Front End Design for Temporally and Spatially Shaped 10 & 100 J Diode-Pumped Solid-State Laser

Thomas Butcher[1], Saumyabrata Banerjee[1], Paul Mason[1], Jan Pilar[2], Martin Divoky[2], Jodie Smith[1], Jonathan Phillips[1], Klaus Ertel[1], Oleg Chekhlov[1], Stephanie Tomlinson[1], Waseem Shaikh[1], Justin Greenhalgh[1], Ian Musgrave[1], Cristina Hernandez-Gomez[1], John Collier[1]

[1] Central Laser Facility, STFC Rutherford Appleton Laboratory, Chilton, Didcot, UK
[2] HiLASE Project, Na Slovance 2, 18221 Prague, Czech Republic

DiPOLE

Science & Technology Facilities Council
Central Laser Facility

Outline

- Motivation
- 10 J DiPOLE Front End Overview
  - Layout
  - Spatial shaping
  - Temporal shaping
    - 10 J Amplifier
    - Front End only
- 100 J DiPOLE Front End Overview
  - Requirements
  - Layout
  - Spatial shaping
  - Temporal shaping

Motivation

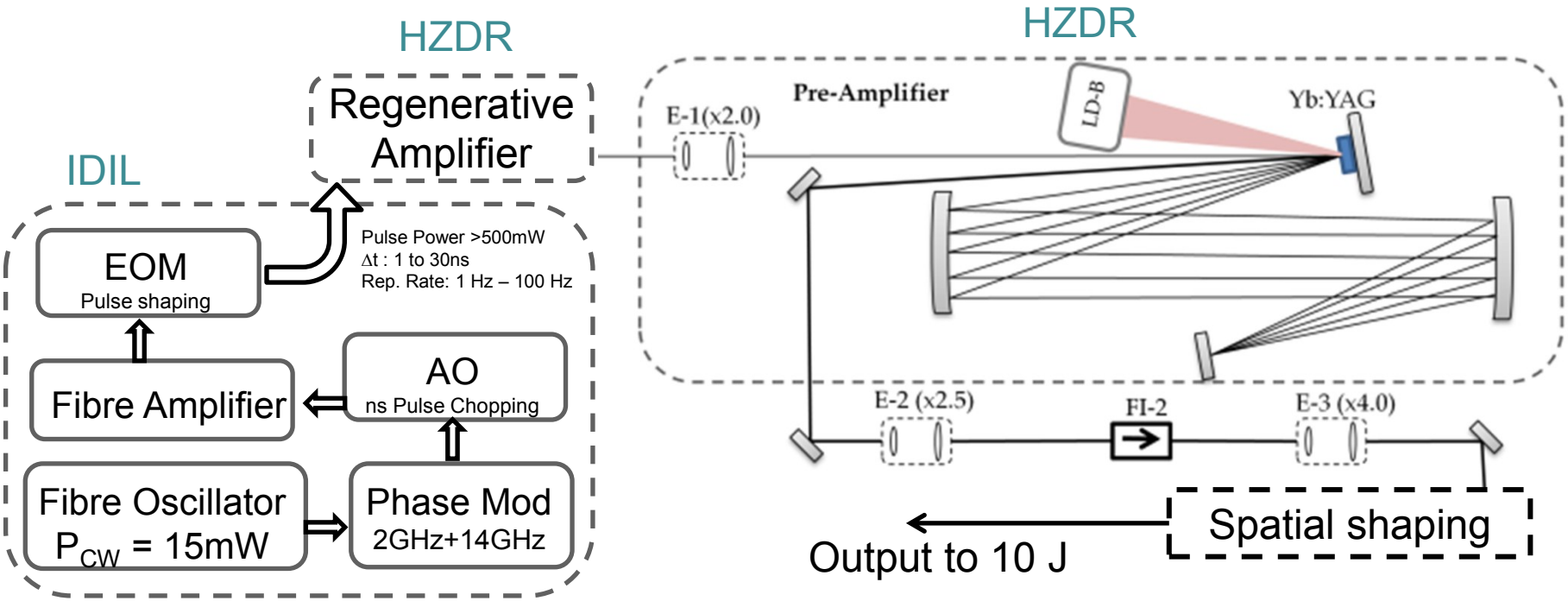
- Every laser starts somewhere

- Spatial shaping:
  - Uniform gain across beam
  - Don’t want to saturate peak and whilst not having sufficient gain at wings
  - Target considerations
- Temporal shaping:
  - Pre-compensate for gain at leading edge of pulse
  - Target considerations
    - Uniform energy transfer
    - Compression
    - Step change in intensity

