IBS Coatings for Ultrafast Laser Applications

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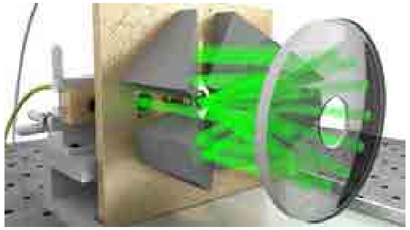
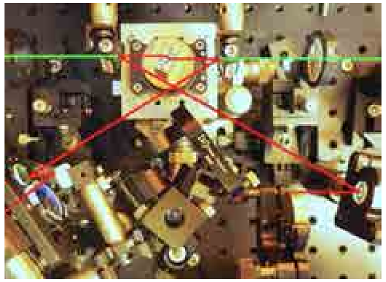
The Time/Frequency Laboratory at the University of Neuchâtel

Novel ultrafast lasers and applications

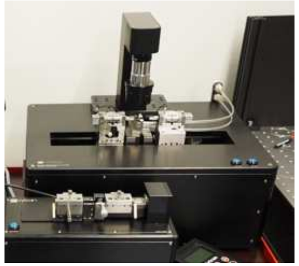
New DPSSLs at various wavelengths. Fiber lasers.
High power thin disk lasers.





Advanced optical technologies

OPTICS platform: IBS coatings, evaluation, optimization.
Fiber technology.

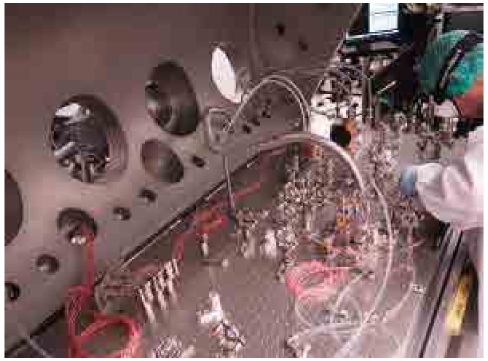


Optical frequency standards, atomic clocks

Vapour cell Rb/Cs clocks. Galileo 2.
ESA ACES mission. EU FACT.

Spectroscopy and sensing

NANOTERA MIXSEL, IRSENS. THz (NCCR), CO_2 spectroscopy (ESA).



Frequency combs

Fiber- and DPSSL combs. Mid-IR OPO & DFG combs. XUV combs with intra-laser HHG (ERC).

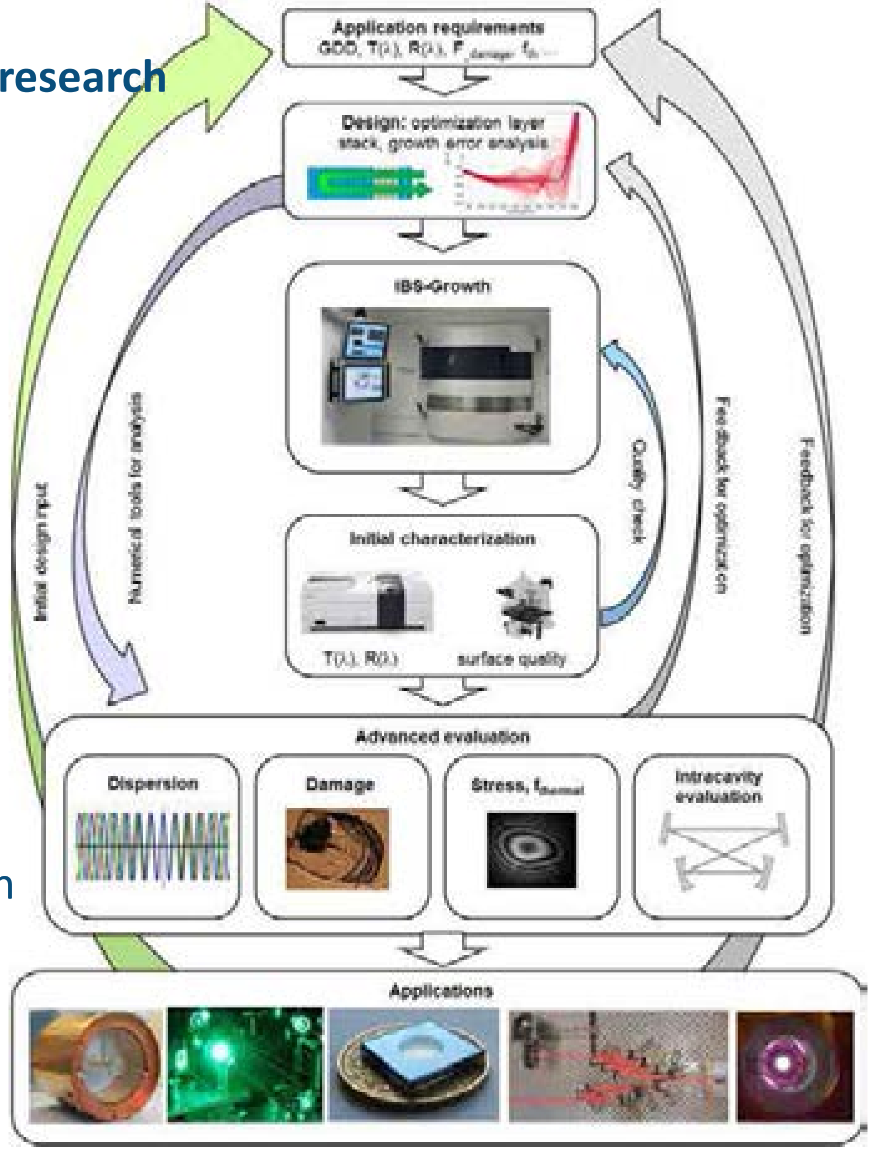
http://patapsco.nist.gov/ImageGallery/details.cfm?imageid=842

