APPENDIX A.

WHAT IS THE INTERFEROMETRIC AUTOCORRELATION?

Interferometric autocorrelation measurement is a technique widely used for characterization of the ultrashort optical pulses generated by modern mode-locked lasers. The pulse durations ranges from several femtoseconds to a few picoseconds. The pulses may have phase modulation and thus may be not bandwidth limited. In contrast to *intensity autocorrelation* (also widely used for characterization of the ultrashort optical pulses) the interferometric autocorrelation provides some additional information about this phase modulation. Although this information can not be processed to the full time domain phase dependence it provides a significant advice to experimenter who develops and uses the laser systems.

Typically, interferometric autocorrelation is achieved by splitting the optical pulse in two replicas. Each replica propagates in different optical path, and the paths difference is controlled by a special translation unit with the generator and the position measurement system (the scanning unit). Finally, two replicas of the source pulse with the relative delay varying in the time are combined in the single collinear beam and passed to nonlinear converter. This could be SHG, or two-photon absorption measurement, or something else depending on particular device construction. Thus the signal from photodetector is proportional to the square of the sum of replicas intensities. Combining the signals from scanning unit as time delay (or as X-coordinate), and from photodetector as amplitude (or as Y-coordinate) one obtains the interferometric autocorrelation of an investigated laser pulses.

For a simple Gaussian shaped bandwidth limited pulses the interferometric autocorrelation can be analytically expressed as:

$$IAC(\tau) = 1 + e^{-2\ln 2(\frac{\tau}{w})^2} + 4e^{-\frac{3}{2}\ln 2(\frac{\tau}{w})^2}\cos\omega\tau + 2e^{-2\ln 2(\frac{\tau}{w})^2}\cos^2\omega\tau \quad (1)$$

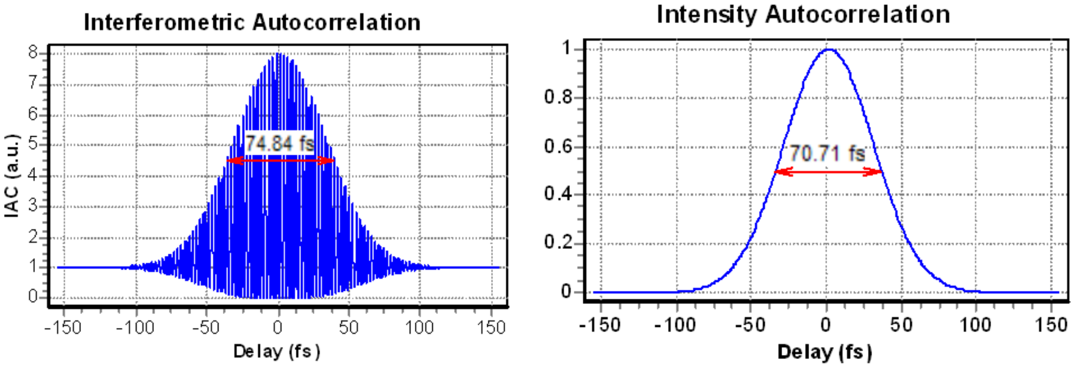
Where τ is the time delay between the two replicas, w is the width of the underlying pulse (intensity FWHM), and ω is the optical carrier frequency.

PROPERTIES OF THE INTERFEROMETRIC AUTOCORRELATION

The terms in equation (1) have the following meanings. The first one is a constant shift (or bias). The second term is an intensity autocorrelation. The third and fourth terms are representing the interference beatings which are also have the intensity autocorrelation envelop.

The maximum amplitude of IAC is 8 while the minimum value is near the zero. Outside the range of time delays where the pulses are overlap the IAC has constant the value of 1.

