A REVIEW OF 14 YEARS OF OPERATION OF HELIOS 2 AT SSLS*

Li Zhiwang, Diao Cao Zheng, Miao Hua, Chew Eh Piew, Alaric Wong, Mark B H Breese
Singapore Synchrotron Light Source (SSLS), National University of Singapore
5 Research Link, Singapore 117603

Abstract

In this paper, we present the current status of the superconducting Helios 2 Synchrotron and review its major problems and their solutions over the last 14 years. We described how various breakdowns in the cryogenics system, the control system, the RF system, Dipole power supplies, Ring gate valves and helium compressor have all been overcome and what valuable lessons have been learned in operating this machine.

HELIOS 2 SYSTEM INTRODUCTION

The superconducting Helios Synchrotron includes the storage ring, microtron injection system, RF system, cryogenics system, vacuum system, control system, deionized (DI) water cooling system, compressed air system, and power supply system for all these sub-systems. The microtron produces an electron beam of up to 10 mA at 2 Hz and an energy of 100 MeV. After injection into the storage ring, the beam current is accumulated to above 300 mA, then the beam energy is ramped up to 700 MeV for synchrotron radiation users. For a 300 mA beam at 700 MeV, the radiation power is about 12.5 kW. The energy lost to synchrotron radiation is replaced by the 55.558 MHz RF system. The vacuum system is not stand-alone. The ring, injection system and RF systems have their individual vacuum system to store or transport the electron beam. The cryogenics system keeps the superconducting dipoles at 4.2 K. The control system controls and monitors the whole Helios system. The DI water cooling system cools the conventional magnets, the RF cavity and dipole absorbers to 20 ˚C. The compressed air system is used to operate all the vacuum valves and cryogenics control valves. Table 1 shows the main parameters of Helios 2 [1].

Table 1: Main parameters of Helios 2

Parameter	Value and unit
Electron energy	700 MeV
Dipole bending field	4.5 Tesla
Characteristic photon wavelength	0.84 nm
Typical current	350 mA
Circumference	10.8 m
lifetime	>10 h
Source diameter horizontal	1.45-0.58 mm
Source diameter vertical	0.33-0.38 mm
RF frequency	55.558 MHZ

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Helios 2 was manufactured by Oxford Instruments, and delivered to Singapore in 1999. The first beam was injected and stored in the ring in June of 2000. During the last 14 years, we have encountered a variety of problems related to Helios 2. Table 2 lists the major problems each year from 2000 to 2013. Despite many technical problems, we have been able to provide 1000 to 2000 hours per year. Fig.1 shows a graph of SSLS beam hours delivered for each year. The low beam hour from 2000 to 2003 was due to the fridge losing its cooling capacity, and the relatively lower beam hour delivered in 2010 was due to a ring gate valve and an air regulator became faulty.

CRYOGENICS SYSTEM PROBLEMS

The cryogenics system includes a Kaeser helium compressor, an oil removal system, a Linde TCF20 fridge, a buffer tank, a storage dewar, and dipoles. Since the cryogenics system became operational in 2000, we have encountered the problem of the fridge losing its cooling capacity. When this happens, helium vents to air, and we could not able to run Helios. Initially we did a rapid purge, but this did not help; then we replaced the oil removal system oil filters, still not improving the performance. We suspected that the oil removal system charcoal was saturated and that oil migrated into the fridge and contaminated it.

Table 2: Helios 2 Major Problems

Year	Problems
2000	Cryogenics lost cooling
2001	Cryogenics lost cooling &T108 broken
2002	Cryogenics lost cooling &SLM1window broken
2003	RF serious mismatched
2004	Microtron extract magnet water leaked
2005	Microtron CX1140 thyratron failed
2006	Control system Decserver failed
2007	Helium compressor jammed
2008	Helium compressor motor burned
2009	Cryogenics lost cooling &absorber flow
2010	Main air regulator and Ring SV3 faulty
2011	Klystron oil tank water tube leaked
2012	RF HV power supply and microtron PLC faulty
2013	Dipole quench and Gun 0 mA output

