Introduction to lasers

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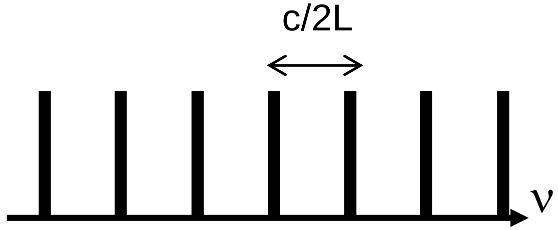
Chapter 5: Laser operating regimes

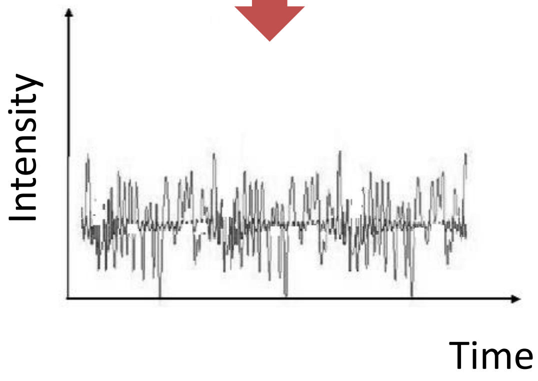
I. Continuous-wave regime

To complete



Longitudinal modes / φ_j are random

F. T. **Fourier Transform**

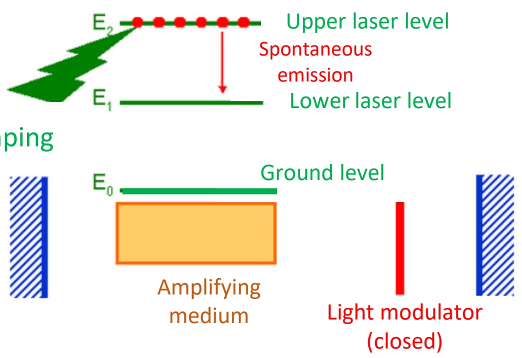


http://optique-ingenieur.org

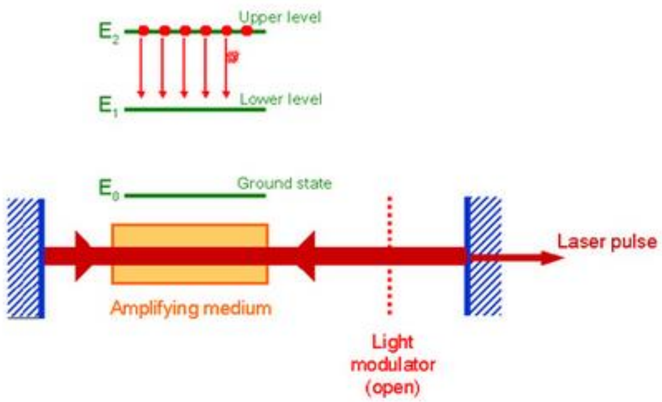
- Periodic temporal noise
- « Temporal speckle » →Duration of grains~1/B

