Simple Laser Pulse Shaping

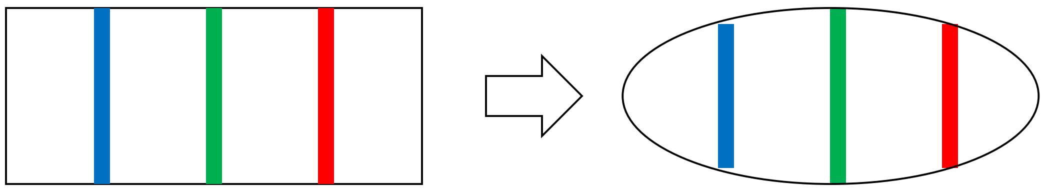
Utilizing dispersion

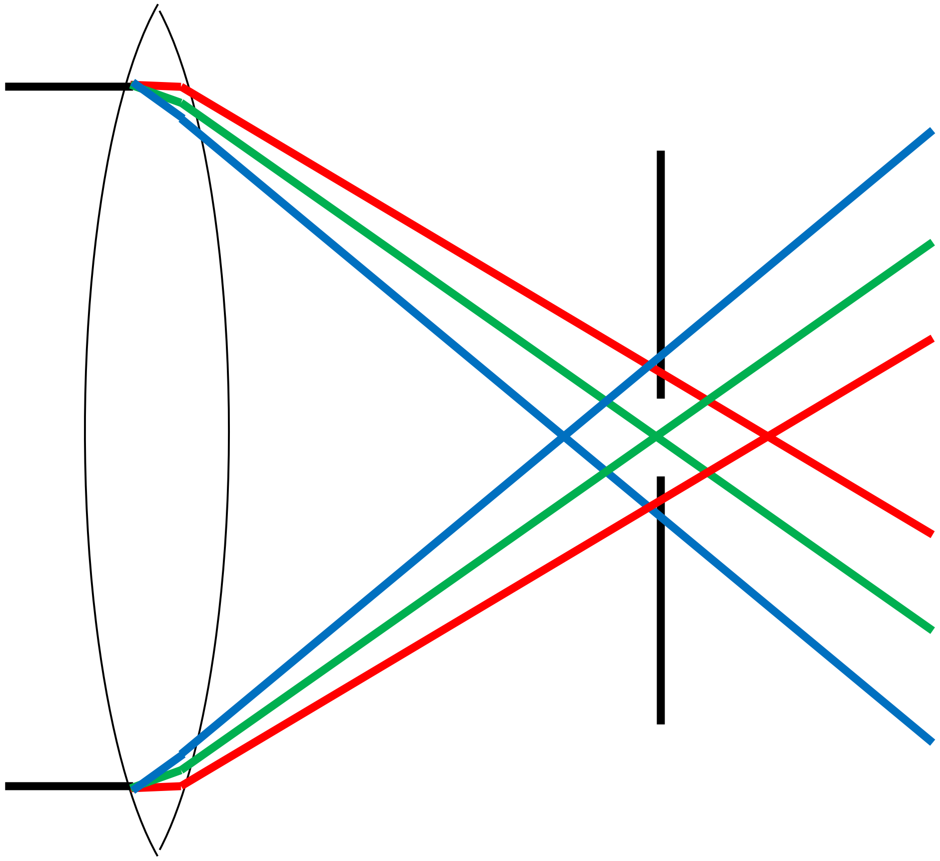
Matthias Groß
Zeuthen, 14. January 2021

Idea

Correlation of optical spectrum with longitudinal pulse shape

- Basic principle of 3D shaping
  - Chirped pulse as input (time – wavelength correlation)
  - Spatial separation of wavelengths is done by dispersion, followed by shaping and re-integration
- ELLA: grating + SLM
- Here: lens (chromatic dispersion) + pinhole
  - Circular (or other) symmetry given by pinhole

