

LEAP Fine Timing Hardware and Software Status

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05-January-1998

SYNOPSIS. Fine timing (with a resolution approaching 1 ps) control and readback for the LEAP experiment is accomplished by sampling an RF frequency (either the accelerating structure 1.3 GHz drive, or a beam-derived 2812 MHz from a pickup cavity) with a fast rise time sampling head triggered by a fast rise time (1 ns) photodiode observing the 83 MHz oscillator pulse train. The fine time delay between the regen-amplified pulse and the electron pulse is set by using (1) manually configured delay box (0.25 ns steps), (2) a remotely switched cable delay (1 ns steps), and (3) the Spectra-Physics mode locker error offset (0.35 ps steps). Measurement of the RF phase of the 1.3 GHz with this setup, under optimum circumstances, has yielded relative timing information with 2 ps uncertainty.

DESCRIPTION

The LEAP fine timing system currently uses a Tektronix S-6 ($t_r < 30$ ps) sampling head and time domain reflectometry sampler module and storage oscilloscope to examine the 1.3 GHz RF directly using triggers from a ThorLabs photodiode (the DET 200, 1 ns risetime) illuminated by Ti:Sapphire oscillator pulses from the split-off line. The scope is presently set up in FEL3, where the oscillator pulse is monitored. Figure 1 below shows the fine timing equipment in its planned form.

A TM_{010} cavity is installed in the straight-ahead line where it will observe the SCA macropulse (less the LEAP pulse). The cavity is tuned to 2812.742418 MHz, the 34th harmonic of the Ti:Sapphire oscillator frequency, 82.727718 MHz (which is also the 238th harmonic of the micropulse repetition rate, 11.818245 MHz, hence is commensurate with both.) The cavity has two inductive coupling loops, one for power input (for its original use as a buncher), which is over coupled ($\beta=2.3$), and one for monitoring, which is undercoupled ($\beta=0.1$). The overcoupled output is amplified and limited in a Watkins-Johnson CLA45-1 limiter (1-4 GHz, 14 dB gain, 18.5 dBm limited output) to give constant power output (within the beam macropulse, and zero otherwise) at 2812 MHz. The thermal controller for the cavity is in the LEAP control room.

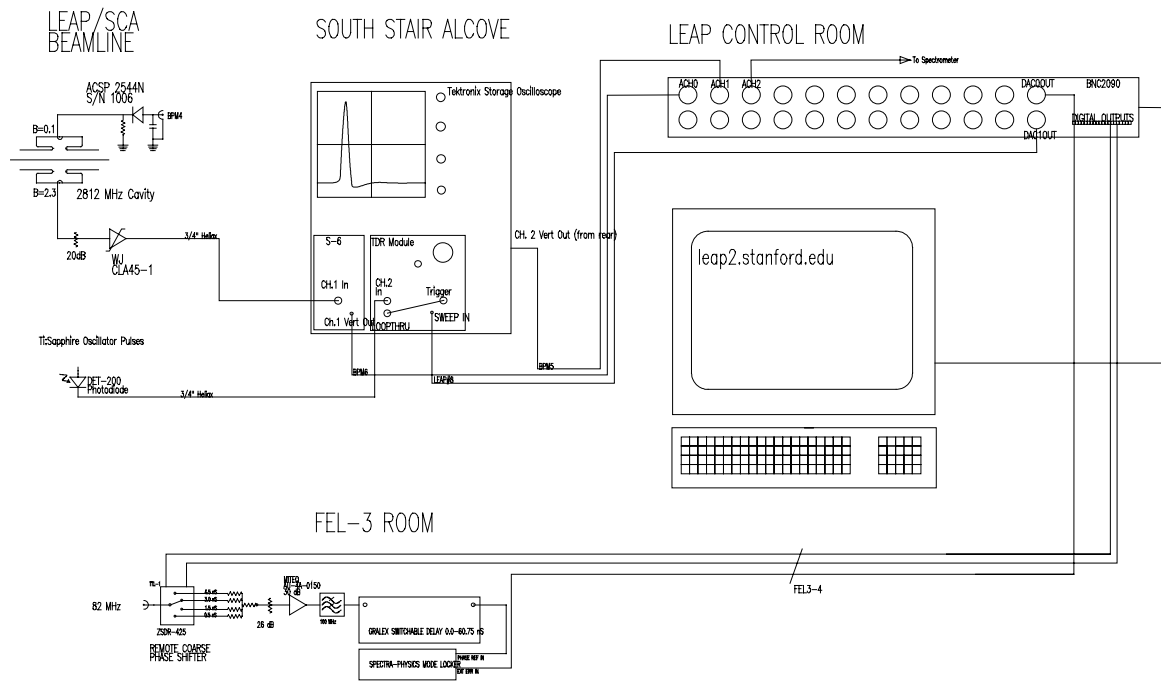


FIGURE 1. Schematic of the fine timing setting and readback electronics.

Remote control and readout of the storage oscilloscope are accomplished through the BNC-2090 interface chassis which in turn is connected to the computer leap2.stanford.edu in the LEAP control room. Slow voltage ramps are generated on channel DAC1OUT to sweep the oscilloscope, and the very low bandwidth (<100 Hz) vertical trace signals are read back on ACH0 (monitoring the RF), and ACH1 (monitoring the photodiode pulses).

