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Application Note for Highly-dispersive mirror for Yb:YAG laser with GDD of -10000 fs²

Highly-dispersive mirrors (HDMs) have become a key tool in the field of ultrafast physics over the last two decades. Presently, the majority of femtosecond lasers include dispersive mirror optics which allow precise control of group delay dispersion (GDD) characteristics.
A highly-dispersive mirror with the unprecedented group delay dispersion of −10000 fs² in the wavelength range of 1025−1035 nm is reported. Reproducible production of a coating with such a high dispersion was possible due to the recently developed robust synthesis technique, see design and measurement curves on Figure 1.

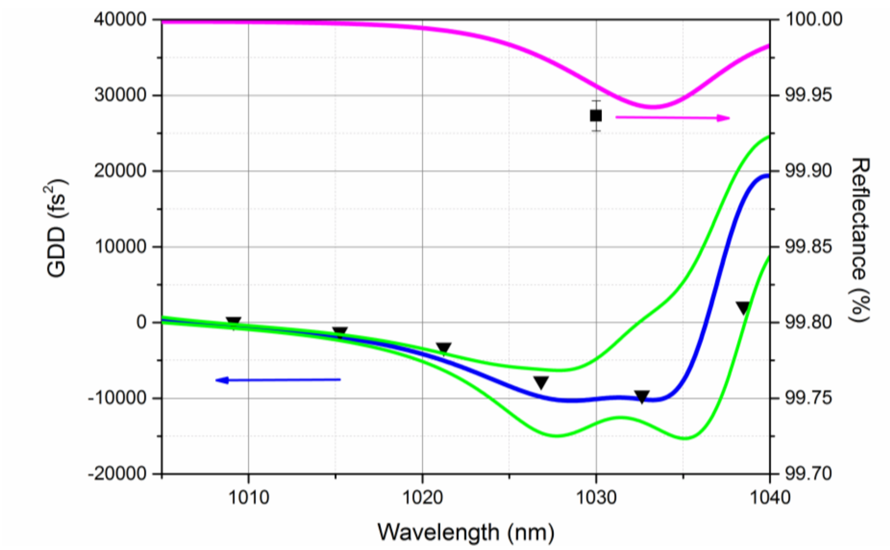

Figure 1. Comparison of the designed and measured data for the new HDM: The designed GDD for 3° angle of incidence (blue curve), error bars ± 0.5 nm (green curves); the measurement performed with a WLI at 3° angle of incidence (black triangles). The designed reflectance for 7.5° angle of incidence (magenta curve), the square at 1030 nm represents the measurement performed with a lossmeter at 7.5° angle of incidence.

The advantage of having only one mirror providing the GDD is that fewer mirrors can be used to build a working cavity. This improves the stability and simplifies the alignment since fewer degrees of freedom need to be taken into account and fewer surfaces are prone to optical damage. The use of fewer mirrors also establishes the possibility to build shorter cavities with higher repetition rates. The produced HD1473 was successfully utilized in an Yb:YAG TD oscillator, operating at 33.7 MHz repetition rate with an output power of about 4 W, which resulted in a pulse duration of 320 fs, see Figure 2.

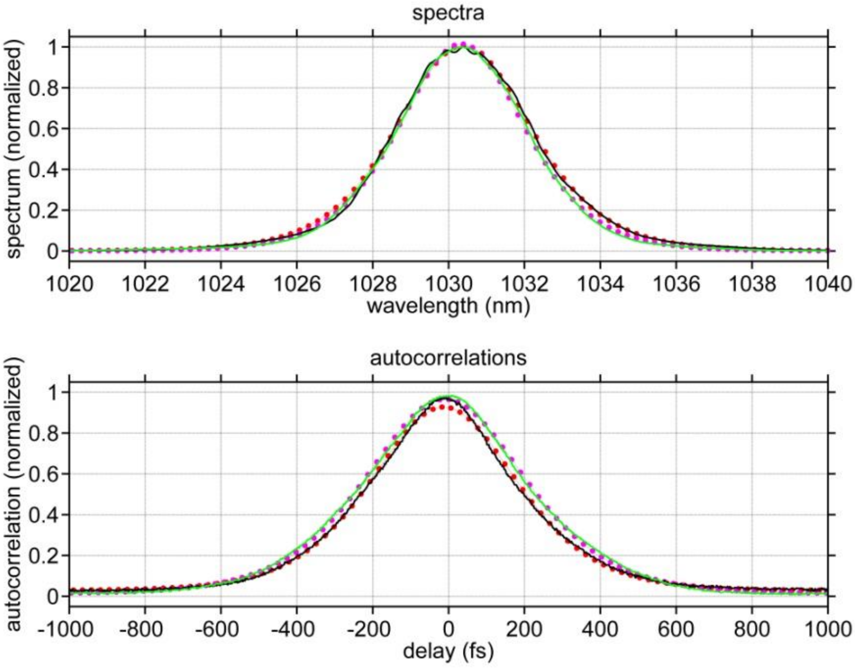

Figure 2. Comparison of spectra (top) and autocorrelations (bottom) of a basic KLM Yb:YAG oscillator working with the known mirror set and with the new HD1473. In both graphs the color coding as follows: measured data with reference setup (3x HD73 +1x HD64) (black line), measured data with test setup (green line), fitted sech2-function to reference data (red dots), fitted sech2-function to test data (magenta dots).

