# 13th International Workshop on Laser Ranging
# October 7-11, 2002
# Washington D.C.

# Zimmerwald Counter Comparisons

**W. Gurtner, J. Utzinger**
**Astronomical Institute**
**University of Berne**
**Switzerland**

E-Mail: gurtner@aiub.unibe.ch

## Abstract

The paper describes the Stanford timer calibration procedures performed at Zimmerwald after the Herstmonceux reference calibration during the EUROLAS workshop in March 2002. One of the surprising results was the problem two out of the three Zimmerwald counters showed when driving the counters with an external 5 MHz reference frequency. The calibration values have been applied to the submitted ranges since end of May 2002.

## 1. Introduction

During the EUROLAS Workshop at Herstmonceux , March 11-13, 2002 counters from several EUROLAS laser stations were compared with the Herstmonceux standard counter by measuring identical time intervals covering the range from 0 to about 160 ms. Zimmerwald compared its spare Stanford SR 620 counter, serial number 3113. The following three series and their average resulted from the comparisons:

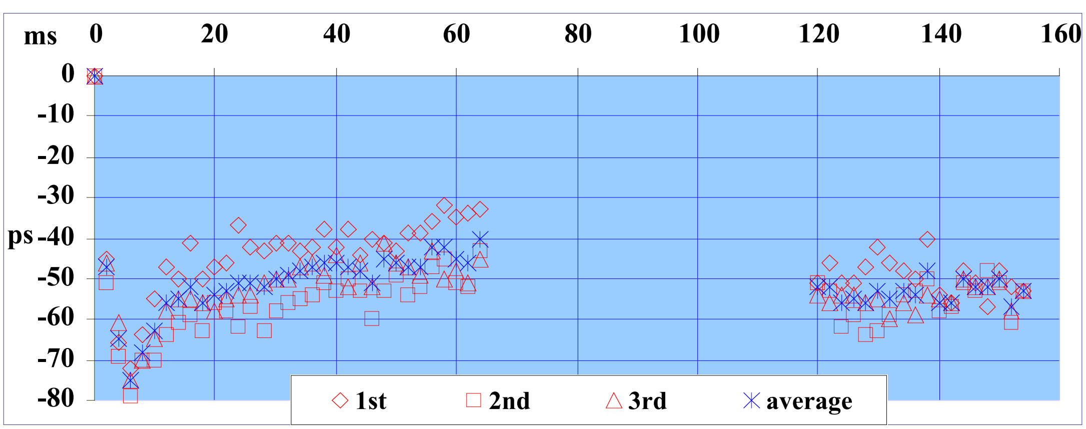


**Figure 1:** SR 620 # 3113, Comparison With Herstmonceux Standard

These calibration values of the spare counter had then to be applied to the two operational counters of Zimmerwald by means of additional counter comparisons in situ.

## 2. Counter Comparisons at Zimmerwald

### 2.1 Experiment Setup

The Zimmerwald laser ranging system uses two Stanford SR 620 counters: # 0236 in the primary receiver chain ($\lambda$ = 423 nm, Hamamatsu photomultiplier) and # 2282 in the secondary receiver chain (($\lambda$ = 423 nm, C-SPAD avalanche diode or $\lambda$ = 846 nm, Hamamatsu photomultiplier).

The easiest way to compare two counters using directly the ranging system without major changes in the existing hardware and software configuration was as follows:

- Generate an artificial satellite ephemeris file in the format used by our tracking system containing constant azimuth and elevation for all generated epochs (to point the telescope high up into the sky) and a range to the „satellite" regularly increasing from zero to the maximum of about 160 ms (the latter being well above the maximum range to a GPS satellite).
- Split the output signal of the primary receiver (by using two parallel outputs of the constant fraction discriminator following the PMT) to feed into the stop input of the two counters to be compared
- Run the tracking program with this artificial ephemeris file at daytime
- Use the laser start pulse (as usual) to start the time interval measurement
- Open the range gate window wide enough to guarantee a background noise return and thus a stop pulse at every cycle
- Collect the measured time intervals of either counter, form the differences and average them into suitable bins (1 to 5 ms width)

The total length of the „satellite pass" needed to cover the full range depends on the number of observations we would like to have in each bin: With, a total of 400 observations per bin, a range of zero to 160 ms, a bin width of say 5 ms, and a rate of 10 Hz = 10 observations per second, the pass has to have a length of 400*160/5/10=1280 s. When the measured time interval approaches 100 ms the rate is automatically reduced to 5 Hz, so the number of observations per bin decreases to about 200.