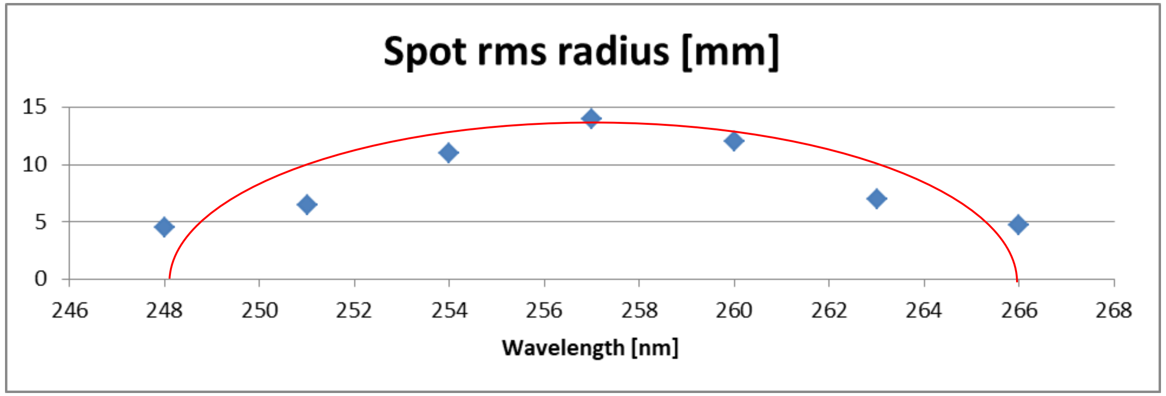


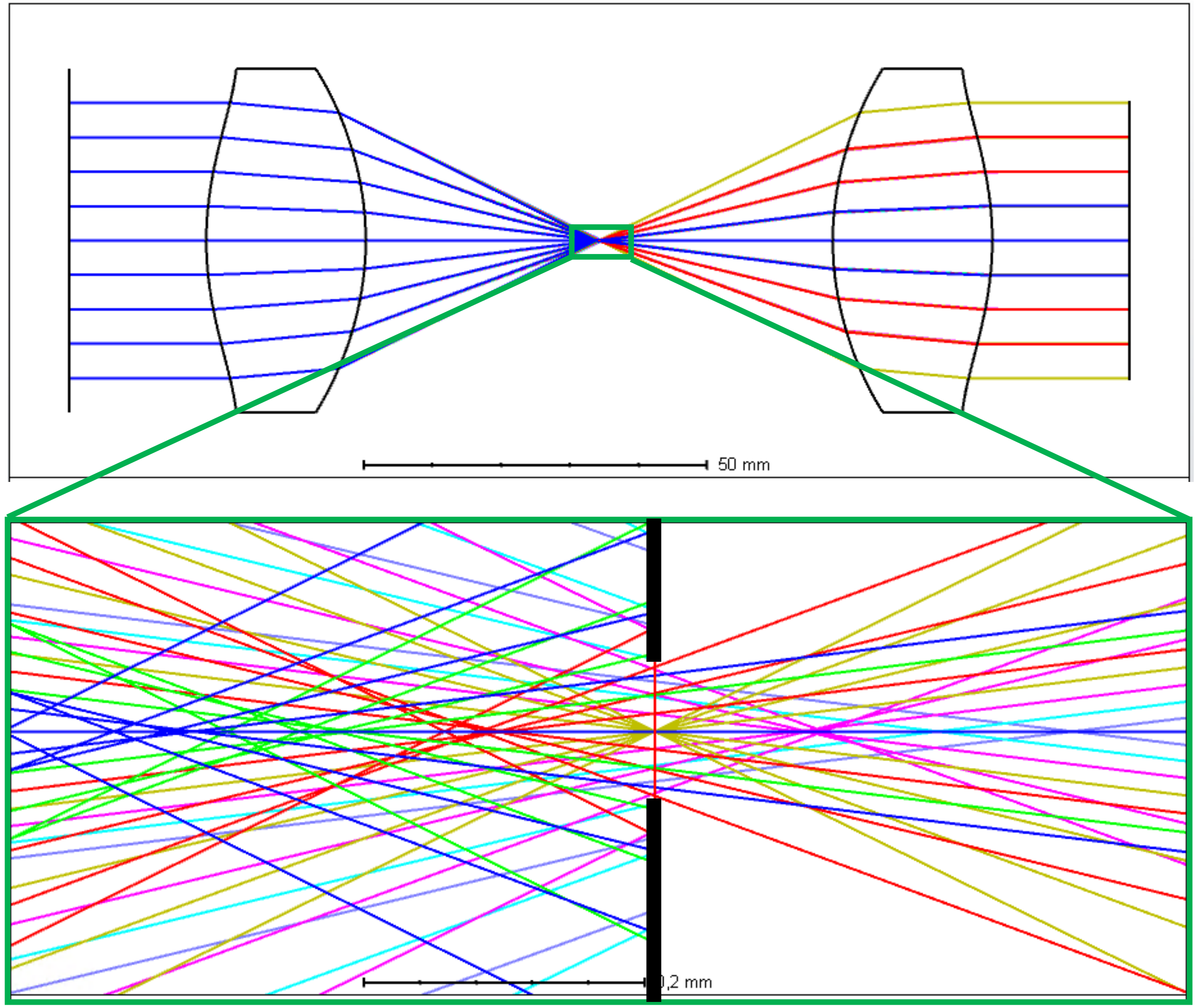


Simulation Setup to Test Principle

Assumption: transverse flat-top distribution at input; simulation: ZEMAX ray-tracing

- 2 optimized quartz aspheric lenses (4f image relay)
- Beam diameter: 40 mm
- Pinhole diameter: 0.1 mm