10 J Front End - Overview

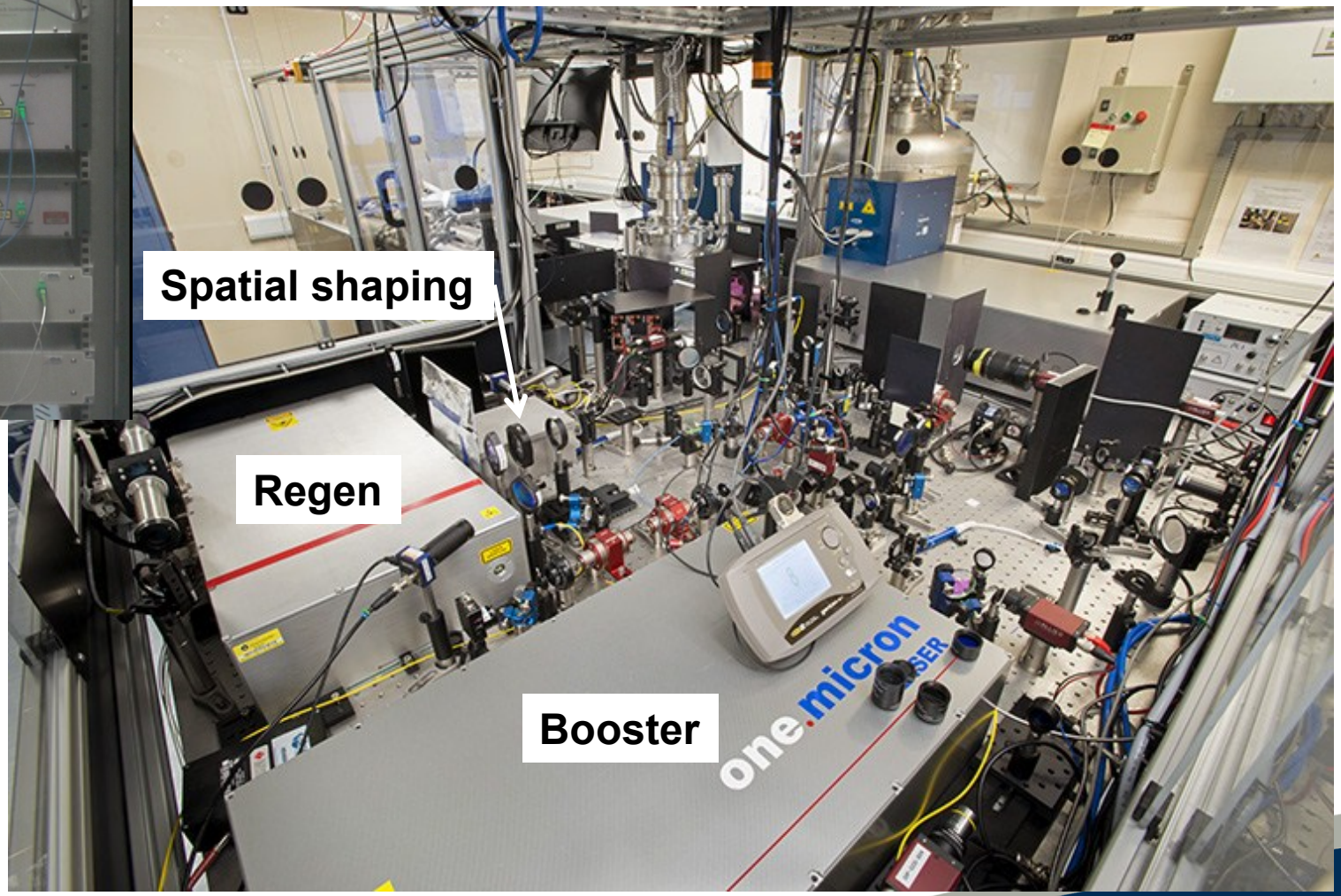
1. Fibre seed source – IDIL
   - 0.5 – 7.5 nJ, 10 kHz
   - Includes temporal shaping
2. Regenerative amplifier – HZDR
   - 1 mJ, 10 Hz
3. Multi-pass booster amplifier – HZDR
   - 100 mJ, 10 Hz
4. Spatial Shaping
   - 20 mJ, 10 Hz

