

Welcome to Salamanca !!!



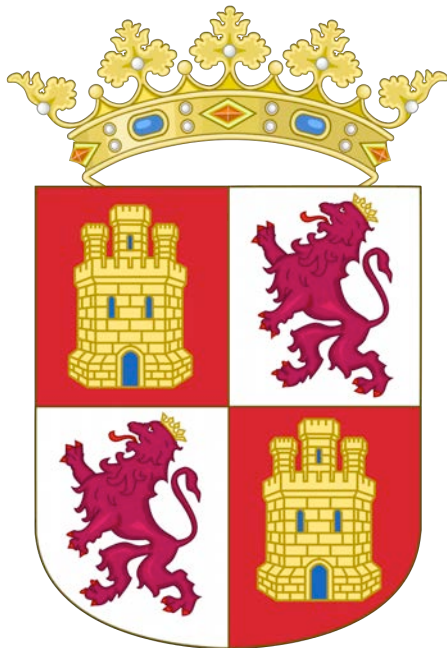
Welcome to Salamanca !!!



Castilla & Leon

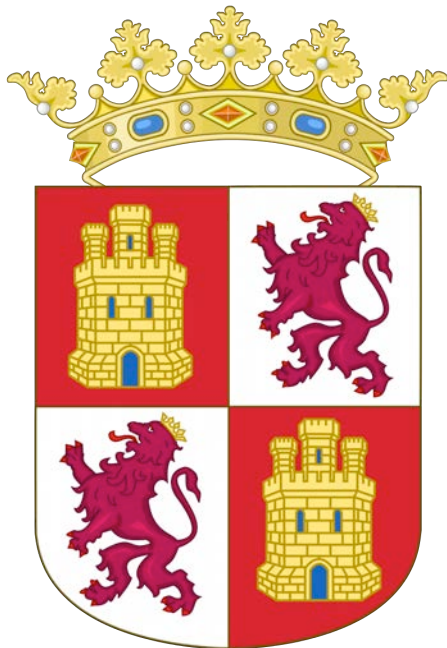


Welcome to
Salamanca !!!



Castilla & Leon

Welcome to
Salamanca !!!

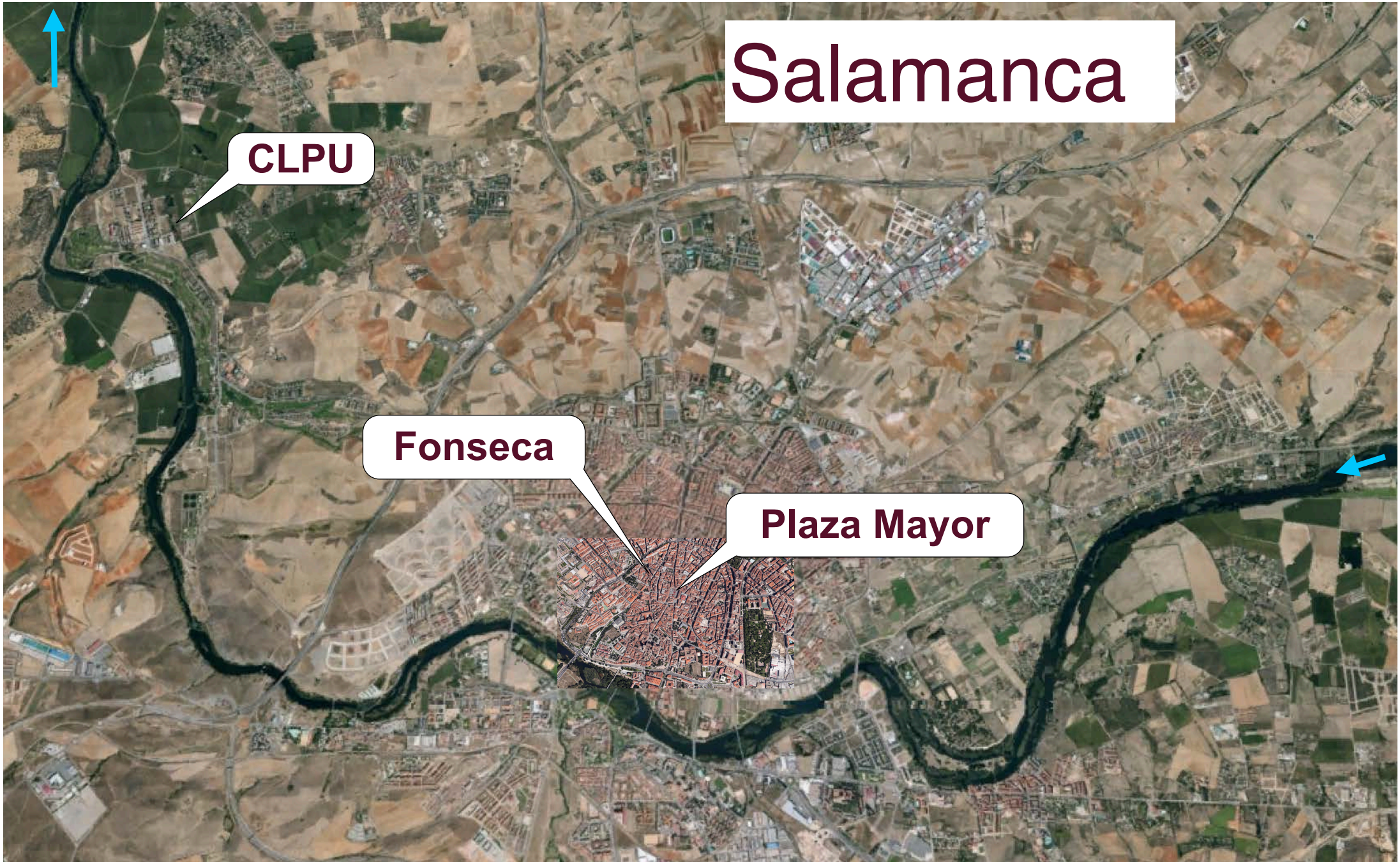


Salamanca

CLPU

Fonseca

Plaza Mayor





Fonseca

Plaza Mayor

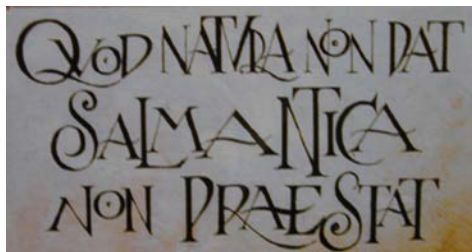
University

Salamanca

University of Salamanca

It was founded in 1134 and given the Royal charter of foundation by King Alfonso IX (King of Leon) in 1218.
General School of the Kingdom

Quod natura non dat,
Salmantica non præstat



What nature does not give, Salamanca does not lend



University of Salamanca

Stablished in 1218, so 2018 will be 800 anniversary!!!

1218 General School of the Kingdom

Fourth oldest European university in continuous operations

The formal title of "University" was granted by King Alfonso X in 1254 and recognized by Pope Alexander IV in 1255.





Homework



Find the astronaut at the facade of the Cathedral



Find the frog at the facade of the University

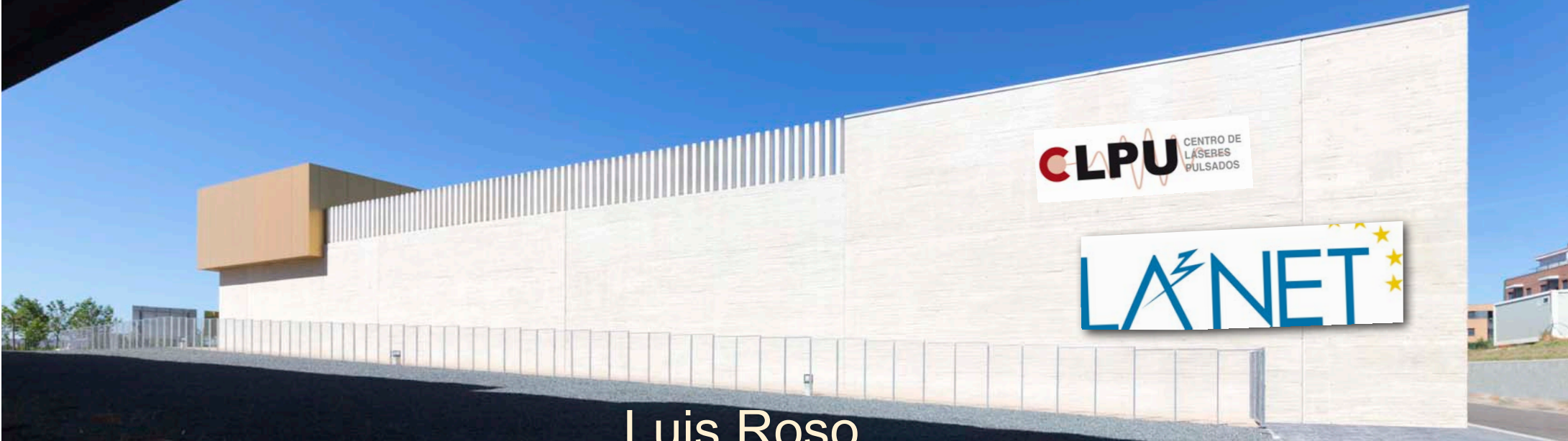
Welcome to Salamanca !!!



Welcome to Salamanca !!!



Introduction to Lasers and to LaserLab



Salamanca,
September 29th, 2014

Luis Roso

Director

Centro de Láseres Pulsados,
CLPU, Salamanca





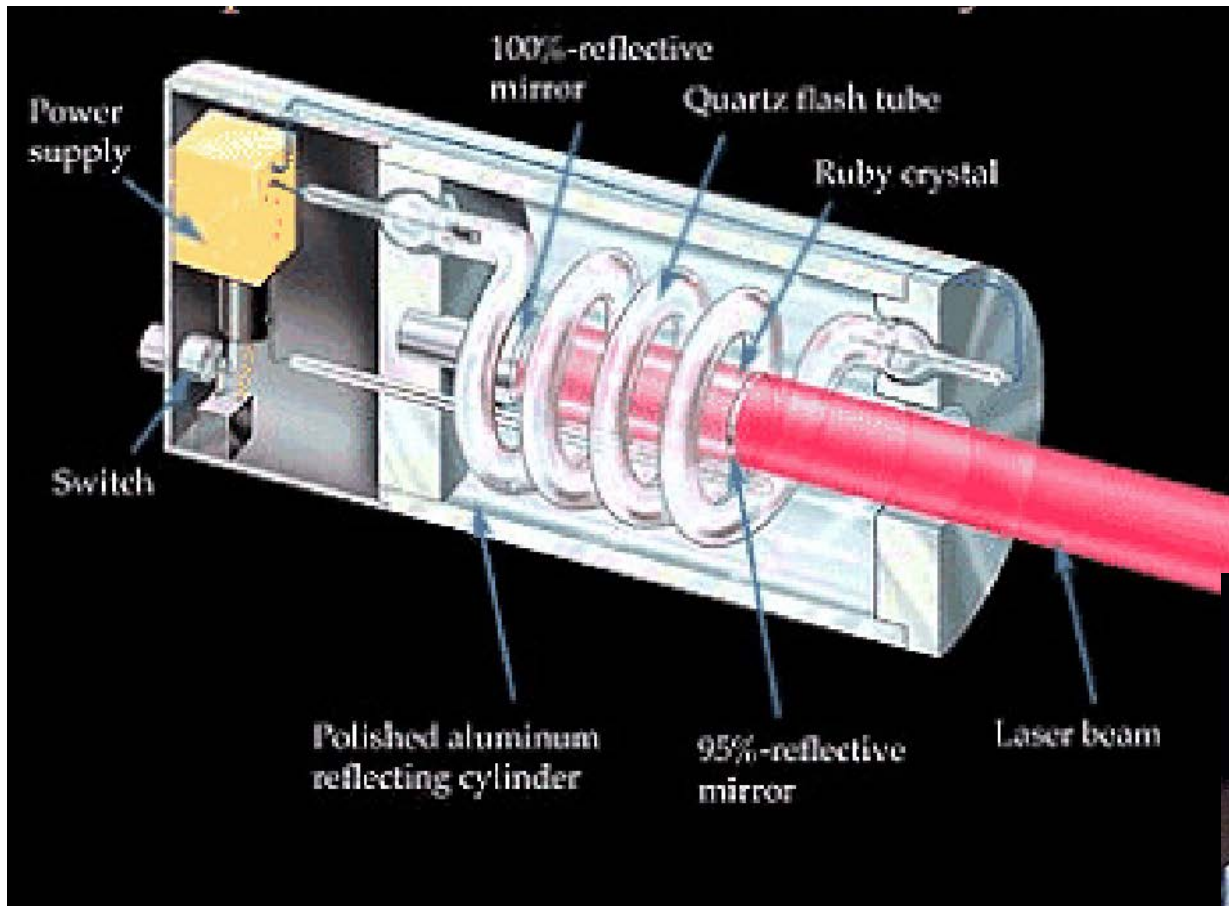
What is laser?



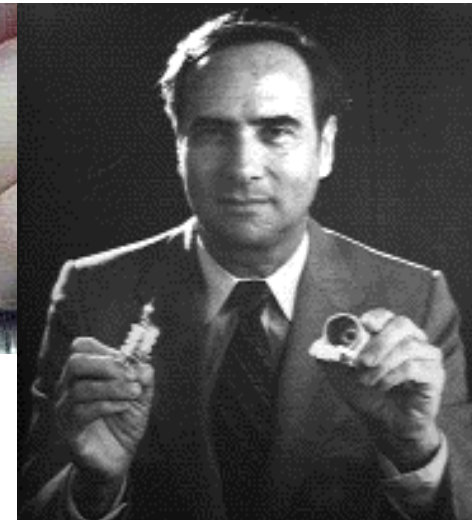
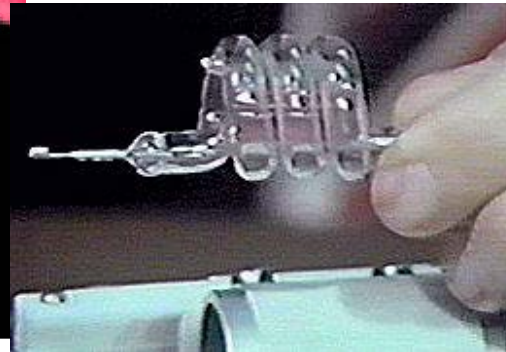
Any system that
generates
coherent
radiation?



First laser 1960 Theodore Maiman



Light
Amplification by
Stimulated
Emission of
Radiation



T H Maiman

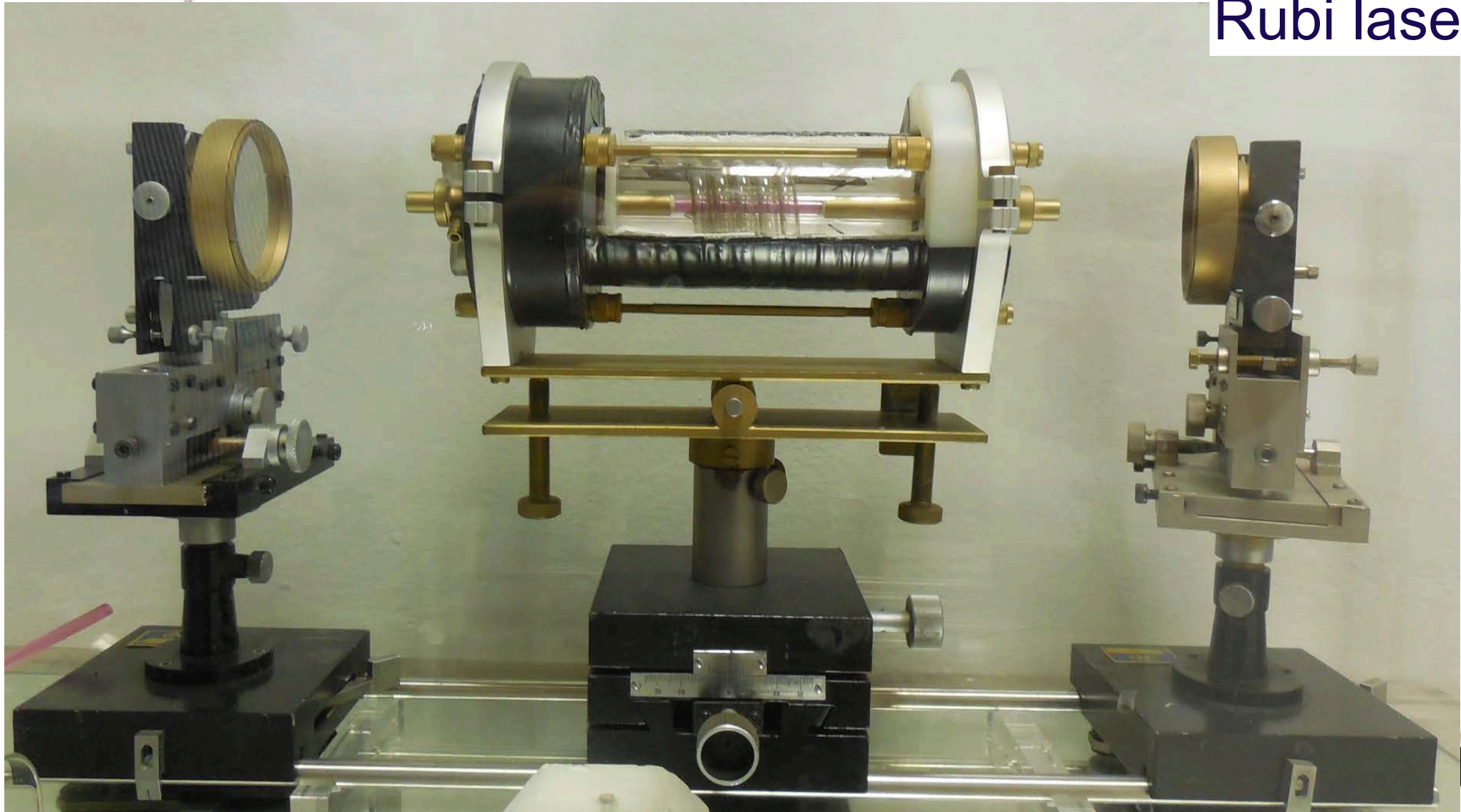
Rubi laser

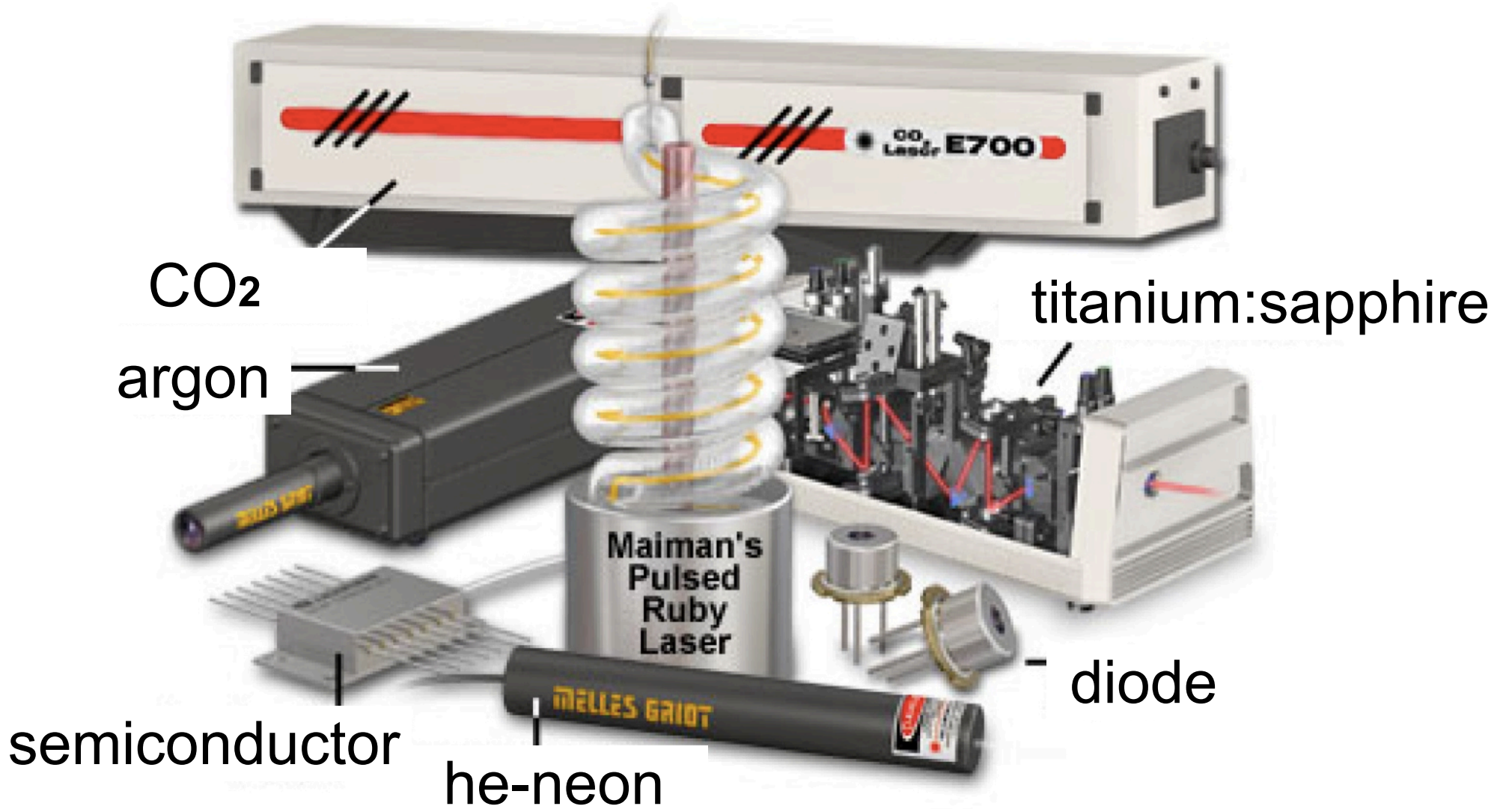
694 nm

First laser 1960 Theodore Maiman



Rubi laser



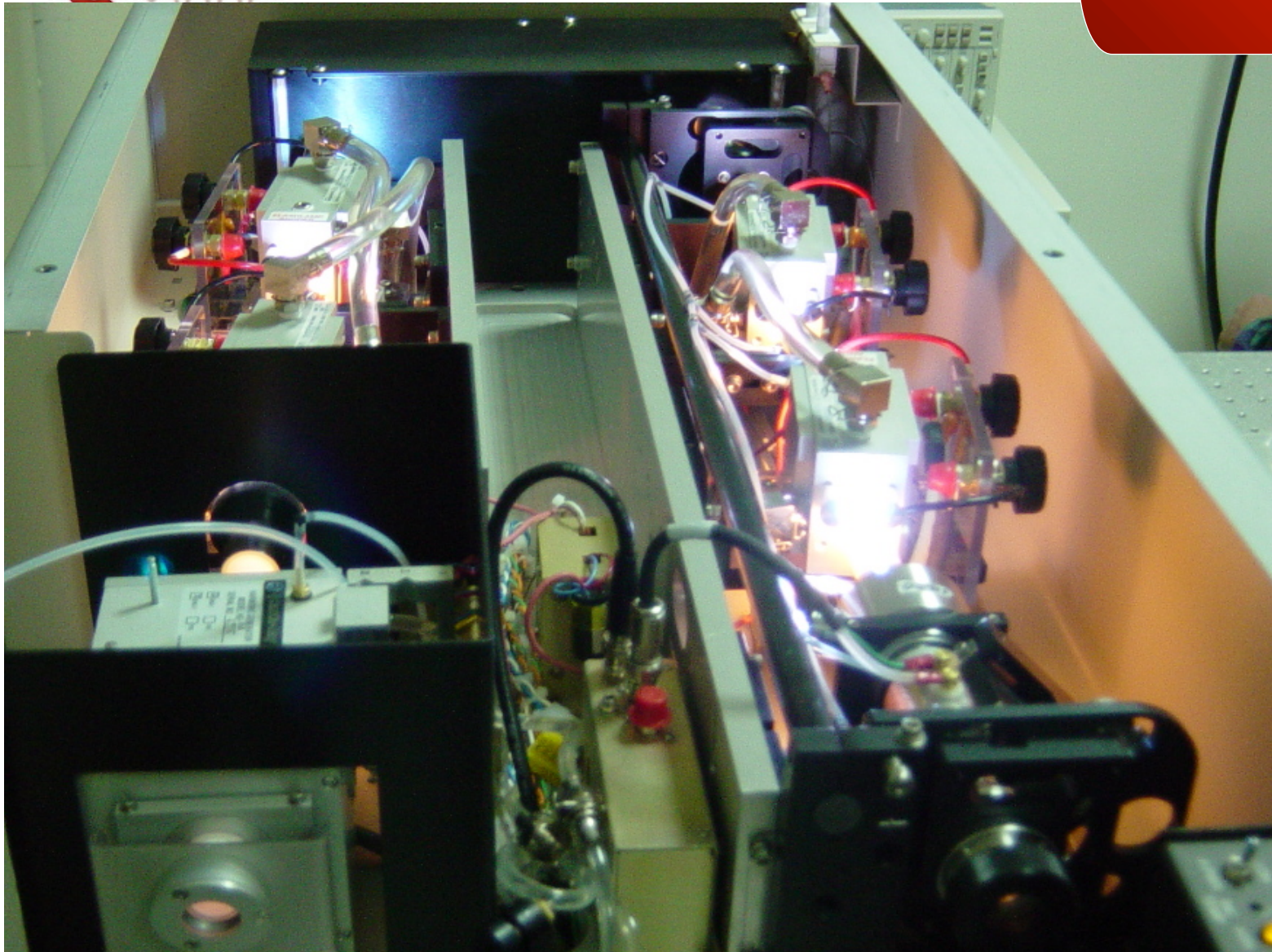


Neodymium laser

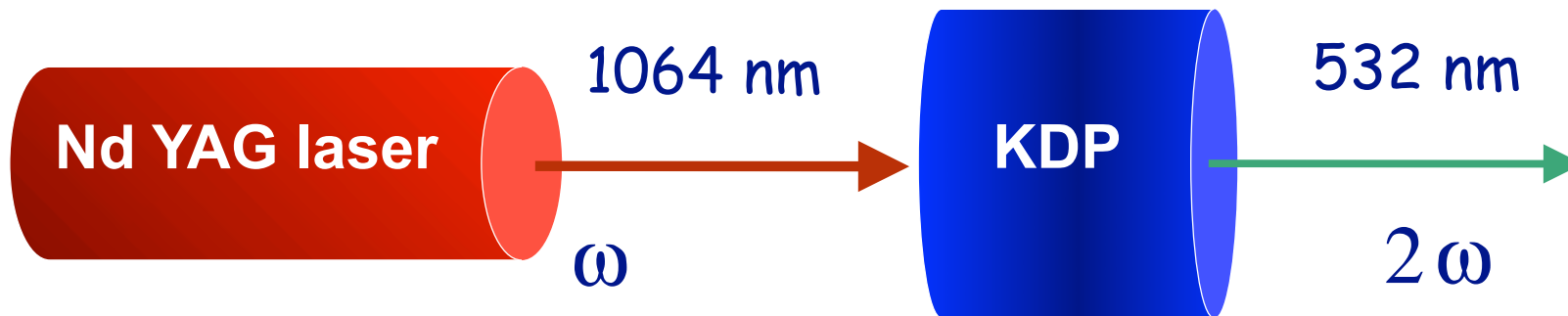
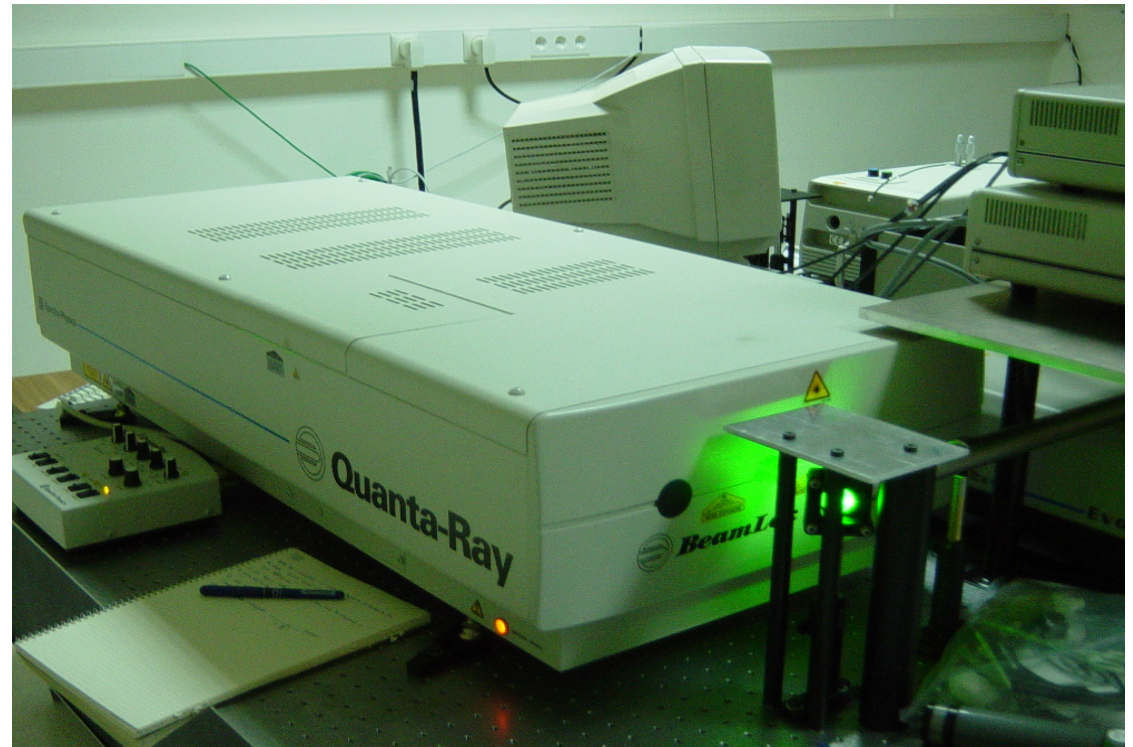
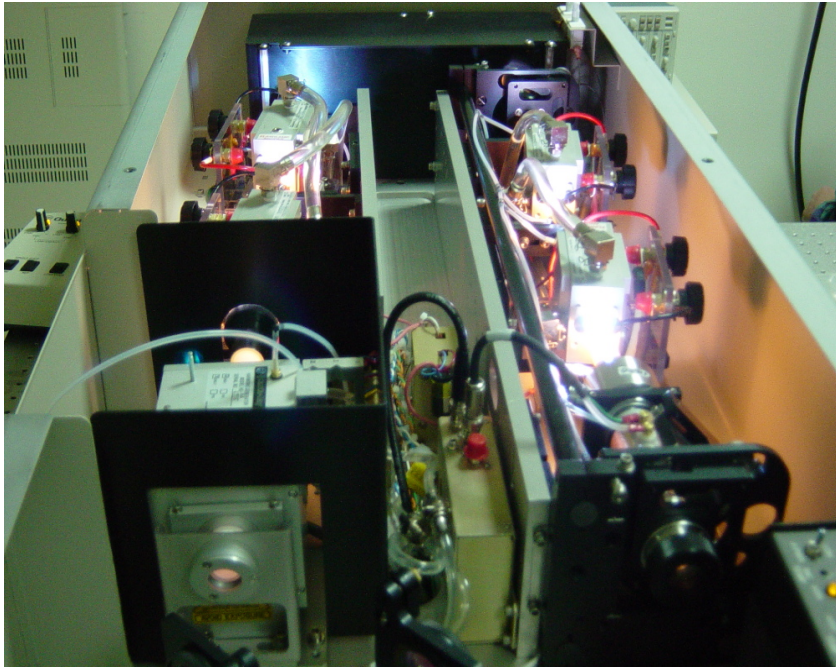
Nd YAG laser