OPTICS: OPTical IBS Coatings for Swiss research

Target: develop a platform for IBS solutions for research

- IBS optimization with coating vendors
  - specific research solutions: low priority
  - time-consuming
  - expensive
  - growth parameters might vary

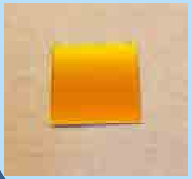
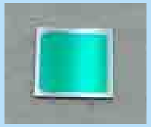
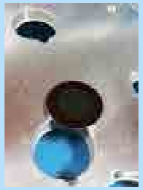
- OPTICS: provide fast development cycle
  - Analysis of application requirements
  - Optimized layer design
  - Growth on dedicated IBS machine
  - Full characterization
  - Immediate feedback to design & growth according to the needs of the application



LTF is Partner of SNOP (Swiss National Optics Platform) with Swissphotonics, NTB, and EPFL

Current research activities for IBS coatings

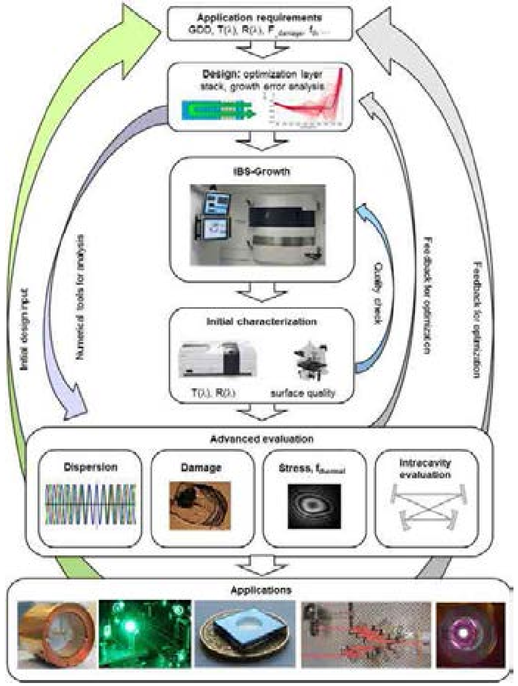
Semiconductor components
Top coatings on: SESAMs, VECSELs, MIXSELs, OOM chips
In collaboration with
ETH Zurich

Ultrashort Pulses from TDLs
Mirrors, OCs,
dispersive mirrors,
Disk coatings
In collaboration with
ULP Group at ETH Zurich and Dr. Christian Kränkel (Uni Hamburg and IKZ Berlin)

High Power Mirrors
Dispersive mirror with high LIDT and mirrors with low losses
In Collaboration with NTB and RhySearch and TFP AG

XUV and DUV Optics
UV outputcoupler for intra-cavity HHG (ERC Project) and development of DUV optics

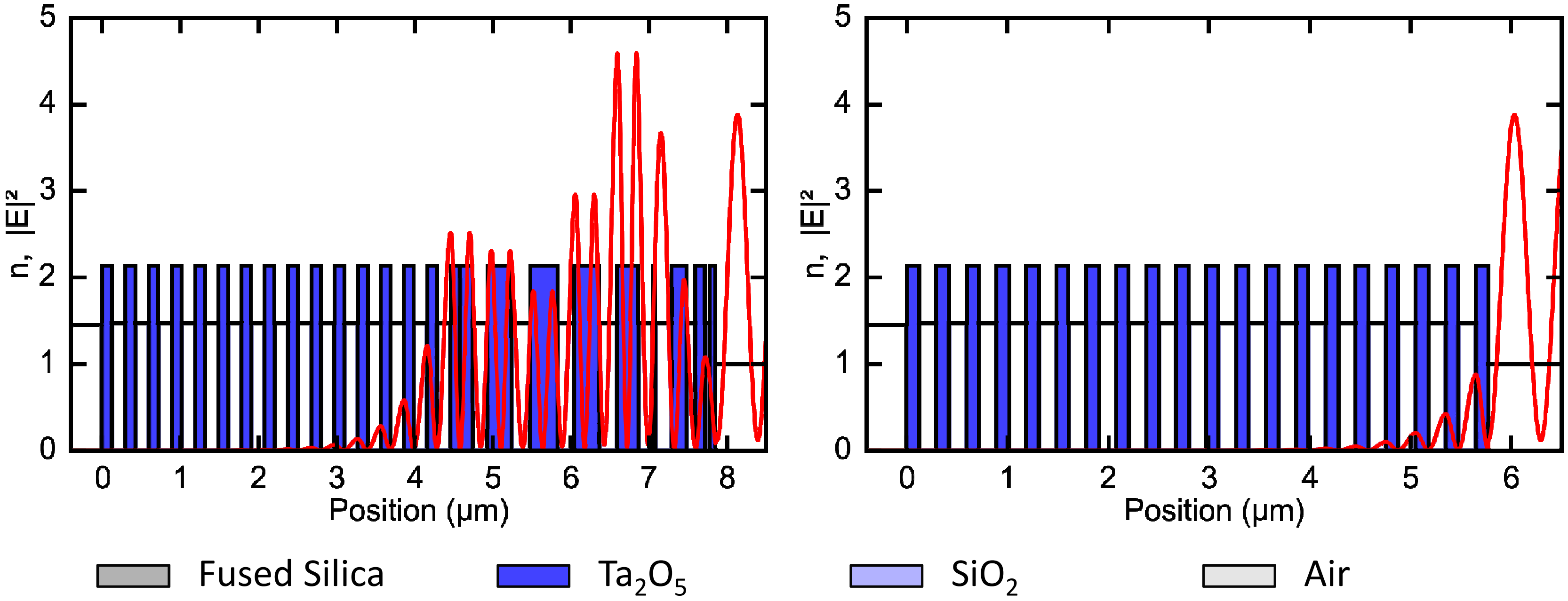


Design of a dispersive mirror

Software (based on Python) developed at UniNE for layerdesign of coatings

Design for an intra-cavity dispersive mirror (HR 1010-1060nm; GDD -500±50fs^2; 47 Layers)

