# *A PASSION FOR EXTREME LIGHT : UNIVERSITY of SALAMANQUE*

*For the Greatest Benefit of Human Kind*

*Presented by*

## ***Prof. Gérard Mourou***

*Nobel Prize for Physics, 2018*

***LE Big Bang se produisait il y a14 milliards d’années. Cependant, il fallut 380.000 ans à la lumièrer pour se libérer de la soupe primordiale des particules.***

***Mais cette lumiére était incohèrente.***

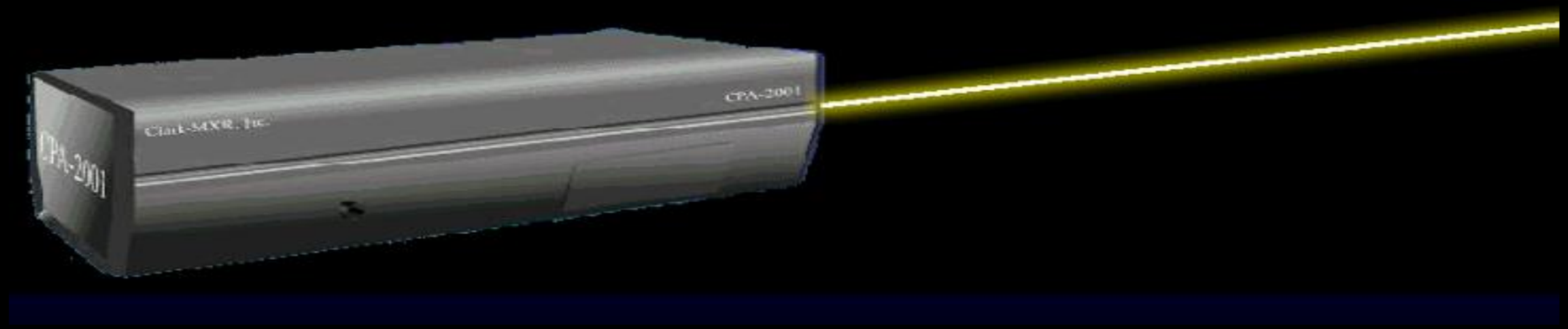
# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

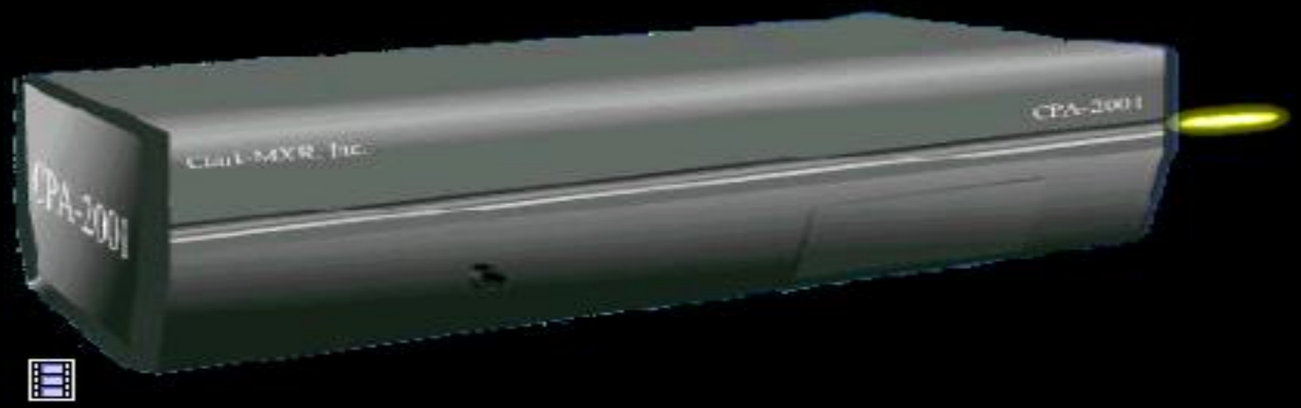
## *A LIGHT BULB,*

*Incoherent Photons are radiated outwards*

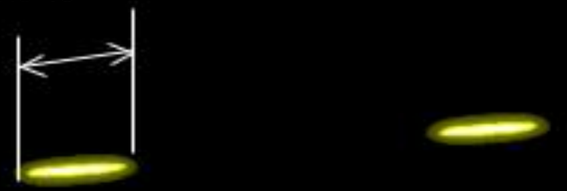
# This is a laser!
# Coherent Light



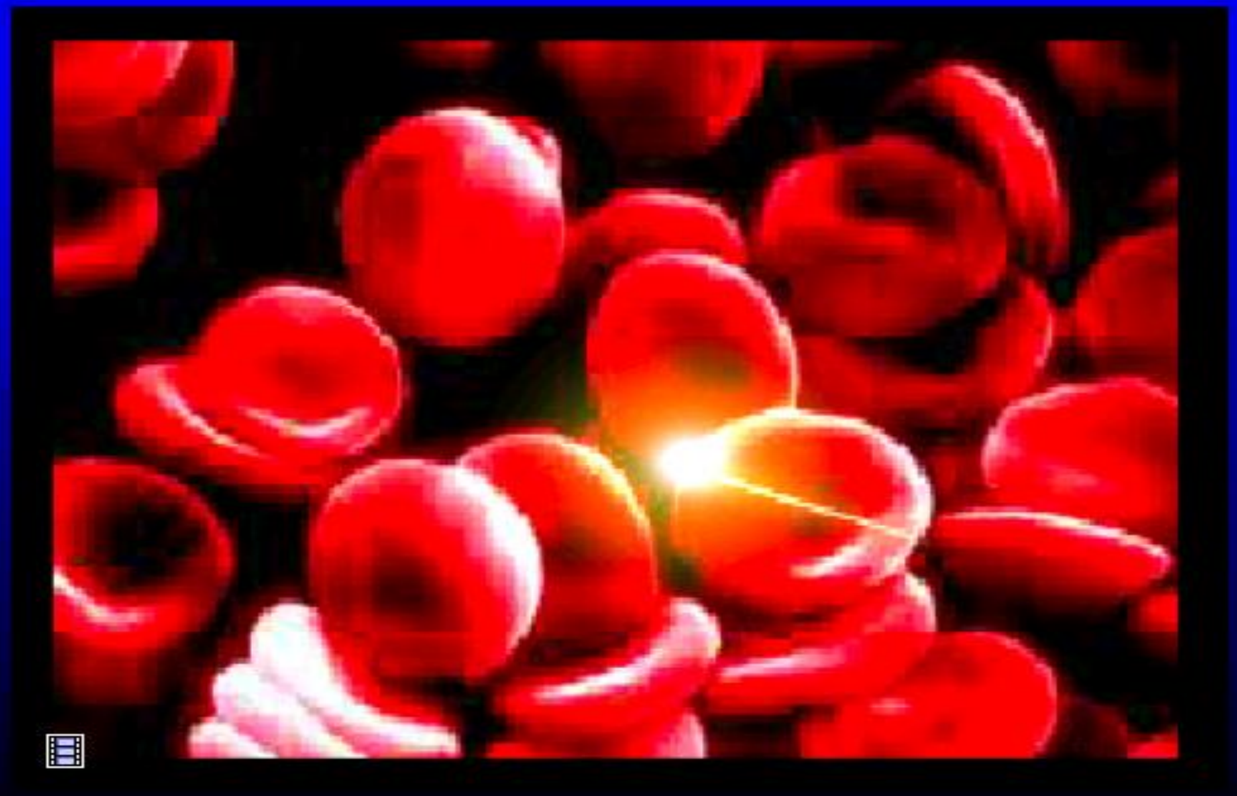
# Laser can emits very short bursts of light




