Compression and characterization of ultrashort pulses at 1.5 and 3 µm wavelength

O. A. Naranjo-Montoya, M. Bridger, A. Tarasevitch and U. Bovensiepen

University of Duisburg-Essen, Faculty of Physics, Lotharstrasse 1, 47057 Duisburg, Germany

oscar.naranjo@uni-due.de

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Motivation

- Ultrashort near-infrared and mid-infrared pulses have become powerful tools in a wide range of fields, ranging from pump-probe spectroscopy [1] to strong-field physics [2, 3]
- We use the compressed pulses for high order harmonic generation (HHG) in the soft x-ray regime, aiming to perform ultrafast absorption spectroscopy

Generation of 1.5 and 3 µm wavelength pulses

- The laser setup consists of a Ti:Sa oscillator, a pump channel, and a 4-stage OPCPA, and is described in [4]
- The OPCPA scheme is shown below

1st NOPA stage (BBO):

- Noncollinearity angle: 2.6°
- Seed-pulse duration: 3 ps
- Amplified bandwidth from 760 nm to 840 nm
- Amplification factor: **10000x**
- Full energy per pulse: **15 µJ**
- Pump efficiency: 7.7%

1st DFG stage (BBO):

- Idler CWL: 1545 nm
- FWHM: ~ 250 nm
- Amplification factor: **3x**
- Output energy : ~ **30 µJ**
- Pump efficiency: ~ 19%

2nd NOPA stage (KTA):

- Noncollinearity angle: 3.7°
- Amplification of the full seed spectrum
- Amplification factor: **10x**
- Energy per pulse: ~ **300 µJ**
- Pump efficiency: ~ 19%

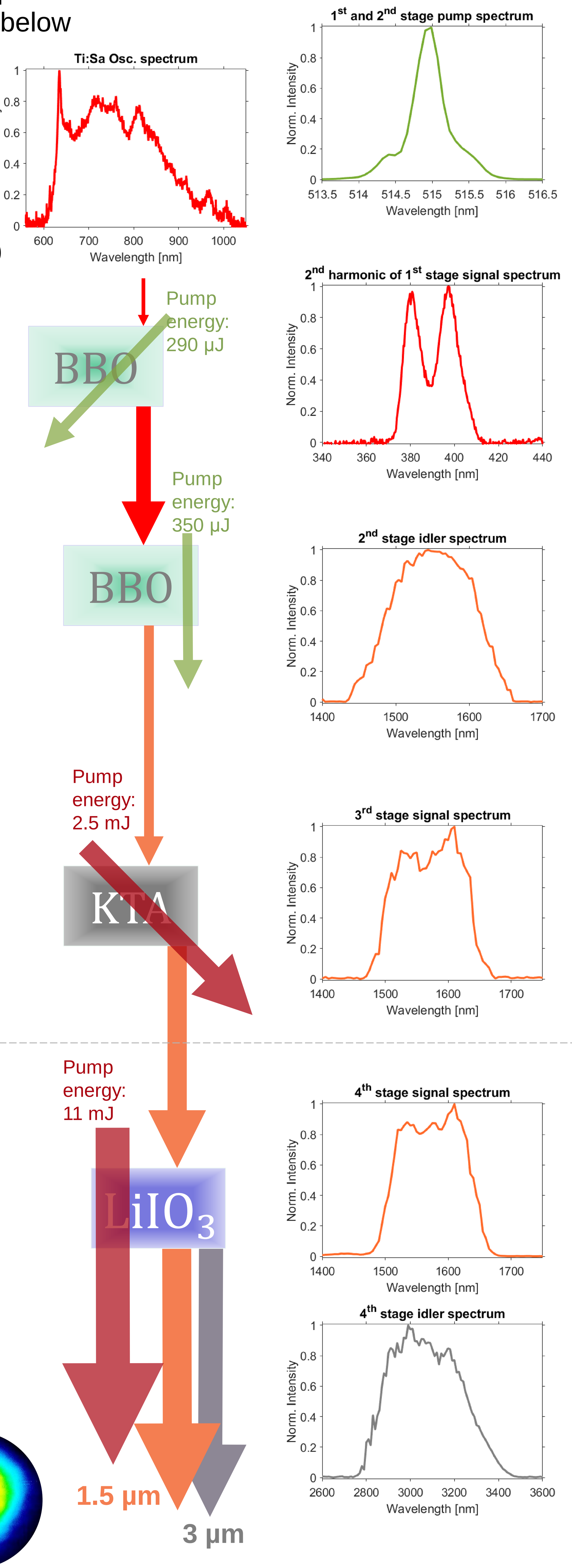
2nd DFG stage ($LiIO_3$):