1064 nm

ω



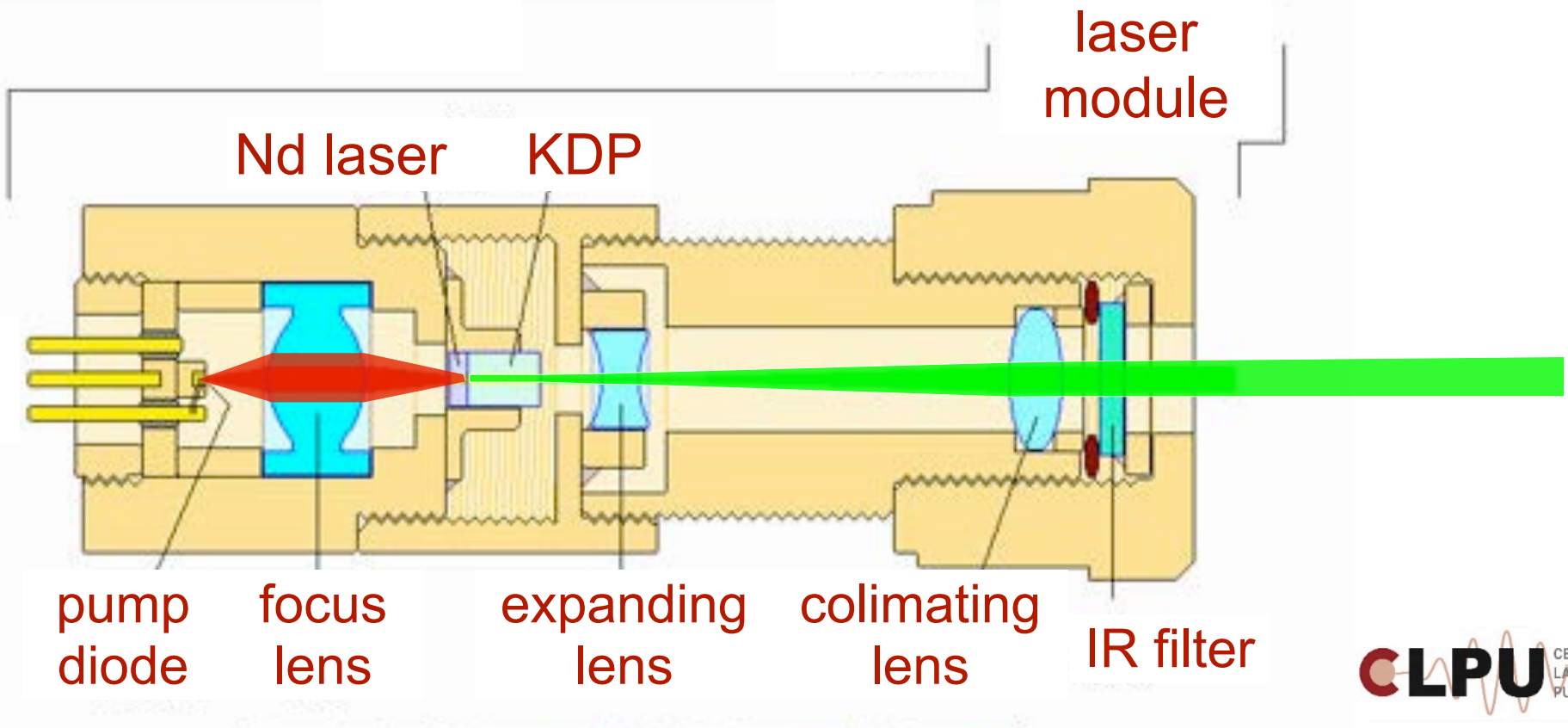
Second harmonic generation



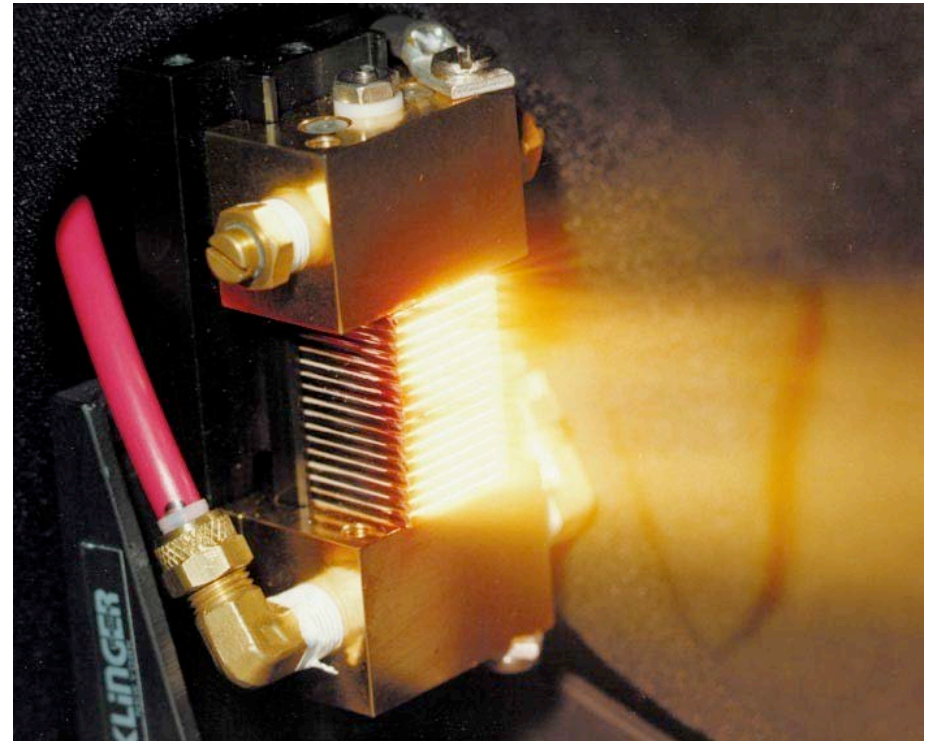
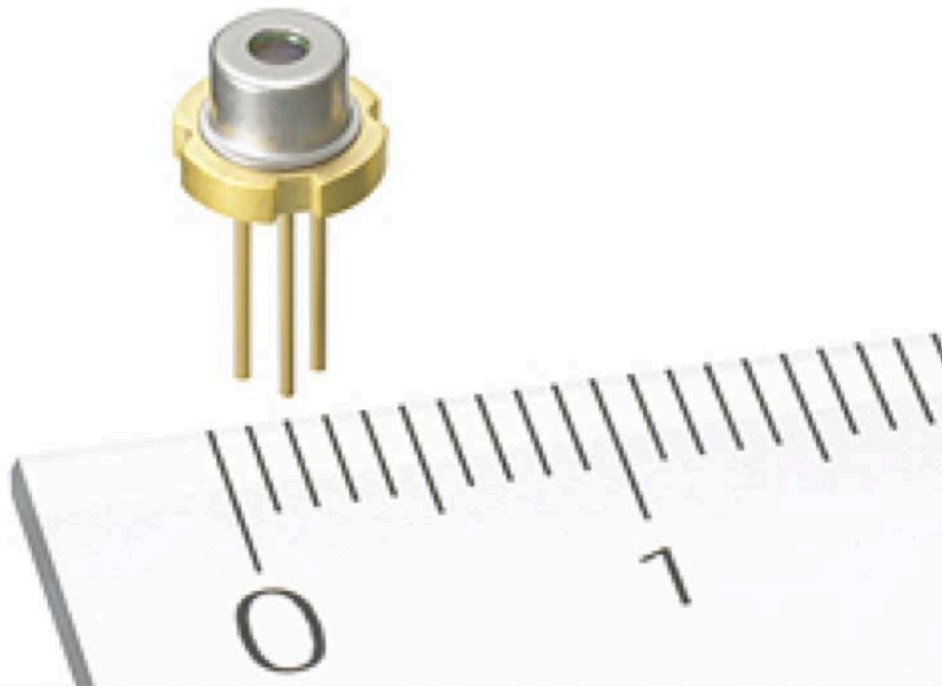


Green laser pointer

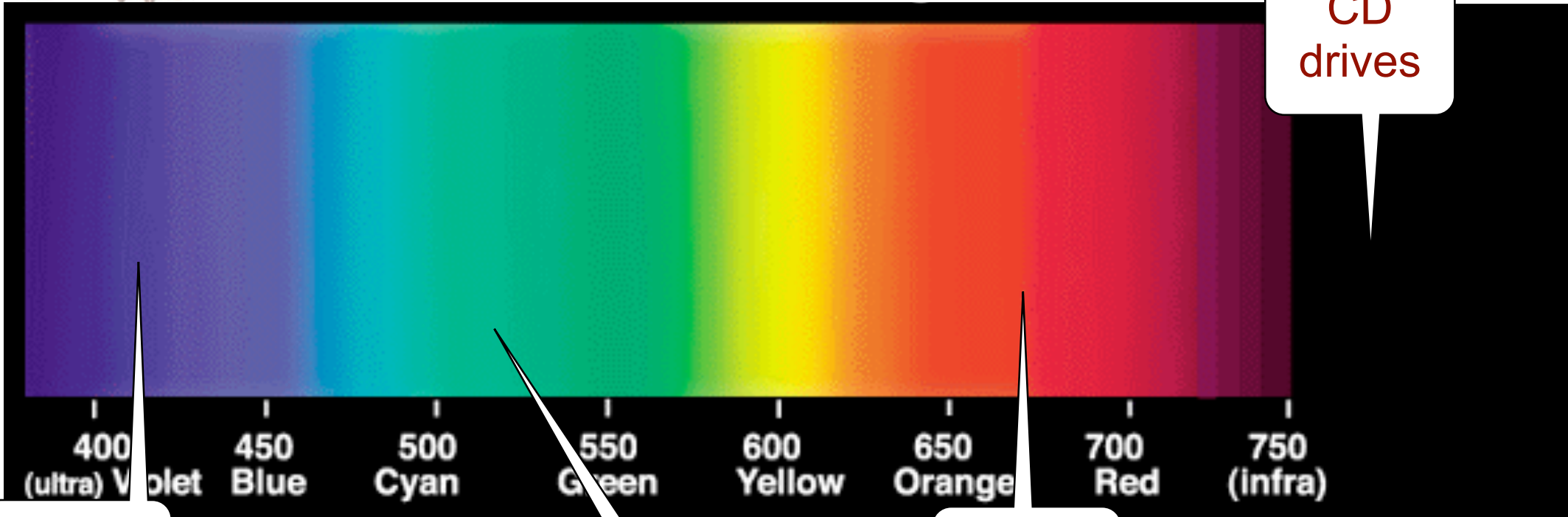
$$1064 \text{ nm} + 1064 \text{ nm} = 532 \text{ nm}$$



Semiconductor lasers



Semiconductor lasers



405 nm
InGaN
Blu-ray
drives



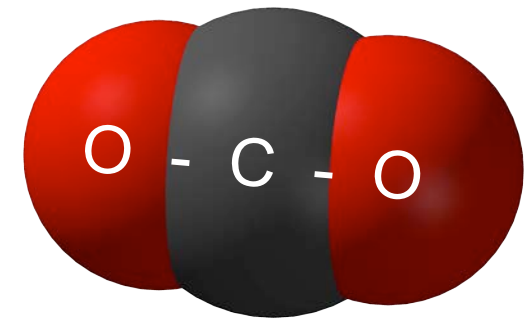
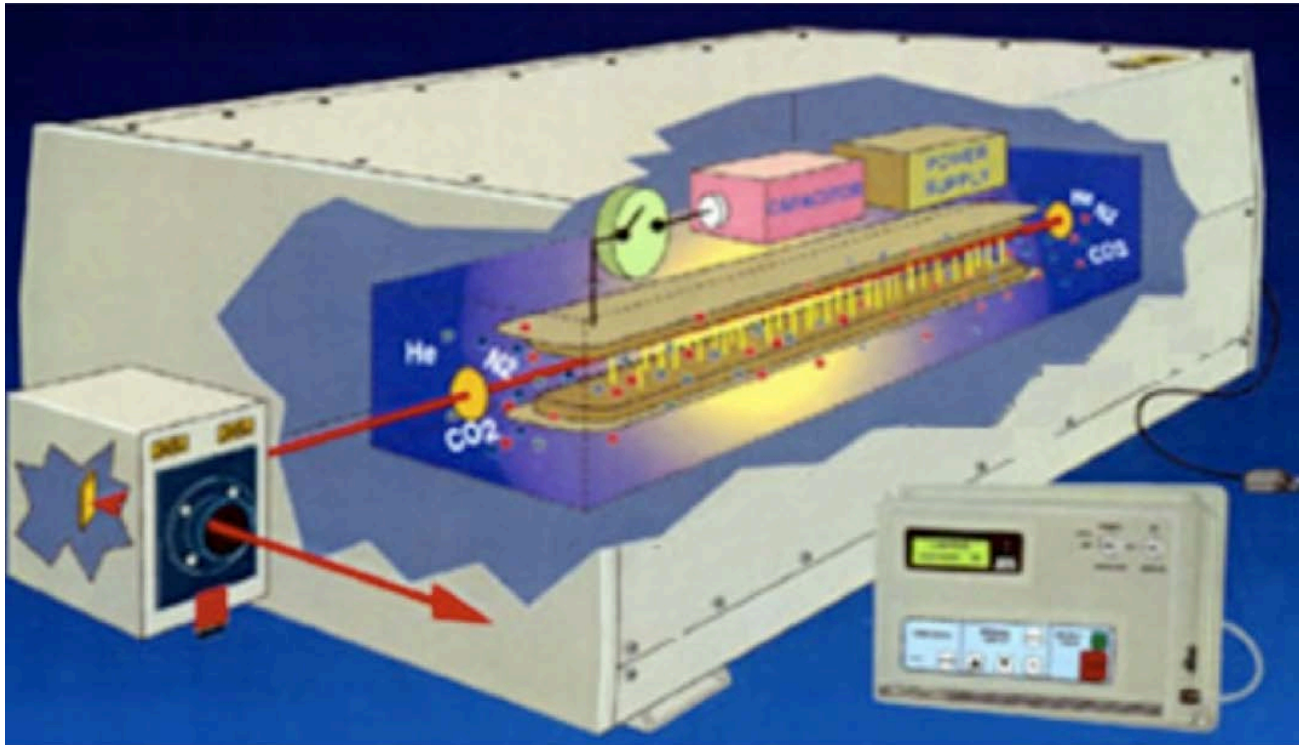
520
true
green
diodes

670 nm
AlGaInP
bar code
readers

785 nm
GaAlAs
CD
drives

 **CO₂ laser**

FIR Far Infrared
10 micron

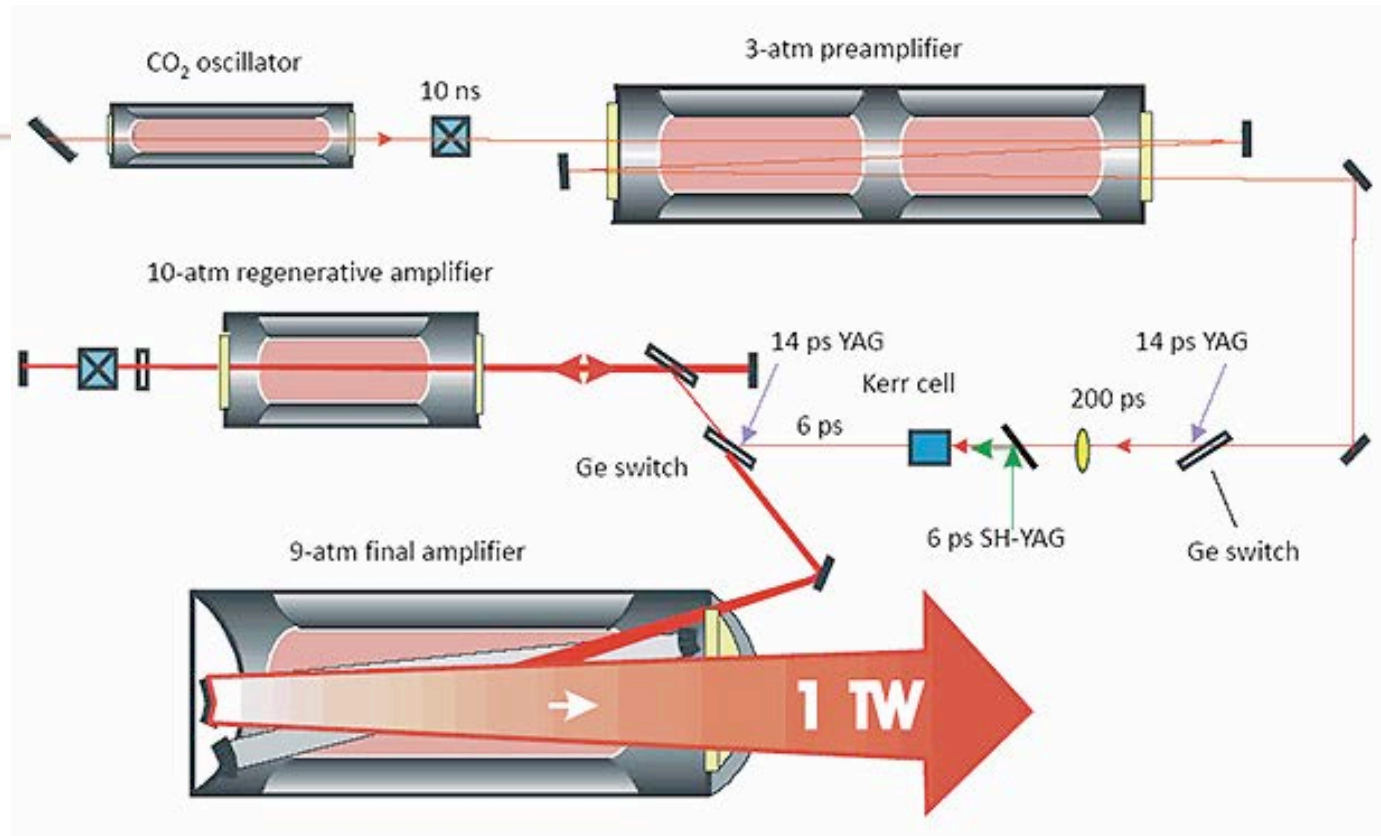


 **10 micron**



 **CO₂ laser**

10 micron



Home made
Air laser

Barcelona, 1980



UAB
Universitat Autònoma
de Barcelona



Copper capacitor
Nitrogen Laser

Ultraviolet

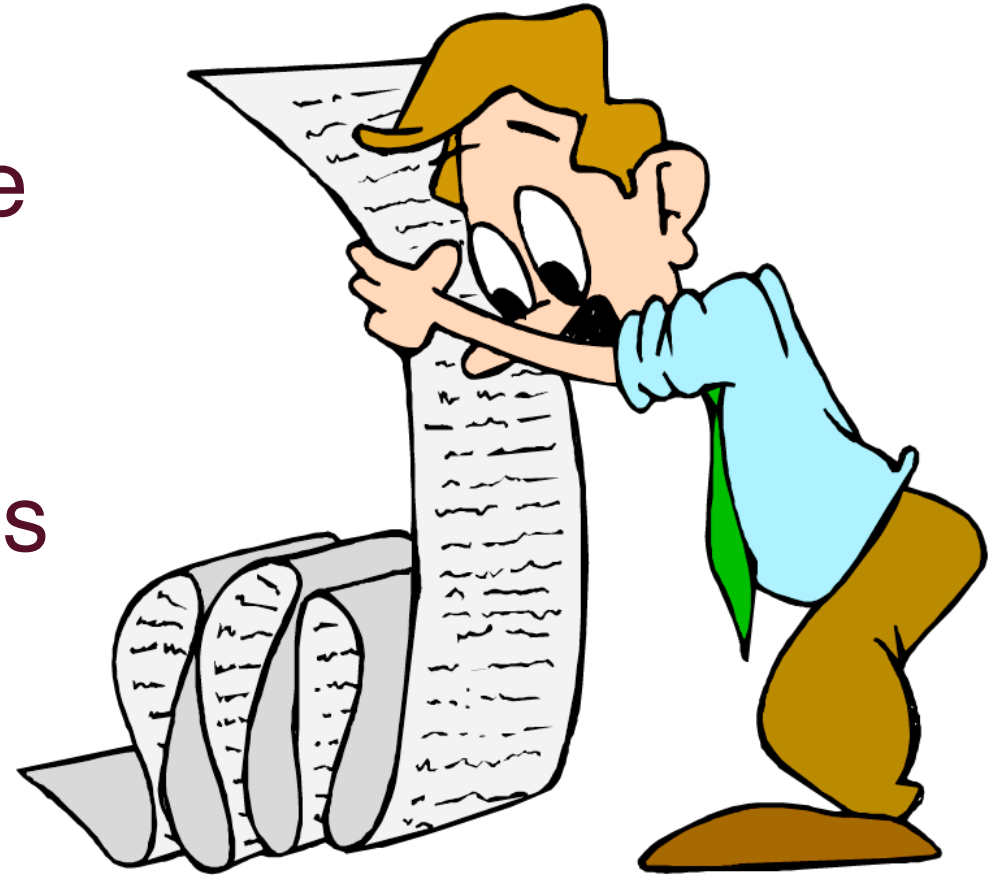
CLPU CENTRO DE
LÁSERES
PULSADOS



What is a laser
good for?

Many many applications

Physics
Chemistry
Material science
Medicine
Biology
Communications
Environment



... and more in progress

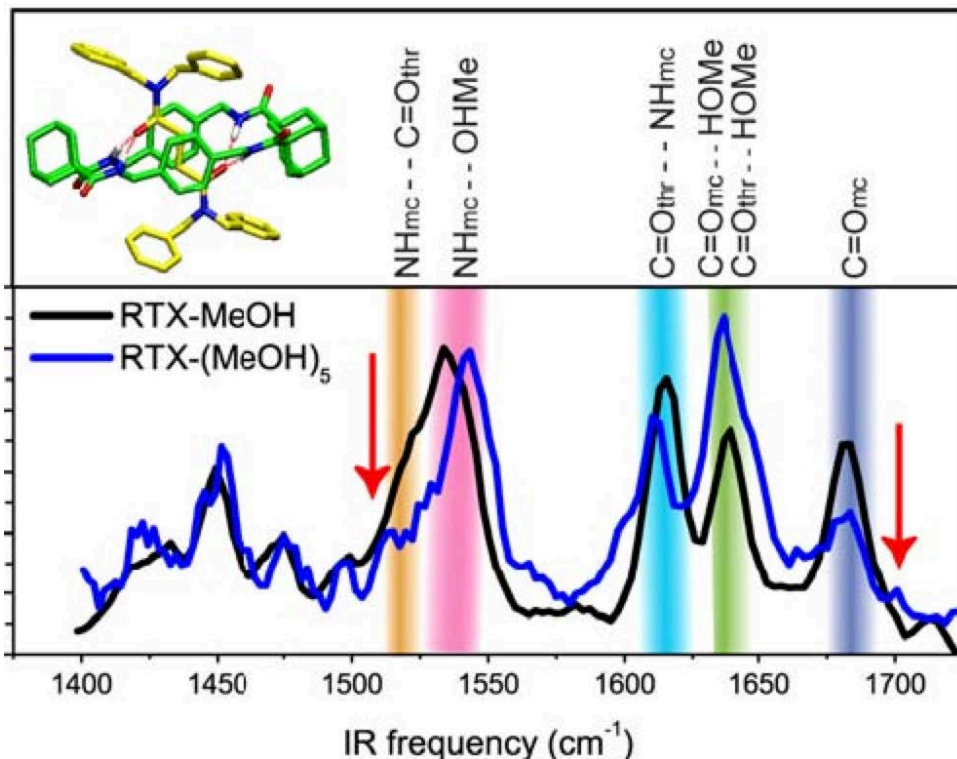


serious applications

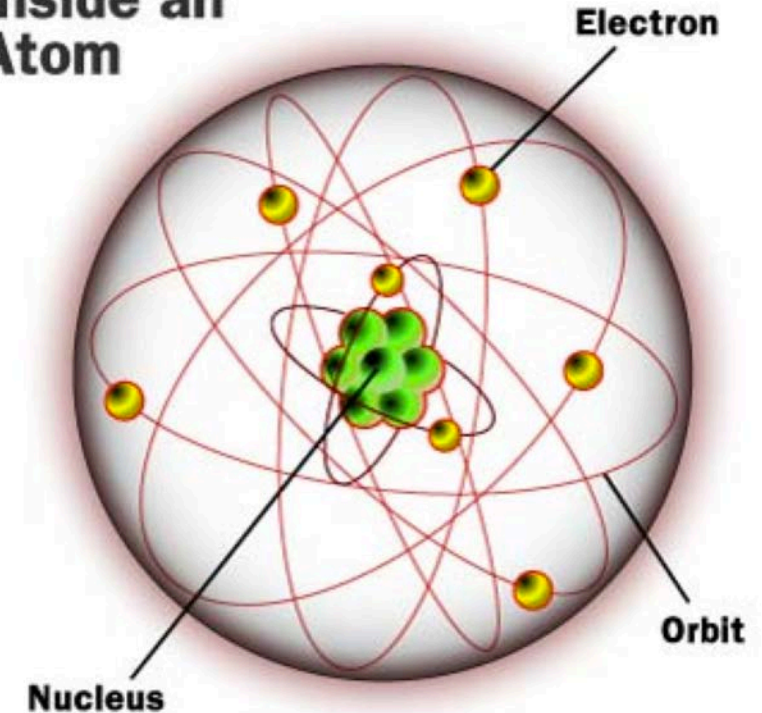


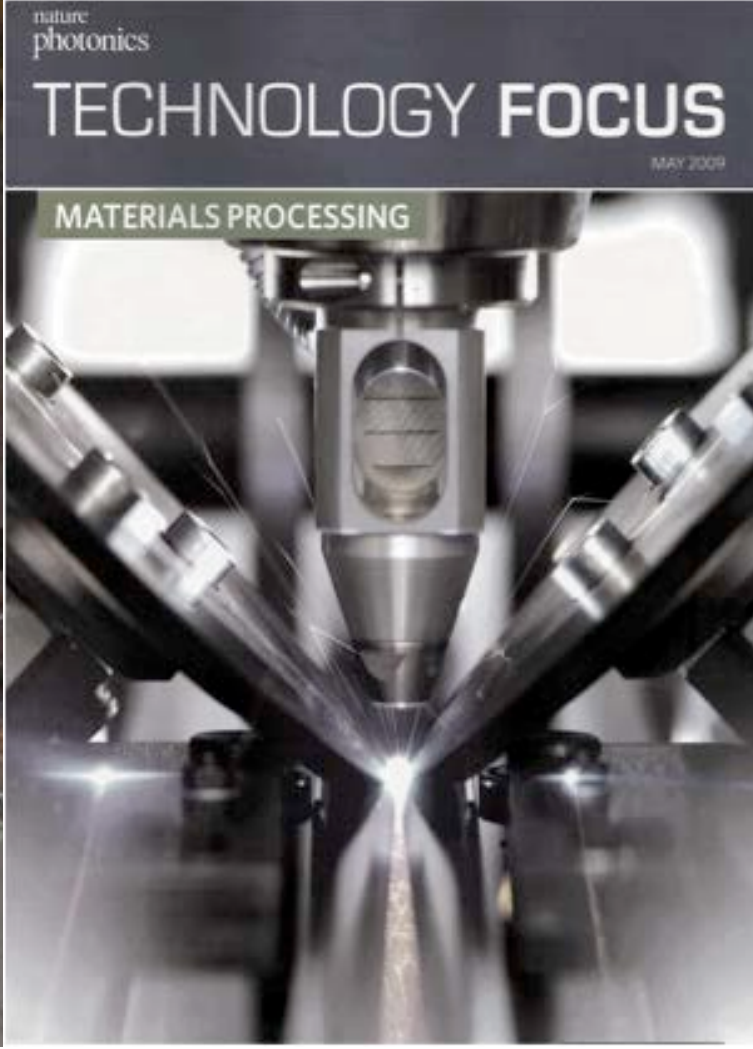
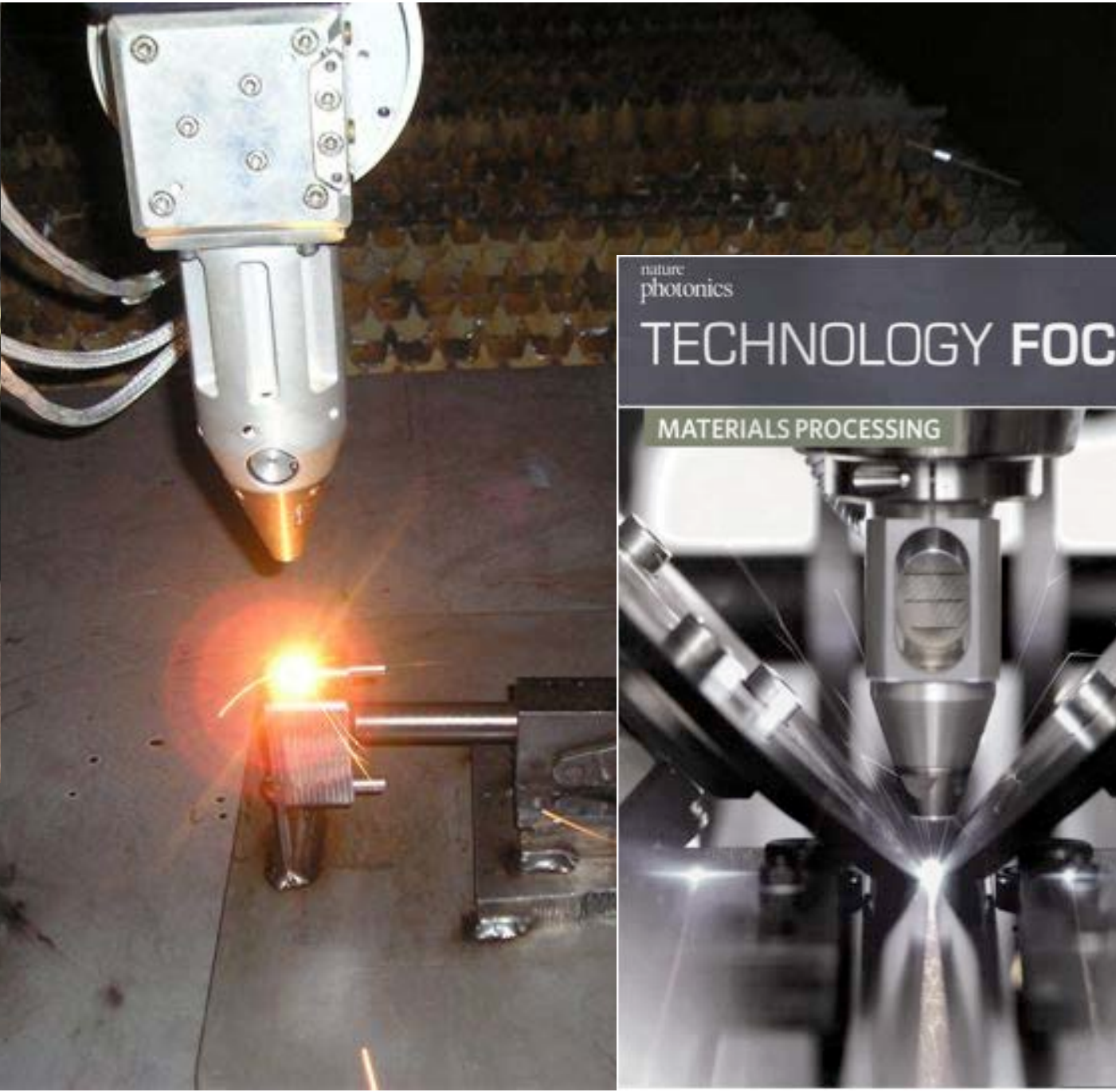
Laser Spectroscopy