ns-fs



# *Red Blood Cell: 10 fs*



# *Incoherent Light*

# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

***The light is coherent, like marching soldiers***

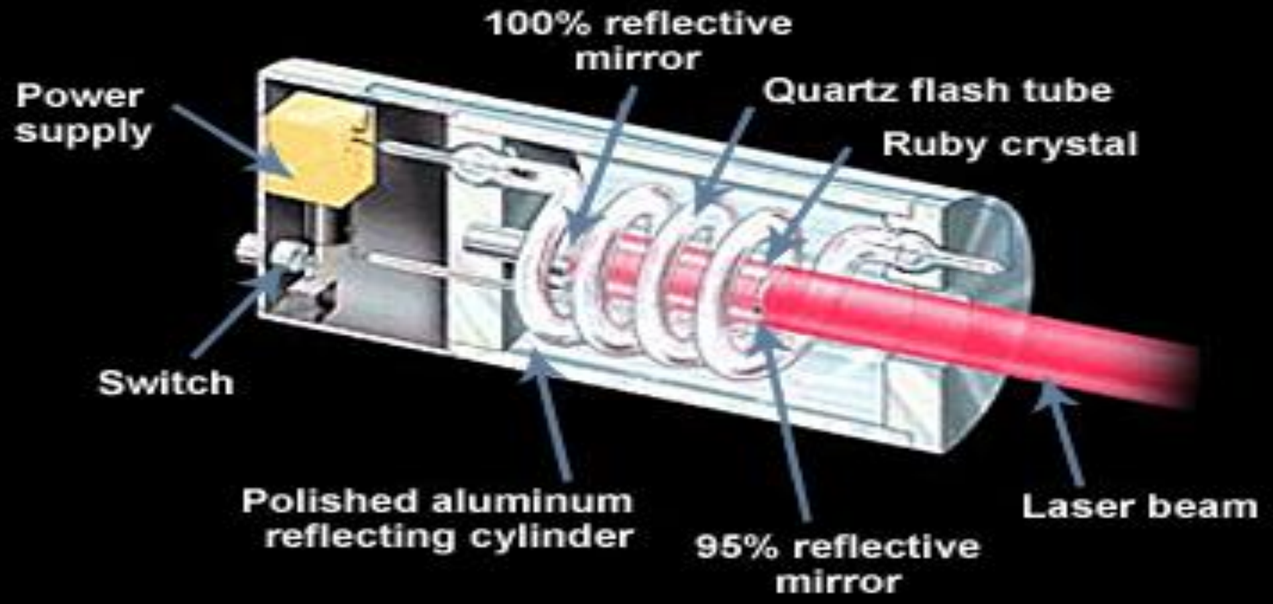
# *A PASSION FOR EXTREME LIGHT*

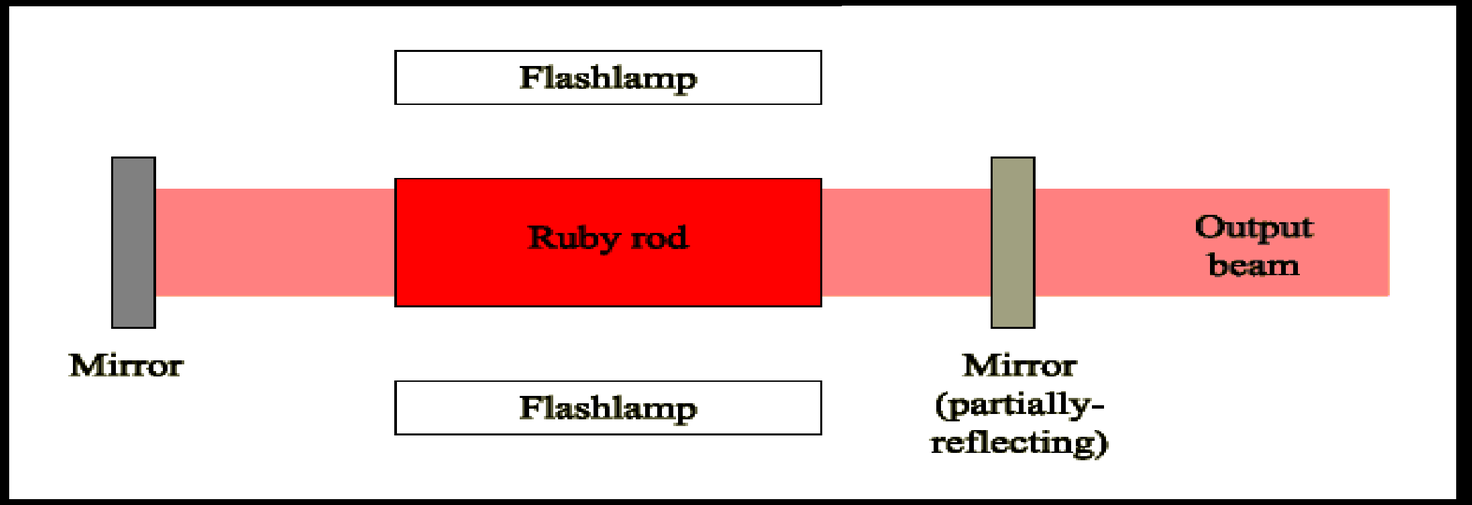
*For the greatest benefit to human kind (Alfred Nobel)*

***Theodore Maiman***

*(July 11, 1927 – May 5, 2007)*

## Components of the first ruby laser



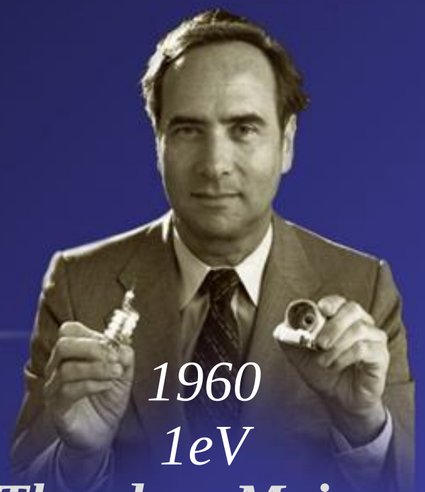



# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

*Slowing down atoms*

*2018*



*1960*

*1eV*

***Theodore Maiman***

*(July 11, 1927 – May 5, 2007)*

# *A PASSION FOR EXTREME LIGHT*

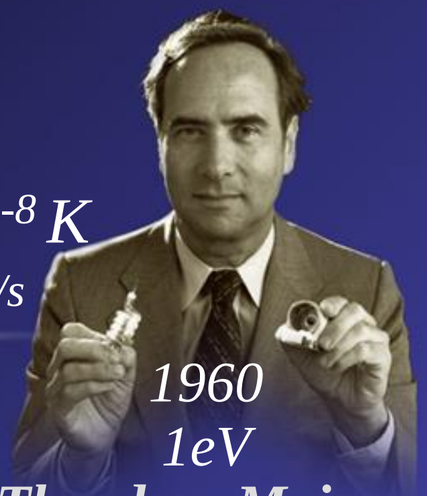
*For the greatest benefit to human kind (Alfred Nobel)*

***Quantum Optics***

*μeV – peV  Temp.= 10 $^{-8}$ K*

*K  Slowing down atoms to cm/s*

*2018*



*1960*

*1eV*

***Theodore Maiman***

*(July 11, 1927 – May 5, 2007)*

***Atomic Molecular Optics***

**** cold atoms***
**** metrology***
**** atom optics***
**** condensed-matter physics***
**** quantum information science***
**** chemistry***

# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

## *Quantum Optics*

*μeV – peV  Temp =10 $^{-8}$ K*

*Slowing down atoms to cm/s*

*2018*

*1960*

*1eV*

***Theodore Maiman***

*(July 11, 1927 – May 5, 2007)*

## *Relativistic Optics*

*GeV - TeV*

*Accelerating particles to C*

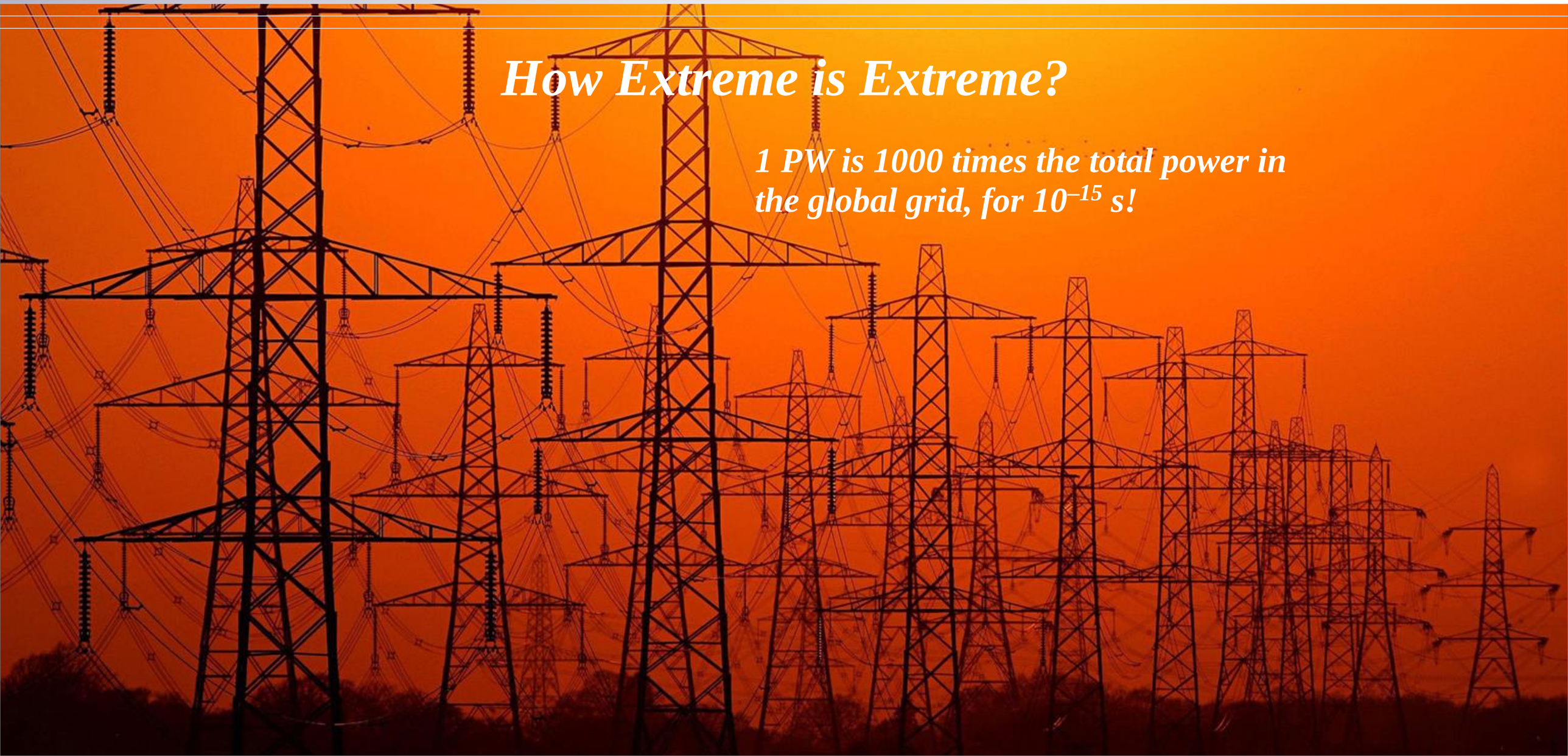
*2018*

***Atomic Molecular Optics***

**** cold atoms***
**** metrology***
**** atom optics***
**** condensed-matter physics***
**** quantum information science***
**** chemistry***

***Relativistic and Ultra-relativistic Optics***

**** accelerator physics***
**** nuclear physics***
**** cosmology***
**** NL QED***
**** general relativity***
**** extradimension physics***



