UPGRADE ALTERNATIVES FOR THE NSLS SUPERCONDUCTING WIGGLER

M.Fedurin#, P.Mortazavi, J.Murphy, G.Rakowsky, BNL NSLS, Upton, NY 11973,U.S.A.

Abstract

The superconducting wiggler (SCW) with 4.2 Tesla field in 5 main poles has been in operation on the NSLS X-ray storage ring for more than 20 years. The inefficient cryogenic system of this wiggler uses a closed-cycle refrigerator requiring constant maintenance. It is possible to replace this insertion device with a 13-pole SCW originally built by Oxford Instruments. The cryostat of this device could be upgraded to reduce the liquid He consumption using cryocoolers, thereby greatly reducing the refrigerator operating expense. A second option is a new design of a SCW featuring internal chicaning.to serve three user beamlines simultaneously All these upgrade possibilities will be described in the paper.

PRESENT STATUS OF X17 WIGGLER

EThe NSLS X17 beamline wiggler was designed and built in the mid-1980's. [1] It has 5 main poles and was designed for 5 Tesla magnetic field operation at e-beam energy 2.5 GeV. After X-ray ring energy upgrade to 2.8 GeV, the magnetic field was reduced to 4.25 Tesla due to radiation safety limits. The present SCW has high heat losses due to the poorly designed liquid-nitrogen (LN2) heat shield, inefficient power leads and a complex, closed-cycle cryogenic system which requires constant maintenance. [In present time X17 wiggler used in closed cycle with cryoplant and as was measured [2] liquid He vessel consume 7 watt of heat losses. This number looks very inefficient regards of modern cryostat technology used cryocoolers for cryoshields.] In the mid-1990's there was a plan to replace this wiggler by a 13-pole, multi-mode SCW built by Oxford Instruments [3]. The cryostat was designed with high-temperature superconducting (HTSC) leads and two intermediate temperature shields, one of which was cooled by LN2. This kind of design reduces heat flux to liquid helium (LHe) to about 1 watt in full operation mode. Although an improvement, this wiggler still would not have eliminated the complexity and maintenance of a LHe refrigerator. This SCW was never installed and is still in storage.

OXFORD WIGGLER WITH CRYOSTAT UPGRADE

One upgrade option is to install the Oxford wiggler, keeping the magnetic structure, but modifying the cryogenic system to use cryocooler technology. We would rebuild the cryostat, adding two Sumitomo cryocoolers: a model SRDK-415D with 45 watts capacity at 50K and 1.5 watt at 4.2K,. and a SRDK-408S with 35 watts capacity at 45K and 6.3 watts at 10K. The high temperature stages of both coolers will provide a good thermal bridge to the first heat shield as well as the top end of the HTSC current leads. And 10K head would cool the second heat shield, while the 4.2K head would cool the LHe vessel. This upgrade requires disassembly and considerable rework of the cryostat, but the end result would be a modern, efficient, self-contained and low-maintenance system.

NEW WIGGLER OPTION

The second upgrade option is to design and build a new SCW with parameters that meet or exceed performance needs of present X17 beamline users, and that could be moved to the proposed 3 GeV NSLS-II. [4]

In the NSLS X-ray ring the heat load limit on the vacuum chamber front end mask is 32 watt/mm^2. Another limit is that photon critical energy may not exceed 22 keV, fixed by radiation safety. This last limit defines the maximum magnetic field at 2.8GeV as 4.2 Tesla, while the heat load limit sets the total number of poles of the insertion device. Here we show two possible solutions to meet these requirements.

The first one is simple – build an insertion device with maximum magnetic field, period length and total number of poles that meet future user needs and expected limits of NSLS-II, but for now, energize only the number of poles permitted in NSLS. For example, a 29-pole, 6 Tesla wiggler designed for NSLS-II (35kW/mrad^2 at maximum of synchrotron radiation in span angle of 140mrad at 3GeV, 500mA) could operate in NSLS X-ray ring with only 7 poles powered to 4.2 Tesla (3.2kW/mrad^2 in 110mrad angle span at 2.8geV, 300mA). The design of the magnet could be similar to the Oxford wiggler, which also has multiple current taps for powering a reduced number of poles

