Precise Alignment of Large-aperture Compressor Gratings for High-power Lasers Using Diffraction Interferometry.

V. Chvykov, V. Yanovsky

Center for Ultrafast Optical Science, University of Michigan, 2200 Bonisteel blvd, Ann Arbor, MI 48109-2099

vchv@eecs.umich.edu

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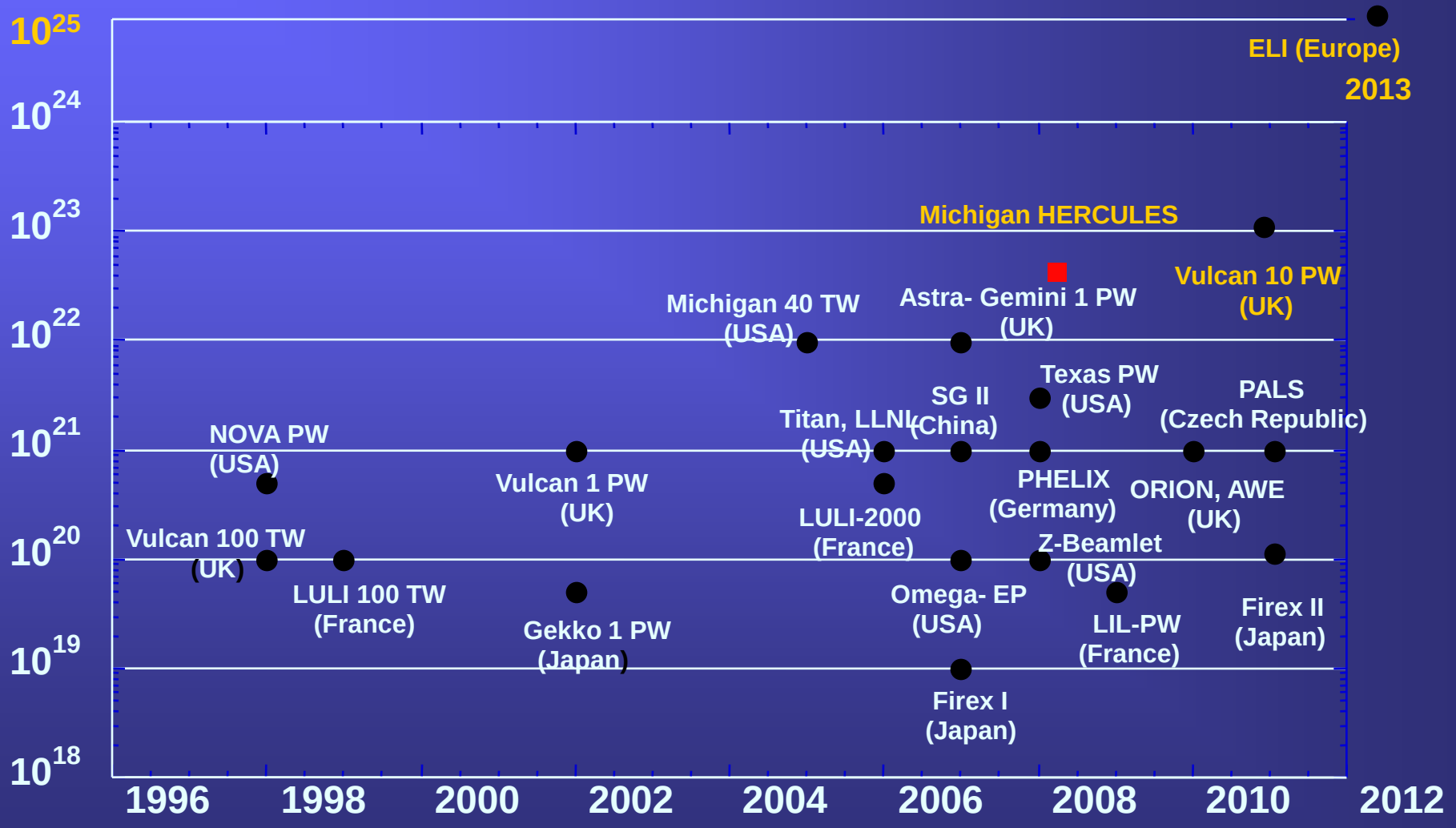
Outline