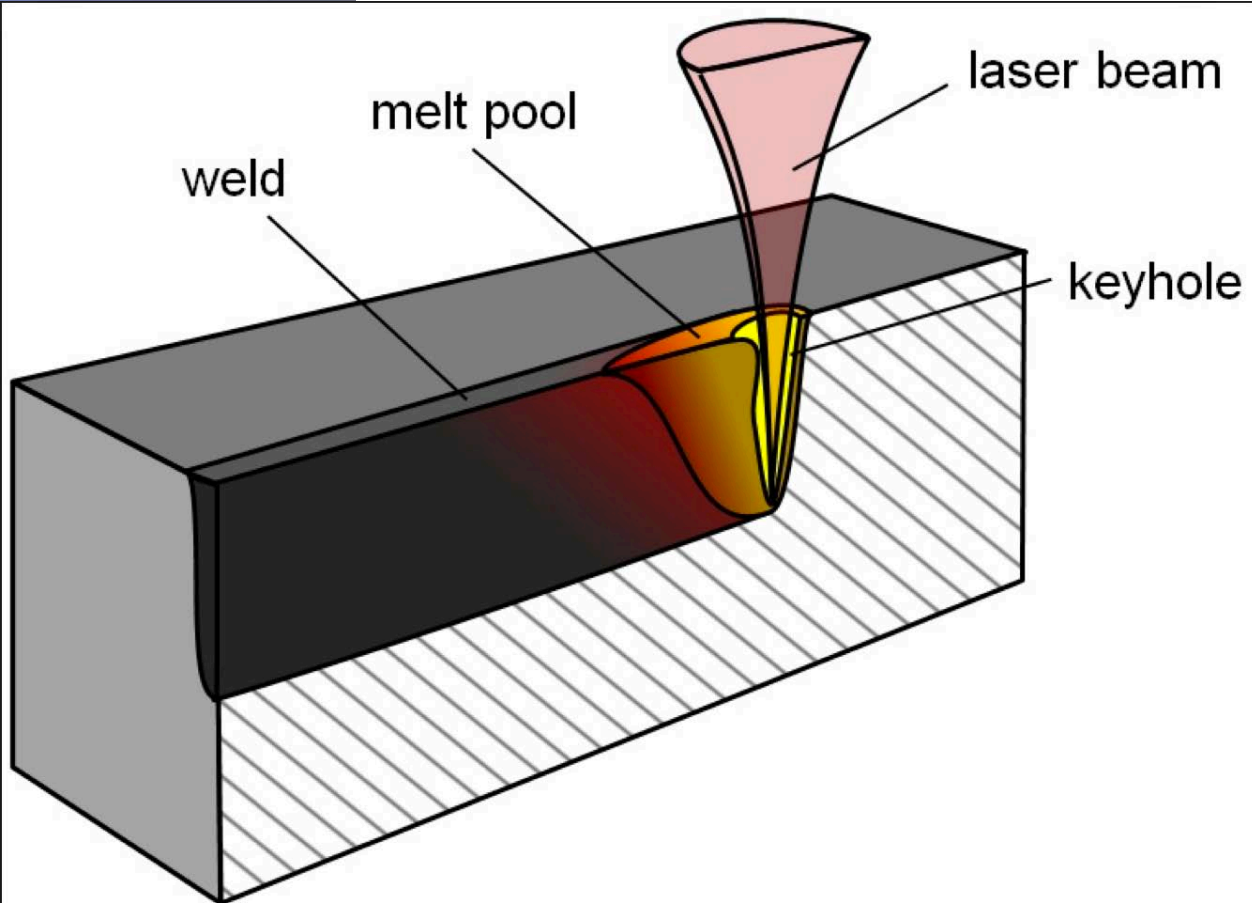
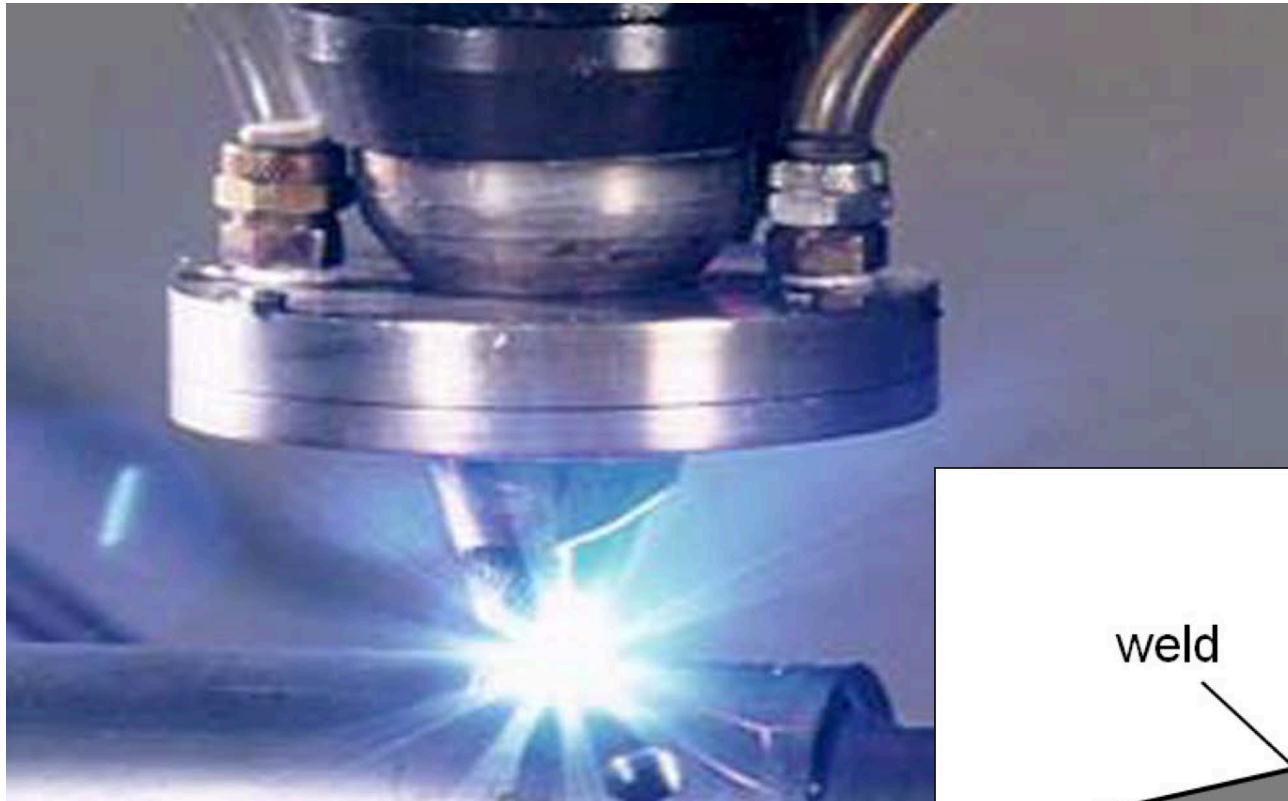
Atomic and molecular structure



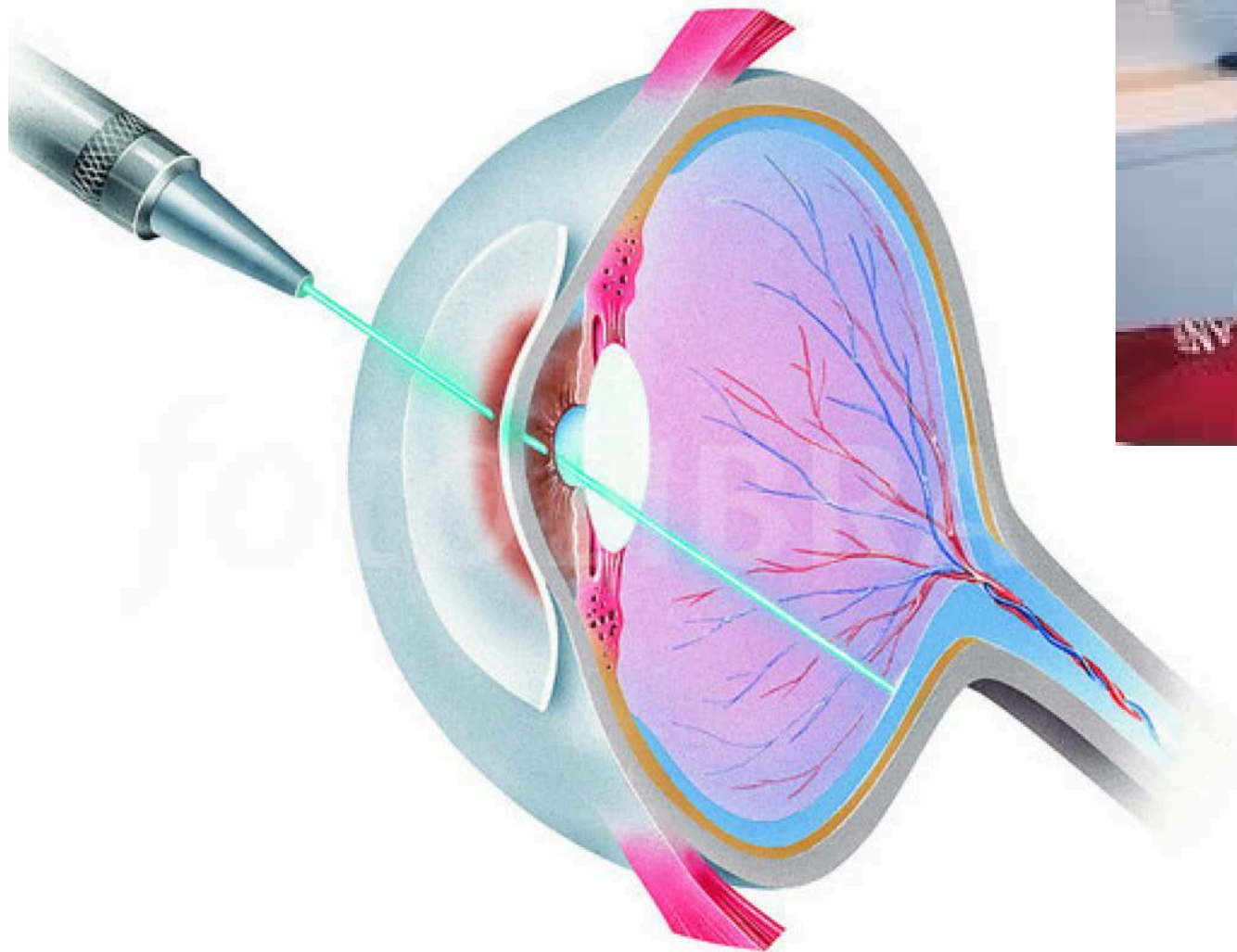
Inside an Atom



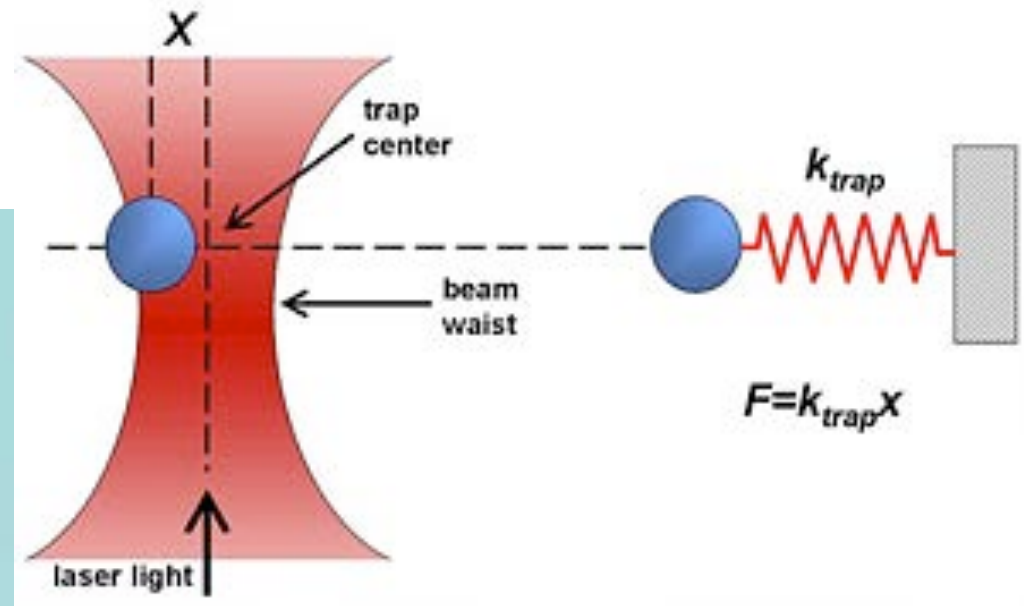
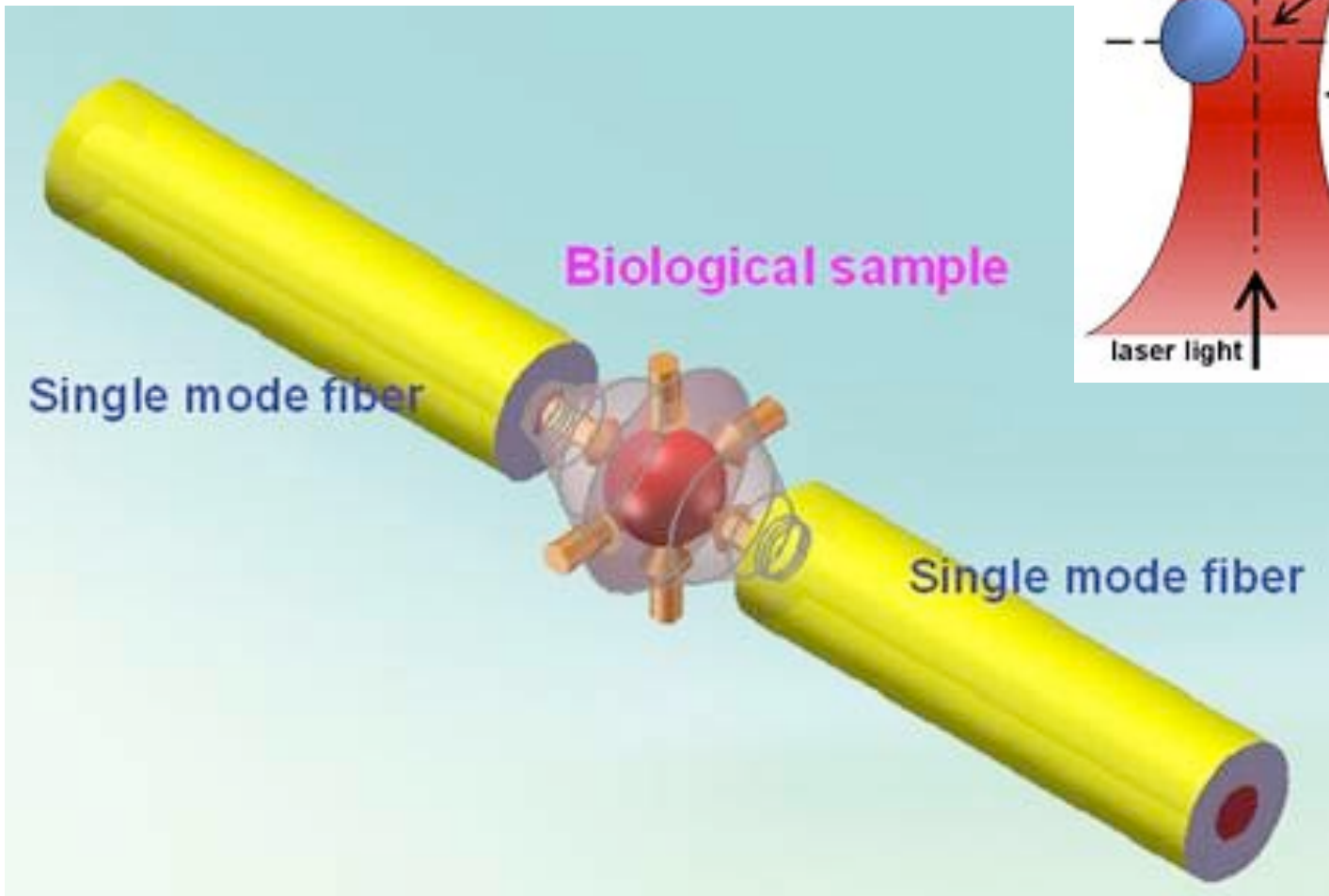




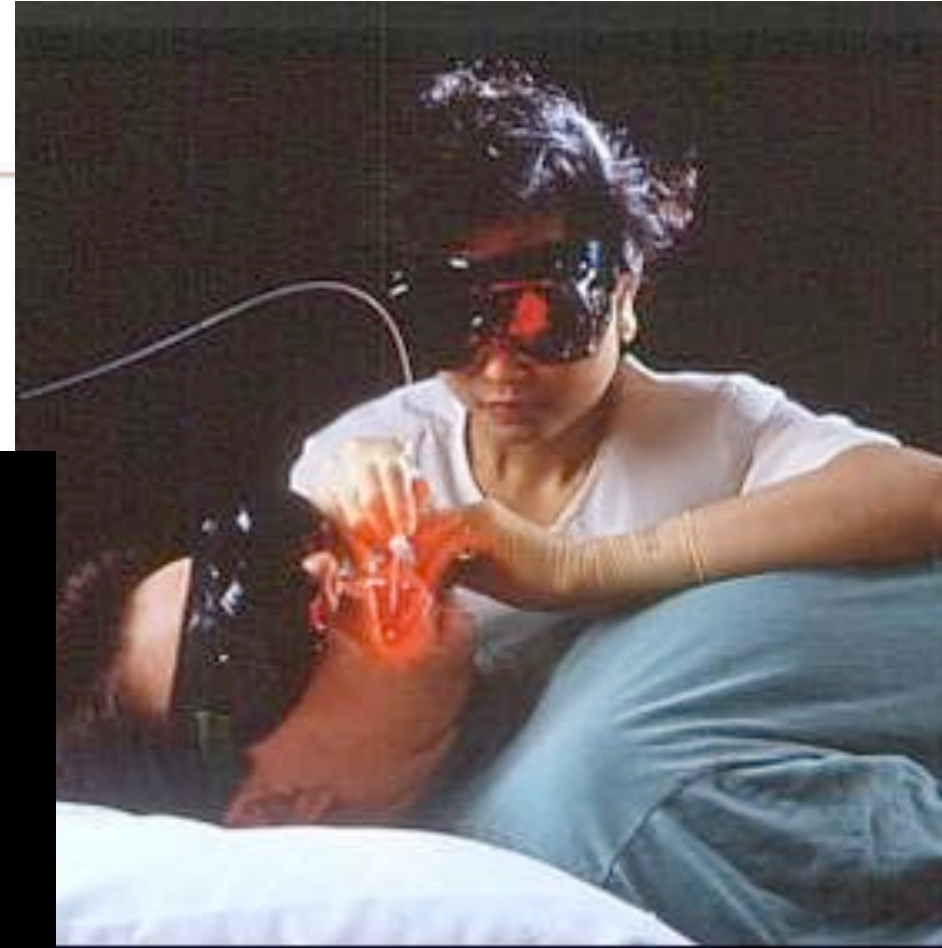
Ophthalmology



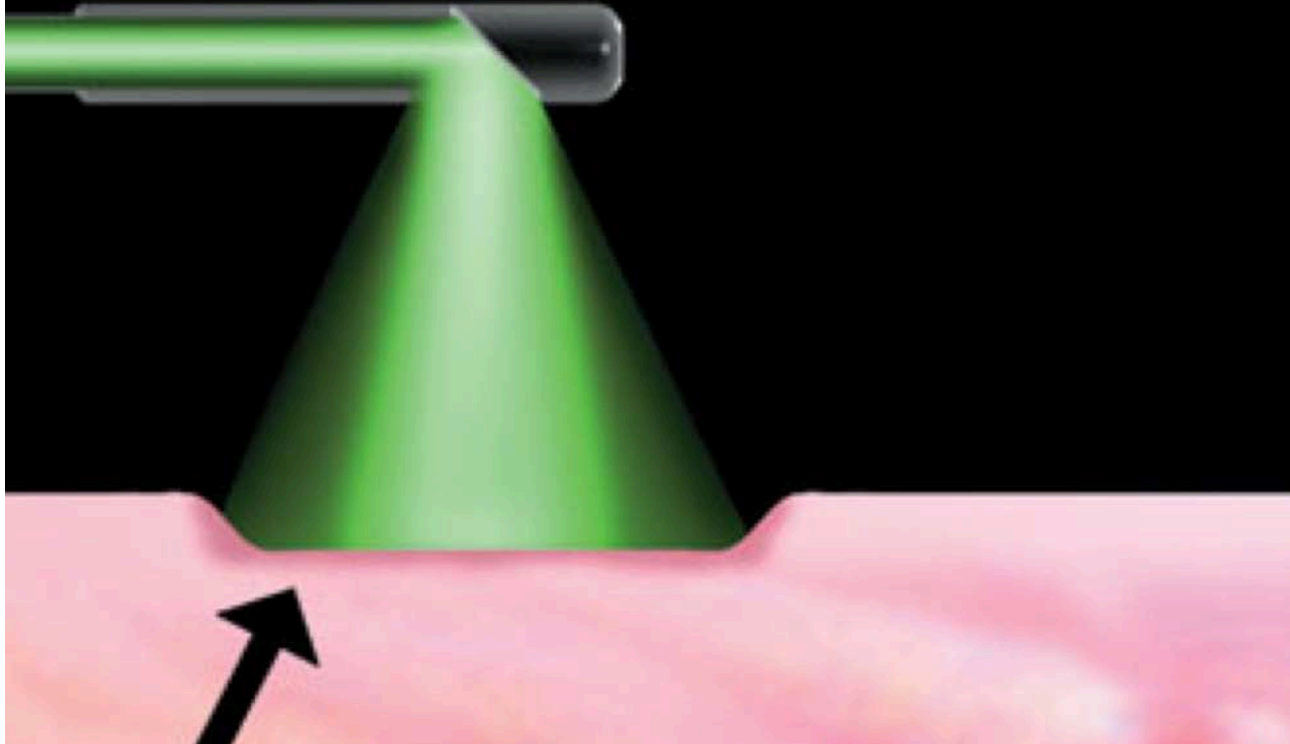
Optical tweezers



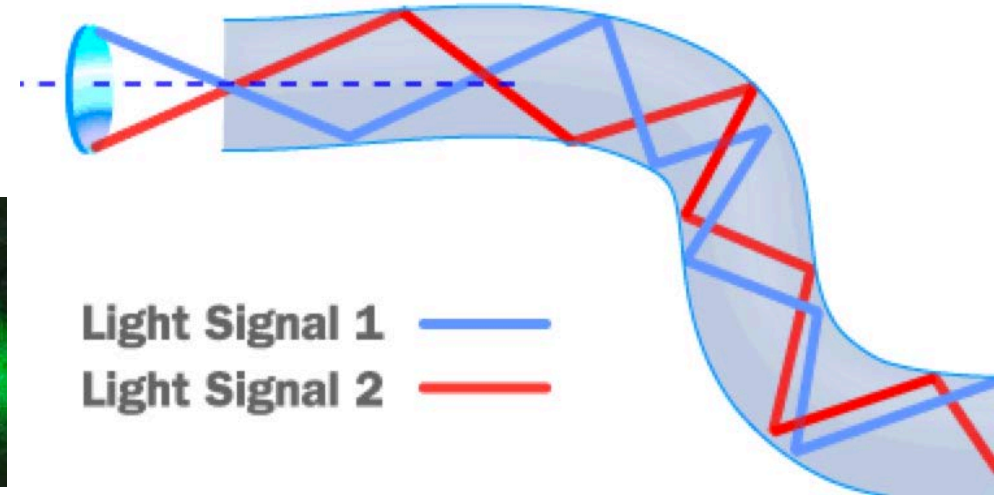
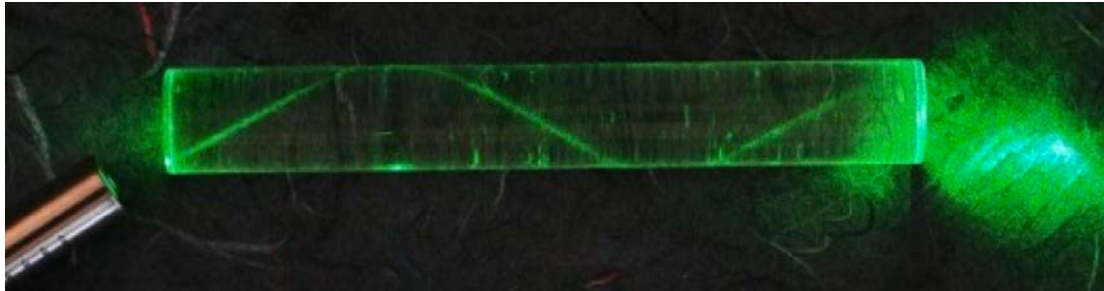
Odontology



Dermatology



Optical communications





Defense



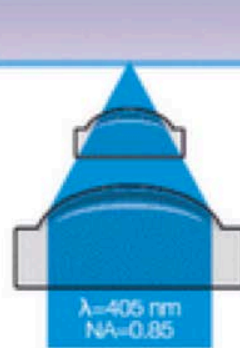
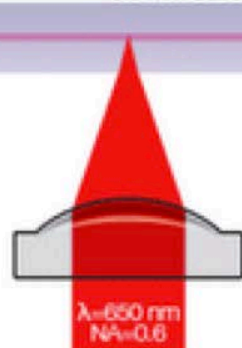
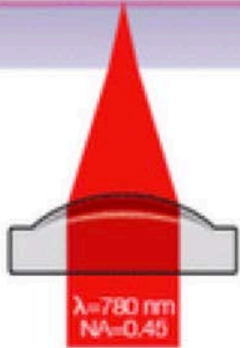
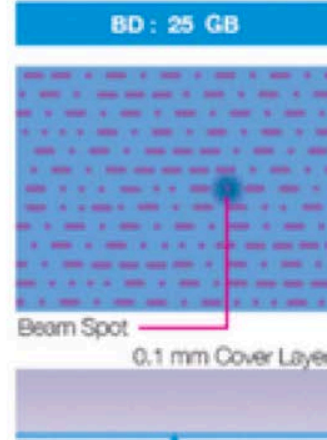
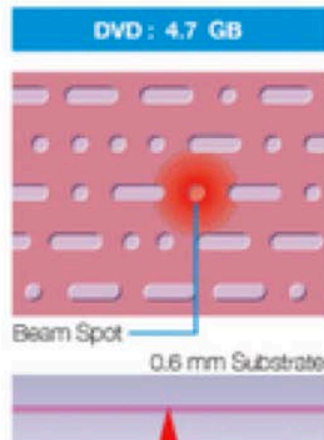
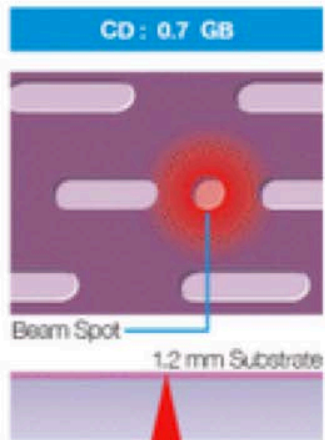
Building construction



Lasers at home



Lasers at home



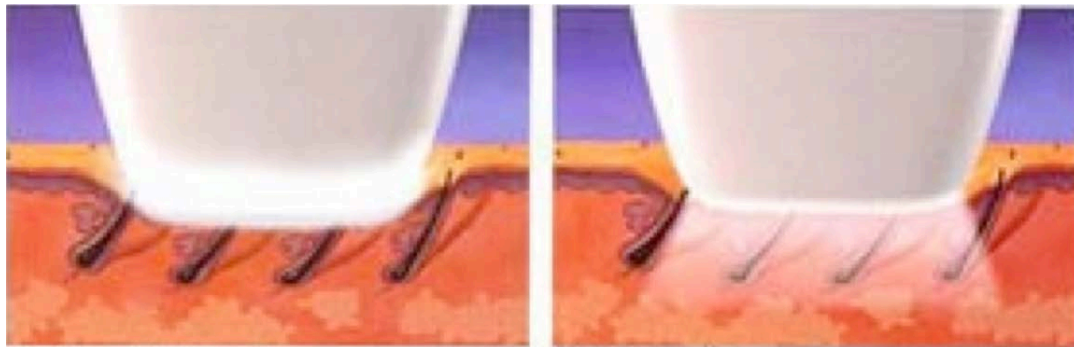
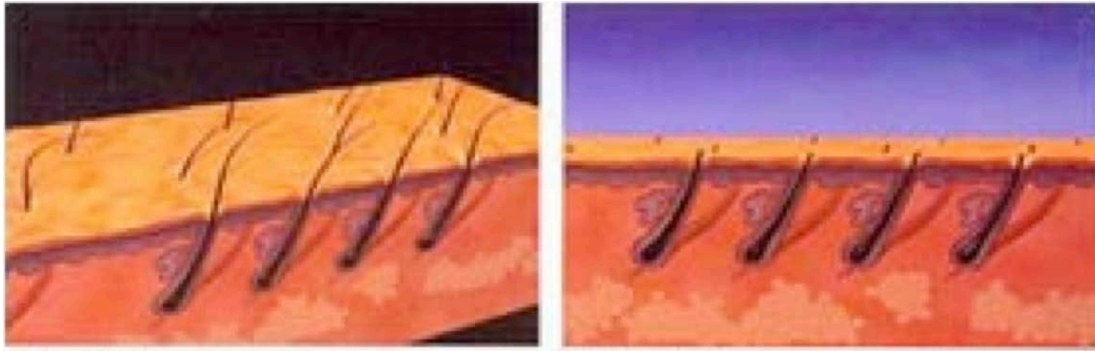
Lasers at home





+/- serious applications

Laser hair removal



Biostimulation

TerraQuant[®] Laser Powerful Pain Relief

Discover Why:

- **Patients in over 30 countries**
- **Special Forces of 7 countries**
- **NBA players**
- **National Soccer Team**
- **Olympic athletes**
- **Chronic pain sufferers**

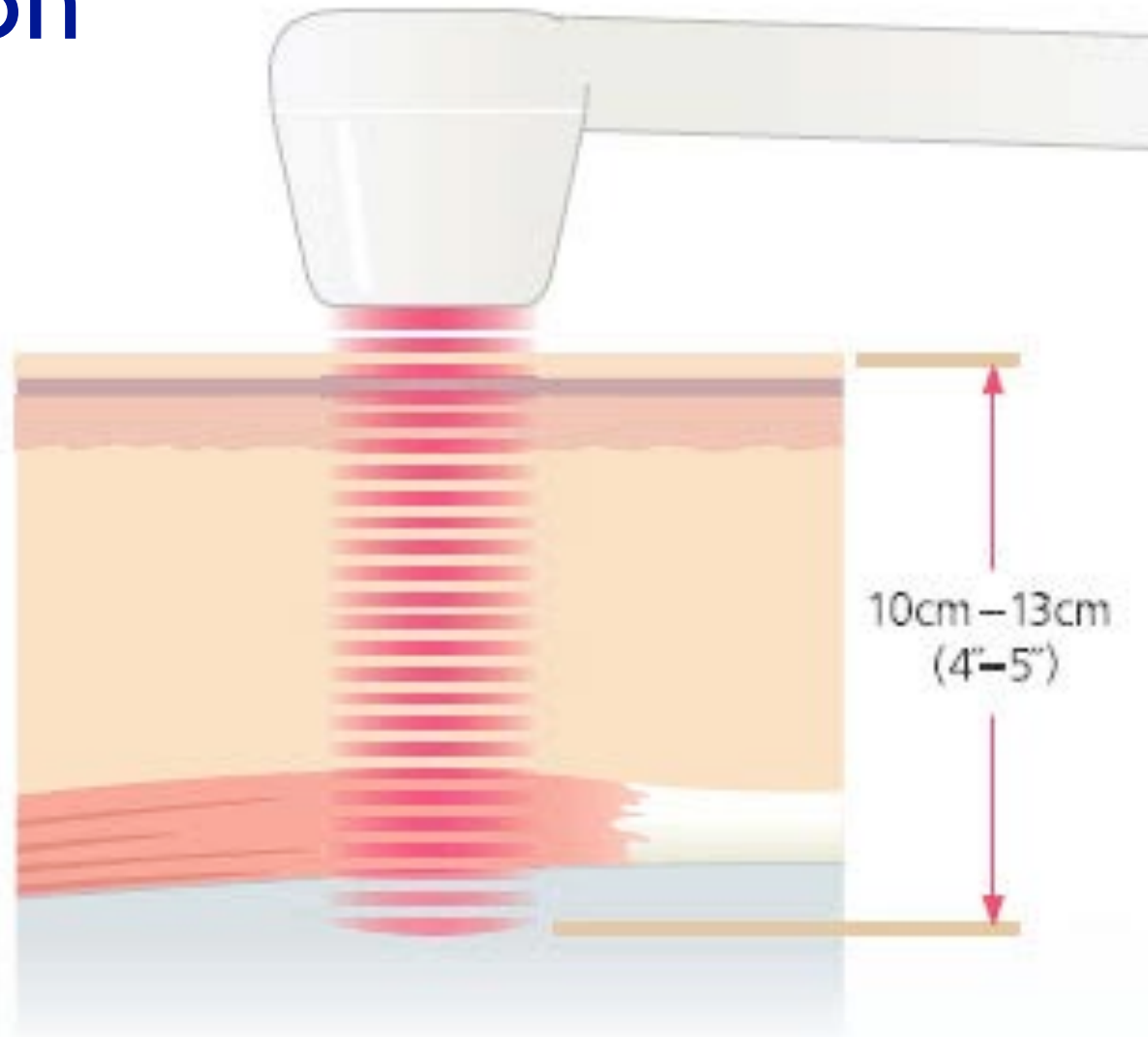
**Use Our Quantum
Laser Therapy Devices!**

**Revolutionary
Super Pulsed Laser**

Biostimulation

Super pulsed laser

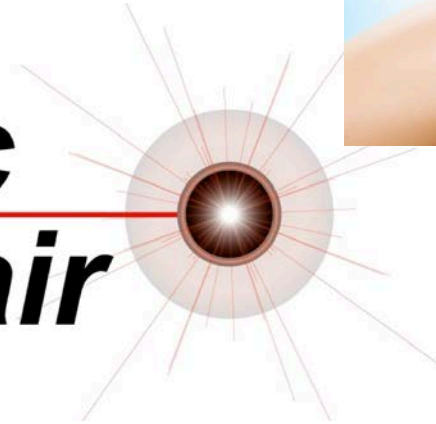
Hands Free therapy armature
Allows for unattended treatment.
Easily attaches to any cart or table.