- Laser spectral width: 18 nm (center at 257 nm)
  - Distribution is almost flat for Pharos bandwidth (~2 nm)



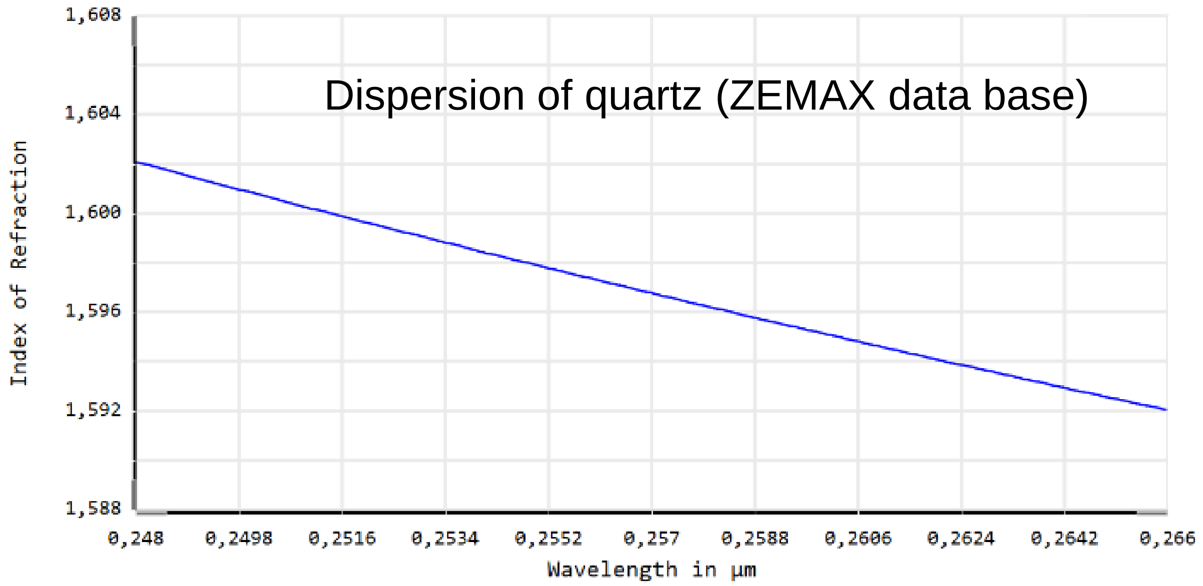


- Shaping works in principle, but needed: strong dispersion with correct shape

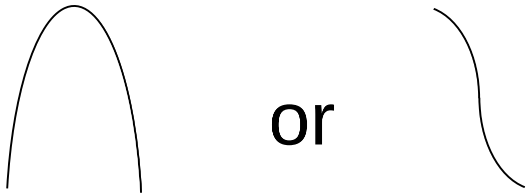
Issues

How to get towards an ellipse with a homogeneous intensity distribution?