B = spectral bandwidth of emission

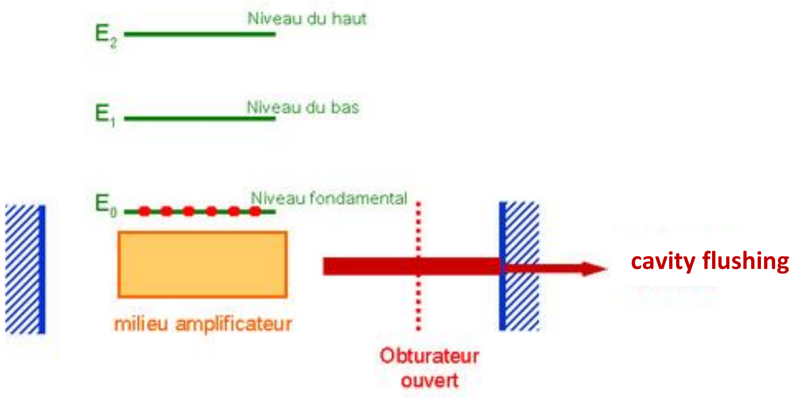
II. Q-switch regime



1) Energy storage



2) Beginning of the pulse



3) End of the pulse

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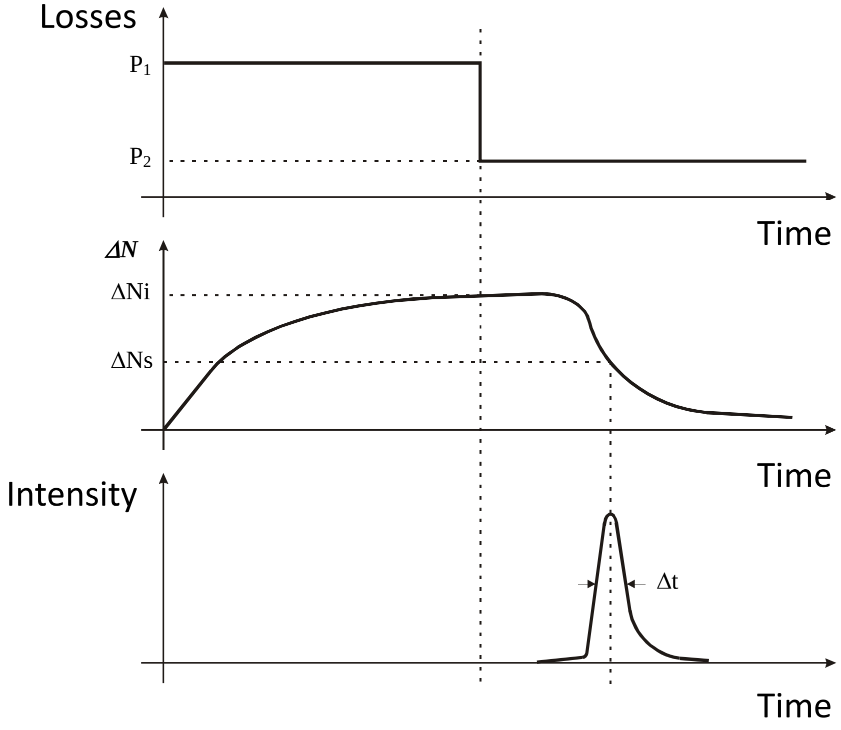


Typical pulse duration: ns – 100 ns
Typical repetition rate: Hz – 50 kHz

To complete

Example of light modulator

Accousto-optic moulator

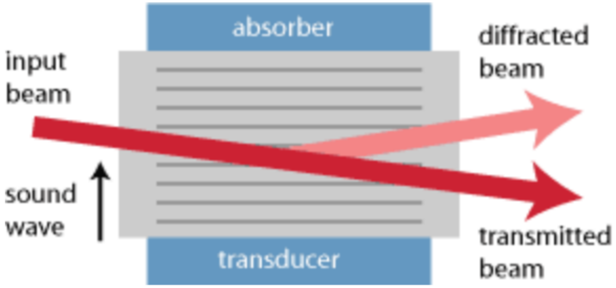
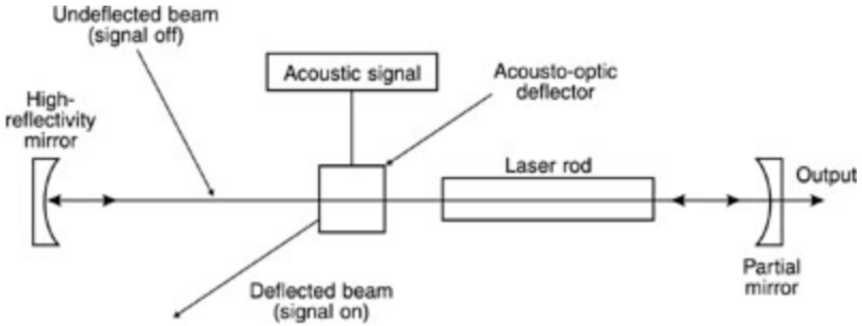


Figure 1: Schematic setup of a non-resonant acousto-optic modulator. A transducer generates a sound wave, at which a light beam is partially diffracted. The diffraction angle is exaggerated; it is normally only of the order of 1°.

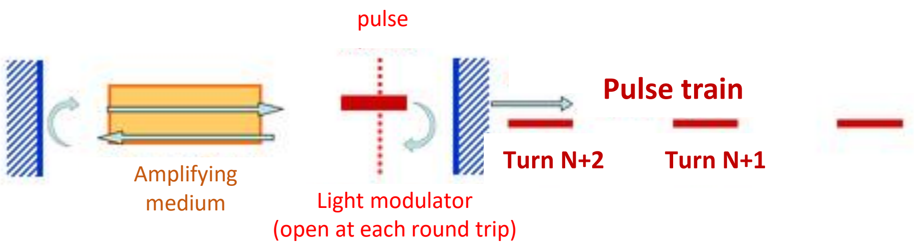
https://www.rp-photonics.com/acousto_optic_modulators.html

