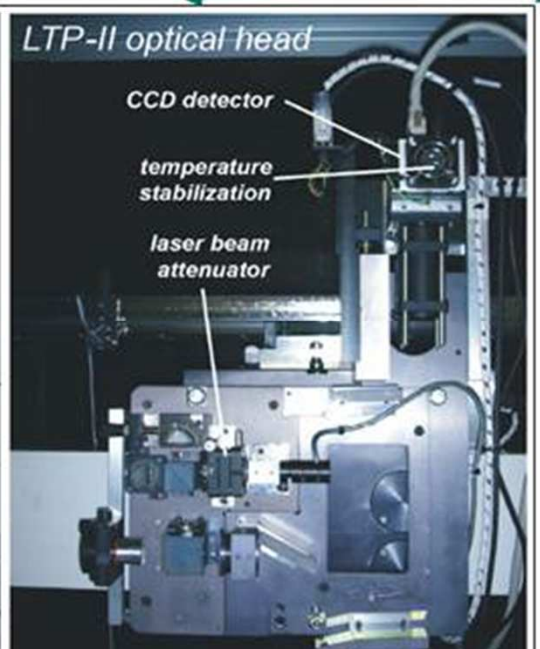
evelopment of Surface Slope Profilers at the ALS OML

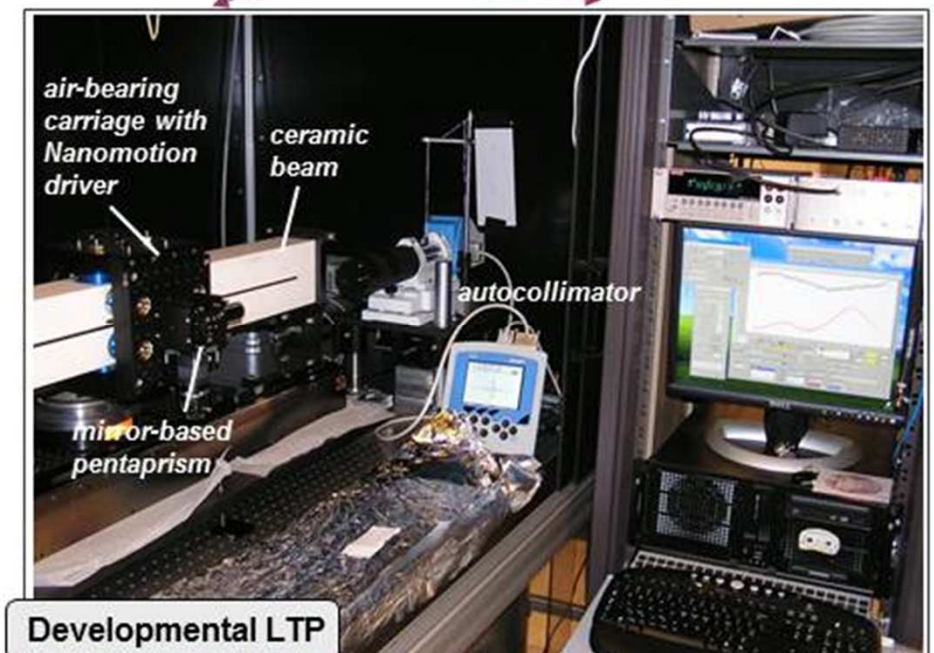
ALS ADVANCED LIGHT SOURCE

BERKELEY LAB

	~1 μrad	~0.7 μrad	~0.25 μrad	<0.2 μrad	0.1 μrad	<50 nrad
stem from l Optics heel- em	Reference arm and dual array detector, drive belt to replace wheel	Enclosures designed to reduce air convection and stabilize temperature	2D CCD detector, LabView control, and original method to reduce systematic errors	DLTP based on autocollimator, optimal scanning to suppress drift error	Precise Calibration with Universal Test Mirror is under development	OSMS - 2D slope measuring profiler a la BESSY NOM
90	1994-1995	2004	2007	2009	2010/12	20($$)$^{-1}$

d ALS LTP-II





Developmental LTP

he Development of Specification for OSMS: st meeting at LBL/ALS, March, 26 2010

Collaborative efforts of metrology groups at DOE Labs

Active participation of industrial vendors of x-ray optics and metrology instrumentation and others

Goals of the meeting:

- Discuss the development of new generation of optical slope measuring system (OSMS);
- Solidify the OSMS design approaches that will meet the needs of tight mirror specifications and also be affordable for all parties involved, both manufacturers and metrology labs; and
- Put together a common specification for fabrication of a high performance mterology gantry system for OSMS
  - Designed to accommodate multiple sensors to cover a wide range of measurement needs in 1-D and 2-D.
  - Capable of <50 nrad absolute accuracy

st Meeting at Argonne/APS, May 6, 2010

…to finalize the specifications.

Valeriy V. Yashchuk, Peter Z. Takacs, Wayne R. McKinney, Lahsen Assoufid, Frank Siewert and Thomas Zeschke “Development of a new generation of optical slope measuring profiler,” NIMA 649 (S1), 153-155 (2011)

esign of the Gantry System

Gantry system with two carriages operating is master-slave mode

- One carriage for slope sensors
- One carriage for long cables and air supply lines for the airbearing
  - Avoids cables torc and motion-induced perturbations

High precision X-linear motor driven carriage with air bearing with 1.5 m scan range:

- 50 nm step size, 50 kg capacity

High precision Y-linear motor driven mirror support table system with air bearing with 300 mm scan range:

- 50 nm step size, 100 kg capacity (to accommodate large mirror bender assemblies)

Mirror kinematic support tip/tilt table with 180 degree rotation platform, fully motorized