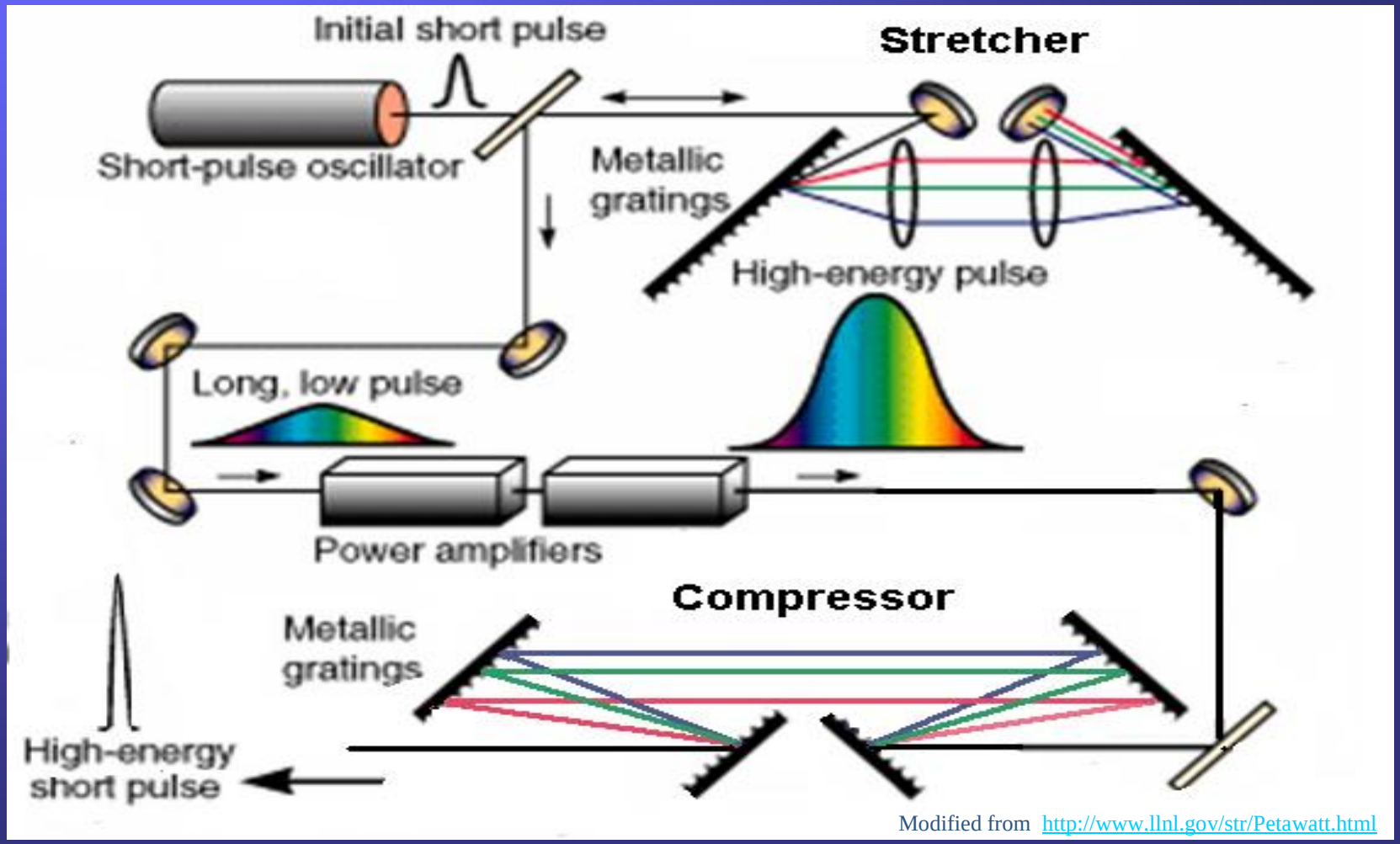
- Requirements for alignment of the large-aperture gratings compressor.
- Previous methods of the compressor alignment
- New method with use of the diffraction interferometry
- Implementation into the “Hercules” laser, PFT measurements

