

# INFLUENCE OF ENVIRONMENT CHANGES ON LIBERA SYNC 3 LONG-TERM STABILITY

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## Abstract

Libera Sync 3 is intended to be used as a reference clock transfer system in the latest fourth generation light sources where the required long-term stability is in the range of a few tens of femtoseconds of drift per day [1]. The system has an outstanding added jitter performance below 4 fs in the 10 Hz to 10 MHz frequency range. The system has been developed in collaboration with the Paul Scherrer Institute (PSI) and first units are already installed in the SwissFEL machine. In this article we present the influence of temperature and humidity changes on the long-term phase stability of the system.

## INTRODUCTION

Libera Sync 3 solution is based on a continuous wave (CW) modulation of an optical carrier in which phase detection and stabilization are done in the radio frequency (RF) domain [2]. The system is composed of a transmitter and a receiver units (Figure 1) connected by two optical fiber links that are laid in the installation tunnel as it is depicted in Figure 2. Additional Ethernet connection is used for data exchange between the units and for remote monitoring and control of Libera Sync 3.



Figure 1: Libera Sync 3 transmitter and receiver units.

The two optical fiber links are used in order to overcome optical limitations, mainly due to the Rayleigh backscattering effect [3, 4]. One fiber is used to transfer a low-noise signal while the second is used to transfer a low-drift reference signal.

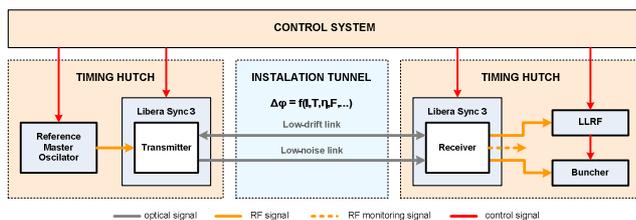


Figure 2: Installation of Libera Sync 3 system in the accelerator environment.

Libera Sync 3 compensates both the phase drifts in the electronics and in the low-drift optical link. All the components outside the phase compensation loops are sensitive to environmental changes, especially temperature and humidity changes. To reduce such influences different compensation techniques like thermal stabilization of critical components and usage of thermally compensated materials are applied, but nevertheless some residual sensitivity to environmental changes still exist.

## PERFORMANCE MEASUREMENTS

Jitter and long term stability are two key performance parameters for Libera Sync 3.

### Jitter performance

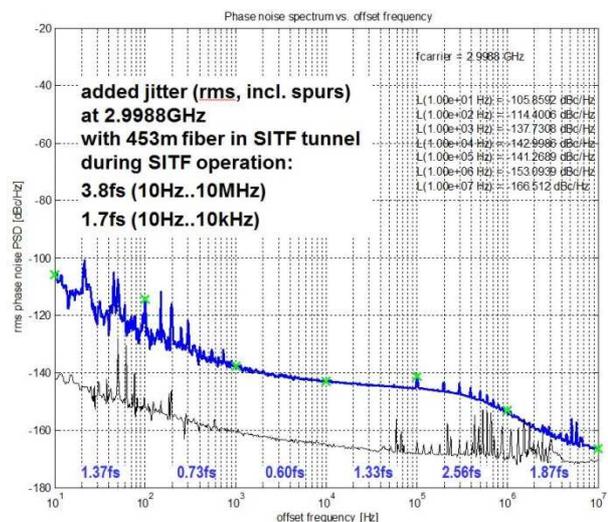


Figure 3: Libera Sync 3 added phase noise and jitter. The black curve shows the limit of the measuring setup.

Figure 3 shows Libera Sync 3 measured phase noise and jitter at 2998.8 MHz that was done at PSI. The added jitter in the frequency range from 10 Hz to 10 MHz is 3.8 fs.

### Long-term phase stability

The long-term phase stability of the Libera Sync 3 was measured using a standalone phase detector unit which compared the output RF signal from the Libera Sync 3 system with the reference signal. The drift of setup itself is estimated to be on the order of a few femtoseconds peak-to-peak per day. Figure 4 shows block diagram of the measurement setup.

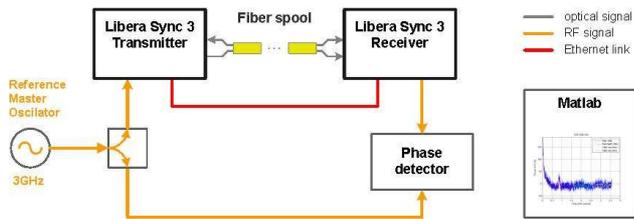


Figure 4: Phase drift measurement setup.