Signal:

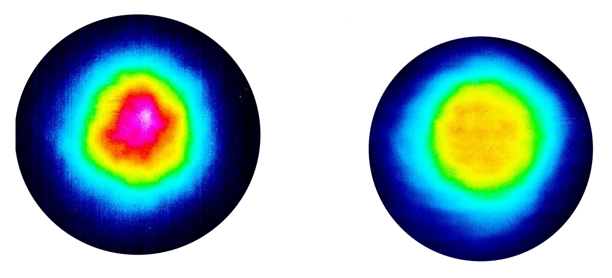
- Central wavelength: 1.5 µm
- Pulse energy: ~ 1.8 mJ

Idler:

- Central wavelength: 3 µm
- Pulse energy: ~ 0.8 mJ



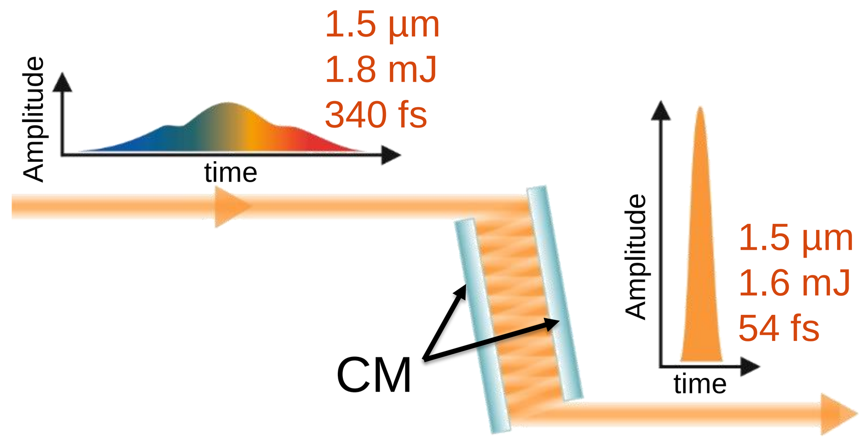
Beam profiles



Compression

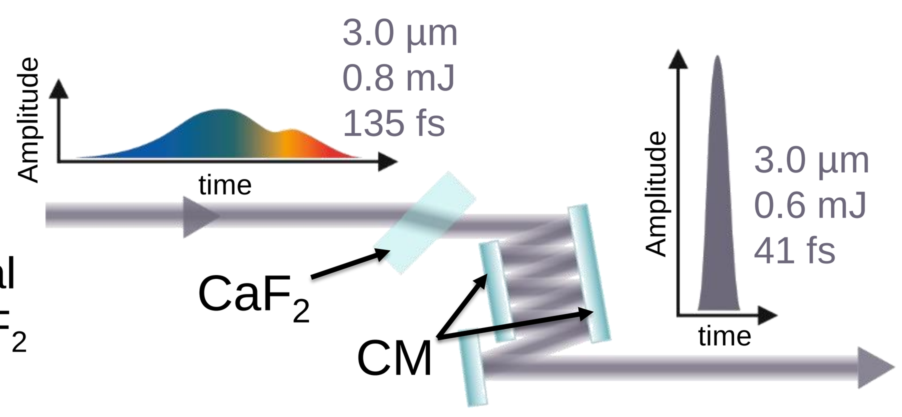
1.5 µm pulses

- The 1.5 µm pulses were compressed using 20 reflections from chirped mirrors (CM)
- Total dispersion compensated: 7100 fs² GDD and 20000 fs³ TOD



