Advanced Photon Source - Upgrades and Improvements*

Horst W. Friedsam, Jaromir M. Penicka
Argonne National Laboratory, Argonne, Illinois, USA

1. INTRODUCTION

The APS has been operational since 1995. Recently upgrades leading to major improvements for the machine operation have been implemented. In addition, a new particle beam lattice to further improve the beam stability is being implemented, requiring extensive survey and alignment support.

2. OPERATION MODES

Today almost all synchrotron light sources are operated in decay mode that results in the characteristic saw tooth pattern of the current history shown in Figure 1.

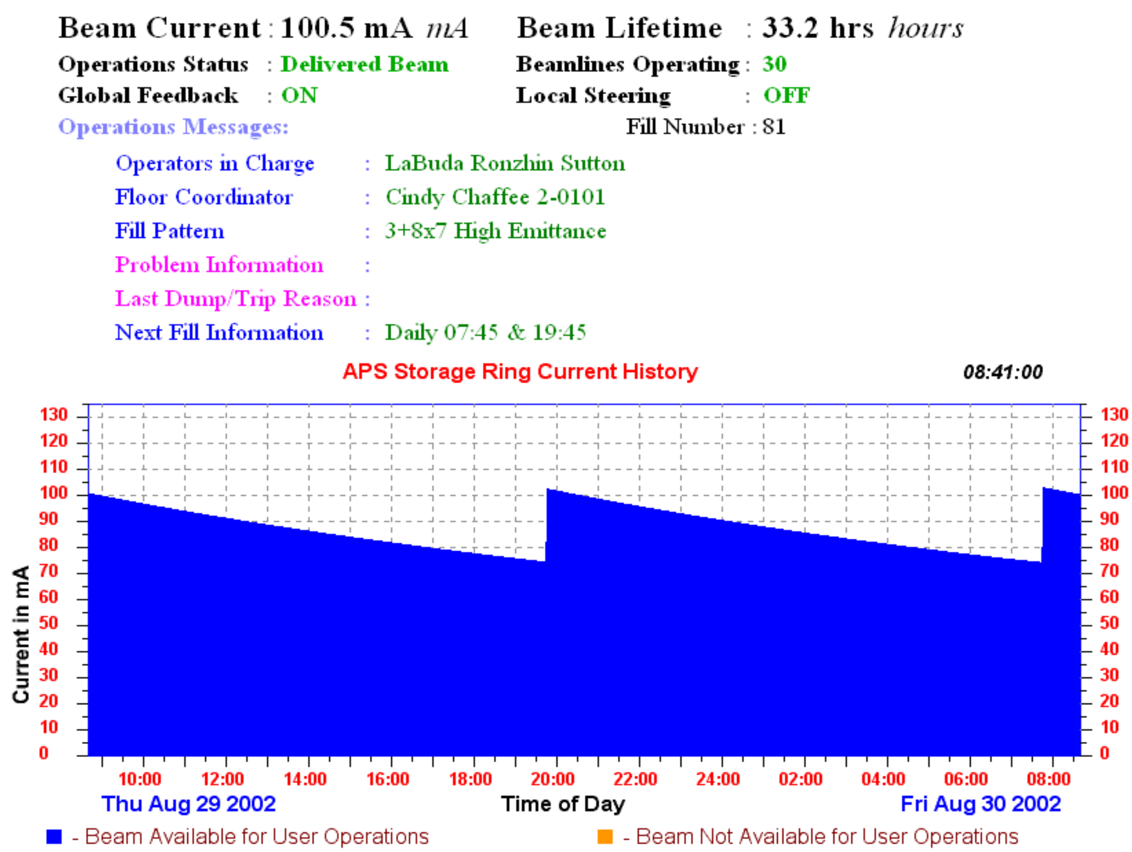

Fig. 1 APS storage ring beam current history in decay mode

* Work supported by U.S. DOE, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

Here a typical fill pattern of the APS storage ring is shown with a fill to 100 mA every 12 hours. In this case the lifetime of the fill is 33.2 hours before the particle beam decays to approximately 50 mA.