Cosmetic applications



**Cosmetic
Laser Repair**



Lim Laser Center

812-234-5273 (LASER)



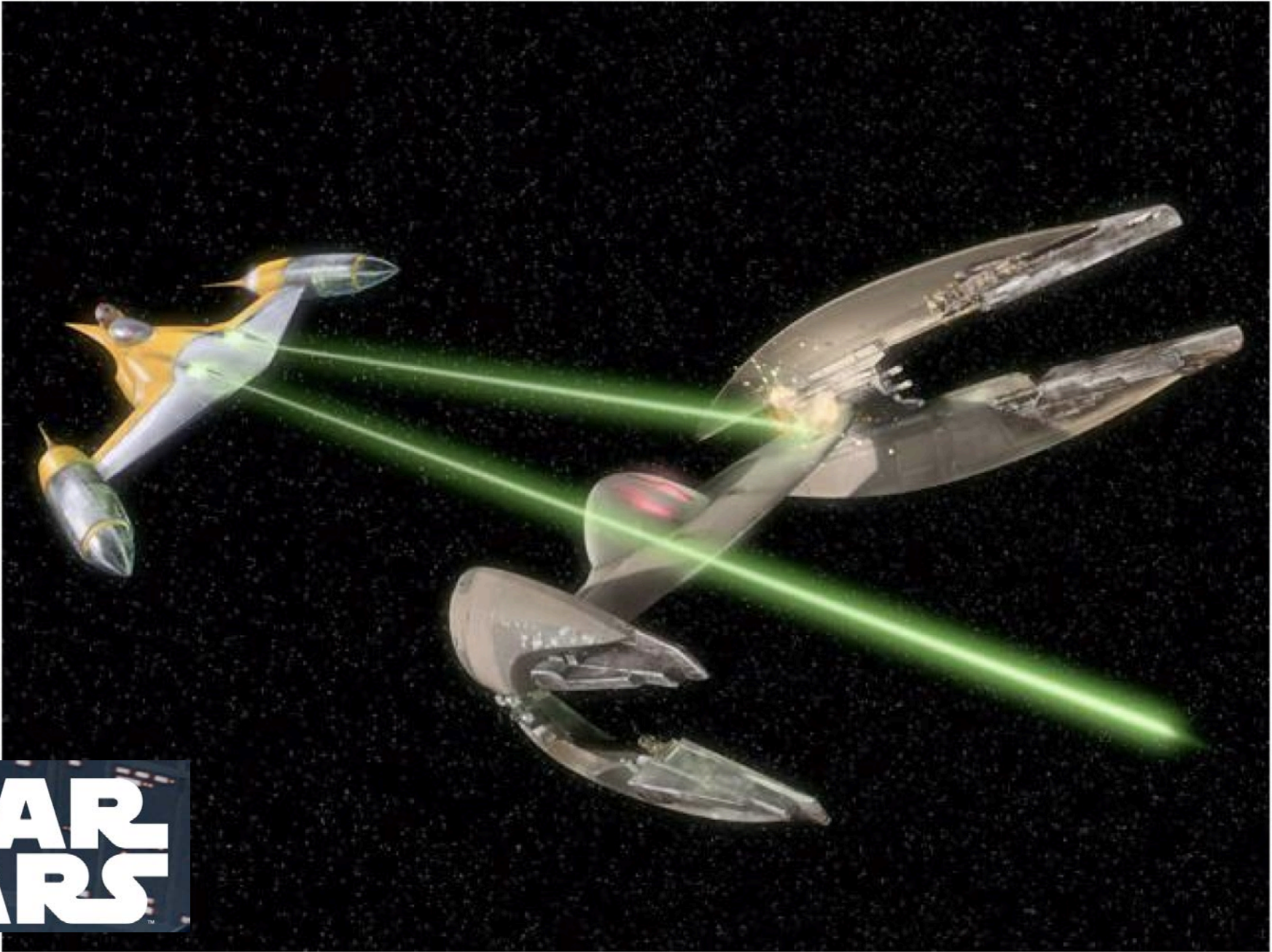


- serious applications



Laser cut ...





**STAR
WARS**

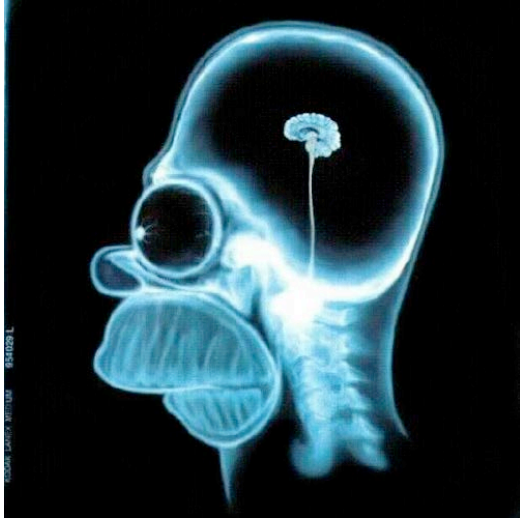


**STAR
WARS**

STAR
WARS
EPISODE I



Laser is like
our brain ...



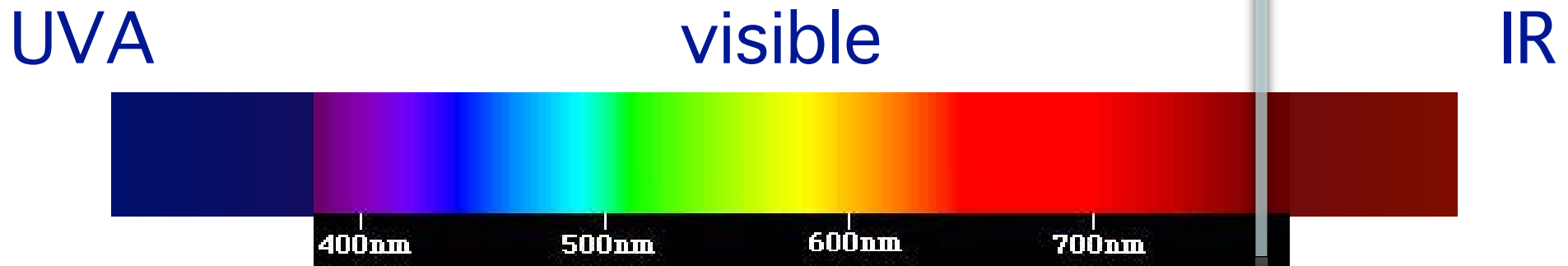
... we only use only a part of its potentiality!



Normal lasers, big lasers, and extreme lasers

 long pulse
quasi-monochromatic

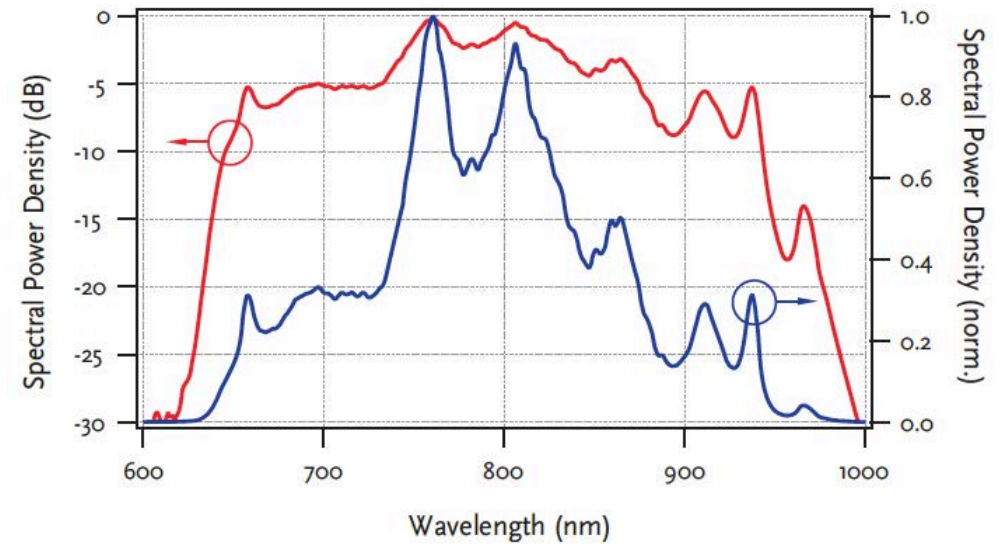
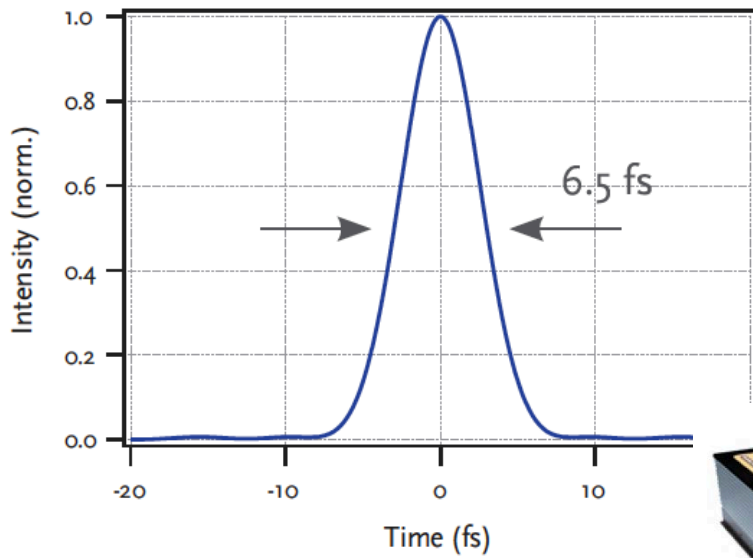
Is monochromaticity a
must for a laser to be a laser?





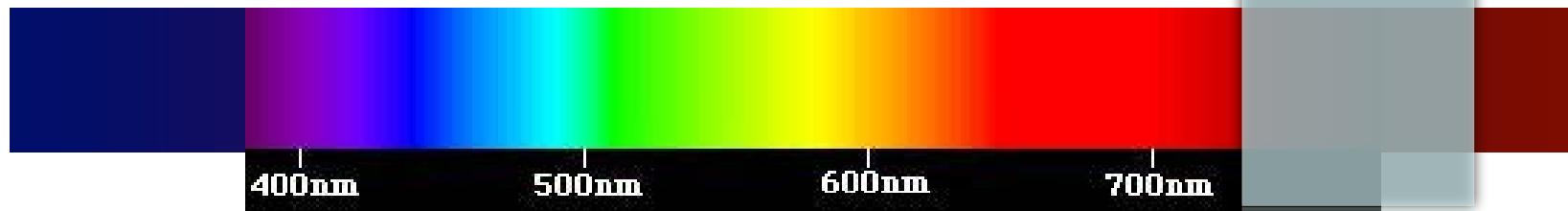
Pulsed Lasers

short pulse ... broad-band



UVA

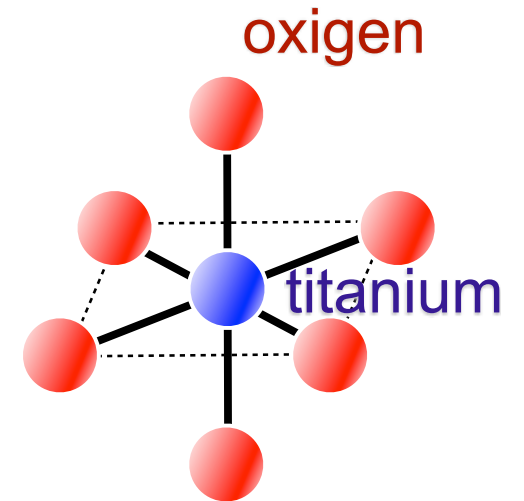
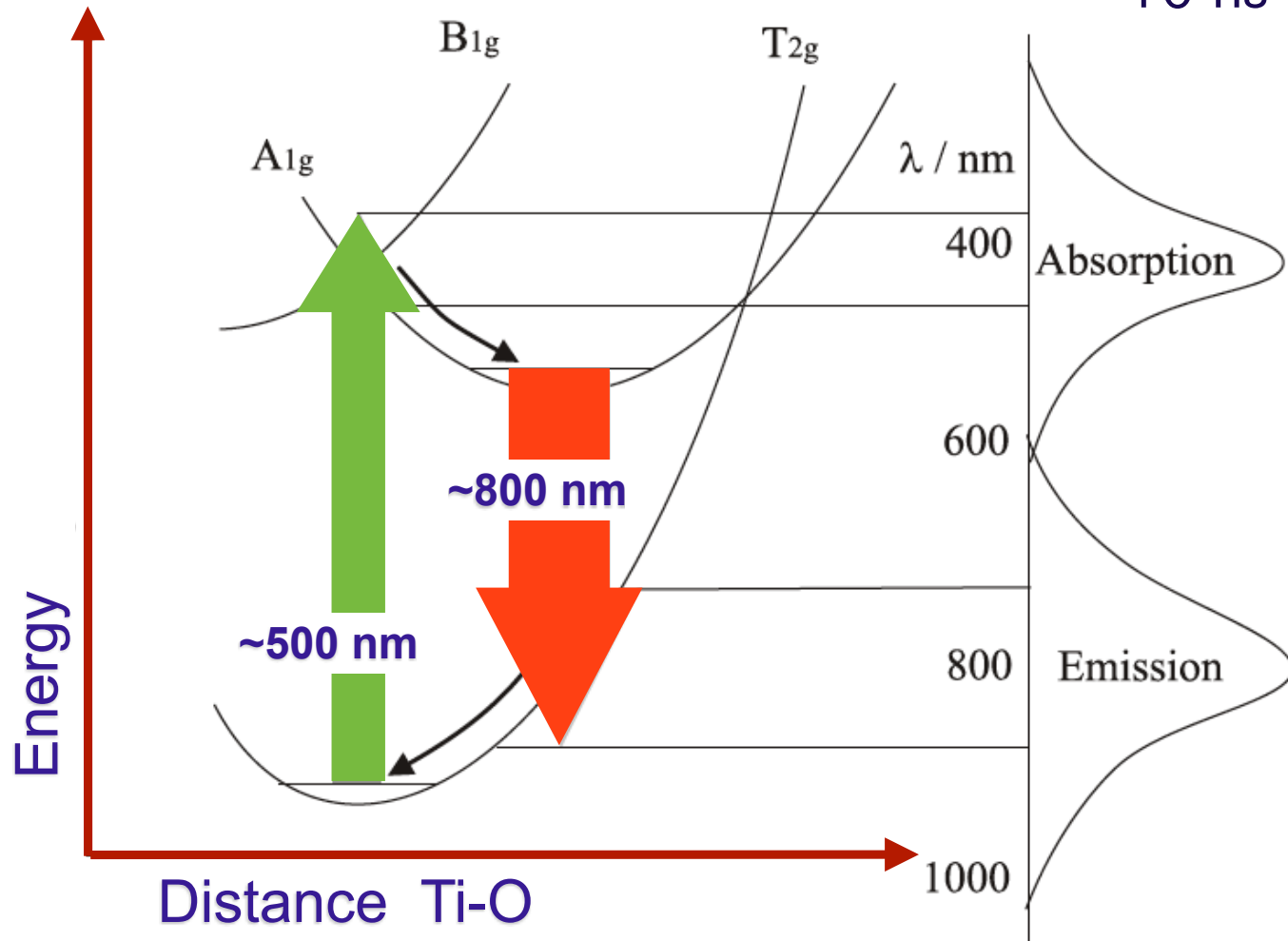
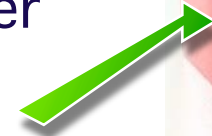
IR



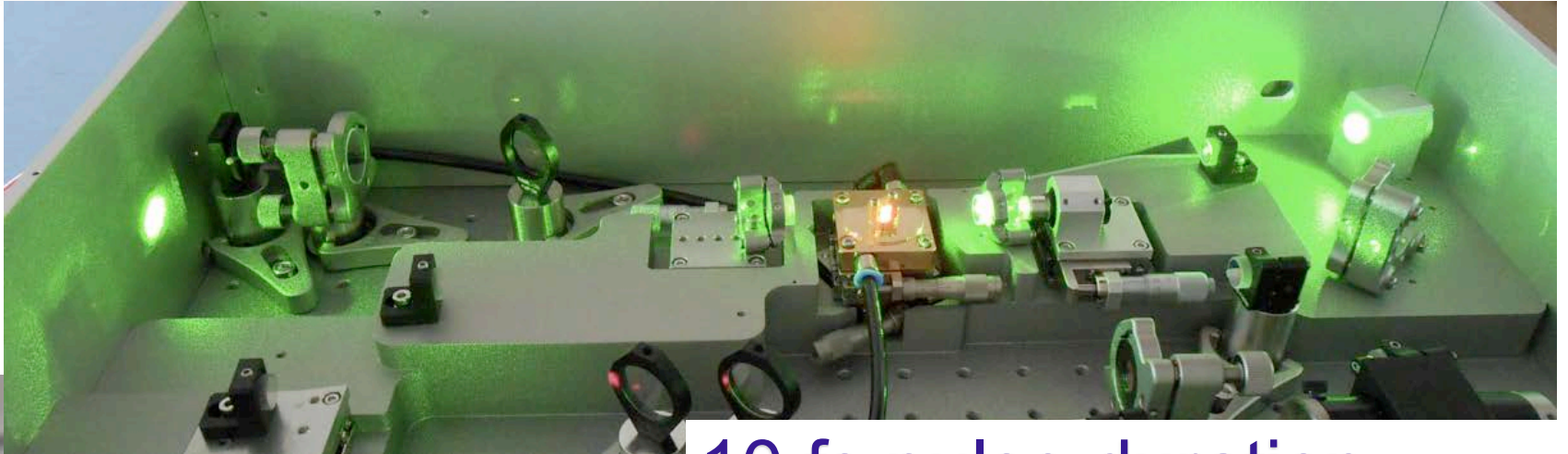
Ti-Sapphire



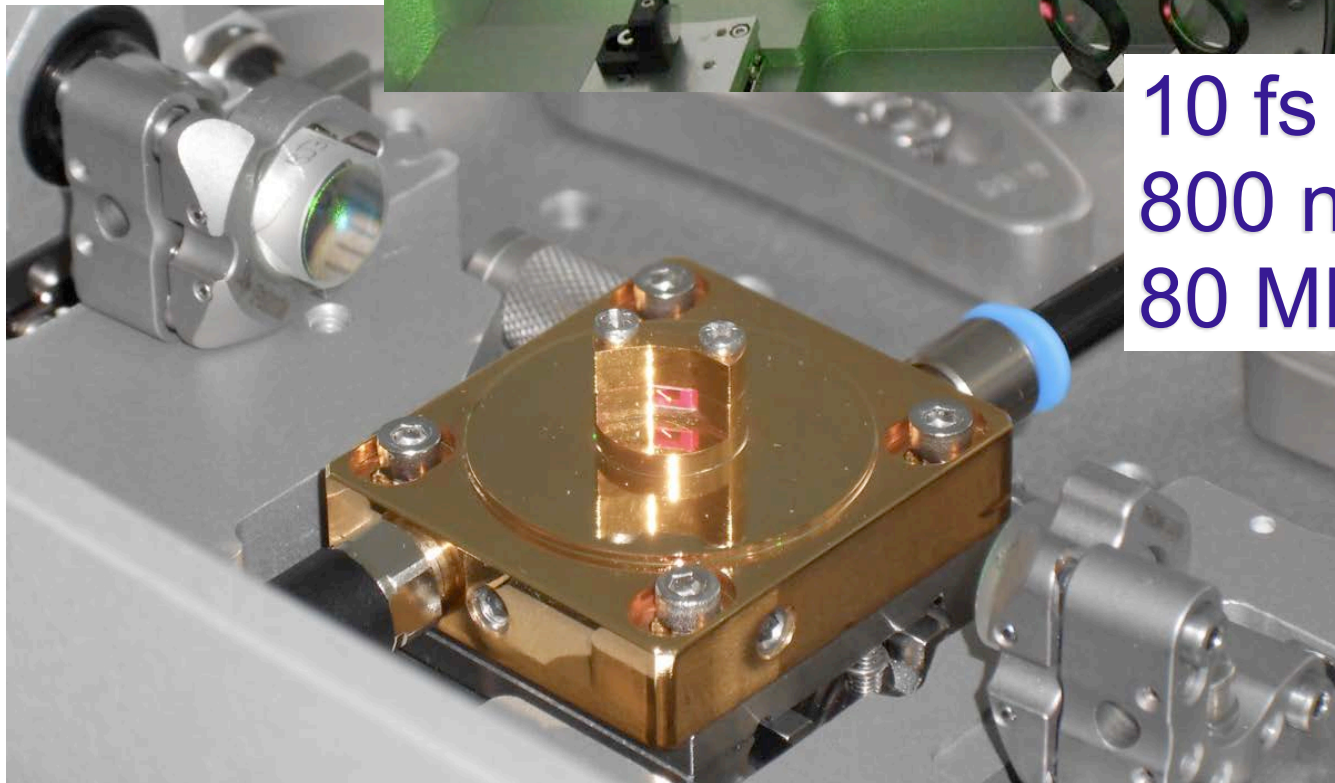
Green Laser
for Pump
10 ns pulses

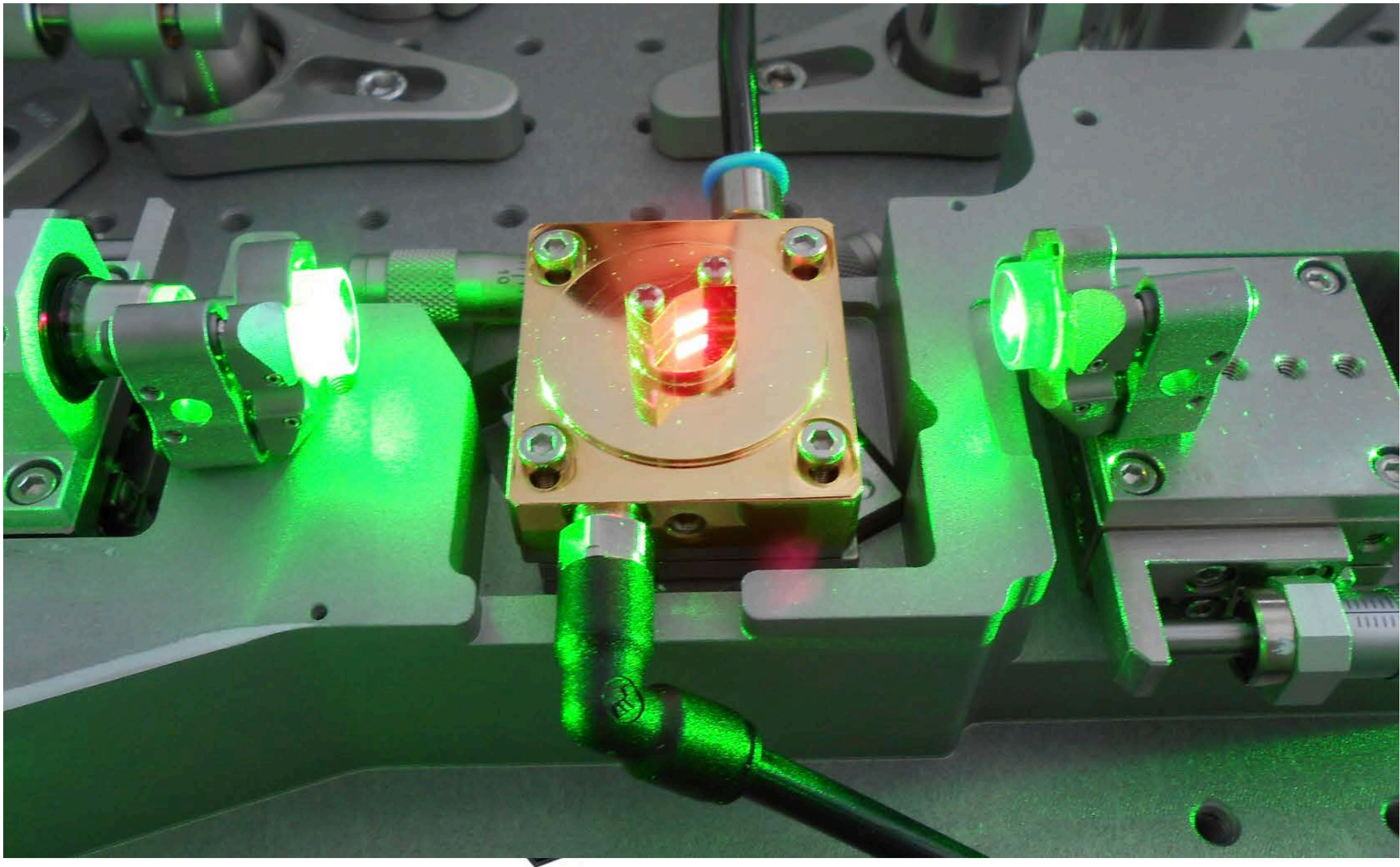


fs mode-locked oscillator



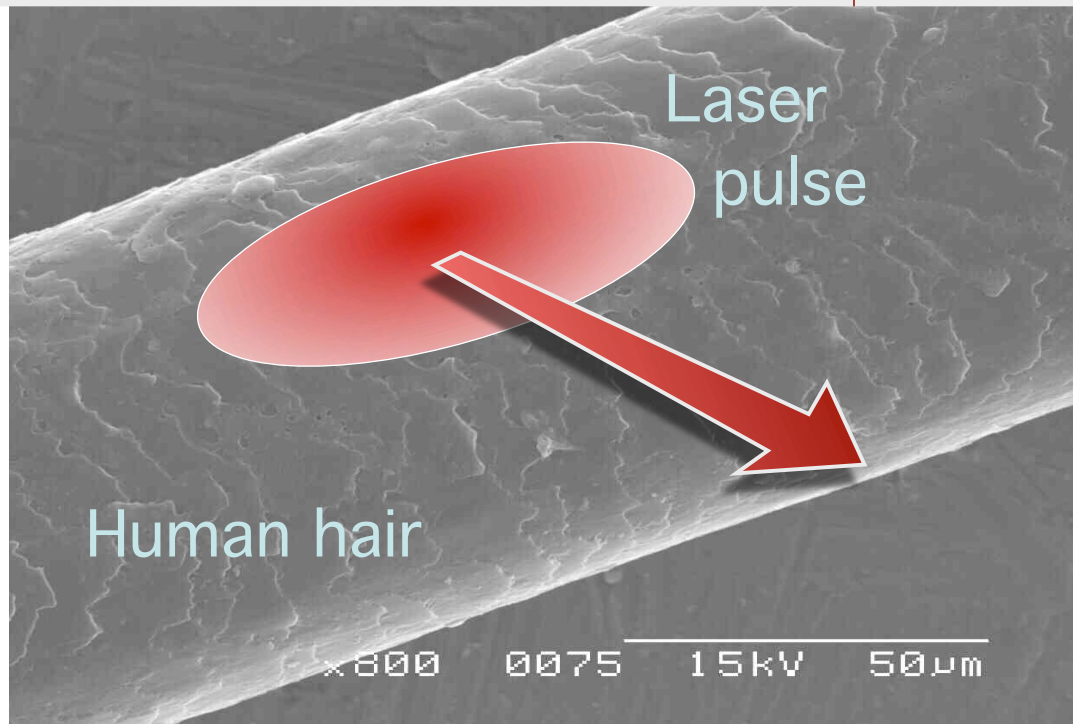
10 fs pulse duration
800 nm central wavelength
80 MHz repetition rate





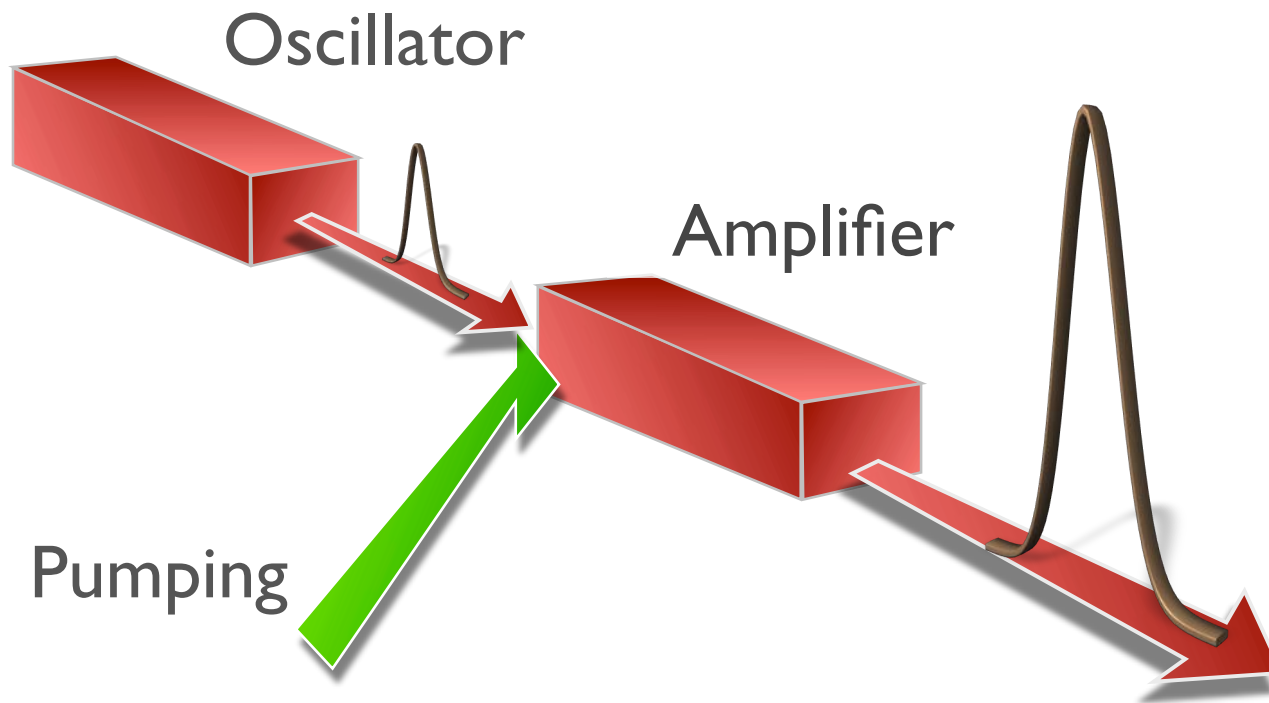
time		light speed	
second	s	1 s	300 000 km
milisecond	ms	0.001 s	300 km
microsecond	μ s	0.000001 s	300 m
nanosecond	ns	0.000000001 s	0.3 m
picosecond	ps	0.000000000001 s	0.3 mm
femtosecond	fs	0.0000000000000001 s	0.3 microns

30 femtosecond
10 microns



Oscillator + Amplifier

Main limitation for amplification is
damage threshold of the amplifier

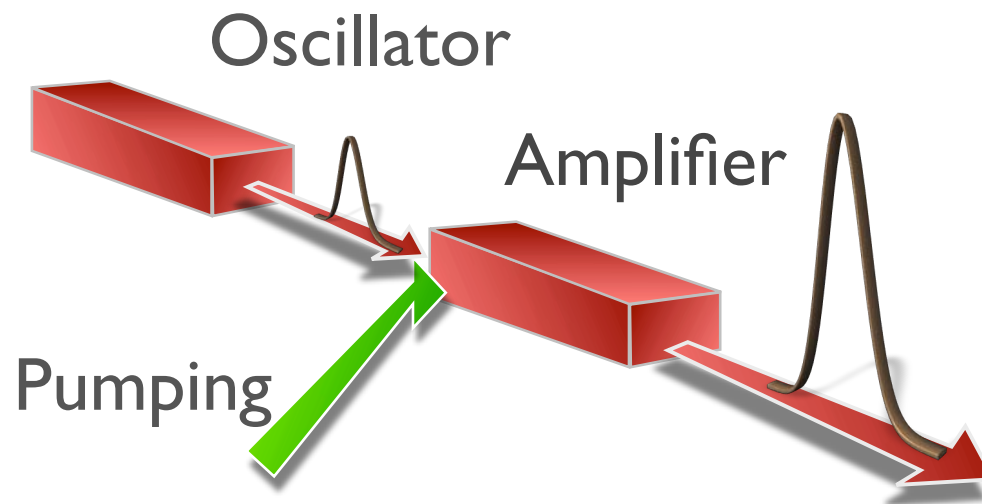


Oscillator + Amplifier

To avoid damage of the amplifier,
there are two options:

Expand the beam in transversally
... big crystals

Expand the beam longitudinally
i.e expand in time
...stretch the pulse





Big lasers

NIF National Ignition Facility

California, USA

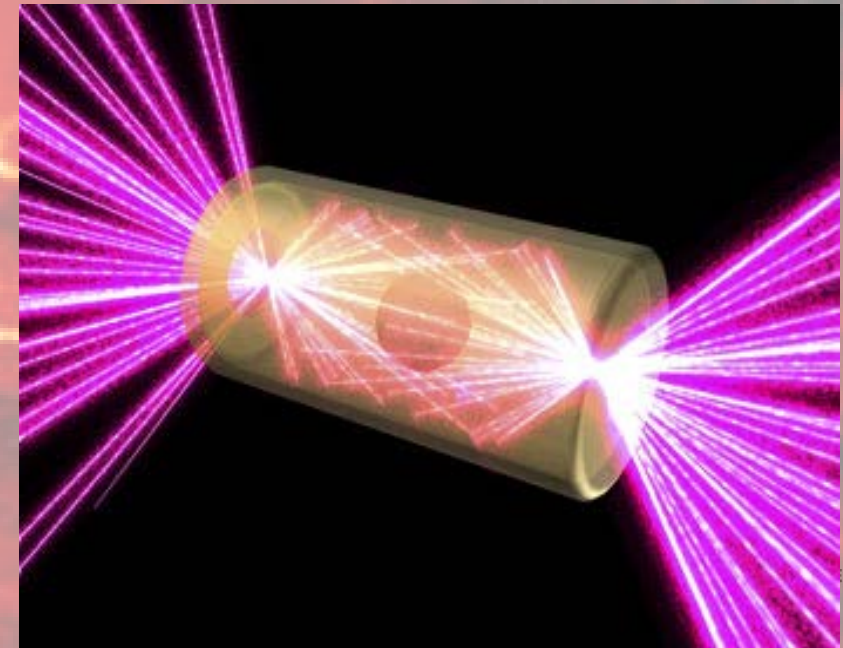
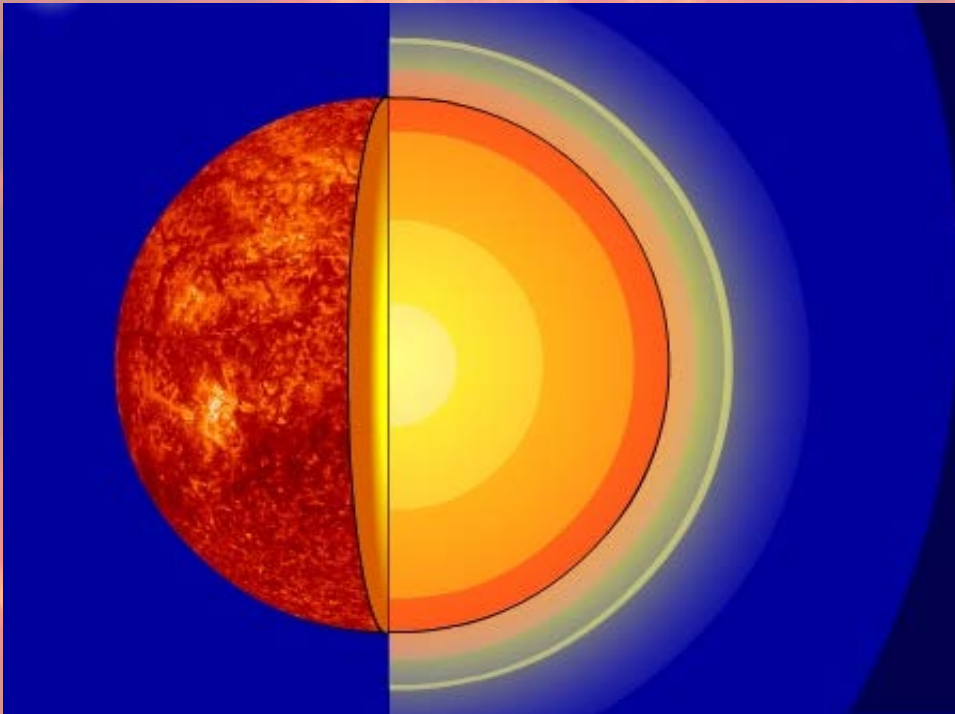


Artificial star...