Standard Quarter-wave mirror

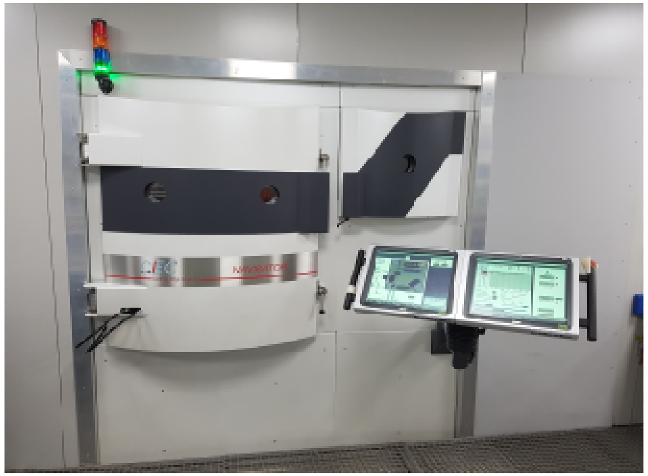


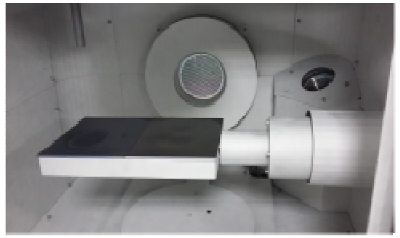
→ **the field intensity in the dispersive mirror is several times higher and penetrates deeper into the layer stack compared to the quarter-wave stack**

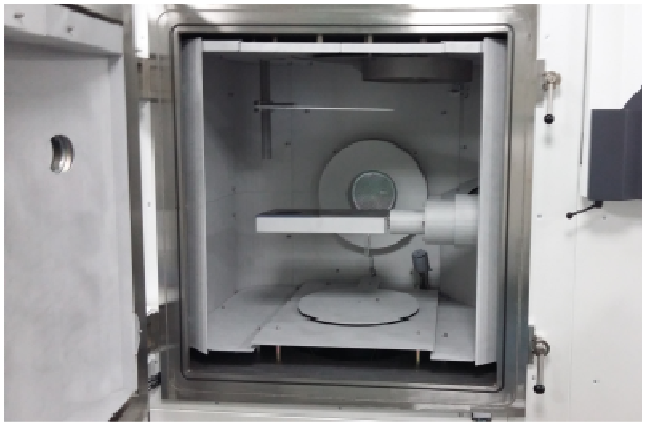
→ **Challenge: Lower damage thresholds, stronger thermal issues**

IBS Navigator 1100 CEC

- Ion beam sputtering (IBS)
- IBS coating system Navigator 1100 from Cutting Edge Coatings (spin-off from Laser Zentrum Hannover e.V.).



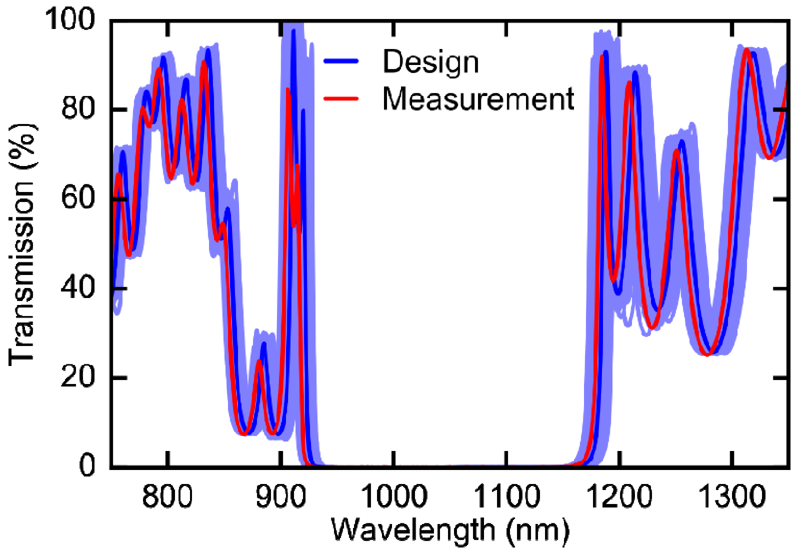


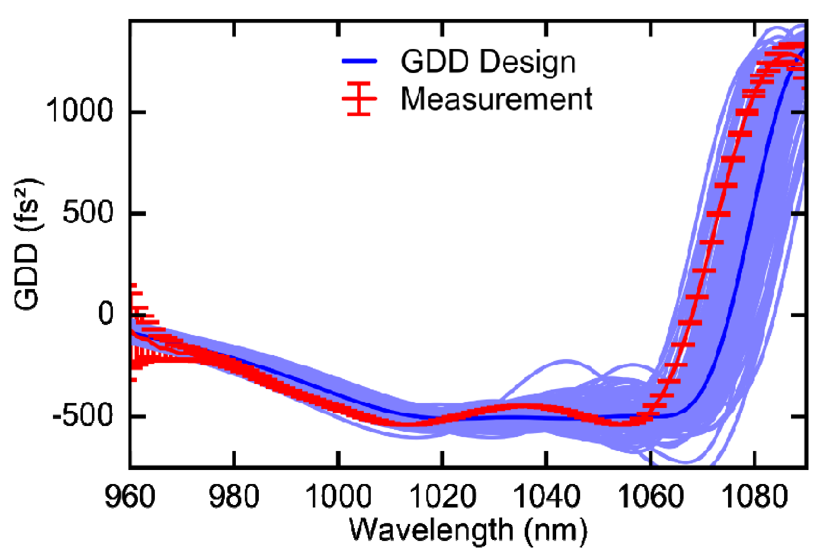


Erroranalysis and characterization

Assumptions:

- **relative layerthickness error of 0.5% (σ) per material taking into account the error from calibration and homogenity of the different materials**
- **absolute Fehler von 0.2nm (σ) per layer**
- **100x randomly chosen errordesigns (light blue) compared to the design (blue) and the measurement (red)**



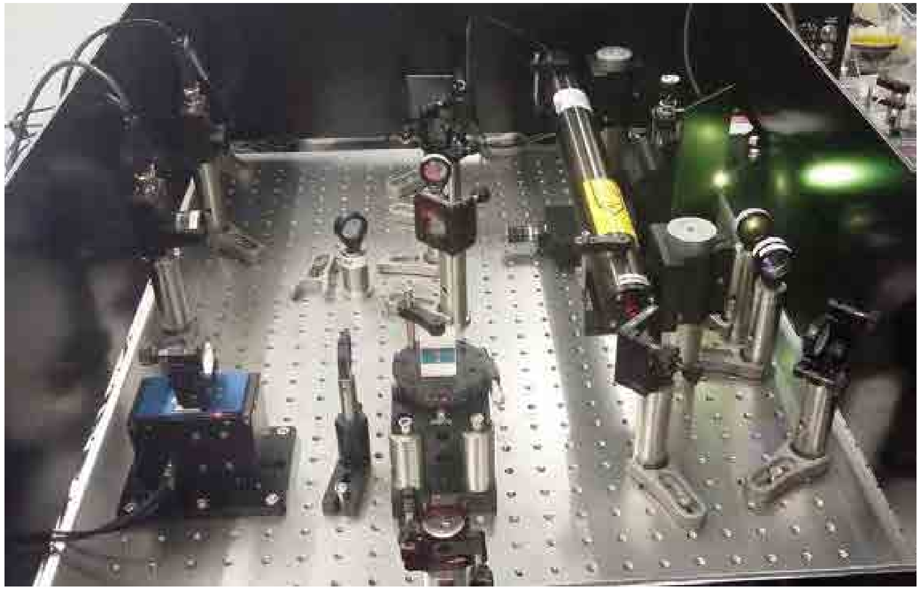


-> the required accuracy can be achieved

Advanced evaluation: dispersion measurement setup

- Broadband white light dispersion measurement system
- high-power supercontinuum source or a which allows characterization from about 400 nm to > 2000 nm
- SLD for smooth measurements between 980 nm to 1100 nm
- He-Ne laser for referencing the position
- Voice-Coil stage with a travel range of 3 mm (=> resolution of <1 nm)
- photodetectors for the different spectral regions.





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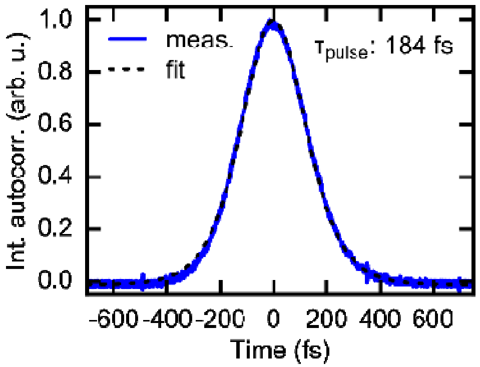
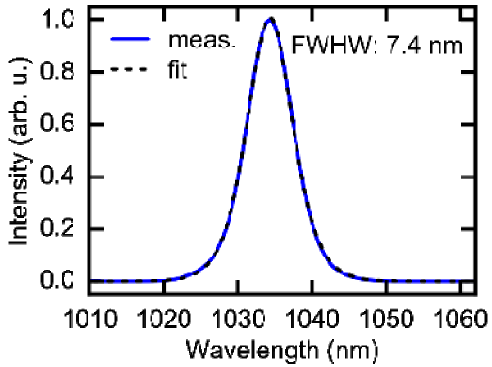
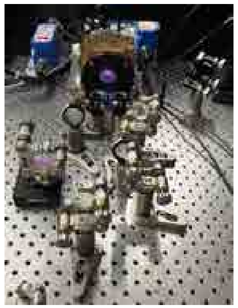
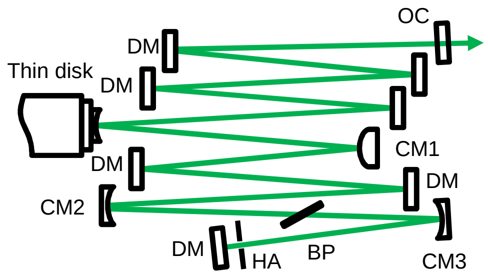
Dispersive mirrors tested in the resonator of an ultrafast Thin-Disk Laser (Yb:LuO)

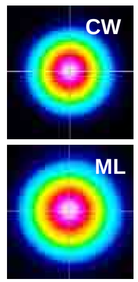
- with 5 of the -500 fs² dispersive mirrors
- Pulse duration <200fs were realized at an
- average output power of >10W (this corresponds to several hundreds of watts in the cavity)