With every fill the accelerator components, in particular the vacuum chambers and the beamline user equipment including the target samples, undergo a thermal cycle. In contrast to this operational mode, top-up provides a thermally more stable environment that benefits the users of the APS. In this mode the APS storage ring is filled every 2 minutes to 102 mA, which keeps the beam current at that level with an accuracy of ± 0.1 mA creating a virtually infinite lifetime. Figure 2 shows the current history when operating the APS in top-up mode.

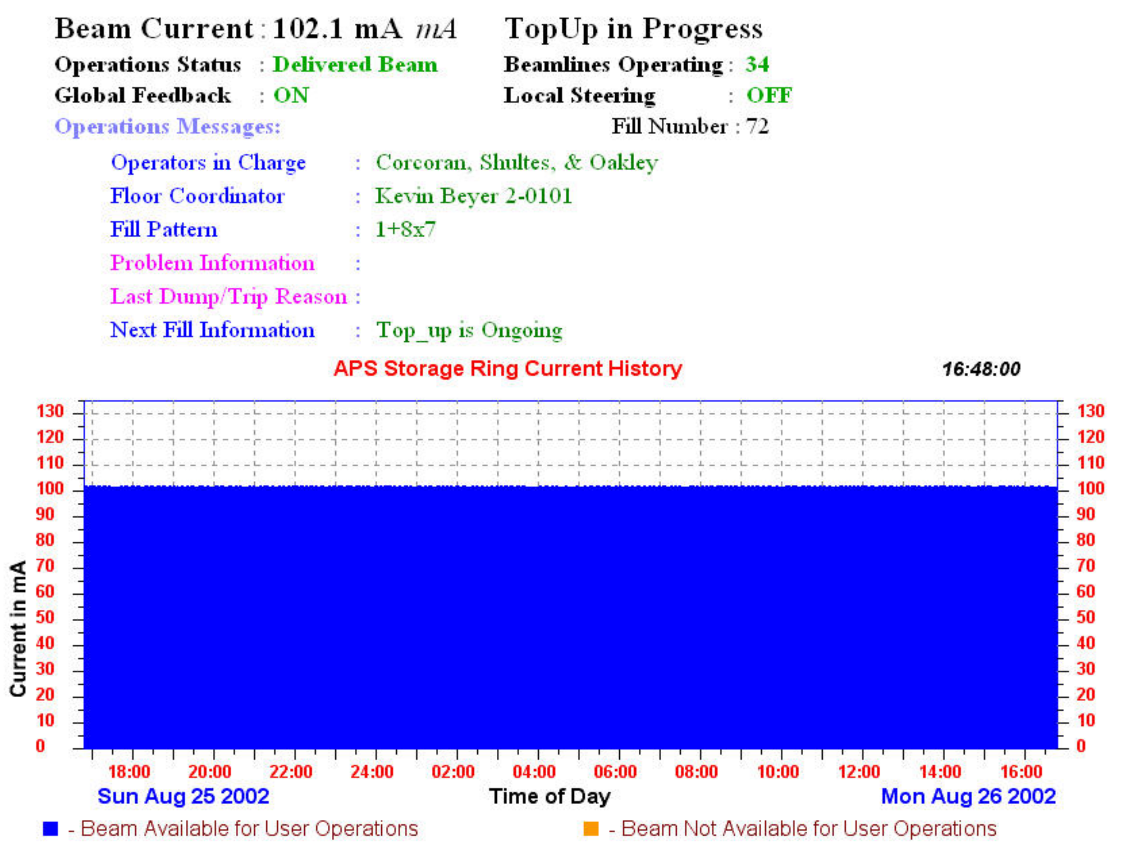

Fig. 2 APS storage ring beam current history in top-up mode

A characteristic for top-up operation is that during the fill the beamline safety shutters remain open. Before top-up could be implemented at the APS the Accelerator Physics Group performed many particle-tracking studies [1] for several failure modes to show that no particle beam can be extracted via a beamline. Certain criteria have to be met for this to be true. One of these criteria assumes the positional stability of the storage ring magnets, vacuum chambers, and beamline safety shutters. For that reason we are required to measure the position of the storage ring components in two-year time intervals. On the other hand the safety shutters are mapped with respect to the magnets before a beamline is commissioned or after modifications have been made to the front-end components requiring the temporary removal of the safety shutter. The requirements for the positional stability of the storage ring magnets is ± 2.5 mm, while the safety shutters have to stay within a window of ± 4.5 mm. Figure 3 shows the documented location of the safety shutter for an insertion device (ID) beamline. It shows the deviation from ideal in red for the safety shutter and those of the storage ring magnets in that vicinity in blue. In addition the required limits are shown as dashed lines in their respective colors.

