IMPROVED SR EXTRACTION CHAMBER FOR KEKB LER SR MONITOR

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Abstract

We have recently replaced the synchrotron light extraction chamber for the KEKB Low Energy Ring (LER) SR monitor. The beam pipe was changed to copper to minimize resistive-wall heating, and the optical apertures were made as small as permitted by light extraction requirements in order to reduce HOM power leakage. The new chamber shows almost none of the heating problems of the old chamber, and previous problems with the orientation of the extraction mirror changing due to heat expansion of the beam pipe have been essentially eliminated. The design and performance of the new chamber are presented.

HISTORY OF OLD CHAMBER

The original LER synchrotron radiation extraction chamber was installed in the ring in 1998 prior to the initial commissioning. The design employs a cylindrical vacuum chamber through which runs a segment of beam pipe.[1] Both chamber and beam pipe are made of stainless steel. The water-cooled beryllium extraction mirror is mounted in a notch in one side of the beam pipe at a 45-degree angle. RF contact fingers are used to mate the mirror to the edges of the notch.

Opposite from the extraction mirror are two titanium-coated windows mounted in the wall of the beampipe. One window is directly across the pipe from the extraction mirror in the synchrotron light path. The other window is located next to the first one and is used for observation of the mirror surface and to check the proper seating of the RF fingers around the mirror. The interior windows are coated with a thin layer of titanium (0.5 microns) to minimize disturbance to surface currents in the wall, however the windows are not vacuum sealed. Sealed windows are located on the outer chamber on axes extending from the mirror and through the inner windows.

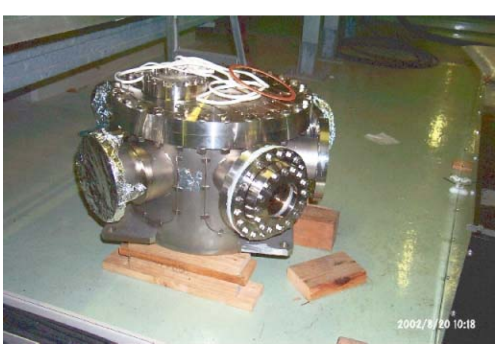

Figure 1: Original chamber, exterior view.

The original chamber exhibited heating problems at high beam currents. A measurement of the temperature of the interior beam-pipe temperature at the middle of the chamber showed temperatures in excess of 200 degrees even at relatively low maximum beam currents of 700 mA in the LER (see Fig. 2). An analysis of the wall-current heating in the stainless steel chamber walls showed that at 700 mA the expected temperature rise would be about 175 degrees, which added to the ambient tunnel temperature of 25 degrees explains the observed temperature rise. At a beam current of 2000 mA, the expected temperature rise would be a catastrophic 500 degrees.

In February of 2002, after about $10,000$ heating cycles (beam current cycles) of the beam pipe, the welds attaching the mounting frame for the windows to the beam pipe failed, due to the thermal-expansion stress. The rest of the Spring 2002 run was completed without the windows present, until the new chamber was installed in the summer.

Upon inspection of the windows, it was found that the titanium coating had largely evaporated away, indicating that the windows had not been providing an effective RF seal. The exterior of the enclosing chamber had exhibited a temperature rise with beam current of $35\,\mathrm{deg}$, up to $60\,\mathrm{deg}$, which may have indicated the leakage of HOM power from the beam pipe windows. Further evidence of this phenomenon was provided when leads to thermocouples inside the beam chamber began arcing to the chamber walls.

Besides structural problems due to heating, the expansion and contraction of the beam-pipe caused the extraction mirror to be moved, which threw the optical axis out of alignment. This problem was corrected for by the implementation of an optical-axis feedback loop, wherein the position of the SR interferogram on the camera CCD face was held constant by continuously adjusting the horizontal and vertical orientations of a movable mirror mounted just outside the extraction chamber.[2] The compensation angles as a function of changing beam current during typical physics runs are shown in Fig. 3. The maximum peak-to-peak excursions in the vertical direction reached 1 milliradian, which if uncorrected would have rendered the interferometer (located 30 meters downstream of the extraction mirror) unusable.

