RF REFERENCE DISTRIBUTION FOR THE TAIWAN PHOTON SOURCE

K. H. Hu, Y. S. Cheng, C. Y. Liao, Y. T. Chang, C. Y. Wu, P. C. Chiu, Demi Lee, S.Y. Hsu, Jenny Chen, C. H. Kuo, K. T. Hsu
NSRRC, Hsinchu 30076, Taiwan

Abstract

Taiwan Photon Source (TPS) is a low-emittance 3-GeV synchrotron light source with circumference of 518.4 m which is being under construction at National Synchrotron Radiation Research Center (NSRRC) campus. Low noise 500 MHz master oscillator and novel fiber based CW RF reference distribution system will be employed to take advantages of advanced technology in this field and deliver better performance. The preliminary test of the prototype system is summarized in this report.

INTRODUCTION

The TPS is one of the latest generation advanced synchrotron light sources. To take advantages of latest development in the 2000s, transfer of continue wave (CW) RF reference and timing will be based on optical technology [1-4]. It was decided to adopt fiber based distribution solution which is commercial available to avoid bulky coaxial cable installation. The RF reference will be generated by a low phase noise master oscillator. The RF signal split into multiple fanouts to distribute to different locations and applications around the accelerator and experimental stations via fiber links. RF reference would need distributed to RF systems of linear accelerator (linac), booster synchrotron, the storage ring and diagnostic stations with phase stabilize, low additive phase noise and could counteract the effects of ambient temperature change. Beamline and experiments might need precision RF reference to do time-resolved experiments or synchronize the laser system also.

MASTER OSCILLATOR AND SIGNAL SPLITTER

The master oscillator should be low phase noise and phase continue when changing frequency [5]. The master oscillator takes reference from a low phase noise 10 MHz rubidium clock which is locked to the atomic standard of GPS via 1 PPS (one pulse per second) signal. The master oscillator and the frequency standard will be installed at the equipments area (CIA, Control Instruments Area) nearby the linear accelerator. The nearby racks will locate the timing master and fiber distribution of the event system [6]. The phase noise of the master oscillator (R&S SMA-100A with B22 option) is shown in Fig. 1. Its jitter is less than 100 fs rms (< 0.015^{o} rms in RF phase, from 10 Hz ~ 10 MHz) which can satisfy the requirements of an advanced synchrotron light source like TPS.

The output power of the master oscillator will be boosted by a high dynamic range low noise linear amplifier with hight IP3 (+38 dBm) to around 25 dBm level. The signal split into eight 15 dBm signals which can connect to the fiber transmitter directly. The fanout circuitry as shown in Fig. 2 is installed at a sub-rack with adequate thermal insulation accompany with temperature monitoring functionality. One port of the first stage power splitter output connects to a 2nd power splitter to delivery another eight 5 dBm output for timing system, linac LLRF, and another diagnostic application. The second signal chain can be implemented later for the future expansion.

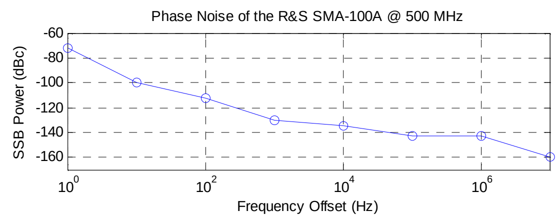

Figure 1: Nominal phase noise in dBc (1 Hz) of the R&S SMA-100A signal generator with SMA-B22 option.

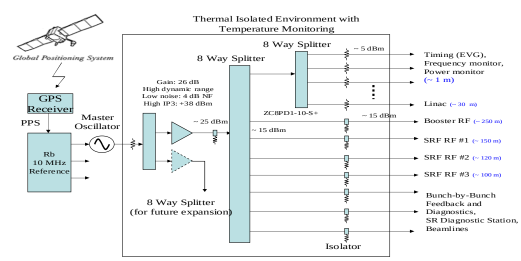

Figure 2: RF reference fanout unit.

OPTICAL FIBER BASED RF REFERENCE DISTRIBUTION

The RF reference will adopt newly developed fiber based RF CW transfer system. This is commercial available Libera Sync [7] which assures clock signal distribution with femtosecond jitter and fiber drift compensation [1-4]. It is suitable for FEL and synchrotron light source machines. Its original version is working in S-band. The 500 MHz version is current available after re-design of its S-band counterpart. The operation principle of the Libera Sync is shown in Fig. 3. Group delay of the RF signal in the clock distribution system is stabilized by the wavelength tuning and the chromatic dispersion of the optical fiber in the forward and backward direction. The wavelength tuning is operated by means of control temperature of the distributed feedback (DFB) laser. The DFB laser is directly modulated by the input RF signal. Telecom grade DFB laser ensures high reliable operation of the system. Health conditions of fiber links are also monitored by the control system and machine monitoring system. Any failures of a link can be identified easily; spare unit replacement is quickly and will not affect machine availability.