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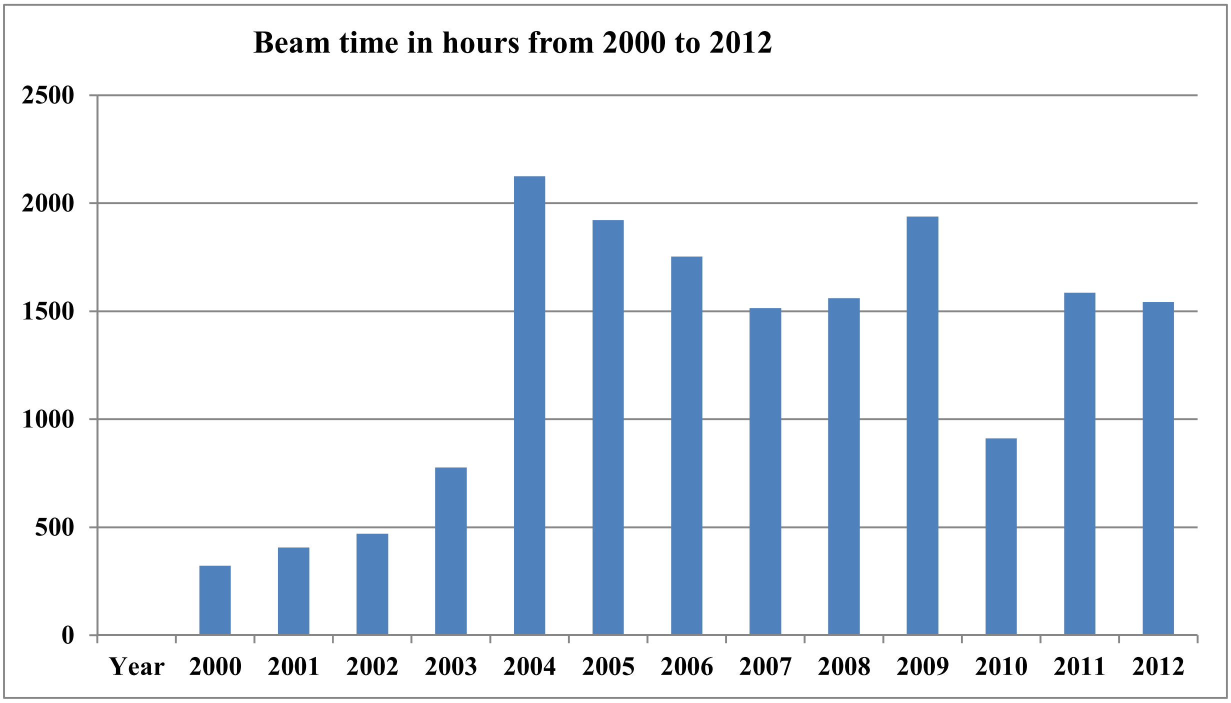

Figure 1: SSLS beam hours for each year.

After replacing the charcoal in the oil removal system, baking, pumping and purging the new charcoal, the fridge resumed its cooling capacity. This process takes at least 4 weeks and therefore we call it a big purge. Between the two big purges, we did several rapid purges to remove the contamination from the fridge; a rapid purge takes less than one week.

Other major problems in the cryogenics system were the helium compressor jamming, followed by the motor burning out. The compressor jam caused Helios to shut down for 3 months due to the supplier having no replacement components for the compressor. This has only happened once in the last 14 years. The common problem in the cryogenics system is the fridge becoming contaminated by oil, air and moisture, especially when the compressor trips. The compressor used to trip when the national power supply dipped from 220 V to 110 V for a period of 100 milliseconds. We have solved this problem by adding a UPS to the compressor control circuit. To reduce the helium loss and contamination and to minimize the Helios down time, we have implemented a call out system to react to the cryogenics problems anytime. We receive call outs quite often due to the fridge's faulty liquid nitrogen supply valve relay. We replaced the normal relay with the solid state relay to solve this problem.

RF SYSTEM PROBLEMS

The RF system came with Helios. In 2003, we have encountered a serious RF mismatch, which caused Helios to shut down for about 3 months. The RF end stage capacitors were burned, the cable between the RF driver stage and end stage was burned, RF frequency card could not generate the stable frequency. The 11 kV RF amplifier high voltage power supply fuse blew and it further caused the whole building power failure. We invited the original Helios RF expert, Bob Anderson, to our facility for one week to match the RF system. To reduce the reflected power, an extra bypass capacitor was added on the voltage controller PCB. To make the frequency card work, a resistive attenuator was added to the 55 MHz PCB.

Last year we encountered again the problem of the RF tripping the building power. The RF amplifier high voltage power supply unit pass banks 1 and 6 were burned, causing the 11 kV fuse to blow, and the 200A incoming power breaker to be burned. To avoid the RF system component fault causing a building power failure, we added three additional HV fuses at the incoming side of the RF amplifier high voltage power supply unit.

