# Femtosecond Timing Monitor for Gemini Laser area

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## Introduction

The Gemini laser has two separate beams, referred to as North and South. Experiments using both beams, fully compressed to 40 fs, require a high level of temporal stability between the two beams. In this paper we present a Femtosecond Timing Monitor (FTM) installed in the Gemini laser area in order to measure femtosecond drift and jitter between the North and the South beams.

## Design

The Femtosecond Timing Monitor is based on a spectral interferometer. The two beams are overlapped onto the slit of an ORIEL spectrometer with a 600 lines per mm grating used to disperse the pulses. This type of diagnostic has been described in other papers [1] and successfully used to measure the temporal overlap of ultra-short pulses [2]. In our arrangement of the FTM we deliberately make the pulses overlap with a small vertical angle onto the spectrometer's slit. This slight vertical tilt to the beams results in a tilt to the spectral fringes due to the difference in pulse delay along the non-dispersed direction. The direction of the fringes gives the direction of the delay. Figure 1 shows the interference produced by the FTM for three different delays. In this case the fringes tilted toward the left correspond to the South beam being early (Fig.1.c).

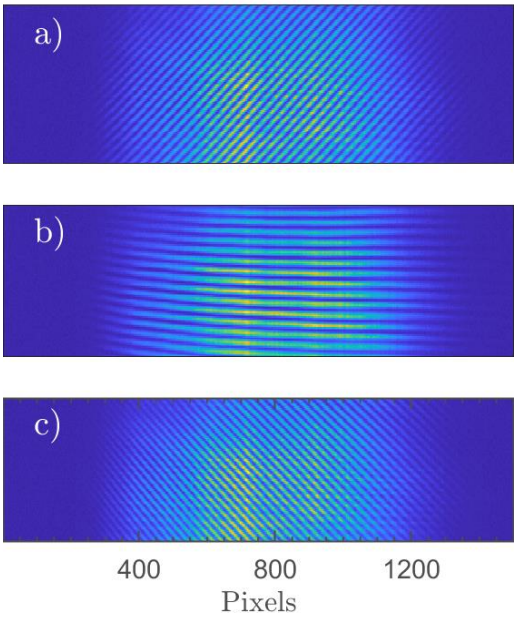


*Figure 1: Timing Fringes from the interference of the North and South beams. a) Δt = 1.26 ps South beam late, b) Δt = 74 fs, c) Δt = 1.40 ps South beam early.*

The difference in pulse delay along the non-dispersed direction can be estimated to 0.5 fs per pixel, from the quadratic fit (dashed line in Figure 2.) The direction of the linear term of the fit gives the direction of the delay.

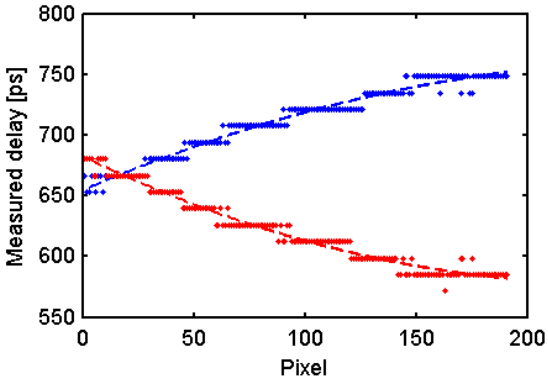


*Figure 2: Difference in pulse delay along the non-dispersed (vertical) direction. The direction of the linear term of the fit gives the direction of the delay: positive values correspond to the South beam being early.*

Like any other spectral interferometer, the pulse separation is calculated by interpolating the image onto a linear frequency axis and then performing a fast Fourier transform (FFT).

The calculated delay was checked against the setting of the delay stage on the Split and Delay (SAD) table that is used to control the delay between the North and South beams.

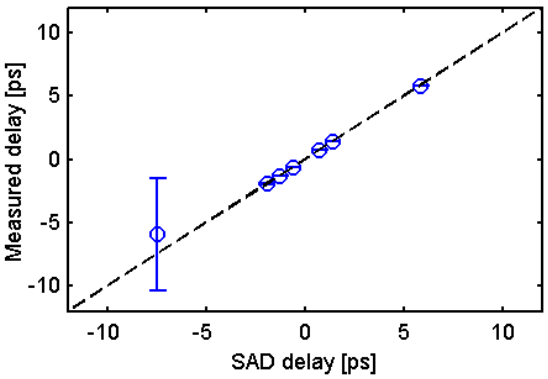


*Figure 3: Measured pulse separation against the delay introduced on the SAD table.*

The dashed line represents the expected measurement, when changing the SAD stage. The error bars come from the root mean square (RMS) difference of the measured values for each pixel line to a quadratic fit.

Finally, to evaluate the shot-to-shot jitter of the temporal overlap, 20 shots were taken for each delay. The RMS from each delay setting was found to be 5.4 fs and the standard error for 20 measurements with 4.8 fs measurement error was 1.11 fs. We have found the shot-to-shot jitter was about 5 fs RMS.

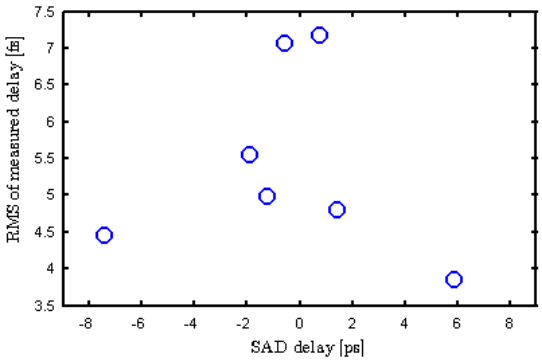


*Figure 4: Shot-to-shot jitter of the temporal overlap.*

## Conclusions

The delay between the North and South beams of Gemini was measured using a new diagnostic installed in the laser area. The diagnostic measures the pulse separation accurately over a 10 ps time window and indicates which pulse is ahead. It was found that the shot-to-shot jitter in the laser area is 5 fs.

## Acknowledgements

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## References

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2. R.J. Shalloo, C. Arran, G. Cheung, L. Corner, J. Holloway, R. Walczak, S.M. Hooker, N. Booth, O. Chekhlov, C.D. Gregory, S.J. Hawkes, C.J. Hooker, B. Parry, Y. Tang, "Measurement of femtosecond-scale drift and jitter of the delay between the North and South Beams of Gemini" Central Laser Facility Annual Report, p. 36, 2015/2016