FUTURE PLANS FOR THE ADVANCED LIGHT SOURCE*

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Abstract

The Advanced Light Source is now in its 15th year of operation. The capabilities and capacities of the facility have continued to grow. Studies have shown that there is still plenty of room for further improvements. This paper will present three new plans to provide substantial and relevant improvements with modest cost. (1) top-off injection, (2) psuedo-single bunch operation, and (3) a new ultralow emittance lattice.

INTRODUCTION

The Advanced Light Source (ALS) at Lawrence Berkeley Laboratory (LBNL) is a synchrotron light source. The ALS was commissioned in 1993 and is one of the first members of the 3rd generation synchrotron light sources. The ALS produces light from the far infrared to the harder x-ray region of the photon spectrum and is optimized for the production of ultraviolet and soft x-ray radiation. Currently the ALS serves more than 2000 users per year.

Since the ALS was commissioned in 1993 there has been many new 3rd generation light sources built and commissioned. The challenge for the ALS facility is to continually evolve and advance the capabilities and capacities of the ALS in order to keep it at the forefront of synchrotron light sources. To this end there are a number of upgrades and improvements that are nearing completion and plans for future upgrades which will continue to advance the capabilities of the ALS.

FUNDED UPGRADES

Currently the major upgrade of the ALS, which is nearing completion, is the Top-off injection upgrade. The upgrade will significantly increase the flux and brightness of the source and improve the thermal stability. In addition to Top-off, a quasi-periodic elliptically polarizing insertion device (MERLIN) was installed and there are plans more insertion devices in the near future. A smaller R&D effort named pseudo-single bunch operation has begun to investigate the possibility of satisfying some of the time of flight users simultaneously with the high flux users. We will now describe the status of Top-off and Pseudo-single bunch operation.

Status of the Top-off Upgrade

Top-off is a mode of operation where current is quasi-continuously injected into the storage ring to keep the current at a constant level. Top-off injection operation was first used at the Advanced Photon Source (APS) [1] and is the standard operating mode of several other light sources. Top-off is very advantageous from the point of view of increased flux and thermal stability. Top-off will become the standard mode of operation for most advanced 3rd generation light sources.

For the ALS, the goal is to operate in Top-off injection mode for both of our two main fill patterns – multi-bunch and 2-bunch patterns. These two fill patterns are now described.

At the ALS it is possible to fill up to 328 bunches. In multi-bunch pattern which consists of 90% of user beam time, beam is filled in a 276 consecutive bunches. There is a gap of 52 buckets between the end and beginning of the bunch train. Inside the gap a single higher current bunch is filled. This bunch is named the camshaft bunch and is used as a gating signal by some users. In two-bunch pattern, which consists of about 10% of user beam time, two bunches are filled on opposite sides of the storage ring.

In multi-bunch operation the beam in the storage ring is filled to 400 mA three times a day. In the 8 hours between fills, the beam decays from 400 mA to 200 mA (See Fig. 1). This gives an average beam current of 250 mA. In 2-bunch operation the beam is filled to 50 mA every two hours. Between fills the beam current decays to below 10 mA.

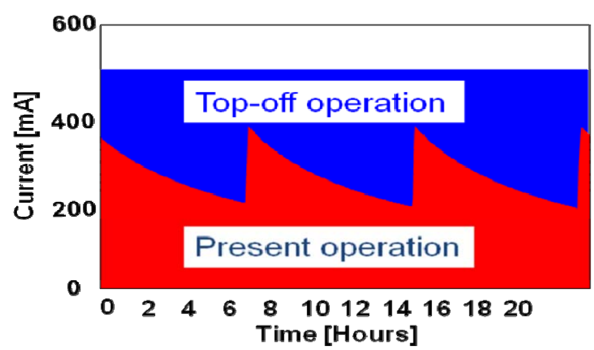

Figure 1: Beam current as a function of time for the present operation (red) and future top-off operation (blue).

For Top-off operation the plan for multibunch mode is to fill the ring to 500 mA and inject roughly every minute to keep the beam current constant at 500 mA (Fig. 1), doubling of the time averaged current would also be accompanied by a 3 times reduction in vertical emittance. The result will be a doubling of the time averaged flux and up to a factor of 10 times improvement in brightness for some beam lines (see Fig. 2). In 2-bunch operation the goal would also be to keep the current constant with frequent injection. Because of the more rapid decay rate, 2-bunch users will realize an even larger enhancement in time-averaged flux.

