Title	***Very High Heat Load R&D***			
Project Requestor	Bran Brajuskovic, Curt Preissner, Yifei Jaski, and Jeff Collins			
Date	2008-03-16			
Group Leader(s)	Patric Den Hartog			
Machine or Sector Manager	Rod Gerig			
Category	Accelerator R&D			
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*This row is filled in automatically on check in to ICMS. See Note [1]

Description:

Start Year (FY)	**2009**	**Duration (Yr)**	**3**

Objectives:

We propose initiating a comprehensive very high heat load experimental research and development project to keep the pace of development for synchrotron radiation components with that of synchrotron radiation sources. This commensurate development of engineered components is necessary to achieve the machine capabilities outlined for APS2020. Our recent research[1] revealed that traditional techniques can keep thermal stresses in beam intercepting components within acceptable limits for 3.3-cm period insertion devices up to 5 m long (K=2.62) and with beam current up to 200 mA. Any further increase in beam power cannot be accommodated with the traditional techniques. Nevertheless, future upgrade plans for the APS and for synchrotron sources throughout the world rely on increasing the photon beam brightness by increasing the stored beam current and the length of insertion devices. If these facilities are to fulfill the increased expectations of users, new means of handling the higher thermal loads must be found.

The objectives of the comprehensive research and development project are:

1. to empirically develop criteria for safe and reliable beam intercepting component designs and operating conditions,
2. to perfect component designs that use novel materials with superior thermal, optical and mechanical properties, and
3. to expand the base of applicable design materials through the investigation of the reaction of new materials with promising thermal, optical and mechanical properties when exposed to the very high density heat loads in the HV-UHV environment.

Benefits:

The benefits of the project are as follows:

1. Empirically determined design and operational criteria that will lead the APS to higher reliability in machine operation, reduced component production costs, reduced maintenance costs, and reduced space needed for the beam intercepting components.
2. Designs based on the empirically determined criteria will prevent catastrophic failures of beam intercepting components resulting personnel radiation exposure.
3. The necessary research to develop the criteria will proceed off-line, under controlled conditions posing no risk to existing APS installations. Furthermore, the off-line work

will negate the need for research beamtime.

4. Production of diamond exit windows that can operate at high heat loads, preserve beam coherence, and reduce x-ray scattering.
5. Demonstration of the performance of new materials that will allow APS engineers to meet the ever-increasing requirements for more reliable, more space efficient and more durable designs of the components for the synchrotron radiation facilities.

Risks of Project: See Note [2]

If this type of research is performed in-situ there is a risk of damaging beamline equipment. The off-line approach will eliminate any risk of synchrotron radiation equipment damage. The absence of synchrotron radiation will eliminate any risk of personnel radiation exposure. The hazards associated with the laser sources will be mitigated through strict regard of ISM.

Consequences of Not Doing Project: See Note [3]

If realization of this project is *not* pursued, the repercussions include:

- Decreased overall reliability of APS, through the inability of the engineering staff to provide the best possible new designs and the most favorable operating conditions for existing components,
- Beamlines that have beryllium windows will not be able to handle the high heat loads from longer undulators and higher current,
- Underserved users due to the inability of the engineering staff to perfect some of the very promising new designs based on the utilization of novel materials (i.e. diamond window at double undulator beam lines), and
- Limited and delayed upgradeability of APS through the inability of the engineering staff to meet increased performance requirements that will inevitably follow the upgrades of APS.

Cost/Benefit Analysis: See Note [4]

The estimated non-effort cost of this project is approximately $200K, spent over a three year period. The modest yearly investment of about $65K could significantly reduce the turn-over time in the design of more reliable and more efficient beam intercepting components.

Description:

The project will be divided in three phases. The initial phase is the building of an off-line experimental set-up that would enable the production of very high heat loads with in-situ monitoring of component failure modes (see [APS Project Proposal - High-precision position and motion metrology system](#)). These heat loads would create thermal gradients and stresses in the samples that are similar to those in the beam intercepting components[2]. The experimental set-up will consist of three units, a continuous-wave high power laser unit, a vacuum chamber with a sample holder, and the data acquisition system. State-of-the-art high-power fiber lasers can provide up to 200 W loads. When focused to a 1.25mm by 1.25mm or smaller footprint, the combined beams from two such devices will produce thermal gradients and thermal stresses similar to those in the beam intercepting components. The vacuum environment will provide heat transfer conditions similar to beamlines by eliminating convective heat transfer and chemical interaction of the hot sample with air. The orientation of the sample will be controllable facilitating the investigation of the influence of the incidence angle on the thermal gradients and thermal stresses. The spectral infrared radiation intensity and subsequent temperature distribution on the sample surfaces will be measured using an existing radiometer system. With micron-level pixel resolution, better than 25 millikelvin temperature sensitivity, and a 50,000 frame per second image rate, the radiometer system is ideally suited for the data collection. This phase will culminate with an off-line, very high density heat load test cell.

The second phase will address the design of the diamond windows. This phase will proceed simultaneously and independently from the first phase. Currently there are only a few vendors in Europe that can produce a limited number of diamond window designs[3]. No vendors exist in US with these capabilities. Vendors have difficulty successfully brazing and sealing the 0.1mm thick diamond windows to copper cooling bodies. We need to collaborate with potential US vendors to develop diamond window brazing and sealing techniques. The second phase will be complete after the domestic production of a few prototype windows.

The third phase of the project will use the experimental set-up to establish beam intercepting component design criteria and characterize the thermal-mechanical response of novel beam intercepting materials when subject to very high density heat loads. Long-term cyclic thermal fatigue data will be acquired for typical beam intercepting materials such as Glidcop. These data will help APS engineers understand how parameters such as surface finish, peak temperature, thermal gradient, and peak stress values influence the fatigue life of these materials. This understanding may allow relaxation of component design limits, extension of existing component life, and operation of the components at higher APS beam power levels. Characterization of novel beam intercepting components will include measurement of the thermal-mechanical behavior of chemical vapor deposition (CVD) SiC, CVD diamond, and pyrolytic graphite. These are promising materials for use as thermal-mechanical interfaces, heat sinks, and heat spreaders[4,5]. After the initial questions from phase three are answered, the test cell will be used to answer subsequent engineering questions.

Funding Details

Cost: ($K)
Use FY08 dollars.

Year	AIP	Contingency
1	$90,000	
2	$70,000	
3	$40,000	
Total	$200,000	$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	1	0.15		0.15	0.5	0.5	0.5	2.8
2	0.5				0.25	0.15	1	1.9
3	0.5				0.25		1	1.75
4								0
5								0
6								0
7								0
8								0
9								0

References

1. Jaski, Y. (2004). New front-end design for multiple in-line undulators at the advanced photon source. *Synchrotron Radiation Instrumentation, 705*, 356-359.
2. Ravindranath, V. (2006). *Thermal Fatigue of Glidcop AL-15*. Unpublished Dissertation, Illinois Institute of Technology, Chicago.
3. Jaski, Y. and Cookson, D. (2007). Design and application of CVD diamond windows for x-rays at the Advanced Photon Source. *Synchrotron Radiation Instrumentation, Pts 1 and 2, 879*, 1053-1056.
4. Brajuskovic, B, Collins, J., Den Hartog, P., and Gruen, D. (2007). Use of CVD Diamond in the Design of Synchrotron Devices Designed to Withstand Extreme Heat Loads. APS Users' meeting.
5. Collins, J., Brajuskovic, B., Preissner, C., Jaski, Y., Benson, C., and Den Hartog, P. (2007) High Heat Load R&D for Front Ends. 2007 Basic Energy Sciences Facility Review.

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.)