10 J Front End Layout



10 J Front End Layout

Fibre Seed

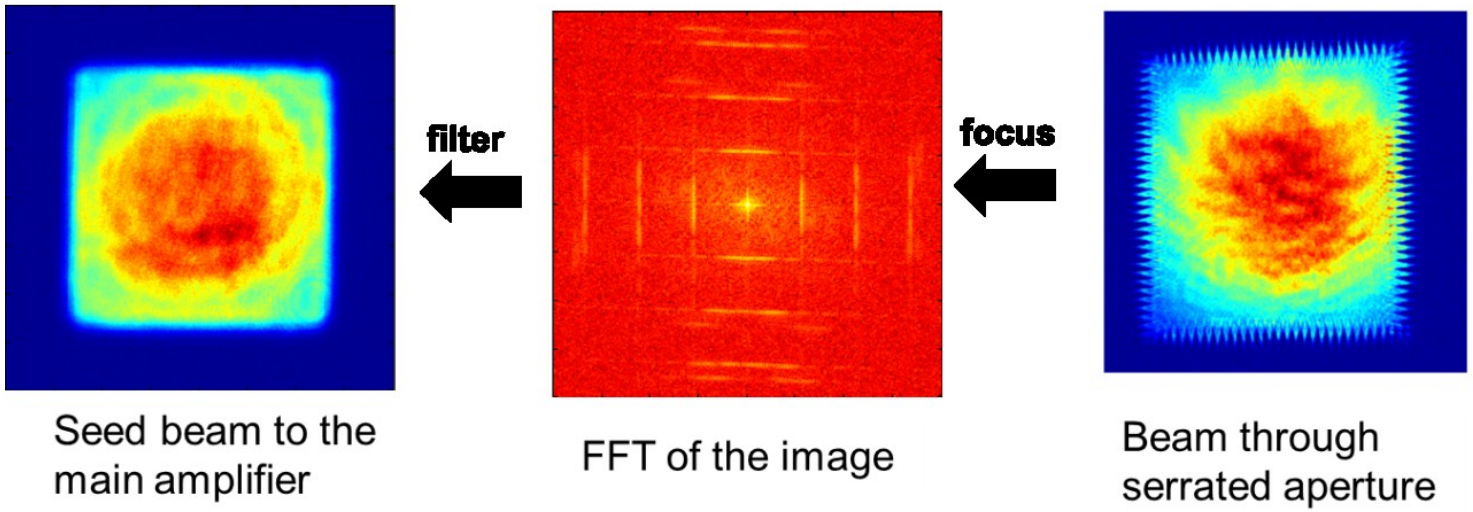


DiPOLE

Science & Technology Facilities Council
Central Laser Facility

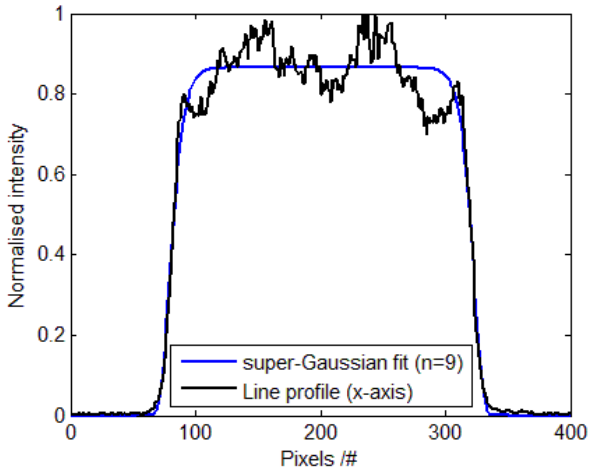
10 J Front End - Spatial shaping

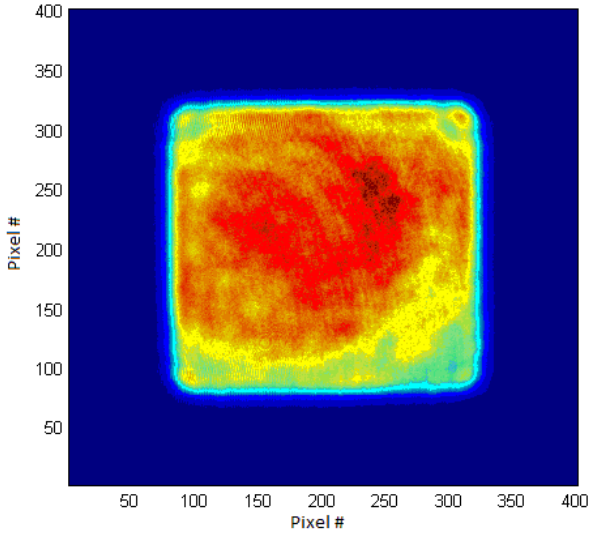
- Utilise a serrated aperture followed by spatial filtering of the beam
- To produce a flat-top profile, need to expand the Gaussian input beam
- This results in high losses ~ 60 – 70 %