Development of The CPA and OPCPA Laser Systems



CPA

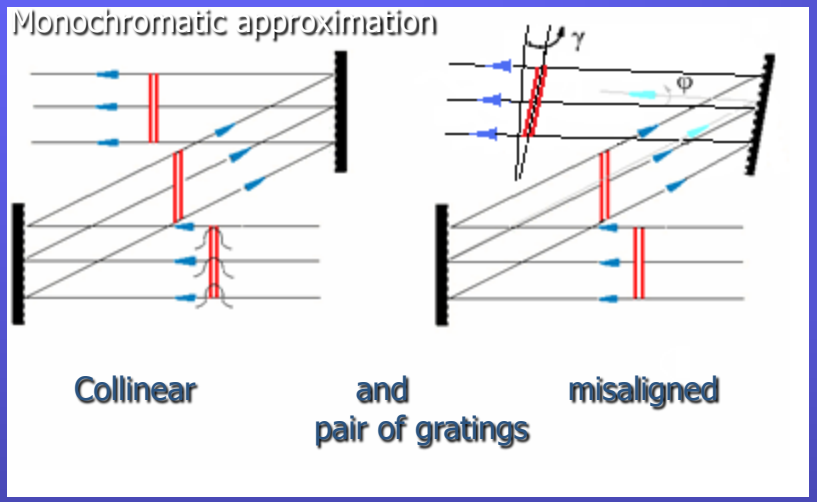
was invented to reduce the required aperture of the optical elements excluding the compressor gratings



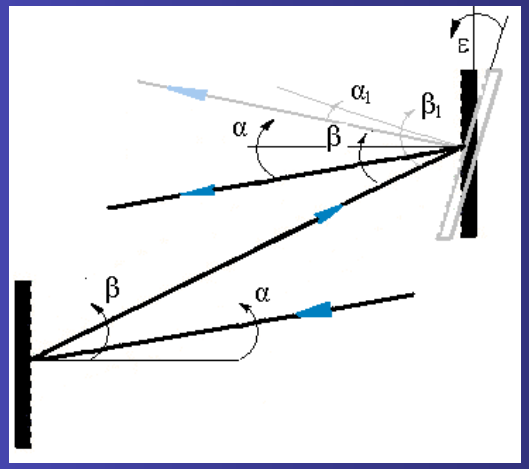
Modified from http://www.llnl.gov/str/Petawatt.html

Compressor, Pulse Front Tilt (PFT)

Source of PFT – non compensated angular chirp



Relation between PFT and angle of misalignment



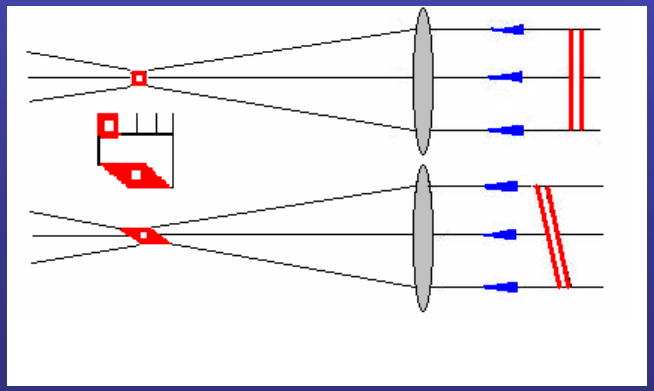
$$\gamma = \lambda_0 \left(\frac{d\varphi}{d\lambda}\right)_{\lambda_0}$$

$$\varphi(\lambda) = (\alpha - \alpha_1) \approx \varepsilon \left(\frac{\cos\beta}{\cos\alpha}\right)$$

$$\left(\frac{d\varphi}{d\lambda}\right)_{\lambda_0} = \frac{\varepsilon}{d}\left(\frac{\tan\beta}{\cos\alpha}\right) \qquad \gamma = \varepsilon\frac{\lambda_0}{d}\left(\frac{\tan\beta}{\cos\alpha}\right)$$

For λ_0 = 800 nm ; d = 1200 gr/mm ; α = 45.5º ;
beam diameter = 10" ; ε = 10^{-4} radians
angle of PFT – γ = $0.7*10^{-4}$ and enlargement
of pulse duration in the focus k~ 3
Keeping k< 1.1 leads to requirement of grating precision
alignment 10^{-5}-10^{-6}

Focusing of the tilted pulse



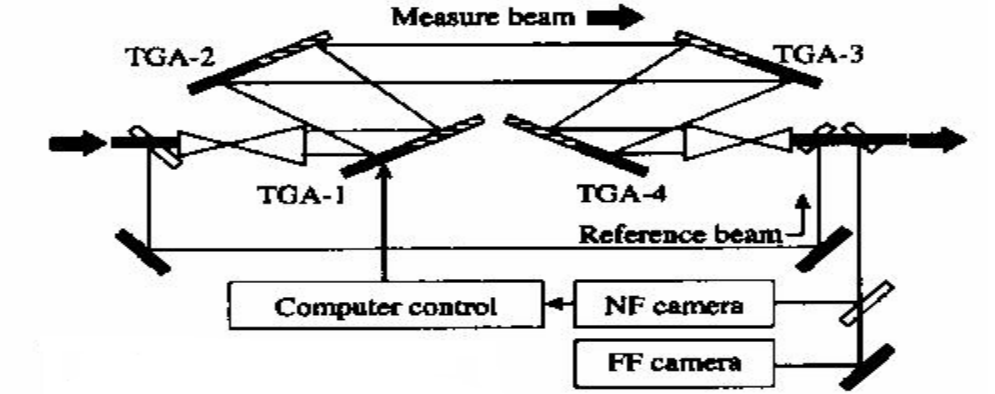
Larger gratings require more accurate alignment to provide for quality compression of the focused laser pulse.