Figure 5 shows typical long-term phase drift of one of the Libera Sync 3 systems compared to the environmental conditions the system has been exposed to. After the installation, Libera Sync 3 and all RF cables normally require a couple of days to relax and stabilize. Typical long-term phase stability of Libera Sync 3 system is in the range of 10 to 30 femtoseconds peak to peak over one day of operation for environmental changes that are within specification ( $\pm 1$  °C and  $\pm 5$  % RH).

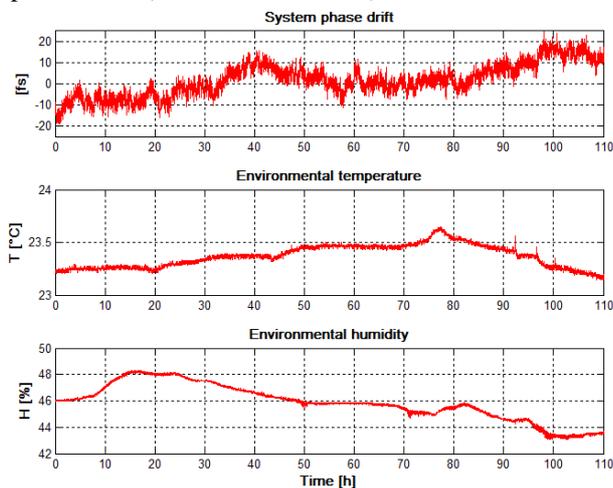


Figure 5: System phase drift and changes in environmental temperature and humidity.

The sensitivity of the Libera Sync 3 system to temperature and humidity changes was measured using environmental test chamber. RF generator, long-term stable phase detector and temperature stabilized RF splitter were placed outside the environmental test chamber as it is depicted in Figure 6. For all the RF connections temperature compensated RF cables with the temperature dependence in the range of some 10 fs/m/K were used. Length of all RF cables inside the chamber was approximately 1m.

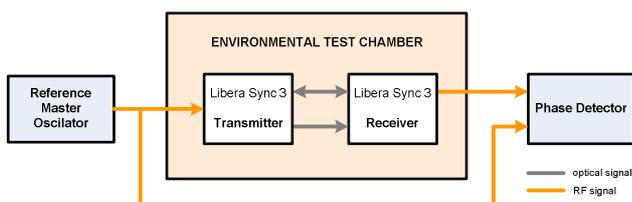


Figure 6: Temperature and humidity dependence measurement setup.

Figure 7 shows phase drift of first Libera sync 3 system in relation to trapezoidal changes in temperature and humidity. Temperature dependence is around 25 fs/°C. System responded to humidity change with some delay. 20 % change in the environmental humidity caused 100 fs of phase drift.

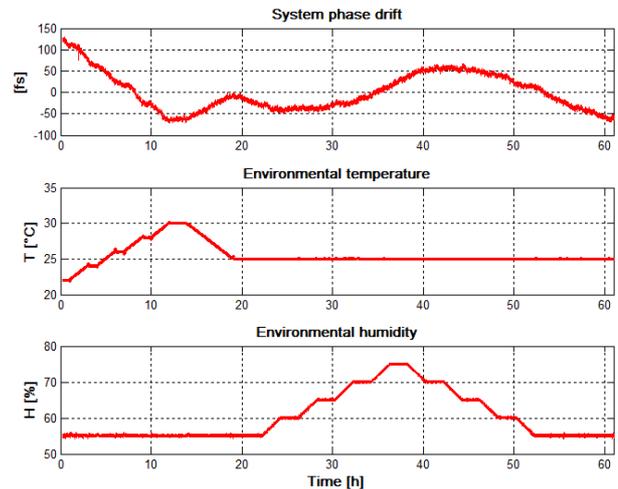


Figure 7: Libera Sync 3 long term phase drift and temperature and humidity changes.

Figure 8 shows the step response of second Libera Sync 3 system to humidity changes. Step change in environmental humidity caused some spikes in environmental temperature and some of them are noticed in the system phase drift too. The Libera Sync 3 system adapts to new conditions in 2 to 3 hours after humidity step change has been applied. Jump from 50 % to 60 % in environmental humidity caused 70 fs of systems phase drift while jump in humidity from 70 % to 80 % caused 110 fs of systems phase drift. Humidity dependence increases with the absolute value of it.