FEATURES OF NEW CHAMBER

The new chamber is shown in Figures 6, 7 and 8. The most significant change was to make the beampipe out of copper, except for a section of beampipe outside the containment chamber connecting to a flange which was made of copper-plated stainless steel. The greater conductivity

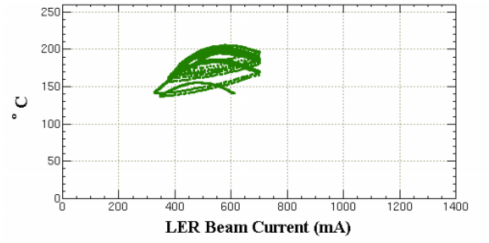

Figure 2: Old beam-pipe temperature dependence on beam current.

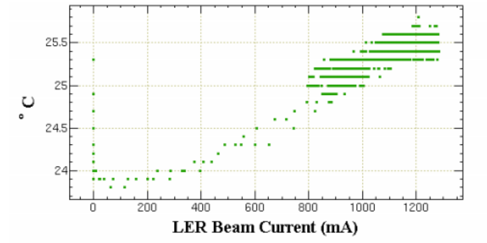

Figure 4: New beam-pipe temperature dependence on beam current.

of copper compared to stainless steel reduces the resistive heating from wall currents, and the higher heat conductance of copper helps dissipate what energy does get deposited and prevent the temperature build-up seen in the stainless-steel chamber.

In the case of stainless steel, a 1 A beam current at 4-bucket, or 8 nsec, spacing, will induce 20 W of heating in the walls. Without full-surface cooling, this heat deposition would generate a temperature gradient of 140 degrees/10 cm along the beam pipe wall. Copper, with its greater conductivity and thermal conductance was estimated to generate only 3.5 degrees/10 cm, a negligible temperature rise. Switching to copper was considered easier than redesigning the cooling system.

Measurements of the temperature of the inside beam pipe wall show that the temperature rise has in fact been reduced by two orders of magnitude as seen in Fig. 4.

MAFIA simulations indicated that at full current potentially problematic levels of HOM power could be expected to leak from the extraction apertures in the inner beampipe used in the original design. The decision was made to reduce all apertures as much a possible while remaining compatible with light-extraction needs.

The inner light-extraction window was replaced by a smaller aperture. The light-extraction port in the outer chamber was also reduced in radius to minimize the leakage of HOM power to the movable mirror assembly located just outside the outer chamber window. A free-space gap was maintained between the beam pipe and the outer chamber in order to dissipate as much of the HOM power inside the outer chamber as possible, before reaching the final light-extraction port.

Since the titanium coating had not proven effective, the quartz windows were eliminated. The observation port was eliminated entirely, a simplification enabled by changing the way the extraction mirror is mounted. Previously the

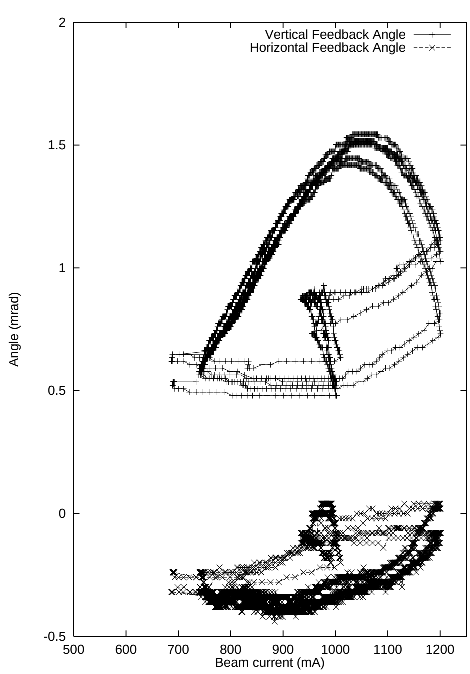

Figure 3: Optical-axis feedback correction angles dependence on beam current with old chamber.

