PITZ Laser Systems

General introduction: systems, layouts

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PITZ Laser Systems
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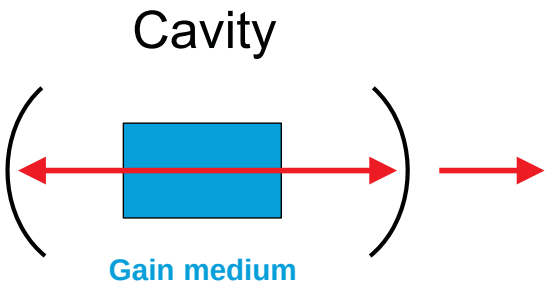
HELMHOLTZ ASSOCIATION

DESY

What is a Laser?

Light
Amplification by
Stimulated
Emission of
Radiation

> General setup



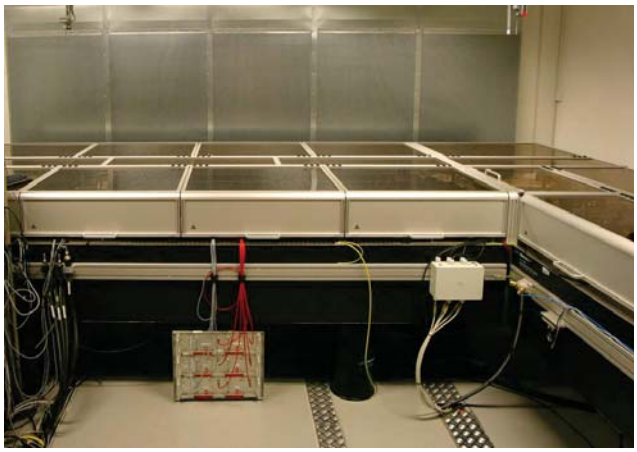
DESY

1) ArF Laser - Basics

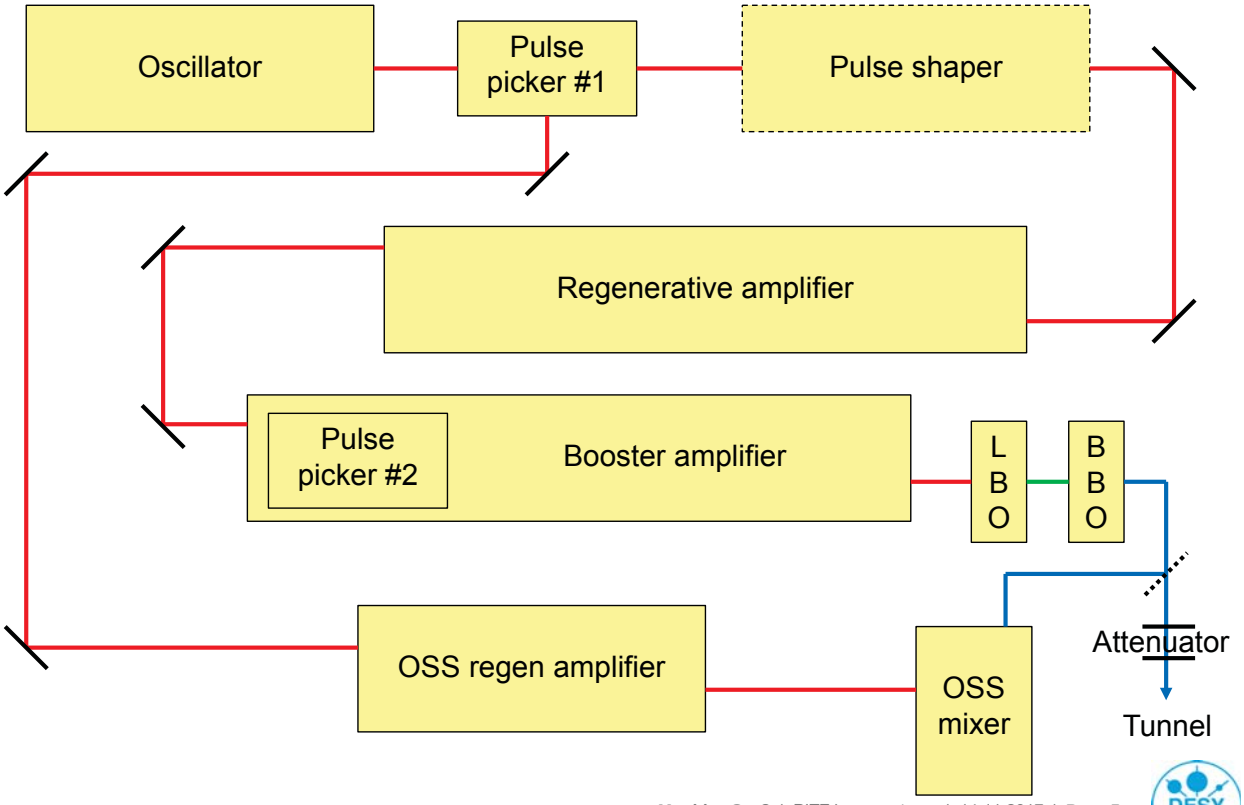
- Basic principle
  - Excimer (excited dimer ArF*)
  - Discharge excitation
- Location
  - 1L18
- Basic parameters
  - Wavelength: 193 nm
  - Pulse length: ≈25 ns
  - Pulse energy: <400 mJ
  - Repetition rate: 10 Hz
- Manufacturer
  - Coherent (commercial product)
- Application
  - Ionization laser for lithium plasma cell