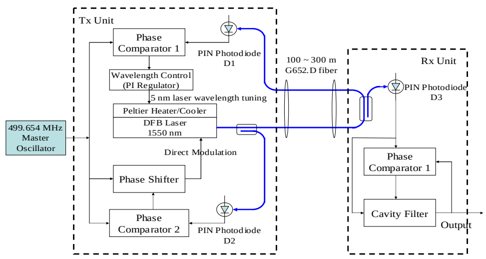

Figure 3: Simple block diagram of the Libera Sync fiber link for 500 MHz operation.

SYSTEM CONFIGURATION

The RF reference generation and distribution system plan are shown in Fig. 4. The SMA-100A signal generator is locked with a GPS disciplined rubidium low phase noise 10 MHz frequency reference. The 499.654 MHz signal is split by multi-ports power splitter delivering 15 dBm output with adequate isolation between ports. Since the instruments rack is installed near by the linear accelerator, one link will connect to the linear accelerator low level RF system by coaxial cable directly. The RF references for the booster synchrotron and the storage ring will be distributed by four fiber links. The RF power which delivers to the RF system can vary from 5 to 15 dBm. Another possible applications need RF reference such as bunch-by-bunch diagnostic and feedback system, synchrotron radiation diagnostics station for streak camera, and beamline laser systems will be distributed by the fiber link also for the future expansion. One of a RF reference port will connect to the event generator (EVG) on the timing system which will generated various machine clocks and trigger signals and distributed to the site which need these signals around the whole accelerator for synchronization, injection control, and synchronize experiment with the stored beam.

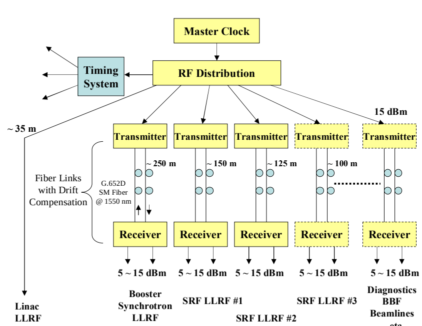

Figure 4: RF reference distribution scheme for the TPS.

All Libera Sync TX and RX units will be accessed by the control system. The working conditions and system healthy can be monitored by control system include housekeeping, conditions of the DFB laser, photo current and power of photo diodes, and RF power. Any fault can dig out quickly. Distance for the fiber links are about from 150 m to 350 m for the TPS configuration.

PRELIMINARY TEST

Prototype master oscillator and the timing master as show in Fig. 5 (a). This system has already supported commissioning and acceptance test of the TPS 150 MeV linear accelerator in the 2nd quarter of 2011 successfully.

Five pairs of the Libera Sync TX and RX units were received in June. Installed at test rack to perform preliminary test is shown in Fig. 5 (b). The check of functionality and performance is on-going.

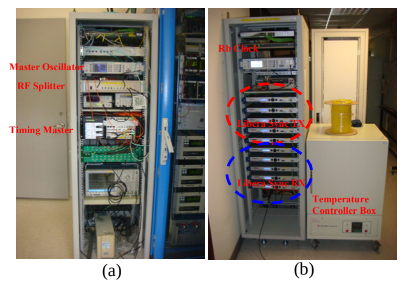

Figure 5: (a) Prototype master oscillator and the timing master. (b) Photo of the Libera Sync pairs in testing.

Instrumentation set up to support this test is shown in Fig. 6. Phase noise is measured by the RSA-3308A real-time spectrum analyzer. However, noise floor of the RSA-3308A might be inadequate for low-phase noise measurement. The long-term drift measurement will be performed by two approaches by handy instruments. The first method will use a calibrated double balance mixer installed at temperature controlled environment as phase detector. The phase errors will be readout by Keithley 2001/2002 7.5/8.5 digits DMM meter. The calibration constant of the mixer phase detector at various conditions are checked, the sensitivity is about 3.3 mV/Deg at working point, i.e., 33 µV corresponding to 0.01 Degree of RF phase. The second approach is down convert the RF signals of the Libera Sync pairs input and output signals to a lower frequency (~ 64 kHz) so that it can be compared with the phase by SR850 lock-in amplifier with 0.01° resolution. Ambient temperature of the instruments set up will be monitored by temperature sensors. Setup of the measurement is in proceed. All instruments can be accessed in the EPICS environment.

