What is a Laser?

- Light
- Amplification by
- Stimulated
- Emission of
- Radiation

> General setup

Cavity

Gain medium
1) ArF Laser - Basics

> Basic principle
  - Excimer (excited dimer ArF*)
  - Discharge excitation

> Location
  - 1L18

> Basic parameters
  - Wavelength: 193 nm
  - Pulse length: \(\approx 25\) 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: \(\approx 2\ldots 25\) ps
  - Pulse energy: <5 \(\mu\)J 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

Oscillator → Pulse picker #1 → Pulse shaper → Regenerative amplifier → Booster amplifier → OSS regen amplifier → OSS mixer → Tunnel

2) MBI Laser - Oscillator

- Short (≈1 ps) pulse generation with passive mode locking with SESAM (SEmiconductor Saturable Absorber Mirror)
- Repetition frequency $f_{\text{Osc}}$ (54 MHz) is given by resonator length: $f_{\text{Osc}} = c/2L$ 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

![Diagram showing pulse picker](image)

For bursts with length = 1.5 ms

2) MBI Laser – Pulse Shaper

> Contains 13 birefringent YVO₄ 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

![Diagram showing pulse shaper](image)

- Free pulse shaping
2) MBI Laser – Regenerative Amplifier

> 15 round trips → pulse energy gain up to \(\approx 100,000\)

> Yb:YAG amplifier crystal → new center wavelength: 1030 nm

> Option: stretch pulse length from 2 ps up to \(\approx 12\) ps
  - Use Lyot filter(s) together with polarizer
  - Polarization rotation dispersion → reduce bandwidth → increase pulse length (pulse is bandwidth limited)

From thesis
Marc Hänel

Lyot filters

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

> Double pass amplifier
  - \(\approx 4\times\) amplification
  - Pulse guiding with \(\lambda/2\) waveplate / Faraday rotator / birefringent wedge

> Pulse picker #2: Pockels cell
  - Definition of laser pulse train length

> Booster amplifier
  - \(\approx 2\times\) amplification
2) MBI Laser – IR to UV Conversion + Attenuator

- BBO: β-Barium borate $\text{Ba(BO}_2\text{)}_2$
- LBO: Lithium triborate $\text{LiB}_3\text{O}_5$
- $\lambda/2$ plate on rotation stage
- Birefringent wedge

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

![Graph showing time scan with 1 μs intervals]
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

2) MBI Laser – Standard Traces on Laser Scope

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