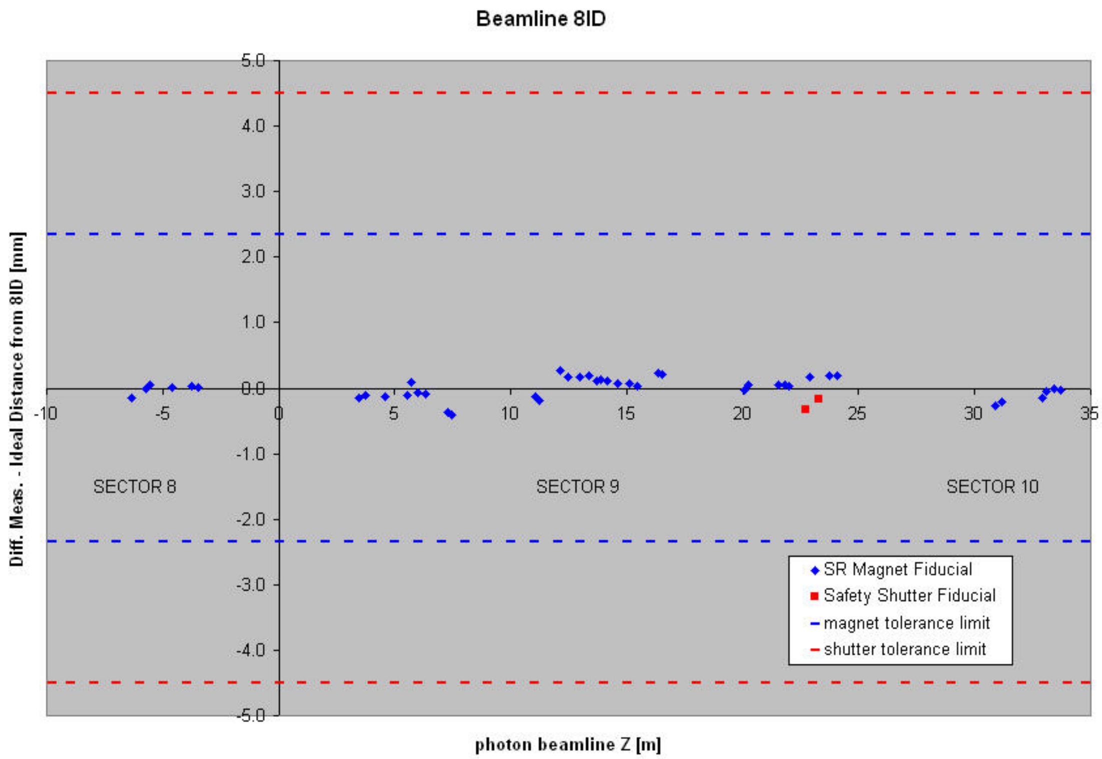

Fig. 3 Verification results for an ID beamline

The APS currently allows for three approximately one-month-long shutdown periods per year. The mapping of the position of all storage ring magnet positions has to be accomplished during one of these shutdown periods. To facilitate this, we purchased 40 open-air 1.5" corner cube reflectors to make maximum use of the laser tracker's auto inspect mode capability utilizing the absolute distance meter (ADM) extensively. In this way the reference markers of an entire sector can be outfitted with retroreflectors [2]. The mapping then becomes a push-button operation once the laser tracker has been oriented in the global network. Pre-established name lists associated with the known coordinate locations are used to automatically direct the laser tracker to each of the targets, hone in on the reflector, and take the measurement. On occasion targets located less than 2 m from the tracker head need to be measured manually. Utilizing the laser tracker in this fashion the entire storage ring can be mapped in one shutdown. In addition to saving time, the amount of mistyped target names is minimized. We took the first set of data using this process in October of 2001 and expect to take the next set of data of the entire storage ring in September of 2003. A comparison of the 1998 and 2001 position information data does not show any appreciable changes in the transverse and vertical relative alignment of the APS storage ring components. The standard deviation of the component position stayed with ±0.4 mm in the transverse and ±0.2 mm in the vertical direction. An in-depth comparison of prior data sets has been presented at the IWAA1999 at Grenoble, France [3].

