

# Laser Pulse Shaping with Lyot Filters

## Calculating the influence of the Lyot filters

- Is the MBI laser pulse modulated?
- What is the pulse length?

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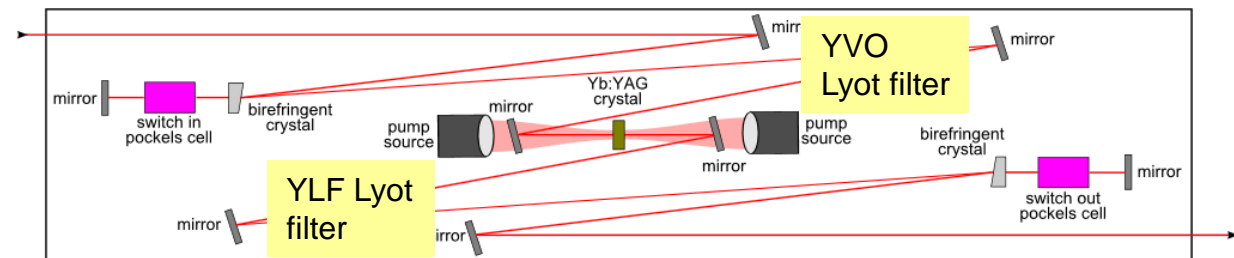
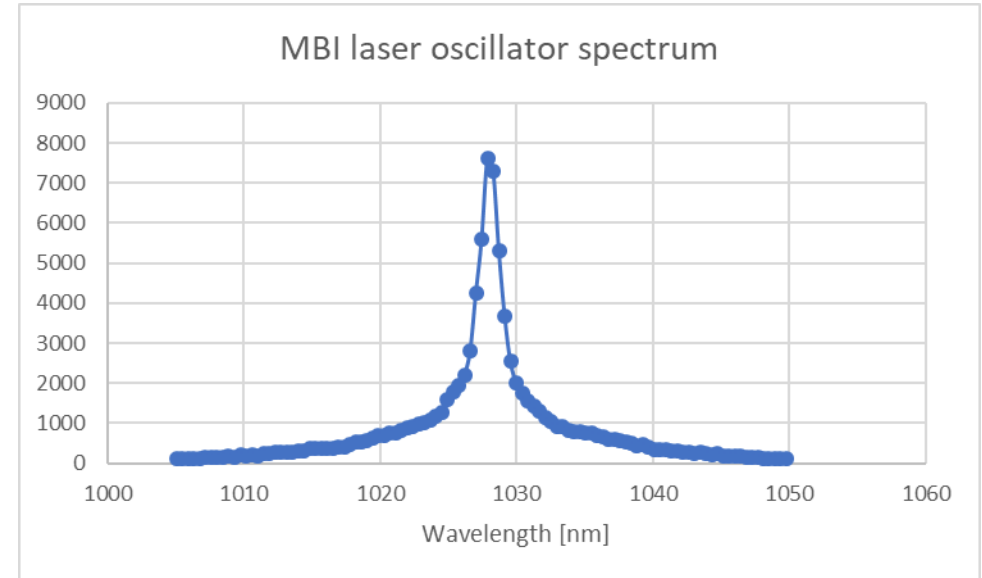
Zeuthen, 4. March 2021

# Basic principle

## Spectral filter

- MBI laser generates **~transform limited pulses** ( $\Delta t \cdot \Delta f \approx 0.44$  with Gauss shape and FWHM values)
- Oscillator:  $\Delta f = 0.6$  THz ( $\Delta\lambda = 2$  nm)  $\rightarrow \Delta t = 0.7$  ps
- How to generate longer pulses?
  - **Cut the spectral width**
  - **Lyot filter** (birefringent crystal, works as lambda plate with **wavelength dependent polarization rotation**  $\rightarrow$  bandpass filter) + **polarizer**
  - Here: built into regenerative amplifier; amplification is strongly polarization dependent

