TEST OF A NEG-COATED COPPER DIPOLE VACUUM CHAMBER

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Abstract

This paper reports on a test carried out at the 1.5 GeV storage ring MAX II where a standard dipole chamber made of stainless steel was replaced by a Non Evaporable Getter (NEG)-coated chamber made of copper. The standard MAX II stainless steel dipole vacuum chamber is connected to an ion pump and a sublimation pump while the NEG-coated copper dipole vacuum chamber has no additional pumps. The NEG-coated dipole chamber made of copper has been demonstrated to work well with a stable vacuum level in the region where it is installed. The coating procedure for the bent dipole chamber copper tube is slightly more complicated than the coating procedure for a straight chamber of similar size due to its curvature and lack of line-of-sight. The coating procedure is also described in some detail. The main motivation for the interest in NEG-coated vacuum tubes is the reduced cost of the vacuum system and also the possibility to build lower cross-section vacuum systems, thus simplifying and optimizing the design of accelerator magnet systems.

INTRODUCTION

NEG coating has been used for several years in synchrotron light sources, e.g. [1]. NEG is a titanium, zirconnium and vanadium alloy. It is deposited on materials through sputtering. The vacuum in a NEG-coated chamber is improved both by a reduced desorption yield and from direct pumping by the NEG material. NEG coating at synchrotron light sources has mainly been used in straight sections, where the results have been positive. At the MAX II light source [2], two NEG-coated straight sections have been in place for 3 years with good results. Using NEG for dipole vacuum chambers in synchrotron light sources have not been tested to the same extent. To gain experience in the area, one of the standard dipole vacuum chambers in MAX II was exchanged with a NEG-coated copper dipole vacuum chamber in July 2007. The exchange went smoothly and no negative effects could be noticed on MAX II operation or the beam lifetime due to the new vacuum chamber. If the test using NEG coating for dipole vacuum chambers turns out to be successful, the plan is to implement the technology in the future MAX IV synchrotron light source currently under consideration [3].

NEG-COATED COPPER DIPOLE VACUUM CHAMBER

The standard dipole vacuum chambers in the MAX II ring are made of stainless steel. They are connected to two pumps each, one ion pump and one titanium sublimation pump. The new NEG-coated copper dipole vacuum chamber on the other hand has no additional pumps. The top part of Fig. 1 shows a drawing of the standard stainless steel vacuum chamber for the second dipole in cell 3 of the MAX II ring. The bottom part of Fig. 1 shows a drawing of the new copper vacuum chamber installed at the second dipole in cell 2.

The NEG coating of the copper chamber was done at ESRF NEG coating facility’s tower no. 2, using a one meter long solenoid producing a maximum field on axis of about 500 G, and with a flat-out field length of ~80 cm. The ~1.3 m long copper chamber and sections of transition chambers made for the purpose were therefore coated in two passes. The NEG material was sputtered onto the copper using a single TiZrV threaded cathode made up of 0.5 mm wires. Due to the curvature of the chamber, and in order to keep the cathode close to the chamber’s axis, four ceramic spacers were evenly spaced along the chamber length, plus two adaptors at the extremities. The process gas and pressure were krypton at ~0.1 mbar, and the chamber temperature around 110 °C.

BREMSSTRAHLUNG MEASUREMENT

To compare the effect on vacuum when switching from stainless steel (with an ion and sublimation pump) to NEG-coated copper (with no additional pumps) two detectors were placed in the ring. The first of these detectors was placed downstream the second dipole in cell 3 of the MAX II storage ring. This cell still has the standard stainless steel dipole vacuum chamber. The second detector was similarly placed downstream the second dipole in cell 2, where the new copper vacuum chamber is placed. The two detectors register the bremsstrahlung radiation generated from the inelastic scattering between the electron beam and the residual gas in the vacuum chamber. The amount of bremsstrahlung radiation should thus give a measure for the amount of residual gas in the vacuum chamber and hence the pressure in the chamber. By comparing the count rates in the detectors an estimate of the ratio between the pressures in the chambers should ideally be achieved.

A complication of the measurement is that detected photons can come from other sources than the inelastic scattering. Electrons lost due to other interactions, e.g. the Touschek effect, can create showers when hitting the vacuum chamber walls. The gamma photons generated from these electrons will also interact with the detectors.

Two different detector setups were used to detect the gamma photons. The first setup used simple Geiger-Müller (GM) tubes, whereas the second setup used sodium iodide (NaI) detectors. Common for both setups were the detector holders, which enabled the vertical position of the detectors to be controlled remotely.