2) MBI Laser - Basics

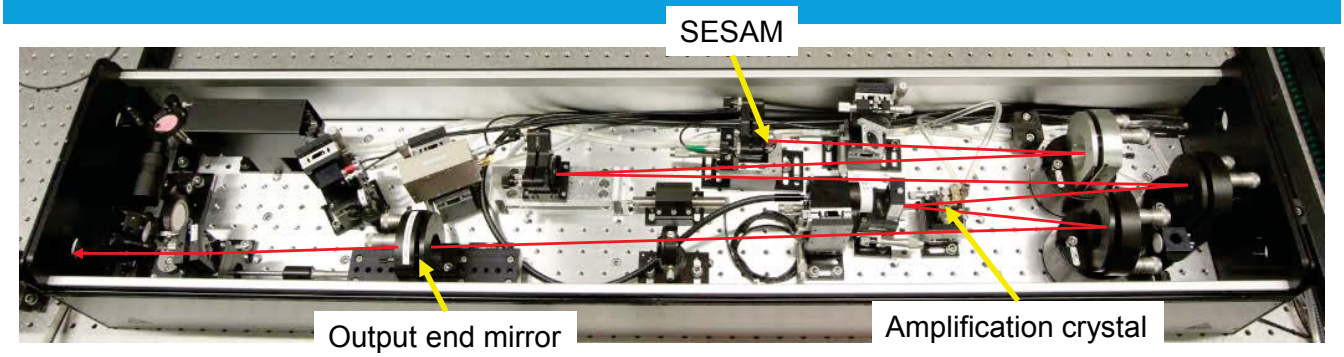
- Basic principle
  - Solid state: Yb:KGW oscillator, Yb:YAG amplifier, 2x frequency doubling
- Location
  - 1K05 (“laser hut”)
- Basic parameters
  - Wavelengths: 1030/515/257 nm
  - Pulse length: ≈2…25 ps
  - Pulse energy: <5 µJ in the UV
  - Repetition rate: 10 Hz (1 MHz in burst)
- Manufacturer
  - Max Born Institut, Berlin (custom product)
- Application
  - Photocathode laser



