

THE ELETTRA SUPERCONDUCTING WIGGLER

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Abstract

A 3.5 Tesla 64 mm period superconducting wiggler has been installed in the ELETTRA storage ring as a photon source for a future X-ray diffraction beamline. After several technological upgrades, a series of measurements were carried out to characterize the device and its effects on the electron beam, such as orbit distortions and dynamic aperture. A description of the upgrades and measurements are presented.

INTRODUCTION

The superconducting multipole wiggler (SCW) fabricated at Budker INP (Novosibirsk, Russia) was installed in the storage ring in November 2002 [1] [2]. The main parameters are listed in Table 1.

Table 1: Main parameters of wiggler.

Maximum field on beam axis:	
Central 45 poles (T)	3.5
Side 2-nd and 48-s poles (T)	2.8
Side 1-st and 49-s poles (T)	1.0
Pole gap (mm)	16.5
Period length (mm)	64
Stored energy at 3.5 T (kJ)	240
Working temperature (K)	4.2
Critical photon energy at 2 GeV (keV)	9.3
Total radiated power at 2 GeV, 100 mA (kW)	4.6
Internal liner gap (mm)	10.7

During the shutdown of November 2003, the SCW was transported to the experimental hall and the liner and RF-transitions were replaced.

The new liner was produced in only one piece of 2 m without any junction in the center and without the 480 slots (15x1 mm²) for the pumping. The vacuum is now pumped only from the slots positioned in the entrance and exit flanges. The new liner installation is showed in figure 1. The new RF transition from the liner to the storage ring vacuum chamber is showed in figure 2: the movable RF contacts are now positioned at the beginning of the transition, where the gap is larger.



Figure 1: The installation of the new liner

HARDWARE UPGRADE

An important parameter for the operation of a superconducting device is the liquid Helium (LHe) consumption, especially if the device is not directly connected to a liquefier able to automatically refill the evaporated Helium. At ELETTRA, the requested time for a LHe refilling with the present transfer line is about 2 hours for 280 litres. During the refilling the electron beam must be absent.

During SCW testing, carried out in November 2002 and April 2003, an anomalous liquid helium consumption (up to 5 l/h, requesting a refilling every 2-3 days) was measured in presence of the electron beam [2]. In order to overcome this problem, the Budker Institute (BINP) modified the design of the copper liner and the RF transitions.

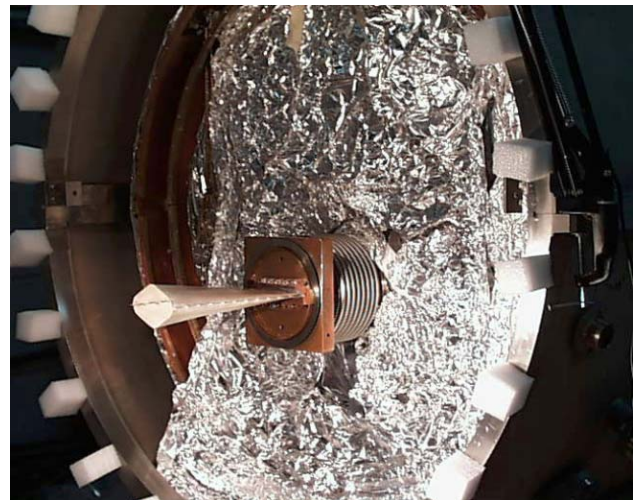


Figure 2: The new RF transition

TEST RESULTS

Liquid Helium Consumption

After these replacements, the SCW was re-installed in the storage ring and tested with the electron beam. Figure 3 shows the new LHe consumption in the presence of the electron beam (max. current 320 mA, 2 GeV). The sensitivity with respect to the electron beam current is now very small (about 0.1 l/h). The typical LHe consumption at 3.5 T in power (persistent) mode is now 0.7 (0.5) l/h.

