BEAM LIFETIME MEASUREMENTS WITH LIBERA BRILLIANCE

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Abstract

The lifetime of the electron beam in a Synchrotron Light Source is an important parameter. Its precise measurement within a short time is an essential tool to evaluate properties and stability of a storage ring. In some cases, for example during short gas outbursts in the UHV vacuum chamber leading to rapid lifetime drops, it can be used as a useful diagnostic tool as well. Traditionally, dedicated PCTs (Parametric Current Transformers) are mostly used for this purpose. The idea to use Libera Brilliance Beam Position Processor instead came after the excellent quality of its sum signal was observed. Moreover, the measurement accuracy is greatly increased by averaging the lifetime measurements of all the individual stations, bearing in mind that there are typically more than hundred BPMs positioned around the ring. First measurements were performed on ESRF, showing very good performance potential. The article discusses the measurements, their results, the comparison with more classical methods, and the implementation of this feature in the Libera Brilliance software.

INSTRUMENTATION

Libera Brilliance is widely used as a beam position processor at third generation synchrotron light sources around the world. Its flexibility allows very fast wideband measurements on one side, fast feedback operation, and narrowband monitoring of the signals on the other. All this data is available simultaneously, enabling complete characterization of the accelerator system.

The native purpose of such instrumentation is of course the beam position measurement at different bandwidths. It was however noticed that the sum signal is very useful as well as it is proportional to the stored current in the ring. Specifically, the Slow Acquisition (SA) dataflow is used for slow monitoring of the position and comes at 10 Sps. It consists of four amplitudes, the derived Δ/Σ position and the derived sum value of four amplitudes.

MEASUREMENTS

All measurements were performed in the ESRF storage ring, where a total of 224 Libera Brilliance units are routinely used for the beam position monitoring. The injection at ESRF is scheduled twice a day, at 9 AM at 9 PM. The typical current in the ring is ~200 mA immediately after the injection, decreasing to a minimum value at ~150 mA before the next injection. A typical graph of sum value of one Libera Brilliance can be seen in Figure 1.

It can be assessed immediately that a single Libera Brilliance unit is already capable of a precise and reproducible beam lifetime measurement. Theoretically, all Libera Brilliances around the storage ring should of course measure the same beam lifetime.

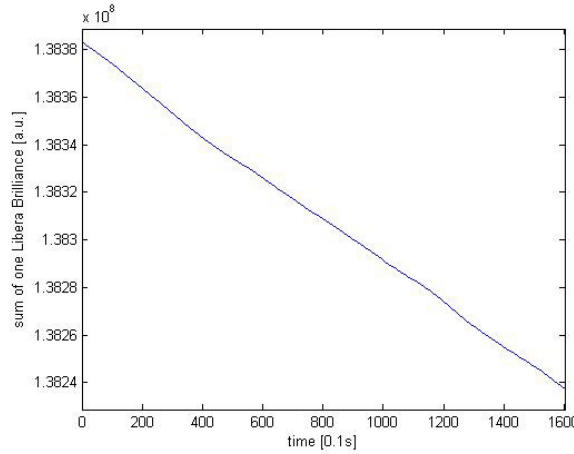

Figure 1: Decrease of the sum value on one Libera Brilliance through 160 s.

However, when reading the data from all units around the storage ring at the same time, few random units reported significantly different beam lifetime from time to time. Jumps in the lifetime value are just short spikes and are not really related to the beam lifetime change. The most frequent reason for them is a change in the fans speed due to temperature control loop inside Libera Brilliance. This phenomenon is depicted in Figure 2.

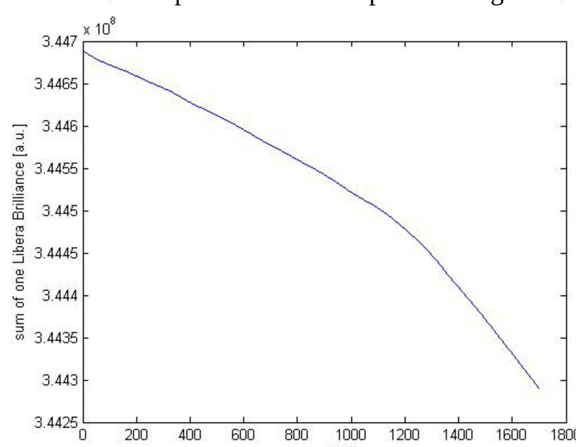

Figure 2: Decrease of sum value on this Libera was affected by the fans speed change.

This actually shows how sensitive the beam lifetime measurement is. The effect of the fans speed change can be even better observed on Figure 3. Six Libera Brilliances lifetime calculations are directly compared to recorded fans speed. Same colour denotes the same

Libera Brilliance unit. At certain point in time, the health daemon, which is controlling temperature inside Libera Brilliances, was stopped. The fans speed was manually set to 4600 rpm at that point. The effect of this change can be seen as a spike in lifetime measurement. Moreover, the Libera Brilliance, marked with red colour, had an oscillation in fan speed prior to daemon's stop. It can be directly seen that its lifetime calculation is not valid in such conditions.