C

not real scale, of course!
reduce space and time

some relevant info
on stellar core



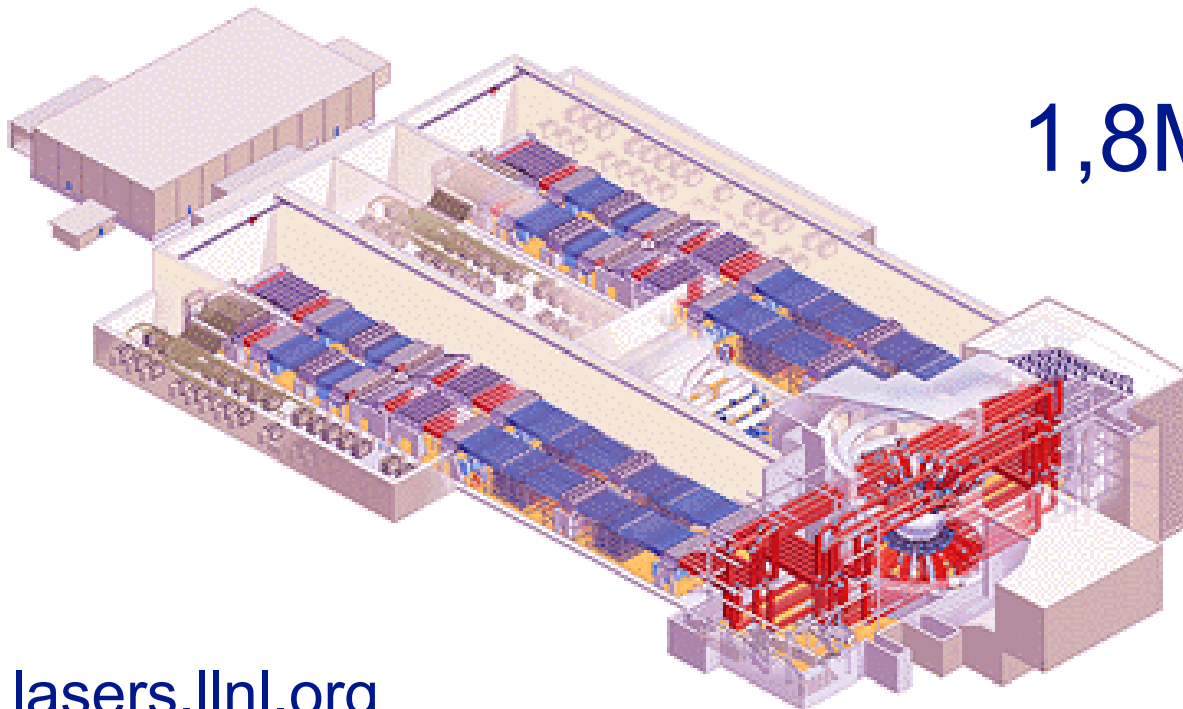
NIF National Ignition Facility ...

244 lasers

1,8 MJ per shot

5 ns a 350 nm (1050 nm /3)

$$1,8\text{MJ} / 5\text{ns} = 360 \text{ TW}$$





NIF
lasers.llnl.org

Big crystals

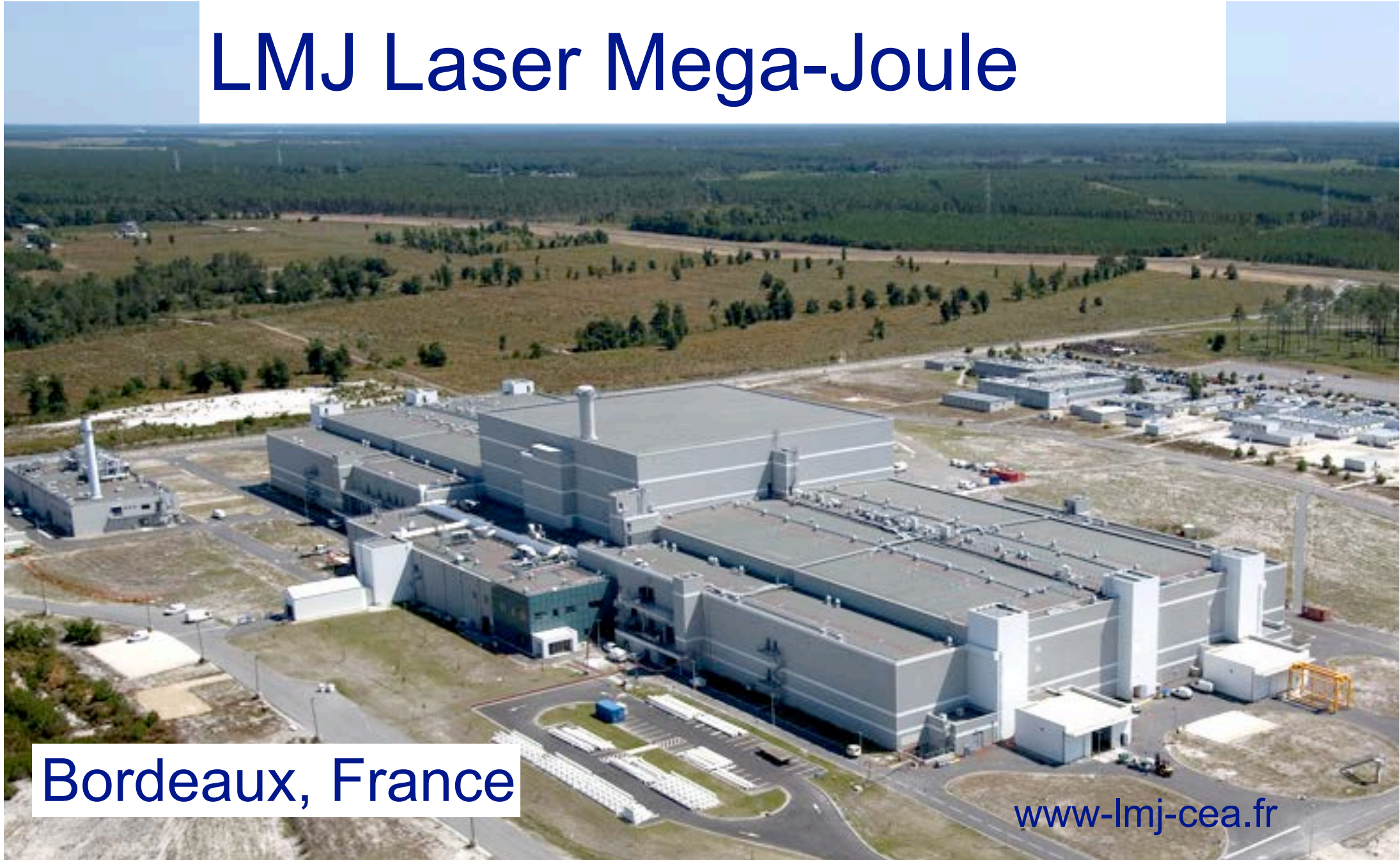


lasers.lnl.org

LMJ Laser Mega-Joule

Bordeaux, France

www-lmj-cea.fr



Laser MegaJoule

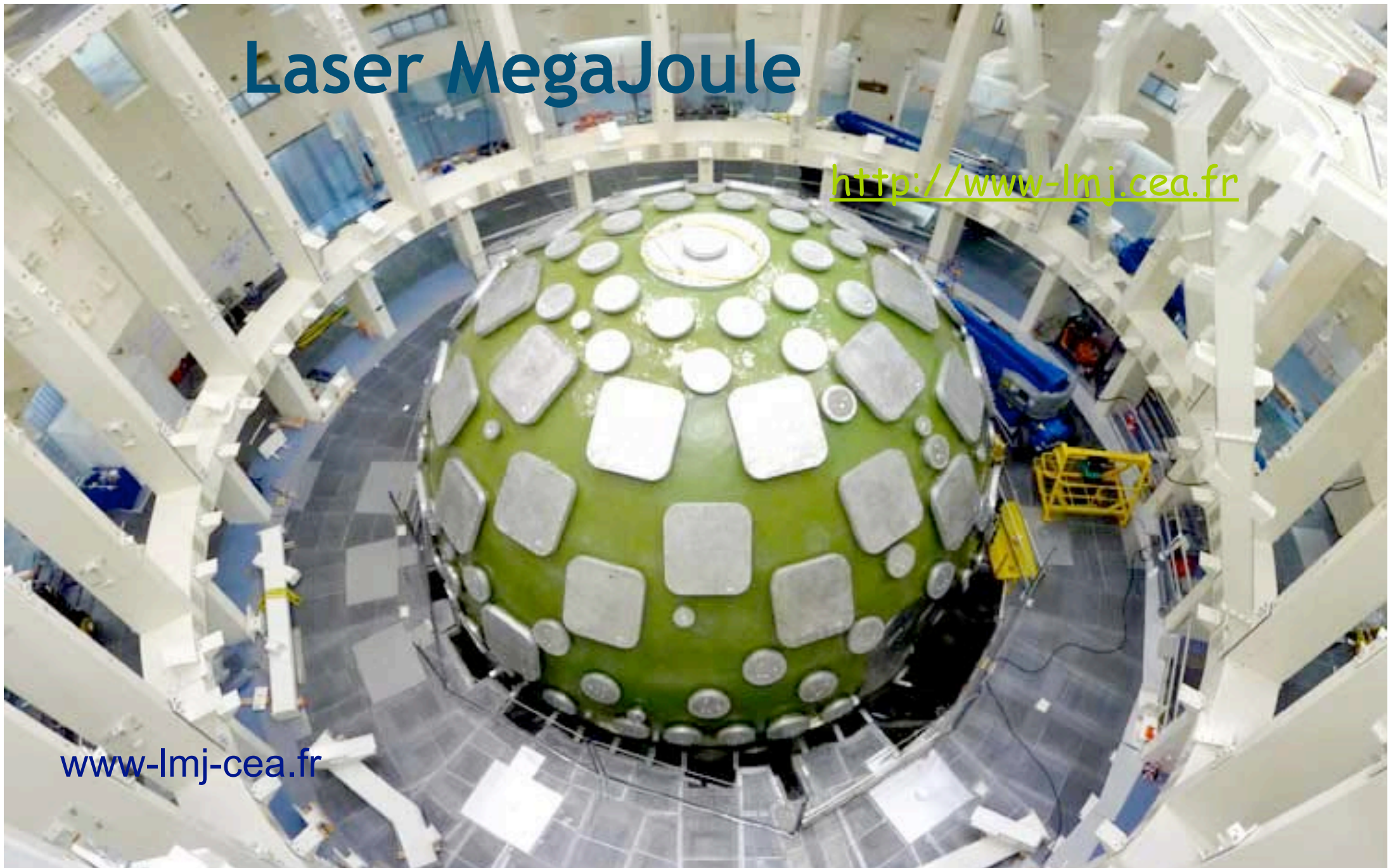
www-lmj-cea.fr

<http://www-lmj.ceia.fr>

Laser MegaJoule

<http://www-lmj.cea.fr>

www-lmj-cea.fr



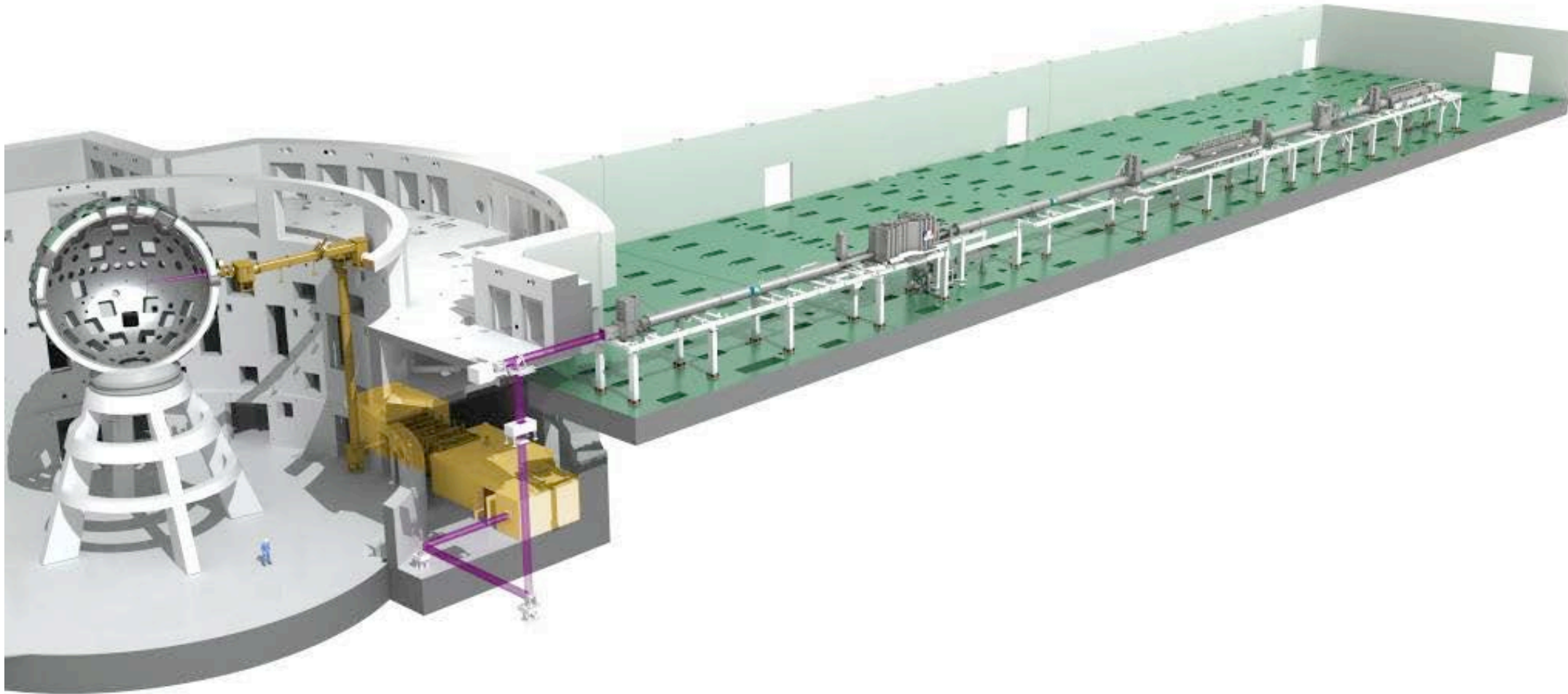
Laser MegaJoule

www-lmj-cea.fr



Laser MegaJoule

fast ignitor



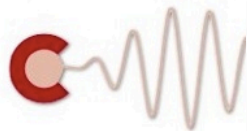
www-lmj-cea.fr



Extreme lasers



Table Top Terawatt T^3



ULTRAHIGH-INTENSITY LASERS: PHYSICS OF THE EXTREME ON A TABLETOP

Over the past ten years, laser intensities have increased by more than four orders of magnitude¹ to reach enormous intensities of 10^{20} W/cm². The field strength at these intensities is on the order of a teravolt per centimeter, or a hundred times the Coulombic field binding the ground state electron in the hydrogen atom. The electrons driven by such a field are relativistic, with an oscillatory energy of 10 MeV. At these intensities, the light pressure, $P = I/c$, is extreme, on the order of giga- to terabars. The laser interacting with matter—solid, gas, plasma—generates high-order harmonics of the incident beam up to the 3 nm wavelength range, energetic ions or electrons with mega-electron-volt energies (figure 1), gigagauss magnetic fields and violent accelerations of $10^{21} g$ (g is Earth's gravity). Finally, the interaction of an ultraintense beam with superrelativistic

By stretching, amplifying and then compressing laser pulses, one can reach petawatt powers, gigagauss magnetic fields, terabar light pressures and 10^{22} m/s² electron accelerations.

G rard A. Mourou, Christopher P. J. Barty and Michael D. Perry

for laser fusion. Lawrence Livermore National Laboratory, Los Alamos National Laboratory, the Commissariat   l'Energie Atomique (CEA) in Paris, the Rutherford Appleton Laboratory in the UK and the Institute of Laser Engineering in Osaka, Japan, have all added subpicosecond pulse capabilities to their nanosecond lasers, pushing their peak power by three orders of magnitude from 1 terawatt to 100–1000 TW.

Figure 2 presents the focused intensity of lasers as a

time-resolved x-ray experiments in the femtosecond range, or at the Stanford Linear Accelerator Center (SLAC) to test nonlinear quantum electrodynamics by the interaction of the high-intensity pulses with superrelativistic electrons.

Some of the new tabletop-laser principles have been implemented on existing large laser systems built



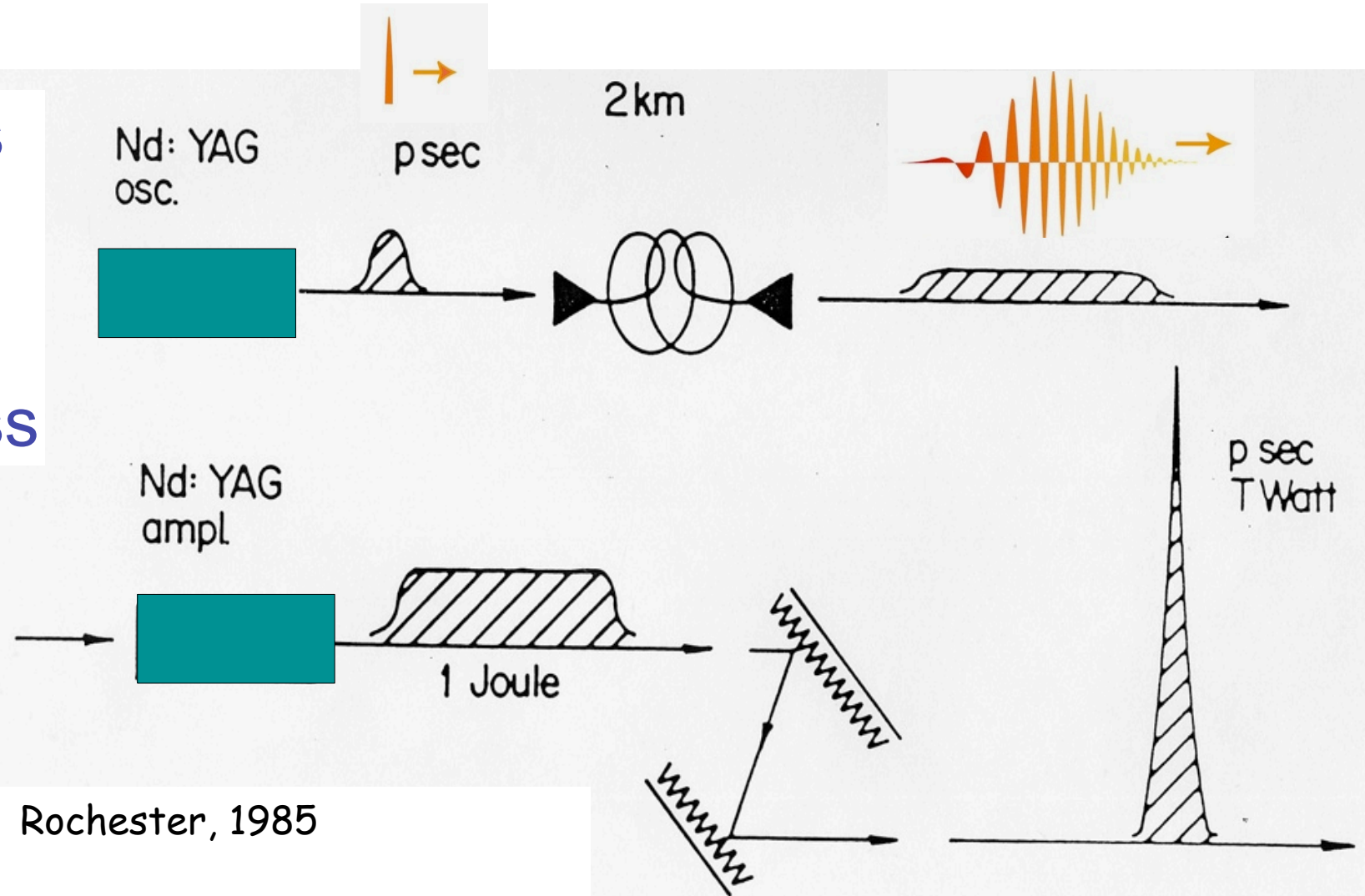
Chirped Pulse Amplification, CPA

Three steps

1.- stretch

2.- amplify

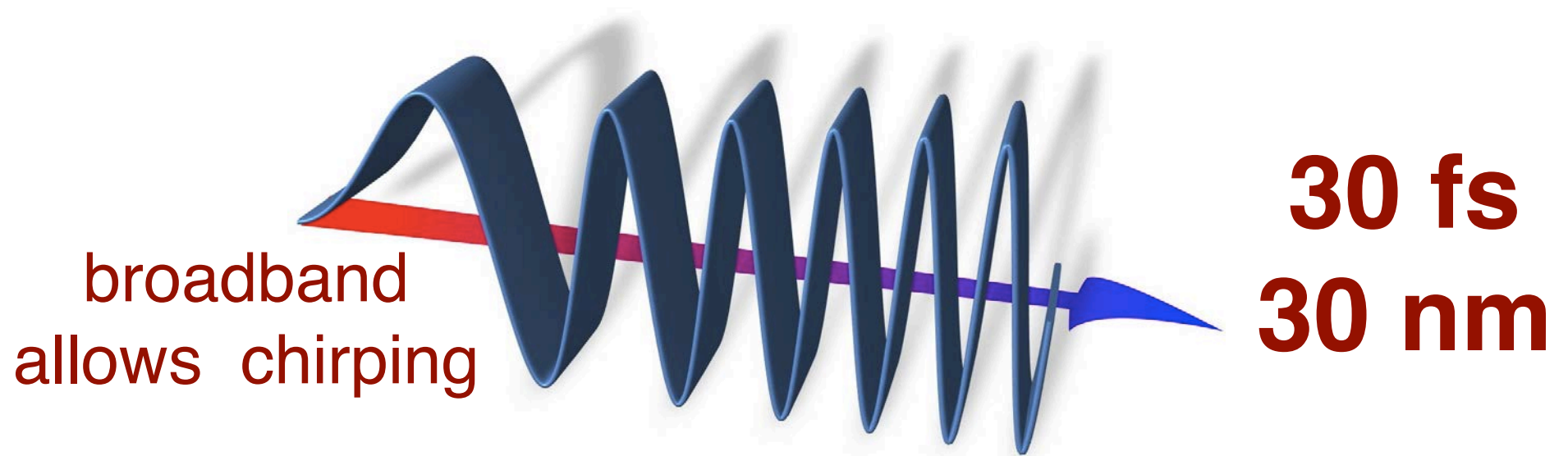
3.- compress



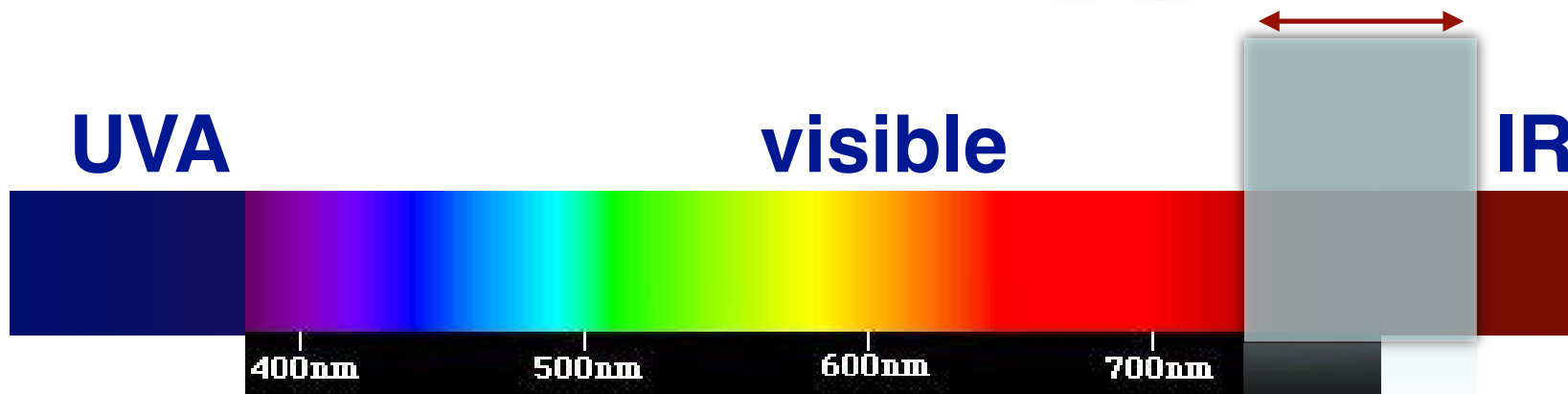
Gerard Mourou, Rochester, 1985
Donna Strickland



