An autocorrelator for Target Area West 10 ps beam line

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Introduction

Due to the recent upgrade [1], a second beam line capable of delivering 500 J in 10 ps has been available in Target Area West (TAW) since September 2008. For this new line, an autocorrelator had to be build to monitor the pulse length.

Because a large temporal window is required, the standard single shot autocorrelator in use was not suitable anymore and it was necessary to design a different one.

The autocorrelator

The characteristics of the beam line allow us to use an old technology: the dye autocorrelator. A dye autocorrelator is an affordable and user friendly way of monitoring the pulse length (we do not need to take into account things like frequency mixing or phase matching, which are inherent in non linear crystals). To have an autocorrelation, you first must split your beam into two, and then overlap both of them into a medium, delaying one with respect to the other. The medium must fulfil two conditions:

- A response to a second order non-linearity,
- The peak of the absorption spectrum is different from the peak of the fluorescence spectrum.

It can obviously be a well chosen dye. With the conditions fulfilled and the help of a CCD camera, we can easily monitor the autocorrelation of the beam produced inside the dye.

If the intensity of the pulse inside the dye is high enough, the dye will be pumped by two photon absorption from the laser light, with pump power proportional to the intensity squared.

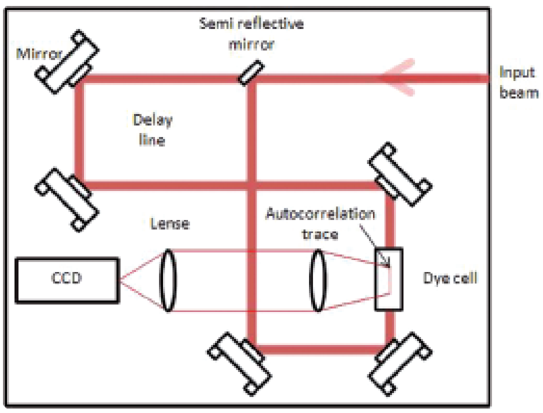

Figure 1. Layout of the autocorrelator.

Therefore, the dye produces spontaneous emission when there is no overlap, and an autocorrelation when there is.

$$S(z) \approx \int_{-\infty}^{+\infty} I(t)^2 dt$$

Each beam can be described as a maximal intensity modulated during the propagation due to the Gaussian shape of the pulse:

$$I_1(z,t) = I_{01} \times J\left(t + \frac{n}{c} \times z\right)$$

$$I_2(z,t) = I_{02} \times J\left(t - \frac{n}{c} \times z\right)$$

$$J(t) = \theta^{-\pi * \frac{t^2}{\delta t^2}}$$

The difference in sign is due to the fact that the pulses have opposite direction of propagation. Consequently, the local total intensity is given by:

$$I_2(z,t) = I_1(z,t) + I_2(z,t)$$

If we assume both intensities are the same, we have the following intensity for the spontaneous emission inside the cell:

$$S(z) \approx (I_{01}^2 + I_{02}^2) *$$

Therefore, when the two pulses collide, they produce an autocorrelation trace with a higher intensity.

$$\int_{-\infty}^{+\infty} J(t)^2 * dt + 2 * I_{01} * I_{02} * \int_{-\infty}^{+\infty} J(t)^2 * J\left(t + 2 * \frac{n}{c} * z\right) * dt$$

$$S(z) \approx \sqrt{2} * I_0^2 * \delta t * \left(1 + e^{\left(-\pi * \frac{\left(z \frac{n}{c} z\right)^2}{t * \delta t^2}\right)}\right)$$

Choice of the dye

The dye must be taken into consideration when building a dye autocorrelator. It needs to have minimal fluorescence at the wavelength of the laser whilst letting the beams propagate through (i.e. no absorption). An easy way to achieve this is to use rhodamine 6G.

Calibration and measurement

We directly see the signal created by the CCD. There will be a constant signal because we pump the dye thanks to the laser. Moreover, part of the signal will have higher intensity due to the autocorrelation trace when the beams overlap.

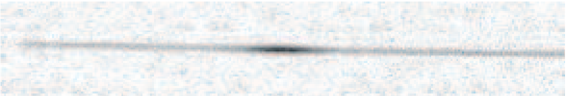

Figure 2. Expected trace from the autocorrelator.

We can easily see that there is a link between position in z and the time of the autocorrelation.

$$\tau = 2 * \frac{n}{c} * z$$

If we add a delay Δt to one of the pulse, we have

$$S(\tau) \approx \sqrt{2} * I_0^2 * \delta t * \left(1 + e^{\left(-\pi * \frac{(\tau + \Delta t)^2}{2 * \delta t^2}\right)}\right)$$

Therefore, if we change the delay between the two pulses, we will only create a translation of the autocorrelation.

To do the calibration, we just change the delay. By measuring the position of the autocorrelation with a different delay, we have a relation between the position and the delay (the pulses will collide in different place). Thus, we have a relation between the peak position of the autocorrelation and the pulse duration.

Conclusions

The principle of the dye autocorrelator is known to work and it could easily have a large temporal window, of the order of tens picosecond. We first have to test and calibrate the autocorrelator in the front end using a picoseconds source. Afterwards we will have to install the device in TAW.

References

1. C. Hernandez-Gomez *et al.*, *"An overview of the Target Area West short pulse upgrade"*, CLF Annual Report 2007-2008.
2. M. Galimberti, *"Realizzazione di un Autocorrelatore a Singolo Impulso a DYE"*, IPCF Internal Report 2002.