2) MBI Laser - Setup



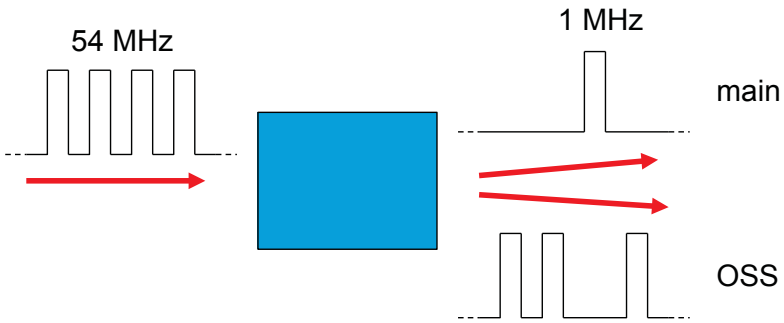
2) MBI Laser - Oscillator

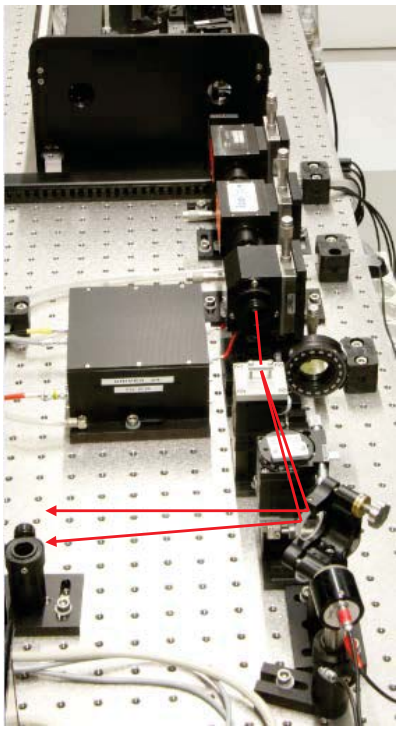


- Short (≈1 ps) pulse generation with passive mode locking with SESAM (**SE**miconductor **S**aturable **A**bsorber **M**irror)
- Repetition frequency f_{Osc} (54 MHz) is given by resonator length: $f_{Osc}=c/2L$ with L=2.78 m
- Pulse length inverse proportional to gain bandwidth: $\tau_p \approx 1/\Delta\nu$
- Synchronized to PITZ master oscillator at 54 MHz and 1.3 GHz
- Output power: 100 mW (pulse energy: 2 nJ)
- Yb:KGW amplifier crystal → center wavelength 1032nm

2) MBI Laser – Pulse Picker #1

- Pockels cell
  - Pockels effect: voltage dependent rotation of polarization
  - Rotate polarization of every 54th pulse by 90°
- Birefringent wedge
  - Spatial separation of pulse trains

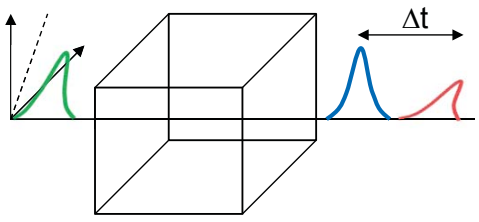


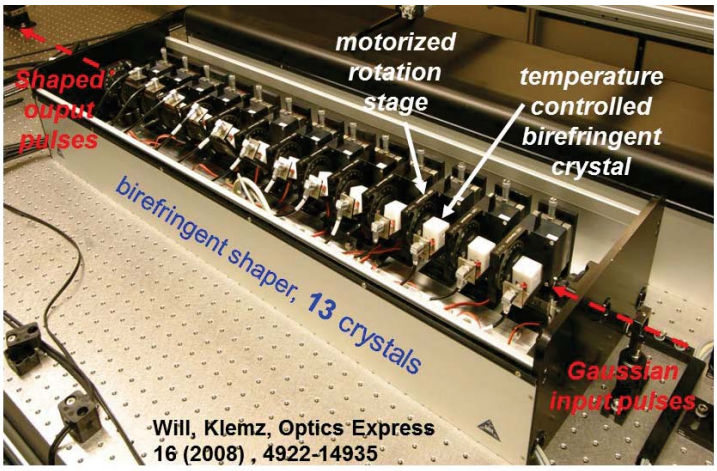


For bursts with length ≈1.5 ms

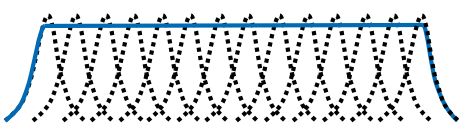
2) MBI Laser – Pulse Shaper

- Contains 13 birefringent YVO_4 crystals. Pulses are split according to polarization. Delay is given by crystal thickness; relative amplitude can be varied freely by adjusting relative angle between crystals
  - Basic process