- Tip/tilt with 1 urad step size

Low thermal extension, highly stable granite

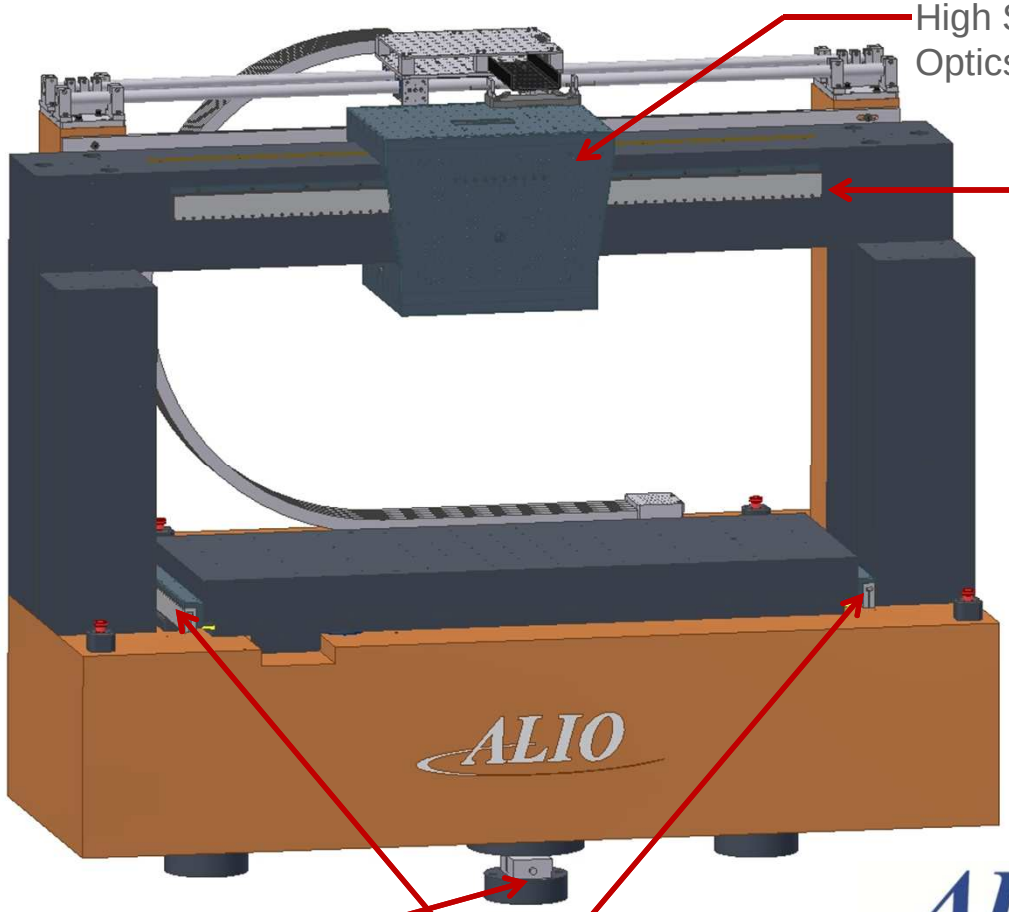
aleriy V. Yashchuk, Peter Z. Takacs, Wayne R. McKinney, Lahsen Assoufid, Frank Siewert nd Thomas Zeschke “Development of a new generation of optical slope measuring rofiler,” NIMA 649 (S1), 153-155 (2011).

he Gantry System Design

tem with separate carriages: one the sensors and one for the cables

Bearing
logy

ced Servo Control



High Stiffness, Highly Rigid, Optics Carriage.

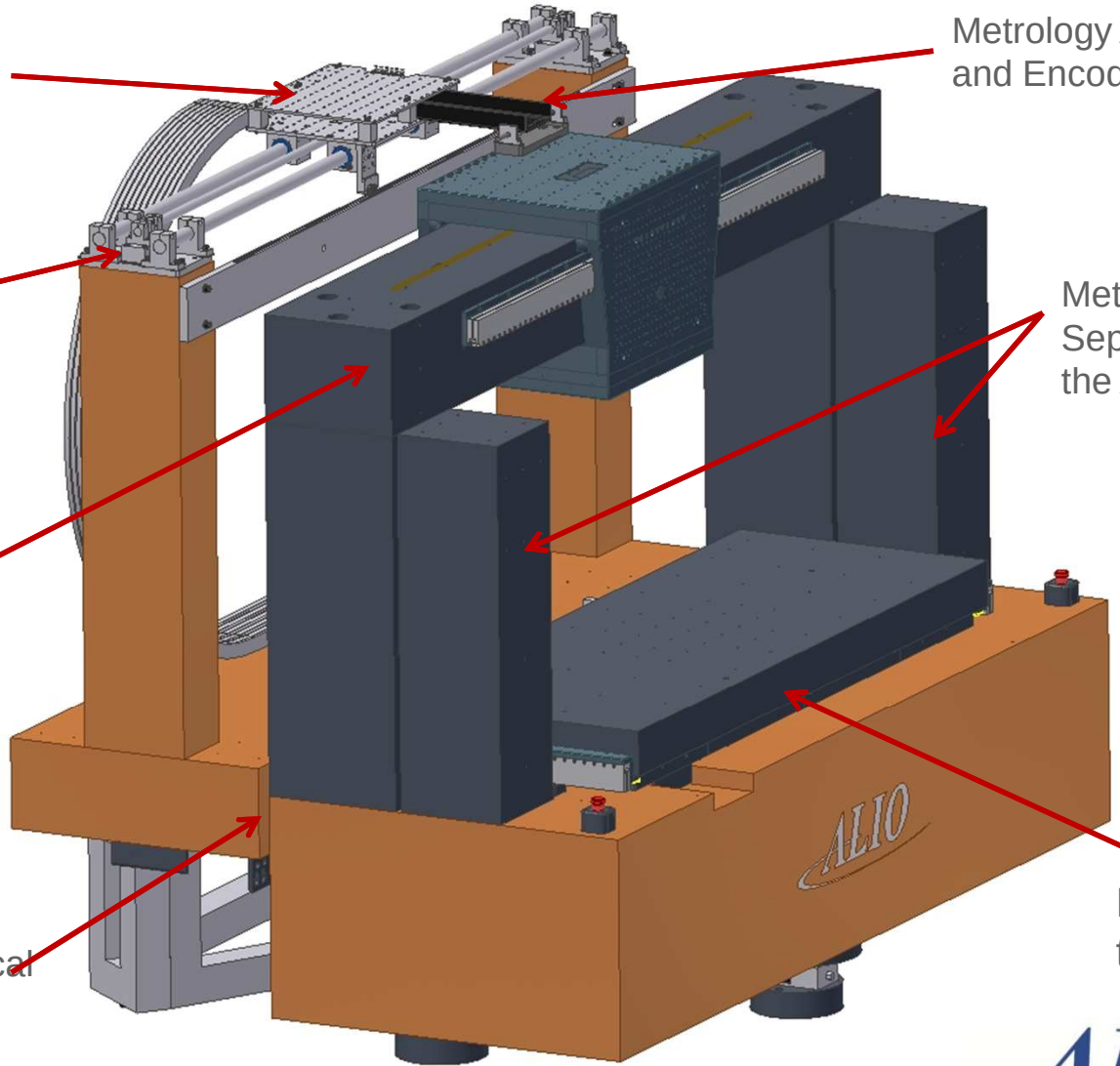
Motors (Front and Back of Granite Beam) Drive Thru the Center of the Moving Mass.

ALIO 6-D

id Kinematic Machine
l Mount for 3-Point
eling Capability.

Y – Y' Granite Platen Drives for Sub Arc-

he Gantry System Design



nal Mounting
n for Additional
dded
nality.

axis

ogy axis

xis 100%
from the Optical
e with Isolated
and Frame.