## Measurement:



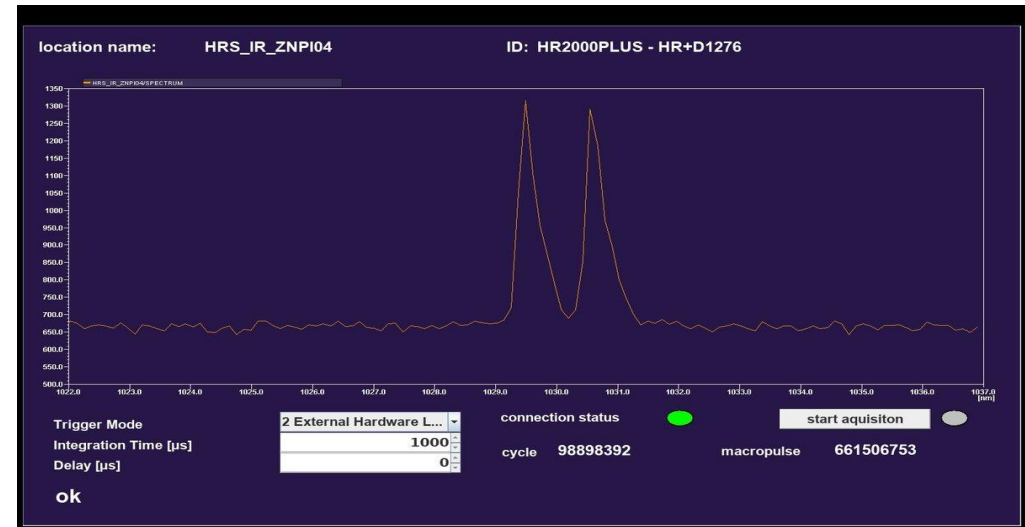
# Simple model for calculation

## Single Lyot filter, no amplification

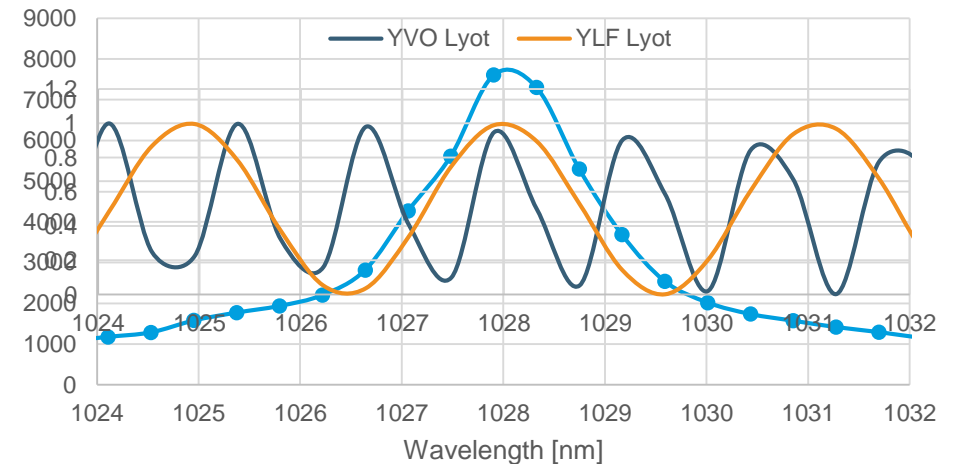
- Lyot filter 1:  $\text{YVO}_4$  (length  $d=4\text{mm}$ )
  - Refractive indices:  $n_o=1.9500$ ,  $n_e=2.1554$ ,  $\Delta n=0.2054$  at  $1.30\mu\text{m}$  (close to  $1030\text{nm}$ )
  - **Optical path length difference** for e and o polarizations:  $d \cdot \Delta n = 821.6 \mu\text{m}$
  - #wavelengths for  $1030\text{nm}$ :  $d \cdot \Delta n / \lambda = 797.67$
  - $\lambda_{797} = d \cdot \Delta n / 797 = 1030.9\text{nm}$
  - $\lambda_{798} = d \cdot \Delta n / 798 = 1029.6\text{nm}$
  - → **free spectral range: 1.3nm** (fits to measurement)

- Lyot filter 2: YLF (length  $d=16\text{mm}$ )
  - → **free spectral range: 3.1nm**
- **Two periodic filters with different periods** → Central peak is cut; no sidebands (wavelength shift due to amplification in regenerative amplifier not taken into account)

Measurement of regen output with offset YVO filter:



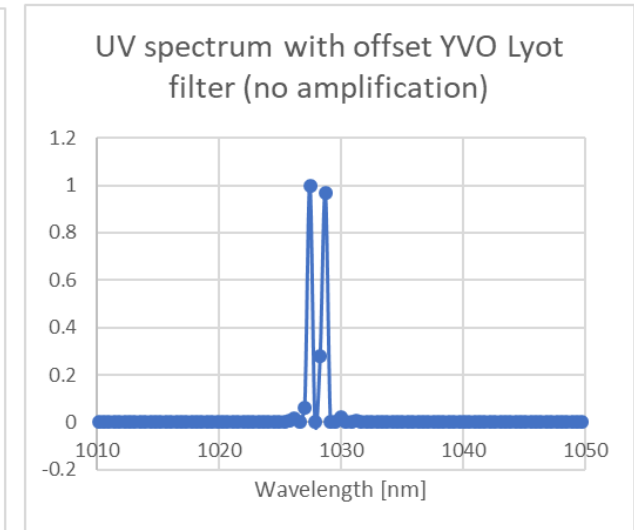
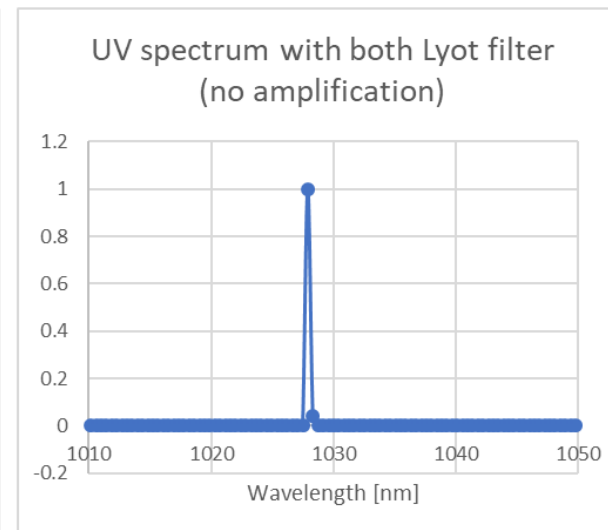
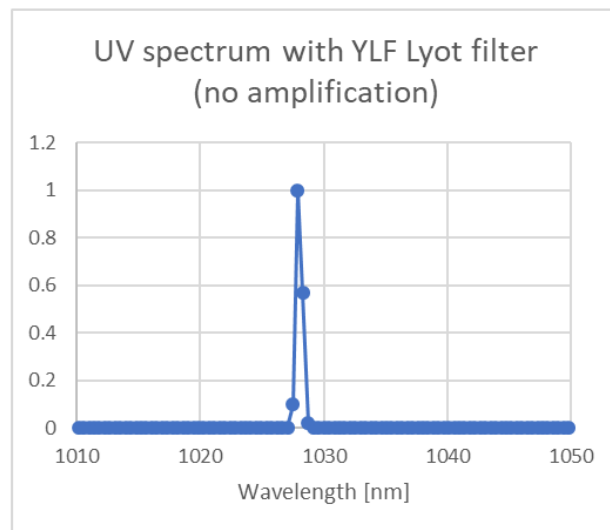
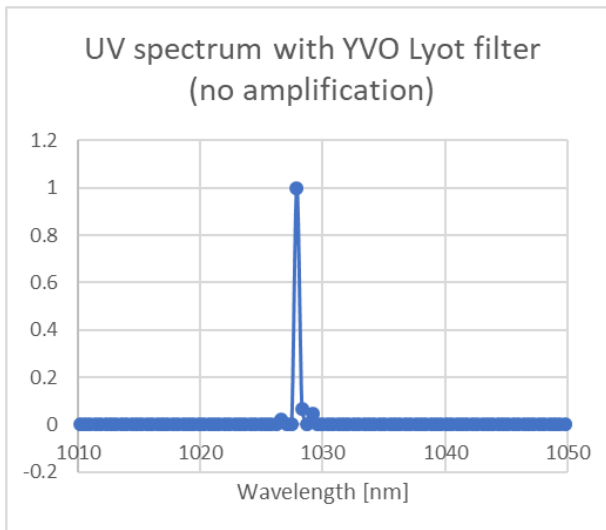