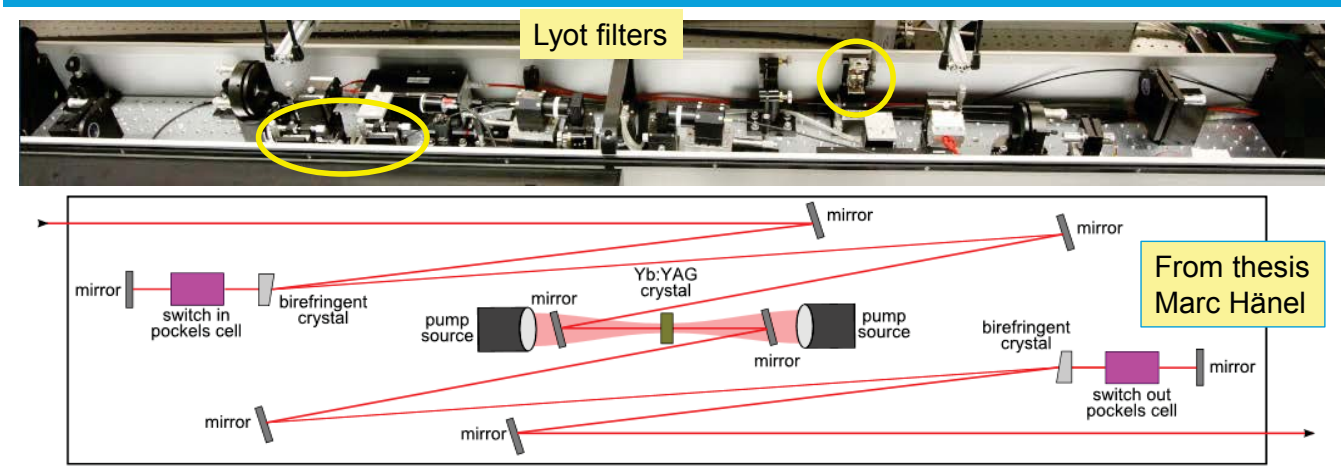




  - Free pulse shaping

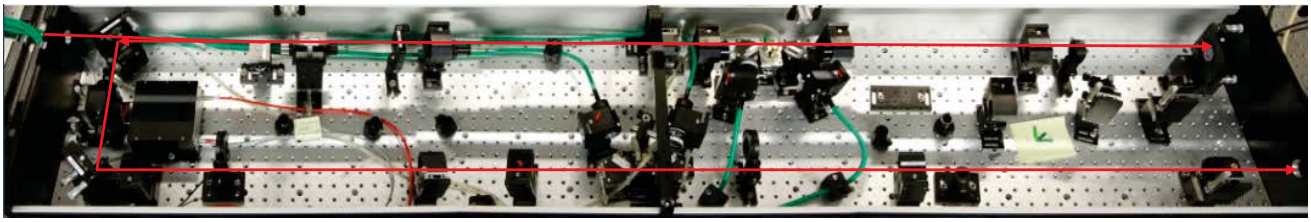


2) MBI Laser – Regenerative Amplifier



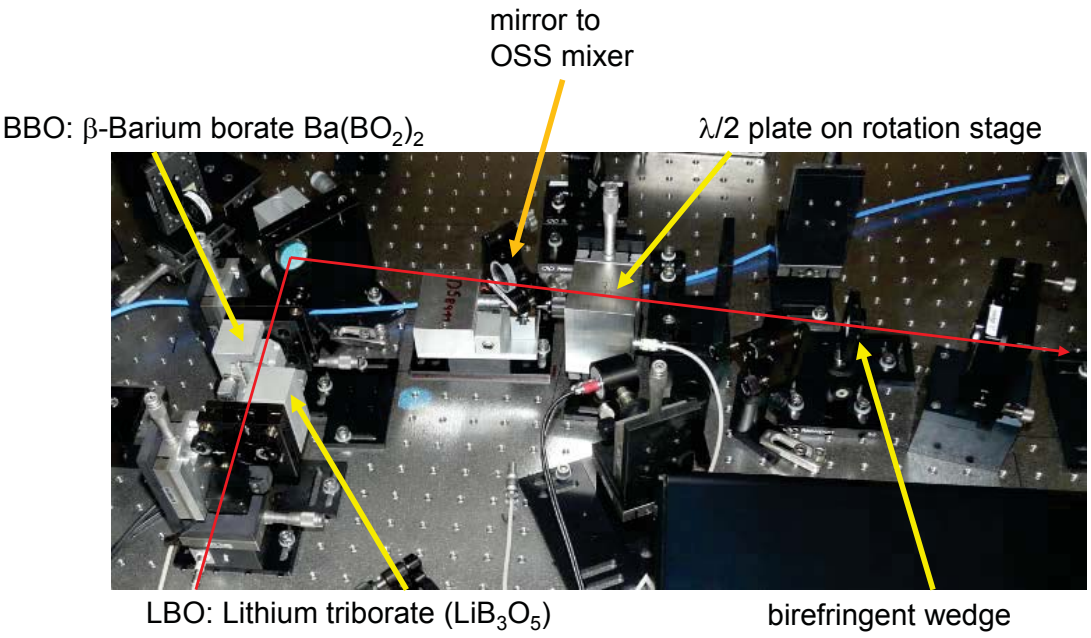
- 15 round trips → pulse energy gain up to ≈100,000
- Yb:YAG amplifier crystal → new center wavelength: 1030 nm
- Option: stretch pulse length from 2 ps up to ≈12 ps
  - Use Lyot filter(s) togther with polarizer
  - Polarization rotation dispersion → reduce bandwidth → increase pulse length (pulse is bandwidth limited)