Over the last year top-up has become the predominant operation mode for the APS, resulting in a beam availability in excess of 97% of the scheduled user beam time.

3. WIRELESS LASER TRACKER

The newer LEICA LTD laser trackers are shipped with large support carts for the tracker and applications processors. In some cases it turned out that the small cross section in the accelerator tunnels, in particular the linac, could not accommodate the tracker equipment. Therefore we started to toy with the idea to separate the tracker head and the bulky connections to the processors and control the entire system from a laptop via a wireless connection as shown in Figure 4.

Fig. 4 Wireless laser tracker setup

First we removed the tracker application processor and mounted it directly to the tracker support tube. Next we asked LEICA to provide us with two 1-meter-long data connection cables so that the tracker is independent of the support cart. We then purchased a small uninterruptible power supply so that the system could still be moved from station to station without losing power to the laser. Finally a 3COM Ethernet Client Bridge with an 11Mbit/s data exchange rate and a media converter was used to provide the laser tracker processor with the wireless LAN while the laptop, in this case a GATEWAY 2000, received a 3COM Ethernet PCMCA card. Additional software drivers for the NT operating system were required to finally make the connection between the two separate devices. It is now possible to control the tracker remotely while applying adjustments to a girder located several meters away from the tracker head. This opens up the possibility to even control multiple trackers remotely. We have used the system on several occasions and are now in the process of implementing it on the Windows 2000 operating system. In-depth tests for thermal and vibration stability are planned in the near future. However, none of the devices attached to the tracker support tube produce excessive heat, and, with the exception of a small power supply cooling fan, no moving parts are involved.

4. NEW LATTICE LAYOUT

Further improvements in beam stability are expected from the integration of the x-ray beam position monitors (x-BPMs) in the particle beam steering feedback system. This development will take the beam stability to submicron levels, an improvement of a factor of ten over today's micron-level stability.

From the beginning the APS design intended to use x-ray beam position monitors to provide position information about the location of the x-ray beams of the bending magnet and insertion devices. However, the original lattice layout, shown in Figure 5 in black, created a large variable background due to stray radiation that rendered the existing x-BPMs virtually useless. The sources for the stray radiation are the upstream and downstream dipoles on girders 2 and 4 on either side of an insertion device as well as the quadrupoles, sextupoles, and correctors on girders 1 and 5 in line with the insertion device.