- Intensity distribution of standard laser pulse: Gaussian both in time and transverse
  - Transverse
    - Transverse flat-top can be easily prepared with BSA, DOE etc.
  - Longitudinal
    - Preparation with e.g. prism pair and aperture ("longitudinal BSA"), SLM, etc. → lossy, but possible (reduces also available bandwidth)



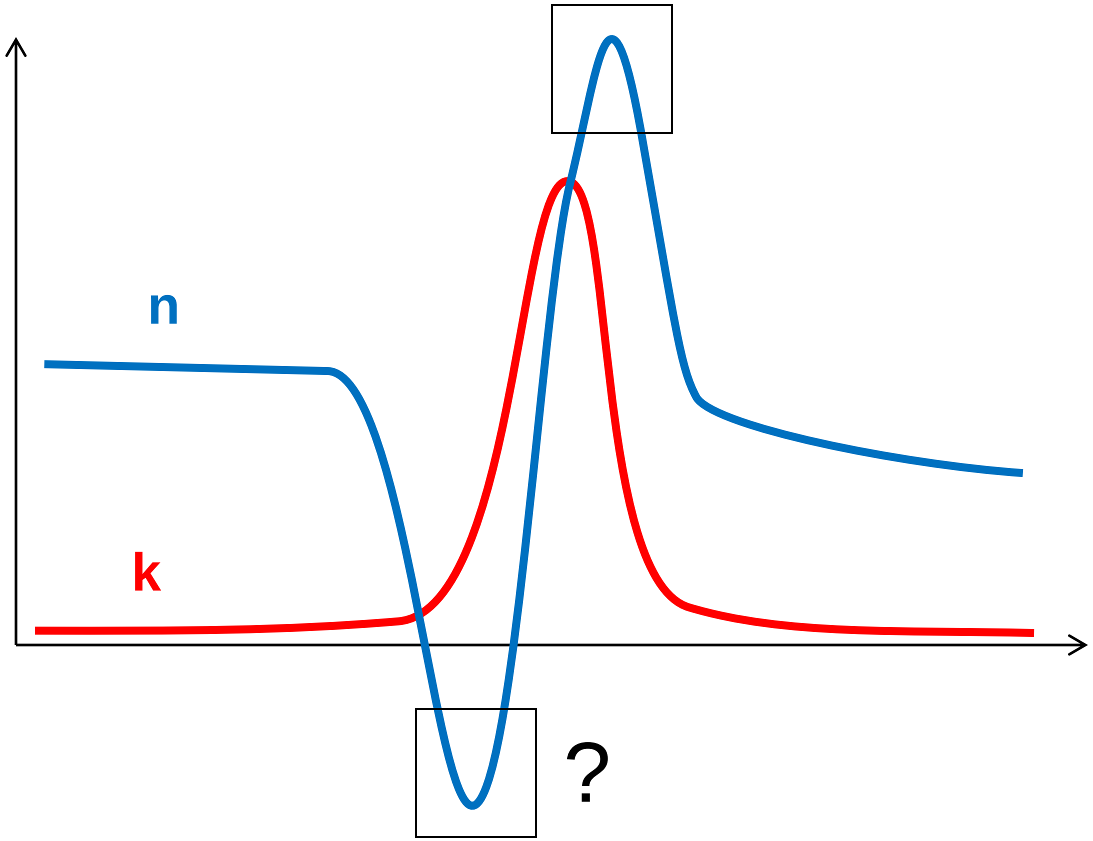
- Shaping
  - Dispersion of quartz is almost linear for the utilized range → shape is about a truncated double cone
  - Needed: strongly curved area of dispersion



Possible Solution

Kramers-Kronig: relation between absorption and dispersion

- Natural occurrence: near absorption peak
- Problems:
  - Strong absorption necessary for strong dispersion
  - Shape is Lorentzian, not elliptic, but could be a good approximation