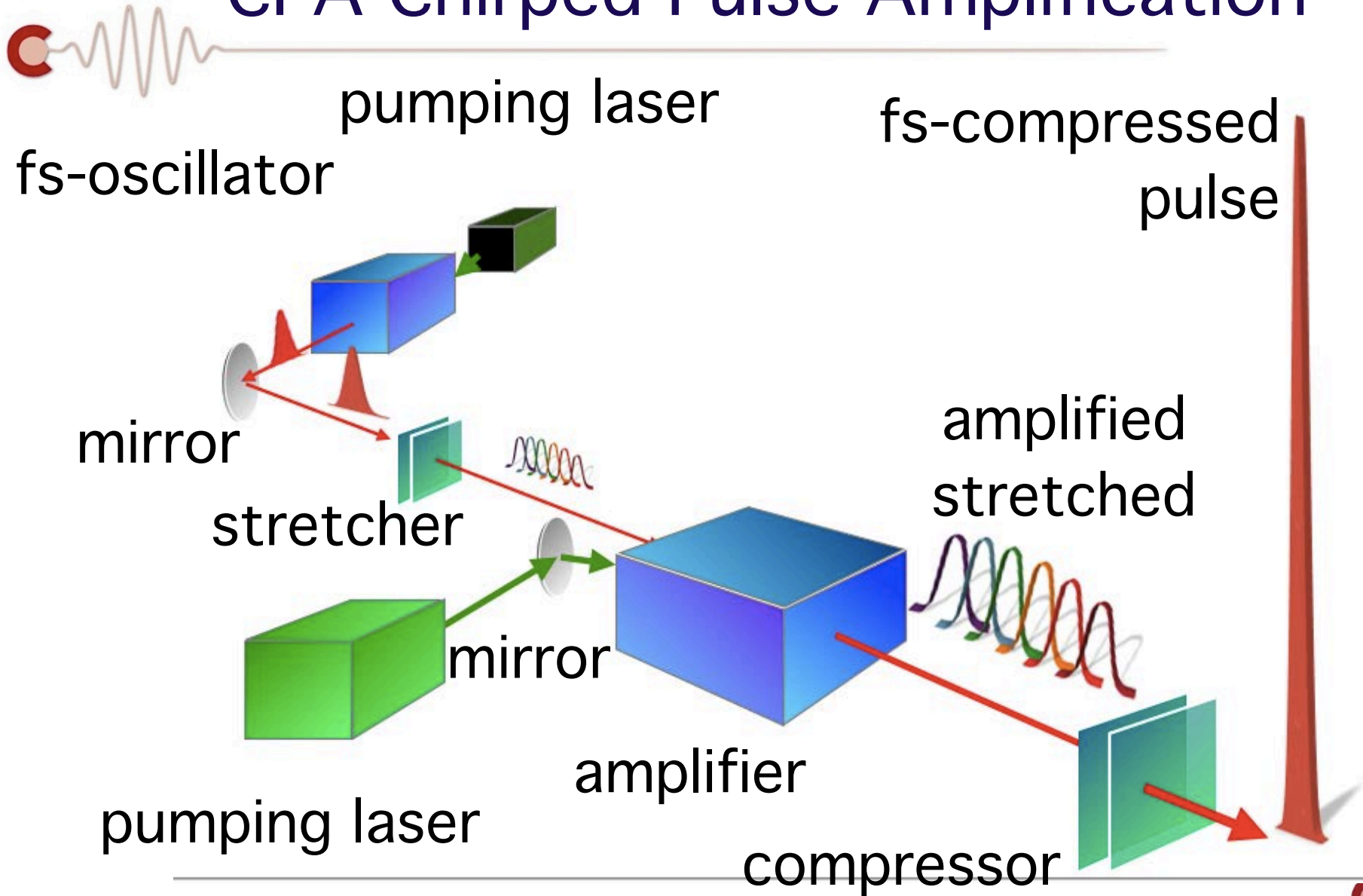
short pulse = broadband laser

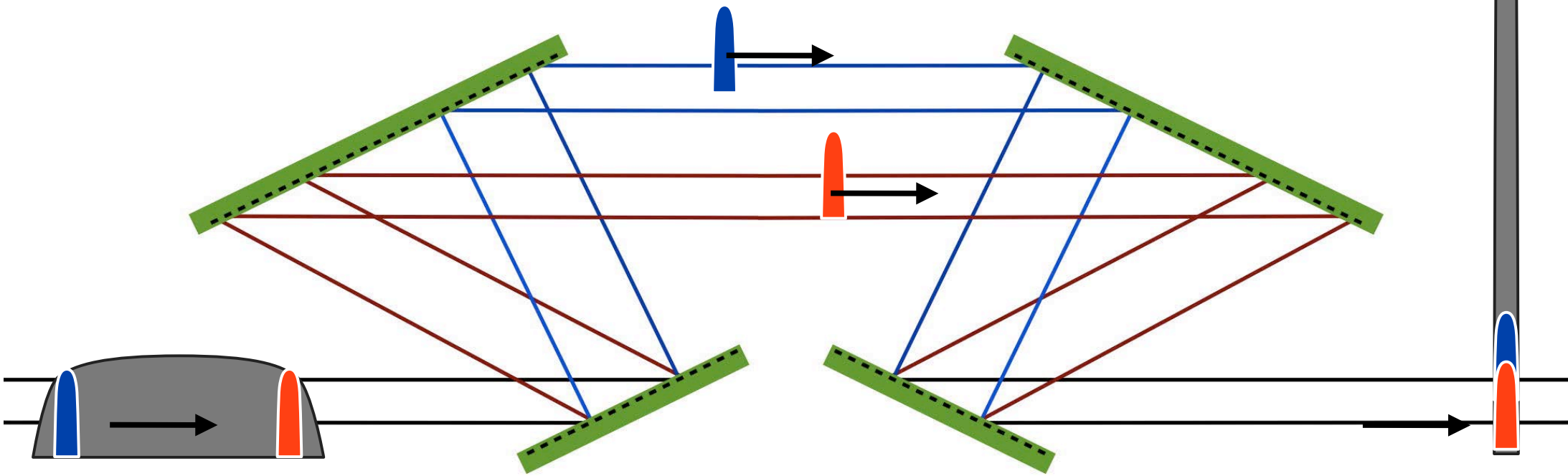


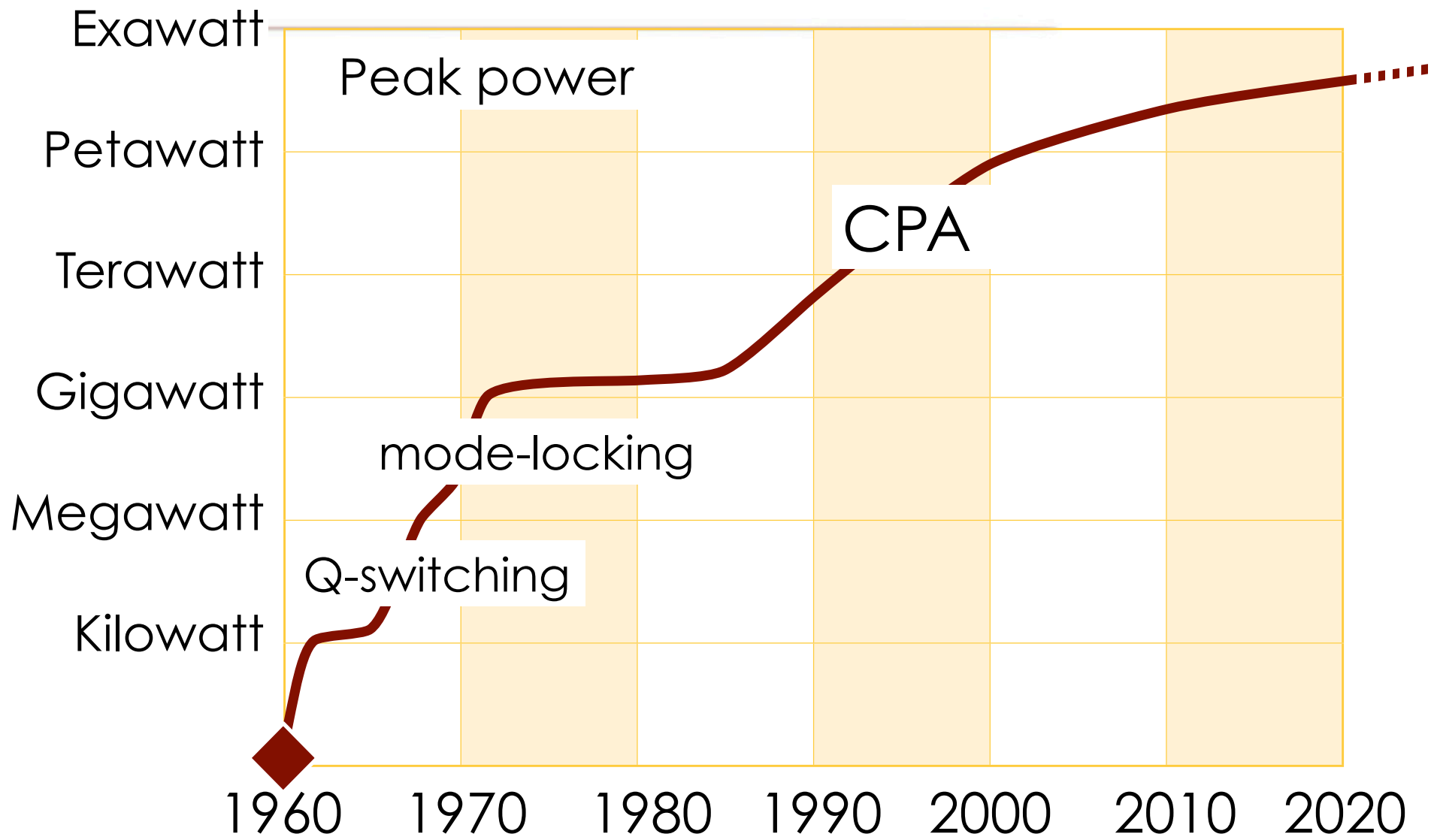
broadband
allows chirping



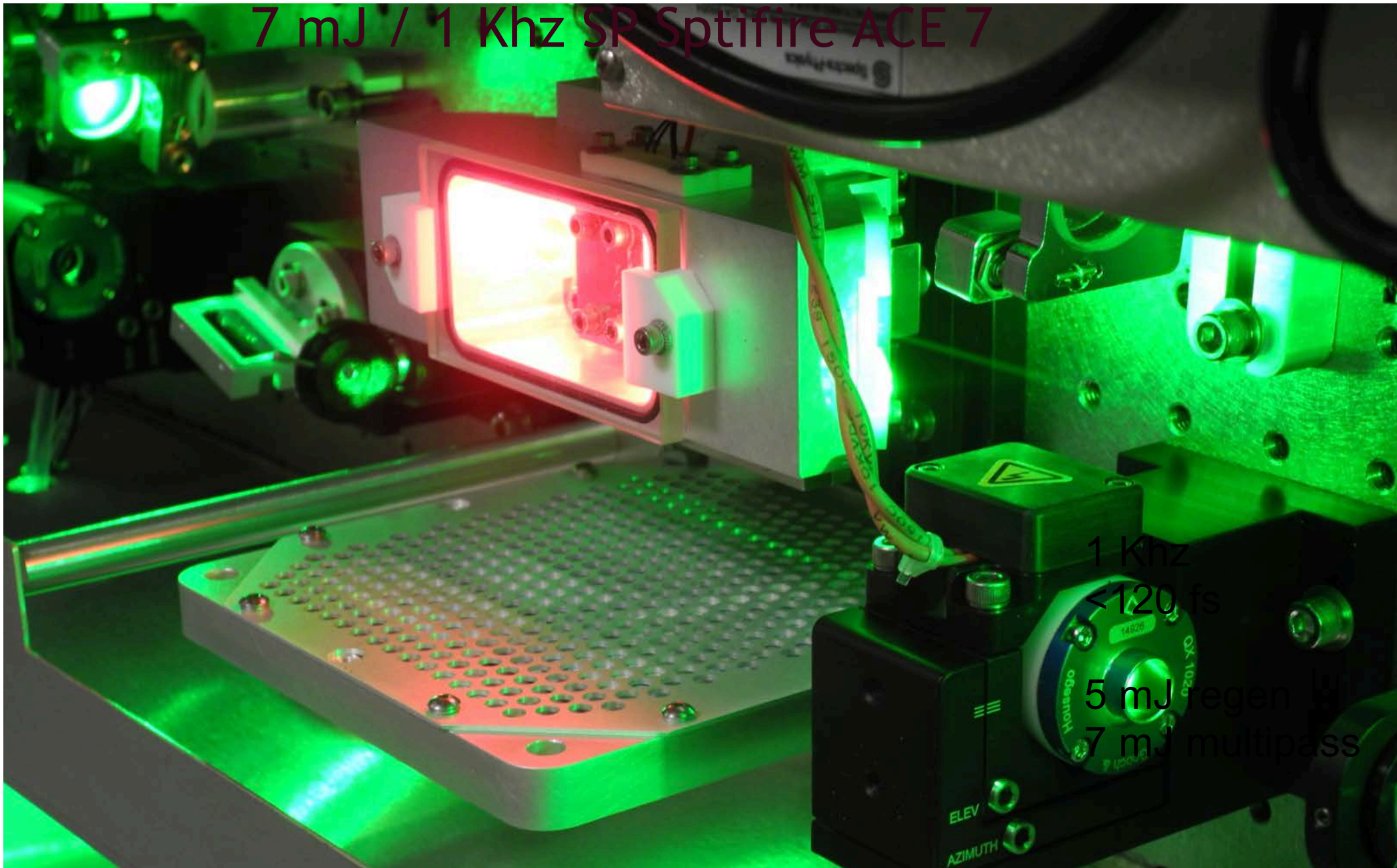
CPA Chirped Pulse Amplification



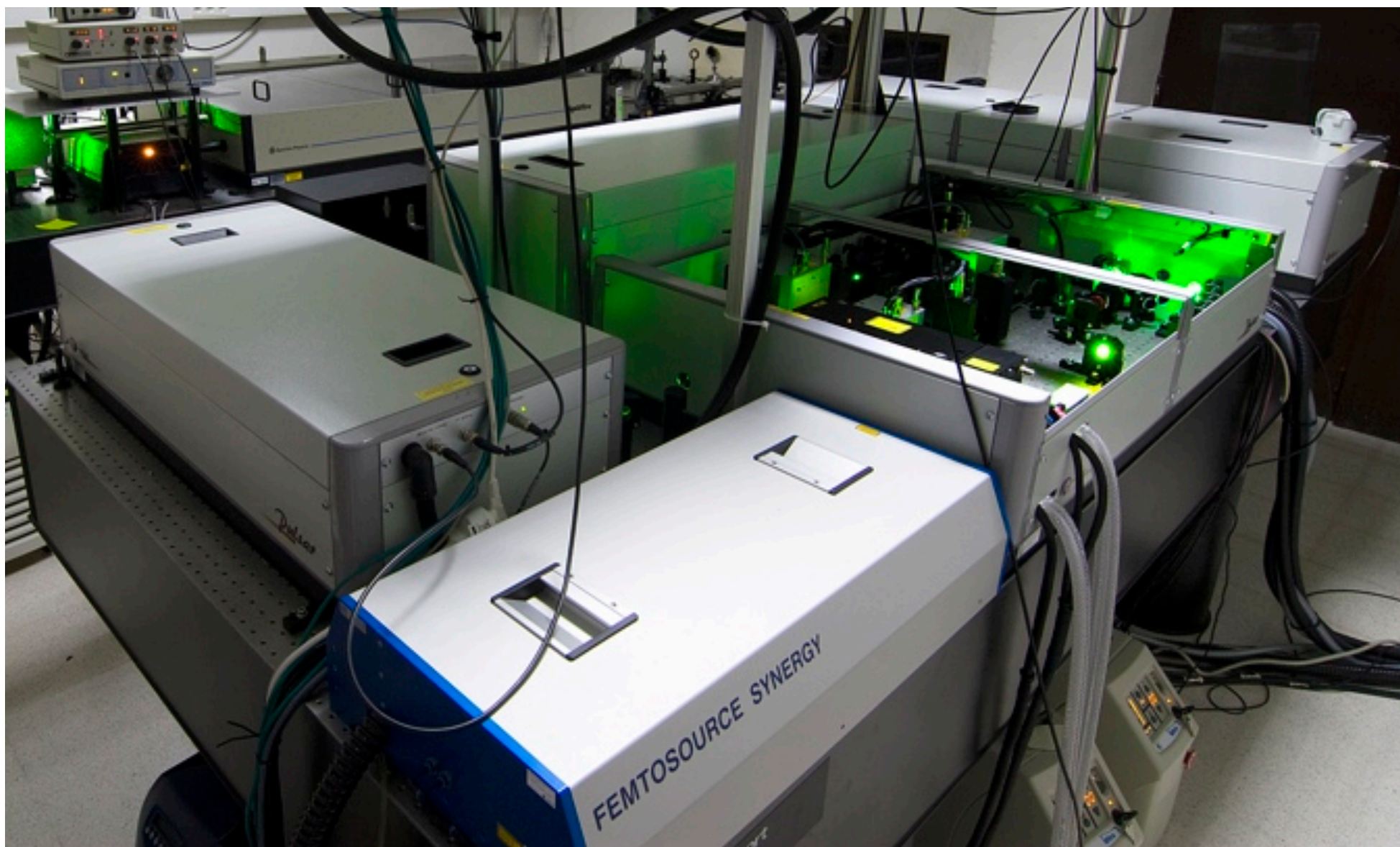


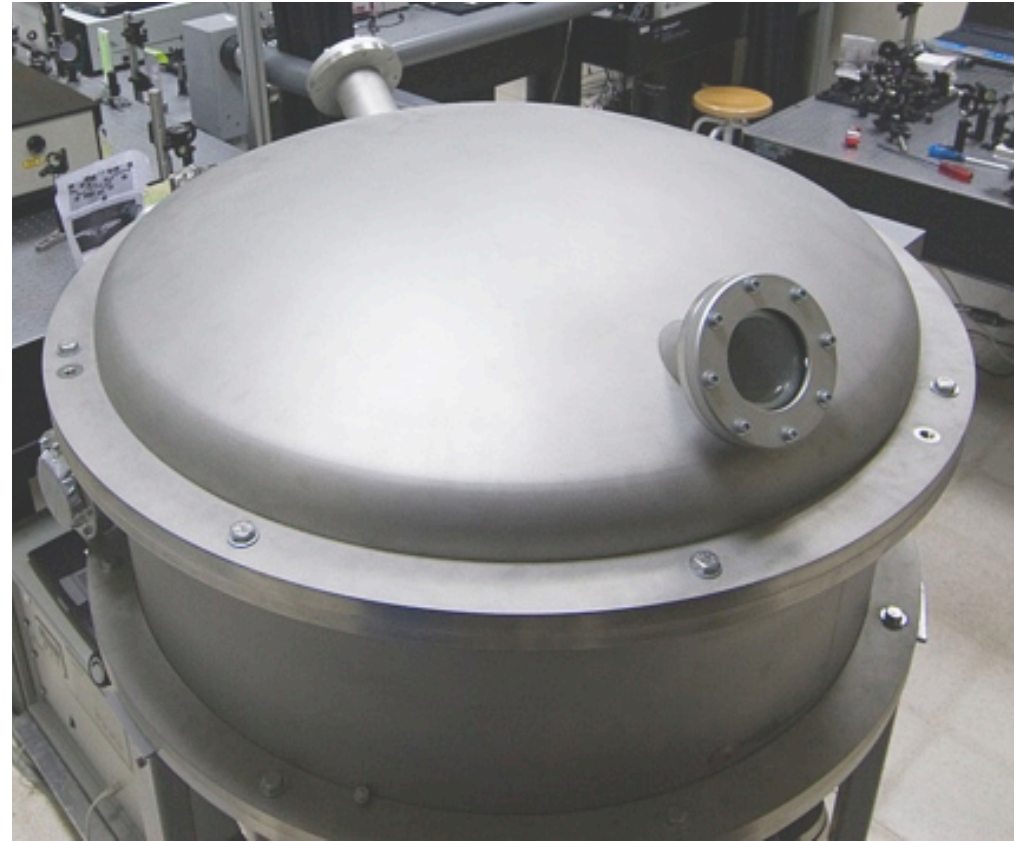


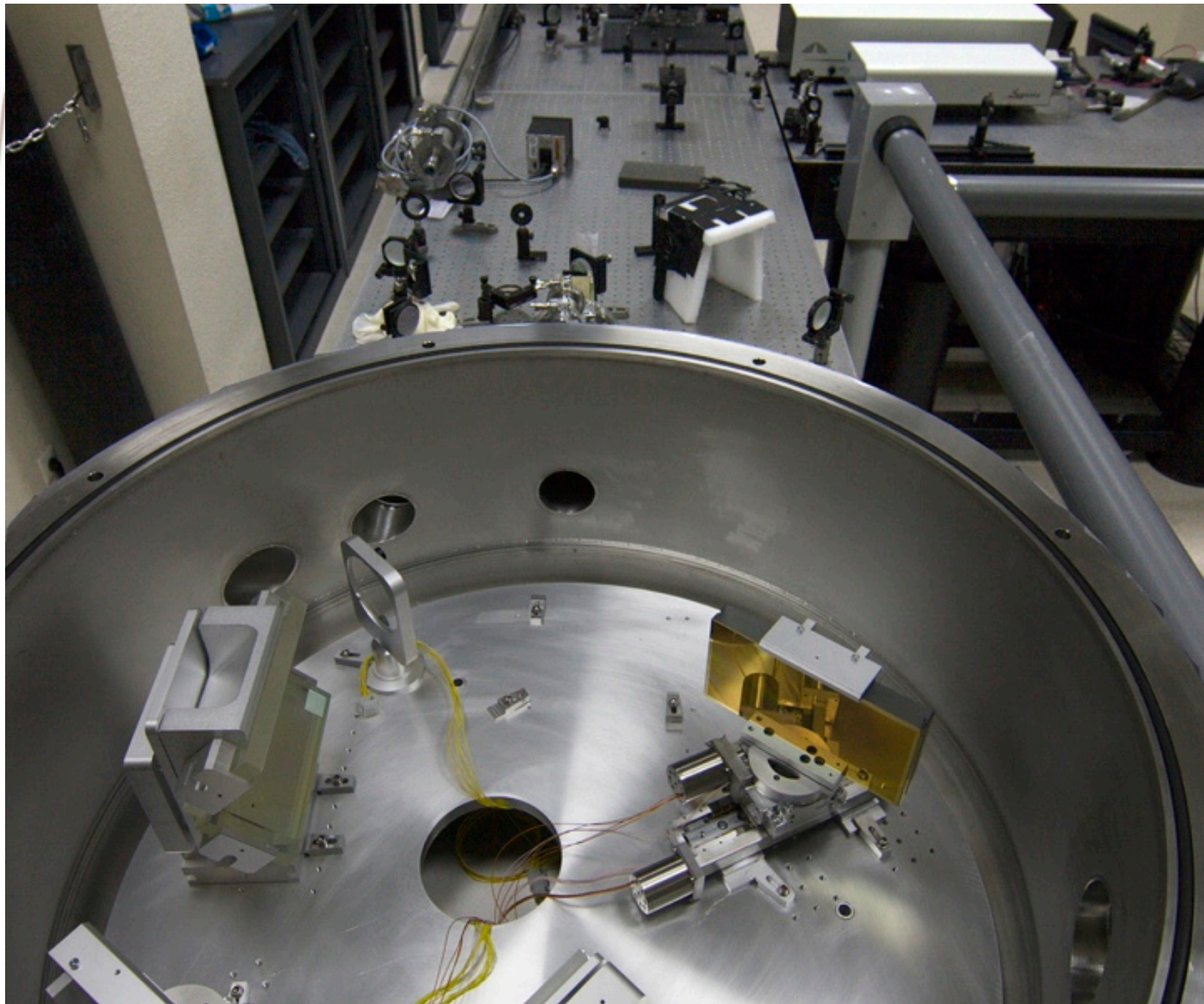
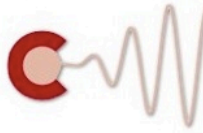
7 mJ / 1 Khz SP Sptifire ACE 7



1 Khz
<120 fs
5 mJ regen
7 mJ multipass

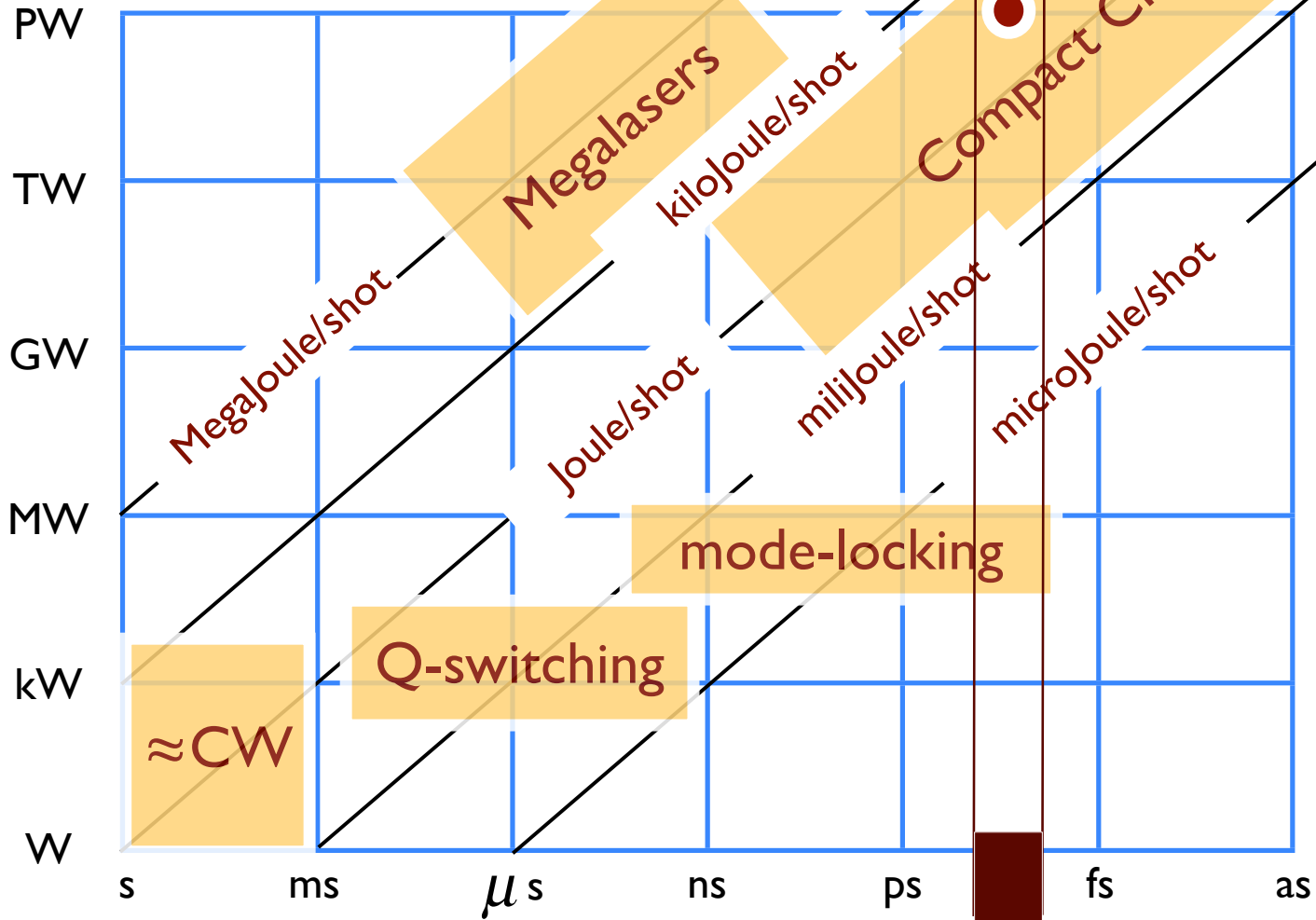








Pulse peak power



Salamanca

Compact CPA

Megalasers

MegaJoule/shot

Joule/shot

millijoule/shot

microjoule/shot

mode-locking

Q-switching

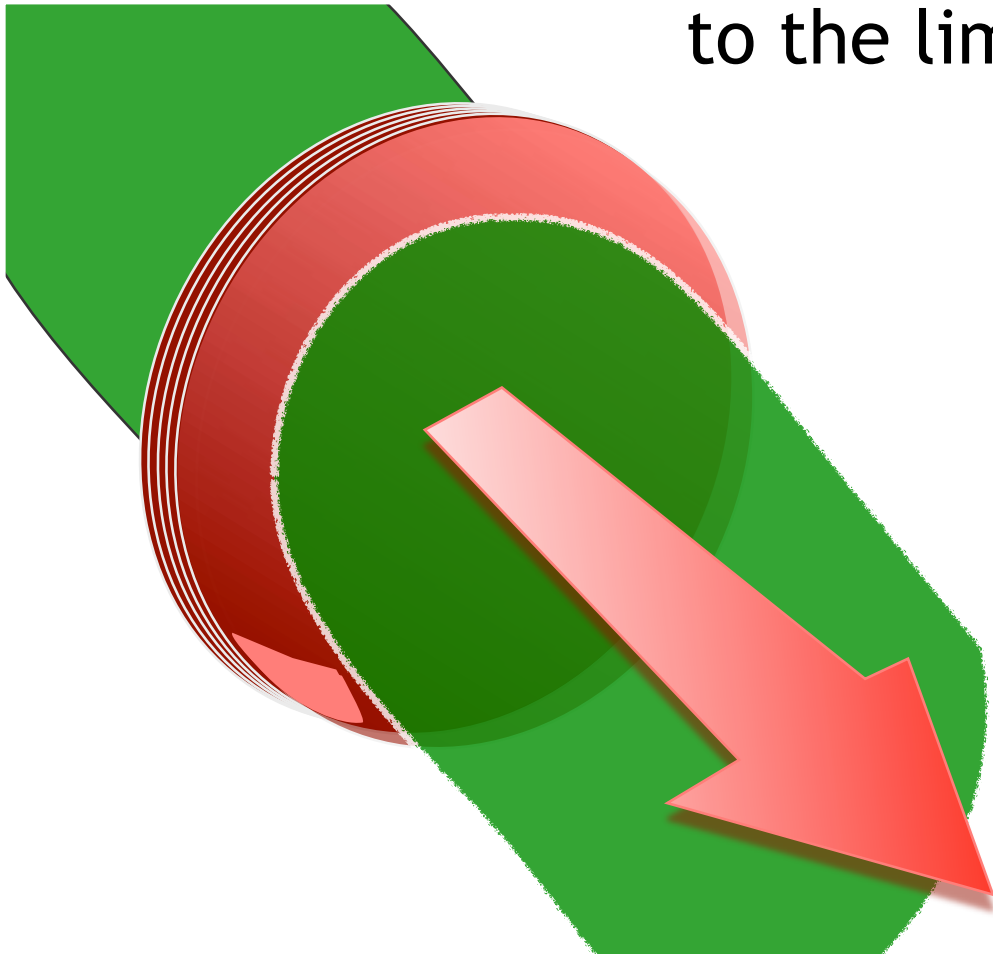
≈ CW

Pulse duration



Petawatt

Technology
to the limit



$$PW = \frac{MJ}{ns} = \frac{kJ}{ps} = \frac{30 J}{30 fs} = \frac{joule}{fs}$$



CLPU **CENTRO DE LÁSERES PULSADOS**

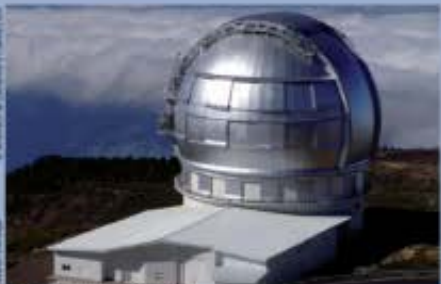
MAPA DE INSTALACIONES CIENTÍFICAS Y TÉCNICAS SINGULARES



Buque de Investigación Oceanográfica Hespérides



Reserva Científica de Doñana



Gran Telescopio CANARIAS



Canal de Experiencias Hidrodinámicas de El Pardo



Centro Astronómico de Yeves



Sala Blanca del Centro Nacional de Microelectrónica



Plataforma Solar de Almería



Instalación de Ingeniería Civil del CEDEX



Centro Nacional de Supercomputación

Islas Canarias

- Observatorio del Roque de los Muchachos
- Gran Telescopio CANARIAS
- Sede de la Red Española de Supercomputación
- Observatorio del Teide
- Plataforma Científica de Canarias

Antártida

- Base científica Vespucio de Castro
- Base científica SAN CARLOS

Áreas de Investigación



Centro de Láseres Pulsados Salamanca

Public Consortium established in Decembre 2007

partners	percent
Ministerio de Economía y Competitividad	50
Junta de Castilla y León	45
Universidad de Salamanca	5



UNIVERSIDAD
DE SALAMANCA



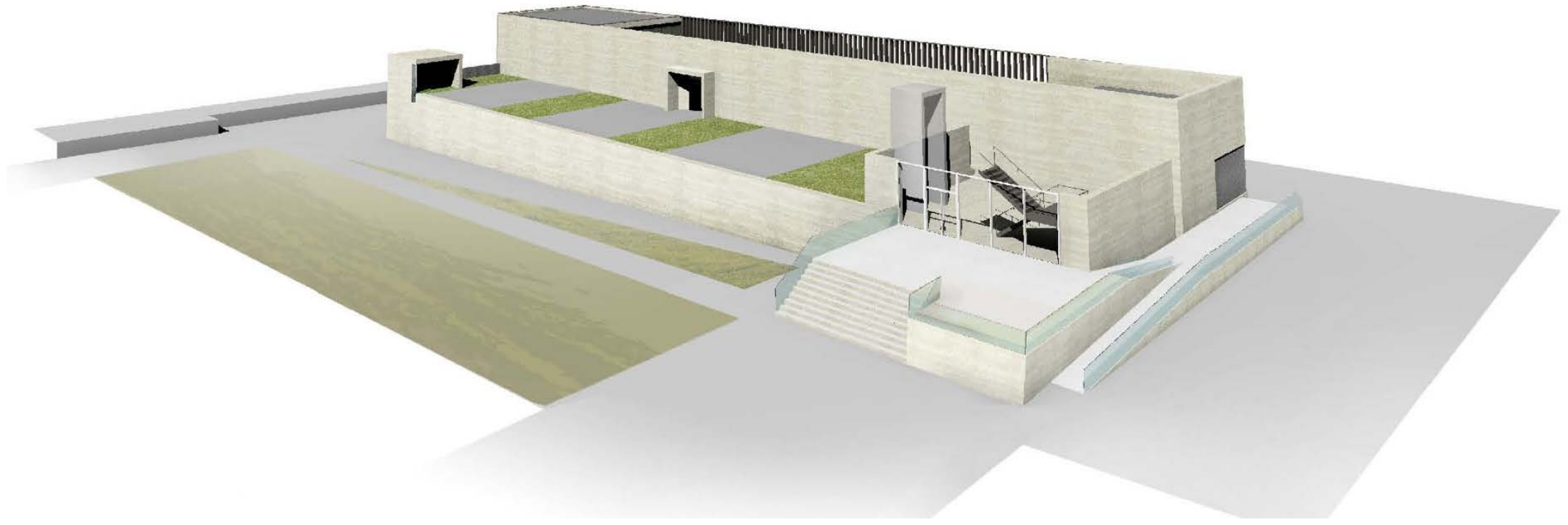


Salamanca's VEGA laser

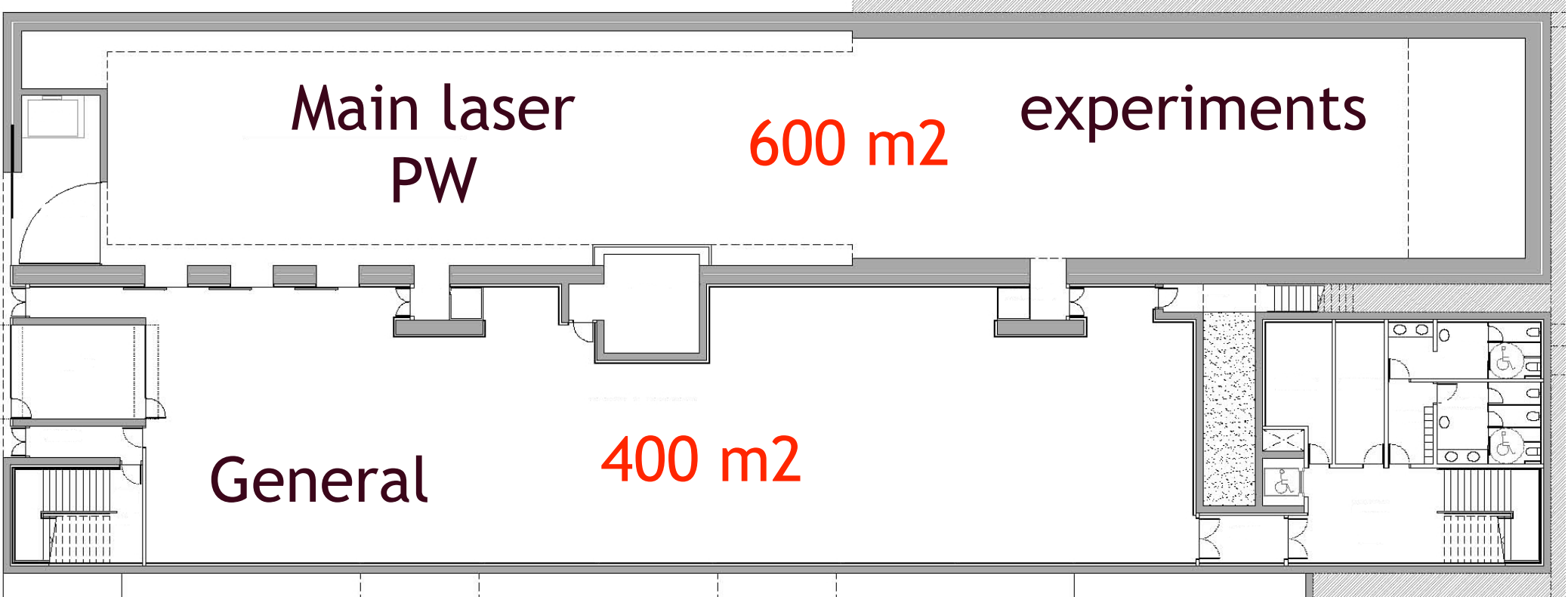
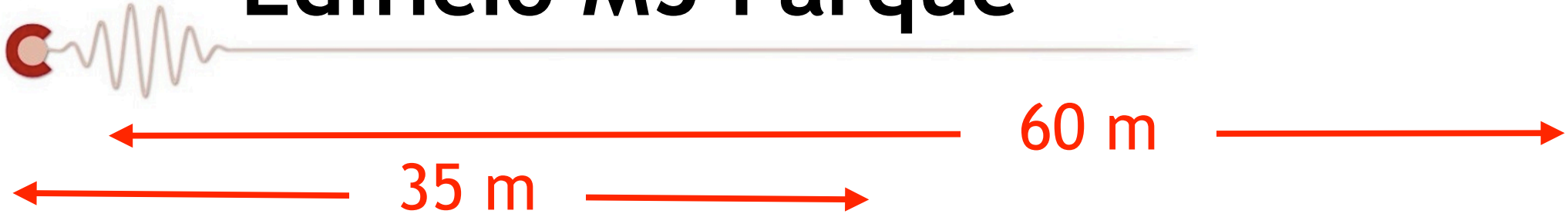