The Top-off project at the ALS began in earnest in 2005 and had two major components – upgrading to full energy injection (from 1.5 to 1.9 GeV) and upgrading the radiation safety systems to make them acceptable for injection with the radiation safety shutters opened. Full energy injection was achieved at the end of 2007. The

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radiation safety systems are now being upgraded. The goal is to completely install and test all systems in this fall and begin initial Top-off operation before the end of the calendar year. The details of the Top-off upgrade will be described in more detail in another paper from this conference [2].

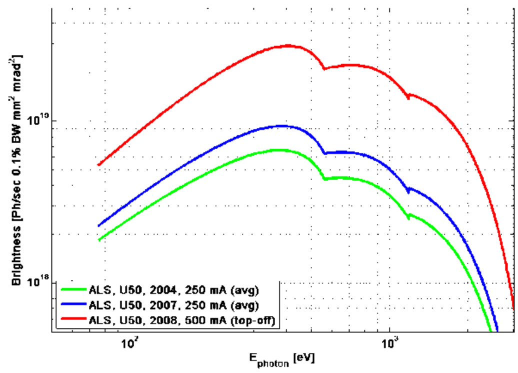

Figure 2: Brightness calculation for our standard 4 meter undulator. Between 2004 and 2007 the vertical emittance was reduced from 30 pmrad to 20 pmrad and with Top-off in 2008 there will be a further reduction to 8 pmrad

Pseudo-Single Bunch Operation

The diversity of science and needs of the ALS users is broad. Many of these needs can be satisfied simultaneously. However satisfying high flux and dynamics/time of flight users simultaneously is more challenging. In fact at present they are not satisfied simultaneously but rather there are two separate modes of operation – multi-bunch and 2-bunch modes. For years the management of the ALS has challenged the accelerator engineers and physics to arrive at a scheme to satisfy both communities simultaneously. The response has been pseudo-single bunch operation [3].

In order to provide more flexible operations and substantially increase the amount of operating time for dynamics/time-of-flight experimenters, it is being proposed to kick one bunch on a different vertical closed orbit. By spatially separating the light from this bunch from the main bunch train in the beam line, one could potentially have quasi-single bunch operation all year round. To test this new method of operation on the beamlines one kicker magnet running at the ring repetition rate (1.52 MHz) has been installed at the ALS.

By kicking the camshaft bunch on a different closed-orbit, it may be possible to create a pseudo single bunch operation during a multi-bunch user run. There are a number of different ways the orbit of the camshaft bunch can be shaped depending on the number and location of the fast kicker magnets. The easiest thing to do is install one kicker magnet and place the camshaft bunch on a different global closed-orbit. This may not be optimal for all single bunch or multi-bunch users, but it would be a relatively easy thing to do to experiment with the method. Another obvious thing to do is locally bump the camshaft bunch in one part of the ring. This would isolate the disturbance to a relatively small section of the ring. A third option is to install kicker magnets all around the ring and profile the orbit much like global orbit correction.

Figure 3: Synchrotron light image when kicking every other turn.

A kicker was installed in January 2008 and first tests of Pseudo-single bunch has begun. Fig. 3 shows how at the diagnostic monitor one sees a separation of orbits. The separation depends upon the phase advance from the camshaft kicker to the observation point together and the beta function at the observation point.

Future plans are to further test the feasibility of pseudo-single bunch with other users interested in 2-bunch operations as well as looking at the possible disturbance from the multi-bunch operation users. More details on Pseudo-single bunch operation and future possibilities are outlined in another paper from this conference [4].

POSSIBLE NEW DIRECTIONS

One direction which looks very promising is a modest lattice upgrade that will significantly increase the brightness of the ALS. This upgrade is called the Ultralow Emittance Lattice.

Ultralow Emittance Lattice

The lattice of the ALS is very flexible and we recently discovered that many of the possible operational modes had not been explored or even known about until recently [5,6]. For example, the ALS storage ring could lower its emittance to one third of the current value by increasing the horizontal tune from 14.25 to 16.25 [5]. The emittance varies strongly with Nux and Eta as shown in Fig.4 and can be significantly reduced to increase the brightness. Our studies indicate that it is possible to tune the ALS lattice for increased brightness by increasing the horizontal tune and raising the dispersion in the straight section. The emittance is reduced by a factor of 3, down to nearly 2 nm-rad. Table 1 shows the major parameters of these modes. This new lattice would significantly improve the performance of many beamlines – particularly those using the central bends (such as the protein crystallography Superbend beamlines.)