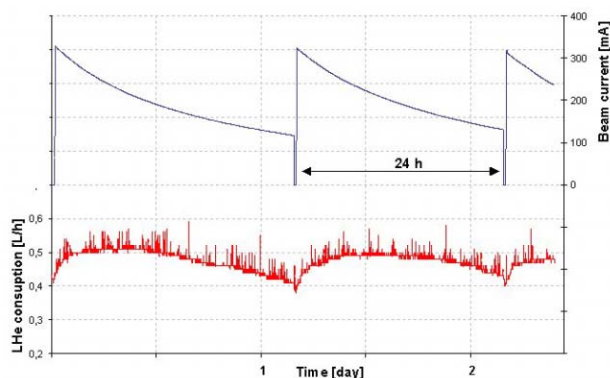


Figure 3: LHe consumption (lower) and the e-beam current (upper) at 2 GeV

Persistent and Power Mode Operation

In order to evaluate the orbit drift of the electron beam induced by the SCW set at maximum field (3.5 T) in both power and persistent mode, a new very stable system with sub-micron stability was used (BPM, [3])

Whereas no evident orbit drift was visible in the power mode (if present, it was at the same level of the thermal drift), in the persistent one with the flux pump on [1], we observed a horizontal drift of about 5 μm in 100 sec, corresponding to a field integral drift of roughly 15 G-mm. This measurement showed that the power of the flux pump is not sufficient to compensate the field integral drift at 3.5 T, due to the effective lifetime of the super conducting circuits (about 77 days at 3.5 T). Furthermore, although the field integral drift is small, after a long time a quench may occur. As a consequence the SCW will only be operated in power mode and the persistent switches inside the LHe vessel will be removed in order to further decrease the LHe consumption of about 0.1 l/h for power mode operation.

Beam Vibration Induced by Cryo-coolers

Two coolers and two recondensors produced by Leybold (Coolpower 130 and Coolpower 4.2 GM) are used to cool the SCW. The test, carried out with the low gap BPM and the SCW set to 3.5 T, showed (figure 4)

that the two recondensors induced a vertical beam orbit distortion of about 3.7 micron at 1.8 Hz, i.e. the same frequency of the motors of the two cryocoolers. For example, a vertical oscillation of the poles of about 3 μm would be able to induce such a noise. The noise completely disappeared after switching off the two recondensors.

The vibration induced on the poles is believed to be due to an unbalanced preloading on the Kevlar strips on which the helium vessel is suspended [1]. If this is true, an adjustment of the preloading of the Kevlar strips should be able to fix the problem.

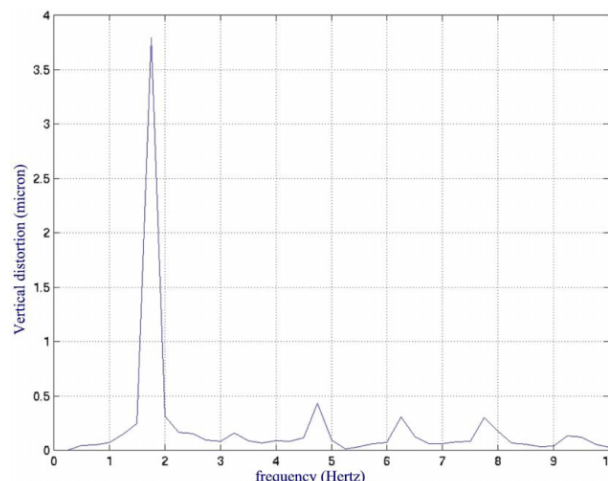


Figure 4: Vertical electron beam displacement measured by low gap BPM, with the SCW set to 3.5 T (2 GeV)

DYNAMIC APERTURE

Previous measurements on the linear effects of the SCW [2] have revealed an agreement between the measured vertical tune shifts and the theoretical one. In order to evaluate the effect of the SCW on the electron beam, dynamic aperture measurements have been made in the following machine configurations: a) with the bare lattice; b) with only the SCW at 3.5 T; c) with the ELETTRA insertion devices in a typical operation configuration; d) case c with the SCW at 3.5 T.

The measurements were performed with a longitudinally and transversely stable beam of 60 mA at 2.0 GeV. In all cases the horizontal and vertical tunes were kept constant to 14.295 and 8.190 respectively with a global compensation. The physical aperture of the machine is the vacuum vessel at the SCW location whose half aperture is 5.35mm.