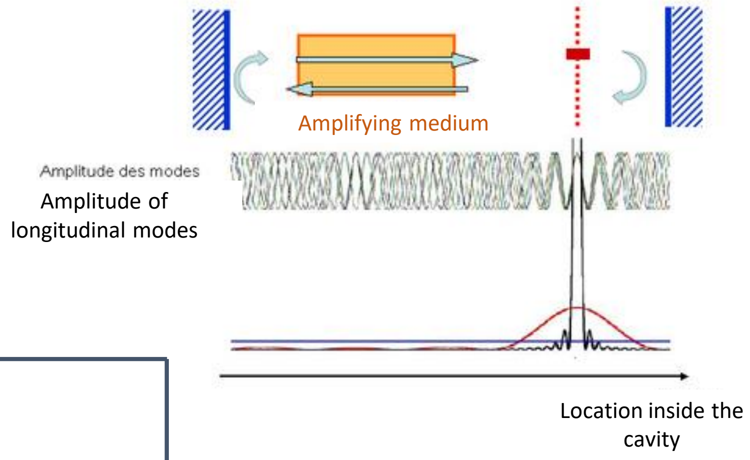


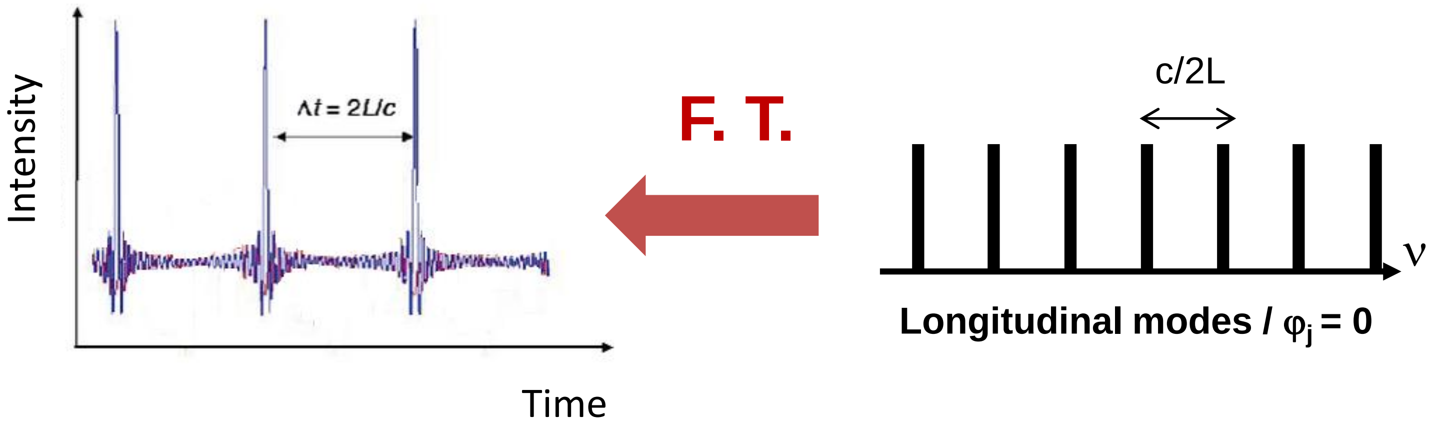
Application of an acousto-optic Q-switch in a solid-state laser