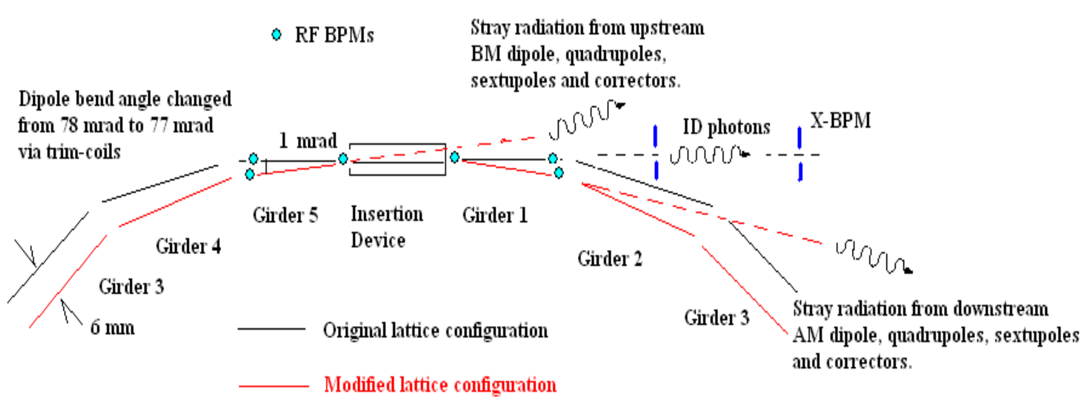

Fig. 5 Schematic lattice configurations

The concept of eliminating most of the stray radiation was developed at the APS by G. Decker [4] and entails distortion of the original lattice as shown in Figure 5 in red. It requires extensive realignment efforts on the part of our group and lateral displacements of girders up to 6.22 mm. All girders have to be placed with respect to the new lattice, which permits the separation of the stray radiation by decreasing the dipole bend angle from 78 mrad to 77 mrad using trim coils. This creates a 1-mrad entrance and exit angle at the insertion device that is corrected for by two corrector magnets on either side of the ID. The path length of the particle beam is decreased by 0.89 mm, resulting in a 568-Hz increase in the rf frequency for each distorted sector This concept preserves the alignment of the existing insertion device beamlines but affects the location of the bending magnet lines. The centerline of the bending magnet 6-mrad-wide x-ray fan is rotated outboard by 0.5 mrad requiring the realignment of the exit port and fixed masks. For the most part this does not pose a problem for the existing bending magnet x-ray beamlines, as they receive just another part of the x-ray fan.

Usually three sectors can be moved during a 3 – 4 week shutdown. This entails the incremental move of five girders per sector under vacuum, the realignment of the bending magnet front-end components, and, if necessary, the repositioning of the insertion device chamber between adjacent sectors. Before the girders can be moved, the installed vibration damping pads need to be replaced temporarily with solid spacer plates. Once the girders are approximately in their final position, the vibration damping pads are reinserted before final alignment. Finally the distorted sectors are mapped once more for a quality check and to keep an up-to-date status of the storage ring. After that the next three sectors are mapped in preparation for those girders to be moved during the next shutdown. Large deviations in the elevation profile across the storage ring magnets as well as steps between girders in the horizontal direction are smoothed out if necessary. Figure 6 shows a 3.5-mm settlement between sectors 15, 16, and 17 in dark blue. The black line shows the resulting elevation profile after the girder move, while the light blue line indicates the proposed magnet elevations for the next three sectors. The yellow points indicate insertion device vacuum chambers that need to be realigned.

As shown in Figure 7 currently a total of nineteen out of thirty six sectors have been distorted. Six sectors in the injection and rf region will never be distorted. It also shows the sectors that will be distorted during the next shutdown and the twelve that still need to be done after that. We anticipate finishing this task by the end of 2004. At that time the dipole main power supply will be changed so that only the six undistorted sectors need to be outfitted with trim coil power supplies. Furthermore, the booster ring may need to be realigned in order to obtain a better rf frequency match between the modified storage ring and the booster and to permit lower emittance lattice configurations of the booster in the future.