Methods previously used for alignment of compressors with large gratings.

1. **Direct control of the grating alignment by a single-shot autocorrelator** leads to a multi-stage-procedure for alignment

   Qihua Zhu, at all Facility Journal of Physics: Conference Series 72 (2007) 012009

2. **Several types of interferometers with beam splitters** introduce additional optical elements and, with them, additional alignment steps and distortions.



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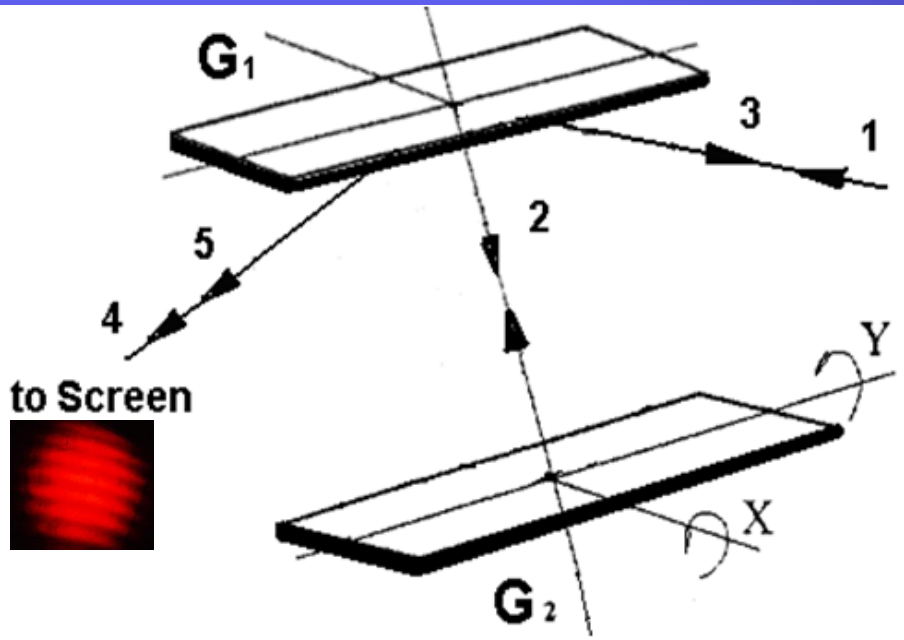
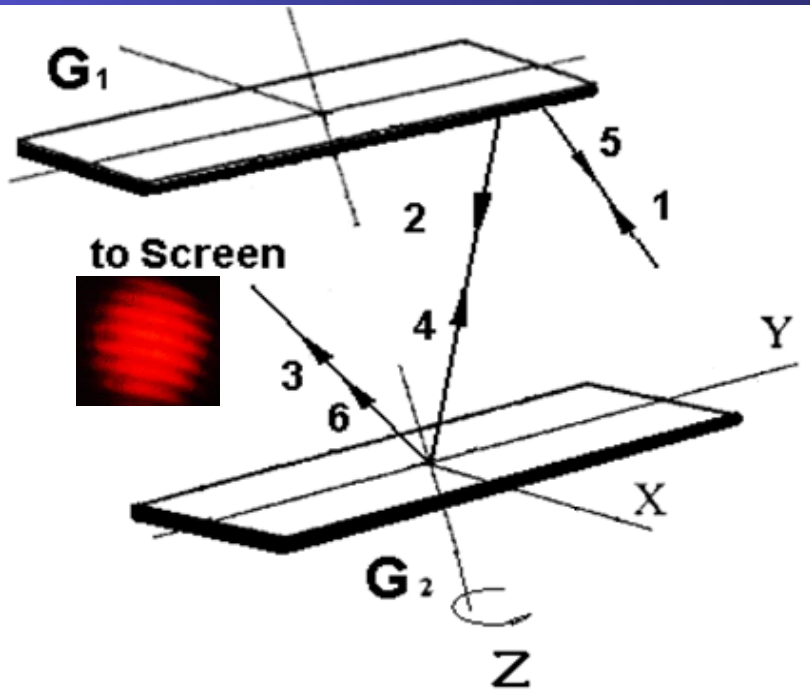
Compressor gratings as gratings of the diffraction interferometer.