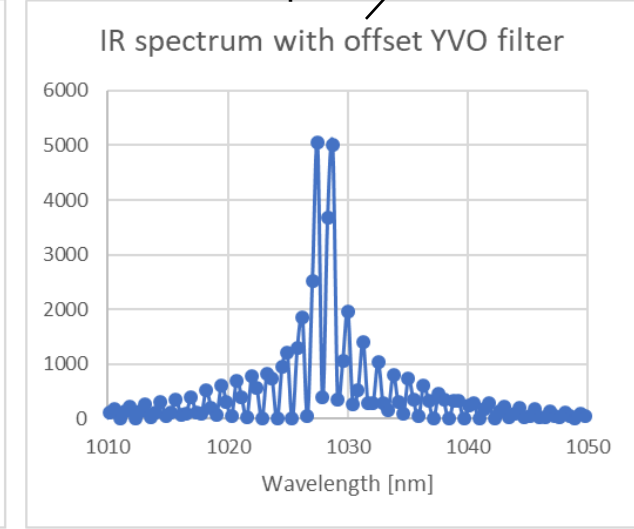
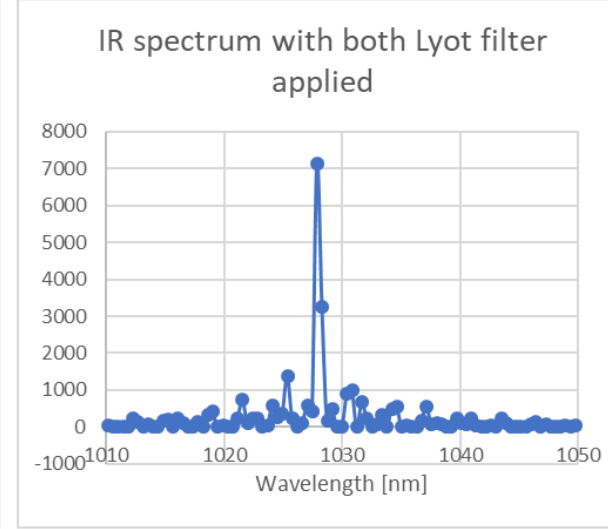
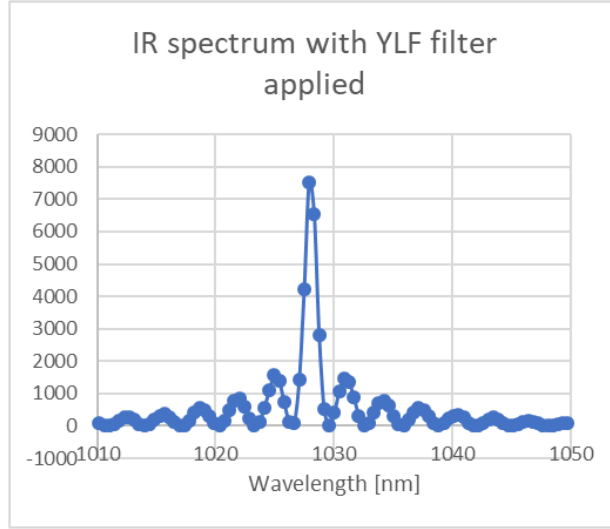
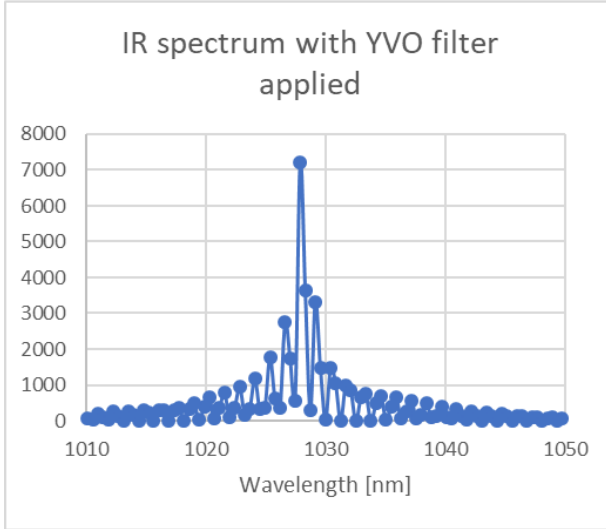
MBI laser oscillator spectrum