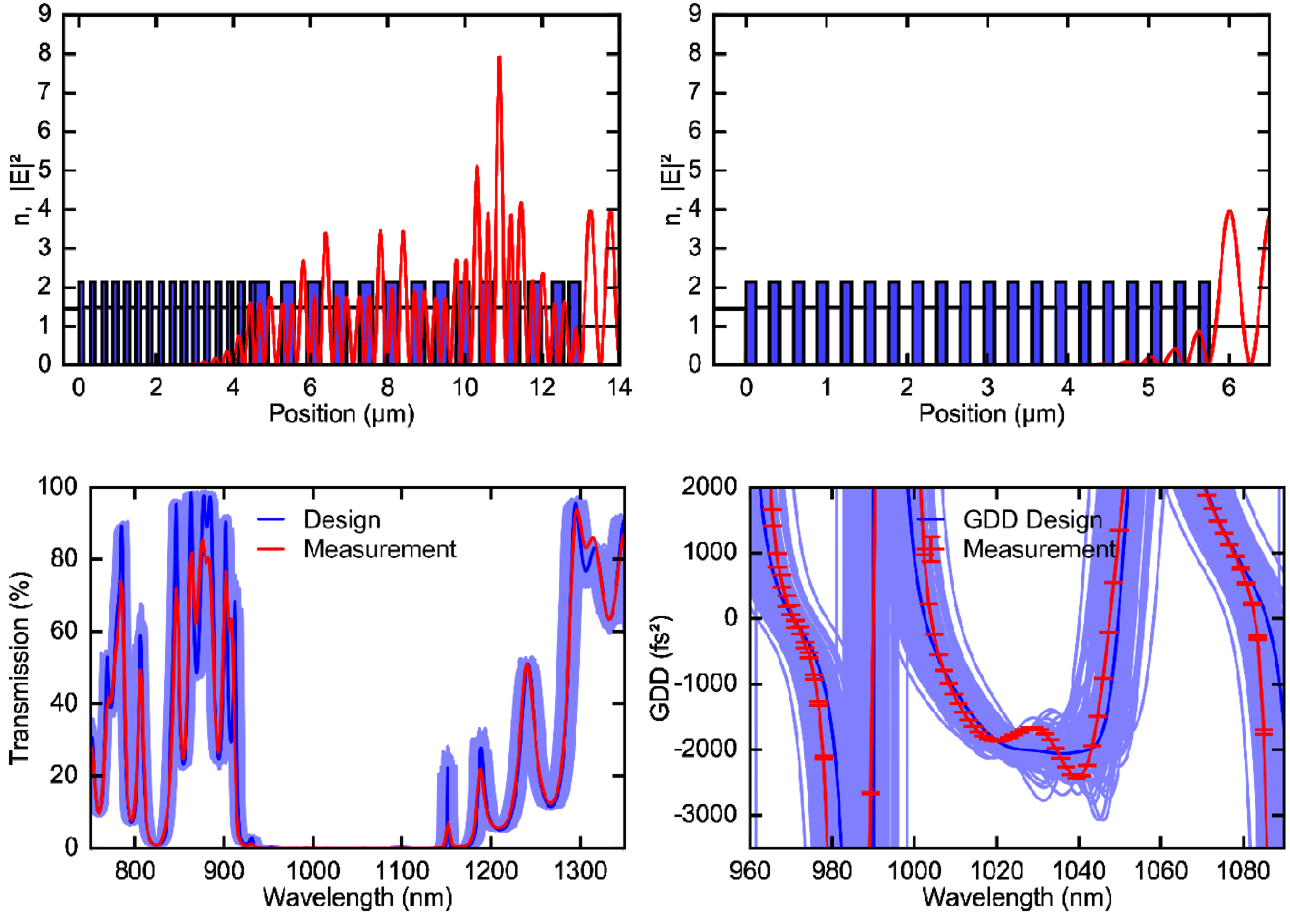






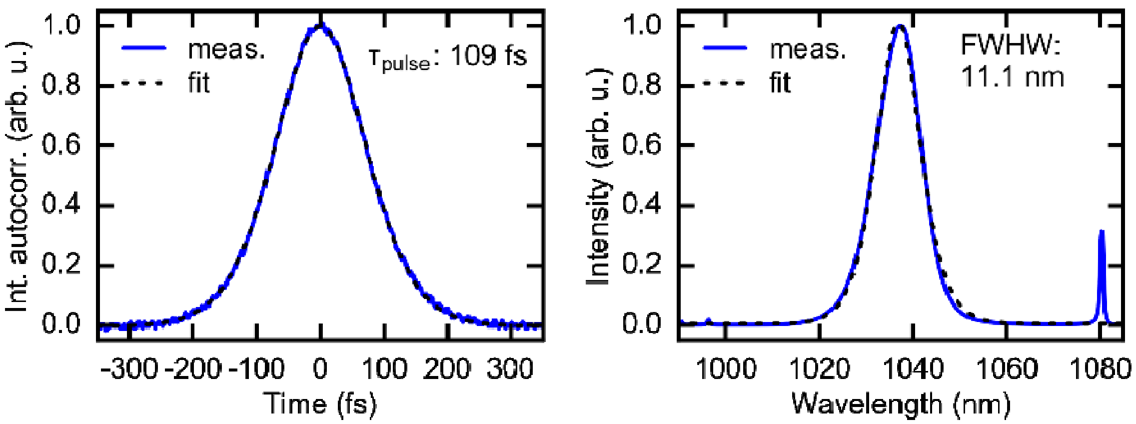
Next Design: more GDD per mirror

Design for intracavity dispersive mirrors
(HR and GDD -2000±400fs^2 in 1015-1044 nm)



Dispersive mirrors tested in the resonator of an ultrafast Thin-Disk Laser (Yb:LuO)

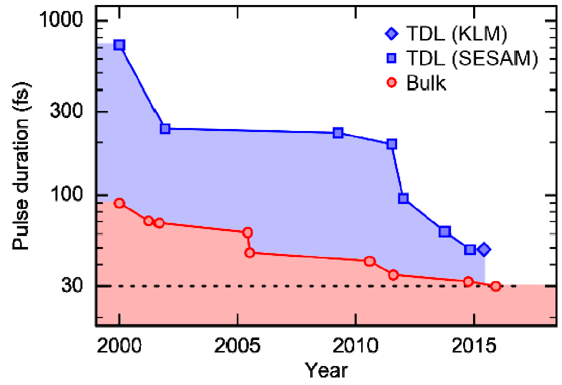
- with 1 of the -500 fs² and 1x -2000 fs² (end) dispersive mirrors
- Pulse duration <109 fs were realized
- average output power of 4.6 W

