Title	***High-precision position and motion metrology system***		
Project Requestor	Curt Preissner		
Date	2008-03-21		
Group Leader(s)	Patric Den Hartog		
Machine or Sector Manager	Denny Mills		
Category	x-ray science enablers		
Content ID*	APS_1254428	Rev. 2	3/21/08 3:17 PM

*This row is filled in automatically on check in to ICMS. See Note [1]

Description:

Start Year (FY)	**2009**	**Duration (Yr)**	

Objectives:

We propose to develop an integrated suite of mechanical motion measurement instrumentation. Unique within the APS, this resource will provide: 1) non-contact, nanometer level measurement of x-ray optic and sample positioning equipment, 2) multi-axis position and motion diagnosis, including angular displacement, 3) access to the acoustic emission and ultrasonic measurement regime for thermal-fatigue crack growth measurement[1,2], 4) offline verification of x-ray optic device performance, including *controls* diagnostics and 5) comparison between analytical models and empirical data for newly designed devices. Each of these specific items address questions brought to the attention of MED engineers through discussions with scientific staff[3] or through discussion with other engineers. The addition of these capabilities to the MED group will enable the engineering staff to better address the needs and questions of the APS, the APS user community, and other APS groups regarding x-ray instrumentation motion and position.

Benefit:

The proposed metrology system will improve motion and vibration diagnostics available to APS users. The equipment adds new capabilities and fills a hole in the mechanical diagnostic and measurement capability at the APS left by out-of-date and unsupported instrumentation. Development of this engineering resource will specifically benefit the APS mission by:

- facilitating correlation of x-ray beam motion to optic motion through the use of non-contacting and/or in vacuum sensors,
- capturing the non-constant influences affecting instrumentation, such as foot falls and day/night cycles,
- enabling offline mechanical diagnostics and motion profiling of instrumentation such as microprobes and diffractometers,
- empirically defining operating limits for current and future photon absorbers through the leveraging of acoustic crack growth monitoring, and
- verifying of x-ray instrumentation mechanical performance during the prototype

phase, similar to verification of thermal analyses.

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Risks of Project: See Note [2]

There will be no adverse affects on other systems.

Consequences of Not Doing Project: See Note [3]

If development of this metrology capability is *not* pursued the potential repercussions include:

- underserved users, through the inability of the engineering staff to best address their motion measurement needs,
- the inability to adequately diagnose and verify the performance of motion systems, and
- the neglecting of a potential avenue for in-situ thermal-fatigue crack growth monitoring.

Cost/Benefit Analysis: See Note [4]

The estimated non-effort cost of this project is approximately $150K, spent over a three year period. The modest yearly investment of about $50K could mitigate significant effort and equipment costs. Diagnosis of instrument instability could raise beamtime efficiency in specific cases for scanning probe and diffraction experiements[3]. Instrument vibration stability specifications could be set and verified for both in-house instruments and vendor sourced instruments. Development of definitive high heatload RSS component monitoring could reduce the cost of spares and maintenance.

Description:

The key items in the offline *and* in-situ measurement suite are a high quality air-isolated optic table, a non-contacting, micro-focusing Laser Doppler Vibrometer (LDV), a 24 bit, large dynamic range vibration data acquisition system, and a servo and stepping motion control system. The non-contacting LDV will provide high precision (.015nm) and large dynamic range (±50mm) mechanical measurements up to 2.5 MHz. We are not aware of hardware currently at the APS with this capability. The proposed 24 bit vibration data acquisition system has a dynamic range of about 150 dB, superior to current hardware at the APS. Software will provide spectral analysis, modal analysis, and motion control for offline testing. The modal analysis software will replace unsupported and out-of-date software that the APS currently owns. The proposal includes a new complement of very quiet (.01 µg/√Hz vs. .09 µg/√Hz of noise for current sensors), vacuum-compatible accelerometers and a three-axis seismic accelerometer.

These instruments provide a comprehensive in-situ and offline position/motion analysis system. Specifically, the LDV may be useful for in-situ, thorough view port vibration measurements and novel measurement of thermal-fatigue crack growth. Acoustic emission in the ultrasonic range (>25 KHz) is associated with micro-crack onset and growth[1] and the LDV can measure the small transient motions associated with these events. Ultrasonic acoustic methods may facilitate monitoring of RSS photon absorbers, allowing for operation at higher power levels, while monitoring micro-crack growth. This is a nondestructive, online technique that can potential detect micro-cracks not previously detectable by the optical techniques used at the APS or other accelerators[4,5].

Multi axis accelerometer based measurements will be able to be made in a more efficient matter, with a lower noise floor than with current instrumentation at the APS. The six vacuum compatible transducers would be used along with the LDV and a new high-sensitivity (DC to 100Hz), three-axis seismic accelerometer to correlate floor, instrument, and beam motions. The behavior of such devices as flexure based K-B mirror systems or other fine focusing x-ray optics can be measured in a single axis to the sub-nanometer level using the LDV and in multiple axes to the nanometer level using the accelerometers.

Funding Details

Cost: ($K)
Use FY08 dollars.

Year	AIP	Contingency
1	$75,000	
2	$37,500	
3	$37,500	
4		
5		
6		
7		
8		
9		
Total	$150,000	$10,000

Contingency may be in dollars or percent. Enter figure for total project contingency.

Effort: (FTE)
The effort portion need not be filled out in detail by March 28

Year	Mechanical Engineer	Electrical Engineer	Physicist	Software Engineer	Tech	Designer	Post Doc	Total
1	0.10							0.1
2	0.10							0.1
3	0.10							0.1
4								0
5								0
6								0
7								0
8								0
9								0

References

1. Williams, R. V. (1980). *Acoustic Emission*. Bristol, England: Adam Hilger Ltd.
2. Rokhlin, S. I., J.-Y. Kim, B. Xie, and B. Zoofan (2007). "Nondestructive sizing and localization of internal microcracks in fatigue samples." *NDT &E International*, 40, p462-470.
3. Holt, M. Discussion with the Project Requestor on 2008-03-07.
4. Ravindranath, V. (2006). *Thermal Fatigue of Glidcop AL-15*. Unpublished Dissertation, Illinois Institute of Technology, Chicago.
5. Kuzikov, S. V., & Plotkin, M. E. (2008). Theory of thermal fatigue caused by RF pulsed heating. *International Journal of Infrared and Millimeter Waves*, 29(3), 298-311.

Notes:

[1] **ICMS**. Check in first revision to ICMS as a *New Check In*. Subsequent revisions should be checked in as revisions to that document i.e. C*heck Out* the previous version and C*heck In* the new version. Be sure to complete the *Document Date* field on the check in screen.

[2] **Risk Assessment.** Advise of the potential impact to the facility or operations that may result as a consequence of performing the proposed activity. Example: If the proposed project is undertaken then other systems impacted by the work
include ... (If no assessment is appropriate then enter NA.)

[3] **Consequence Assessment.** Advise of the potential consequences to the facility or to operations if the proposal is not executed. Example: If the proposed project is not undertaken then ____ may happen to the facility. (If no assessment is appropriate then enter NA.)

[4] **Cost Benefit Analysis.** Describe cost efficiencies or value of the risk mitigated by the expenditure. Example: Failure to complete this maintenance project will result in increased total costs to the APS for emergency repairs and this investment of ___ will also result in improved reliability of ____. (If no assessment is appropriate then enter NA.)