As the ranging system has been prepared to accept two counters for dual wavelength observations, the changes needed for this experiment were marginal: Unplug the secondary receiver output, split the primary output signal and feed it into the two counters.

The measurements at zero time interval were performed separately to our internal calibration target (~ 100 ns flight time).

## 2.2 The 5-MHz-Problem

We compared the three counters pair-wise:

- # 0236 (primary counter) against # 3113 (spare, calibrated at Herstmonceux)
- # 2282 (secondary counter) against #3113.

The first comparisons showed a very strange behavior of the measured differences.

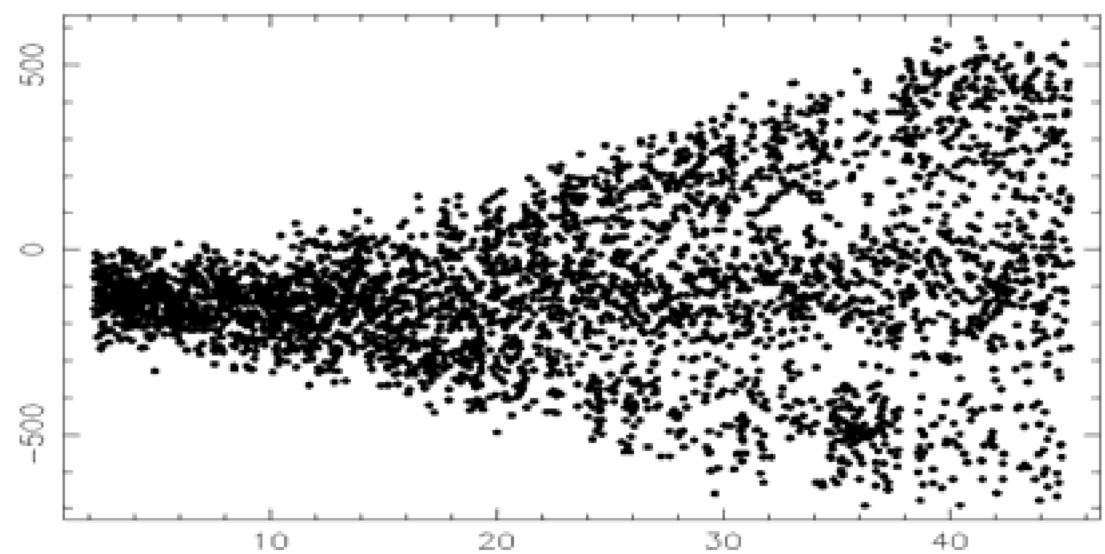


**Figure 2:** 3113-2282, Differences in ps, Time Intervals in ms

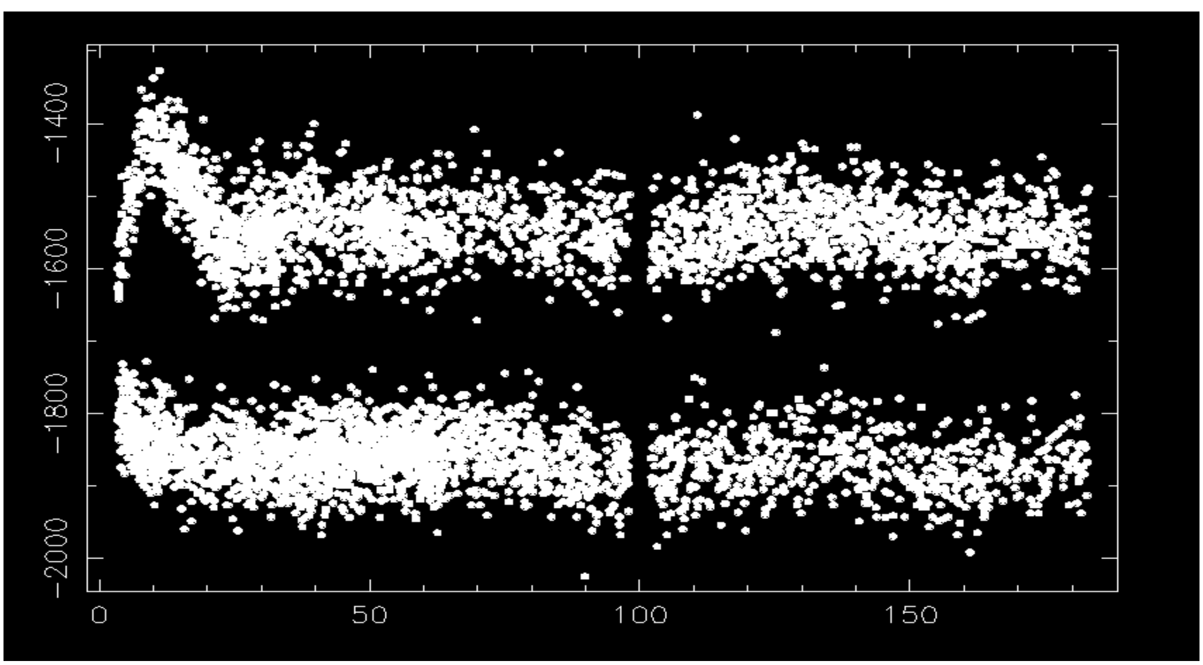


**Figure 3:** 3113-0236, Differences in ps, Time Intervals in ms

The raw observations of the comparison of counter 3113 at Herstmonceux did not show any such strange behavior: Figure 4 shows the raw observations within each bin and the bin averages of one series:

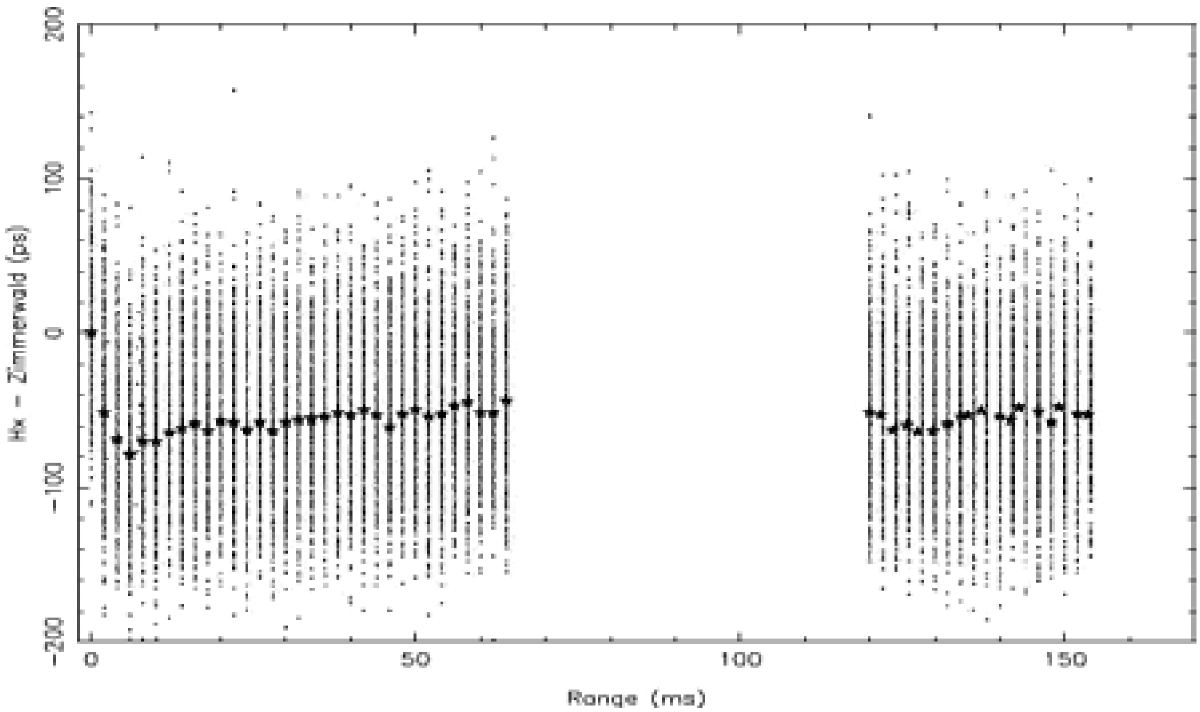


**Figure 4:** Raw Observations 3113-HERS

Within one bin the raw observations showed the following distribution:

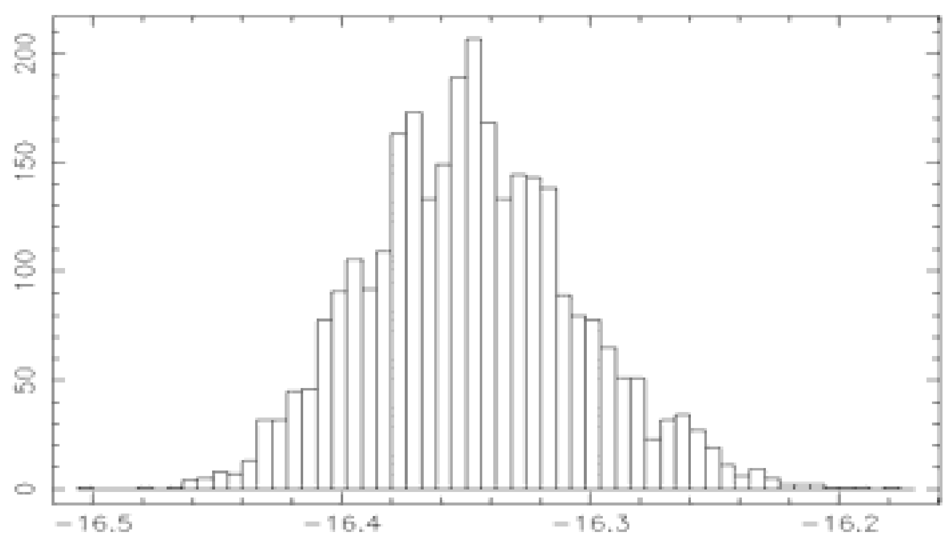


**Figure 5:** Distribution Within One Bin (HERS-3113 at 150 ms)

This behavior obviously had to be generated by the setup in Zimmerwald, either within the spare counter 3113 or both operational ones or a combination thereof.

Looking at the residuals of an actual satellite pass (Starlette) tracked with the counters 0236 and 3113 showed that the problem certainly appeared in the 3113 data:

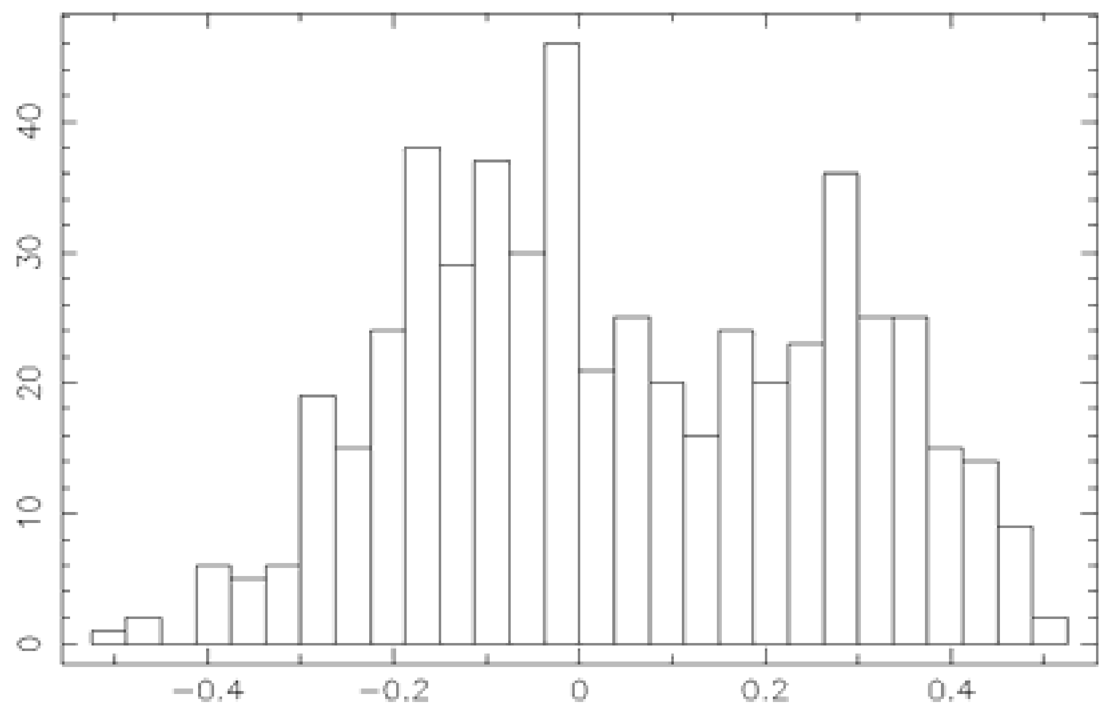


**Figure 6:** Distribution of Starlette Residuals, Counter # 3113

Obviously there are indeed two populations approximately 0.4 ns = 400 ps apart, corresponding to the average difference of the two populations at around 10 ms time of flight in Figure 2.

The residuals of counter 0236 didn't' show any strange behavior.

The major difference in the Zimmerwald setup and the Herstmonceux test configuration was the source of the external frequency for the counters: In Herstmonceux it was a 10 MHz source, whereas in Zimmerwald the counters have traditionally been locked to a 5 MHz frequency. The counters do allow for either one, a corresponding parameter has to be set in the counters.

Changing the external frequency to 10 MHz immediately solved the problem! Neither the pair 0236-3113 nor 2282-3113 now showed the strange behavior of Figures 2 and 3 anymore. It seems that the two newer counters, # 2282 and #3113, generate a problem when locked to an external 5 MHz frequency. Fortunately the older one, # 0236, having been used for years in the primary receiver chain with 5 MHz, is fine.

### 2.3 The Results

Figure 7 now shows the bin averages between the two counters # 0236 and #3113, determined with the procedure described in paragraph 2.1:

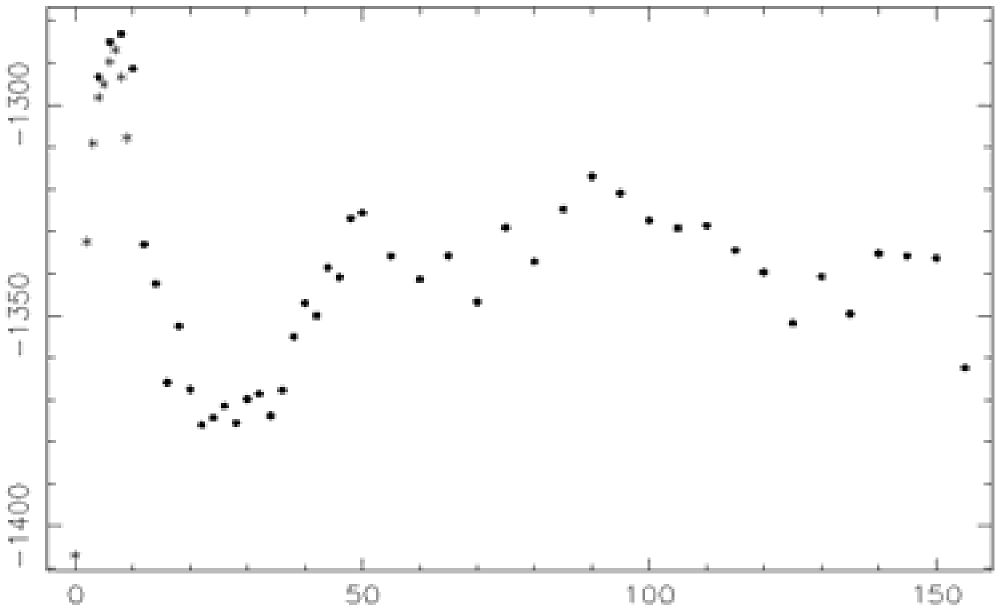


**Figure 7:** 5 ms - Bin Averages of the Differences Between # 0236 and #3113

These values are added to the Herstmonceux calibration values of counter #3113 to finally get the corrections to be applied to the counter # 0236 to refer the observed times of flight to the Herstmonceux standard counter.

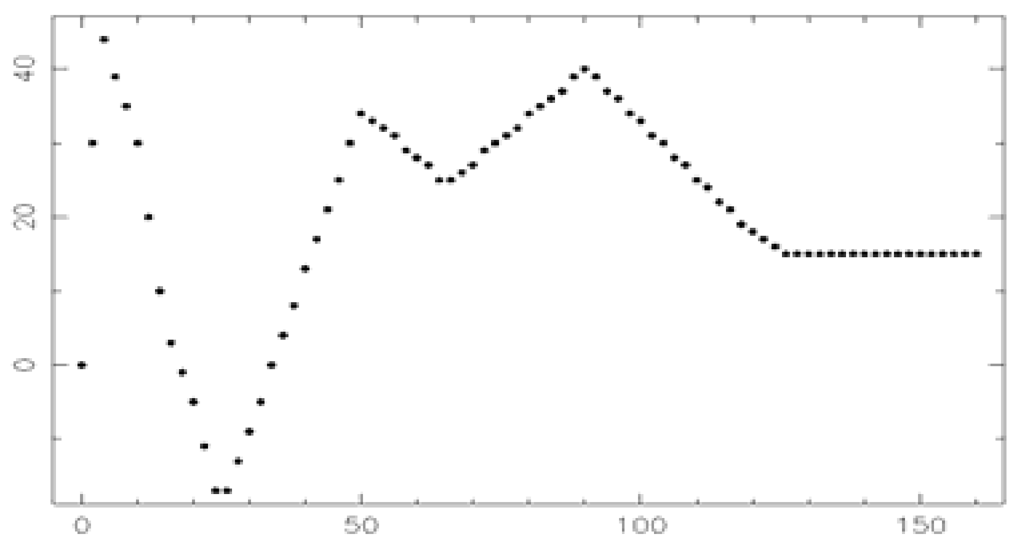


**Figure 8:** Piecewise linear differences between #0226 and Herstmonceux

For the operational application we approximate piecewise the corrections with linear functions (Figure 8).

Finally the values, i.e. the boundary points between the linear approximations, are tabulated to be used by the post-processing programs (Figure 9):

```
! Counter differences 0236-HERS
! Computed from 0236-3113
! and 3113-HERS
! May 2002
!
! time of flight  correction
!      (ms)          (ps)
!
         0             0
         2            30
         4            44
        25           -17
        50            34
        65            25
        90            40
       125            15
       160            15
```

:**Figure 9:** Correction Table for Counter # 0236

Similar tables have also been generated for counter # 2282 (secondary chain) and counter # 3113 (spare).

The correction tables have been introduced into the data post processing at Zimmerwald on 29 May 2002, 00:00 UT.

## Acknowledgements

We would like to thank Philip Gibbs from Herstmonceux for the calibration measurements of our counter during the EUROLAS workshop in March 2002.