

# Femtosecond pulse generation and characterization

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## Abstract

The main goal of our project was to measure the real parameters of femtosecond's pulses after laser's system revision and optimalization. During this, a smart and cheap method for beam analyses was invented.

## 1 Introduction

In our laboratory of femtosecond spectroscopy we are interested mainly in time-resolved pump-probe spectroscopy, supercontinuum generation and optical parametric amplification. For this research we need high optical quality and high peak intensity femtosecond pulses.

Such a specific output we can obtain due to the chirped pulse amplification technique, Fig.1. For applications in pump-probe spectroscopy it is very important to precisely characterize the output pulse generation of our system [s. "2 System description"]. To attain this we improved some of commonly used methods [s. "3 Methods of measuring"].

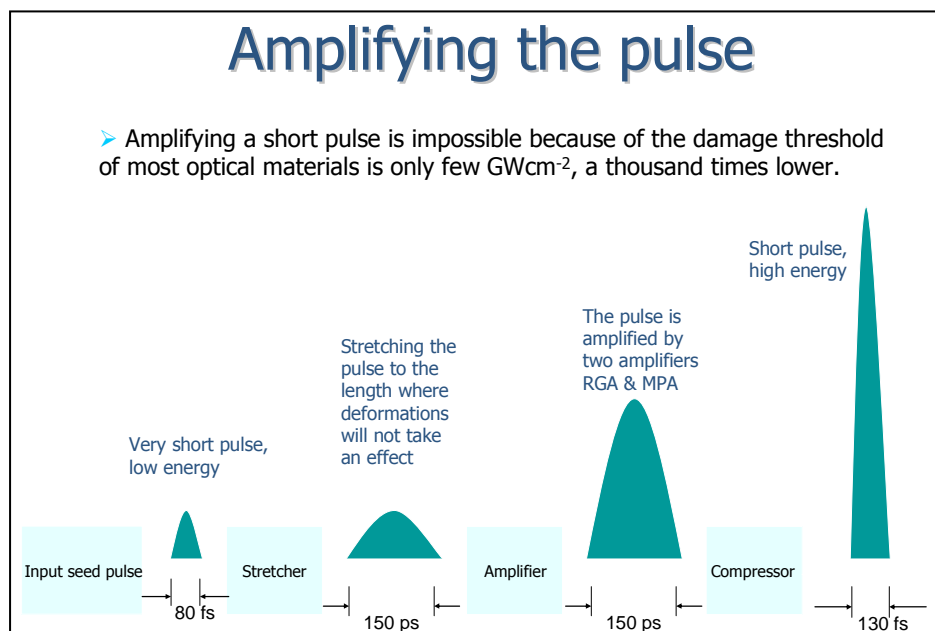


Fig. 1 The principal of chirped pulse amplification technique

## 2 System description

The heartbeat of our system is commercial femtosecond pulse system Integra-i made by Quantronix Corporation [www.quantronixlasers.com], Fig.2. An oscillator produces a 48 MHz 18 mW train of pulse of 82-fs duration. Each pulse is first stretched up to 400 ps in an aberration free stretcher. After that, the pulses are going through Pockels cell, which selects pulses at repetition rate 1 kHz, into the regenerative amplifier. Pulses are then amplified in second two passes trough amplifier and then are re-compressed to 130 fs, Fig.2. It is not so easy to tune up the whole femtosecond system.

Additionally for spectroscopic purposes we use two optical parametric amplifiers – TOPAS and TOPAS white. Both amplifiers need high quality pump beam on the input.