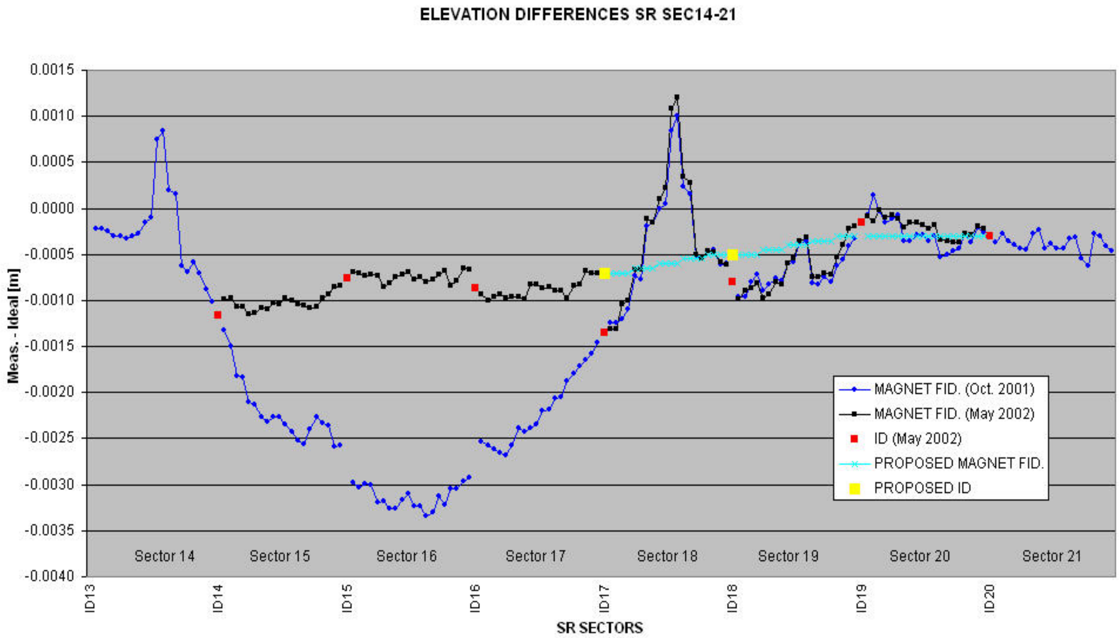

Fig. 6 Storage ring elevation profile

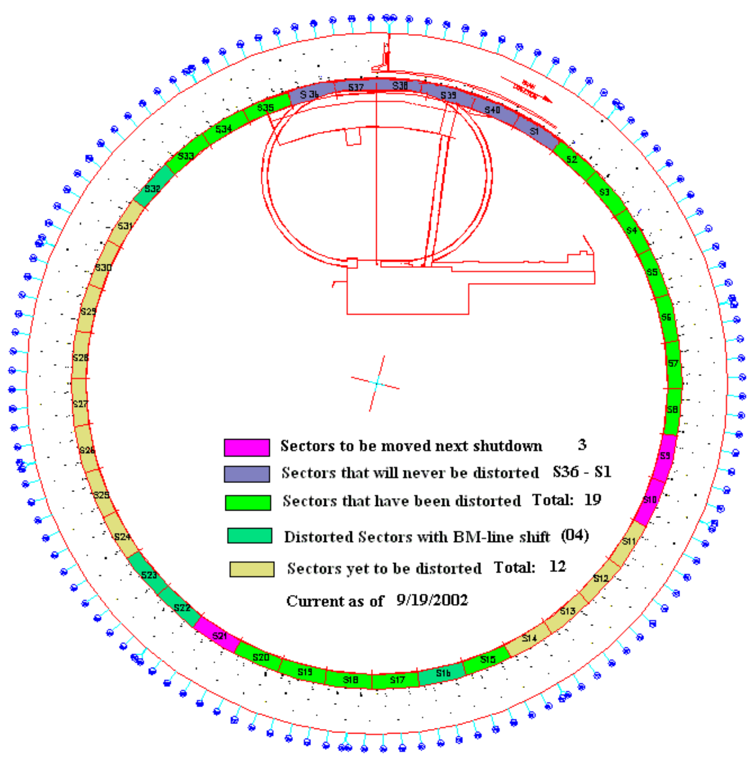

Fig. 7 Current status of distorted sectors

5. CONCLUSION

The position stability of the APS has remained the same when comparing 1998 and 2001 data. Progress has been made in implementing new concepts to improve the availability and stability of the delivered x-ray beams to the users. The original design has proven to be flexible enough to accommodate even the large lattice distortions that are now being implemented at the APS. The development of the wireless tracker system has proven to be beneficial, especially when trying to gain access to small enclosed areas.

6. ACKNOWLEDGEMENT

I would like to acknowledge the APS survey and alignment personnel for their effort in obtaining the data as well as Cathy Eyberger and her staff for the helpful suggestions while editing and refining this paper. In particular I would like to acknowledge the help provided by Tadas Budraitis in setting up the wireless tracker system.

7. REFERENCES

[1] L. Emery, M. Borland, “Analytical Studies of Top-Up Safety for the Advanced Photon Source,” Proc. of the 1999 Particle Accelerator Conference, A. Luccio and W. MacKay, 4, IEEE, (1999) pp. 2939-2941.

[2] B. Jones, “Laser Trackers Keep Synchrotron on Target,” Photonics Spectra, October 2002, p 102.

[3] H. Friedsam, M. Penicka, J. Error, “Long-Term Stability of the APS Storage Ring,” Proceedings of the Sixth International Workshop on Accelerator Alignment, Grenoble, France, October 1999 (CD-ROM).

[4] G. Decker, O. Singh, “Method for Reducing X-ray Background Signals from Insertion Device X-ray Beam Position Monitors,” Phys. Rev. Spec. Top., Accel. Beams 2 (11), 112801 (November 1999).