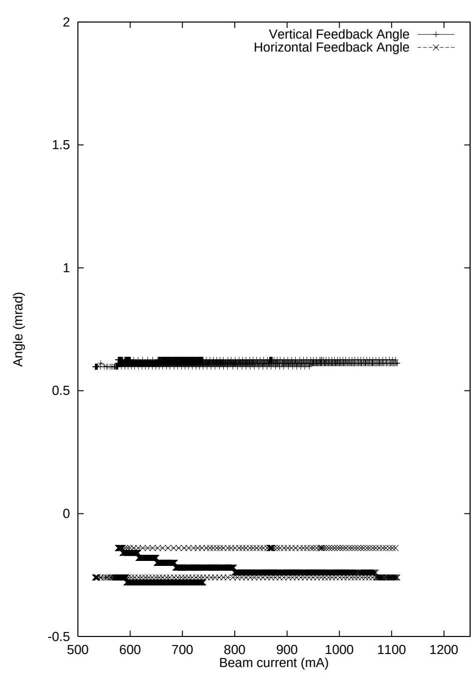

Figure 5: Optical-axis feedback correction angles dependence on beam current with new chamber.

mirror was suspended from a micrometer stage mounted on the lid of the chamber, necessitating fine-tuning of its seating after the lid had been shut. Now the mirror is mounted from the bottom of the chamber, so its seating can be checked while the lid of the outer chamber is still open, eliminating the need for the observation port to check the mirror seating from the outside of the chamber.

The thermocouple leads for monitoring the internal beam pipe temperature are encased in a grounded sheath and carefully routed to avoid any possibility of arcing from leaking HOM fields. In addition, mounting flanges (see Fig. 7, lower right corner) are provided in the ceiling and floor of the outer chamber as locations in which to mount SiC absorbers should they prove necessary. However, as the outer chamber temperature shows negligible temperature rise with beam current, such absorbers have proven unnecessary.

PERFORMANCE

Due to the reduction of the beam-pipe temperature rise, the motion of the mirror as a function of beam current has been greatly reduced. The optical axis feedback compensation angles for the new chamber are shown in Fig. 5. Comparison with Fig. 3 shows that the optical axis alignment drift has been greatly reduced, to the point that the operation of the feedback loop is no longer required. This has made setup of stable optical beamlines for SR studies much easier.

The HER SR chamber is of a similar design to the original LER one, and exhibits the same heating and optical-axis drift problems. Therefore we will be replacing the HER chamber with one similar to the new LER chamber during the summer 2003 shutdown period.

Figure 6: Installation of new LER synchrotron radiation extraction chamber.

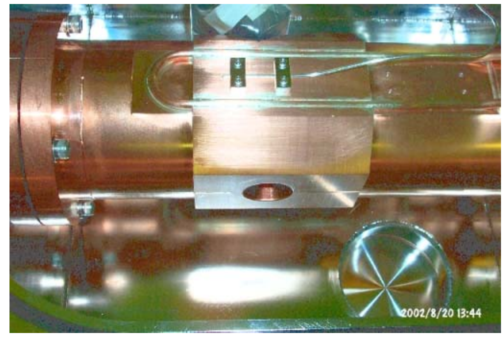

Figure 7: Inside of new LER synchrotron radiation extraction chamber, showing light extraction aperture in beam-pipe (center).

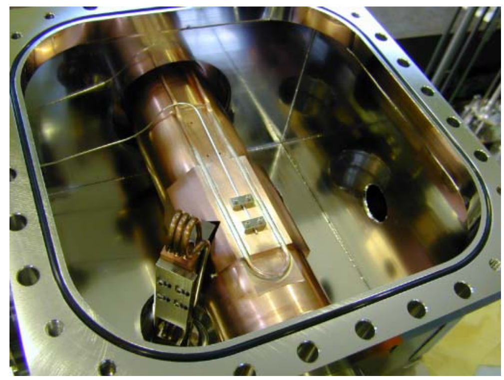

Figure 8: Inside of new LER synchrotron radiation extraction chamber, showing extraction mirror (lower left) and light-extraction aperture in outer chamber wall (middle right).

REFERENCES

[1] M. Arinaga et al., “KEKB beam instrumentation systems,” Nuclear Instruments and Methods in Physics Research A 499 (2003) pp. 100-137.
(SR extraction-mirror system described on p. 124.)

[2] J.W. Flanagan, S. Hiramatsu, H. Ikeda, and T. Mitsuhashi, “Improvements to Automated Beam-size Measurement System at KEKB,” Proceedings of the Second Asian Particle Accelerator Conference, Beijing, China (2001) pp. 639-641.