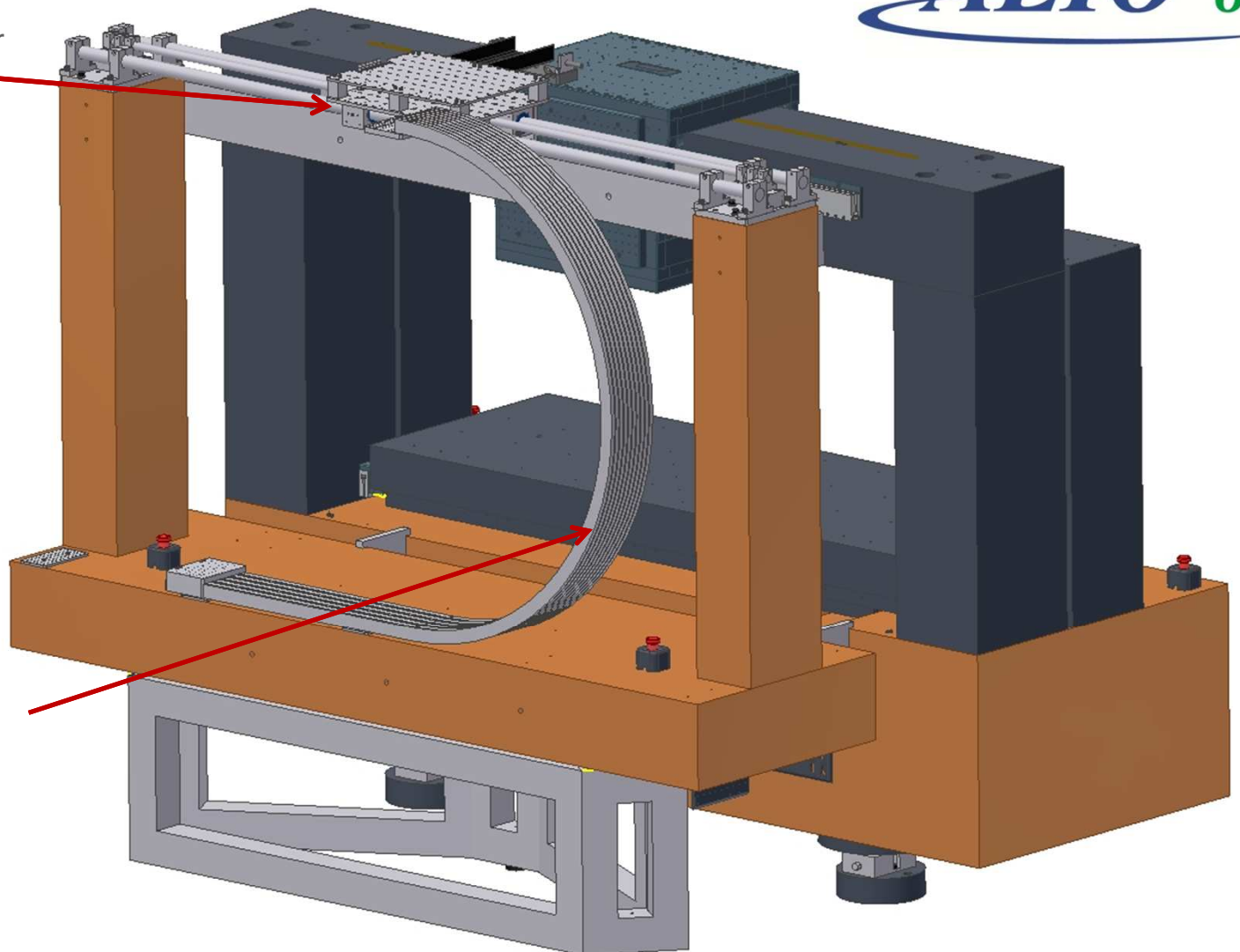
Soft / Gentle Cable Loop from Cable Axis to Metrology Axis for Motor and Encoder Cables.

Metrology Risers Separate / Isolated from the Axis / Motion Risers

Mirror granite table

he Gantry System Design

ely Separate Air
Servo Axis for
is. Axis Mirrors
f Optical
Thus Isolating
ag and
.



Radius Cable
o Minimize
ion and Drag.