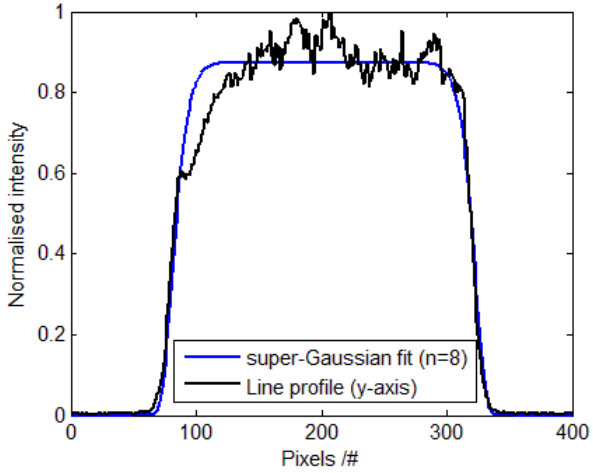


10 J Front End - Spatial shaping

- Super-Gaussian fit shows n ~ 8 or 9
- Plateau is not smooth
- Better way to do this?



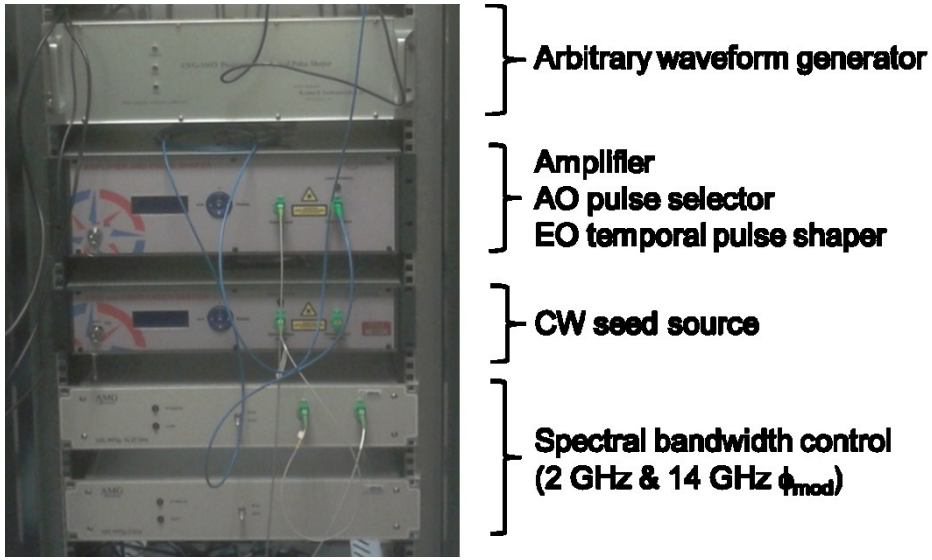




Recent data taken from DiPOLE Front End

10 J Front End - Temporal shaping

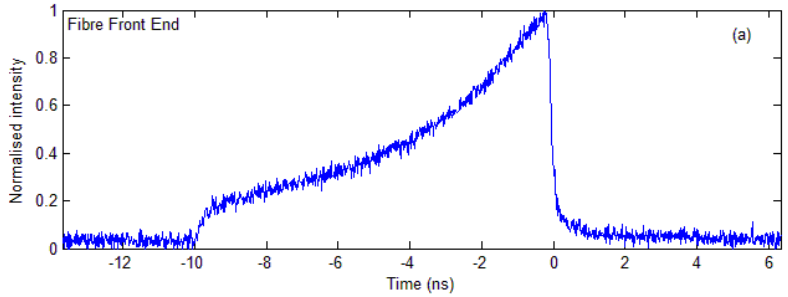
- Performed by *IDIL* Fibre Seed source

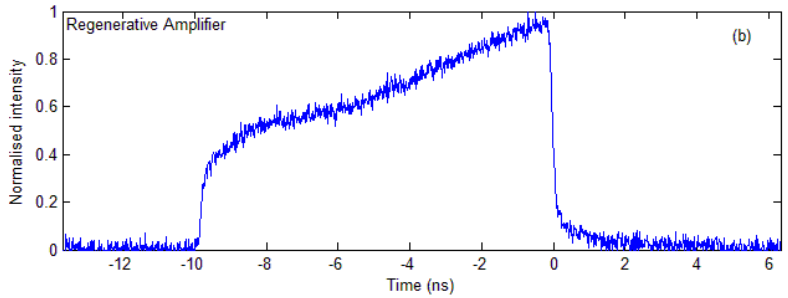


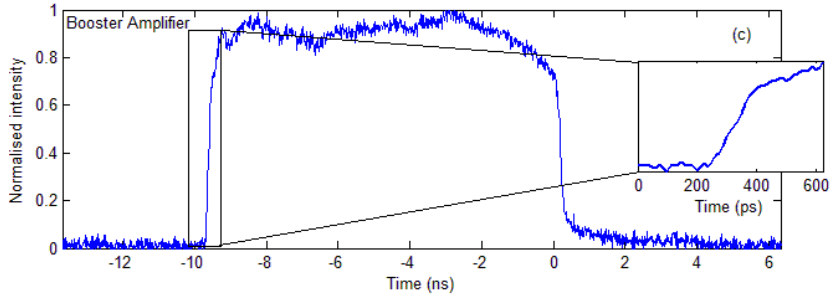
- AWG produces well defined voltage pulse shape
- Mach-Zehnder EOM selects pulse shape based on AWG input

10 J Front End - Temporal shaping

- 20 mJ output energy
- 2 - 10 ns pulse duration
- 150 ps rise time
- No active control over pulse shape
  - pre-loaded waveforms
- 125 ps resolution on AWG
  - longer in practice