INTERFEROMETRIC AUTOCORRELATION OF THE BANDWIDTH LIMITED OPTICAL PULSES

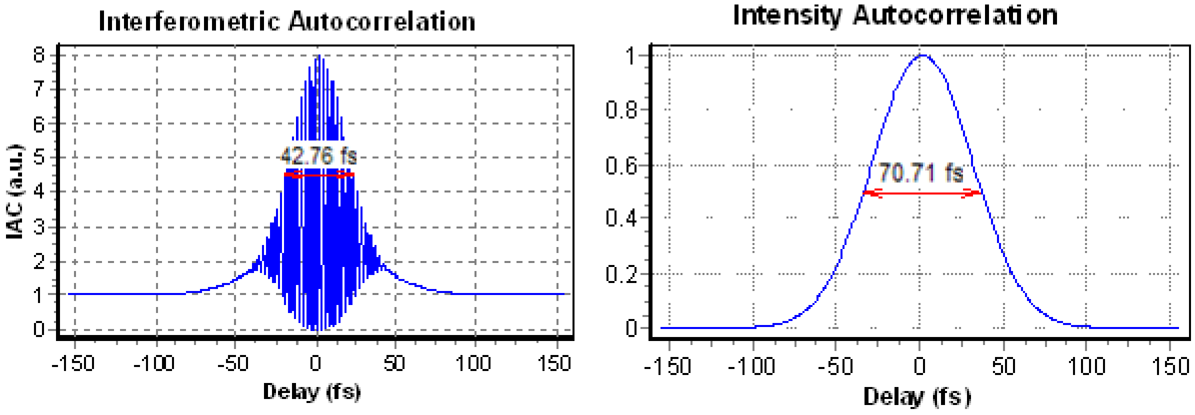


In the chart below we represent the IAC for the 50 fs Gaussian pulse with no phase modulation at the wavelength of 800 nm. And in the following picture the corresponding intensity autocorrelation chart is displayed.

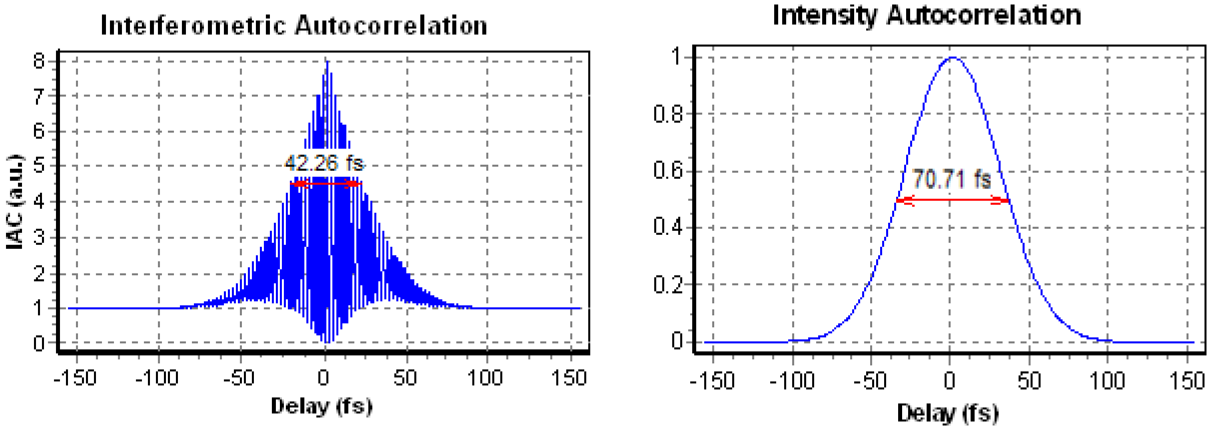
Notice the difference between FWHM of the top envelop of the IAC and FWHM of the intensity autocorrelation curve. If we want to estimate the underlying pulse width from the intensity autocorrelation curve, we will divide its FWHM by 1.4142 and obtain the value of 50.01 fs which is perfectly close to the source pulse width. This is not the case with the interferometric autocorrelation. In this case we need to use the divisor of 1.5331 to obtain estimated pulse width of 48.82 fs (note that the width of IAC in this case is underestimated because one need to calculate envelop of IAC while in the example above the width was measured using IAC fringes).

Interferometric Autocorrelation of the Phase Modulated Optical Pulses

Now we need to discuss the case of the phase modulated pulses. As noted above IAC is sensitive to phase modulation. Its form changes with the amount and type of the modulation. One may see these changes in the figures below for the pulse with the same width of 50 fs and carrier of 800 nm.



Linear chirp.



Second order chirp.

Note that intensity autocorrelation width is independent of phase modulation type and amount while width of the top envelop of IAC varying significantly.

CONCLUSION

From these examples it is obvious that the width of the top envelope of IAC cannot be used as a source for the underlying pulse width calculations.

To estimate the pulse width from the interferometric autocorrelation one need to remove terms 1, 3, and 4 from the acquired data to obtain the underlying intensity autocorrelation.

This can be done by some averaging of the IAC data. **Irtac** uses Fourier filtering algorithm to attain this goal. With intensity autocorrelation extracted from IAC data Irtac is able to provide you a valid estimation of the pulse width with any kind of the phase modulations.