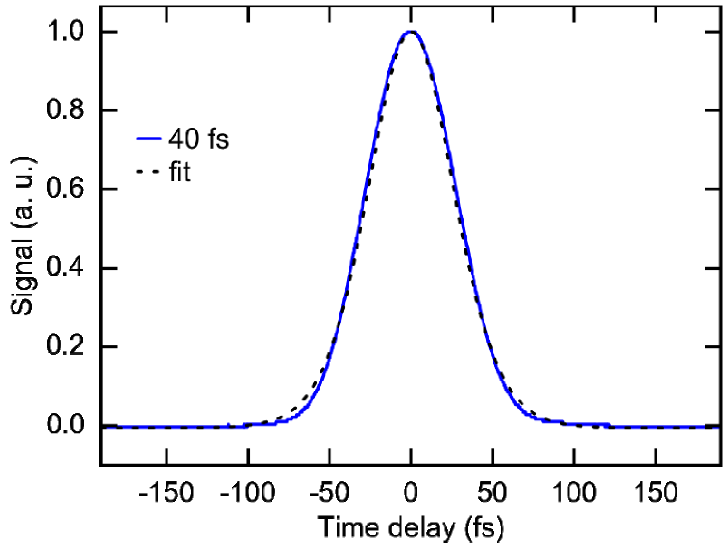


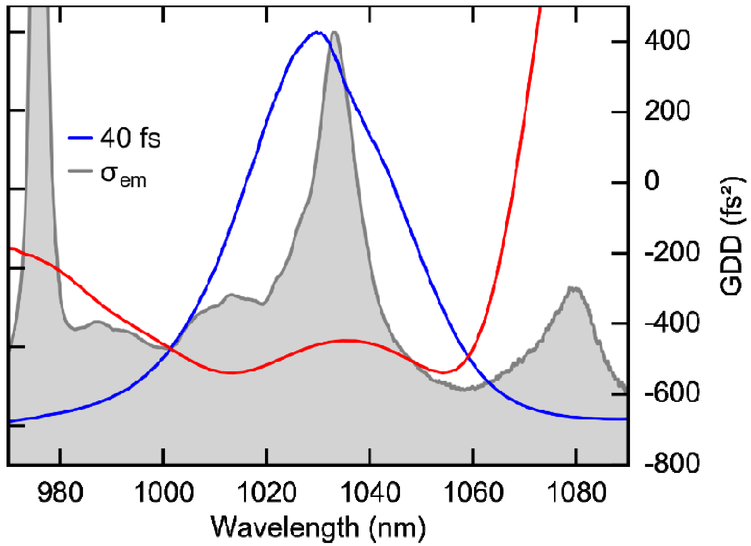
Application: Pushing to the limits of pulse duration

Dispersive mirrors tested in the resonator of an ultrafast Thin-Disk Laser (Yb:LuO)

- **with 1 of the -500 fs^2**
- **Pulse duration 40 fs were realized**
- **Average output power of 1.5 W**