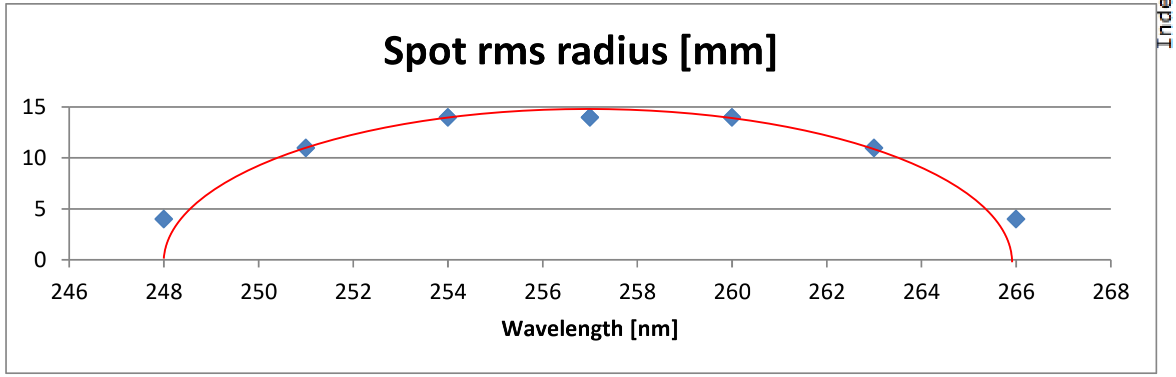


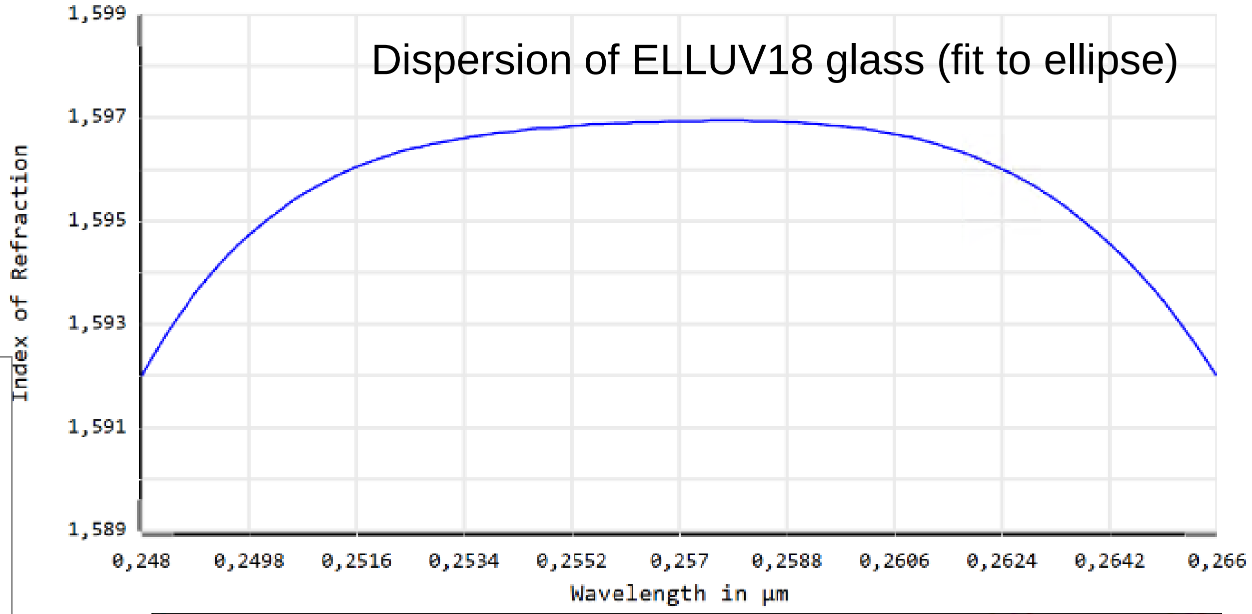
- Exotic solutions?
  - Dispersion engineering with nanomaterials
  - Metalens
  - Special grating
  - …