MICROTRON SYSTEM PROBLEMS

We use a Scanditronix RTM100 microtron system for Helios injection. Starting from 2004, the microtron extract magnet upper and lower coils' cooling water tube leaks from time to time; we have to bypass the coils to clear the cooling interlock. The microtron cooling water copper tubes seem to be becoming more fragile and leak one by one. Starting from 2008, the klystron tube TH2074 cooling water 10 mm copper tube leaked, we had to replace the klystron TH 2074. In 2010, inside the klystron oil tank, a 3/8" OD cooling water copper tube leaked, water and oil were flooding the power room floor. Because there is no supplier who could redo the cooling tube coils for us, we simply put new 3/8" copper tube coils inside the oil tank to perform the cooling job. In the same year, the klystron magnet 15 mm OD cooling water copper tube leaked, we had to weld it ourselves. Starting from 2009, five of the 24 cooling circuits copper tubes on the microtron main dipole magnets leaked one by one. We had to bypass the leaked circuit due to the extreme confined space for welding.

Last year, after RF tripped the building power, one challenging problem in the microtron control system has happened; the SIEMENS PLC became faulty and we lost data completely. It took us two weeks to understand the problem and reload all the programs to PLC from back up disks.

We have encountered the gun output current of 0 mA from time to time. Early in 2003, we had the problem of gun producing no output at all, the gun cathode assembly was replaced but the problem remained. Later it was found that the two FETs inside the gun grid power supply unit were faulty and caused the gun to produce no output. Since 2004, the thyratron tube CX1140 inside the gun modulator started to fail, which caused the microtron to produce no output. We have to replace the CX1140 regularly. In 2005 and 2012, two of the twenty 3kV capacitors inside the gun grid power supply broke and caused gun to produce no output. We cut the faulty capacitors and resumed operation. Recently, we encountered very low output from gun after 14 years. We suspected the cathode was dead and have replaced it.

CONTROL SYSTEM PROBLEMS

The Helios control system uses a DEC 3300X AXP control computer (alpha) running the OpenVMS operating system to control and monitor Helios. The alpha connects the control racks HECAMS though a hub, four port transceivers, thick wire Ethernet and DECserver 700. The two HECAMS control racks talk to the subsystem using RS 232 interfaces. The major problems in the control system are the DECserver 700 and the Ethernet controller becoming faulty. Both components are critical and need special configuration. The alpha hard disks used to fail every 6 months. We found that the control room temperature is crucial to the hard disk lifetime. Therefore we now keep the control room temperature constant to extend the hard disk lifetime to more than 2 years. In future we may upgrade our Alpha to a new HP Itanium server running V8.4 OpenVMS and Vsystem software.

RING SECTOR VALVE JAM

There are four sector valves on the ring to isolate dipoles and the straight lines. In 2010, no. 3 gate valve, SV3, jammed completely in a closed position. Because the space on the ring is very limited, we had to order the exact same VAT model gate valve and vent the dipole 2 and the RF straight to fit the new gate valve on the ring. The delivery time for the valve is about 3 months. During replacement of the valve we used dry nitrogen to purge the dipole and the RF straight vacuum chambers; in the meantime, we use two dehumidifiers to keep the room humidity to less than 50%. After replacing the gate valve, without baking the dipole and the RF straight vacuum chambers, the ring vacuum resumed 2×10^{-10} mbar after few months' pumping.

DIPOLES QUENCH

Since 2010, the dipoles have started quenching during normal beam operation. The machine operation parameters before quench seemed fine. The quench can be reset; no component seems to fail, but quench can re-occur. We are still troubleshooting the root cause of the quench. On possible reason could be heavy equipment which was moved to laboratory floor near dipole 2 in 2010. We speculate that the heavy load could impact the floor level and generate some stress on the Helios dipole 2 coils.

COMPRESSED AIR

We have two air compressors to supply compressed air to Helios and the beam lines. The major problem in the compressed air system was the main pressure regulator broke in 2010 and lost all the liquid helium in the Dewar and dipoles. We replaced the regulator and added a bypass to avoid such problem from happening again.

SUMMARY

Helios 2 has faced many challenges and problems such as cryogenics contamination and compressor trip; RF mismatch and tripping building power; microtron copper water tubes leakage and SIEMENS PLC faulty, and control system critical part Ethernet controller failure. However, with a small accelerator team we have successfully managed to fix the Helios 2 problems one by one, and have operated Helios 2 for 14 years. Despite many challenging problems, we have been able to provide 1-2 thousand beam hours per year. With the experience we have, we are also confident that we will continue to maintain the Helios in good states for more users in the future.

ACKNOWLEDGMENT

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REFERENCE

[1] http://ssls.nus.edu.sg/facility/helios2.html

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