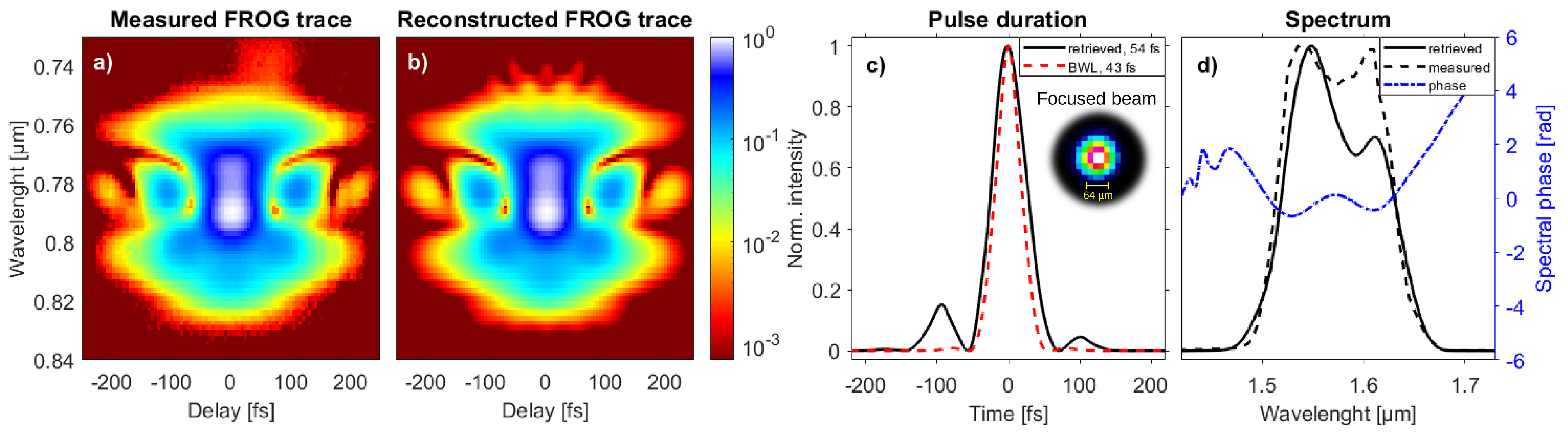
3.0 µm pulses

- The 3.0 µm pulses were compressed using 7 reflections from chirped mirrors and material dispersion on 15.1 mm thick CaF_2 platelet
- Total dispersion compensated 5000 fs² GDD and 30000 fs³ TOD