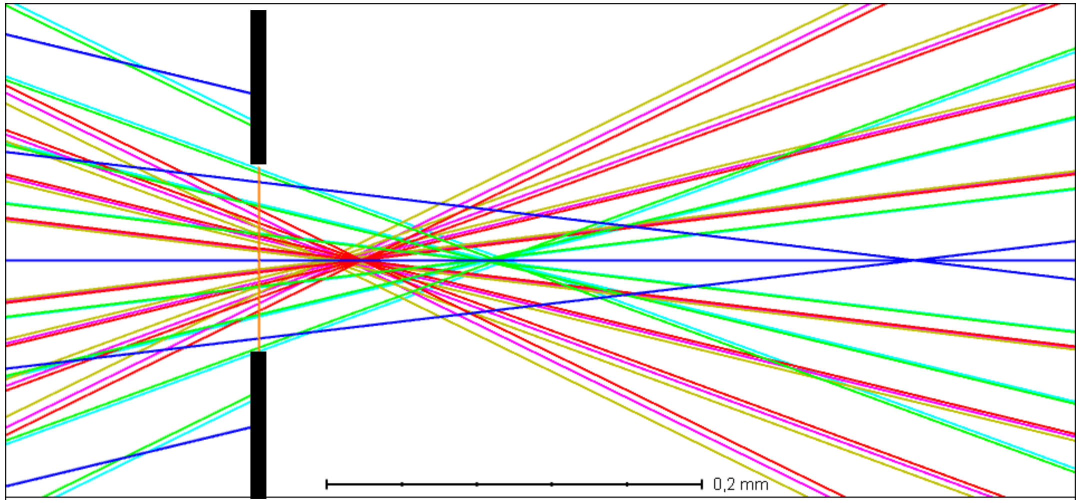
ZEMAX Simulation

Elliptical index profile in UV for wide spectrum

- Ray tracing with ideal material in UV
- Lenses re-optimized (only small difference)





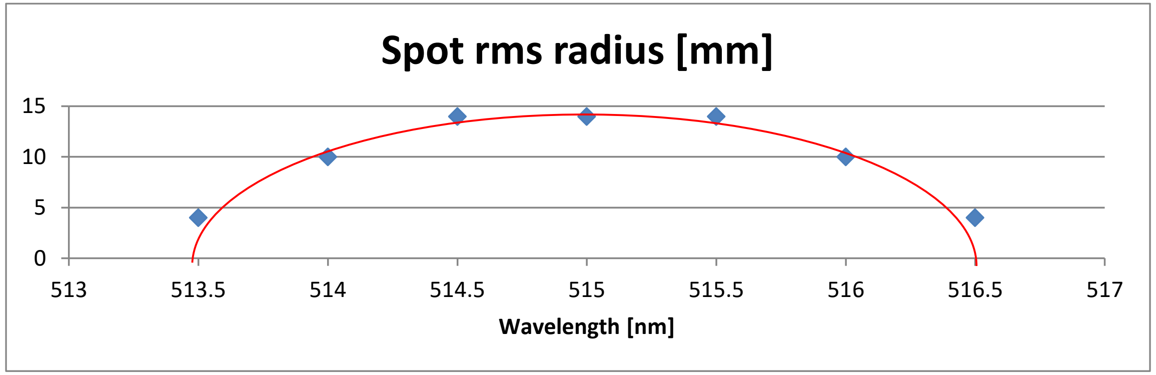


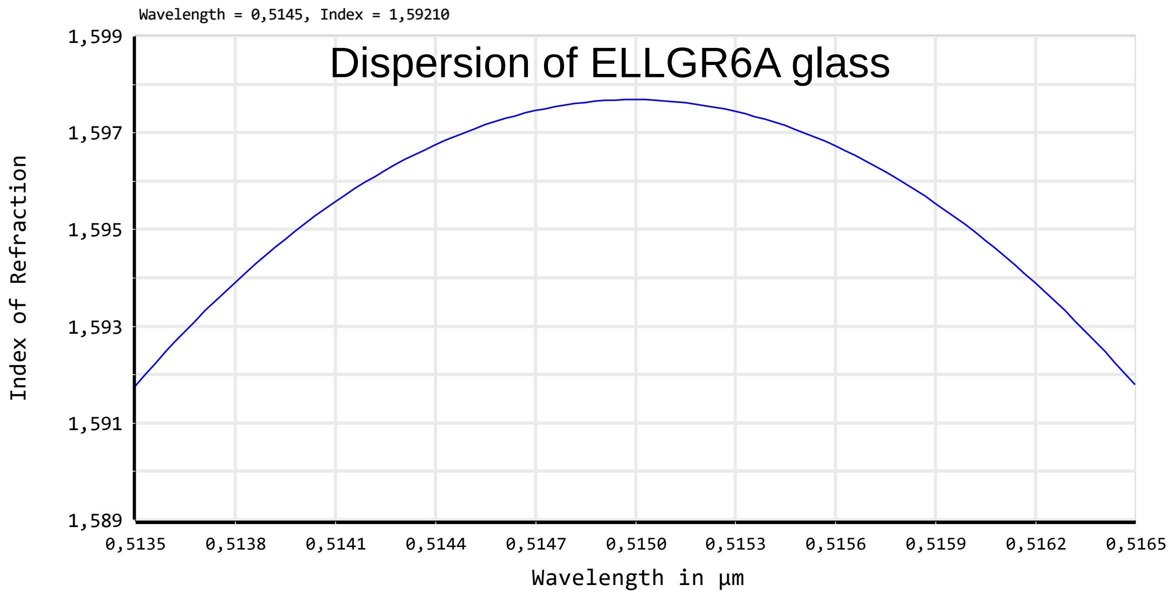
- Roughly elliptical shape can be produced
- Shape can be optimized by adjusting z-position of pinhole