However, existing magnet locations and strengths in a given ring may be inadequate to implement such an operational mode. Preliminary dynamic aperture studies indicate that including additional sextupole components in the straight section correctors or quadrupoles will provide the ALS with a sufficiently large dynamic aperture.

The ALS ring layout is already crowded and there is not a lot of room for adding new magnets. Fortunately, existing elements can be replaced by hybrid multifunction elements and in particular for the proposed high brightness upgrade, two couples of correctors at the straight section extremes can be replaced by the same number of sextupole-correctors hybrid magnets (Fig. 5). In this way, two extra families of sextupoles can be added to the existing two of the ALS lattice allowing for a relevant increase in flexibility. In fact, the four families would permit chromaticity correction and dynamic aperture optimization in a variety of new lattices including the higher tune-lower emittance one mentioned above, but also in a lower momentum compaction one that would allow to operate the ALS in (a few ps) short bunch mode or in another one optimized for the generation of coherent synchrotron radiation in the THz frequency range.

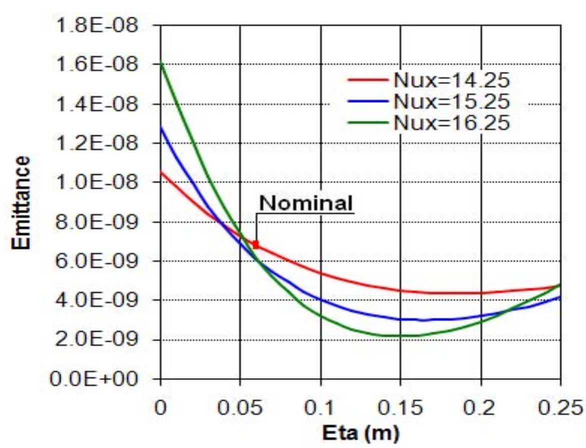

Figure 4: Emittance of ALS at 1.9 GeV

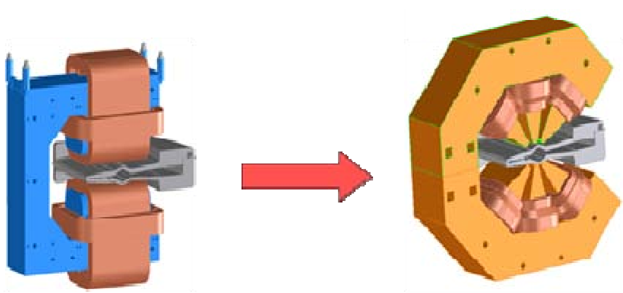

Figure 5: Replace our corrector magnet by sextupole/corrector combined magnet

The necessary hardware modifications to provide sextupole components in the lattice are presently under evaluation and appear to be feasible and could be done in typical yearly shutdowns. The benefit to cost ratio seems to be very favorable and at the same time lattice studies are going on to see if there are even further lattice improvements that would be of even further benefit [7].

Table 1. Major parameters of the nominal mode and the low-emittance mode. (*) straight section / center bend.

Parameter	Nominal	Low E.
Nux	14.25	16.25
Nuy	9.2	9.2
Dispersion [m] (*)	0.06/0.067	0.15/0.022
Beta H [m] (*)	13.85/0.79	22.39/0.31
BetaV [m]	2.26	2.07
Mom.Compaction	1.37E-03	8.72E-04
Energy Spread	9.77E-04	9.57E-04
Chromaticity H	-27.02	-50.02
Chromaticity V	-32.33	-35.06
Emittance	6.81E-09	2.17E-09
Beam Size [mm] (*)	0.31/0.10	0.26/0.033

SUMMARY

In addition to the upgrades discussed in this paper there are plans to install more elliptically polarizing undulators, chicane more straights, and add new diagnostics as well as performance improvements for stability and extending the capabilities of the ALS in the Terahertz region.All with the goal of keeping the ALS at the forefront of synchrotron radiation sources through continual improvement and revitalization of the facility.

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