CLPU CENTRO DE
LÁSERES
PULSADOS

 UNIÓN EUROPEA
FONDO
EUROPEO DE
DESARROLLO
REGIONAL
"Una manera de hacer Europa"



Edificio M5 Parque





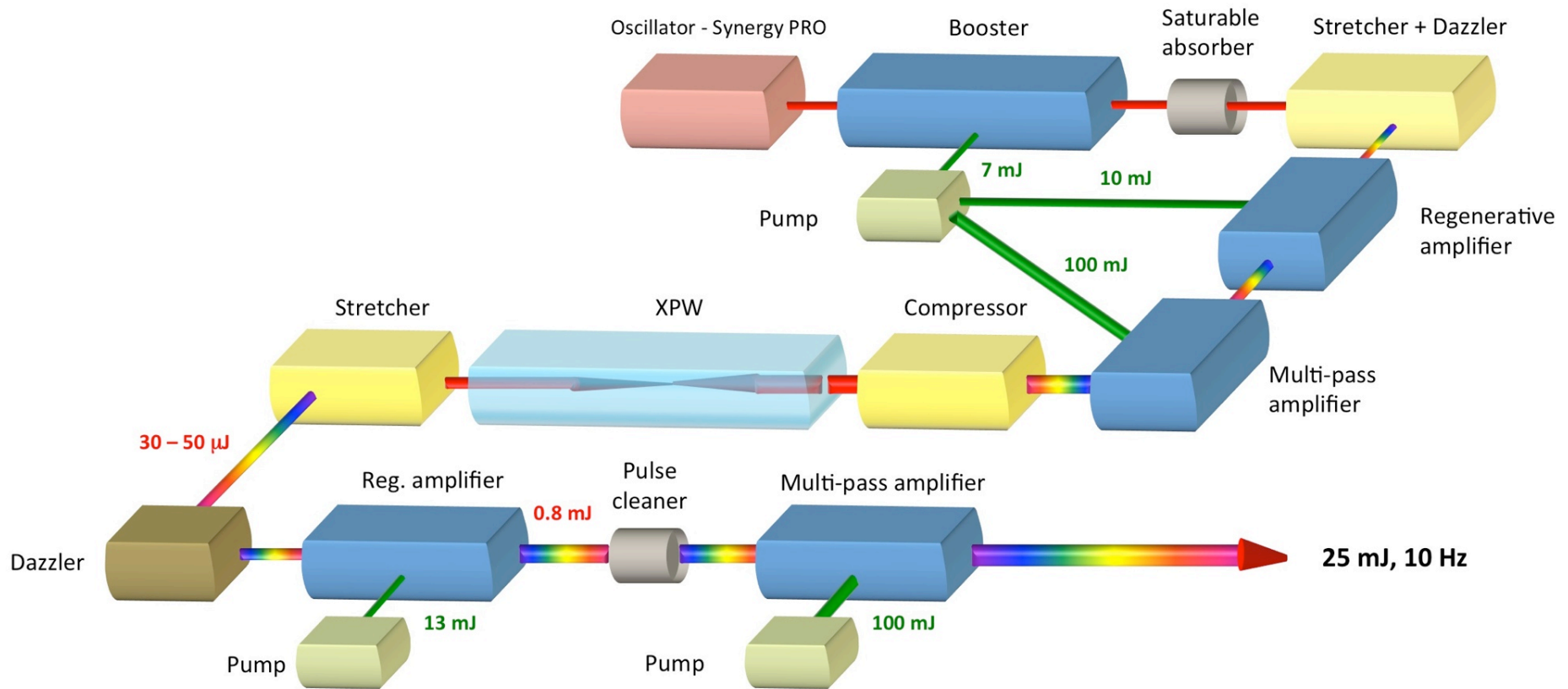


30 J
30 fs
800 nm
1 shot/second



VEGA Front End

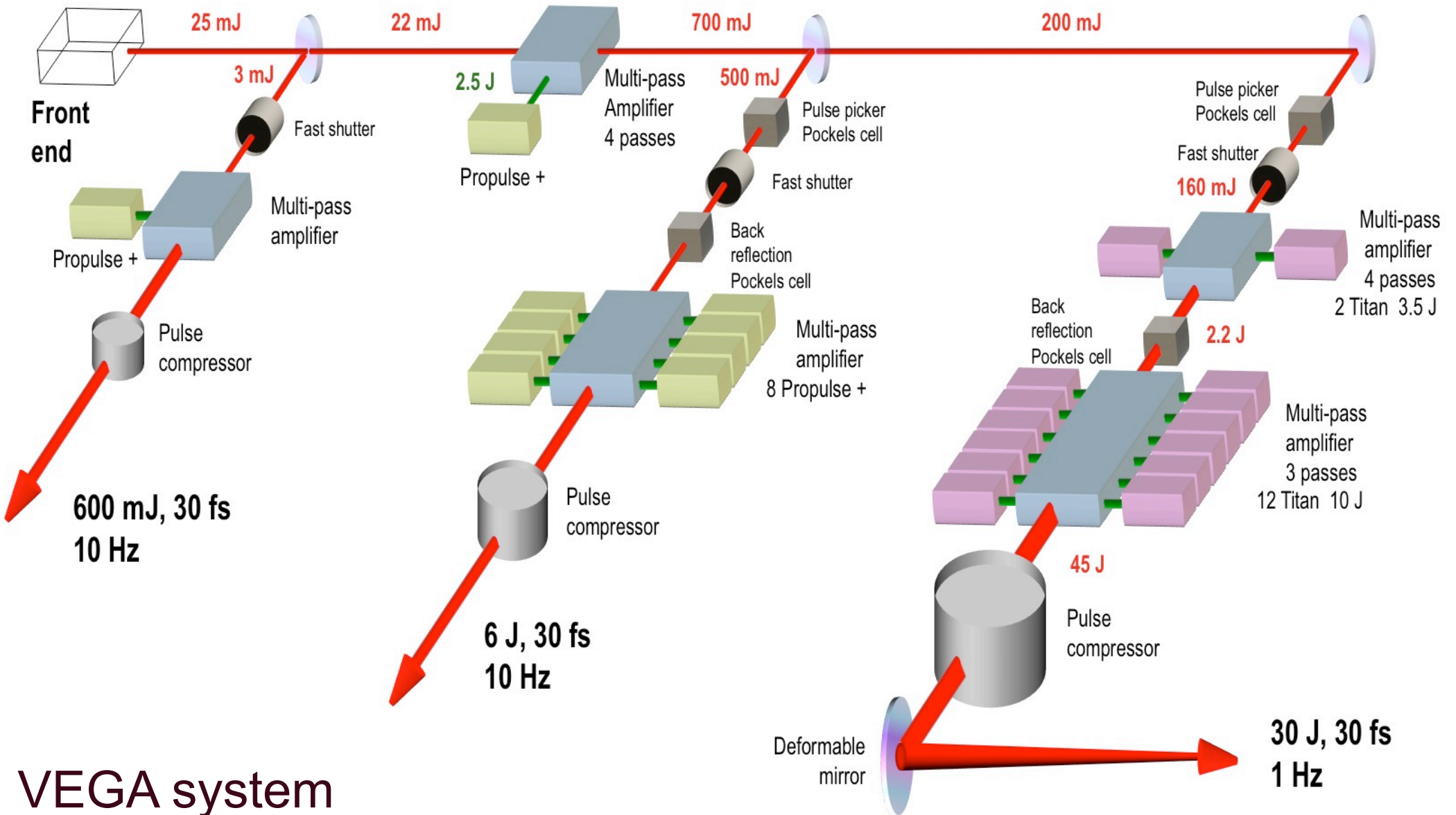
Front End



Phase I – 20 TW

Phase II – 200 TW

Phase III – 1 PW



VEGA system



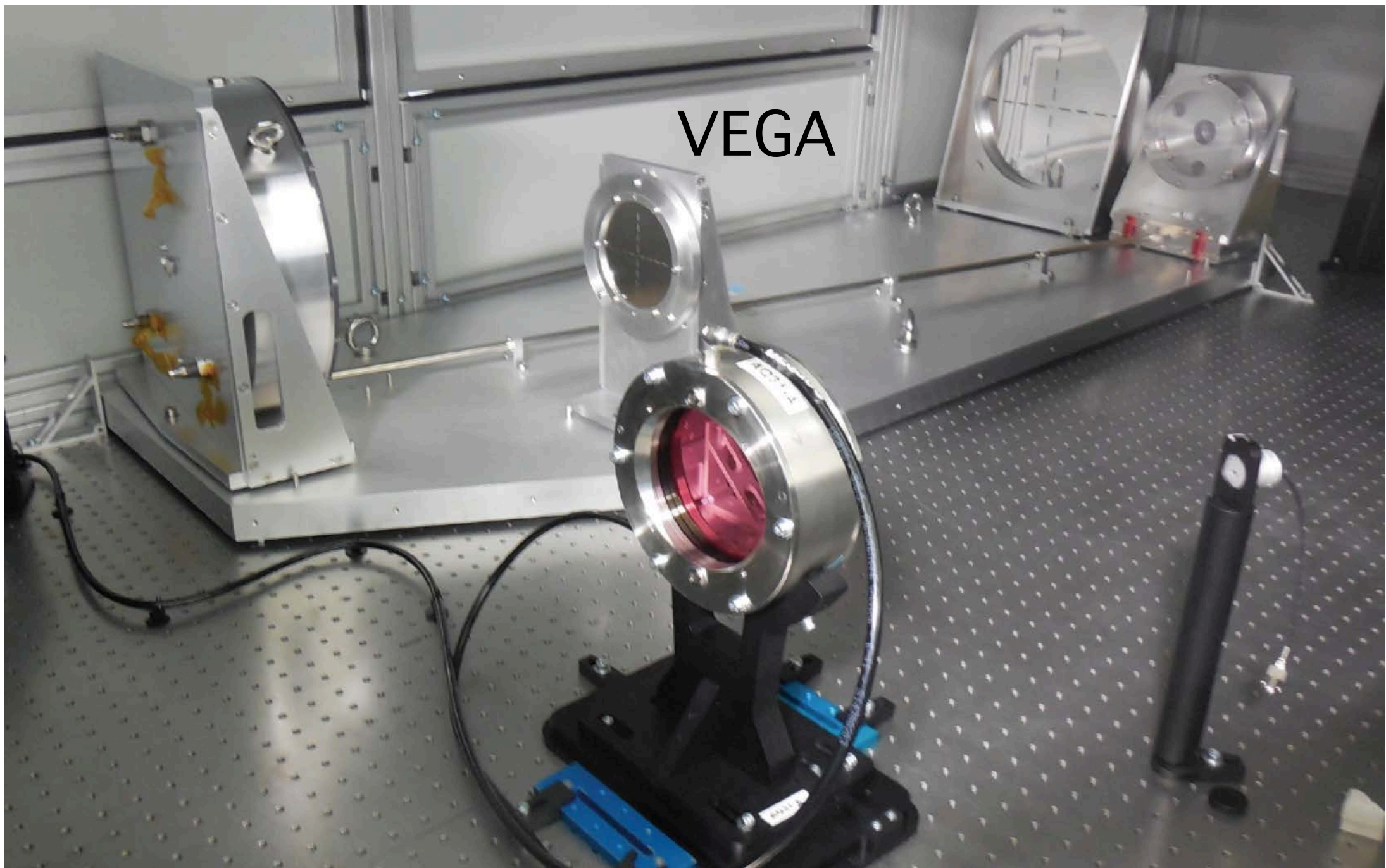
The VEGA laser

Titanium:sapphire technology
robust and well under control

VEGA	peak power	energy	duration	repetition rate	operation
VEGA 1	20 TW	600 mJ	30 fs	10 / sec	2007
VEGA 2	200 TW	6 J	30 fs	10 / sec	2013
VEGA 3	1 PW	30 J	30 fs	1 /sec	2015



VEGA



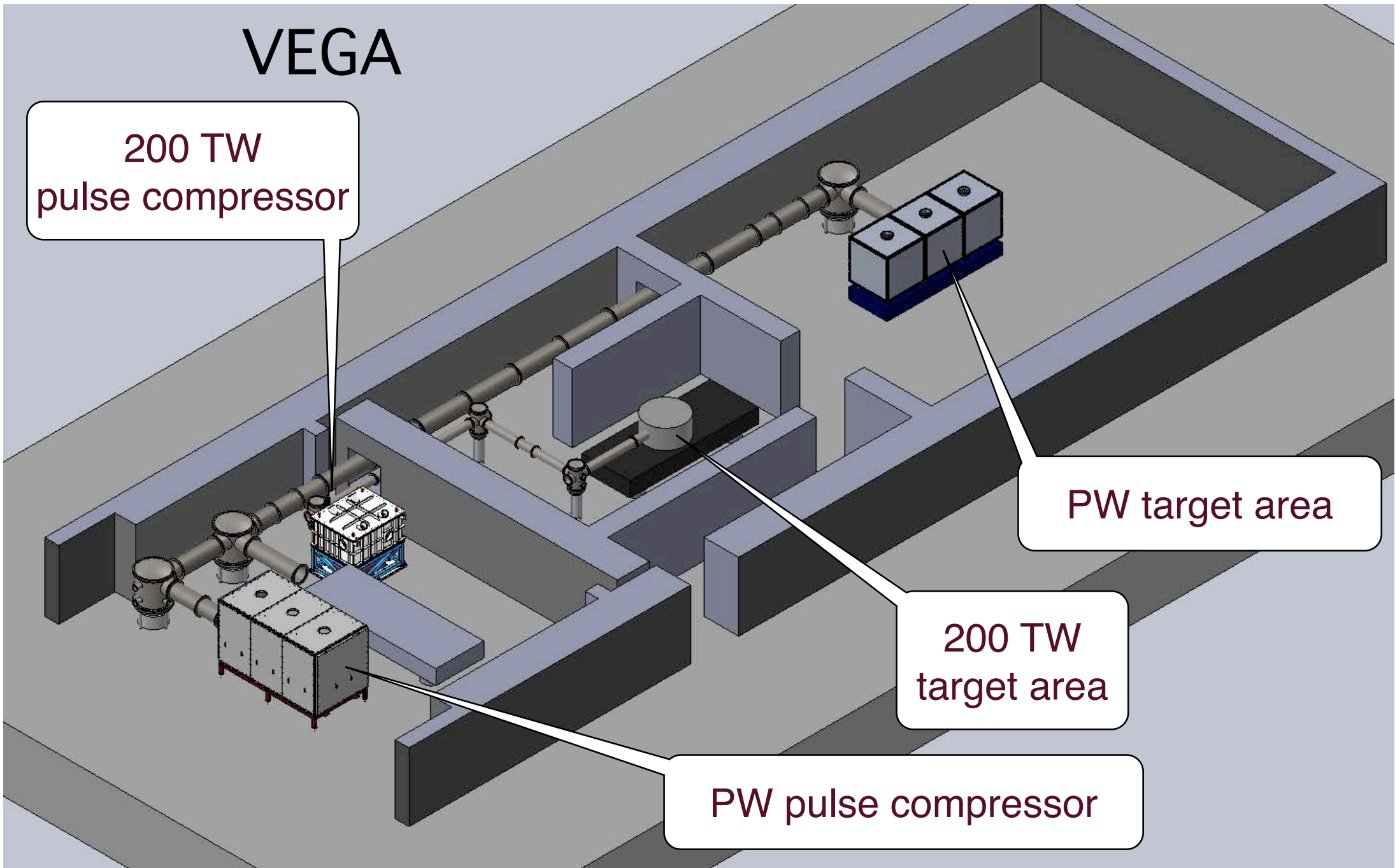
VEGA

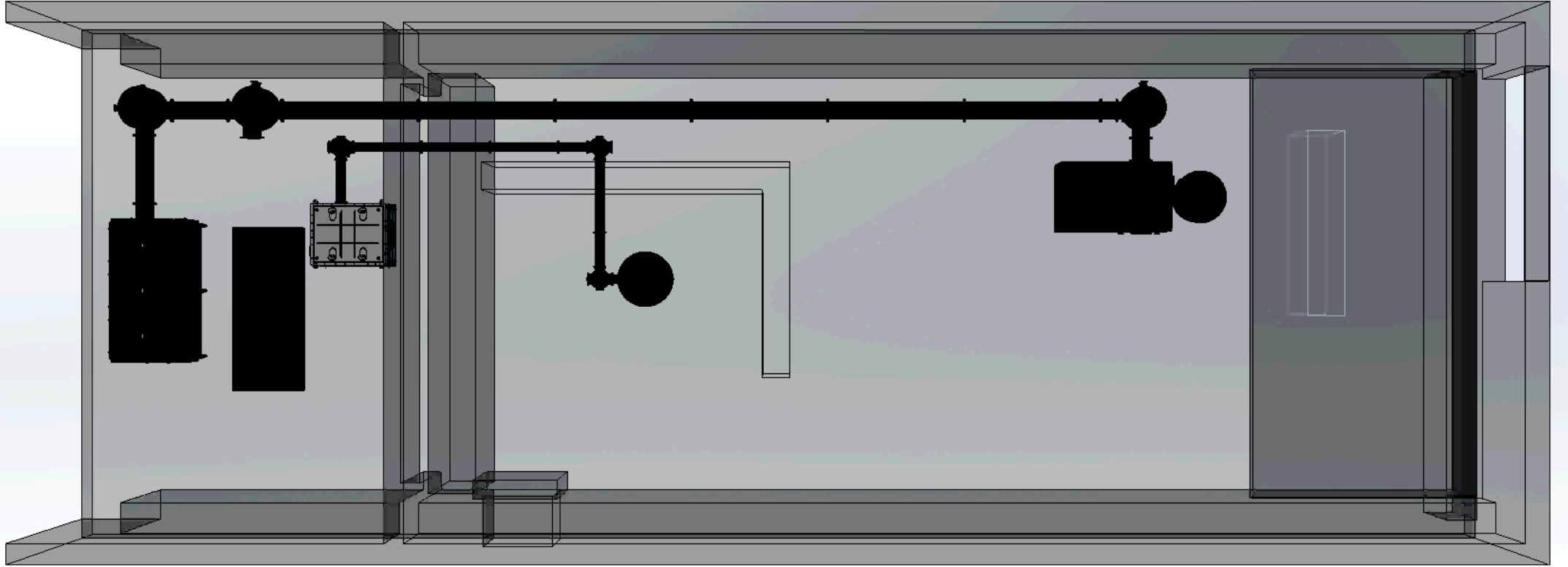
200 TW
pulse compressor

PW target area

200 TW
target area

PW pulse compressor







What are
extreme lasers
good for?

Wavelength

800 nm Titanium:Sapphire ... my favourite now

1040 - 1080 nm Ytterbium in some crystals

1050 nm Nd glass for longer pulses (ps)

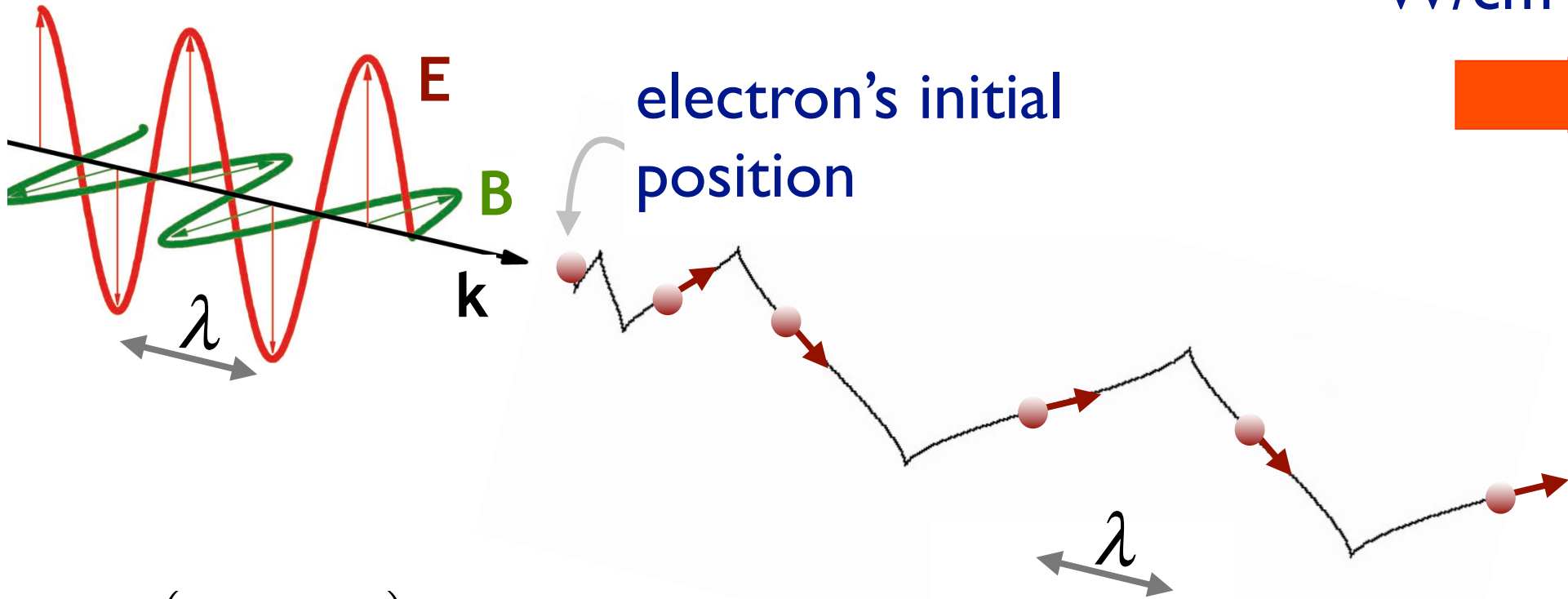
and

1 micron CO2 lasers



Relativistic acceleration of charged particles

Electron driven by a laser field



W/cm²



- 10e24
- 10e23
- 10e22
- 10e21
- 10e20
- 10e19
- 10e18
- 10e17
- 10e16
- 10e15
- 10e14
- 10e13
- 10e12
- 10e11
- 10e10

$$-e \left(\vec{E} + \frac{\vec{v}}{c} \times \vec{B} \right) = \vec{F} = \frac{d\vec{p}}{dt}$$

800 nm
2 10¹⁹ W/cm²

Coupling laser-charge

The max energy of a charged particle in the field is given by

Intensity	Max energy (electrons)
10^{16} W/cm ²	1 KeV
10^{19} W/cm ²	1 MeV
10^{20} W/cm ²	10 MeV
10^{21} W/cm ²	100 MeV
10^{22} W/cm ²	1 GeV
10^{23} W/cm ²	10 GeV

$$E_{\max} = mc^2 + \frac{1}{4} \frac{q^2}{m \omega^2} I$$

Diagram illustrating the equation with labels and arrows:

- mc^2 is labeled "mass".
- ω is labeled "frequency".
- q is labeled "charge".
- I is labeled "intensity".

For
800 nm wavelength
Ti:Sapphire laser

Coupling laser-charge

The max energy of a charged particle in the field is given by

$$E_{\max} = mc^2 + \frac{1}{4} \frac{q^2}{m \omega^2} I$$

Better to use
long wavelength lasers !!! ???

frequency 

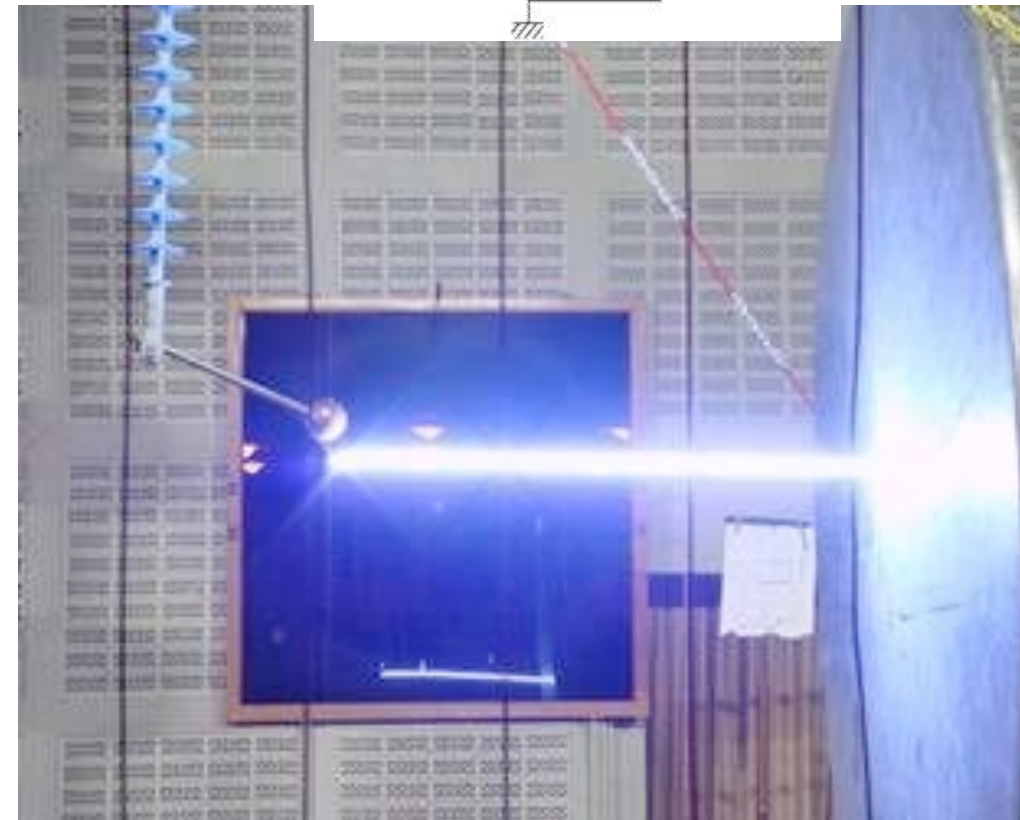
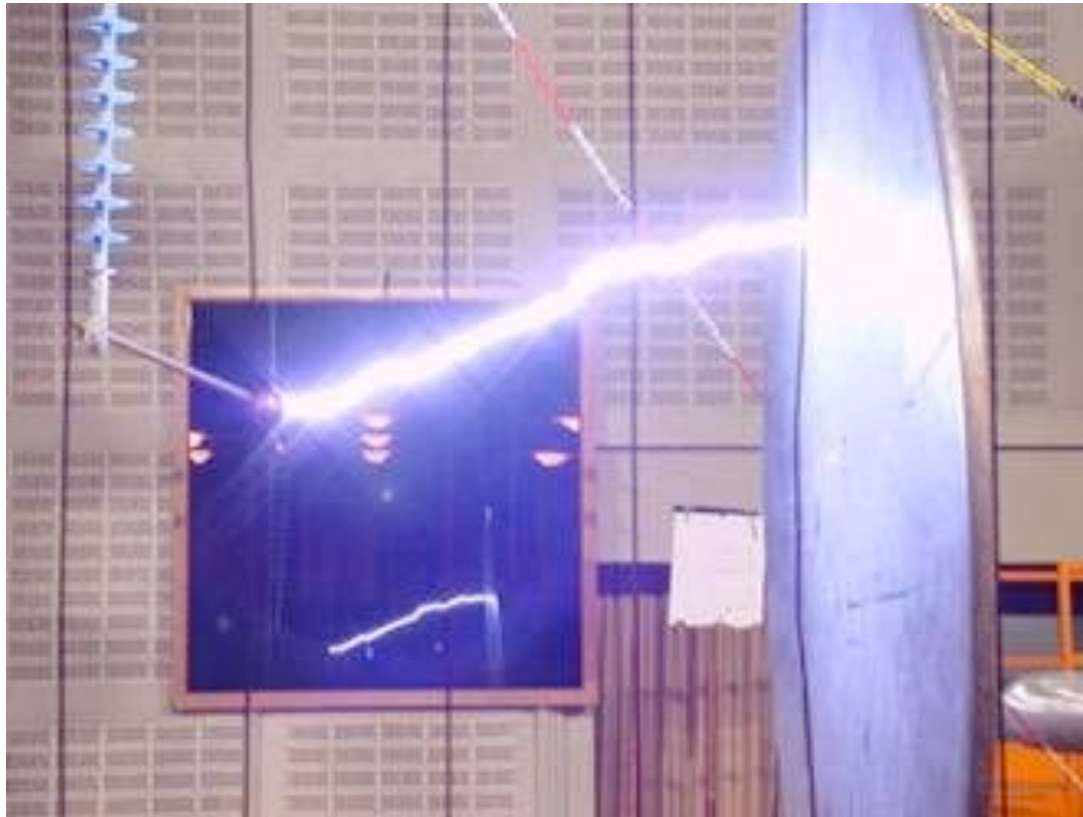
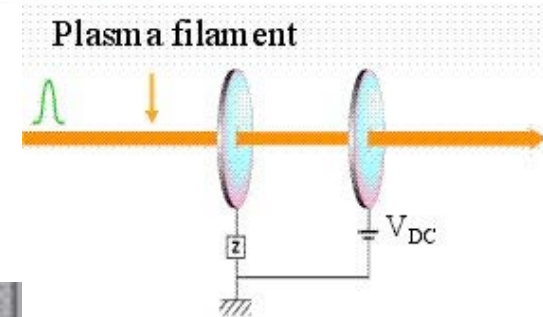