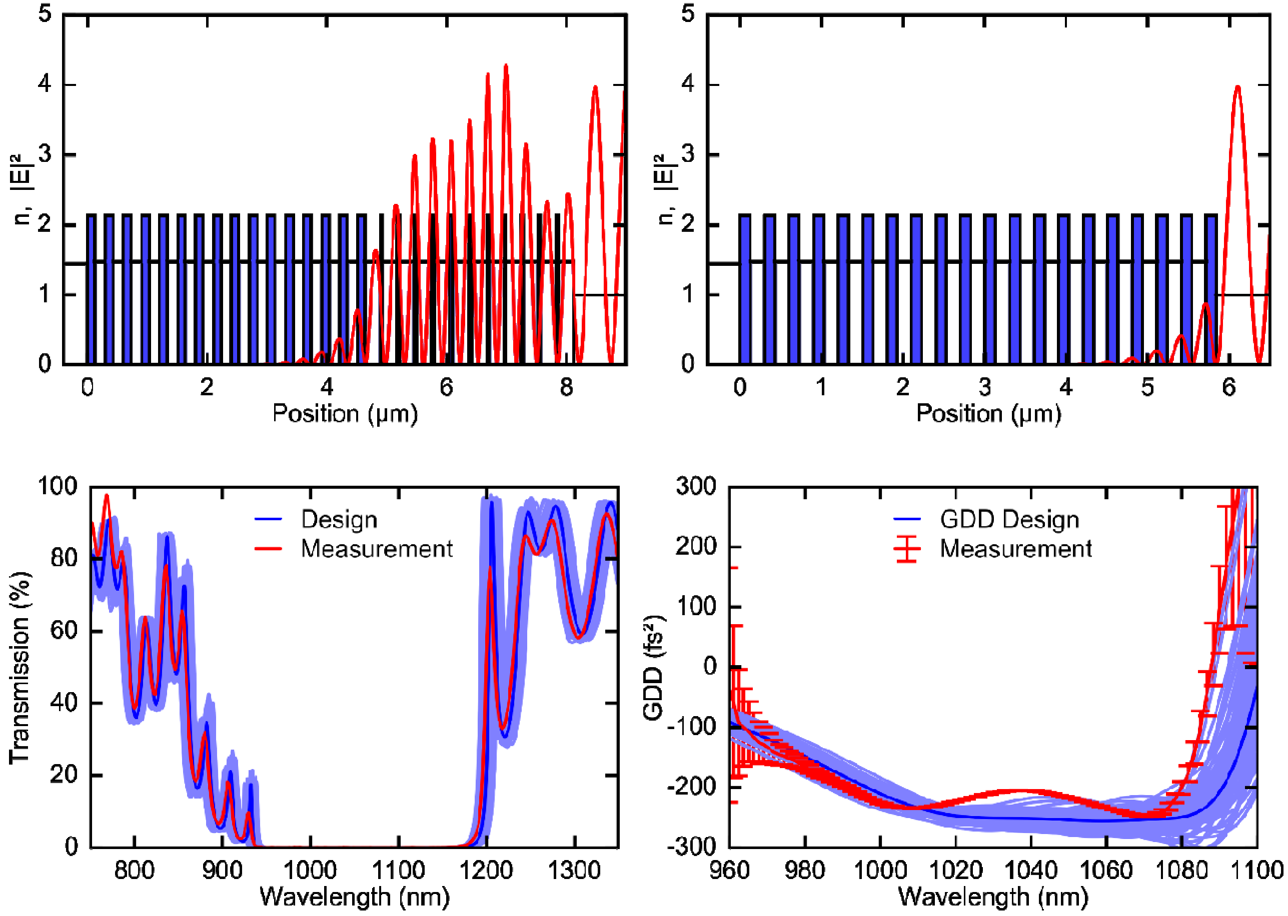






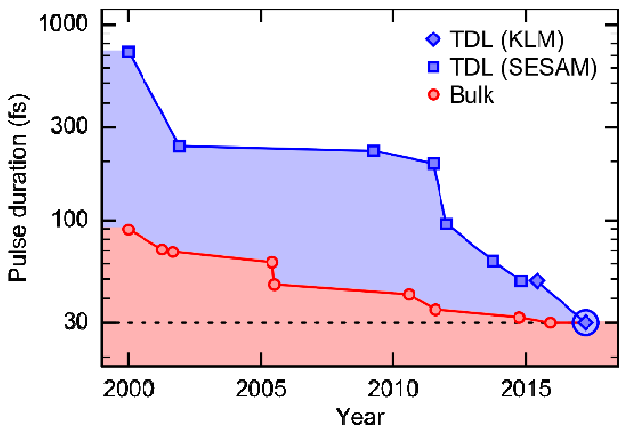
Dispersive mirrors -250 fs^2

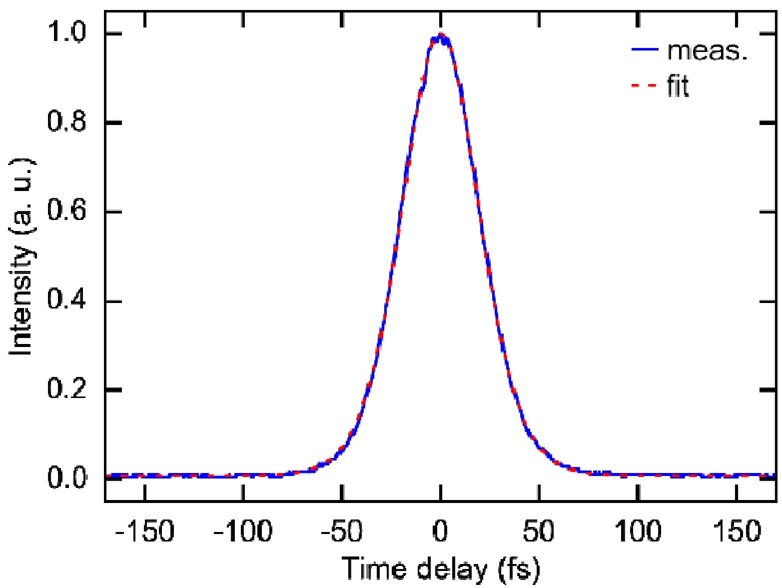
Design for intracavity dispersive mirrors -250 fs^2
(HR and GDD -225±25fs^2 in 990-1080 nm)

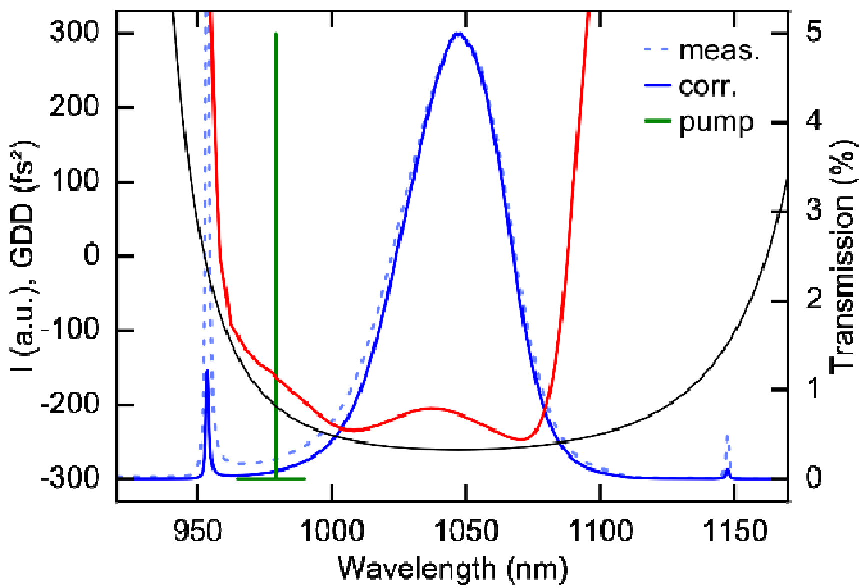


The shortest pulses from a Thin-Disk Laser

- Yb:CALGO Thin Disk Laser with 2x -250 fs^2 (4 passes per RT)
- 30 fs puse duration (equal to the shortest pulses from a Yb based gain material)
- The dispersive mirror seems to be limiting for further pulse shortening