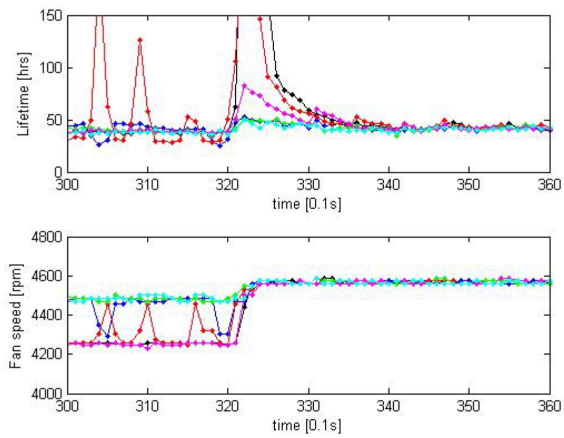

Figure 3: Fans speed fluctuation (below), affecting beam lifetime measurement (above).

In Figure 4, the sum value from all 224 Libera Brilliance units around the storage ring is normalized and plotted together:

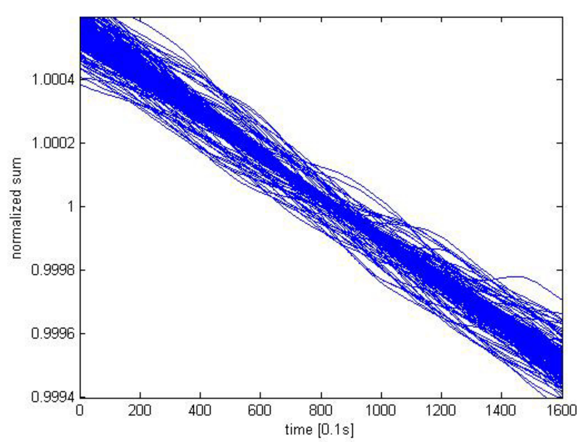

Figure 4: Normalized sum value from all 224 Libera Brilliance units around the storage ring.

It can be observed that majority of Libera Brilliance units report the sum values that are consistant, however, some are fluctuating around. The beam lifetime calculation, based on this data is given in Figure 5. It can be seen here even more easily how some calculated beam lifetime values are not stable. However, the big advantage of having a large number of instruments, each calculating the beam lifetime value, is that it can be easily determined which measurements are not valid.

Validity of data can be defined by setting the criteria. Individual values, which are considered as invalid, are discarded. Typically, beam lifetime value is useful for more than 3/4 of Libera Brilliance units around the storage ring. With ¾ of 224 units (=168) the improvement factor because of averaging is 13.

The beam lifetime measurements after this clean-up is shown in Figure 6, and after averaging in Figure 7.

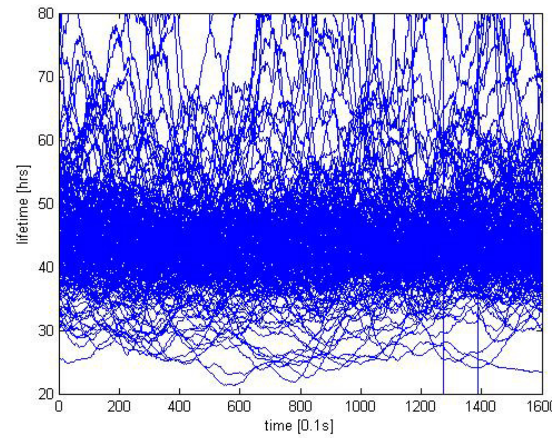

Figure 5: The lifetime from all 224 Libera Brilliance units, calculated from data on Figure 3.

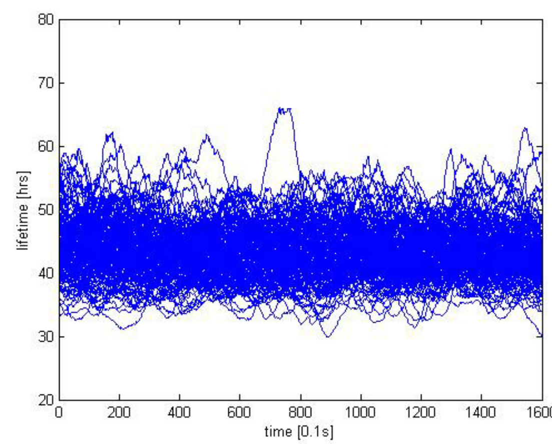

Figure 6: The beam lifetime measurements after the unstable ones are discarded.

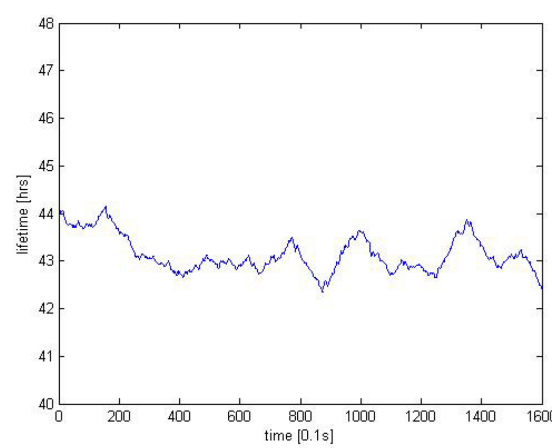

Figure 7: Accurate beam lifetime as the final result. Note: vertical scale is zoomed compared to Figures 5 and 6.