Electrical guiding. Filamentation



Electrical discharge guiding

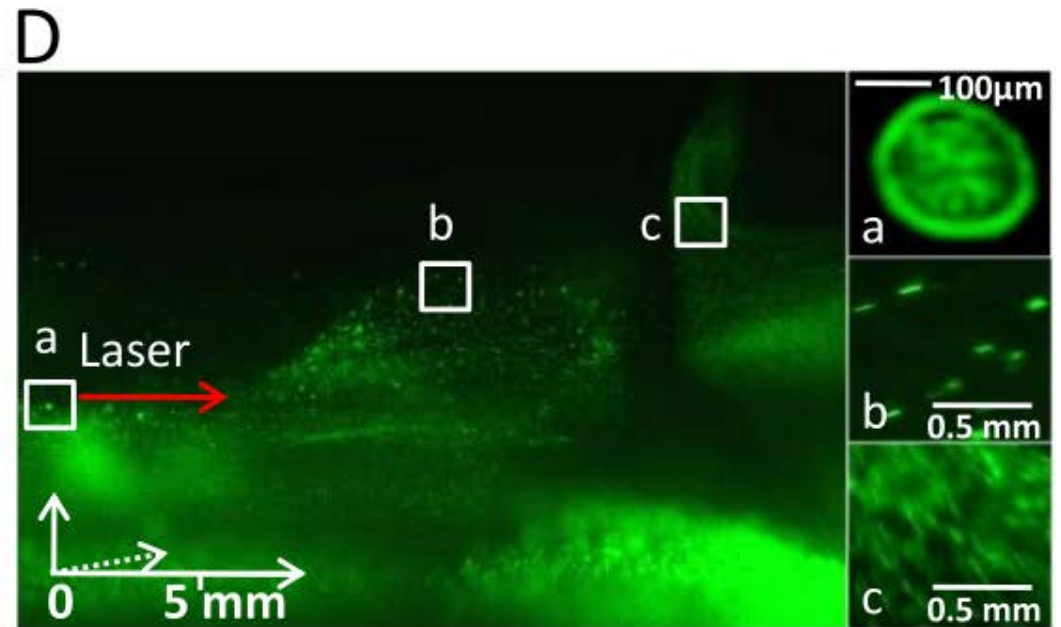
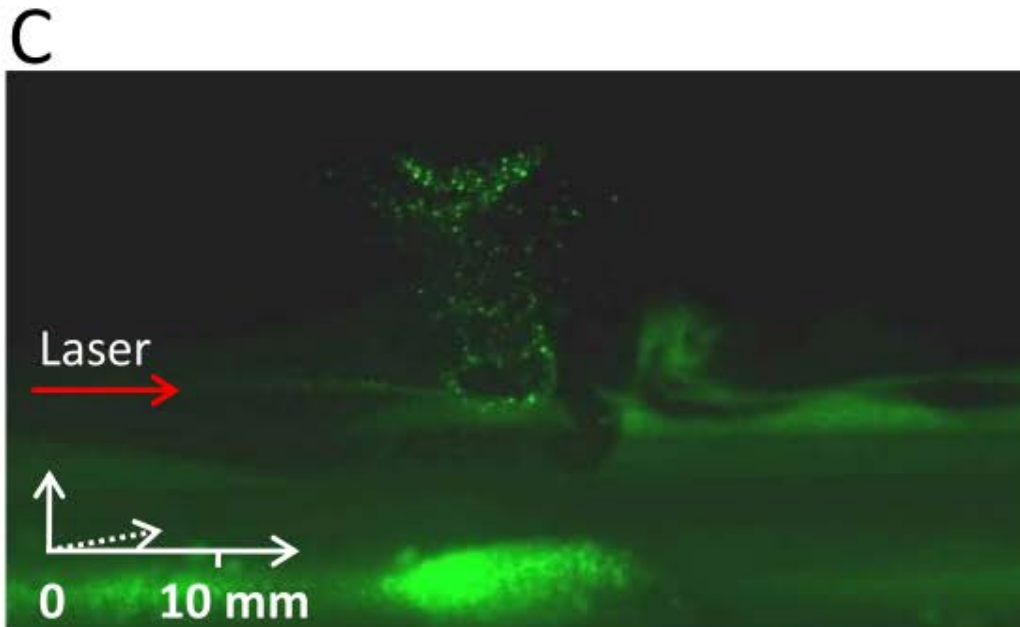
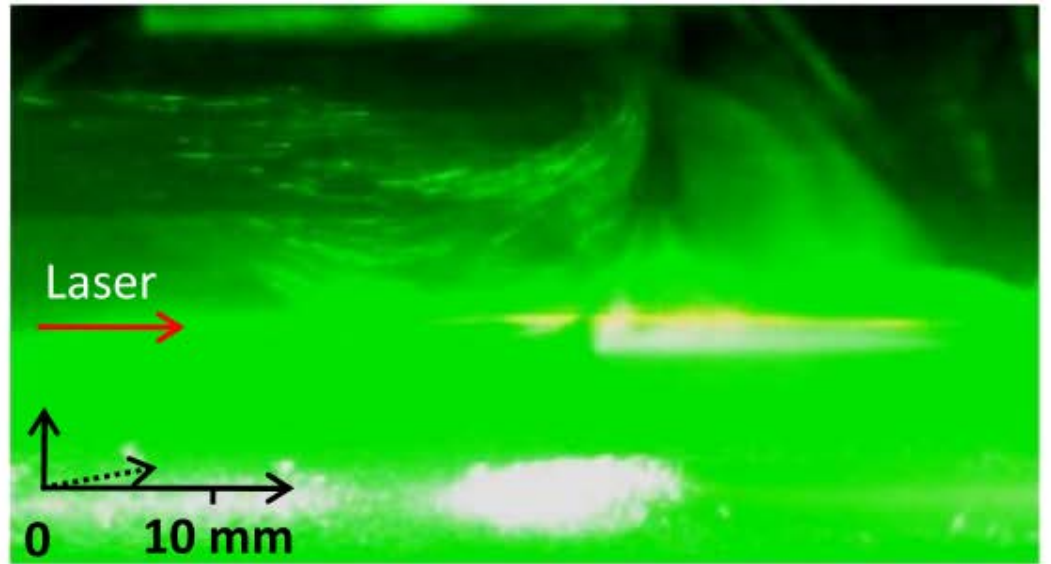
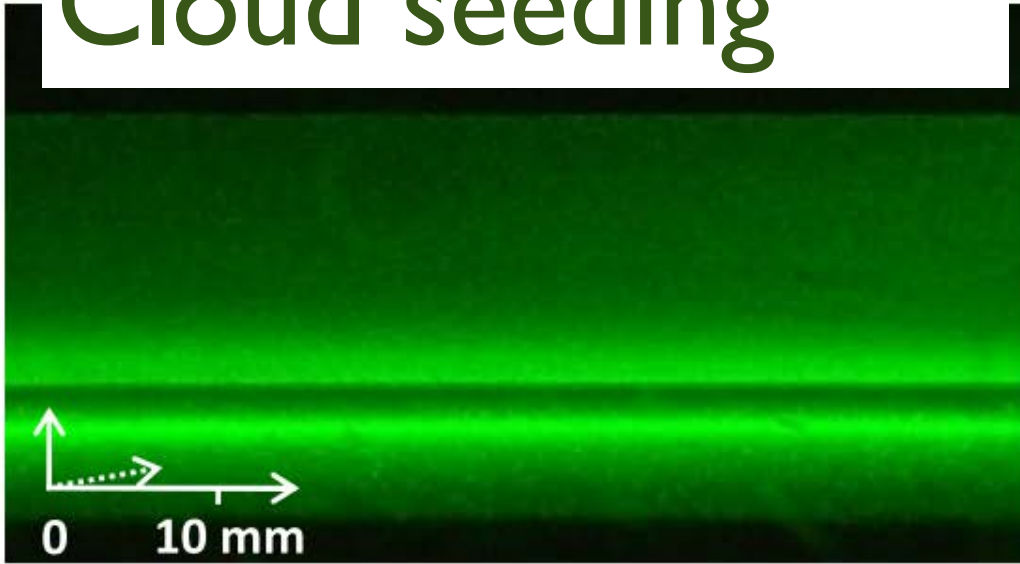
Laser plasma



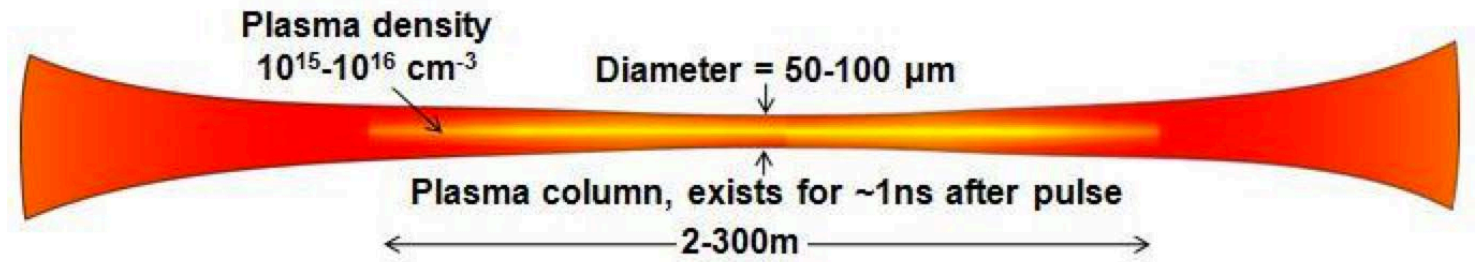
Laser lightning rod



Cloud seeding



Train power supply ...



No need of mechanical contact
pantograph-catenary



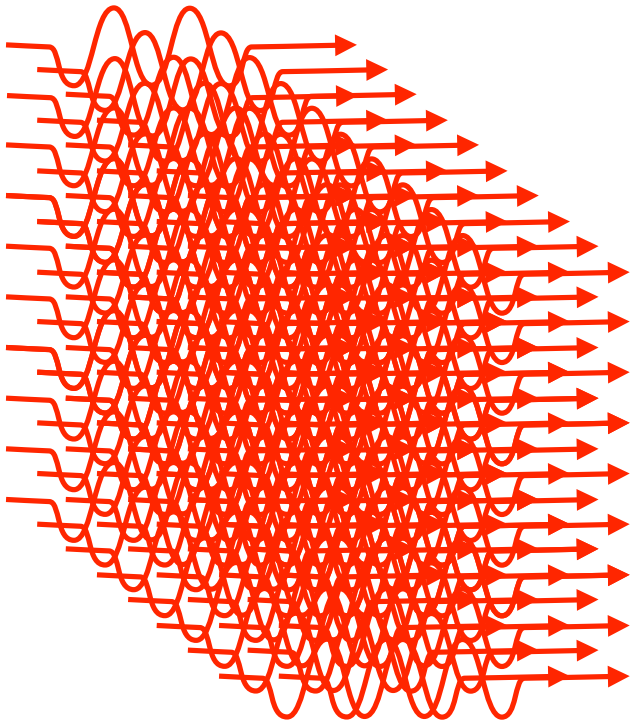
Quantum vacuum

One basic question



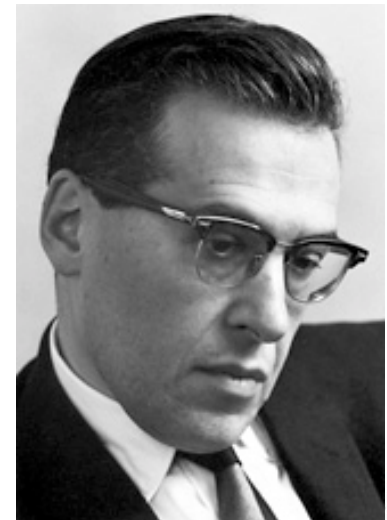
Photons are bosons,
a laser is a collection on bosons in the same
quantum state.

How many can we pack?
Is there any fundamental limit?



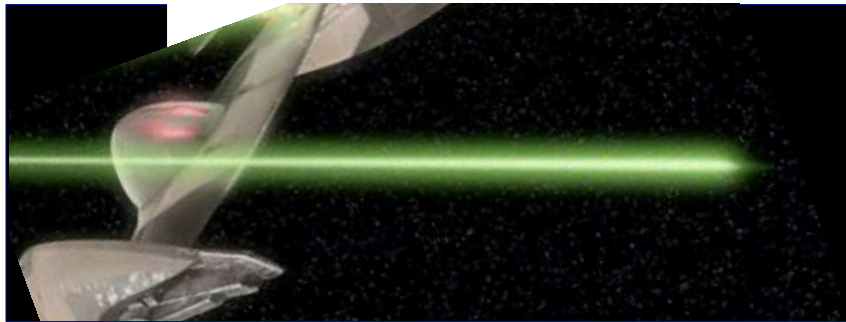
10^{29} W/cm^2

Schwinger
limit





Is this an absolute barrier???



energy
density

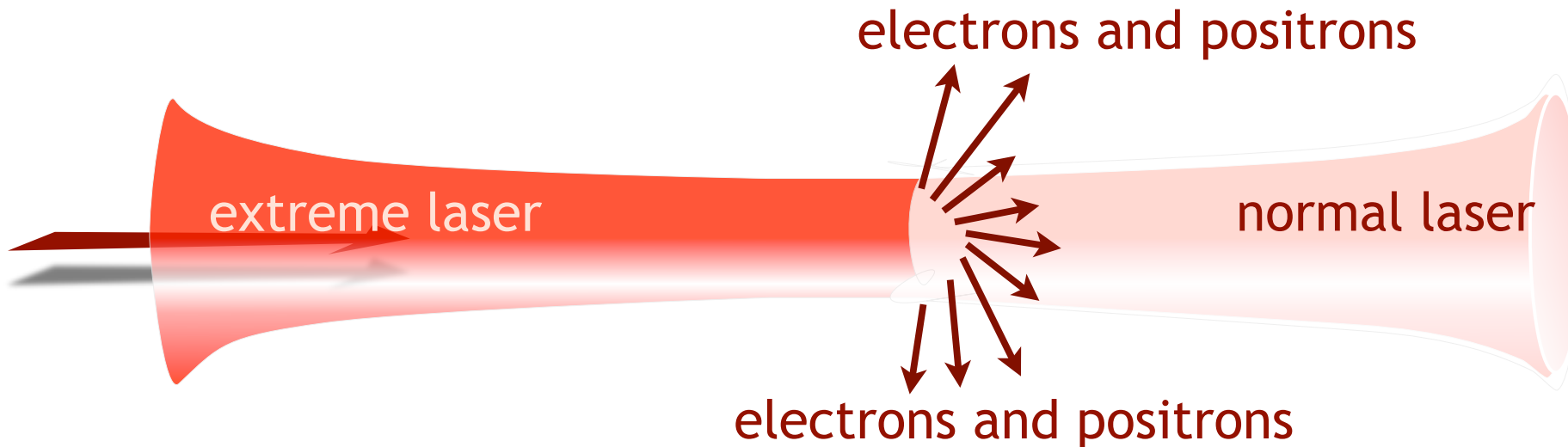
3 mJ/nm³

3 MJ/microm³

laser

intensity

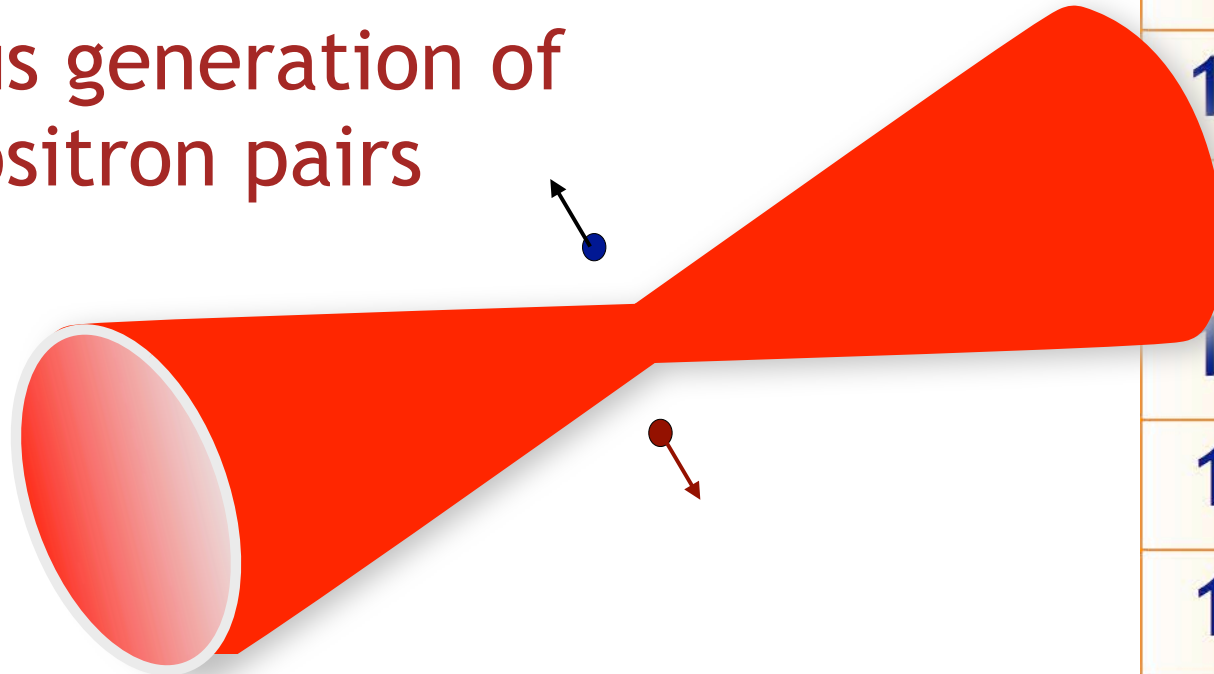
10²⁹ W/cm²





Vacuum anihilation: Schwinger

Spontaneous generation of electron-positron pairs



Non-linear QED

Beyond 10^{29} W/cm^2 vacuum seems to be unstable

10^{21} W/cm^2

10^{22} W/cm^2

10^{23} W/cm^2

10^{24} W/cm^2

10^{25} W/cm^2

10^{26} W/cm^2

10^{27} W/cm^2

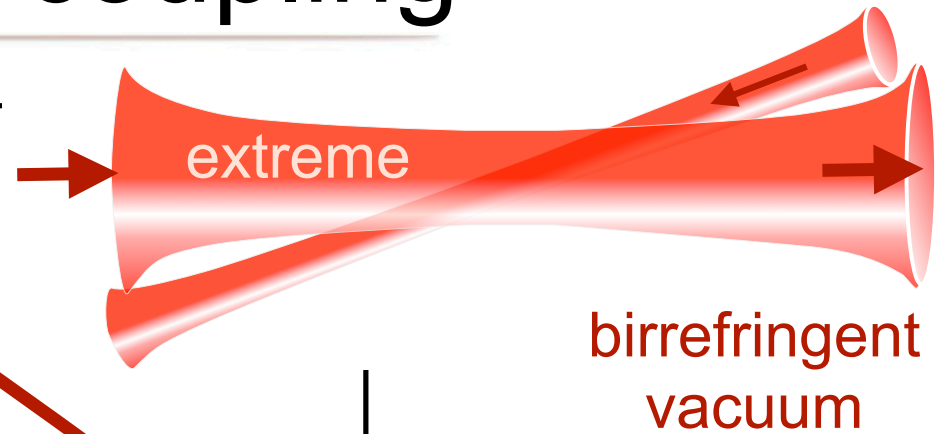
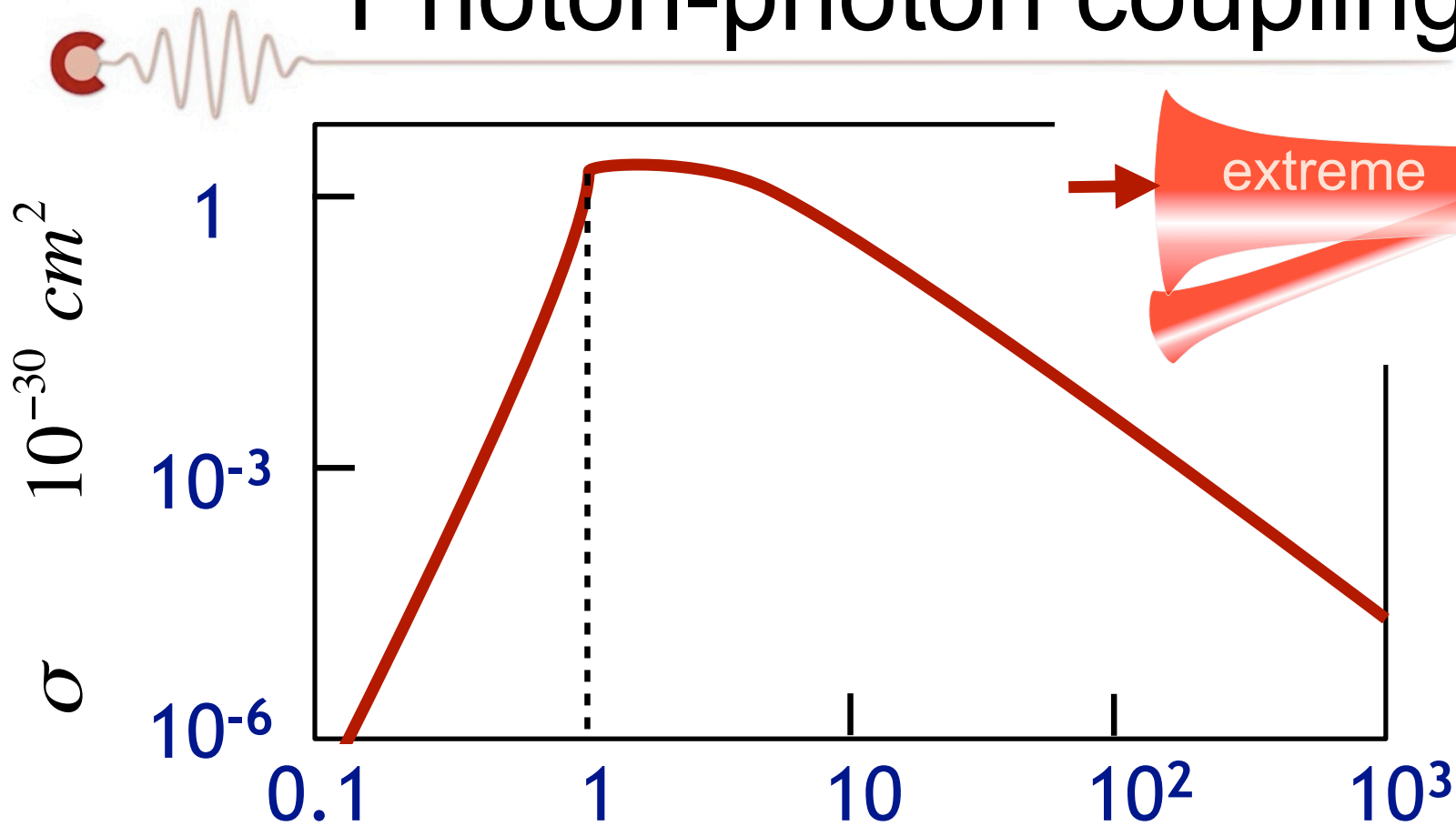
10^{28} W/cm^2

10^{29} W/cm^2

10^{30} W/cm^2

10^{31} W/cm^2

Photon-photon coupling



$$\sigma_{\gamma-\gamma} \lesssim 10^{-60} \text{ m}^2$$

$$\hbar\omega / mc^2$$

at optical wavelengths





Future trends in lasers



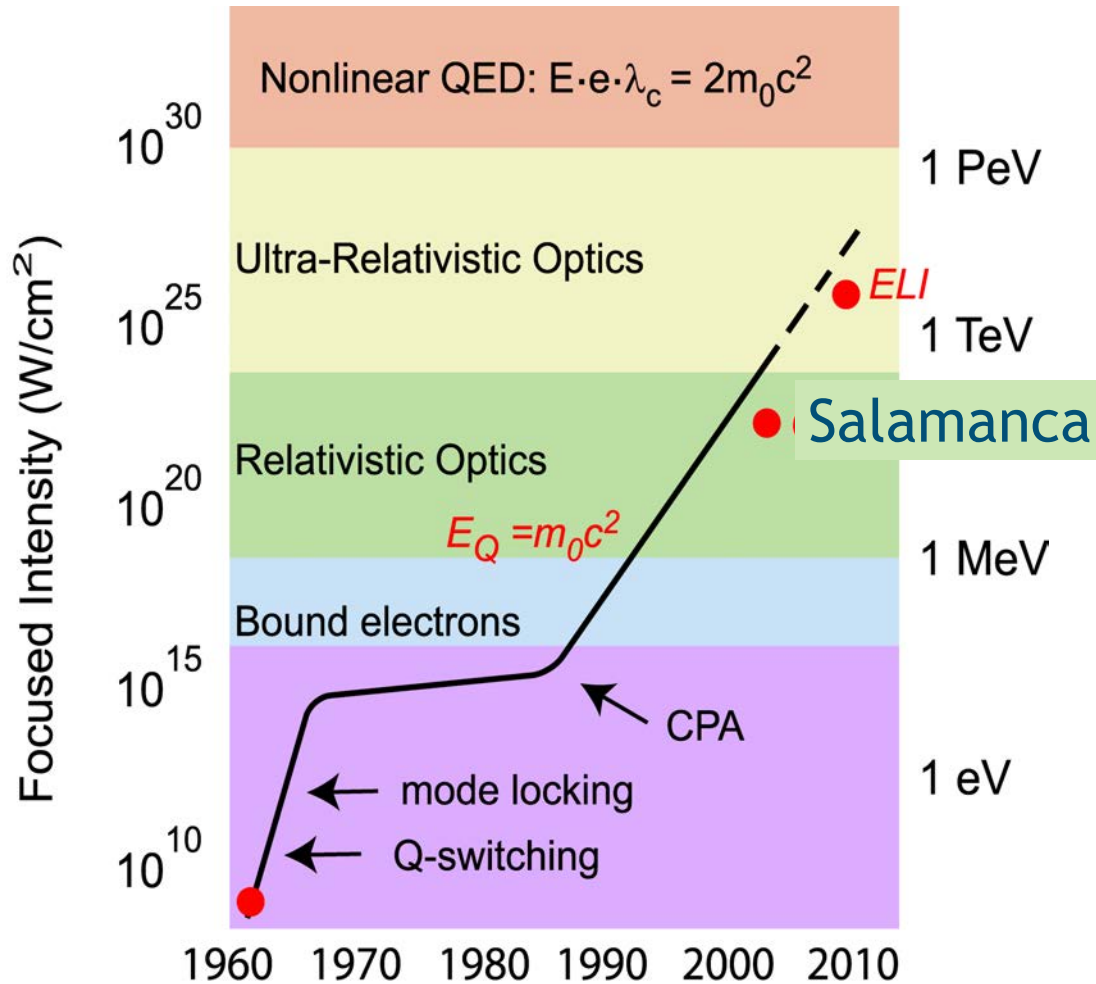
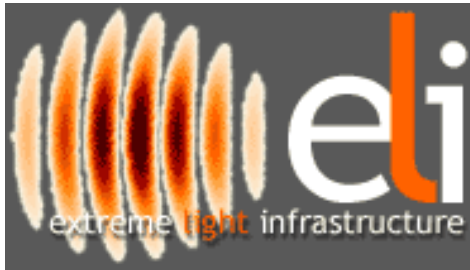
Extreme power



Extreme Light Infrastructure

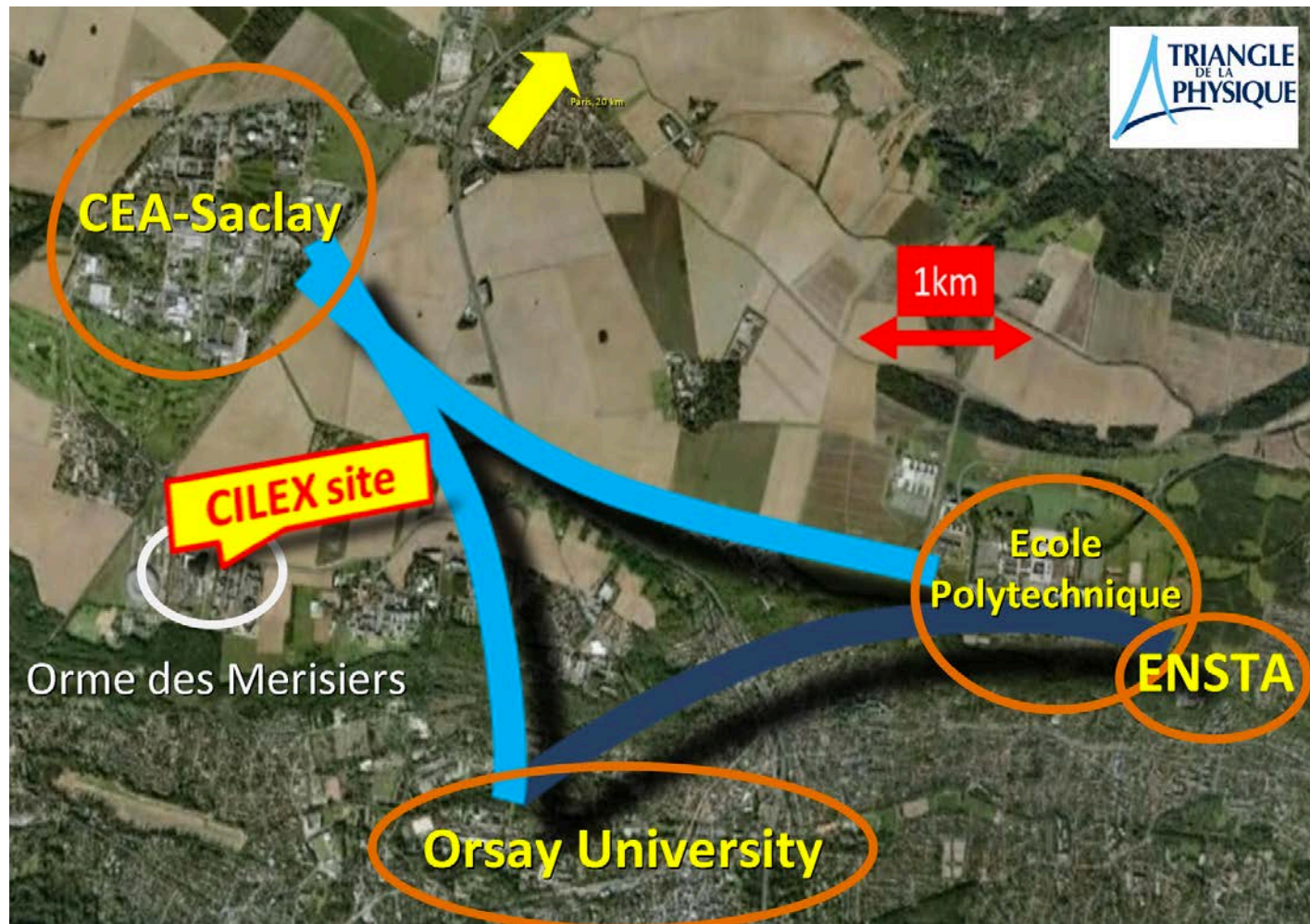
10 PW

100 PW





Centre Interdisciplinaire Lumière Extrême





Extreme frequencies

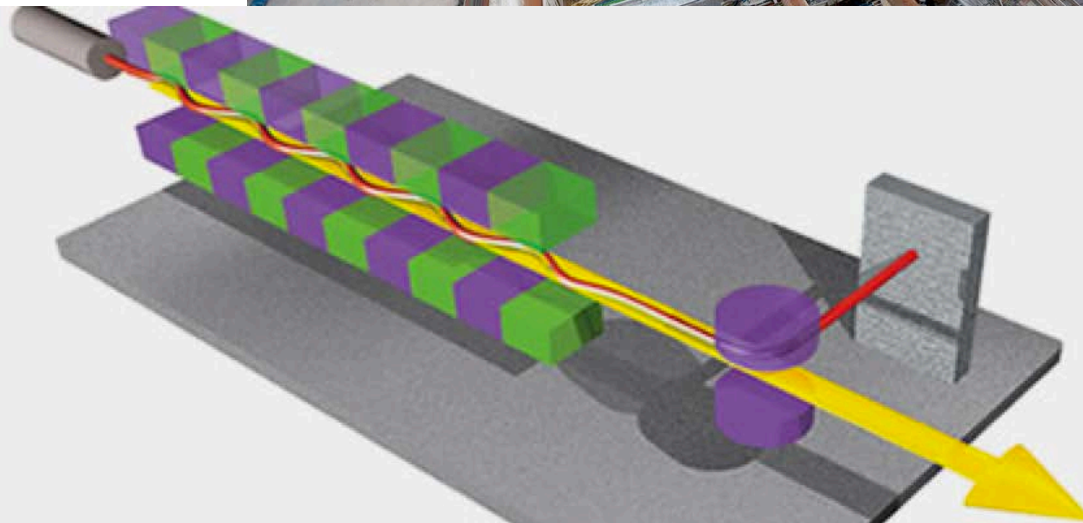


X-ray lasers

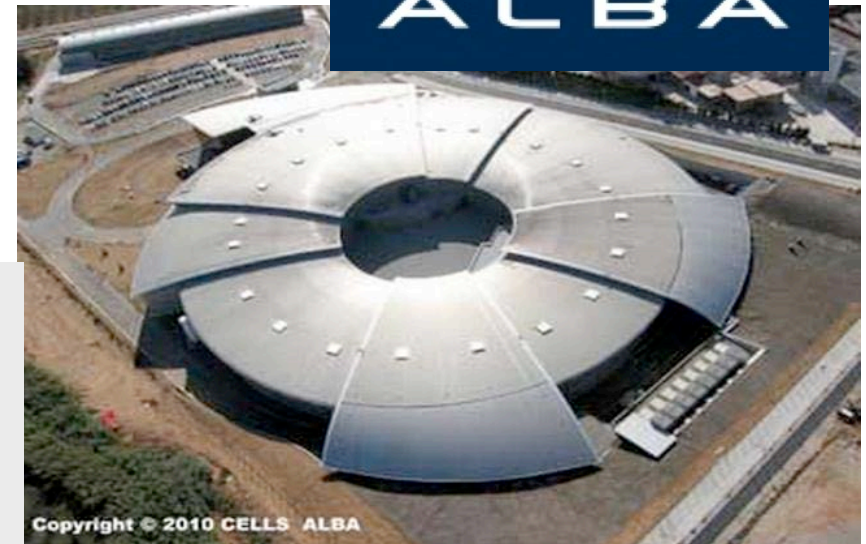
10 - 0.1 nm

Free-electron Lasers

European
XFEL



Modern Synchrotrons





LaserLab Europe



The Integrated Initiative of European Laser Research Infrastructures

Laserlab-Europe is in the third phase of its successful cooperation: the Consortium now brings together 30 leading organisations in laser-based inter-disciplinary research from 16 countries.



ope



Structures
European Union



The Integrated Initiative of European Laser Research Infrastructures

Laserlab-Europe is in the third phase of its successful cooperation: the Consortium now brings together 30 leading organisations in laser-based inter-disciplinary research from 16 countries.



LaserLab Europe main objectives

Networking.-

To maintain a competitive, interdisciplinary network of European national laser laboratories;

Joint Research Activities.-

To strengthen the European leading role in laser research through Joint Research Activities (JRA), pushing the laser concept into new directions and opening up new applications of key importance in research and innovation;



LaserLab Europe main objectives

Transnational access.-

To offer transnational access to top-quality laser research facilities in a highly co-ordinated fashion for the benefit of the European research community;

To increase the European basis in laser research and applications by reaching out to neighboring scientific communities and by assisting in the development of Laser Research Infrastructures on both the national and the European level.



LaserLab Europe main objectives

Jobs

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Conclusions



Conclusions

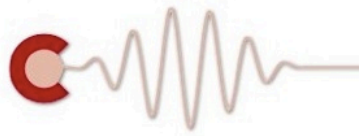


Laser technology is moving ahead very fast

Enough peak power

Lack of average power





Pedro García Managing Director

Alvaro Peralta Head Scientific Division

Cruz Méndez Head Technical Division



Jose Antonio Pérez

Mauricio Rico

Enrique García

Marina Sanchez

Juan Hernández

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Carolina Romero

Oscar Varela

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Javier Lozano

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Thanks!

Salamanca - Spain



www.clpu.es
roso@clpu.es



LA3NET

The exploitation of **LA**sers for **A**pplications at **A**ccelerator facilities for ion beam generation, acceleration and diagnostics is the goal of the **NET**work (LA³NET) within the FP7 Marie Curie Initial Training Network (ITN) scheme.

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