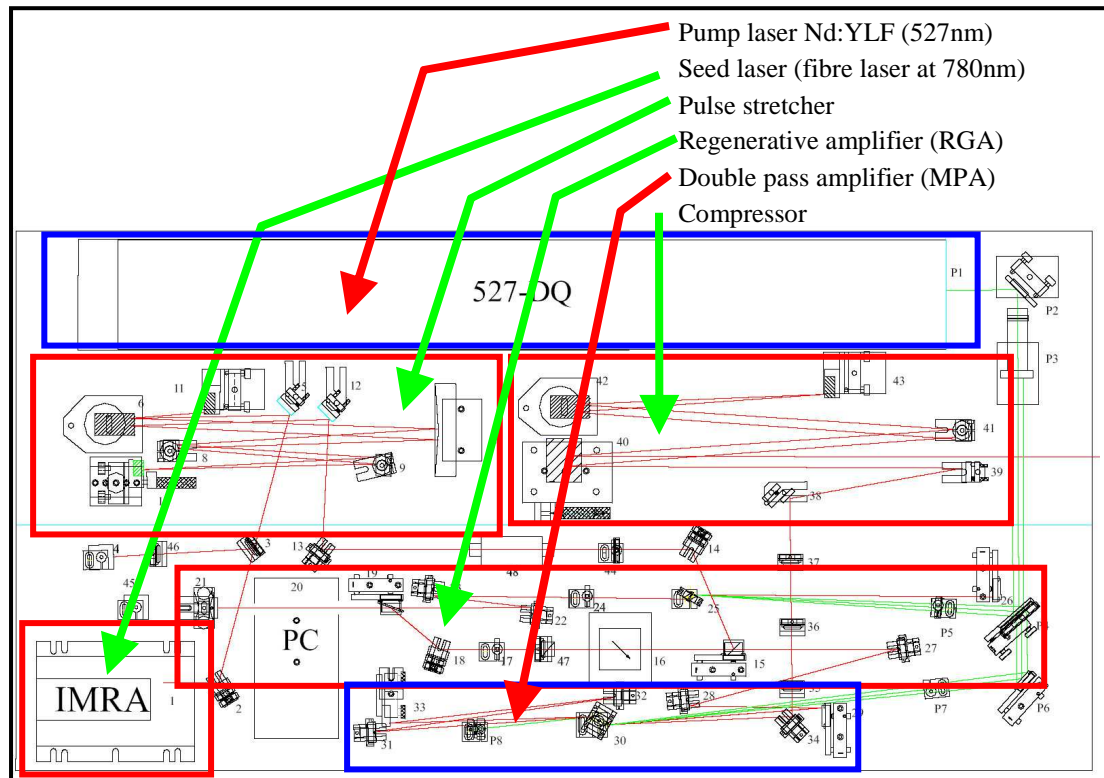


Fig. 2 Integra-i layout schematic, 2.5 mJ model [2]

### 3 Methods of beam's parameters measurement

We need to measure pulse half-width, power output, bandwidth and central wavelength (spectrum analysis) and pre-pulse and post-pulse contrast ratio. Finally we need to find out how beam profile looks like.

#### Pulse half-width

The most important characteristic of a compressed pulse is a pulse half-width. Because of spatial and temporal optical dispersion, the half-width of stretched, amplified and compressed pulse is longer than the half-width of oscillator pulse. We are able to measure this parameter thanks to the autocorrelation technique [1]. For precise detection a single shot autocorrelator set is required, Fig.3. This measurement is based on non-collinear second-harmonic autocorrelation. As a result we get autocorrelation curve, Fig.4, and correspondent pulse half-width.

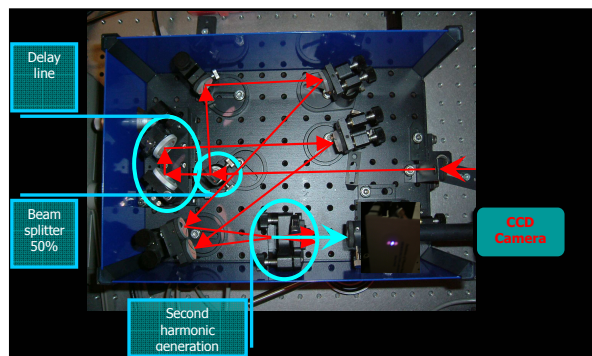


Fig. 3 Autocorrelator scheme

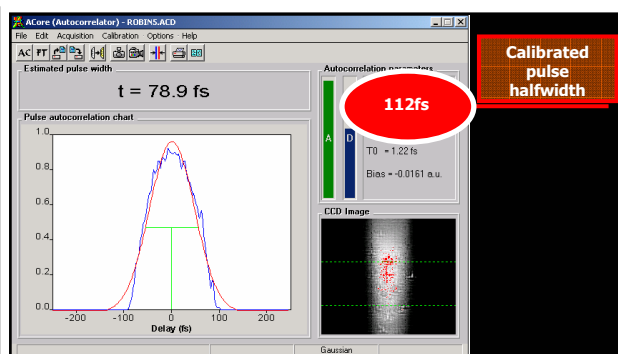


Fig. 4 Obtained curve

#### Pulse energy

The femtosecond pulse energy in Joules can be simply measured with a MOLECTRON EPM 1000 Joulmeter. For mean output power in Watts we also have to check frequency using digital oscilloscope TEKTRONIX.

### Spectrum half-width of the pulse

Spectrum analysis was made by commercial spectrometer OceanOptics USB2000. On Fig.5 is possible to see a shape of spectrum line of the femtosecond pulse.