2) MBI Laser – Booster Amplifier with Pulse Picker #2



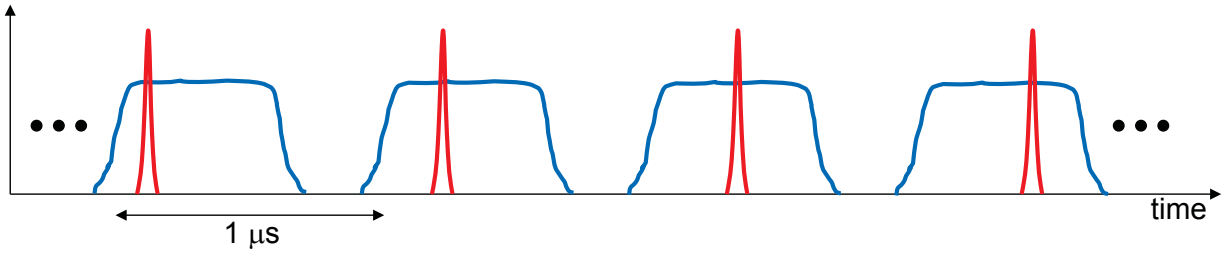
- Double pass amplifier
  - ≈4x amplification
  - Pulse guiding with λ/2 waveplate / Faraday rotator / birefringent wedge
- Pulse picker #2: Pockels cell
  - Definition of laser pulse train length
- Booster amplifier
  - ≈2x amplification

2) MBI Laser – IR to UV Conversion + Attenuator



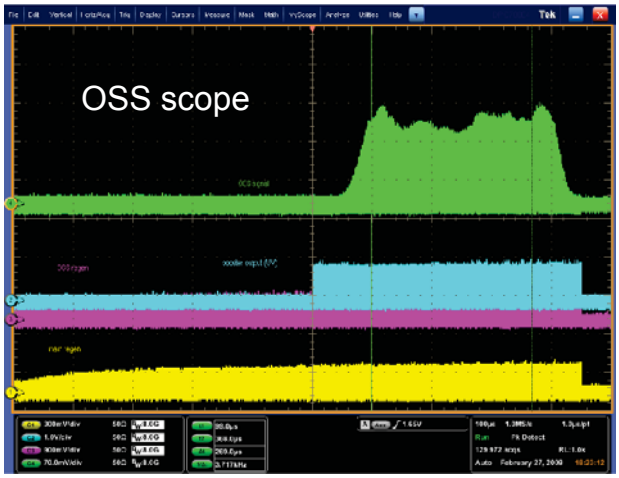
2) MBI Laser – Optical Sampling System (OSS)