# *How Extreme is Extreme?*

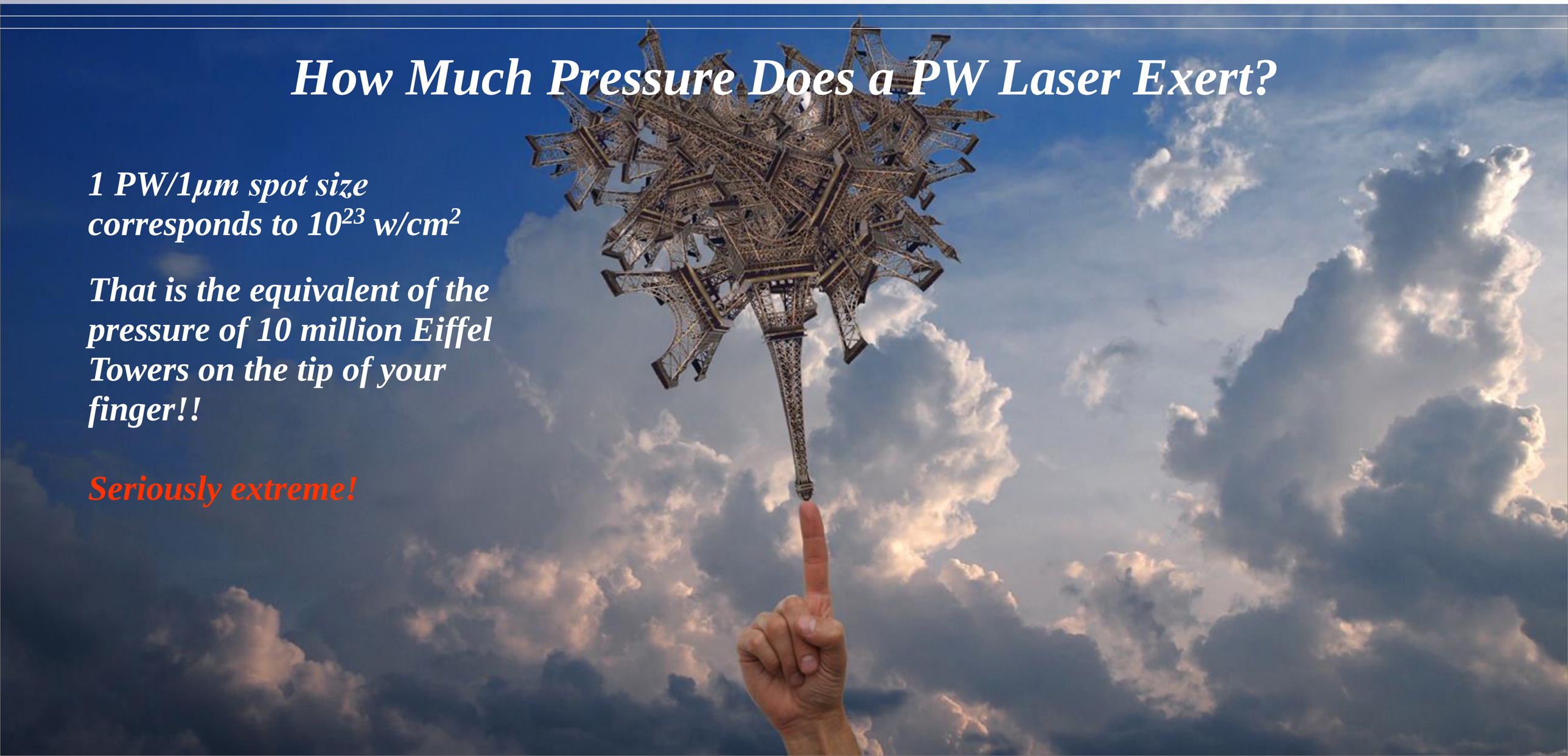
***1 PW is 1000 times the total power in the global grid, for $10^{-15}$ s!***

# *How Much Pressure Does a PW Laser Exert?*

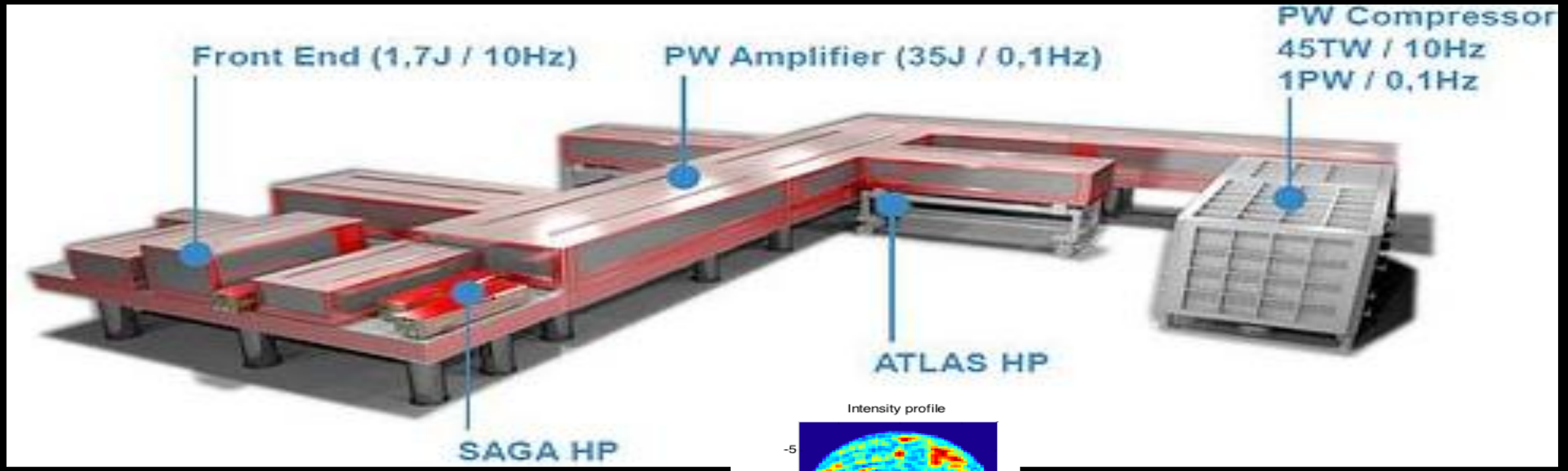
***1 PW/1μm spot size corresponds to $10^{23}$ w/cm$^2$***

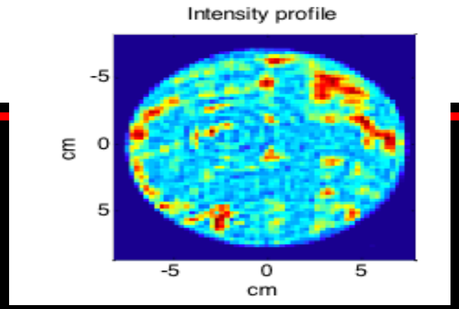
***That is the equivalent of the pressure of 10 million Eiffel Towers on the tip of your finger!!***

***Seriously extreme!***



# *Petawatt Laser Provides A 10-1000J Uniform wave front in Phase and Amplitude*



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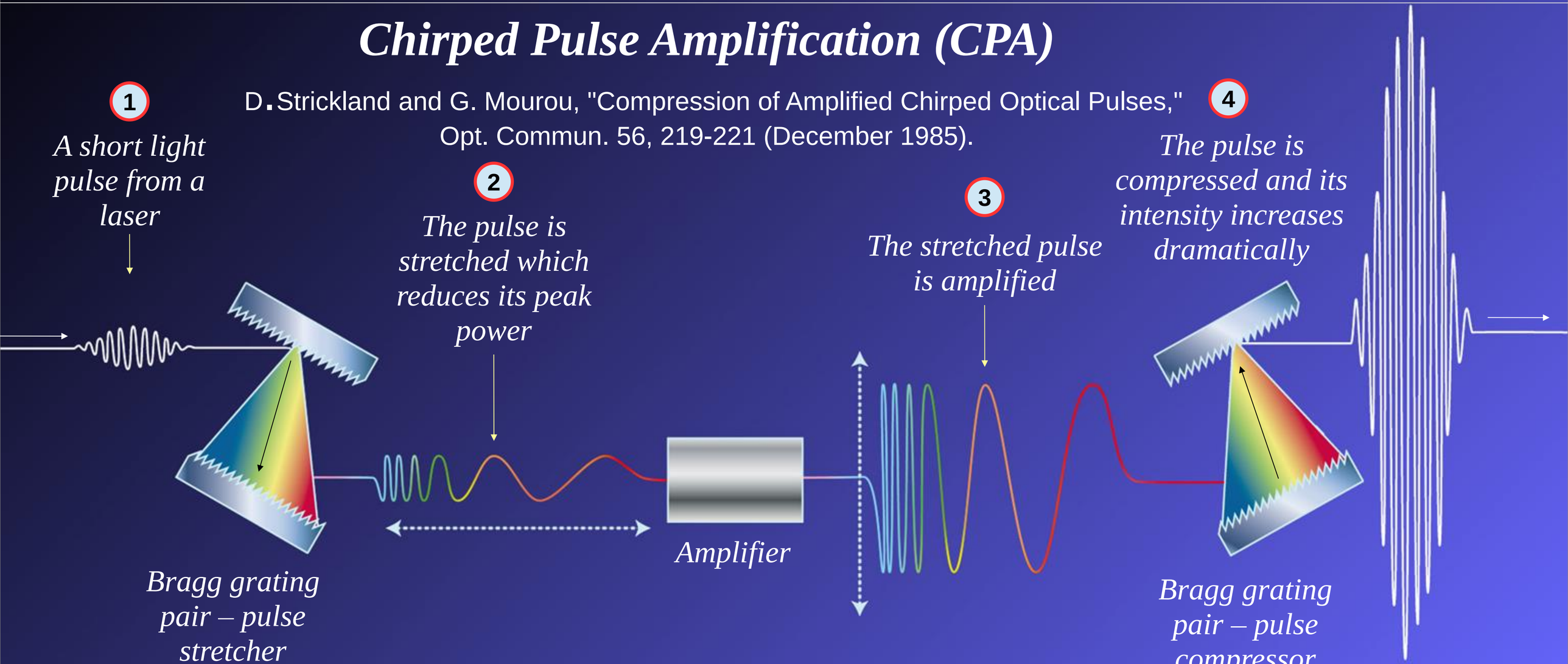
## *Chirped Pulse Amplification (CPA)*

D. Strickland and G. Mourou, "Compression of Amplified Chirped Optical Pulses," Opt. Commun. 56, 219-221 (December 1985).



# *A PASSION FOR EXTREME LIGHT*

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Extreme light Laser is capable to produce,

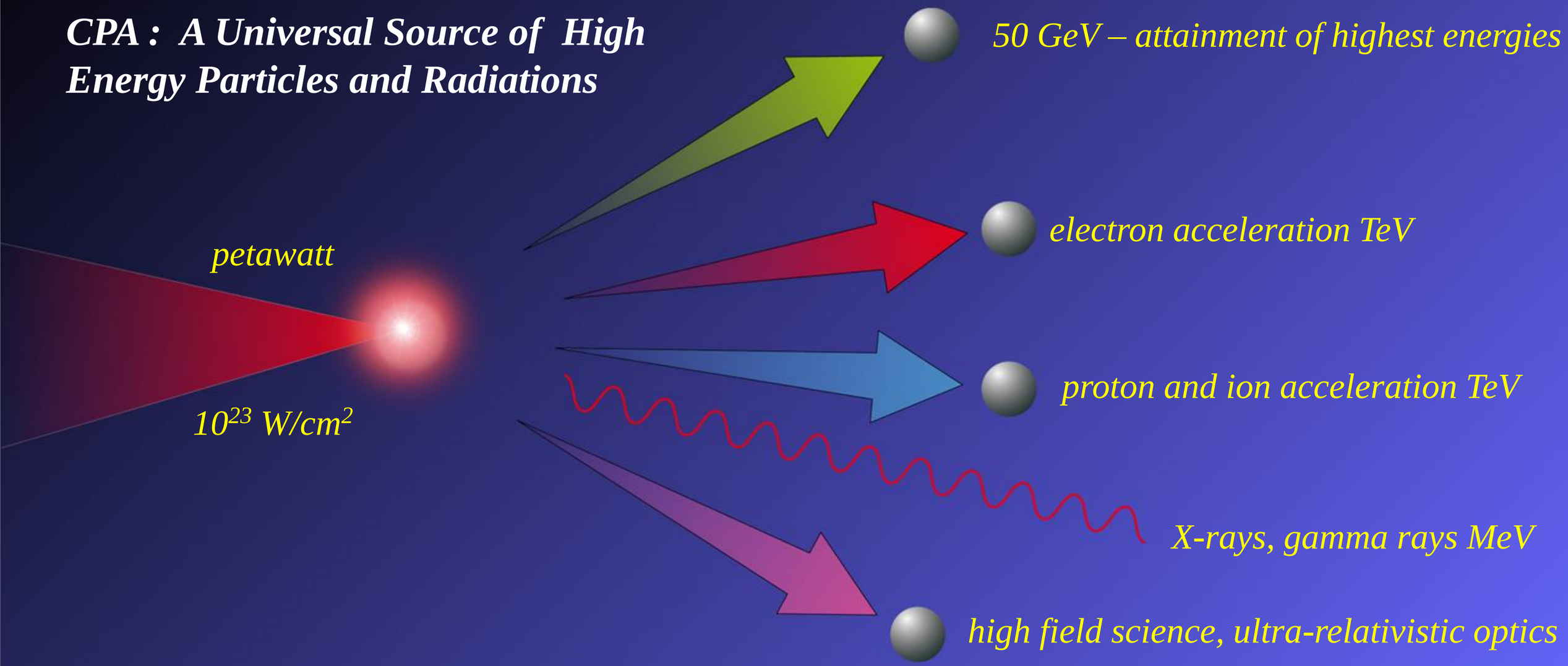
1. the largest peak power,
2. the largest temperature,
3. the largest pressure,
4. largest acceleration,
5. the largest field.