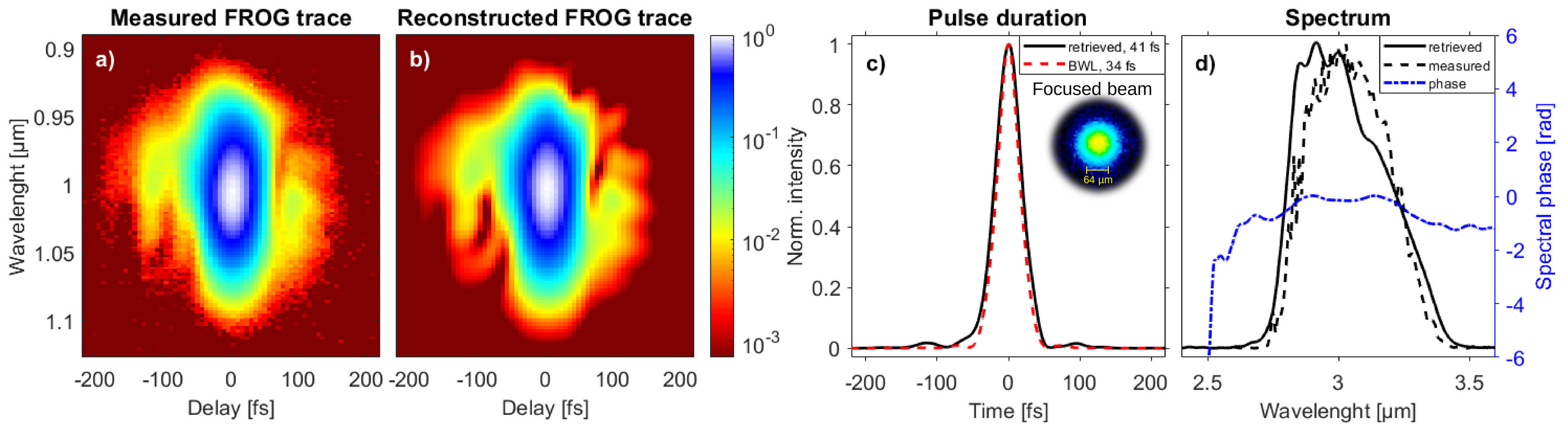
Characterization

1.5 µm pulses



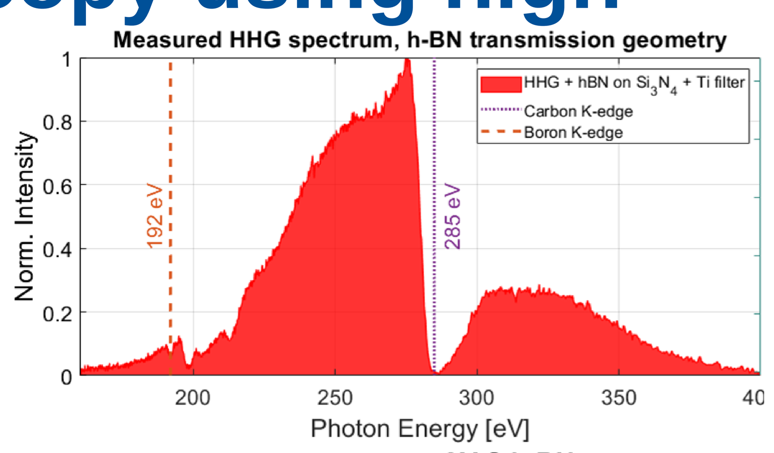
- Second harmonic FROG traces generated using a 60 µm thick type I BBO crystal
- The retrieved and measured FROG traces is in good agreement (*a* and *b*)
- Retrieved pulse (*c*) has the duration of 54 fs
- Residual non-zero higher order spectral phase (*d*) explains the longer pulse duration compared to the bandwidth-limited one of 43 fs (*c*)
- The retrieved pulse spectrum is in qualitative agreement with the independently measured one (*d*)
- The pulse energy after the compression was 1.6 mJ
- The high beam quality allowed coupling the compressed pulses to a hollow core fiber with the diameter of 100 µm with an 80% efficiency

3.0 µm pulses

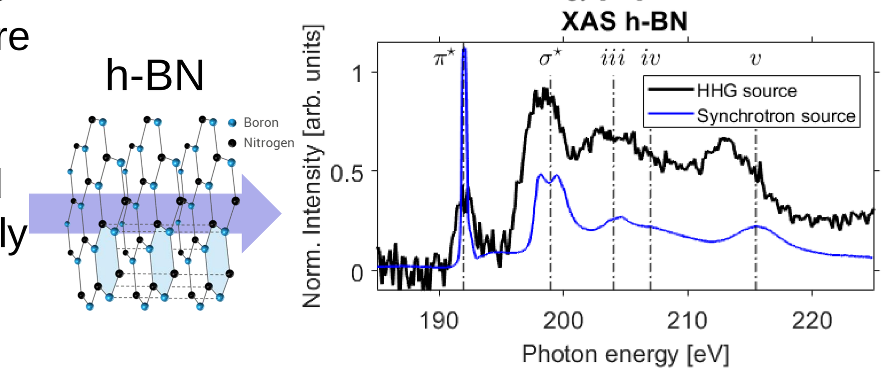


- Third harmonic FROG traces generated using a 200 µm thick type II KTA crystal
- The retrieved and measured FROG traces is in good agreement (*a* and *b*)
- The retrieved pulse (*c*) has the duration of 41 fs
- Residual non-zero higher order spectral phase (*d*) explains the longer pulse duration compared to the bandwidth-limited one of 34 fs (*c*)
- The retrieved pulse spectrum is in qualitative agreement with the independently measured one (*d*)
- The pulse energy after the compression was 0.6 mJ
- The high beam quality allowed coupling the compressed pulses to a hollow core fiber with the diameter of 100 µm with an 60% efficiency

X-ray absorption spectroscopy using high harmonic generation



- Focusing the 1.5 µm beam into a 100 µm inner diameter hollow-core fiber, filled with Helium at 6.5 bar, high order harmonics up to 350 eV photon energy and 10^5photons/s in 1% bandwidth were generated
- The generated high order harmonics allowed us to performed near edge x-ray absorption fine structure spectroscopy (NEXAFS) of h-BN in transmission geometry.
- From the NEXAFS recorded spectra, we identified signatures at the boron K-edge reported previously in [5]



Conclusions

- We report generation of 54 fs, 1.6 mJ and 41 fs, 0.6 mJ pulses at the wavelengths of 1.5 and 3 µm, respectively
- The pulses were compressed using chirped mirrors and material dispersion
- Further compression can be achieved by implementing a phase modulator that controls dispersion of higher-orders
- Efficient coupling of the radiation to a capillary demonstrates a high beam quality at both wavelengths
- We have demonstrate the application of the generated 1.5 µm in HHG
- We have used our source to measured NEXAFS of h-BN in transmission geometry

References

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