# Calculated spectra

Simple model: single Lyot filter and no amplification; frequency conversion: 4<sup>th</sup> power

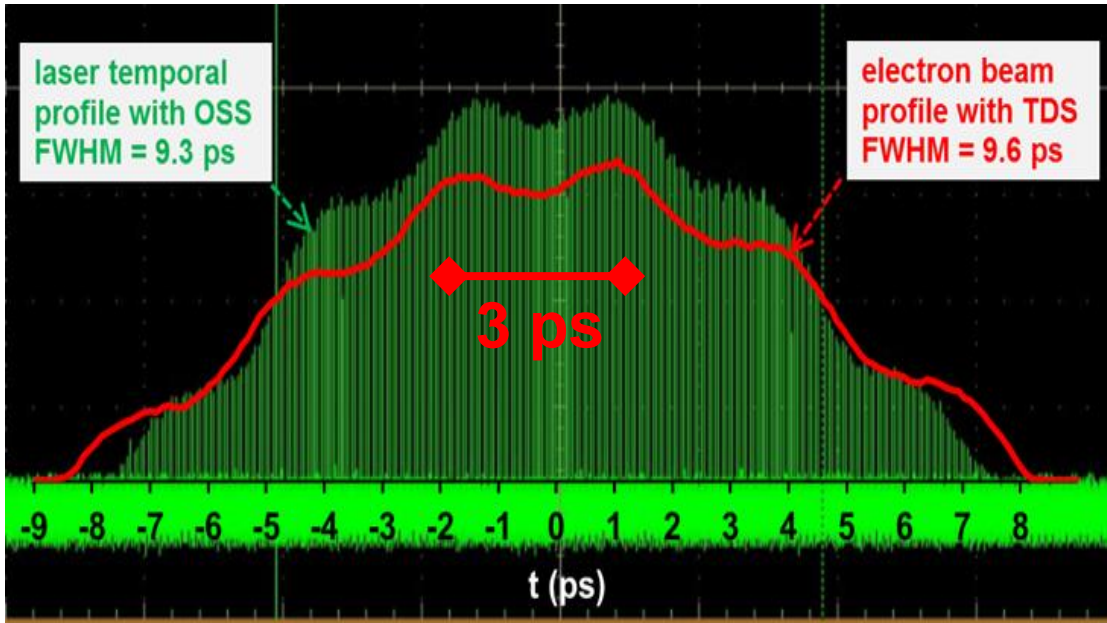
0.65 nm to have filter minimum at oscillator peak