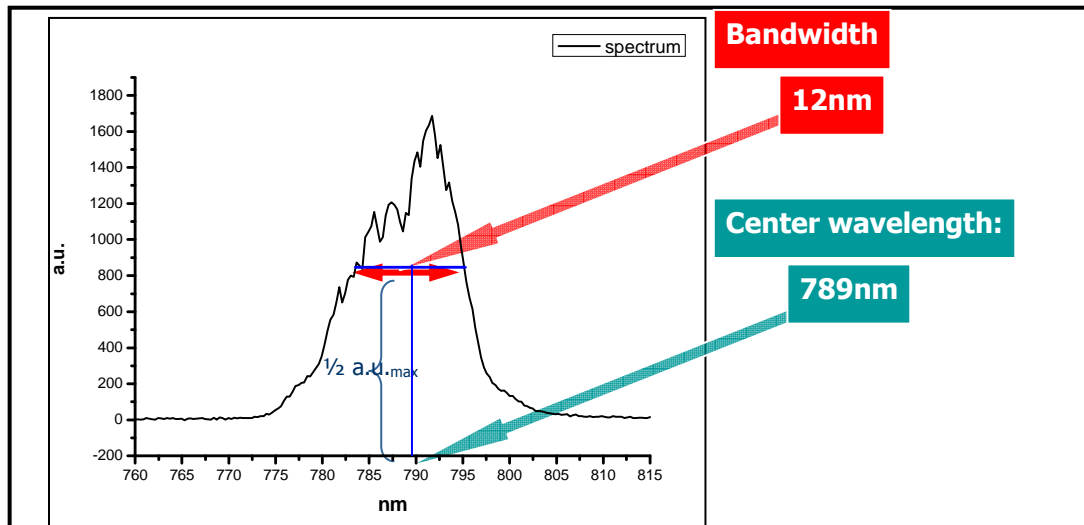


Fig. 5 Spectrum curve

### Contrast ratio

Contrast ratio is a ratio between pre-pulses and the main pulse or post-pulses and main pulse. The reason for these unwanted pre-pulses and post-pulses is relatively small extinction ratio, because of inhomogeneous electric field in Pockels cell electrooptic crystal, Fig. 2, PC [3].

Contrast ratio is measured by a fast photodiode at time of several ns. Its value is typically 100 or more for both, pre-pulse and post-pulse as well. There are several ways in optimizing contrast ratio: the Pockels cell orientation and also correct adjustment of amplitude of applied high voltage.

### The beam profile analysis

For beam profile analysis is usually used beam analyzer, which is not very cheap. It provides the correlation information between the measured beam profile and the ideal profile shape such as Gaussian beam profile is, Fig.6. Conventional method such as pin-hole scan can be used as well for this measurement if the beam analyzer is not available.

We improved an optical chopper by adding non-transparent disk with a pin-hole on the chopper's head, Fig.7. Then we used PIN diode and interconnect it with an oscilloscope for pulse reading. The optical chopper's head had been setup to the level we wanted to measure.

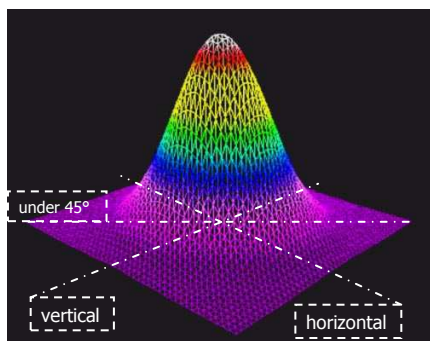


Fig. 6 Ideal Gaussian beam profile

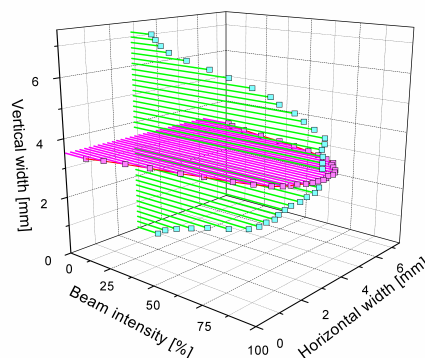


Fig. 8 Real beam profile

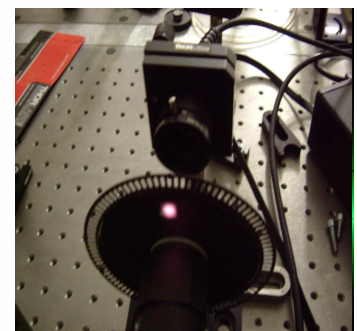


Fig. 7 Tuned chopper's head

By moving the pin-hole we are scanning beam profile. Each scan gives us voltage trace on the oscilloscope. This trace corresponds to the beam profile.