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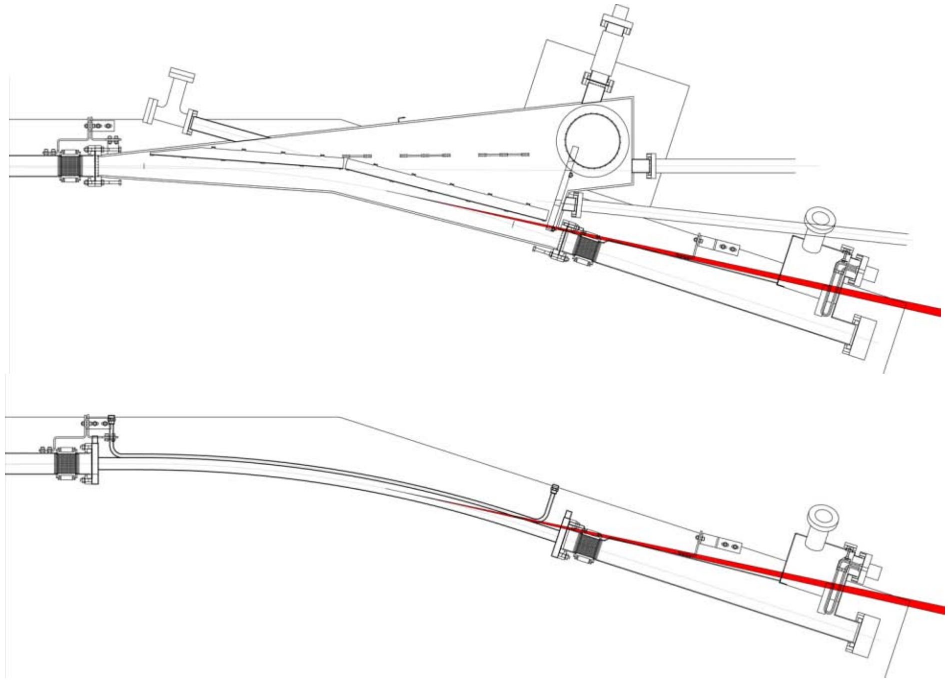

Figure 1: Drawings of the second half of cell 3 (*top*) and cell 2 (*bottom*) in the MAX II storage ring. The added red beam paths show the cone of bremsstrahlung radiation detected by the NaI detectors.

GM Tubes

The first detector setup used two GM tubes. The active volume of the detectors was cylindrical with approximately 1 cm diameter and 1 cm length. The GM tubes were placed 1.1 m downstream the end of the dipole vacuum chamber 8 cm outside the chamber centre.

Comparing count rates from the detectors, the detector situated after the NEG-coated copper vacuum chamber consistently counted a factor 1.2 higher than the detector located after the standard stainless steel vacuum chamber. Calibration with a cobalt-60 source and studies of the count rate from cosmic events showed the detectors to have close to identical efficiency, indicating that the 20% higher count rate from the NEG-coated vacuum chamber was not detector differences.

The GM tubes had several disadvantages. The dead time was 90 μs, the data transfer was buggy and the signals from the detectors could not be observed externally on an oscilloscope. To get more trustworthy data a second experimental setup was built using better detectors.

NaI Detectors

The second detector setup replaced the GM tubes with NaI detectors. The NaI crystals were cylindrical with 5 cm diameter and 5 cm length. The dead time of the detectors were less than 1 μs. Due to interference from the quadrupole magnets the NaI detectors were moved further downstream to a position 3.1 m downstream of the end of the dipole vacuum chamber 32 cm outside the chamber centre. Added to the drawings in Fig. 1 are the bremsstrahlung cones that hit the detectors further downstream. The bremsstrahlung detected by the NaI detectors emanates from a 5 cm region approximately 5 dm into the dipole vacuum chambers. As can be seen in Fig. 1, the bremsstrahlung cone unfortunately travels through different amounts of material in the different cells before interacting with the detectors. In cell 3 the bremsstrahlung passes through an absorber, whereas in cell 2 it passes through the walls of the copper vacuum chamber and through the cooling water.

The signals from the NaI detectors were connected to a data acquisition system outside of the storage ring. The energy cut-off of the detectors could be controlled externally and, after an energy calibration using radio-active sources, the cut-off was set to 13 MeV. The signals from the detectors were studied during MAX II operation. They were clear and stable with no signs of pile-up.

Figure 2 show a typical measurement with the NaI detectors during a twelve day period. The count rates per 10 s in the NaI detectors can be seen in left hand plots of Fig. 2. The upper left plot shows the count rate in the detector placed downstream of the standard stainless steel dipole vacuum chamber, whereas the lower left plot shows the count rate in the detector placed downstream of the new NEG-coated copper dipole vacuum chamber. The upper right plot in Fig. 2 shows the current in the MAX II storage ring. Finally, the lower right plot in Fig. 2 shows the ratio between the count rate in detector 2 and the count rate in detector 1.