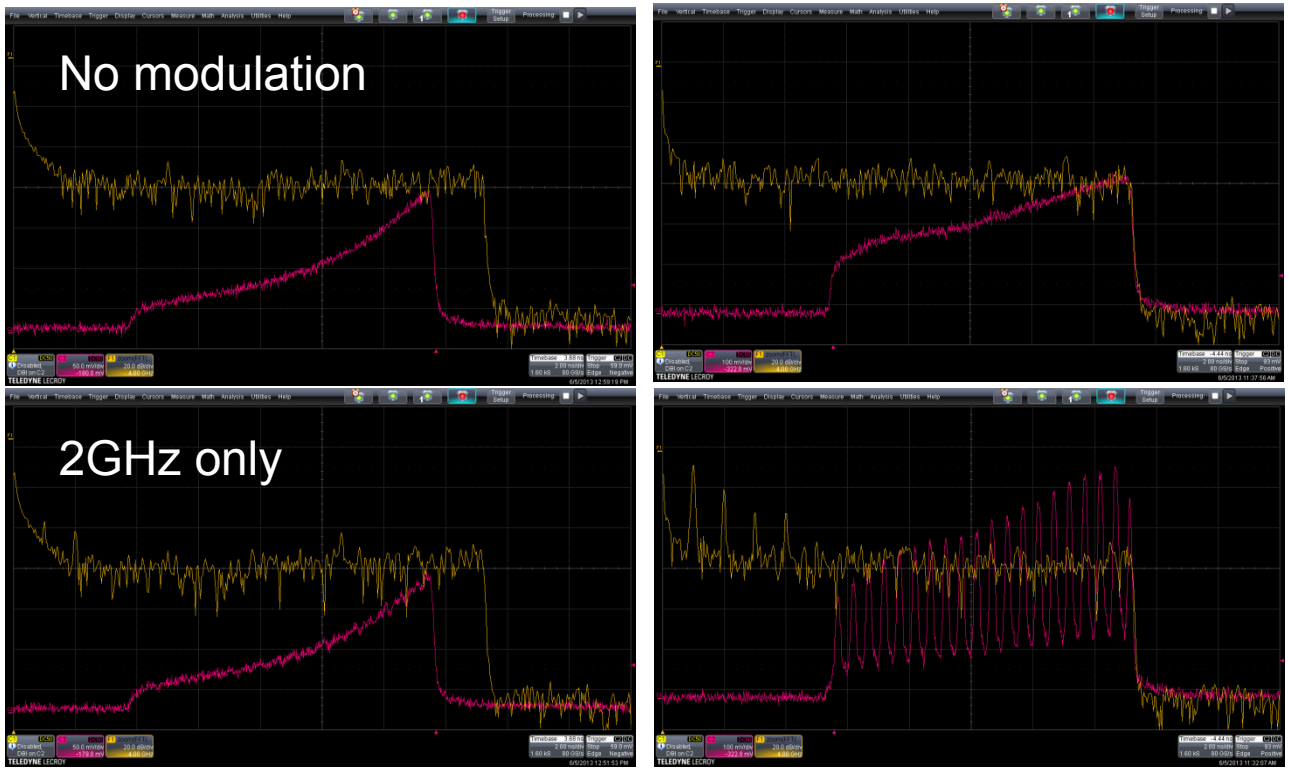
DiPOLE

Science & Technology Facilities Council
Central Laser Facility

10 J Front End – FM-AM

Fibre output

Regen output



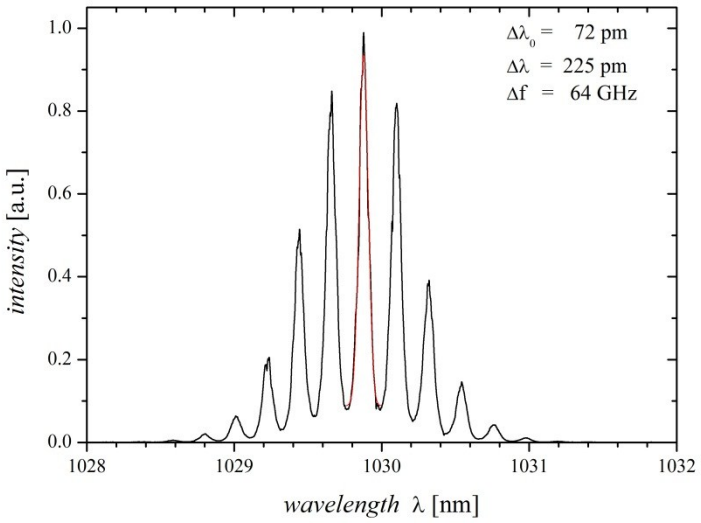
Smooth temporal profile

