

ALS STORAGE RING RF SYSTEM UPGRADE *

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Abstract

ALS is one of the first third generation synchrotron light sources which has been operating since 1992 at Berkeley Lab. Presently, the ALS Storage Ring System is comprised of a single 330kW klystron feeding two normal-conducting single-cell RF cavities via a WR1800 circulator and magic-tee transmission system. The klystron has operated well beyond its expected lifetime and even though replacement klystrons are available from a different manufacturer, we have opted to build the replacement amplifier with a system of four Inductive Output Tubes, (IOT). The new amplifier system will use Cavity Combiners (CaCo) to combine IOT outputs and a magic-tee to combine IOT pairs to feed the existing transmission line connected to the cavities. The existing HVPS will be upgraded to interface with the four IOT amplifiers and its crowbar will be replaced with a series solid-state switch. The system is being designed to operate with the industry standard external cavity IOTs (80kW) and integral cavity IOTs (90-100kW). In this paper we will present the details of the upgrade of each of the sub-systems in the ALS Storage Ring RF System.

EXISTING SYSTEM

ALS has been operating since 1992 with its originally installed 330kW CW klystron, a Philips-Valvo YK-1305. Though it has not shown any signs of an impending failure, it does have >100k filament hours and with a stored beam upgrade from 400mA to 500mA in the near future it has been decided to replace it. The High Voltage Power Supply (HVPS) has a 3-phase 4160V input with a 6-phase full-wave rectified output all controlled by a Variable-Voltage Transformer (VVT) on the primary. It is voltage regulated and has an operating range is from -30kV to -56kV at 12A DC. The klystron is protected by an ignitron based crowbar which is housed with the klystron filament supply, klystron modulation anode circuit, HVPS filter, and crowbar test circuit.

The single klystron feeds the two normal conducting RF cavities via a WR1800 transmission system comprised of a 350kW circulator, a magic-tee, and one phase shifter, one E & H-plane bifurcated HOM filter, and matcher per cavity. The reject loads for the circulator and magic-tee are 225kW waveguide water wedge loads [1].

The cavity signals are controlled via a low-level analog RF amplitude and phase systems [2] and the klystron's gain is controlled to maximize the system's efficiency. All loop parameters are hard-wired and very difficult to change.

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SYSTEM UPGRADE PLAN

The new system will be replaced in steps over the next three years during annual 3-5 week maintenance and installation shutdowns. In the first phase of the upgrade the HPA's will be installed, their outputs combined and the existing HVPS will be connected to the HPA's for testing into RF dummy loads. Each pair of HPA's outputs will be combined with CaCo combiners and their outputs combined with a magic-tee, which will be connected to the existing RF transmission system where the existing klystron is now connected. It will be decided after testing whether to operate the ALS for the next year in this configuration or to revert back to the klystron.

In the second phase of the upgrade the existing High Voltage Power Supply (HVPS), which has sufficient input power to meet the needs of four IOT's and the higher stored beam current requirement (see Table 1) will have its rectifier transformer, rectifier stack, and its output filter replaced. The HVPS after modification will have an output range of -19kV to -38kV at 18A DC. The IOTs will be protected by a High Voltage Disconnect Switch (HVDS).

In the final phase of the upgrade, the single analog low level RF system will be replaced with two FPGA based digital systems, one each per combined pair of HPA's, along with reconfiguring the RF transmission system to connect each RF cavity to a pair of HPA's. After this final phase the ALS will have independent control of each RF cavity. See Figure 1.

Parameter	400 mA	500 mA
RF Cavity Pwr	43 kW	48 kW
Beam Power	141 kW	176 kW
RF Pwr Required	231 kW	277 kW
Combined HPA's Output (min)	320 kW	320 kW

Table 1: Storage Ring RF Requirements

IOT Based High Power Amplifiers

ALS has chosen to use IOT based HPA's due to our recent experience with an 80kW IOT based HPA in operation since January 2007 in the Booster Ring [3], their larger commercial availability, active development, and price-performance. Recent development by several manufactures has produced a new generation of tubes built specifically for science applications. CPI has a K5 series IOT that has an integral output cavity that is capable of 90kW and Thales has developed a tube (TH793 LS) with a 6 1/8" coaxial output also capable of 90kW. The HPA's will be designed to work with IOT's from CPI,

components, faster switching time, and a simpler driving circuit. Our new HVDS will use a stack of 16 IXYS 4kV 40A(170A peak) IGBTs.

The major operational challenge when using the stack of IGBTs is to maintain the equal voltage distribution across each unit in static and dynamic transient conditions. To achieve this goal our switch will be equipped with a simple RC voltage balancing circuit [4]. Our Spice simulations indicated significant improvement in the voltage drop across the stack of 4 IGBTs in the function of the unequal gate drive delay.

Each IGBT unit will be driven by a single MOTOROLA MC33153 gate driver with an active desaturation protection. Opto-isolators will be used to deliver the triggering signals to the IGBT gate drivers and to transfer output fault signals to the switch protection unit. The construction of the prototype of the 40kV, 20A unit is under way and the estimated cost of the switch will be a small portion of the cost of a commercially available unit.

Cavity Combiners (CaCo)

ALS has chosen to use Cavity Combiners (CaCo) designed by ALBA [5] to combine the output of two 80-90kW IOT based HPAs. These units consist of 6 1/8" coaxial inputs, pill-box cavity with a WR1800 waveguide output. There is a pneumatic controlled tuner to compensate for one IOT going off-line. Though ALS doesn't intend to operate at lower RF power levels and therefore lower stored beam current when an IOT fails, we still will have the option.

The outputs of both CaCo's will be initially combined with a WR1800 magic-tee to connect into the existing transmission line system to the two cavities. After the low level RF system is replaced we will remove the magic-tee and have each pair of HPA's drive a RF cavity separately.

Low Level RF

The low level system will be replaced in the third phase of the upgrade project with a digital FPGA based system.

The system's design details are not set at this time, but system will contain the following functionality: down converting to a convenient IF frequency for the ADC, signal processing handled by FPGA, control system host connectivity handled by FPGA, DAC output and up conversion to ring's fundamental frequency. The FPGA clock, ADC clock, IF, and DAC clock will all be chosen after the full plant of HPAs and cavities are characterized. CORDIC computations will be employed to calculate the phase and amplitude parameters and additional processing can be added to handle specific issues such as ring dynamics. See Figure 1 for a conceptual block diagram of the entire system.

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