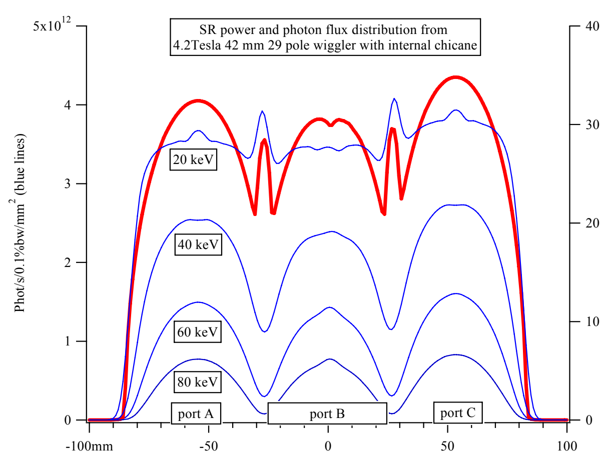

Figure 1. Distributed SR power on ports of X17 beamline

1-4244-0917-9/07/$25.00

A second, novel solution would tailor the photon beam profile to illuminate optimally the three user ports of beamline X17. This could be accomplished by breaking up the wiggler into three chicaned segments, with the photon beam of each segment directed to its respective beam port. The period length would be reduced to produce a narrower beam to increase the flux delivered into each port, without exceeding the present thermal and radiation limits. The e-beam orbit inside such an insertion device is shown in Figure 2.

ID with internal chicane

To estimate gap, field and period length of such insertion device, the parameters of the most recent SCW built by Budker INP was used [5]. It appears possible to build a SCW with 4.2 Tesla field, 42 mm period and 12 mm magnet gap. The number of poles (29) was chosen to meet the heat load limit of the existing X17 front end.

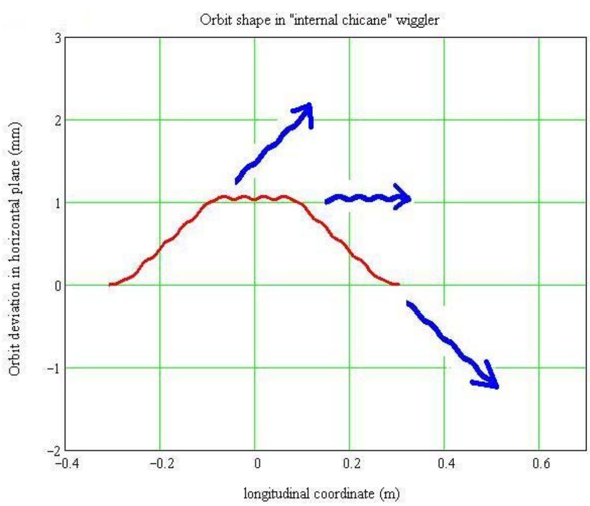

Figure 2. Orbit shape in wiggler with internal chicane

Chicaned wigglers to serve multiple user ports have been proposed before [5]. The novel feature of this proposal is an "internal chicane", which produces a trapezoidal trajectory inside a single, longer wiggler. There are two ways to bend the orbit inside wiggler. One way is to increase the field in a pole by increasing the current in its coil. Normally this is impractical, as the baseline currents are already near critical limits. Another is to reduce field in a pole by suppressing current in its coil. In Figure 3 both cases shown on one picture. Red line shows increased positive field in n^{th} pole and resulting positive orbit bend angle. Blue is with reduced *negative* field on $(n+1)^{st}$ pole, so orbit was bent less in this pole, again resulting in a net *positive* orbit bend angle. For 4.2 Tesla, 29 poles wiggler with period 42 mm to make trapezium shape with angles -5.5mrad, 0mrad, +5.5mrad, the field in the chicaning pole have to be suppressed by ~90%.

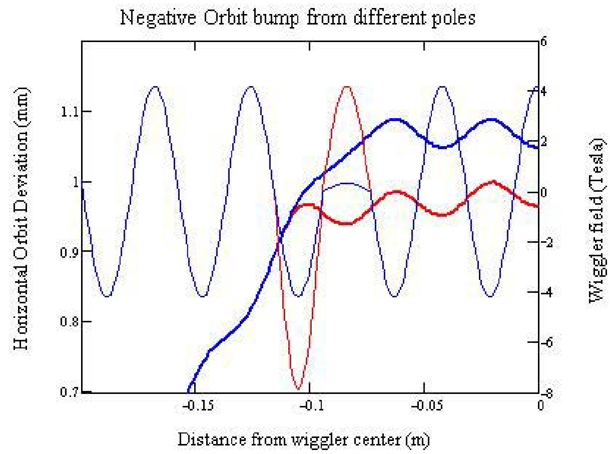

Figure 3. Magnetic field and orbit inside internal chicane wiggler.