livery of the gantry system: August 2011

allation Septmber 2011


ARGONNE
DRIVING

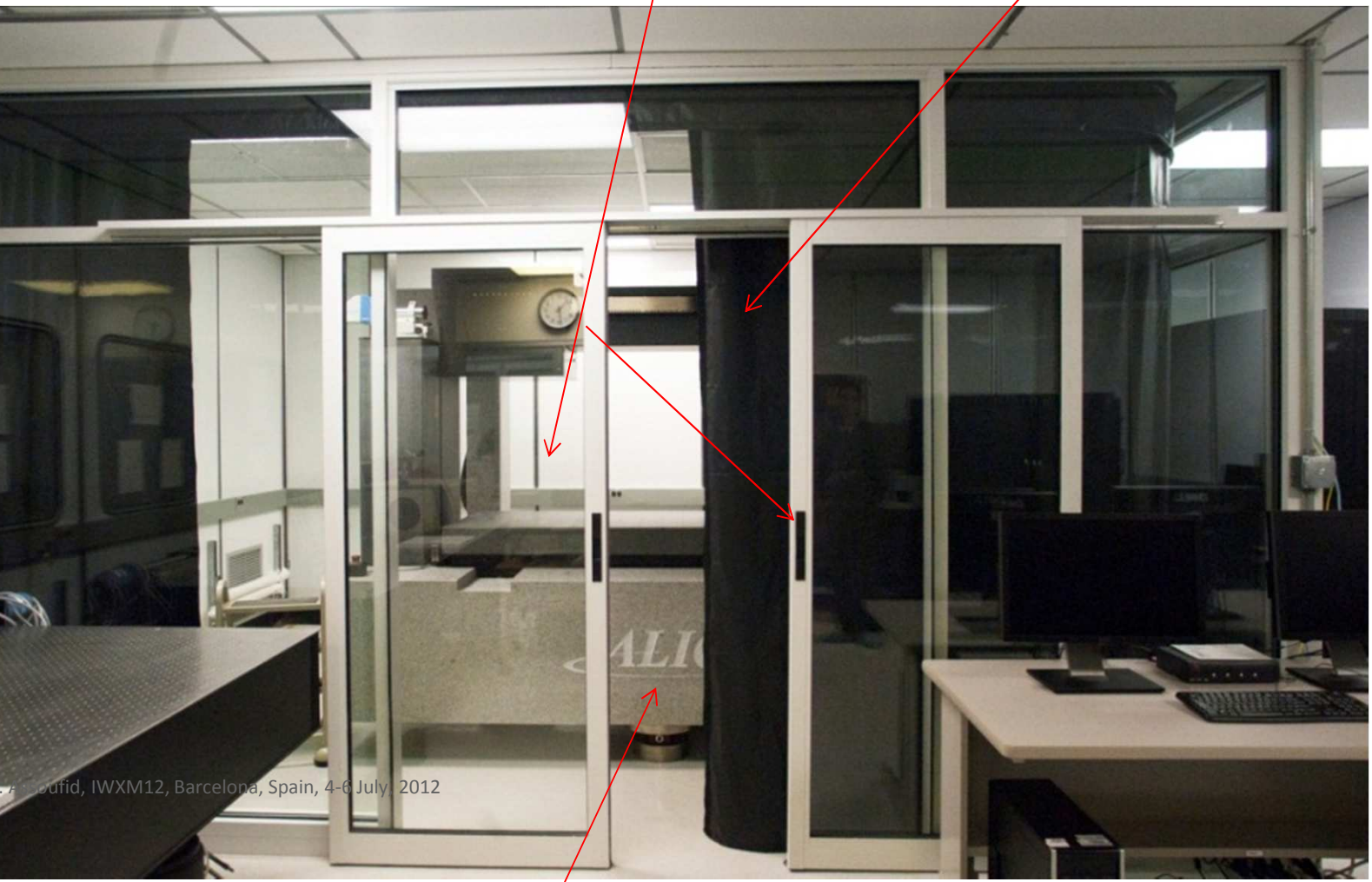

ALIO


ALIO

onstruction of the Enclosure (October 2011)