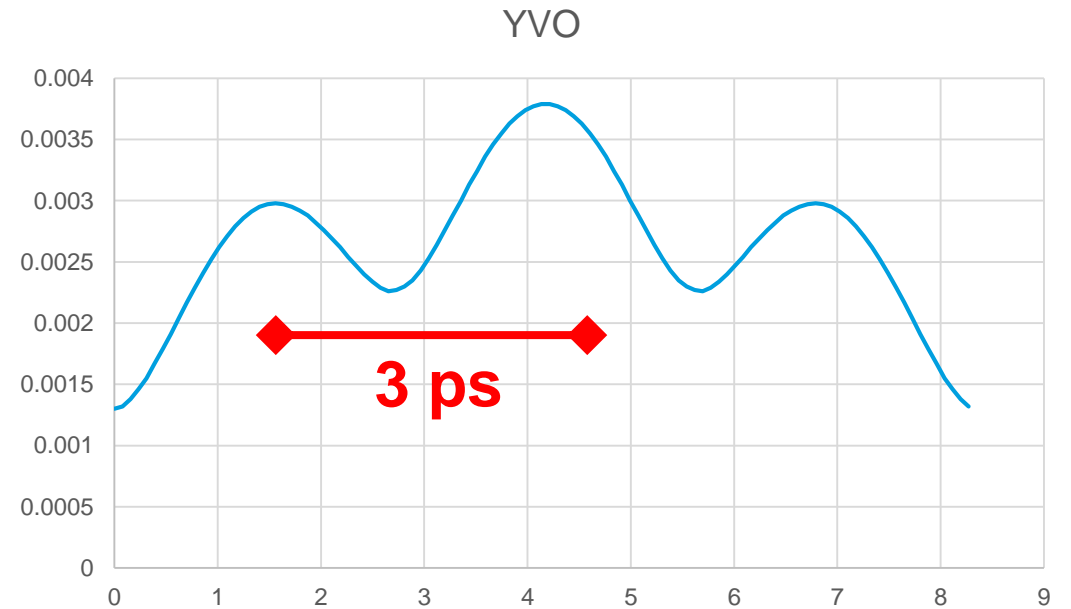
# YVO filter

## Inverse FFT of calculated spectrum

- From annual report 2018



- Calculated pulse shape

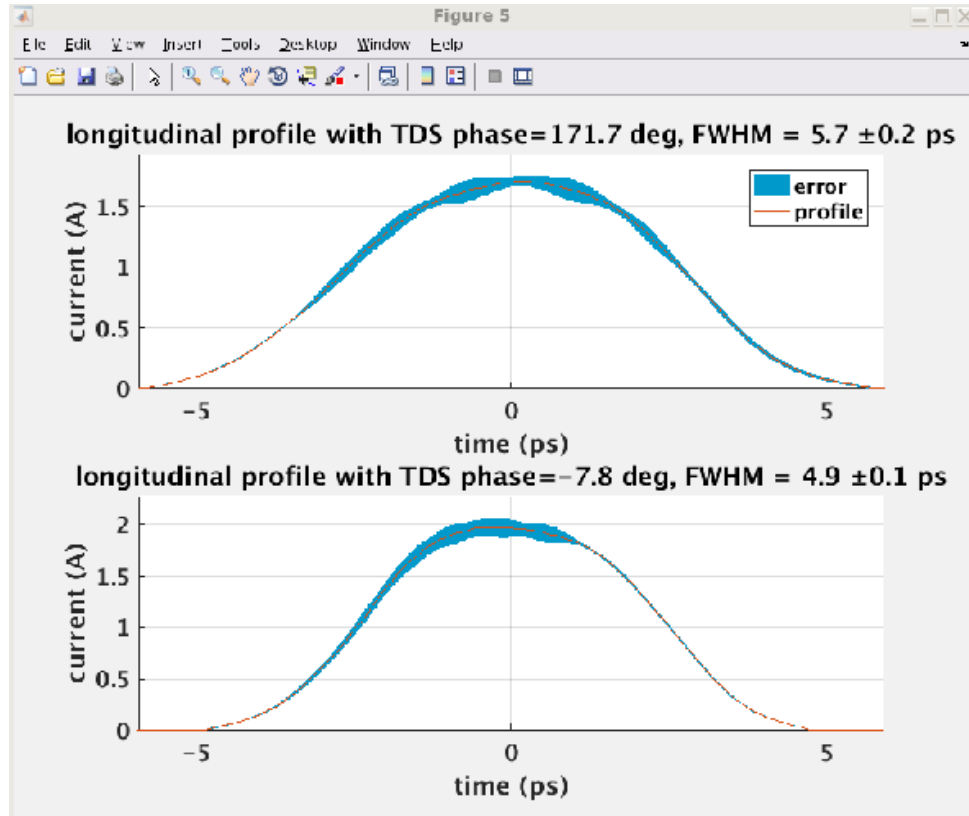


- Calculated range is restricted by resolution of measured oscillator spectrum
- Modulation period is the same as in measurements