It is a universal source of High Energy Particles and Radiations

# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

## *CPA : A Universal Source of High Energy Particles and Radiations*

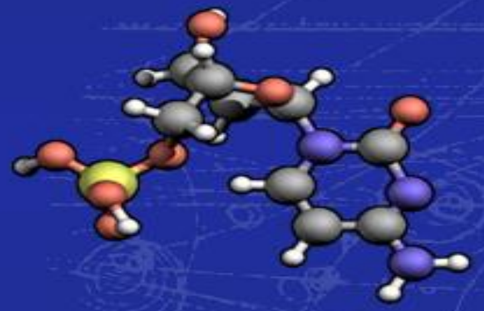


# Laser Exploration : From Atomic to Sub-Atomic

eV → TeV

## ATOMIC

molecules

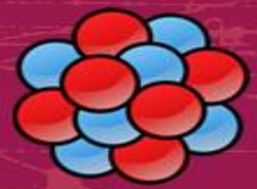


atoms

$10^{-10}$ m

## SUB-ATOMIC

nucleii

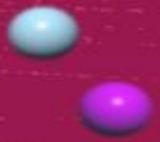


$10^{-14}$ m

protons

$10^{-15}$ m

electrons/quarks



?

$\leq 10^{-18}$ m

Nobel NSF

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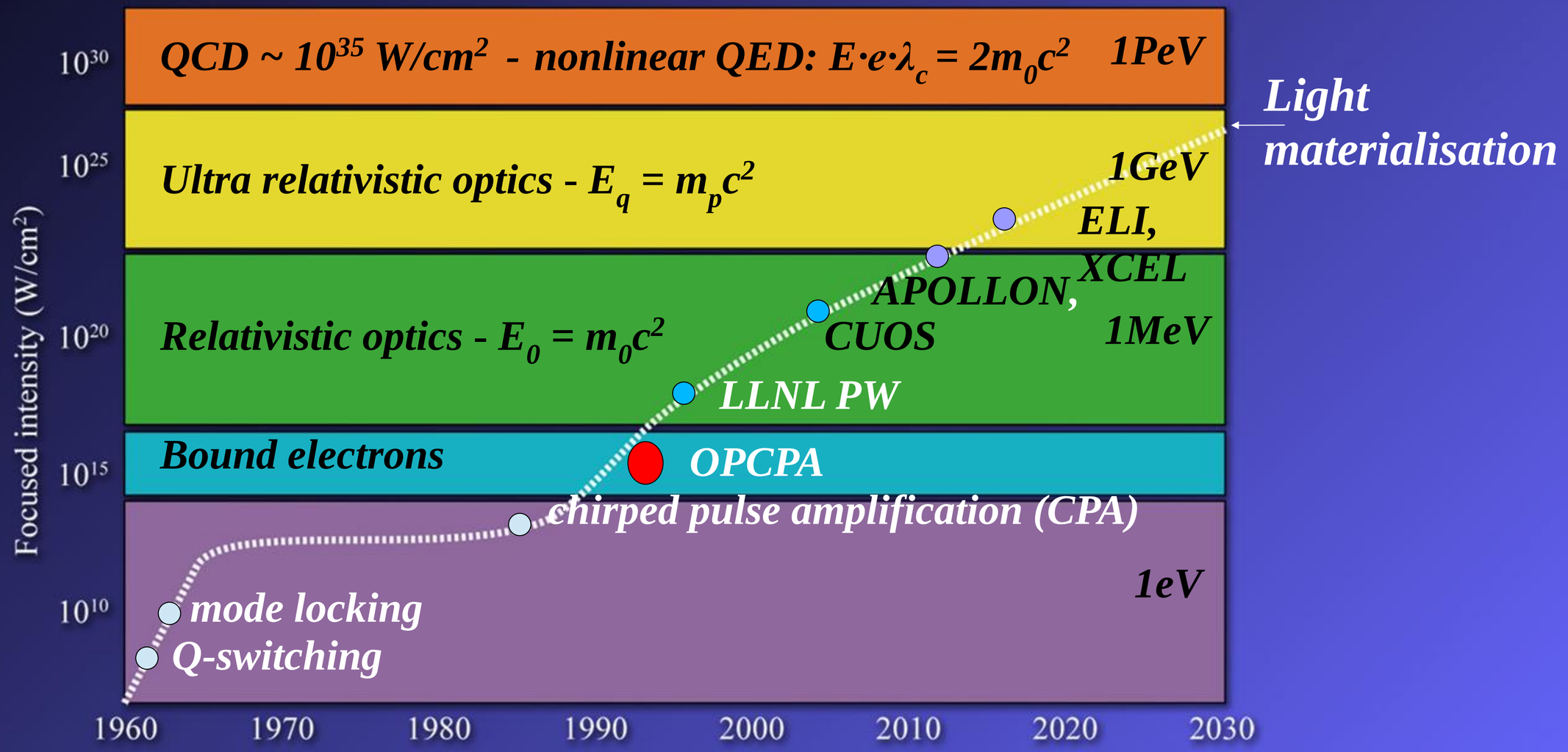
## *Extreme light ultra high intensity roadmap*



# Extreme Light Infrastructure - ELI

## The Largest Civilian Laser Infrastructure

**Initiated and Coordinated(PP) by, G. Mourou (EP)**
**ELI (Delivery Consortium) W. Sandners**


*Czech Republic*

*Hungary*

*Romania*



Trondheim University

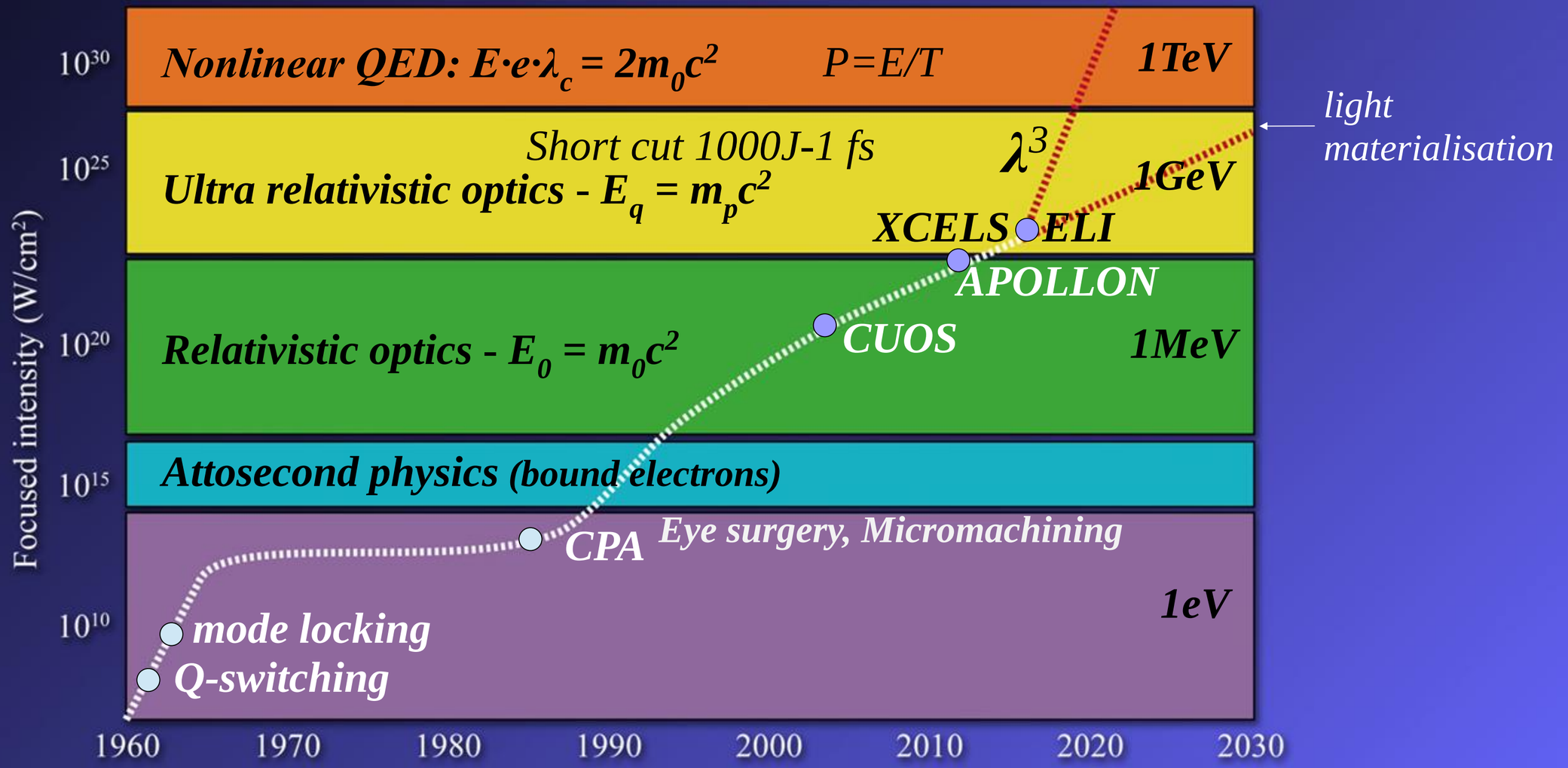
IZEST
International Zeta-Exawatt Science Technology