Comparison with existing current monitors

ESRF storage ring is equipped with three current monitors (PCTs). The comparison of the beam lifetime measurements with both systems was the next step. On Figure 8, the three PCTs are compared to Libera Brilliance units, separated into three groups [1]:

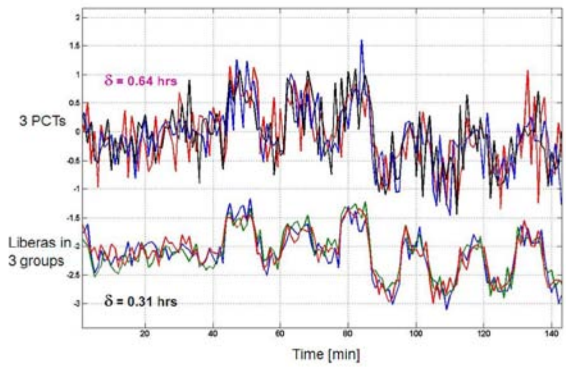

Figure 8: The comparison of three PCTs with Libera Brilliance units in three groups.

It can be seen that after averaging, the RMS of the measurement is lower with Libera Brilliance units. The long term performance was compared as well (see Figure 9), showing good matching of two instruments [1]:

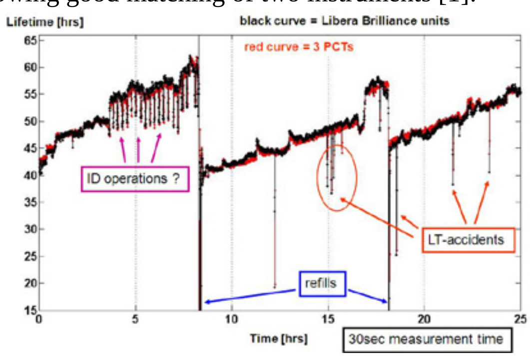

Figure 9: The measurements from both systems match and reveal the same phenomena.

Closer look at the beam lifetime accidents show that the measurement from Libera Brilliance units is a bit faster than the one from the PCTs [1]:

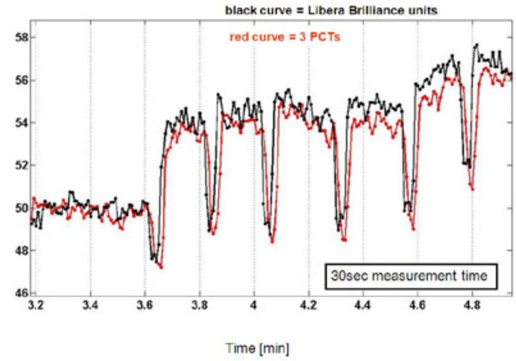

Figure 10: The zoom into real beam lifetime measurements.

The speed of measurements is important since it directly indicates the quality of the vacuum and the nature of so-called lifetime accidents. Such lifetime accidents are of serious concern for the ESRF, which is an aging Ring (20 years old) with many UHV chambers & components.

IMPLEMENTATION ON LIBERA BRILLIANCE

All the measurements and analysis above were done outside Libera Brilliance, based on the SA sum data, in Matlab®. It is however clear that by doing the calculation of beam lifetime on Libera Brilliance one could save a lot of data transport and network bandwidth. The measurement is faster and more reliable as well.

The implementation was done recently and is being tested on ESRF. Calculation is done continuously on latest SA samples (moving window). Beam lifetime value is calculated using the following equation [2]:

LT = (-1 *dt / ln (S(p) / S(p-dt))) / 3600 [hrs]

Where:
LT ... lifetime;
N ... window for calculation [SA samples];
n ... current SA sample;
dt ... time interval over which the LT is calculated [sec];
S(p) ... mean(S(n : n-N));
S(p-dt) ... mean(S(n-N-1 : n-N-N-1));
dt ... N * Tsa;
Tsa ... FREV / (SA_dec * DFA);
FREV ... revolution frequency in Hz;
SA_dec ... SA decimation factor, always 1024;
DFA ... FA decimation factor;

Most of the parameters are of course fixed because they are accelerator specific. The only parameter which can be set for beam lifetime calculation is the time window for calculation. It can be set runtime. The correct setting of this window is a compromise between resolution and response time. For all the measurements in this article the window of 30 s was used.

CONCLUSION

The use of the Sum signals of the numerous Libera Brilliance units in a Ring is shown to be very suitable for highly accurate beam lifetime calculations and of better resolution and response time than with PCT current monitors. This Lifetime measurement output is now added in the Libera Brillianc's functionality.

REFERENCES

[1] K. B. Scheidt, Status of ESRF BPM system, ppt presentation, Solkan, November 2009
[2] Instrumentation Technologies, Libera Brilliance User Manual v2.10, Solkan, February 2010