Timing of the LEAP regenerative amplifier by the DG535 in the LEAP control room was changed during the last run. The regen requires a positive edge to trigger. The DG535 couples together the timing of the later transitions (the falling edge for a positive pulse) of the A and B, C and D timing outputs. To get a fully independent positive edge for timing the regen, the polarity of output C was inverted via the NIM-TTL level converter as TTL-NIM-jumper-NIM-(¬TTL).

Setting of the laser phase with respect to the electron beam is done through three devices of varying time delay range and sensitivity. A Gralex variable delay allows switched delay values from in the range 0.0(0.25)60.75 ns, and is located physically in FEL3. For convenience, a remotely programmable delay comprised of the Minicircuits ZSDR-425 RF switch, splitter, and amplifier may be programmed in the range 0.0(1.0)4.0 ns (approximately). For finest resolution, an analog voltage is sent to the Spectra Physics mode locker “external error” input to determine a timing offset, with a range of 0.0(0.0004)1.5 ns. Programming digital and analog signals for the remote phase shifters again come from the BNC-2090 in the LEAP control room.

Five virtual instruments have been modified or created to permit phase setting and reading, as well as recording of the data to file. All Vis run on leap2.stanford.edu, and are in the D:\Labview\User.lib directory.

RampPhase – Continuously ramps the time delay from 0-5 ns in user-defined steps (limited by the 12-bit resolution of output DAC to approx. 2.5 mV \approx 0.35 ps steps) at a user-defined rate.

GetOtherData – Reads the analog voltages corresponding to the phase delay and the beam energy (actually the voltage drop across a precision series resistor) and generates a U8 array that can be directly inserted into a video image for storage. This is really a subroutine for Leap Vision IV. Do not modify the BNC-2090 Channel Setup (in box at lower left of panel) unless you know what you are doing. Data for this VI are heavily filtered using a 2-pole Butterworth low pass filter with a user-defined rolloff (in units of the Nyquist frequency), and a user-defined transient skip distance. (Low pass filtering a square wave produces rounding of the rising and falling edges; the data value desired is the “plateau” value on top of the rounded square wave, the “transient end” setting value controls how many data points to skip on the rising edge of the square wave before averaging begins.)

Weighted_Moments – Calculates the sum of weights, mean, standard deviation, skewness and kurtosis of the distribution using discrete sums over the entire image. Very simple routine with no advanced fitting techniques employed.

LEAP Vision IV – Modified version of the original **Leap Vision** program, modified to provide the following features: (1) Region of Interest (ROI) definition, allowing higher data rates and smaller file sizes, (2) X- and Y- projections of the image, displayed “real time” if desired, (3) calculation of distribution moments in “real time”, if desired, (4) incorporation of phase and energy information into image data for subsequent saving. Use with RampPhase to get automatically recorded phase scans.

Data recorded into the video image in this fashion may be recovered with the Matlab subroutine “parseimdata.m”, available in V:\ARDB\Matlab. The subroutine simply parses the image data and loads the result into two arrays, RIMDATA and CHIMDATA, real and character representations of the data, respectively. The data is stored in the image in self-describing format, i.e. with descriptive labels and units; see the VI viscera for details.

Phase_Read – A balky, patience-testing surrogate front panel for the Tektronix storage scope. Can be used to “sweep” the sampling scope to examine the voltage waveforms (RF and photodiode) in “real time”. Use the VI in “Single Point” mode for averaged, low-noise phase measurements. Use the VI in “Scan” mode for observing the signals. Set “ADC Channel” to (0) to examine the sampled RF, to (1) to examine the photodiode pulse.

TASKS FOR THE NEAR FUTURE

Software improvements that will increase the chances of success include:

- 1) Calculating and displaying in “real time” a figure of merit (other than kurtosis) that is a better indicator of laser/electron interaction.
- 2) Recording other settings data with the image, to allow more accurate energy determination and more complete comparison with theory. Slit width should be recorded with the data, and perhaps the steering and quad settings closest to the IR chamber as well. It is a straightforward matter to add more data to the video image.

Hardware improvements:

- 1) Once signal amplitudes from the in-tunnel photodiode (also monitoring the Ti:Sapphire oscillator, but near the end of the regen transport system) and 2812 MHz pickup cavity signal amplitudes are correctly adjusted, and cabling available, the scope will be moved into the HEPL tunnel into the south staircase alcove, to monitor the beam-derived 2812 MHz signal from the TM010 cavity in the straight ahead line using triggers from the Ti:Sapphire oscillator.
- 2) Timing of the regen amplifier should also be adjusted by the same time delay as the oscillator pulse to provide consistent amplification of the selected oscillator pulse. At present the oscillator pulses move in time relative to the regen pump pulse, causing unwanted intensity modulation and occasionally double-pulsing (the reduced amplification of two oscillator pulses). The necessary change can be made by adjusting the DG535 timing, but will require a GPIB card to be installed in the leap2 computer.