How does one accomplish this local field suppression? Simply reducing the ampere-turns in one pole of a wiggler with a common ferromagnetic yoke will cause flux to redistribute into neighbouring poles, distorting the orbit and spreading the beam fans. This effect can be compensated by appropriately trimming the coil currents in the neighbouring poles. Corresponding bends at the entrance and exit of the wiggler can be similarly accomplished. One disadvantage of this scheme in a SCW is that it requires numerous additional cryogenic current leads into the cryostat, as well as extra power supplies.

Another scheme to reduce the field in the chicane poles is to add ferromagnetic side plates on wiggler yoke to shunt the pole flux.(Figure 4) Coils on these side plates can provide additional field bucking and trimming. Similarly, powered side plates at the entrance and exit provides the necessary bends there as well. Detailed modelling of such a structure is needed to optimize dimensions and positioning of the shunt plates and the currents in their coils.

PERSPECTIVE USE OF NEW WIGGLER

On many Light Source the synchrotron radiation from wigglers is often shared by multiple ports on a common ID beamline. By varying currents in the field suppression power supply photon flux could be effectively distributed among these ports. In figure 5 the photon flux and radiation power could be received by suppressing field in chicane poles by 50%. By switching off suppress current power supply, the photon flux from whole wiggler may be used in the central beamline as well. Maximum power in this configuration will be 24.5kW/mrad^2 in full radiation fan span 60 mrad.

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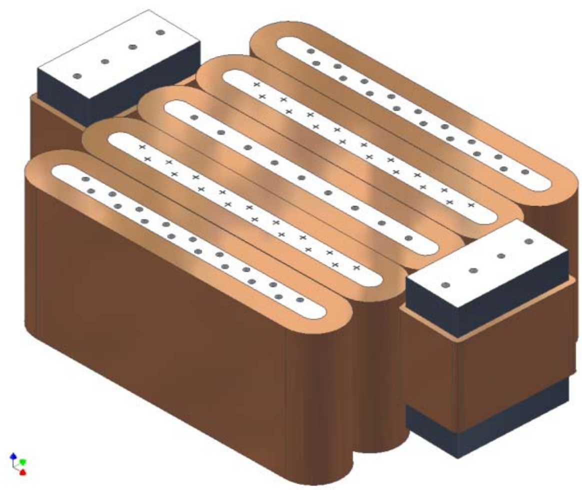

Figure 4. View of the wiggler poles with chicane pole. Coil on side plate helps to pull magnet field flux from chicane pole. Magnet field flux direction shown as dotes and crosses on poles surface. Quantity of dots on side plates and chicane pole equal to normal pole.

CONCLUSION

There is three different way to upgrade is proposed. Use wiggler built by OXFORD in 1998 with improved cryostat. Build new wiggler with usual periodic magnet field structure and structure with internal chicane. Each way will be effective for cryogenic side of view. Proposed magnet system design by using internal chicane has flexibility but limited by maximum field 4.2 Tesla for future NSLS II use. All these proposals have to be reviewed by users for the best choice. Internal chicane idea could be used in limited length wigglers as well. Influence of wiggler with internal chicane on beam dynamics have to be carefully estimated

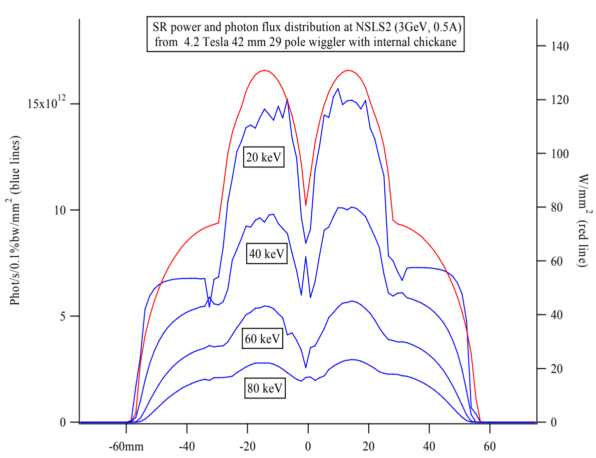

Figure 5. By vary current in chicane wiggler photon flux could be distributed in any beamline span

AKNOWLEDGEMENTS

Thanks to Zhong Zhong, X17 beamline scientist for initiate upgrade process as wishes for future use of superconducting wiggler at NSLS II storage ring. Thanks to Nikolay Mezentsev (Budker INP, Novosibirsk) for fruitful discussions. Thanks to all people who work at NSLS and participate in discussions about X17 possible upgrades.

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