TIMING JITTER MEASUREMENTS AT THE SLC ELECTRON SOURCE*

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ABSTRACT

The SLC thermionic gun and electron source produce a beam of up to 15×10^{10} e^- in a single S-band bunch. A 170 keV, 2 ns FWHM pulse out of the gun is compressed by means of two subharmonic buncher cavities followed by an S-band buncher and a standard SLAC accelerating section. Ceramic gaps in the beam pipe at the output of the gun allow a measure of the beam intensity and timing. A measurement at these gaps of the timing jitter, with a resolution of < 10 ps, is described.

1. INTRODUCTION

The SLC thermionic electron source (CID) and injector (Sectors zero and one) are fully described elsewhere.[1] The timing jitter measurements described here were done at CID using a ceramic gap monitor located in the beam pipe at the 200 keV (max) point (Gun Gap) and a gap at the 40 MeV point (Accelerator Gap). A schematic of CID is shown in Fig. 1. Briefly, consists of a dispenser-type cathode thermionic gun, a pair of 16th subharmonic buncher cavities, an S-band buncher, and a 3 m SLAC accelerating section. The gun is currently operated at a DC voltage of 155 keV and generates 2-3 ns FWHM electron pulses. A representative signal of such a gun pulse, observed at the Gun Gap monitor prior to any bunching, is shown in Fig. 2. Typically, 60% of the gun pulse charge is captured and bunched. The fully bunched beam emerges at the end of the CID accelerating section with an energy of about 40 MeV, compressed into a bunch length of about 25° of S-band. A representative signal of such a single, relativistic S-band bunch beam at the 40 MeV Accelerator Gap is shown in Fig. 3.

2. BEAM TIMING STABILITY

The reason beam timing jitter is of concern at the SLC is that any timing change of the beam relative to the accelerating S-band phase results in a beam energy change. Thus, beam

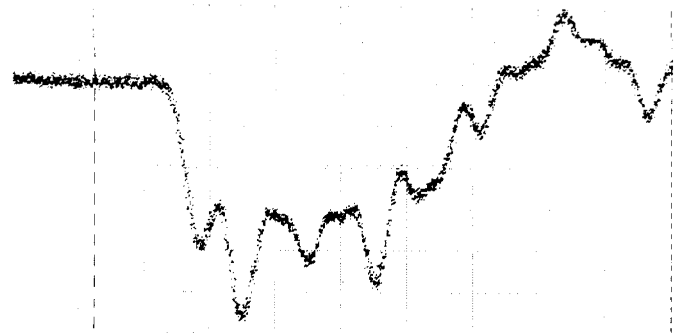

Fig. 2. The full, unbunched Gun Gap monitor signal viewed with 63 dB attenuation on a digitizer sampling scope. (Gun Gap calibration is 10 V/A.) Scope settings: 500 ps/div and 10 MV/div.

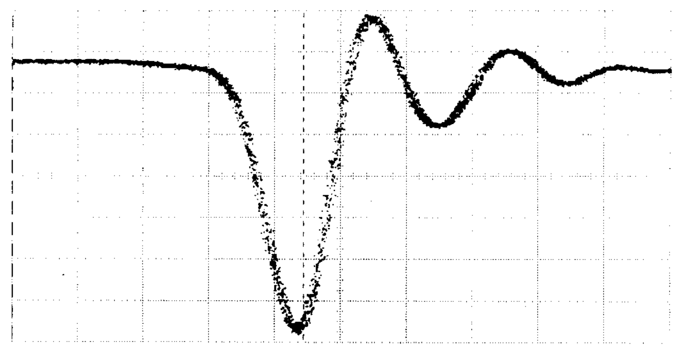

Fig. 3. The single S-band bunch Accelerator Gap monitor signal viewed with 56 dB attenuation on a digitizer sampling scope. (Accelerator Gap calibration is 10 V/A.) Scope settings: 200 ps/div and 20 MV/div.

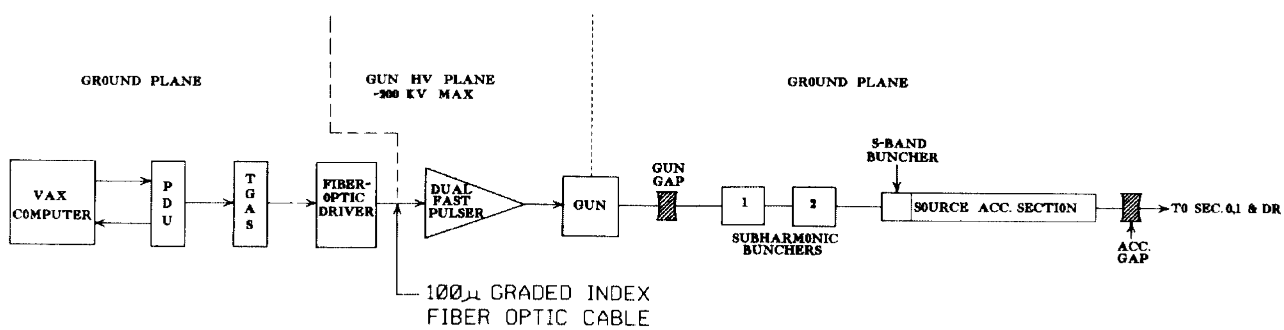

Fig. 1. Schematic drawing of the SLC electron source (CID) with associated gun trigger/pulser system. Abbreviations used are PDU for pulsed delay unit, TGAS for trigger gate and synchronization, and DR for damping ring.