In all four cases the measurements with the vertical scraper revealed a change in lifetime for both the upper and lower blades at 4 mm. However, scaling this value with the theoretical beta functions at the vessel reveals a 1 mm reduction when the SCW is set to 3.5 T with respect to the corresponding cases when it is switched off. Figure 5, where $(\tau I)^{-1} [(A \cdot h)^{-1}]$ is plotted versus the square of the blade position, shows the measurement results between

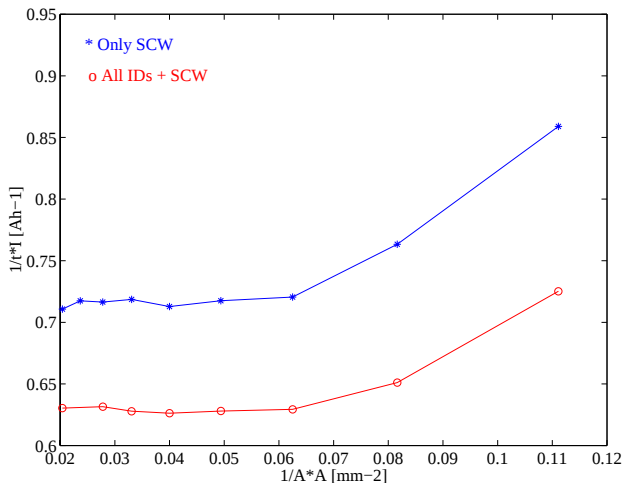


Figure 5: Comparison of dynamic aperture measurements between case b) with only the SCW and case d) all ELETTRA's insertion devices and the SCW.

case b) and case d).

Associated with the switching on of the SCW, a noticeable lifetime drop of 28% was noticed with respect to case a), where the bare lattice is considered. It is retained that this is mainly due to the out gassing of the front end which has not yet been commissioned. Whereas the reduction in lifetime between the standard insertion device configuration (case c) and the bare lattice is 9%, no additional reduction occurs between the two cases when the SCW is set to 3.5 T.

CONCLUSIONS

The redesign and substitution of the copper liner and RF transitions of the vacuum vessel have reduced noticeably the Helium consumption by a factor of ten. Horizontal orbit measurements have shown that in persistent current mode the power of the flux pump is not sufficient to compensate the field integral drift at 3.5 T, due to the effective lifetime of the super conducting circuits. As a consequence the SCW will be operated only in power mode and the persistent switches inside the LHe vessel will be removed.

Furthermore the motors of the recondensors induce a 1.8 Hz oscillation on the vertical orbit, which is equivalent to a 3 μ m peak amplitude oscillation of the poles. The problem will be solved by an adjustment of the preloading of the Kevlar suspension strips.

Finally, dynamic aperture measurements have been carried out in order to compare the effects of the device with respect to the bare lattice and to a typical user insertion device configuration. From the investigations, a 1 mm reduction in the dynamic aperture has been estimated when the SCW is set to 3.5 T. A noticeable drop of 28% in the lifetime has been noticed when the SCW is switched on, but it is retained to be associated with the out gassing process. In order to obtain a more thorough understanding of its effects on the lifetime and

to be able to compare them with the simulations performed during the design stage [4], measurements should be repeated once the conditioning of the front end with the SCW is performed.

REFERENCES

- [1] A.Batrakov et al., "A Superconducting 3.5 T Multipole Wiggler for the ELETTRA Storage Ring", Proc. EPAC 2002, pag. 2634.
- [2] D. Zangrando, L.Tosi, B. Diviacco, S. Di Mitri, C. Knapic, "Commissioning of two new Insertion Devices at ELETTRA", proc. PAC 2003
- [3] M. Ferianis and R. De Monte, "The low gap BPM system at ELETTRA: commissioning and results", DIPAC '01, Grenoble, May 2001.
- [4] L.Tosi and R. P. Walker, "Dynamic Aperture Simulations for a Figure-8 Undulator and a Superconducting Wiggler", Sincrotrone Trieste Internal Note ST/M-TN-09, 2000.