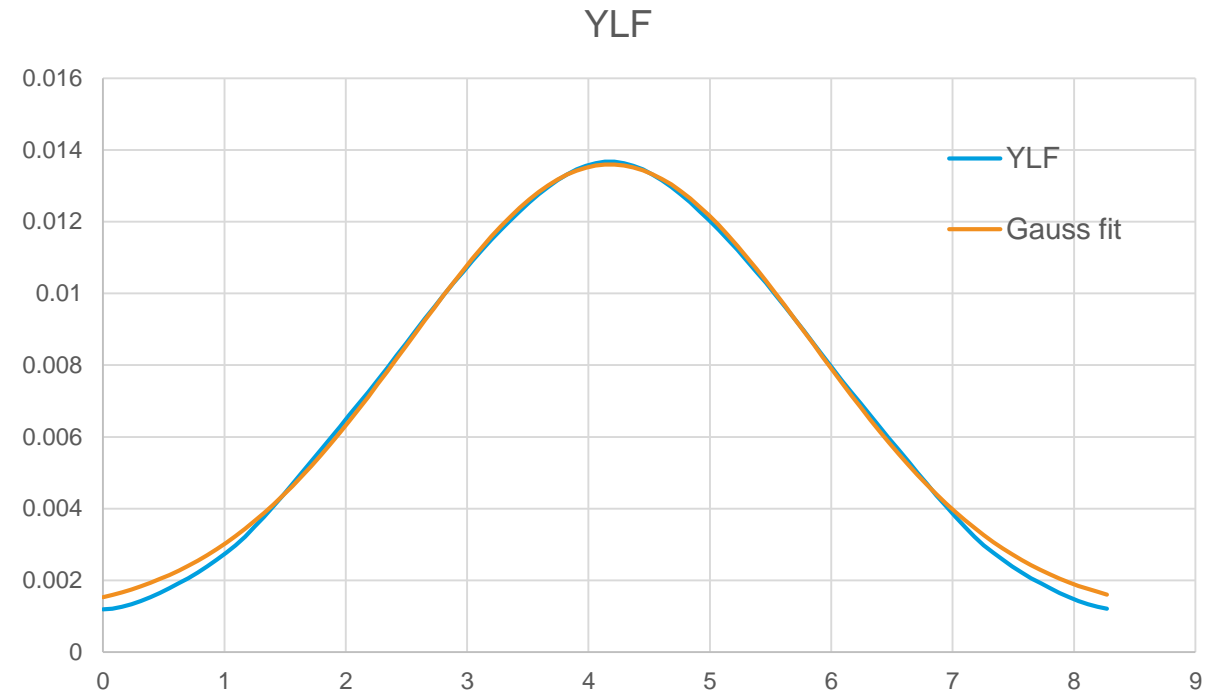
# YLF filter

## Inverse FFT of calculated spectrum

- TDS measurement 20210223A, 18:30



- Calculated pulse shape with Gauss fit

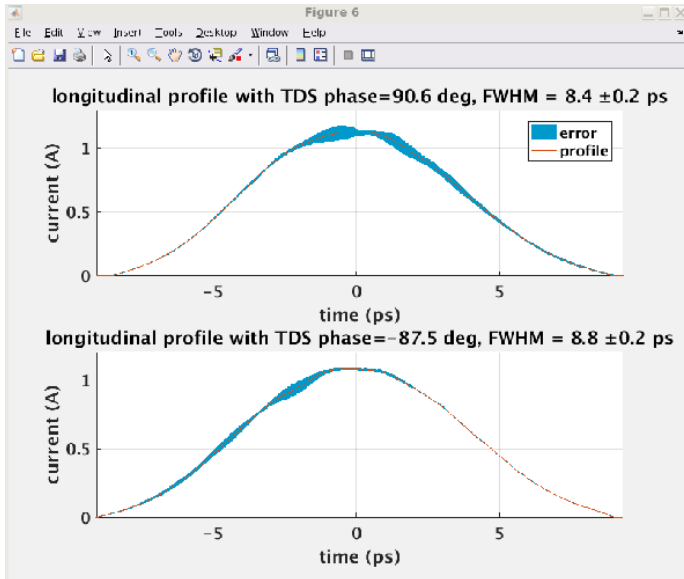


- **Gauss FWHM: 4ps**
- **BUT careful: very simple model!**

# Both Lyot filters

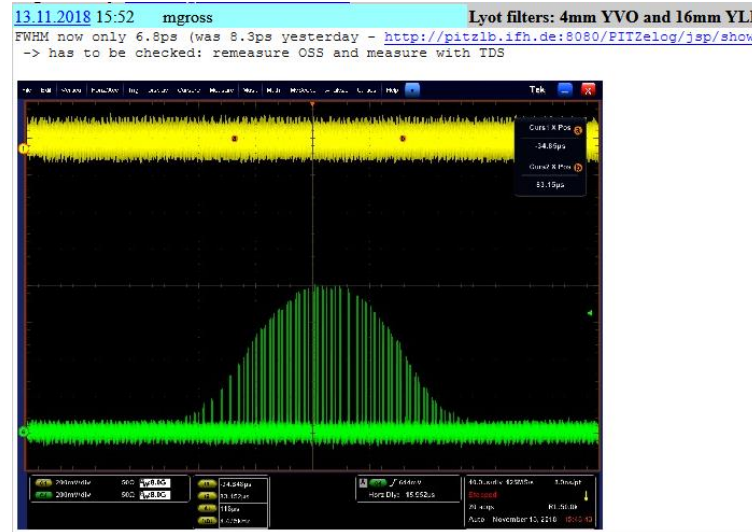
## Inverse FFT of calculated spectrum

- TDS measurement  
20210223A, 18:41



