STABLE LOW NOISE RF SOURCE FOR MAIN RING *

G.Kurkin #,
Budker Institute of Nuclear Physics, SB RAS, 630090, Novosibirsk, Lavrentyev ave, 11, Russia

Ping Wang
FEL Laboratory, Department of Physics, Duke University, Box 90319 Durham, NC 27708 – 0319, USA

Abstract

The Duke Storage ring is a 1 Gev electron ring, which is designed for driving UV-VUV FEL [1]. It also provides variable energy high intensive gamma rays by Compton back scattering. It requires an RF master oscillator with very low phase noise. We built a Surface Acoustic Wave (SAW) Oscillator. However, the long-term stability does not meet requirements for FEL ring. Previously we used a commercial signal generator HP 4400B as the master oscillator. It has excellent long-term stability, but the phase noise is not acceptable. A phase feedback loop has been added between the SAW oscillator and the HP source, which provides us an excellent RF source. The design details and the test results are presented in this paper.

MASTER OSCILLATOR REQUIRMENTS

A master oscillator is the heart of a storage ring, which determines its performance. At Duke Storage Ring, for the FEL and gamma operations, it requires the RF frequency being adjustable over a relative large range and with a sufficient frequency resolution. It also requires the RF source with long term frequency stability and low noise spectral density at the sidebands, which are offset from the carrier by the synchrotron oscillation frequency. Previously we used a commercial signal generator HP 4400B as the master oscillator for its excellent frequency modulation accuracy and stability. We need that for the RF frequency adjustment. It also has a very good longterm frequency stability of 10^{-8}. But its phase noise is bad, and the amplitude modulation makes it worse when the RF cavity is detuned off the resonance. This phase noise will result in an excessive energy spread to the stored electrons beam, which will degrade the FEL operation.

HARDWARE

A Surface Acoustic Wave (SAW) Oscillator from Andersen Laboratories is chosen as the master oscillator for the Duke 1 Gev storage ring. The circuits operate at 357 MHz, which is the second harmonic of the RF frequency (178.5 MHz). The frequency of its output signal is controlled by DC voltage in the range of 0.15%. The signal phase noise of the SAW oscillator is very low, but the frequency of its output signal is temperature dependent with ~2 ppm/°F.

This parameter is quite unacceptable, so we decided to stabilize the SAW oscillator by a phase lock loop by using the HP 4400B as a reference source. Figure 1 is a block diagram of the master oscillator. In order to prevent the SAW oscillator modulation, the following

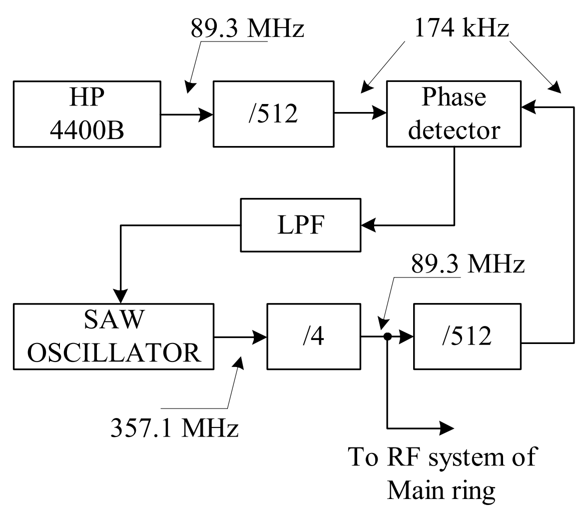

Figure 1: Block diagram of master oscillator.

techniques have been employed in the circuit design:

1. The frequencies of the output signals from the oscillator and the HP4400B have been divided by digital counters down to 174 kHz before the Phase detector. (Fig. 1).
2. The frequency control range of the SAW oscillator is made as low as possible.
3. A Low Pass Filter (LPF) has been inserted into the loop between the Phase detector and the SAW oscillator for the further rejection of the signal.

PERFORMANCE MEASUREMENT

The frequency of the unit open loop gain is as low as 15 Hz. The whole device is operating as the band pass filter for the signal of HP4400B with a bandwidth of ~30 Hz.

*This work is supported by the DOD MFEL program as administrated by the AFOSR, grant F49620-001-0370
#G.Ya.Kurkin@inp.nsk.su

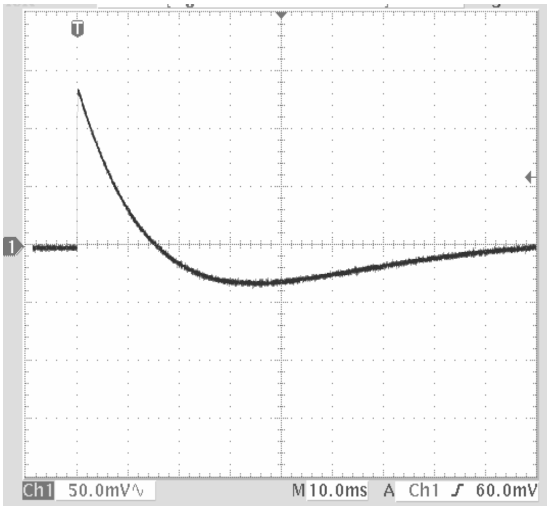

Figure 2: Phase detector output of the SAW Oscillator. Transient response in the feedback loop is shown after it is disturbed by a step-function voltage.

The phase noise rejection of the HP4400B is more than 60 dBC at the sidebands 5 kHz off the carrier, so the noise of the output signal from the Master oscillator in this region is determined only by the SAW oscillator itself. Such a narrow bandwidth of the feedback loop also damps the occasional jumps in the synthesizer's frequency, when it is being adjusted to different operation RF frequency.

Figure 2 shows a transient response in the phase lock loop when a step function voltage applied to the phase detector. The time constant of the transient is ~10 ms.

We have examined the RF signal spectrums from the RF cavity sampling output by a HP Spectrum Analyzer. The signal side band phase noise, at a frequency offset of 20 kHz, has been reduced by ~20 dBc with the phase lock loop switched on.

REFERENCES

[1] S.F. Mikhailov, V.N. Litvinenko (Duke University), Y. Wu (LBNL), "Low Emittance Lattices for the Duke FEL Storage Ring", Proc. of the 2001 Particle Acc. Conf., Chicago, Illinois USA, June 18-22, 2001, vol. 5, pp. 3528-3530,

0-7803-8859-3/05/$20.00 ©2005 IEEE