Significant amplitude modulation

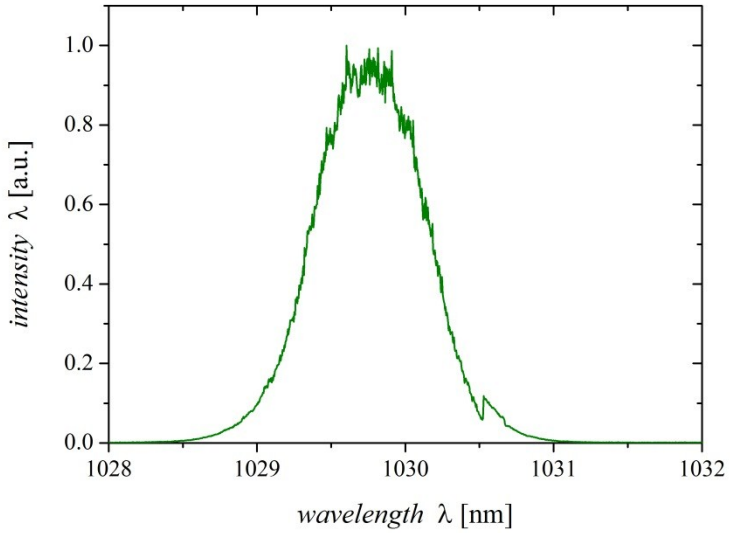
10 J Front End – FM-AM

- HZDR regenerative amplifier currently uses a plane-parallel thin disk
- Replace this with wedged gain medium to remove / reduce FM-AM