- Regenerative amplifier – same functionality as in the main laser path
- Specialty: one end mirror is oscillating ‘flying mirror’, mounted on voice coil → time scan



2) MBI Laser – OSS Mixer

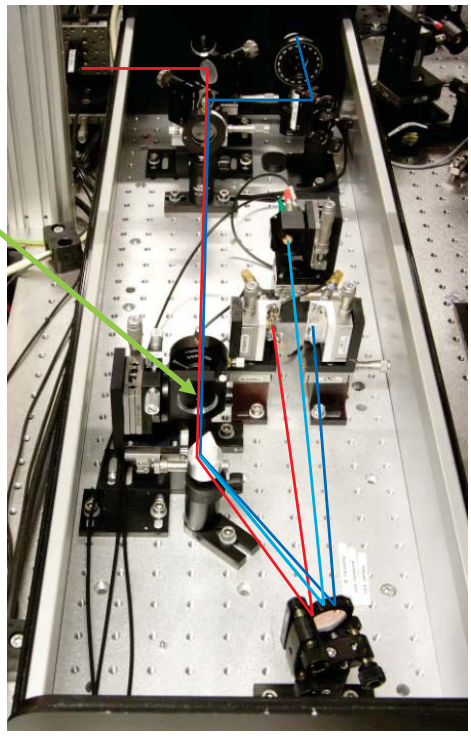
- Spatial overlap of IR and UV pulses with dichroic mirror
- Frequency conversion in BBO crystal: difference frequency generation (DFG)
- Spatial separation with prism
- Detection with 3 fast photo diodes



DFG

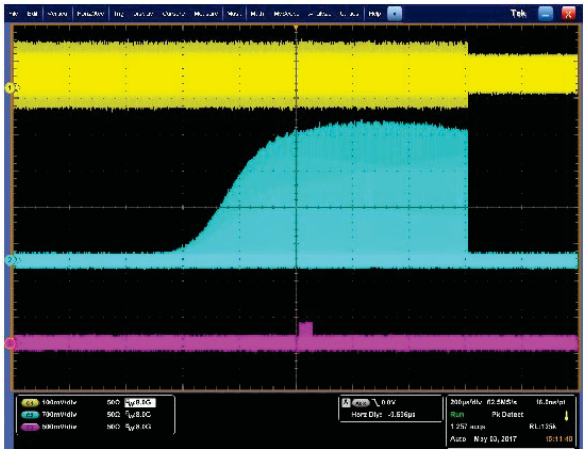
UV

IR

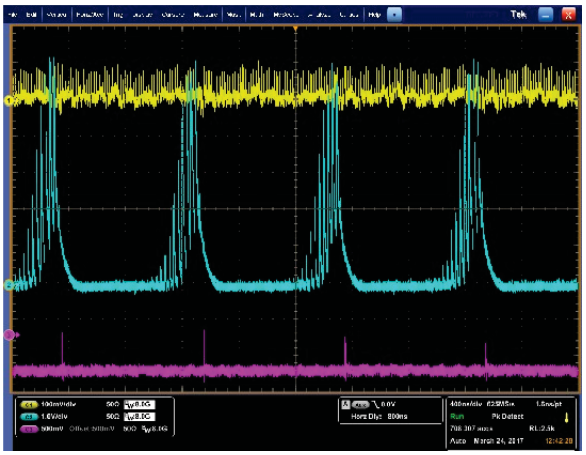


2) MBI Laser – Standard Traces on Laser Scope

- Yellow: oscillator
- Cyan: regenerative amplifier (internal)
- Magenta: UV output