As can be seen in the lower right plot in Fig. 2, the ratio between the count rates stays more or less constant with time, both in the longer timeframe and during individual fillings. The count rate is a factor 3-4 higher in the detector downstream of the NEG-coated copper vacuum chamber than in the detector downstream of the

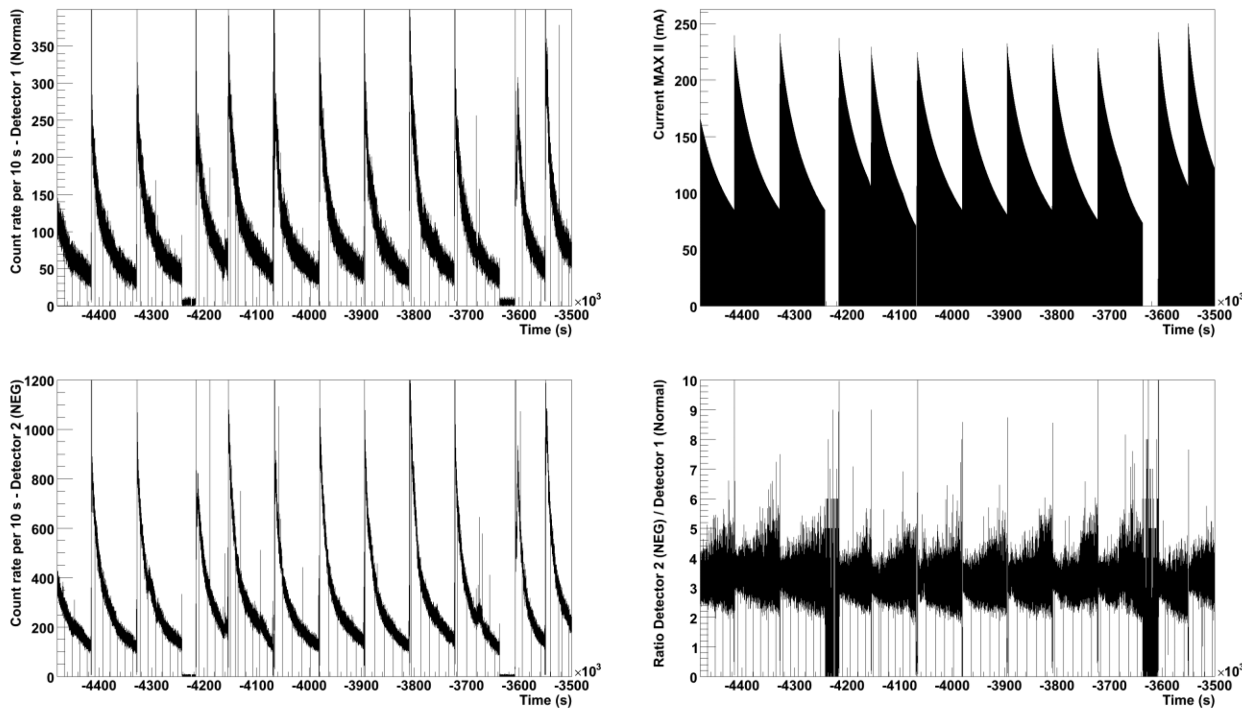

Figure 2: Typical measurements with the NaI detectors during twelve days. *Upper Left*: Count rate per 10 s in detector 1 placed downstream the standard stainless steel dipole vacuum chamber. *Lower Left*: Count rate per 10 s in detector 2 placed downstream the NEG-coated copper vacuum chamber. *Upper Right*: Current in the MAX II storage ring. *Lower Right*: Ratio between the count rate in detector 2 over the count rate in detector 1.

stainless steel vacuum chamber. At two points during the measurement period shown in Fig. 2 MAX II was down for weekly maintenance. The ratio between the count rates from cosmic radiation during this these hours was close to one, indicating that the high ratio during operation is due to differences between the two dipole vacuum chambers. If the detectors only registered bremsstrahlung photons this would indicate that the residual gas pressure is considerably higher in the NEG-coated dipole vacuum chamber than in the standard stainless steel chamber.

To further study the origin of the detected photons, different parameters were changed during MAX II operation. The effect on the count rates when changing the beam position in the dipoles and when changing the betatron tunes was negligible. Similarly, no effects could be seen from wigglers ramping or undulator gap changes. However, when minimizing the vertical beam size a significant increase in the count rates was observed. This indicates that the detectors are sensitive to particles emanating from Touschek losses. Further studies are ongoing to determine to which extent the events registered by the detectors emanate from other sources than residual gas bremsstrahlung.

CONCLUSIONS

In July 2007 one of the standard stainless steel dipole vacuum chambers in the MAX II synchrotron light source was exchanged to a NEG-coated copper dipole vacuum chamber. From a MAX II operational standpoint, the new vacuum chamber has been working well. No negative effects have been observed on beam stability or lifetime. Detectors positioned downstream the vacuum chambers have shown a higher count rate from the new NEG-coated copper vacuum chamber than from the standard stainless steel vacuum chamber. Studies are ongoing to determine to which extent this indicates a higher residual gas pressure in the new NEG-coated copper dipole vacuum chamber.

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