Plane-parallel thin disk

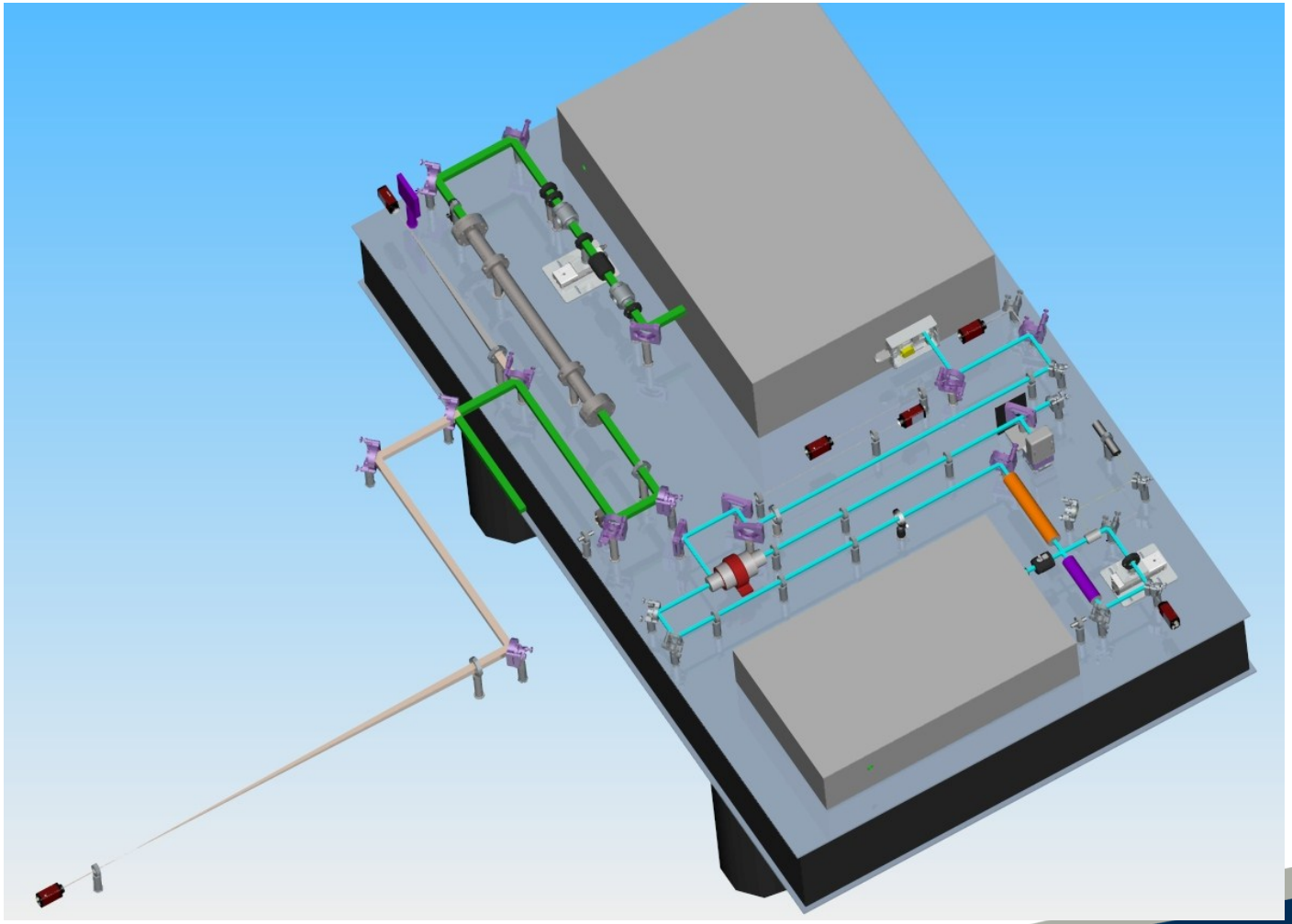


Wedged thin disk



Results courtesy of Mathias Siebold, HZDR

100 J Front End Overview



100 J Front End - Requirements

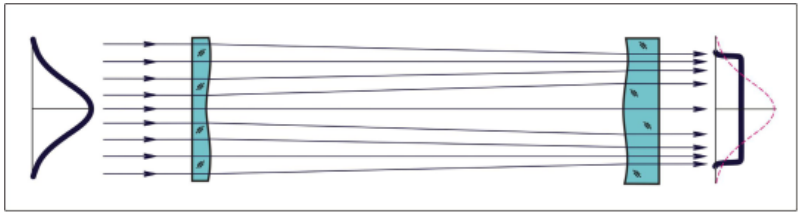
- Variable centre wavelength: 1029.5 ± 0.3 nm (air)
- Variable pulse length: 2 ns – 10 ns
- Arbitrary pulse shaping
  - Flat top
  - Ramp
  - Step function
- Spatial shaping – square super-Gaussian
  - Smooth flat-top
  - Ability to mask damage spots (would like)
- Shaped alignment laser for 10 J amplifier
- 10 Hz repetition rate
- Output energy: 50 – 150 mJ @ 2-10 ns
- Fully automated control

100 J Front End - Differences

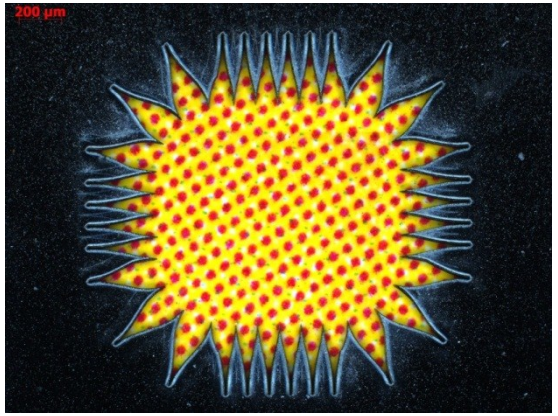
- Improved beam quality
- Active control of beam shape
- Active control of temporal shape
- Improved long term stability
- Increased pulse energy
- Automated control of system