https://pe2bz.philpem.me.uk

III. Mode lock regime







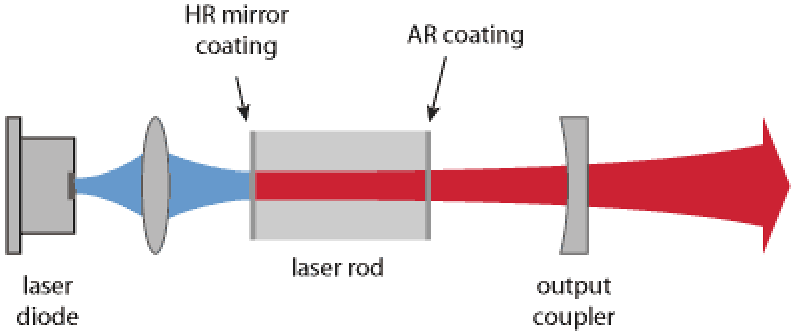
http://optique-ingenieur.org

Typical pulse duration: 10fs – 1 ps
Typical repetition rate: MHz – GHz

To complete

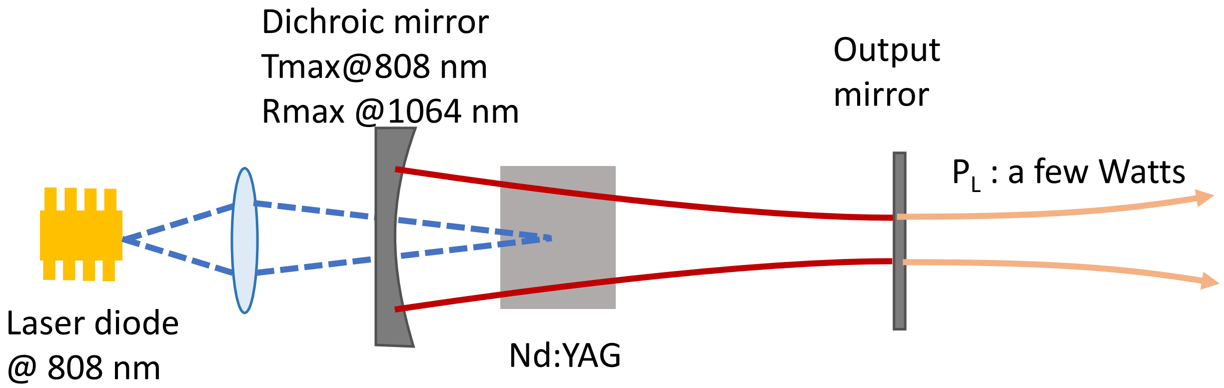
Chapter 6: Some solid-state lasers

❑Typical set up of a end-pumped solid-state laser



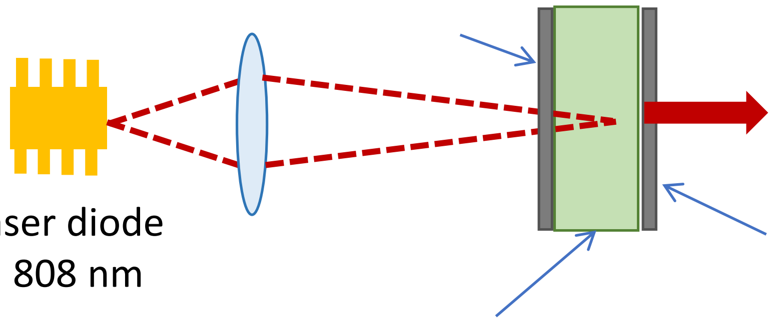
https://www.rp-photonics.com/end_pumping.html

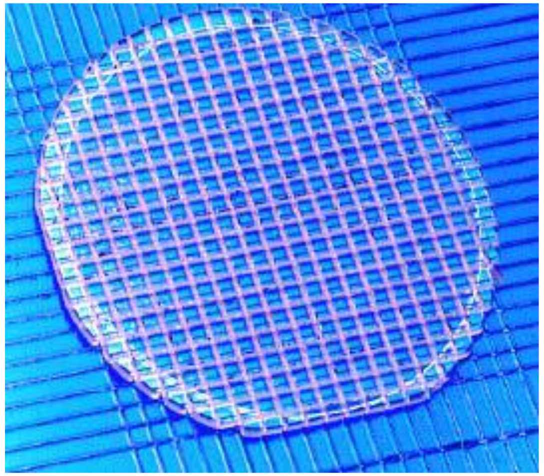
Suitable for Gaussian single-mode operation : higher-order modes then have too low gain to reach the laser threshold.



- Free space cavity, ~1m long
- Other end-pumping scheme

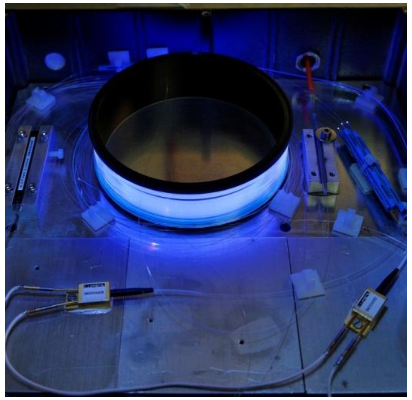
❑ Laser chip (~1 mm ^{3})