*Work supported by Department of Energy contracts DE–AC03–76SF00098 and DE–AC03–76SF00515.

timing stability is required to avoid excessive beam energy jitter or drifts. This issue has been discussed in detail elsewhere.[2] Since CID provides an electron beam which—upon further acceleration to an energy of 1.2 GeV in Sectors 0 and 1 of the SLC injector—is transported to the emittance damping ring, the timing stability required for the SLC electron source is determined by the $\pm 1\%$ energy acceptance of the electron damping ring.

An energy change of 1% can be produced when the timing of the *accelerated, single bunch* beam changes by as little as 3 ps[2]. The timing jitter downstream of the gun, however, is reduced by the bunching process roughly equivalent to the beam compression ratio achieved. As stated in Ref. 2, this ratio is about 75, but varies depending on the tuning conditions of the CID bunching system.

A previous measurement[2] showed an upper limit on the gun timing jitter measured at the Gun Gap of $\sigma = 20$ ps, limited by the resolution capability of the measuring instrumentation (a Tektronix 7834 Sampling Scope). It further showed that the beam energy jitter observed at an analyzing station at the 200 MeV point was about one tenth the energy acceptance of the damping ring, and was due mainly to jitter in the phase of the RF accelerating field.

3. NEW TIMING JITTER MEASUREMENT

Since Ref. 2 was written, a new module, the Trigger Gate and Synchronization (TGAS) module,[3] was installed in the CID Gun pulser system (see Fig. 1), allowing gating of the gun trigger, as well as continuous timing adjustment of the trigger in several picosecond steps. The timing adjustment is achieved by synchronizing the gun trigger to an RF signal (178.5 MHz, *i.e.*, the 16th subharmonic of the S-band RF) whose phase is then varied to achieve the desired gun timing. The timing jitter measurement presented here is the first that has been done since this trigger system modification , and it was done with a newly available digitizer sampling scope (HP54120T Digitizing Oscilloscope). This scope has a resolution of about 10 ps, better than the instrument in Ref. 2. In addition, the jitter was measured both on the unbunched beam at the output of the gun, *i.e.*, at the Gun Gap monitor, as well as on the single S-band bunch beam at the output of the CID 3 m accelerating section—*i.e.*, at the Accelerator Gap monitor.

The measurement at both monitors was done by expanding the leading edge of the beam gap monitor signal and collecting one hundred samples of timing values within a small voltage window of the signal. The jitter at the Gun Gap was measured to have a $\sigma = 12.1$ ps, as shown in Fig. 4.; the jitter at the Accelerator Gap was measured to have a $\sigma = 8.7$ ps, as shown in Fig. 5. The Accelerator Gap measurement is almost certainly a measurement of the scope time resolution. Subtracting in quadrature the measured resolution from the Gun Gap jitter results in $\sigma = 8.4$ ps.

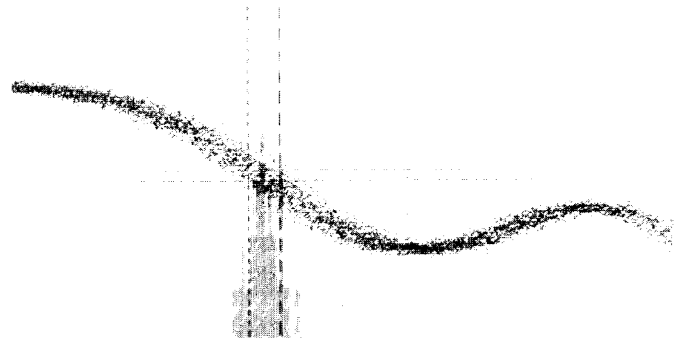

Fig. 4. Gun Gap signal leading edge of Fig. 2, expanded for time jitter measurement. Scope settings: 50 ps/div and 10 MV/div. Timing jitter sigma = 12.1 *ps.*

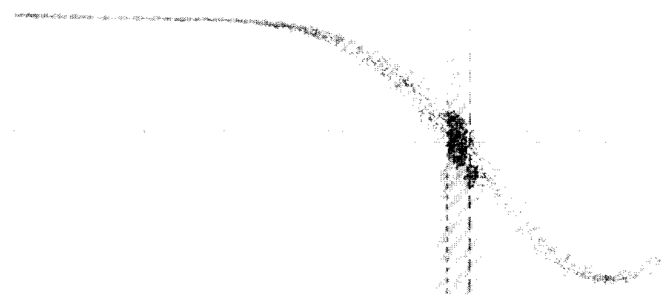

Fig. 5. Accelerator Gap leading edge of Fig. 3, expanded for time jitter measurement. Scope settings: 50 ps/div and 10 MV/div. Timing jitter sigma = 8.7 *ps.*

4. CONCLUSION

The timing jitter of the SLC beam at the electron source now has a measured upper limit of $\sigma \leq 8.4$ ps at the gun output. This timing stability falls well within the stability requirements for injection into the SLC emittance-damping ring.

REFERENCES

1. J. E. Clendenin, S. D. Ecklund, M. B. James *et al.*, *Proc. of the 1984 Linear Accelerator Conference*, CSI-84-11 (1984), p. 457; and J. C. Sheppard, "'Commissioning of the SLC Injector," *Proc. of the 1987 IEEE Particle Accelerator Conf., Washington, D. C. (1987)*, p. 43.
2. J. E. Clendenin, M. J. Browne, R. A. Gearhart *et al.*, "Timing Stabilization for the SLC Electron Source," *Proc. of the 1987 IEEE Particle Accelerator Conf., Washington, D. C. (1987)*, p. 369.
3. SLC Hardware Reference Manual, internal SLAC Document.