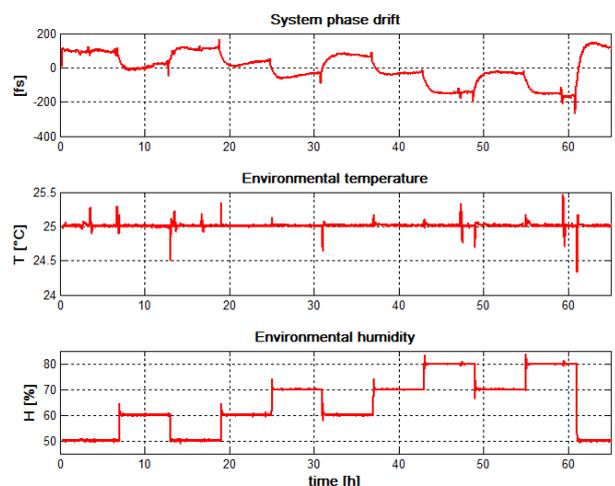


Figure 8: Libera Sync 3 phase drift response to step changes in environmental humidity.

Additional long-term performance measurements were done. In this case Libera Sync 3 system was removed from the environmental test chamber and only approximately 1 m of connecting RF cables remained inside the chamber. Figure 9 shows measured setup phase drift for the same humidity profile inside the chamber as it was used in previous case. Beside RF cables that are susceptible to environmental changes all other instruments that are outside test chamber are also exposed to some environmental changes that chamber is introducing to the room where it is located. A jump from 50 % to 60 % in humidity caused a 20-30 fs phase drift while a jump in humidity from 70 % to 80 % caused a 40-50 fs of setup phase drift. The correlation between humidity profile and phase drift measurement is not as obvious as in previous measurements.

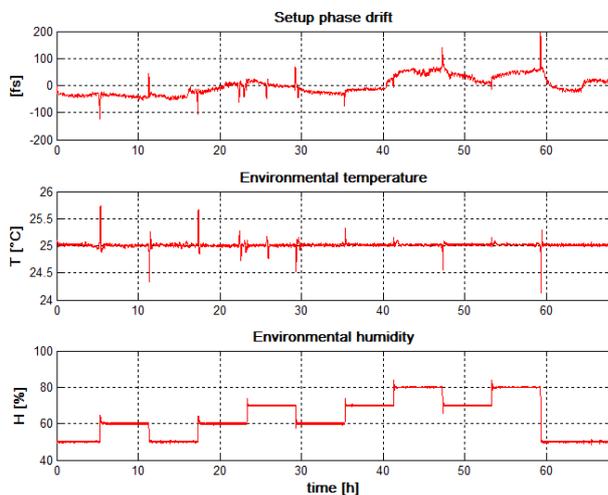


Figure 9: Setup phase drift.

## CONCLUSION

In the presented paper one Libera Sync 3 system was exposed to trapezoidal changes in environmental temperature and humidity and one to the step changes in environmental humidity. The system adapts well on smooth changes in temperature and humidity while step changes introduce some transient response in systems performance that settles down in 2 to 3 hours.

The presented measurements include the contribution of the RF cables inside the chamber that were exposed to the same environment changes as the system itself. Furthermore all the instruments and cables outside the chamber were also exposed to some environment disturbances that chamber caused to the room where it is installed. The estimation how much the testing setup contributed to the Libera Sync 3 long-term drift performance can be seen in the last measurement. The measurement error can be as high as 30 % of the measured value. This gives an insight about the complexity of the presented long-term measurements.

Libera Sync 3 system needs moderately stable environment to reach its nominal performance. The long term measurements of other Libera Sync 3 systems

confirm these observations. On the other hand additional and improved measurements of systems dependence to environmental changes need to be performed in order to cancel out measurement uncertainty and get better statistics.

## REFERENCES

- [1] V. Schlott et al., "Reference distribution system for SwissFEL", Libera Workshop (2012)
- [2] M. Vidmar et al., "Chasing Femtoseconds – How accelerators can benefit from economies of scale in other industries", IPAC (2011)
- [3] P. Orel, S. Zorzut et al., "Next generation cw reference clock transfer system with femtosecond stability", NAPAC (2013)
- [4] P. Orel, S. Zorzut et al., "Test Results of the Libera Sync 3 CW Reference Clock Transfer System", IPAC (2014)