100 J Front End – Spatial shaping

Passive Shaping system

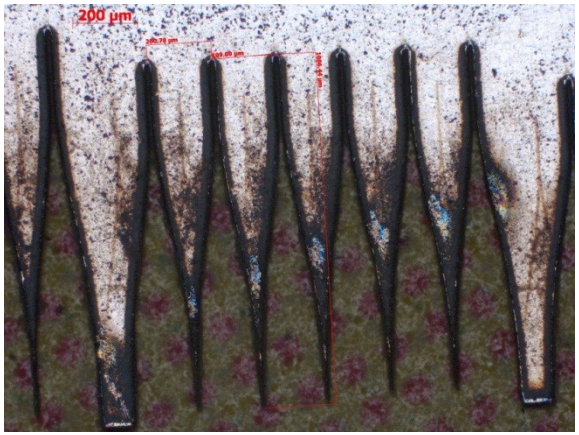


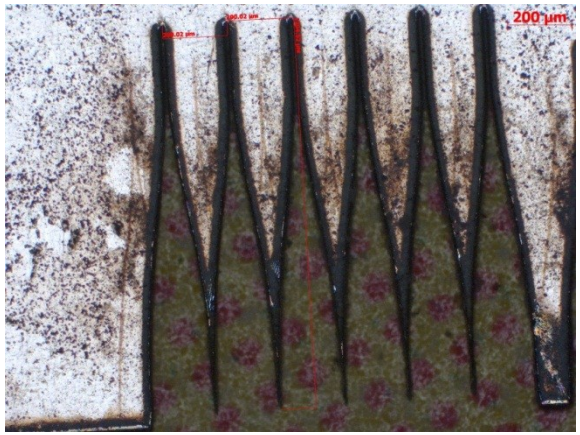
Refractive beam shaping



Serrated aperture

Ratio 5:1
1000:200 um





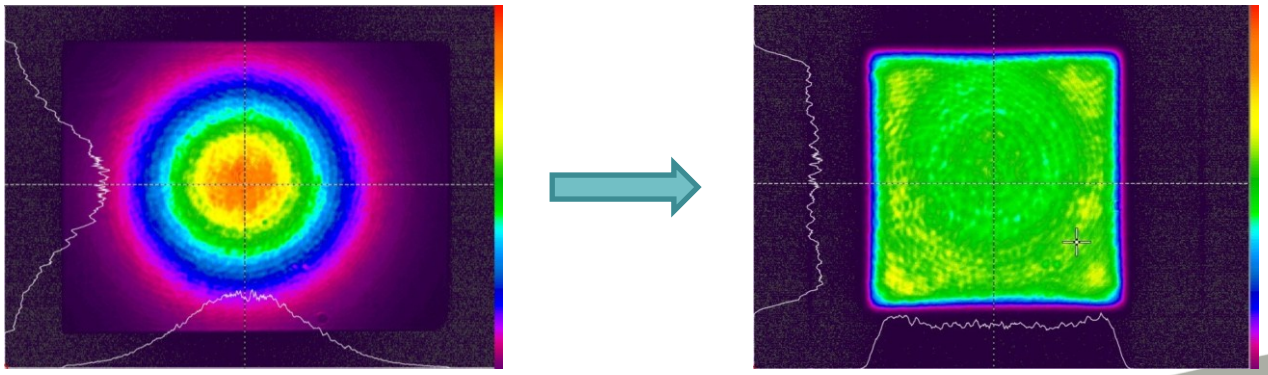
Ratio 6:1
1200:200 um

100 J Front End – Spatial shaping

Active Shaping system

- Spatial light modulation based on Liquid Crystal phase change
- Allows active control of beam profile and masking damage

Beam shape | Required shape | Transfer function



Thanks to Martin Divoky

100 J Front End – Temporal shaping

- Similar to current DiPOLE fibre front end
- IDIL supplying rack mounted system
- In-house control software to individually address ‘pixels’
- Adjust the pulse shape ‘on the fly’
- Closed loop control

100 J Front End – Diagnostics

- CW alignment laser injected immediately following Pre-amplifier 1
- 3 x Beam steering systems
  - Automated CW alignment to main beam
  - Inputs to Pre-amplifier 2 and 10 J Amplifier
- 7 x cameras; 2 x Farfield, 5 x Nearfield
- 4 x 10 GHz photodiodes
- 2 x spectrometers
- 4 x energy meters

Thank You!