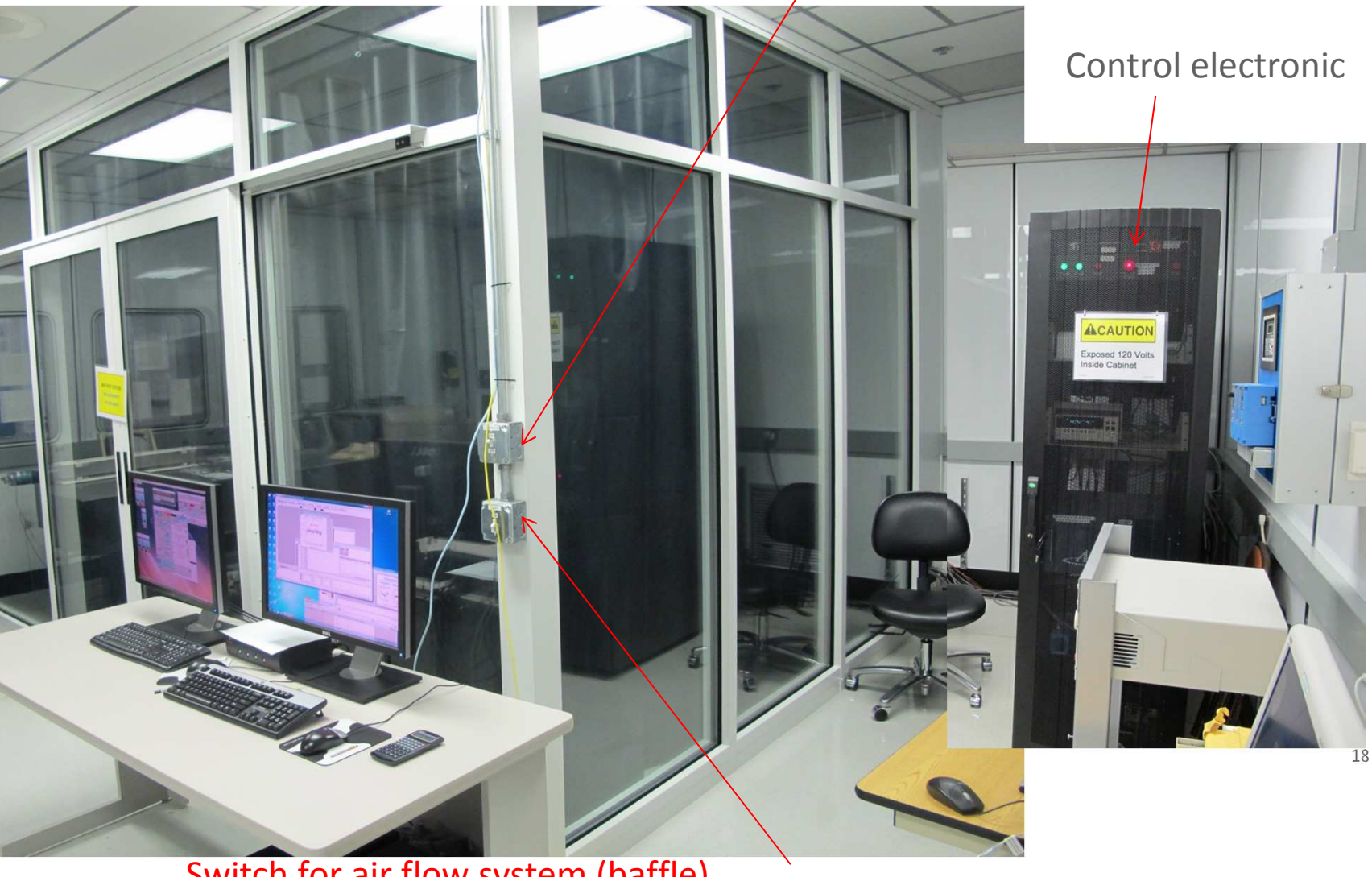
nclosure

ompleted November 2011

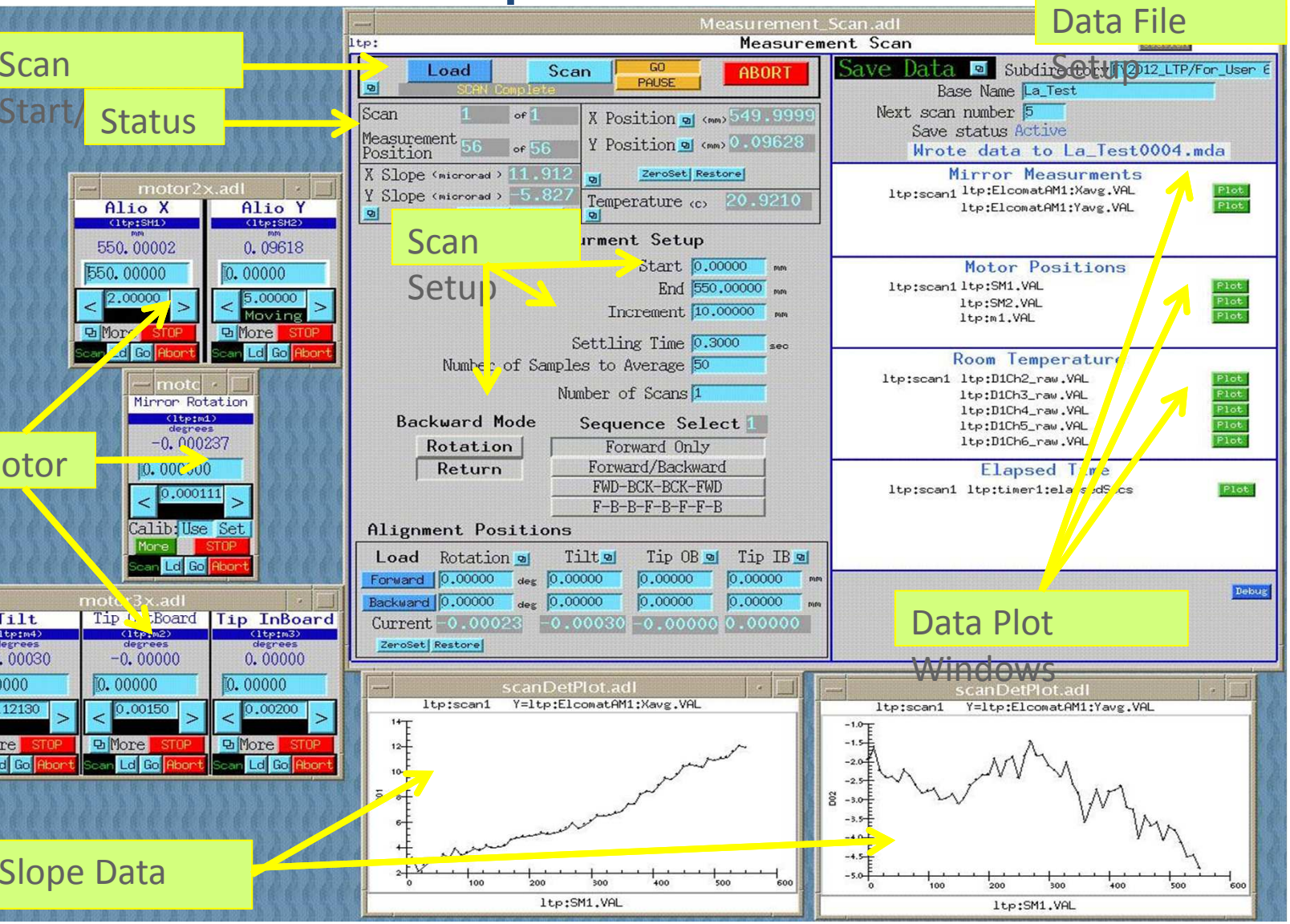


nclosure

ompleted November 2011



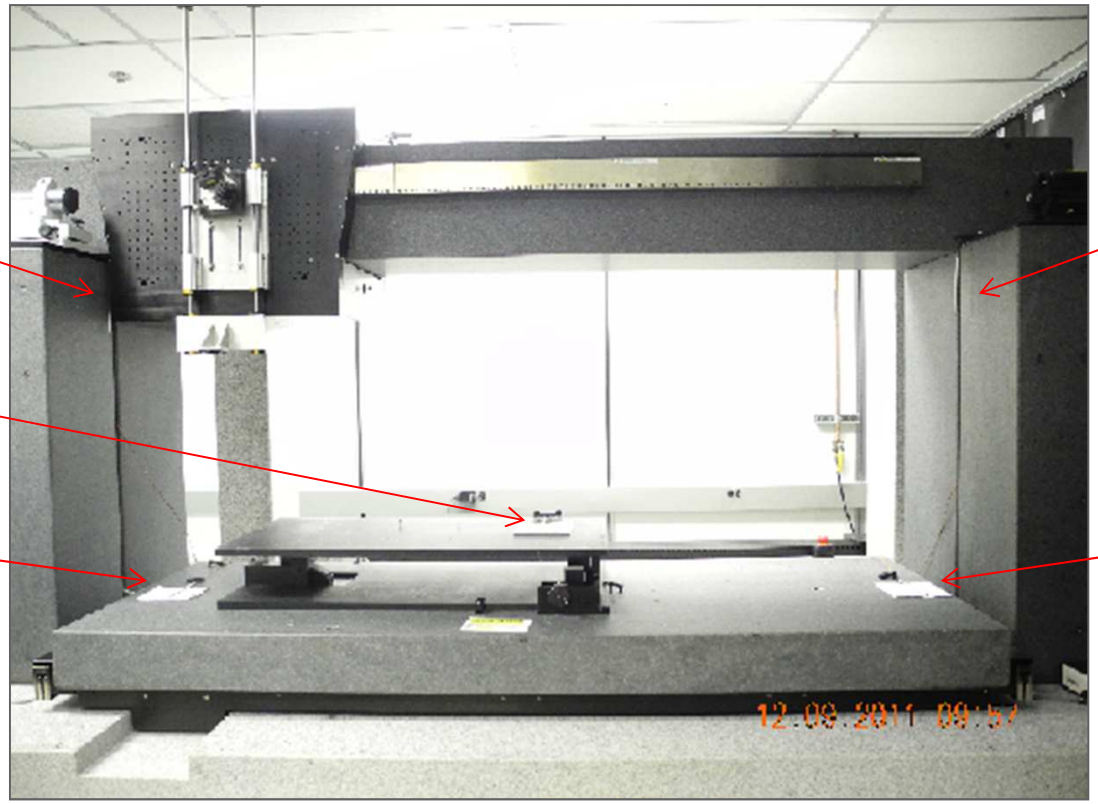
PICS-based Data Acquisition



Still under testing

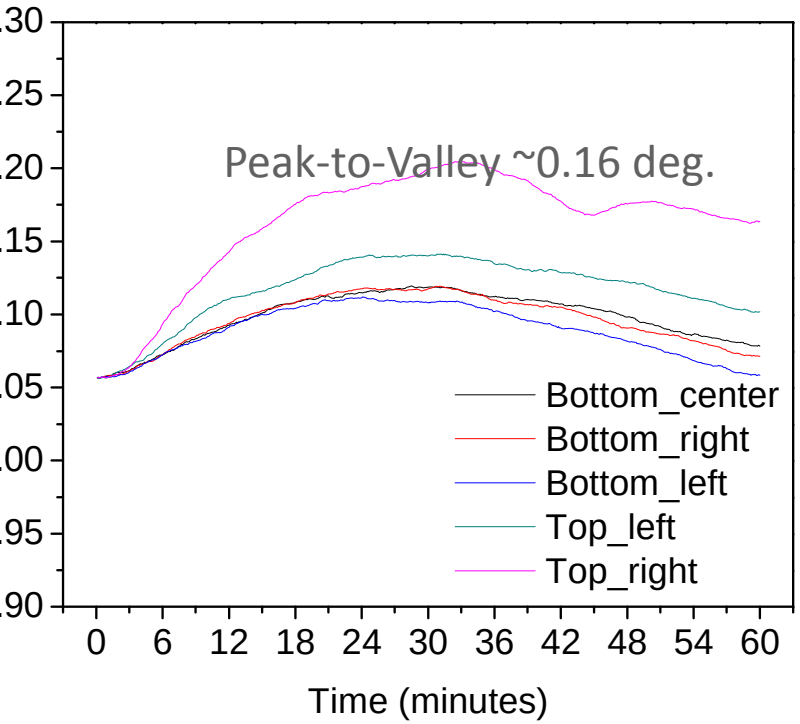
emperature monitoring and stability

- Survey with both temperature point probes (placed around the measurement volume) and an IR Camera.