ZEMAX Simulation

Elliptical index profile in green for narrow spectrum (spectrum of second harmonic Pharos)

- Ray tracing with ideal material in green using Pharos FWHM spectral width
- Lenses re-optimized (only small difference)

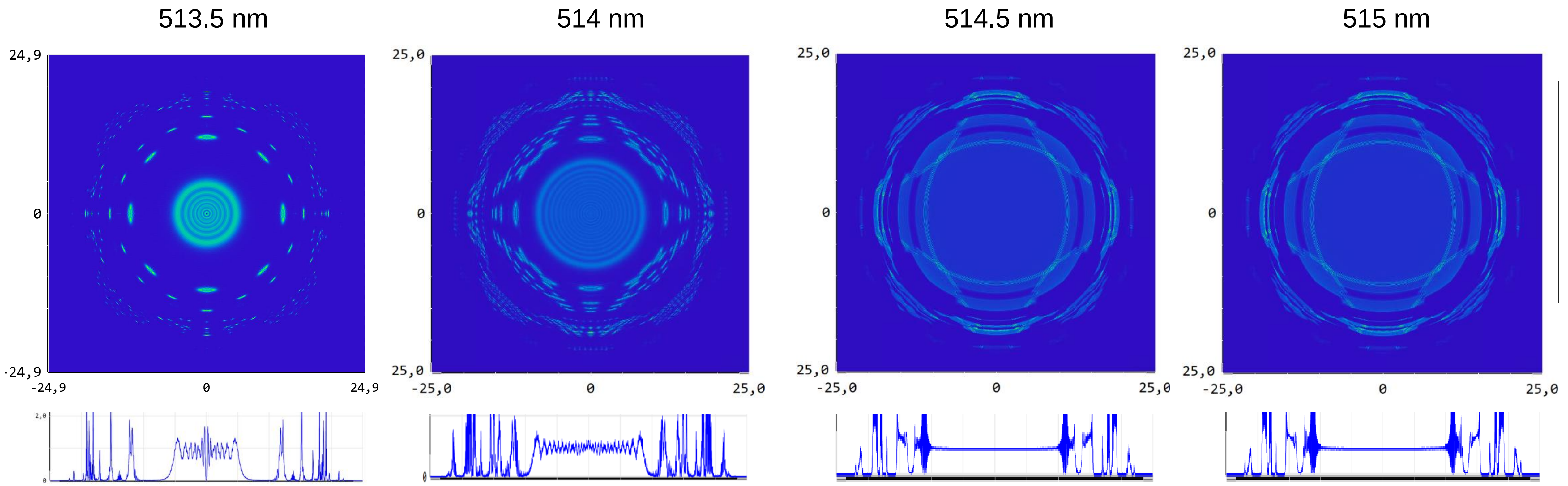




- Works reasonably well

ZEMAX POP Simulations

Influence of diffraction – small pinhole?



- Diffraction effects are visible: modulations when cutting into original flat-top (spatial low-pass filter), but shaping functionality is still visible
- Regular structures in and around beam: numerical artifacts

Summary / Outlook

Simple laser pulse shaping

- Summary
  - Novel pulse shaping method based on dispersion and spatial filtering
  - Preliminary simulations show that the method works in principle
  - Pro
    - Simple setup (beam preparation + lens + pinhole)
    - Small setup: portable, stable
  - Con
    - Need lens material with special dispersion
    - Pulse shape is fixed (as with VBG)
    - Low efficiency (absorption in lens)

- Outlook
  - Find way to produce the lens material with designed index profile and low enough absorption in the needed range
  - Only one lens is needed when using mirror and beam splitter
  - Optimize setup to reduce transverse intensity modulations: e.g. bigger pinhole (need bigger lens?)
    - Check with ASTRA simulations the influence of those modulations (how much can be tolerated?)
  - Could help:
    - adjustment of transverse (and longitudinal) intensity distribution with lens material (GRIN etc.)
    - Add spatial intensity modulations in or near pinhole plane (modulated AR coating …)