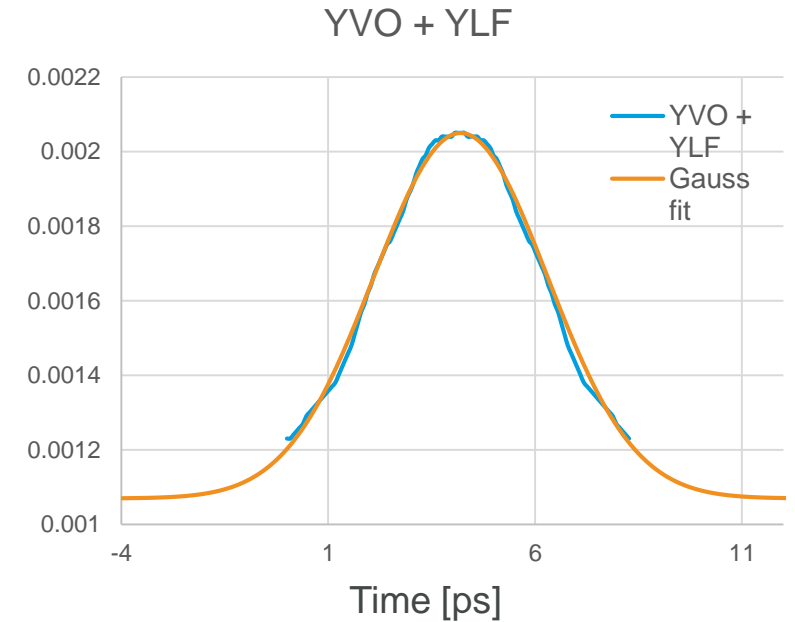
- FWHM: 8.6 ps

- OSS measurement  
20181113A, 15:52



- FWHM: 8.3 ps (6.8 ps)

- Calculated pulse shape with Gauss fit

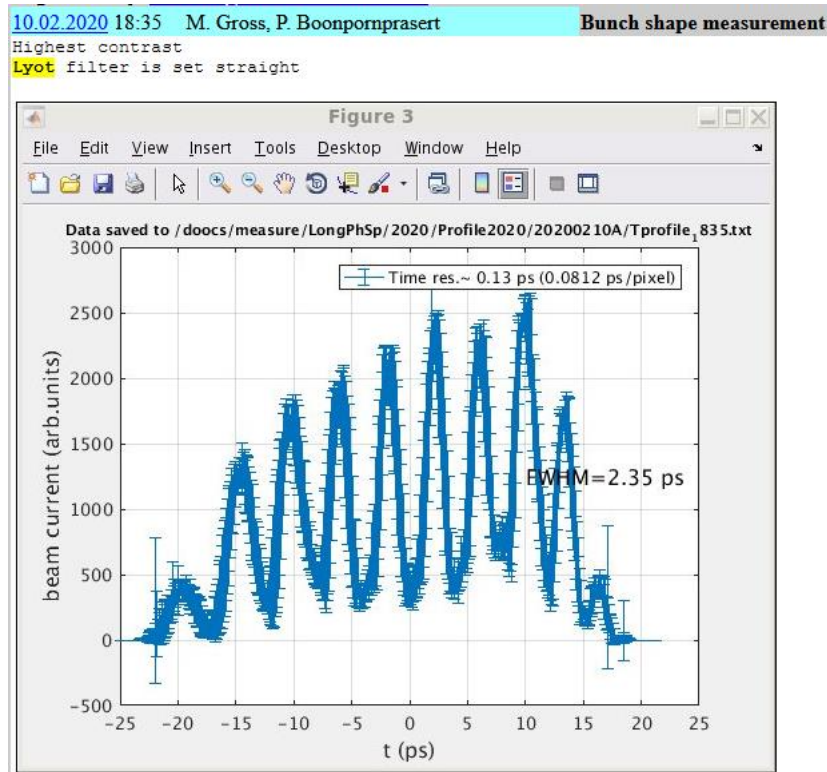


- **1) No modulations**
- **2) Gauss FWHM: 5ps (BUT careful: very simple model!)**

# Offset YVO filter

## Inverse FFT of calculated spectrum

- Booster off-crest measurement



- Calculated pulse shape