- Measurements performed under various conditions and duration

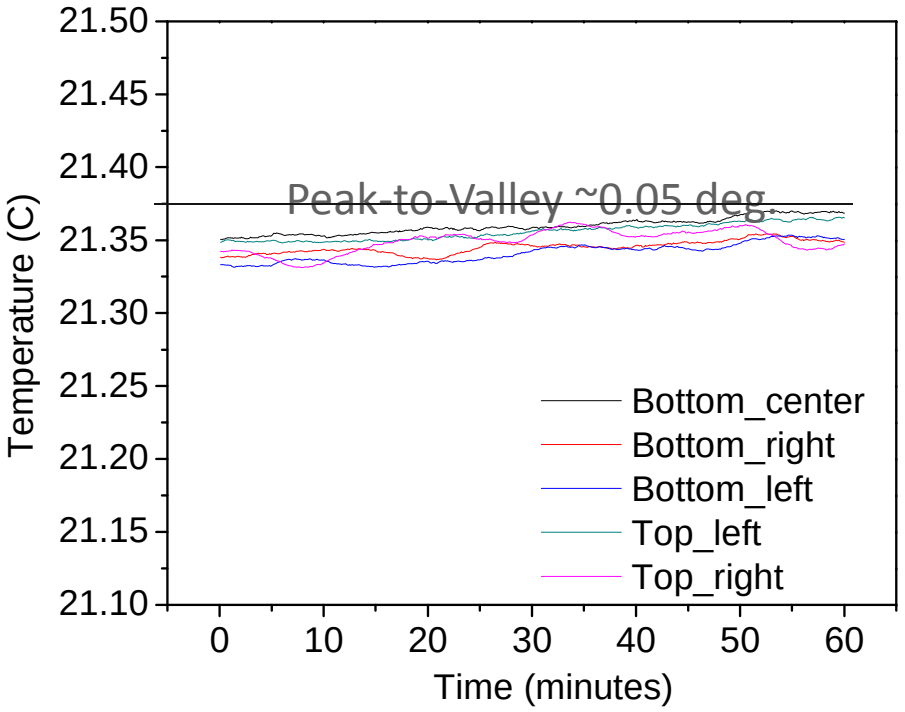


irst temperature stability survey (January 2012)

Measurement with temperature point probes over 60 minutes

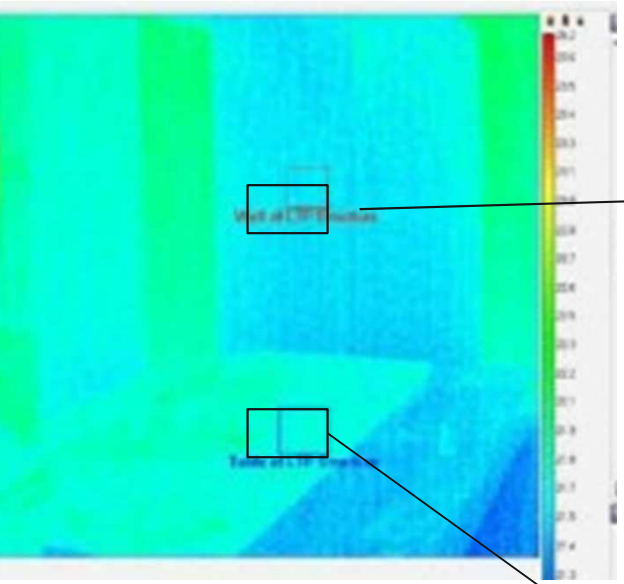


Room AC on; Enclosure AC on;
Enclosure door closed



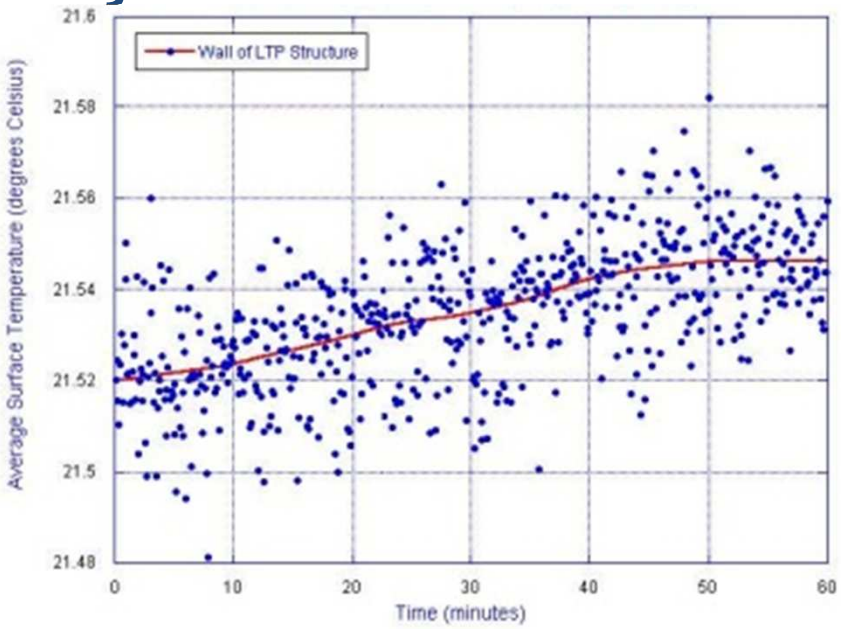
Room AC on; Enclosure AC off;
Enclosure door closed