We mix the beams of different diffraction orders from different gratings and use interference patterns for indication of the grating collinearity.





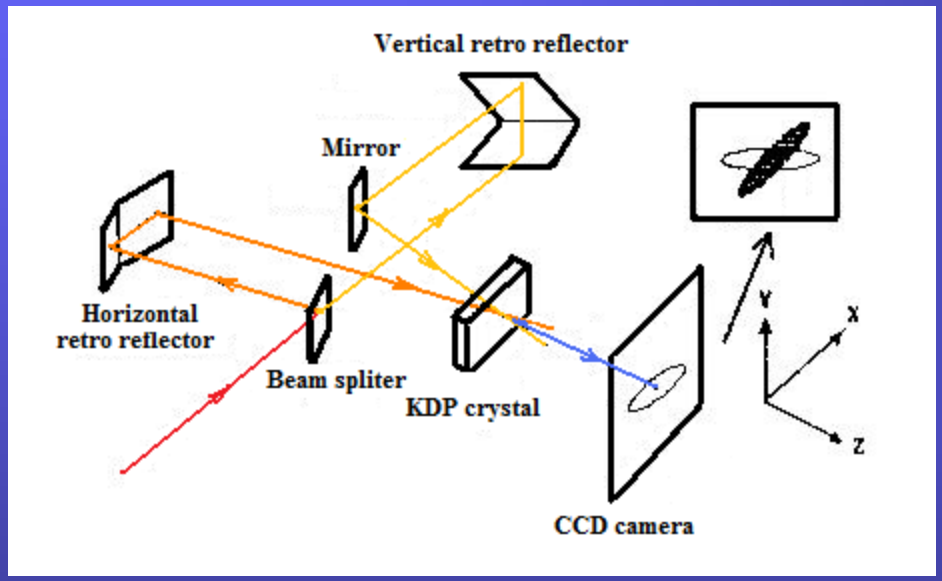
a b

Schematic diagram for grating alignment:
a – collinearity of the gratings, b – collinearity of the grooves,

“Hercules” laser’s compressor

The 6” diameter output beam is compressed to 30 fs pulse duration. To keep the pulse duration at this value +10% during focusing, the precision of the grating alignment has to be not worse then 10^{-5} radians. For this, the beam of the HeNe laser was expanded to 2.5” diameter.

Measurements of the pulse duration and PFT by a single shot autocorrelator with inversion.



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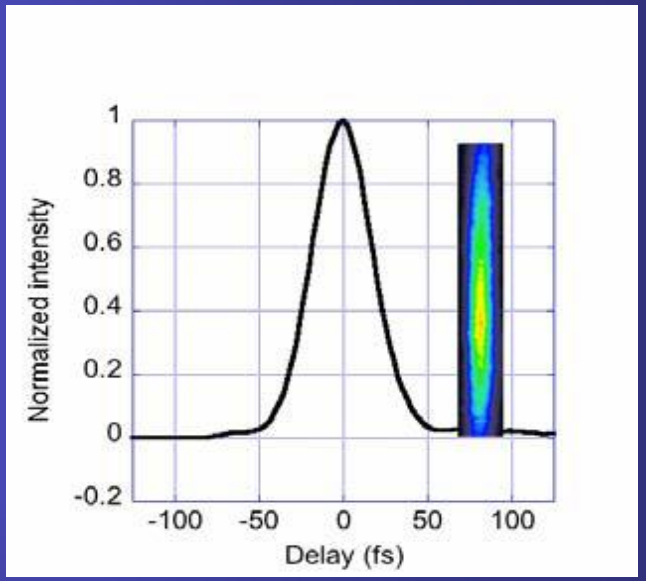

Autocorrelation of 300 TW "Hercules" pulse

Accuracy of the tilt measurements.

The angle of PFT could be estimated to be not worse then $0.6*10^{-5}$ radians because,

- **the autocorrelation tilt angle is no more then 10^{-2} radians.**
- **the ratio between autocorrelation tilt and PFT tilt is about $6*10^{-2}$.**
- **the output beam from the compressor is down collimated for measurements by 100 times.**

Conclusion

- Novel method of the precise compressor alignment was suggested for Petawatt-scale CPA lasers.
- Method was implemented into the Hercules laser.
- Precision of the grating colinearity of 10^{-5} radians was reached.