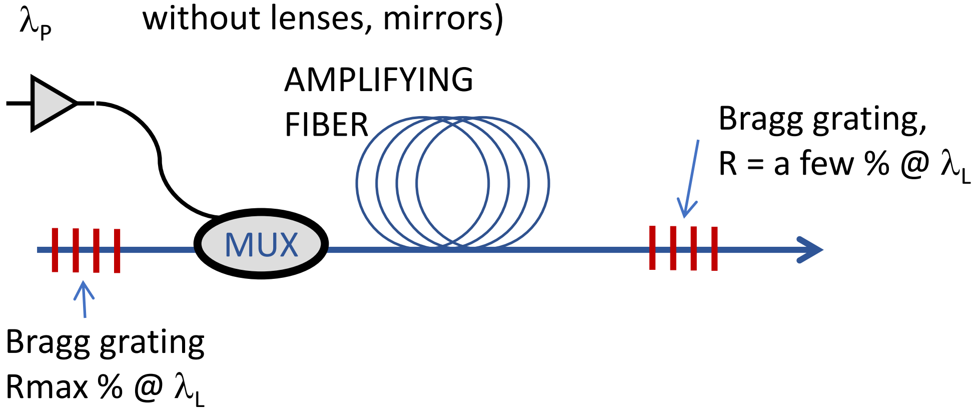


High reflectivity coatings deposited on the crystal
→ monolithic system
→ no adjustment required
Mass production on a one-inch wafer

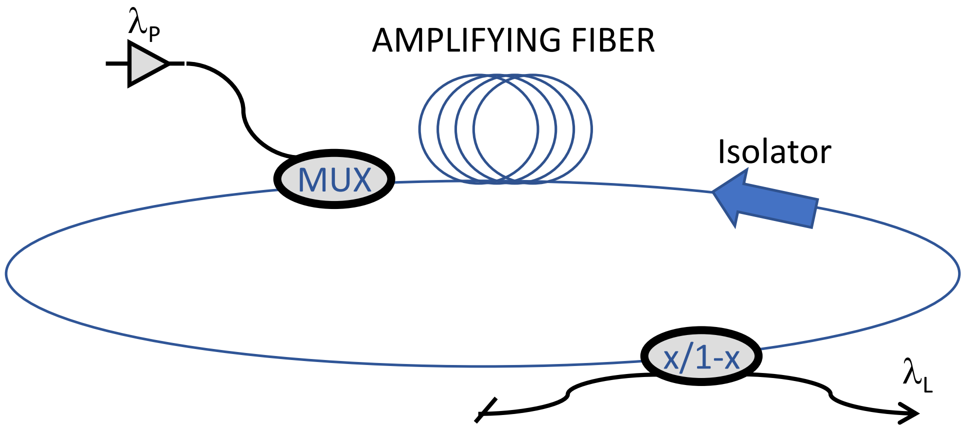
❑Fiber lasers



- Amplifying fiber
- Modal selection by the optical guide
- High ratio (exchange surface with the environment)/(doped volume) + index gradients due to thermal effects << Δn of the fiber
- Low sensitivity to thermal effects
- High electrical/optical efficiency
- Power rising mainly limited by non-linear effects
- Compactness, environmental resistance (climatic, vibration), Maintenance free (the entire optical fiber setups without lenses, mirrors)