International Year of Light 2015

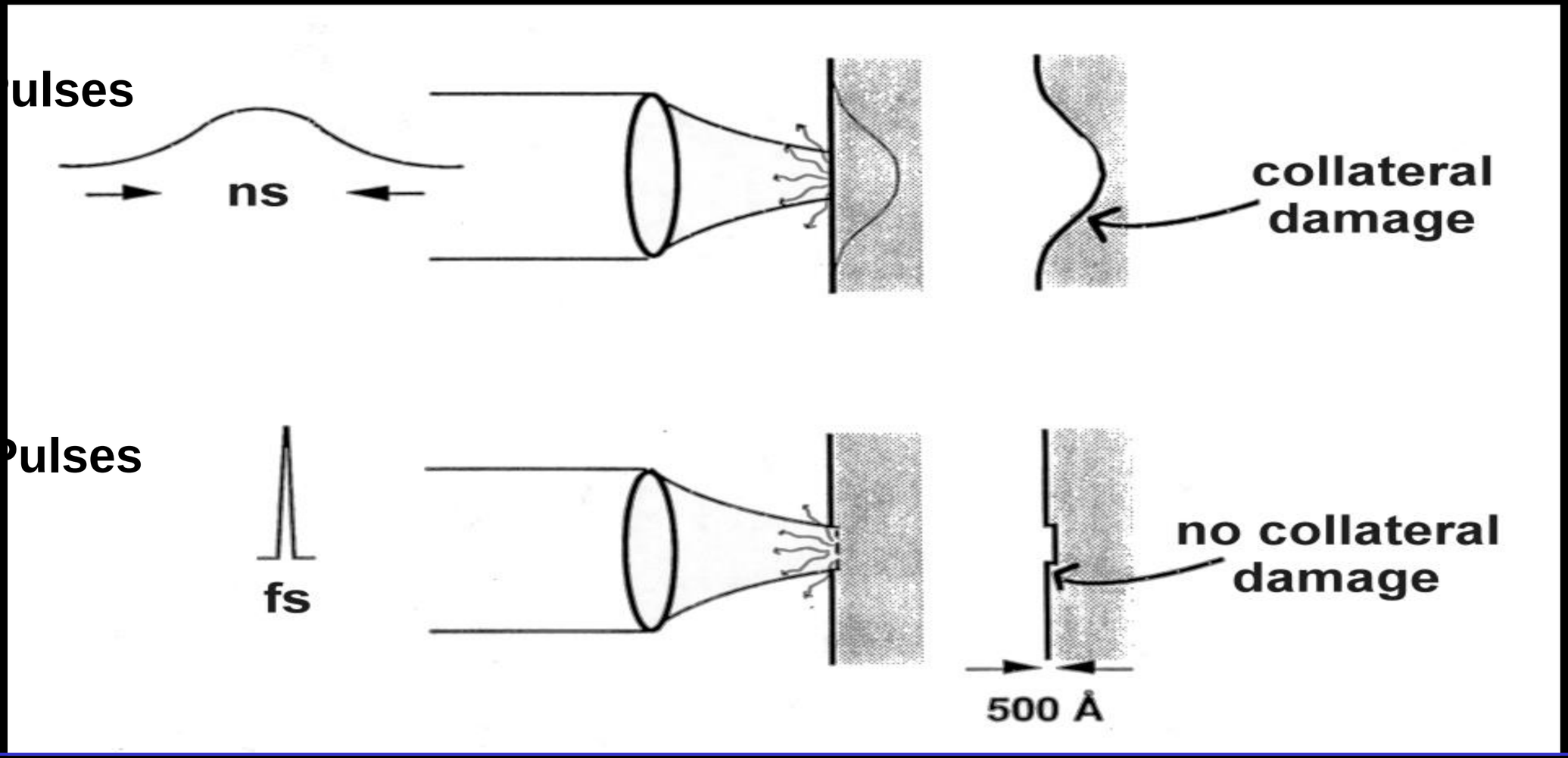
# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

## *Extreme light roadmap and ultra high intensity shortcut*



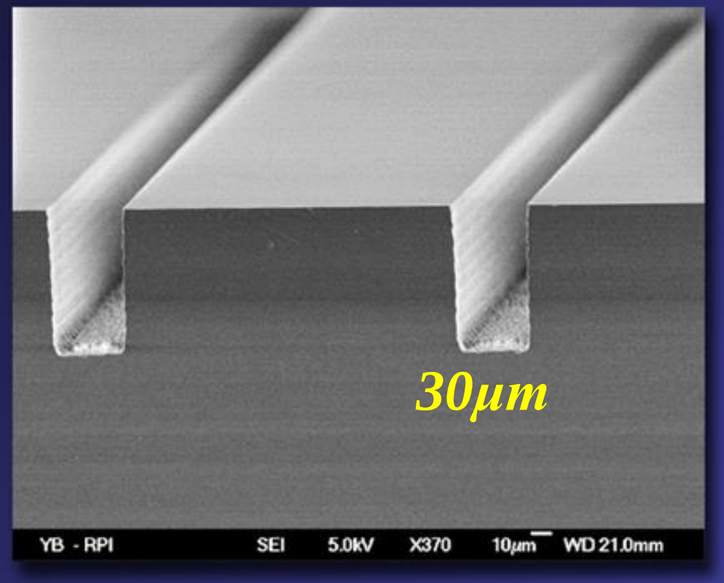
# Micromachining: Long pulses vs. short pulses

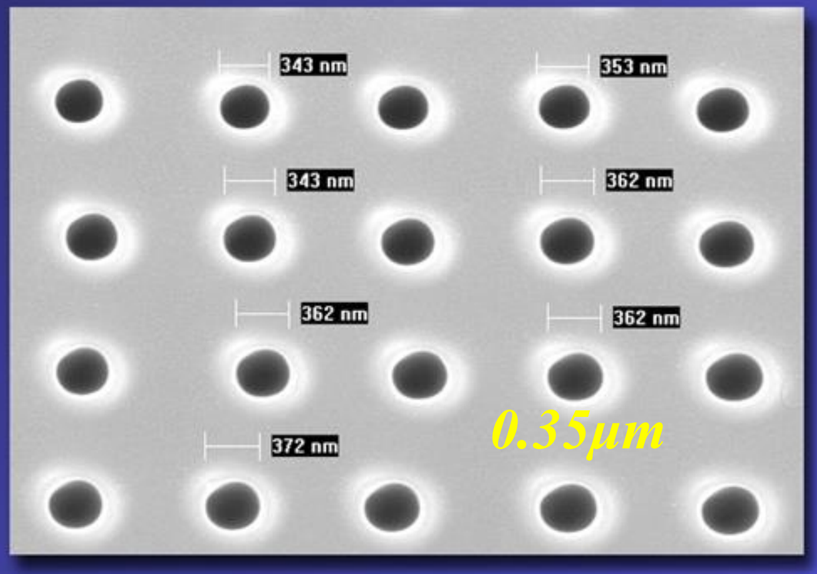



With femtosecond pulses, thermal diffusion is suppressed,
so a minimum volume is ablated.

# *High Precision Micro Machining*

## *A femtosecond (fs) laser will cut the material without damaging it*



# *A PASSION FOR EXTREME LIGHT*

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***CPA femtosecond lasers revolutionised ophthalmology***
***24 million eye operations since 2001!***

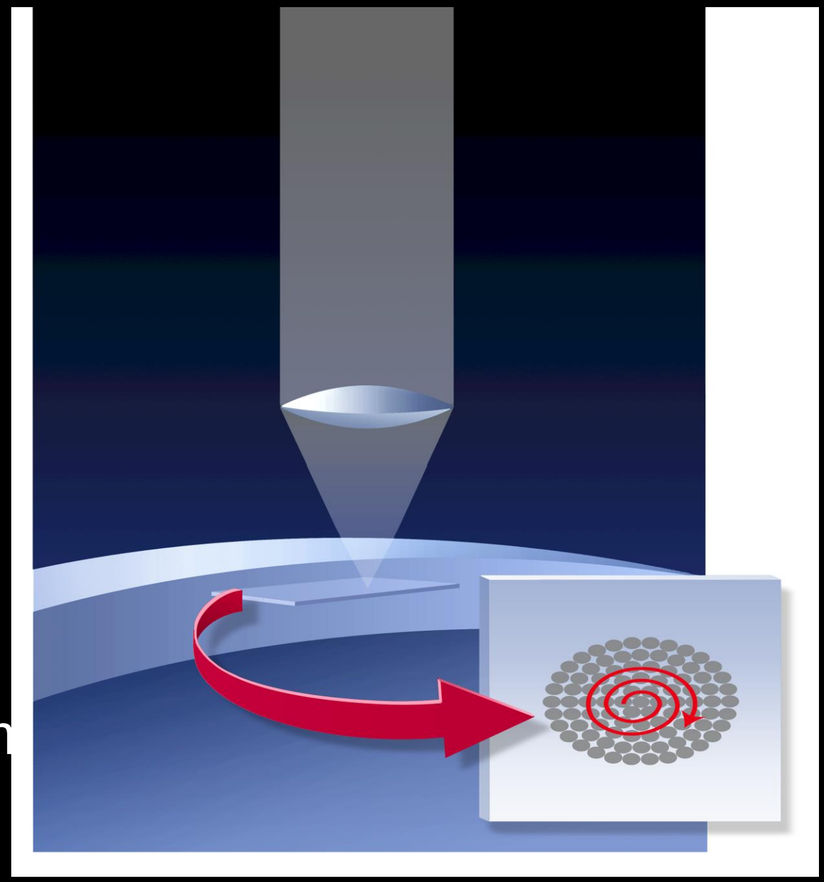
# Ophthalmology of  High Intensity

## CUOS University of Michigan

Low energy,  short duration pulses focused to small spot size (I=E/t A)

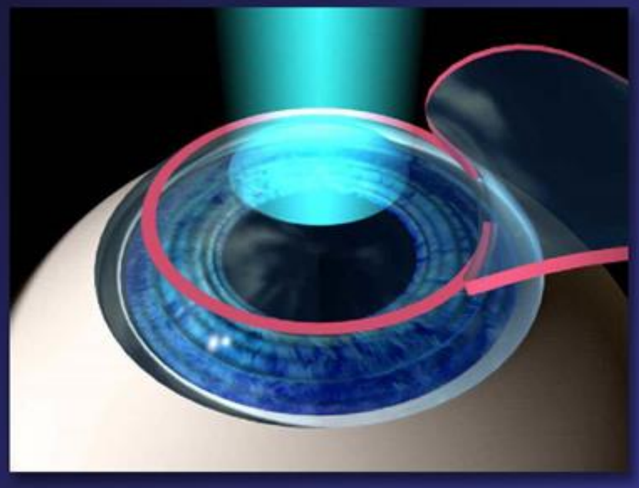
Three dimensional surgical patterns created by contiguous micro-cavitations