Output of oscilloscope is in milliseconds, so how to find out beam width in micrometers? Repetition rate of the laser is 1 kHz. The pin-hole lies on a circle of radius 31 mm and frequency of the chopper is 2 Hz. The question is what distance  $s$  covers pin-hole in 1ms?

From equations  $v=2\pi r f$  and  $v=s/t$  we calculated  $s = 195\mu\text{m}$ . Now we can calculate all parameters for real beam profile reconstruction, Fig. 8.

On Fig. 9 is a Gaussian fit of obtained real beam profile in horizontal plane. On Fig. 10 is that one for vertical plain as well. The real shape is very close to the Gaussian one.

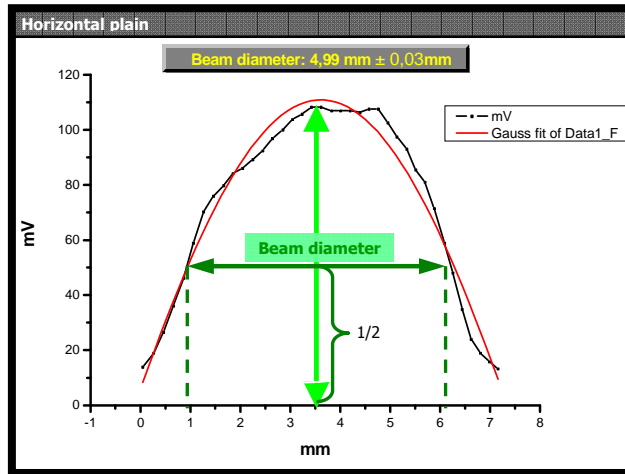


Fig. 9 Horizontal plain beam profile

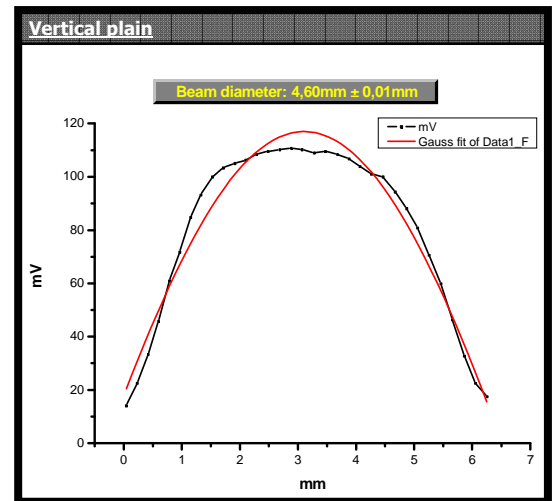


Fig. 10 Vertical plain beam profile

## 4 Conclusion

Review of measured parameters and parameters declared by Quantronix Company are in the Table 1. below. Obtained parameters are in good agreement with official one. The femtosecond system is very good aligned. Smart and cheap method for beam profile analyses was successfully applied.

Integra-i output parameters	Official	Real
Pulse halfwidth (FWHM, sech2 fit) / (FWHM, Gaussian fit)	130 fs	<b>112 fs</b>
Repetition rate	1.0 kHz	<b>1.0 kHz</b>
Average energy output	2.5 mJ	<b>1,8W</b>
Centre wavelength	780 nm ± 5 nm	<b>789 nm</b>
Bandwidth	8-10 nm	<b>12 nm</b>
Contrast ratio (pre-; post pulse)	100:1	<b>120:1</b>
Beam size (Gaussian fit FW1/e2M)	~ 8 mm	<b>4,99mm ± 0,03mm</b> <b>4,60mm ± 0,01mm</b> <b>4,98mm ± 0,04mm</b>
Beam size (Gaussian fit FW1/2); horizontal plain		
Beam size (Gaussian fit FW1/2); vertical plain		
Environment temperature	22±5 °C	<b>21°C</b>

Table 1 Parameters review

## 5 Acknowledgements

I would like to thanks to the head of the project, Petr Hribek, for his great leading, patience and all acquired knowledge and skills. My thanks merits also Marcel Fuciman for his help in calculating deviation of the circular trajectory of scanning pin-hole and Pavel Chábera for his advice in the technical area and shared background papers. The project was supported by EAGGF (European foundation) and SDRUŽENÍ RŮŽE.

## References

- [1] Optical autocorrelation , Wikipedia, [http://en.wikipedia.org/wiki/Optical\\_autocorrelation](http://en.wikipedia.org/wiki/Optical_autocorrelation)
- [2] Integra-i User's manual
- [3] Pockels effect, Wikipedia, [http://en.wikipedia.org/wiki/Pockels\\_effect](http://en.wikipedia.org/wiki/Pockels_effect)