Fabry Perot cavity

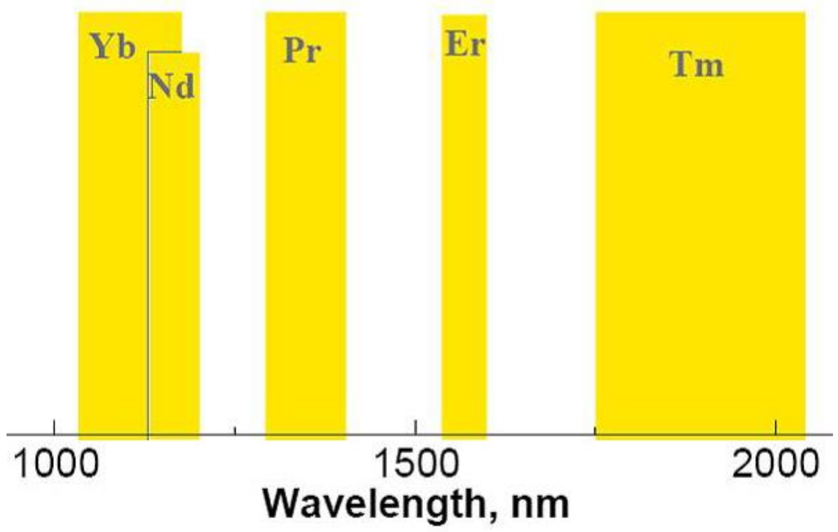


Ring cavity

Rare-earth doped fibers

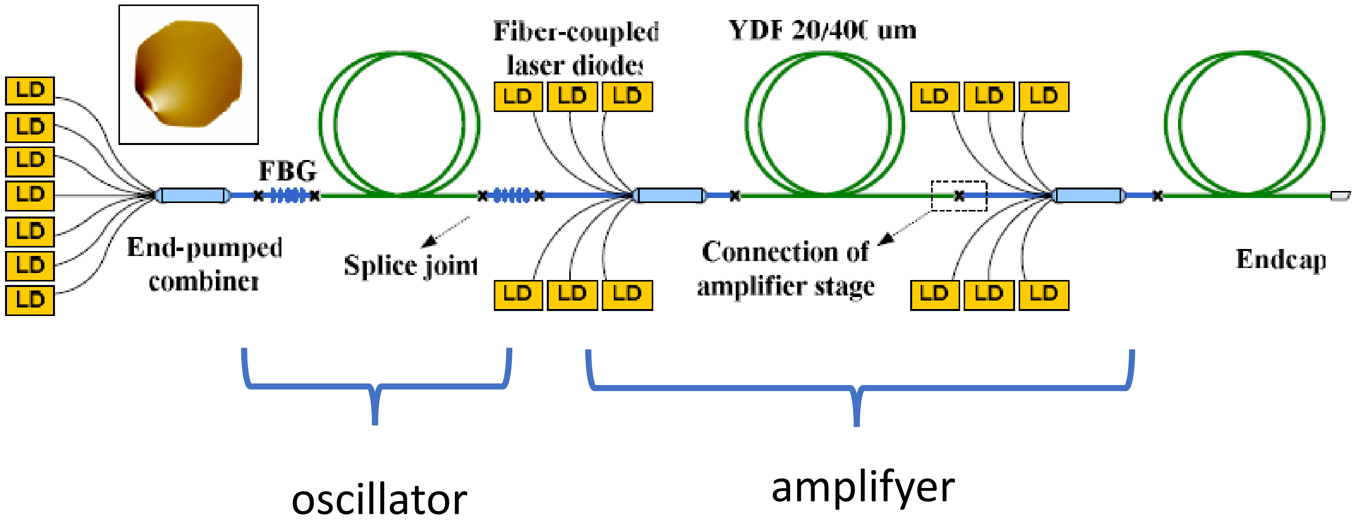
- Optical-to-optical efficiencies (typical):
  - Yb-doped fused silica fibers: 70% – 85%
  - Tm-doped fused silica fibers: 50% - 65%
  - Er and Er/Yb doped silica fibers: 20% - 40%

- Er: 1.55µm, minimum loss, telecom/eye-safe
- Yb: 1µm, high efficiency, ~1ms life-time, broad bandwidth.
- Tm: 2µm, eye-safe



MOPA configuration (Master Oscillator Power Amplifier)

For high power fiber laser



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Conclusion

Laser light –> High capability to be focused in:

- Space domain → Gaussian beam (flat phase)
- Time domain → Mode-lock regime (flat phase in the spectral domain)

$\hat{P}$ = peak power = $\frac{E}{\Delta t}$

$\bar{P}$ = average power = $\frac{E}{2[L]/c}$

$2[L]/c$ = t_{RT}

t_{RT} : Round trip duration

E : energy; Δt : pulse duration

$$\hat{P}.\Delta t = \bar{P}.t_{RT}$$

With $t_{RT} = \frac{1}{Rep}$

$$\boxed{\hat{P} = \frac{\bar{P}.}{t_{RT}.Rep}}$$

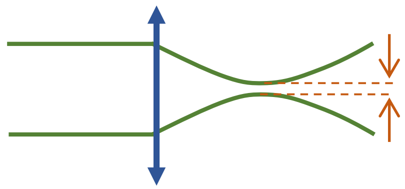
Rep = repetition rate

$\bar{P}$ = 10W

$\Delta t = 1ps$

$Rep = 100MHz$

$\hat{P} = 10^5 W$



$\lambda \Longrightarrow s = \lambda^2$

Average power density at the focus:

$$\frac{\bar{P}}{s} = \frac{10}{(0.5.10^{-4})^2} = 4GW/cm^2!!$$

Peak power density at the focus:

$$\frac{\hat{P}}{s} = 400TW/cm^2!!$$

~from a nuclear plant!