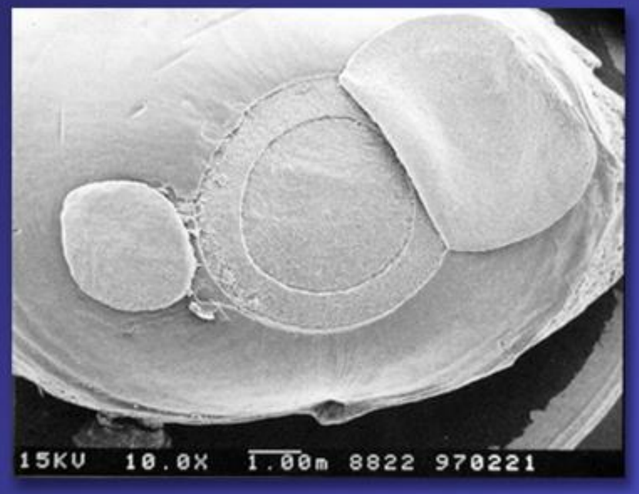
Limited adjacent tissue effects and no disruption of the tissue surface



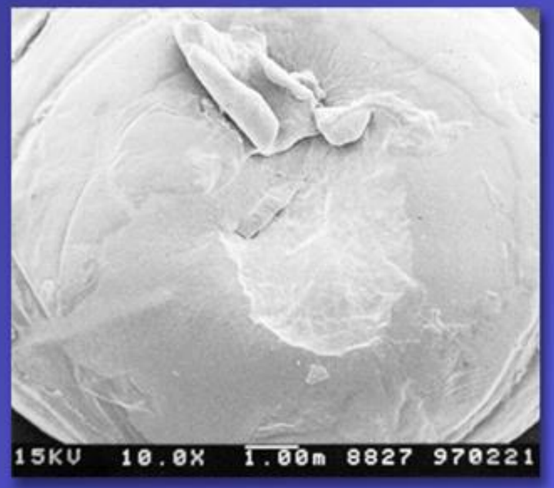
T. Juhasz, F. H. Loesel, R. M.  Kurtz, C. Horvath, J. F. Bille, G. Mourou, Refractive surgery with femtosecond lasers¡±, IEEE Journal of Selected Topics in Quantum Electronic on Lasers in Medicine and Biology, 1999..

***CPA femtosecond lasers revolutionised ophthalmology***
***24 million eye operations since 2001!***






***300 fs***




***50 ps***

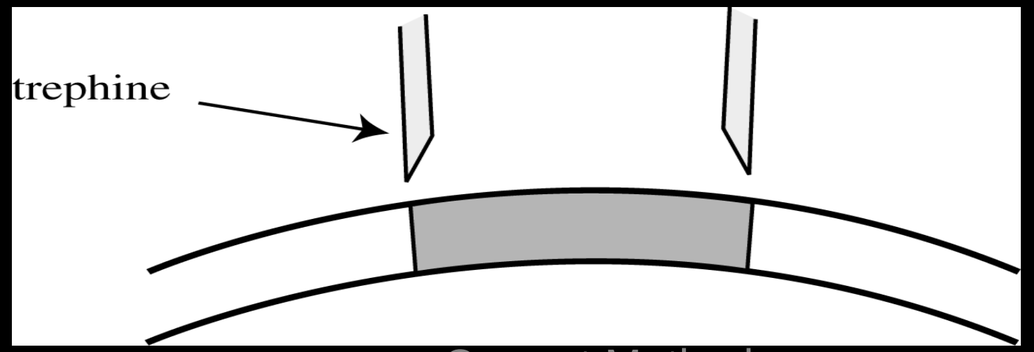
# *High Intensity Corneal Transplant Laser Surgery*

## *CUOS University of Michigan*

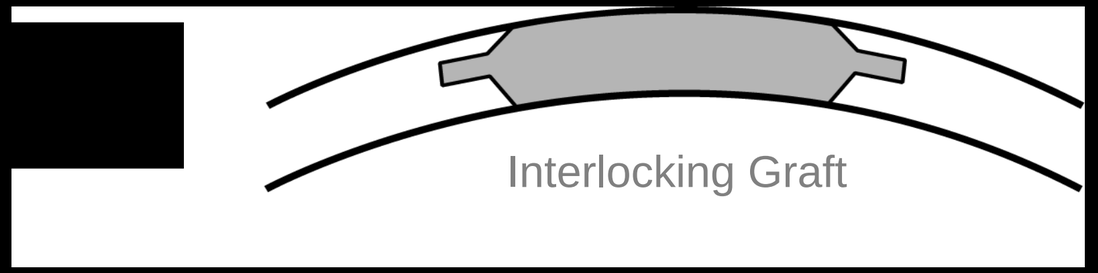
*~ 45,000 transplants/yr in US*

*Mechanical instruments, such as trephines create full thickness transplants that require extensive suturing, long healing times*

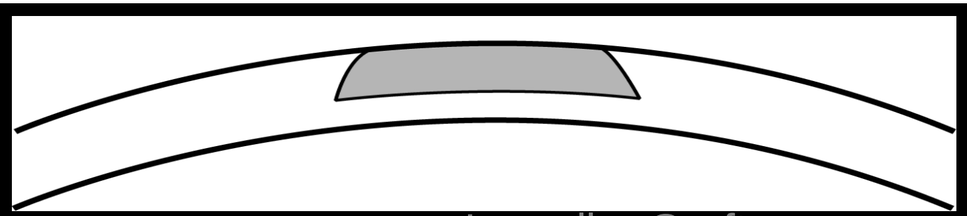
*Femtosecond lasers can create complex shapes, permitting self-locking and partial thickness transplants*




Current Method



Interlocking Graft



Lamellar Graft

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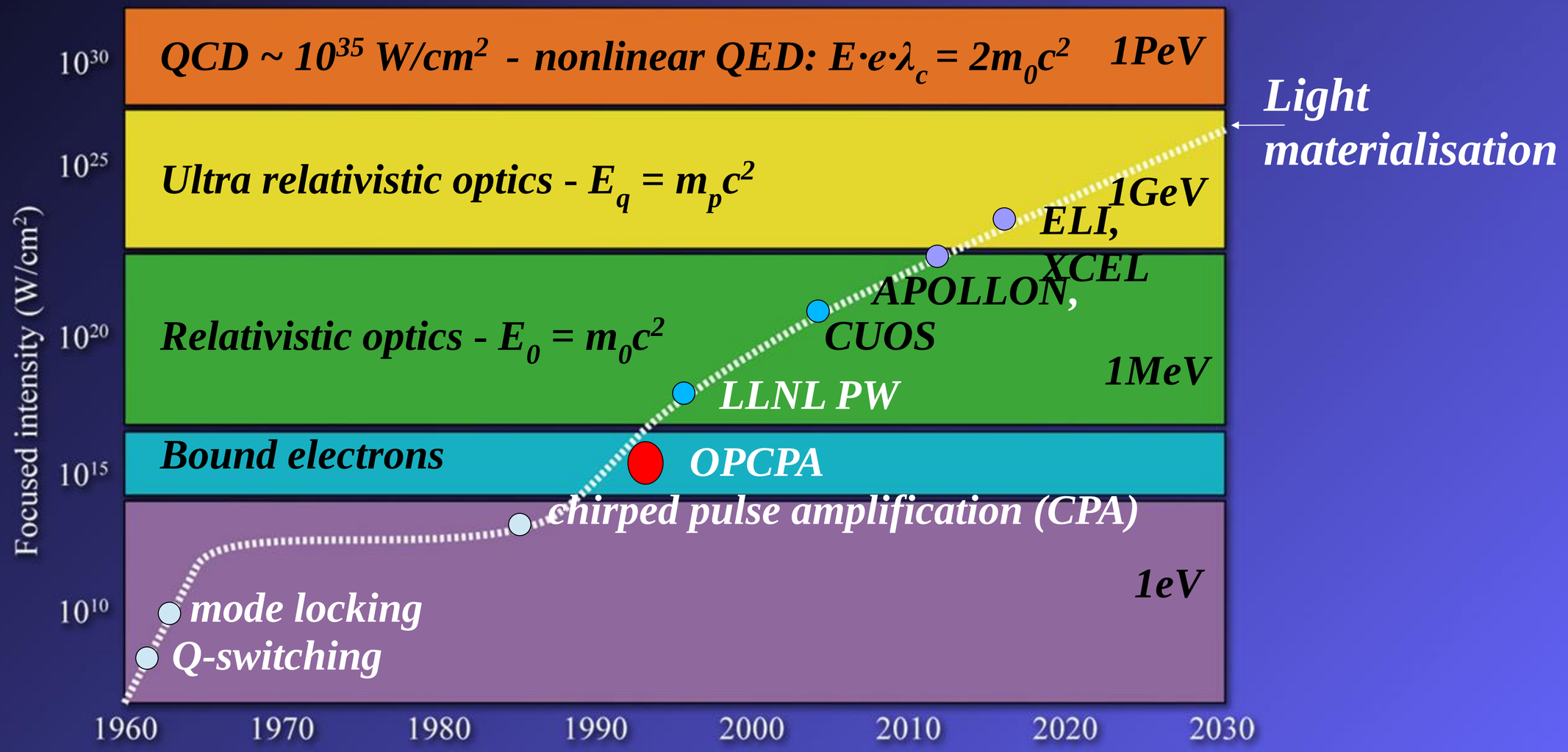
## *Extreme light ultra high intensity roadmap*



# *A PASSION FOR EXTREME LIGHT*

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## *Giant wakefield acceleration in gas and solid*