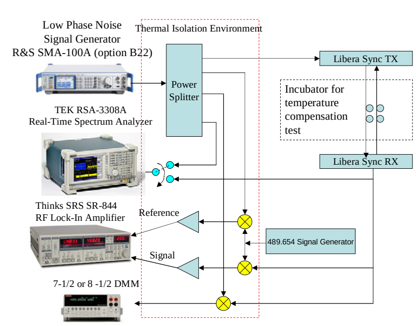

Figure 6: Functionality and performance test set up for Libera Sync pairs by using instruments in hand.

Functionality

Test of the functionality of the Libera Sync units is on-going. All these functionality includes setting and monitoring of fiber spool parameters, photocurrent and power of photo diodes, RF input and output power, drift compensation PI controller parameters, …etc. Integrated to the TPS EPICS control environment is in planned.

Spectrum and Phase Noise Measurement

The Libera Sync pair input and output spectrum were measured by the RSA-3308A real-time spectrum analyzer as shown in the Fig. 7. It cannot distinguish both spectrum, this might indicate that the additive jitter contributed by the Libera Sync pair is below the noise floor of the spectrum analyzer. It cannot be identified by current measurement setup. The RSA-3308A can measure phase noise directly using the carrier to noise measurement (C/N). This measurement can be made with direct reading that provide the C/N in a specific bandwidth as well as the C/N in a 1 Hz bandwidth (C/No). It is hard to distinguish the Libera Sync pair input and output signal phase noise from the measurement. The measured phase noise is shown sideband phase noise from 10 Hz to 10 MHz shown in Fig. 8. The measured SSB noise is most likely the noise floor of the RSA-3308A, the real signal SSB noise cannot be measured correctly with current instrument setup. The measurement is not sufficient to extract the additive jitter contributed by the Libera Syns pair. New instrument set up is in study.

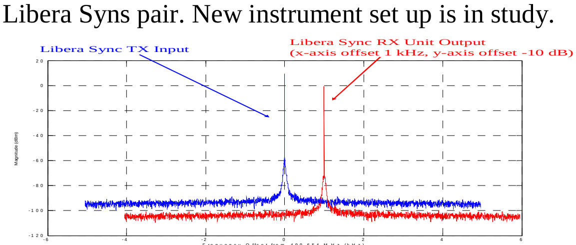

Figure 7: RF signal spectrum of Libera Sync pair input and output.

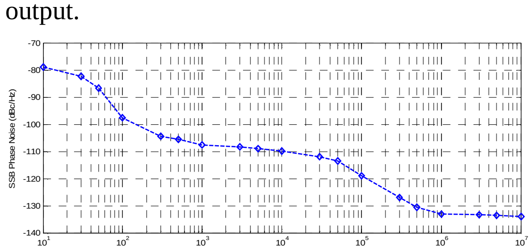

Figure 8: Measured SSB phase noise from 10 Hz to 10 MHz.

Long-term Drift Test

The long-term drift measured by the mixer type phase detector and lock-in amplifier is shown in Fig. 9. The drift is combined of instruments stability and fiber link stability. The measured phase drift for 25 hours are within $\pm 0.1^{o}$ RF phase and might be the worst case due to instrumentation contribution in the same level. The instruments installed in an open rack might suffer from the ambient temperature variation for this preliminary measurement. Further improvement is on-going. Despite the reading of the lock-in and mixer phase detector have the same trend, further effort need to dig out the reason of the discrepancy of both detectors.

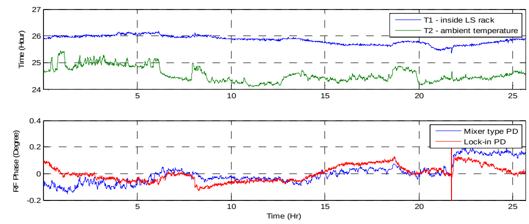

Figure 9: Preliminary long-term drift measurement results. The phase drift is most likely contributed by the phase detector which is installed at a rack without thermal isolation.

SUMMARY

The scheme of the RF reference generation and distribution are summarized in this report. Prototype of RF reference system and fiber based distribution system test is in proceeded. Setup test bench and instruments to verify the performance are on going. Functionalities of the fiber link are examined. Long-term test is scheduled after preparation works done which is probably in the 4th quarter. The shortage of current plan will be identified and revised plan can be proceed during the course of the test.

ACKNOWLEDGEMENT

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