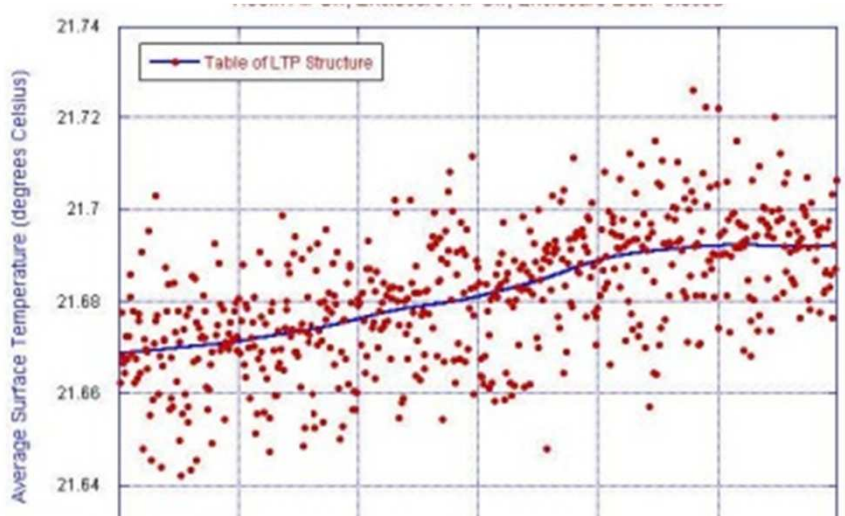
irst temperature stability survey with IR Camera



Granite Post

Granite table

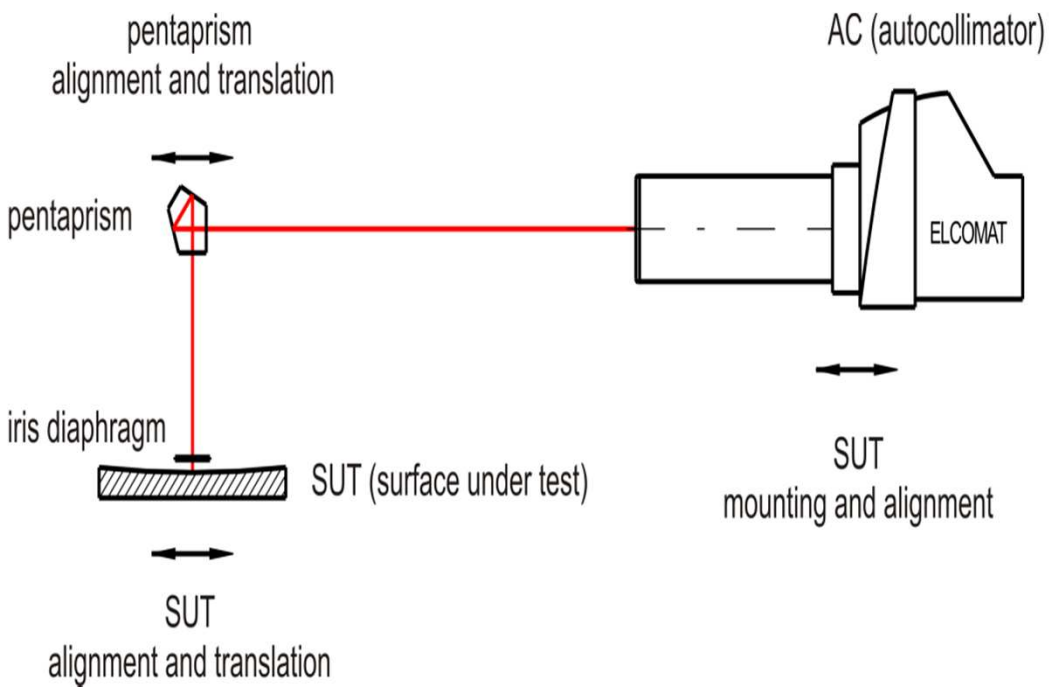




Peak-to-Valley <0.05 deg.

camera measurement (by Jeff Collins)

eliminary tests performed using an AC and a mirror ntaprism (NOM concept)



uary 2012: first measurements carried out using 350 mm Si mirror (see talk by Jun n on Friday)

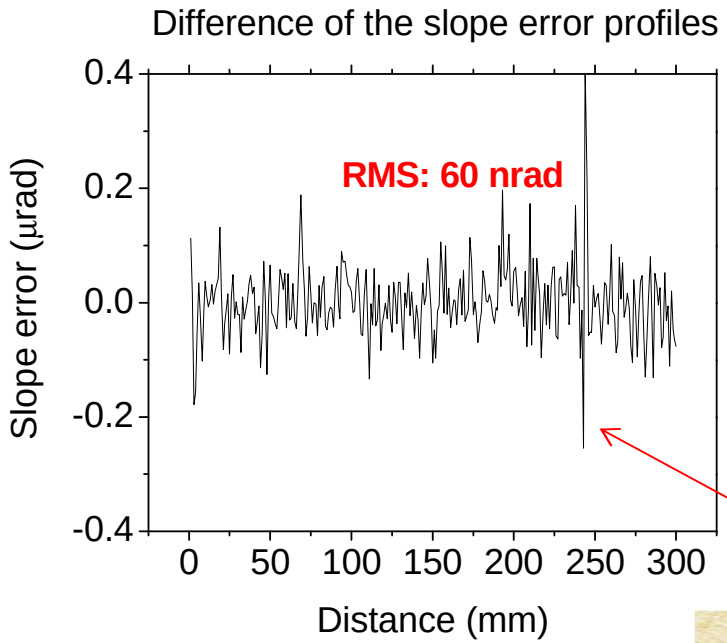
y 2012: Characterization of the gantry system (carried out in collaboration with ALS)

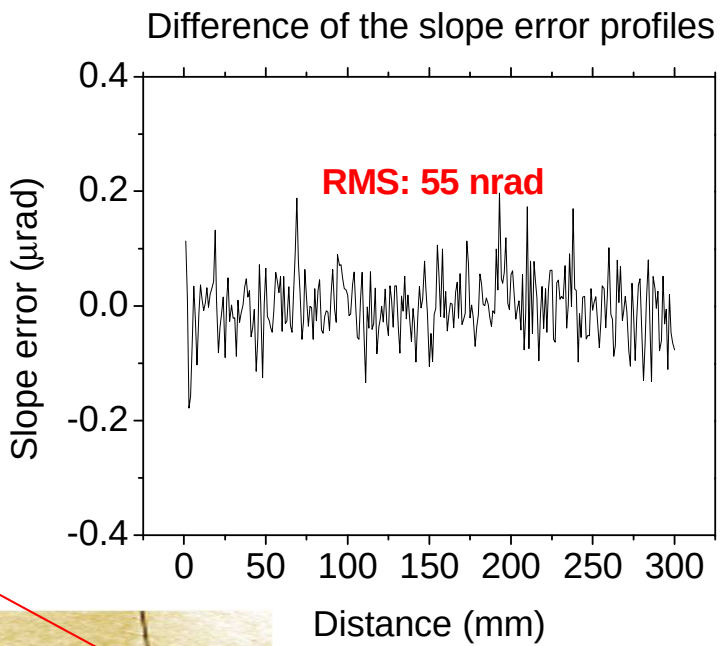
ewert, H. Lammert, T. Zeschke, Modern Developments in X-ray and Neutron Optics, ger 2008