*Tajima et Dawson (1979)*

***A surfer riding down the face of a wave is accelerated by energy of the wave***

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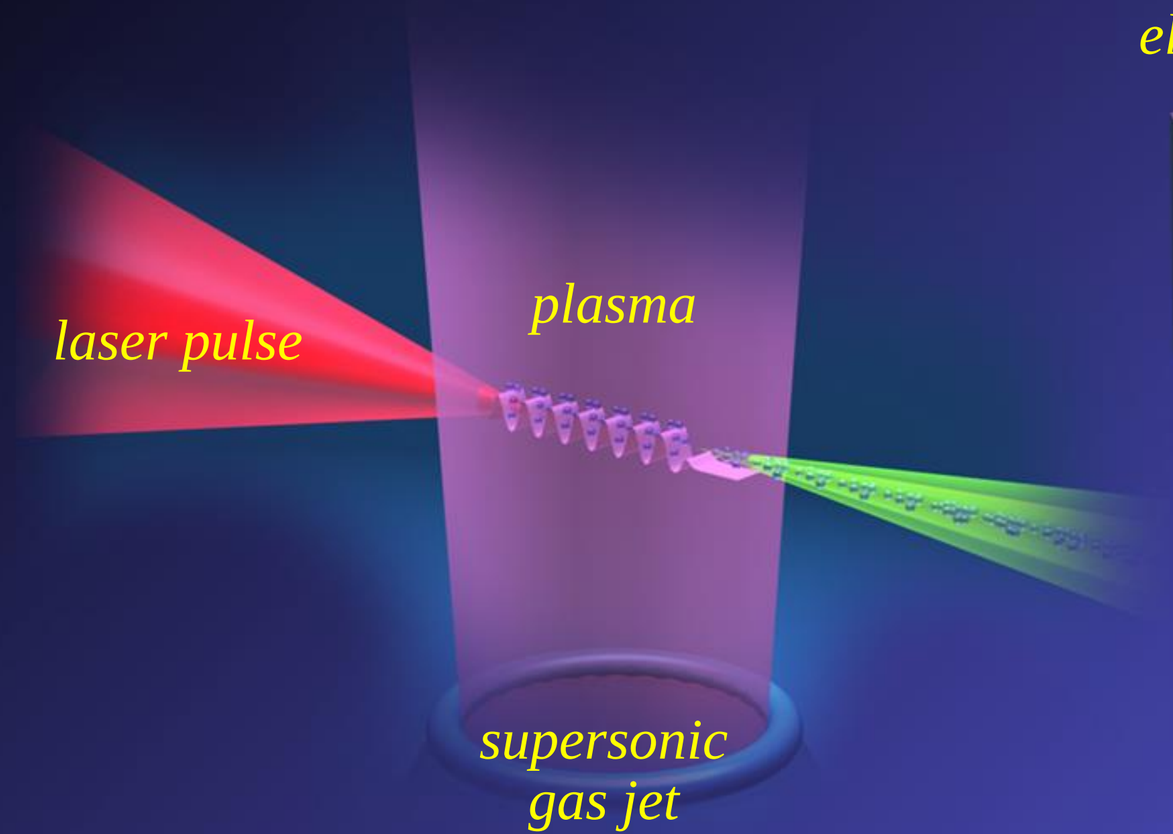
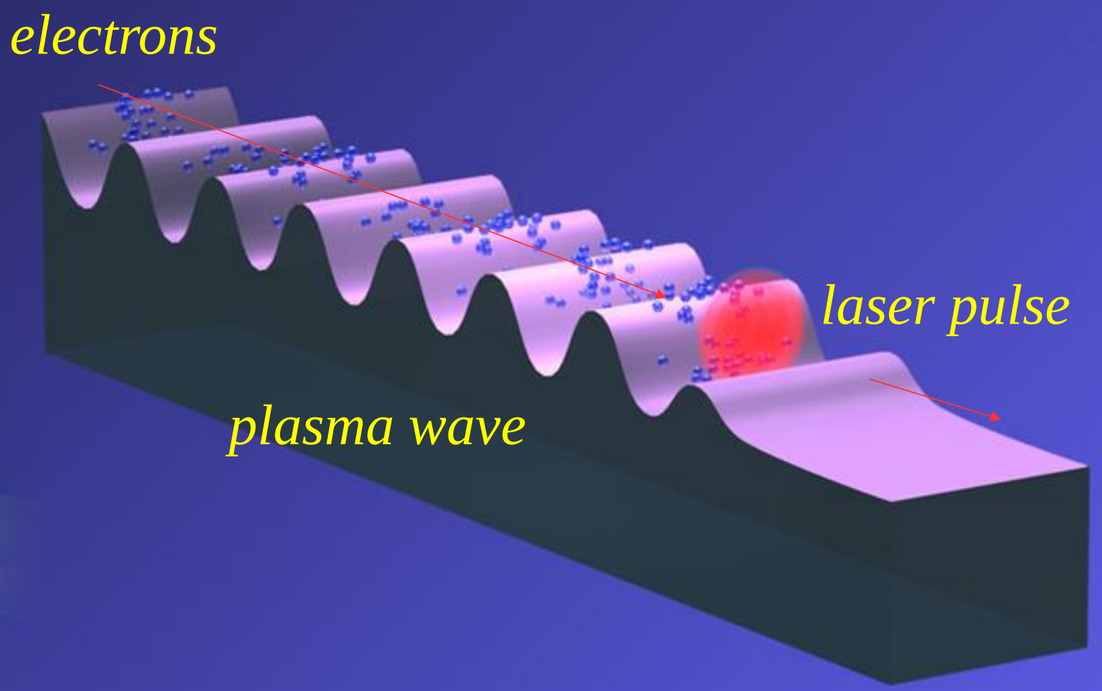
## *Giant wakefield acceleration*

*Tajima et Dawson (1979)*




***High Energy beam***
***GeV/cm***

# Synchrotron SOLEIL 3GeV

S

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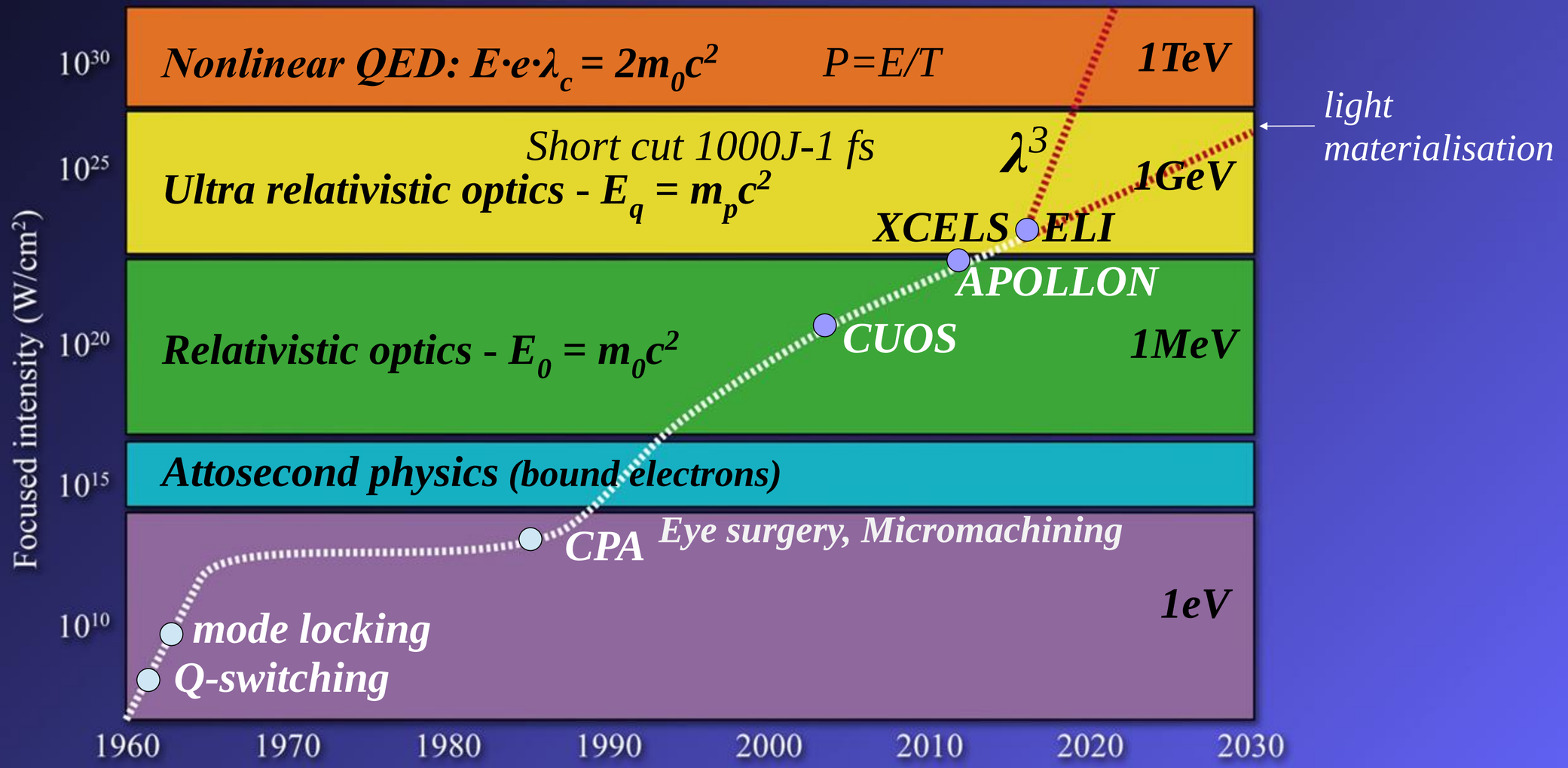
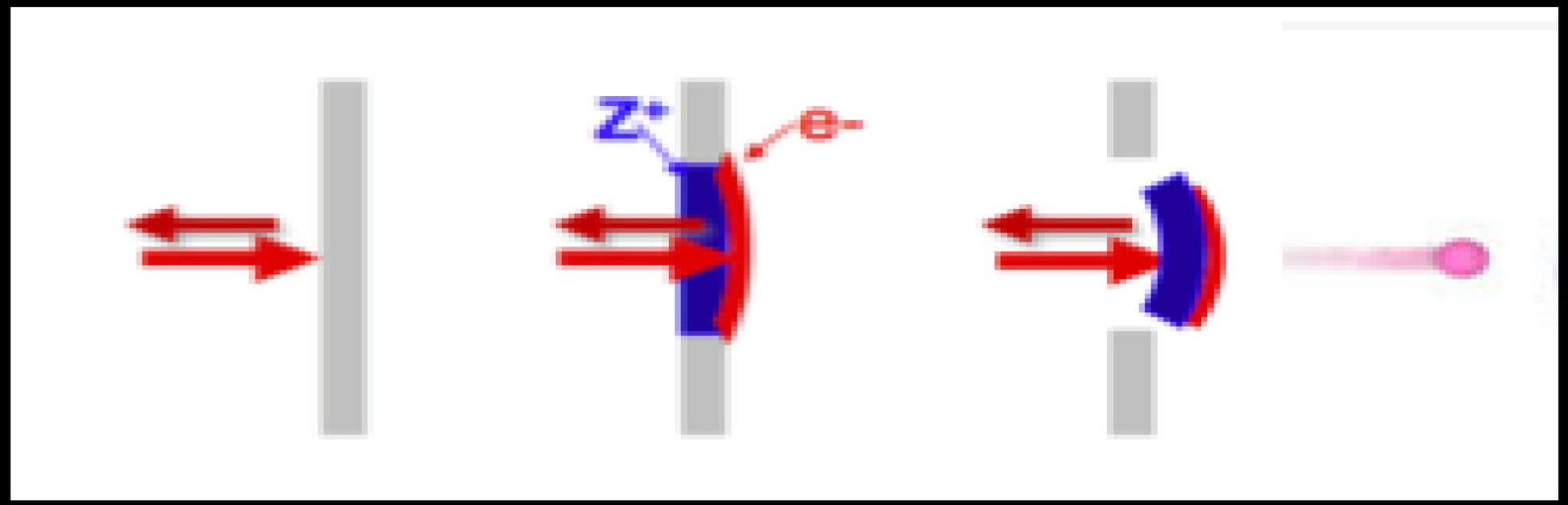
## *Extreme light roadmap and ultra high intensity shortcut*