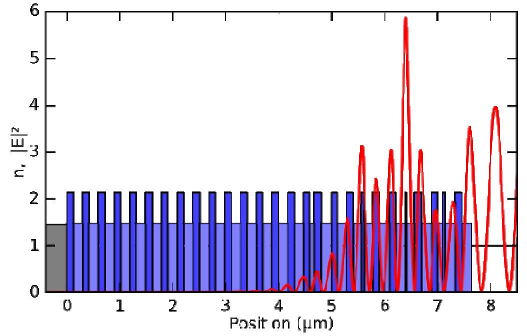


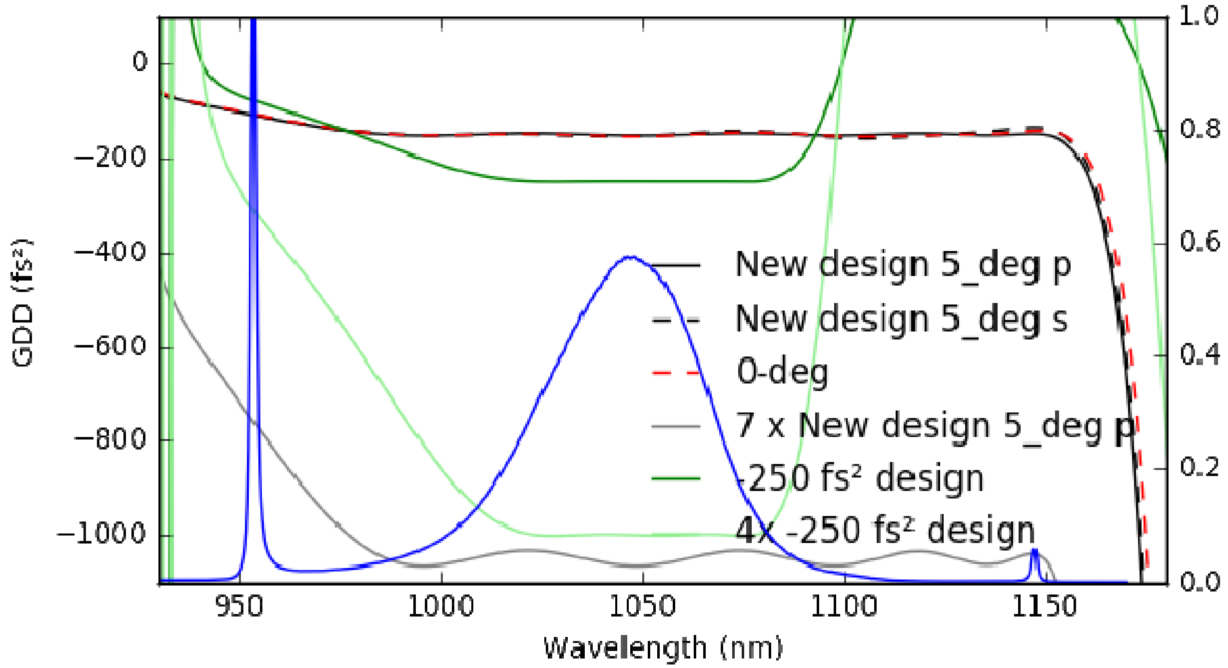


Outlook

Approach: less dispersion per mirror => broader dispersion

New Design for -150 fs² dispersive mirrors allows for much broader dispersion profile



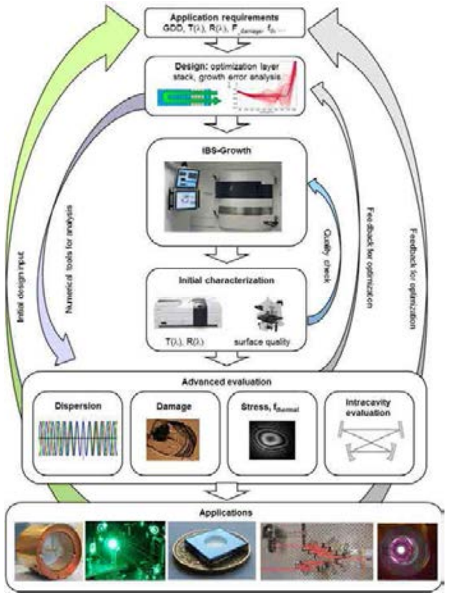


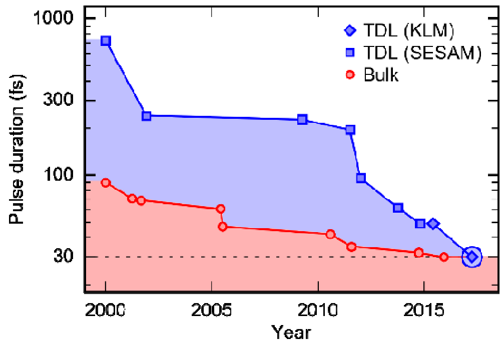
Conclusion

Closed development from the OPTICS platforms enables fast development cycles for state of the art optical coatings

Enabled the demonstration of the Shortest pulses from a Thin-Disk Laser to the level of bulk lasers

Strong indication to go further within the next development cycle





Acknowledgements

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Schweizerische Eidgenossenschaft
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RhySearch
Das Forschungs- und Innovationszentrum Rheintal

NTB
Interstaatliche Hochschule für Technik Buchs
FHO Fachhochschule Ostschweiz

THIN FILM PHYSICS

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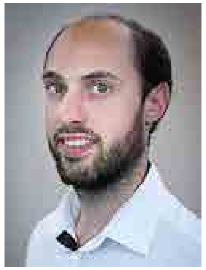
Thank you for your attention



Experimental work on the KLM TDL: Clément Paradis and Norbert Modsching