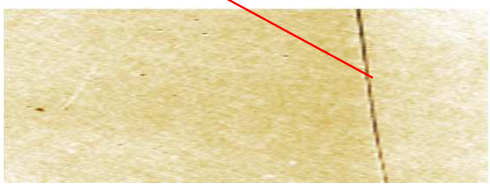
eatability measurements on 350 mm flat Si mirror

rge spike due to defect in the mirror, ssibly for positioning error

More representative with the large spike filtered …





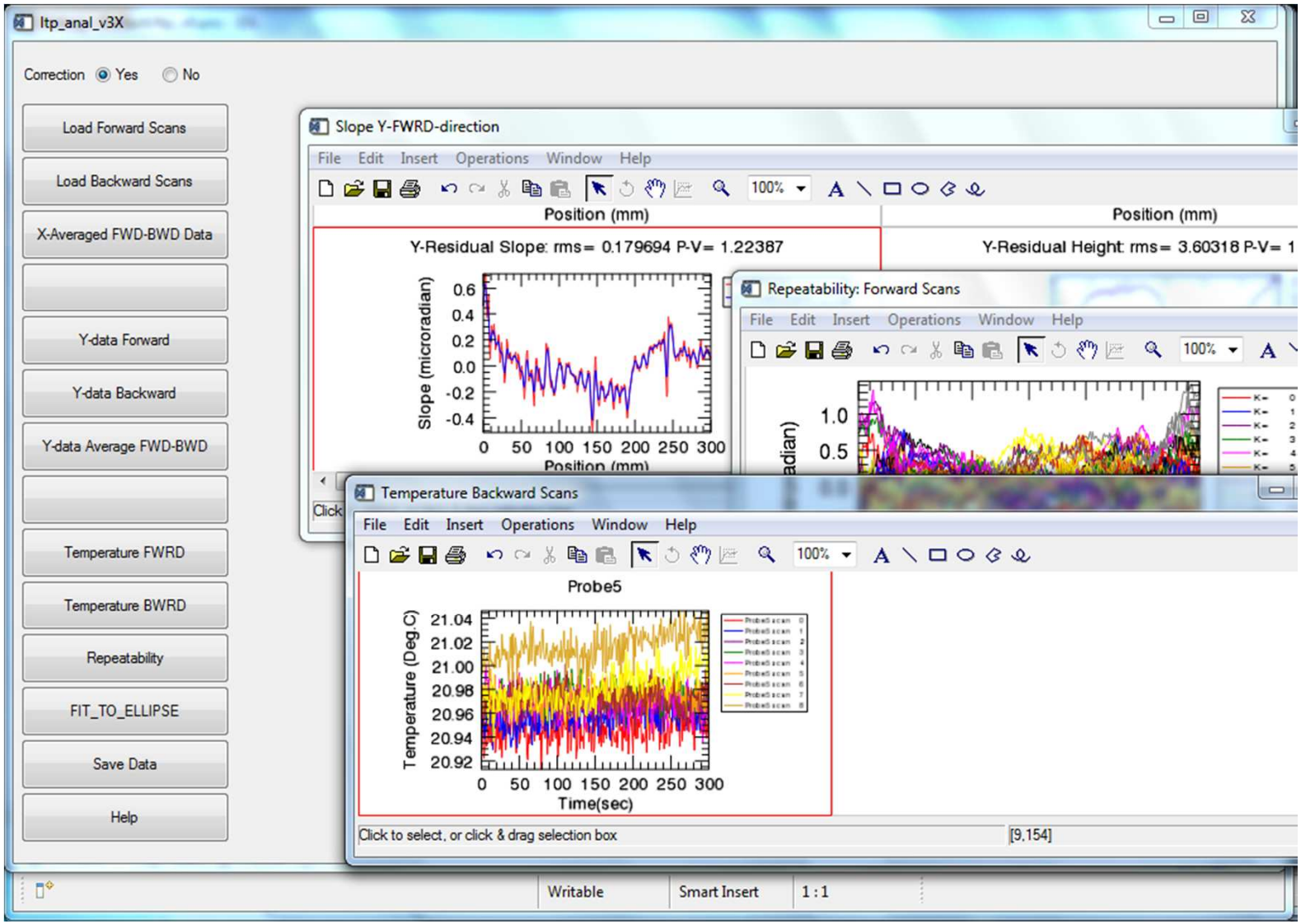


ted from J. Qian et al. Talk at this workshop)

sues to be addressed and Future Work

- Improve long term temperature stability
- Improve the data acquisition
- Develop the data analysis software
- Complete the comprehensive characterization tests initiated in May 2012 in collaboration with ALS
- Develop and integrate new slope sensors
- Develop standard calibration tools and methods
- A new series of worldwide Round robin measurements may be helpful
- Suggestion for further improvement are welcome!

nalysis Software



ummary

We developed a high-performance metrology gantry system with the goal to develop a new generation of optical slope measuring system (OSMS)

The system is designed to :

- be modular, with multi-functional translation/scanning capability
- accommodate multiple sensors to cover a wide range of measurement needs in 1-D and 2-D.
- achieve absolute accuracy <50 nrad

The first gantry system was built by ALIO Industries (USA) for APS and commissioned anuary 2012

Preliminary rounds of tests achieved satisfactory results:

- <70 nrad repeatability was obtained using the NOM configuration, thus meeting the APS goal for Phase-I of the development

Future work (Phase-II): Achieve <50 nrad absolute accuracy. This requires:

- Improving the temperature stability and data acquisition software
- Developing and implementing: 1) advanced sensors, 2) advanced calibration tools and methods, and 3) data analysis and processing software

These enhancements and others will contribute to the development of the next system to be acquired by ALS

cknowledgements

lf Geckler and Michael Shultz (PTB) : autocollimator calibration & useful interaction

non Alcok (Diamond Light Source), Amparo Vivo (ESRF) and Haruhiko Ohashi pring-8) for useful interaction

ka Bender and Curt Preissner (APS): Mechanical engineering

f Collins (APS): Temperature survey

nn Sidarous, Andy Stevens, Marvin Kirshenbaum (APS): Enclosure

Work supported by the U.S. Department of Energy, Office of Science, under ontract # DE-AC02-06CH11357

Thank you!

xtra Slides