the approach and the reproducibility of the manufacturing process, DMs of this type and of similar bandwidth were designed, produced and also successfully tested in a 60-nJ Ti:Sa CPO operating at a repetition rate of 70 MHz [A. Fernandez, A. Verhoef, V. Pervak, G. Lermann, F. Krausz, A. Apolonski, "Generation of 60-nanojoule sub-40-femtosecond pulses at 70 megahertz repetition rate from a Ti:sapphire chirped pulse oscillator," Appl. Phys. B 87, 395-398 (2007).]

References:

1. J. Brons, V. Pervak, E. Fedulova, D. Bauer, D. Sutter, V. Kalashnikov, A. Apolonskiy, O. Pronin, and F. Krausz, "Energy scaling of Kerr-lens mode-locked thin-disk oscillators," Opt. Lett. 39, 6442-6445 (2014).
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High-peak power multi-100 W Yb:YAG KLM oscillators.

The oscillator represents the new generation of high average power/high pulse energy ultrafast compact Yb:YAG thin-disk lasers. The oscillator is only amplification-free laser operating in the >50 W average power and >4 MW peak power range [1, 2]. The oscillator has drastically reduces setup complexity, is much more compact and provides superior to amplifiers intensity and carrier-envelope phase (CEP) noise performance [3].

Applications:

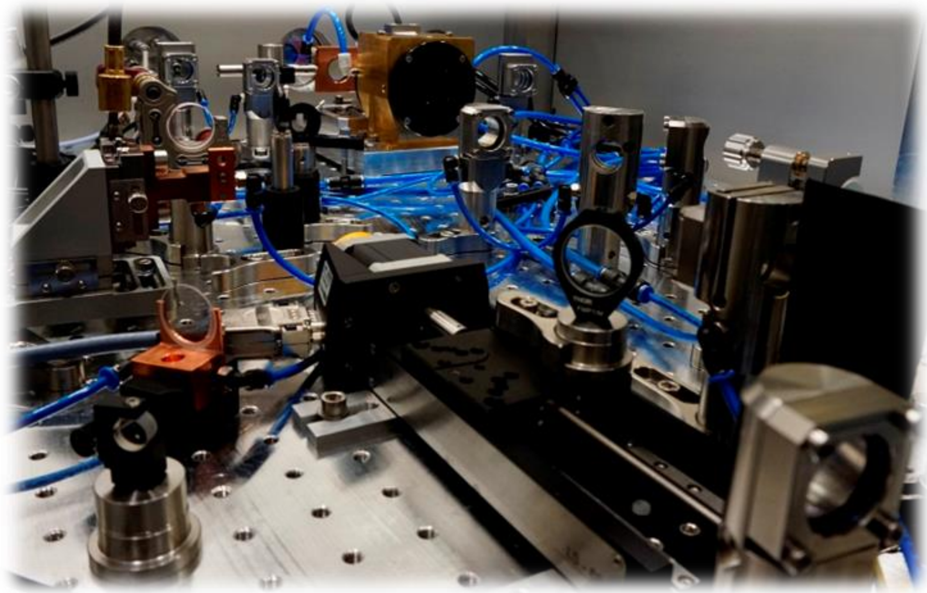
- Seed oscillator, front-end for amplifiers [4]
- Seed oscillator, front-end for enhancement cavities [5]
- Pump source for OPA, OPO [6]
- Driving laser for nonlinear conversion to XUV, MIR and THz spectral ranges [7]

Oscillator parameters:

	Oscillator	Compressor
Pulse energy	1-10 µJ	0.5-5 µJ
Pulse duration	140-250 fs	30 fs
Average output power	80-250 W	40-100 W
Bandwidth @1032 nm (FWHM)	< 8 nm	≈ 50 nm
Repetition rate	20-200 MHz	20-200 MHz
Peak power	< 30 MW	< 100 MW
Beam diameter ($1/e^2$)	< 4 mm	< 5 mm
Spatial mode	$M^2 < 1.1$	$M^2 < 1.2$
Intensity noise (1 Hz-0.5 MHz)	< 0.3 % RMS	< 0.3 % RMS
Polarization linear, horizontal	1:100	1:100
Max footprint (L x W x H cm^3)*	1200 x 700 x 260	740 x 640 x 210

*Footprint of the oscillator unit strongly depends on the repetition rate.

Yb:YAG KLM oscillator in the LMU lab:



Oscillator extension. Ultrashort-pulse unit comprises fiber-free spectral broadening and compression unit.

Publications:

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7. Pupeza I, et al., *High-power sub-two-cycle mid-infrared pulses at 100 MHz repetition rate.* Nat Photon, 2015. advance online publication.