1 ms

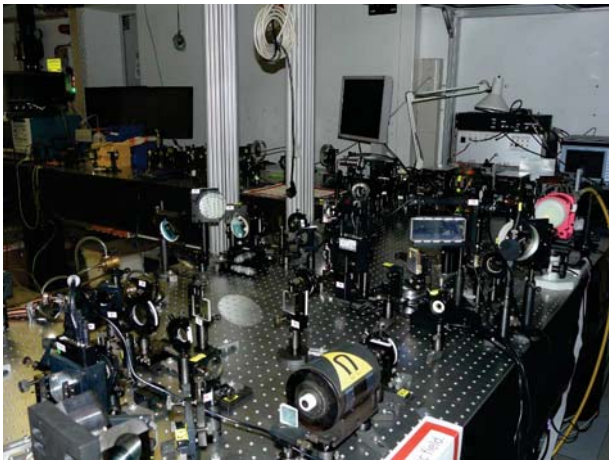


1 µs

3) ELLA: Ellipsoidal Laser

> Basic principle
  - Yb fiber oscillator, Yb:KGW disk amplifier, 2x frequency doubling

> Location
  - 1K05 (“laser hut”)



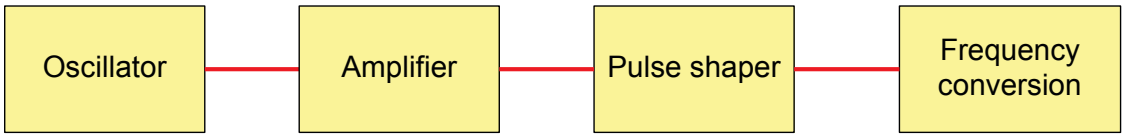
> Basic parameters
  - Wavelengths: 1030/515/257 nm
  - Pulse length: ≈6 ps
  - Pulse energy: <1 µJ in the UV
  - Repetition rate: 10 Hz (1 MHz in burst)

> Manufacturer
  - IAP RAS, Nizhny Novgorod (custom product)

> Application
  - Photocathode laser

3) ELLA: Setup

> General setup very similar to MBI laser

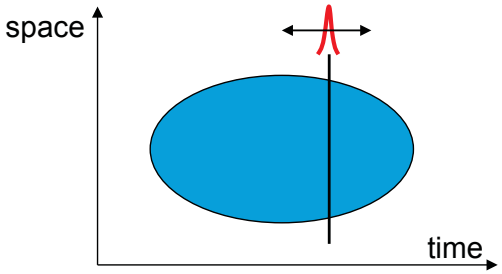


> Main difference: pulse shaper
  - Main gadget here: spatial light modulator (SLM) “pixelized mirror” to form ellipsoidal pulses
  - Basic principle:
    - Oscillator/amplifier generate pulses with energy chirp
    - Grating in pulse shaper translates energy to spatial position
    - Imprinting elliptical shape with SLM (in 2 orthogonal directions)
    - Reversing spatial stretch with second grating

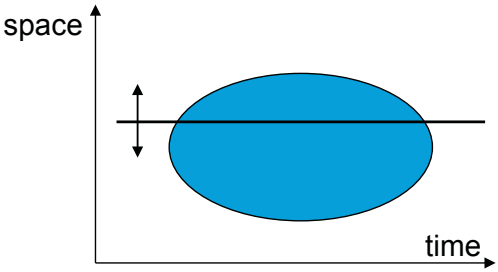
3) ELLA: Diagnostics

> Cross-correlator → temporal slices

- Similar to OSS, but use camera instead of photodiode



> Image spectrograph → transversal slices



3) ELLA: Status

> Currently: major changes in setup

> Oscillator / amplifier

- Replacement of current modules from Nizhny Novgorod with commercial laser front end (PHAROS from Light Conversion)

> Pulse shaper

- Alternative to SLM: 3D volume Bragg grating (3 dimensional pulse shaping)

> Optics / Optomechanics

- Replacement with highly stable posts/ mirror holders etc.
- Optimization of optical setup on laser table

Summary: 3 Laser Systems at PITZ

- ArF Laser
  - Ionization laser for lithium plasma cell
  - Commercial product from Newport
- MBI Laser
  - Photocathode laser
  - Custom built for PITZ by MBI (Berlin Adlershof)
- Ellipsoidal laser (ELLA)
  - Photocathode laser
  - Custom built for PITZ by IAP (Nizhny Novgorod, Russia)
  - Currently: major changes in setup