# Low Hanging Fruits

# *Low Hanging Fruit: High Energy Proton Generation*

GeV Proton Generation



# *A PASSION FOR EXTREME LIGHT*

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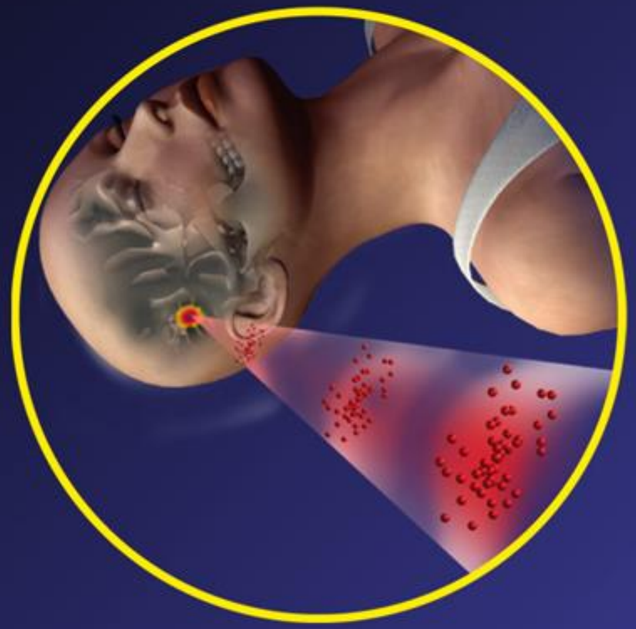
## *RELATIVISTIC PROTON ACCELERATOR for TRANSMUTATION*

## *Projet MYRRHA*

# *CPA in Nuclear Medicine*

## *Proton therapy*



*Extreme light technology will be tens of times more compact, more precise and less expensive*

## *Nuclear therapy*

*Radionuclides are used to implant radioactive pellets directly into a tumour*

## *Nuclear diagnostics*


*When a scanner needs a radioisotope, extreme laser acceleration in the clinic would make this fast and safer*

# *A PASSION FOR EXTREME LIGHT*

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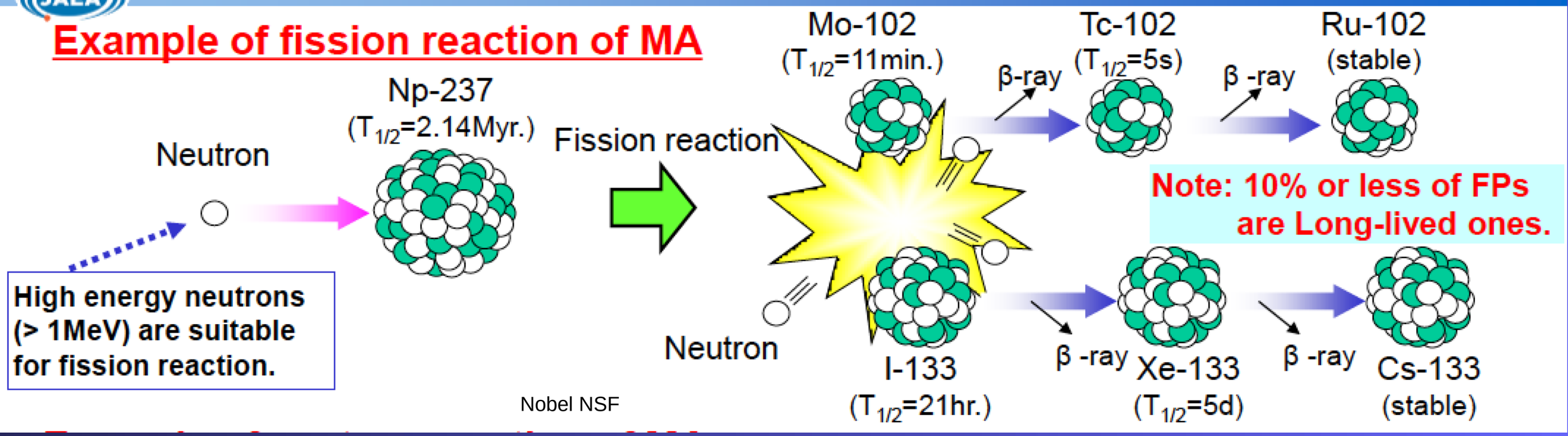
## *CPA Mitigating Nuclear waste*

# NUCLEAR TRANSMUTATION CONCEPT

## How to Transmute MA and LLFP

JAEA

**Example of fission reaction of MA**




Nobel NSF

# *Space Debris*

*Millions of orbital debris are cluttering  space*

# SPACE DEBRIS - A state of emergency!

4x 7,000 tons = **28,000 tons!!!**

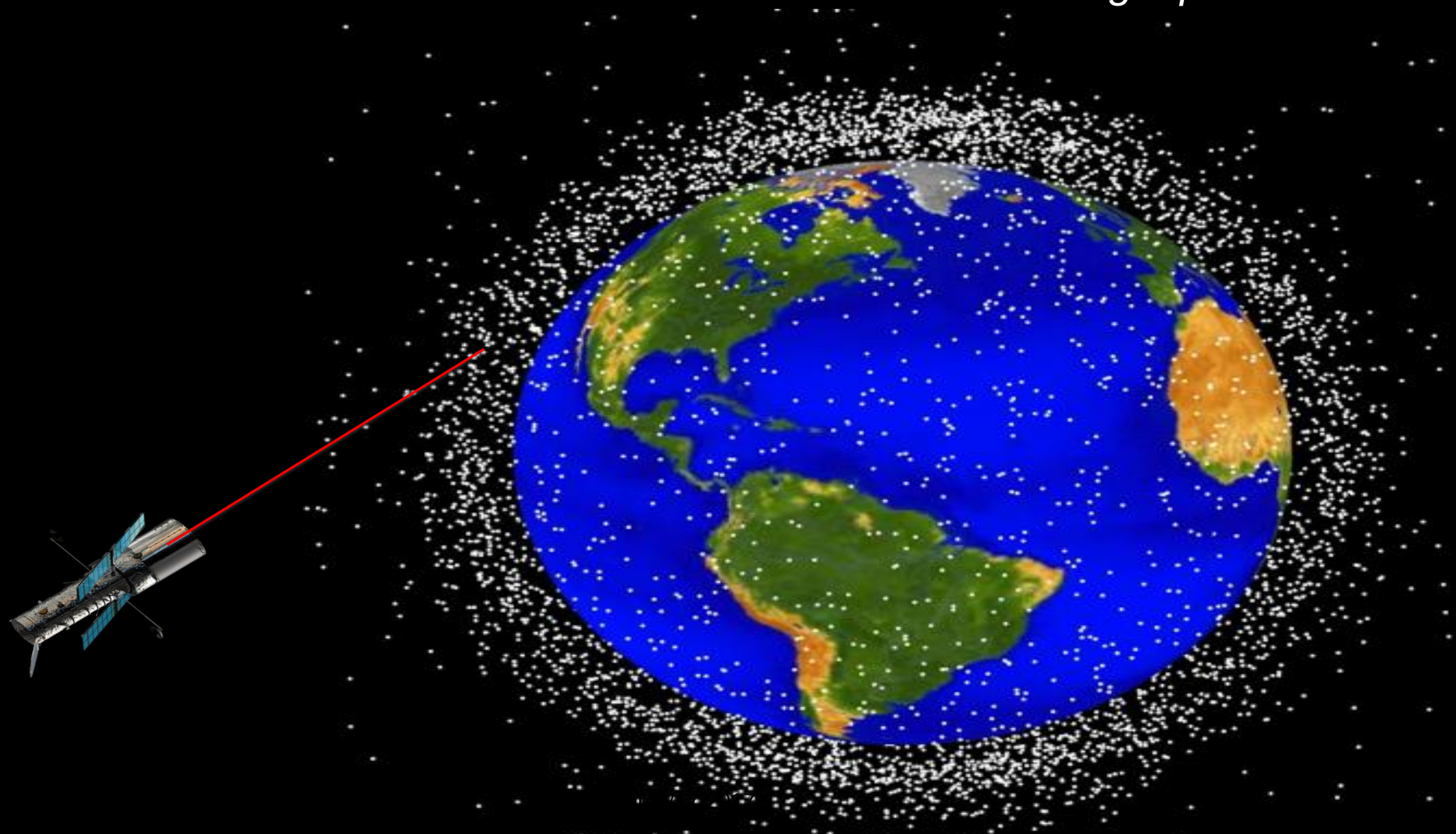
## How much is that?

***We have put the equivalent of over 4 Eiffel Towers into space!***

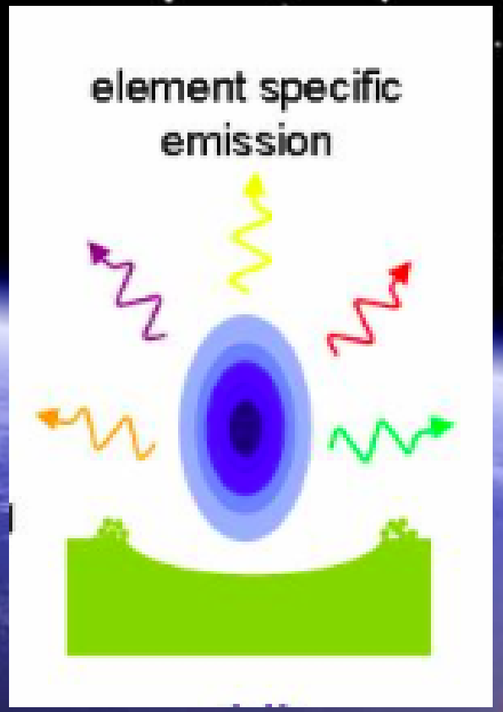
ÉCOLE POLYTECHNIQUE
UNIVERSITÉ PARIS-SACLAY

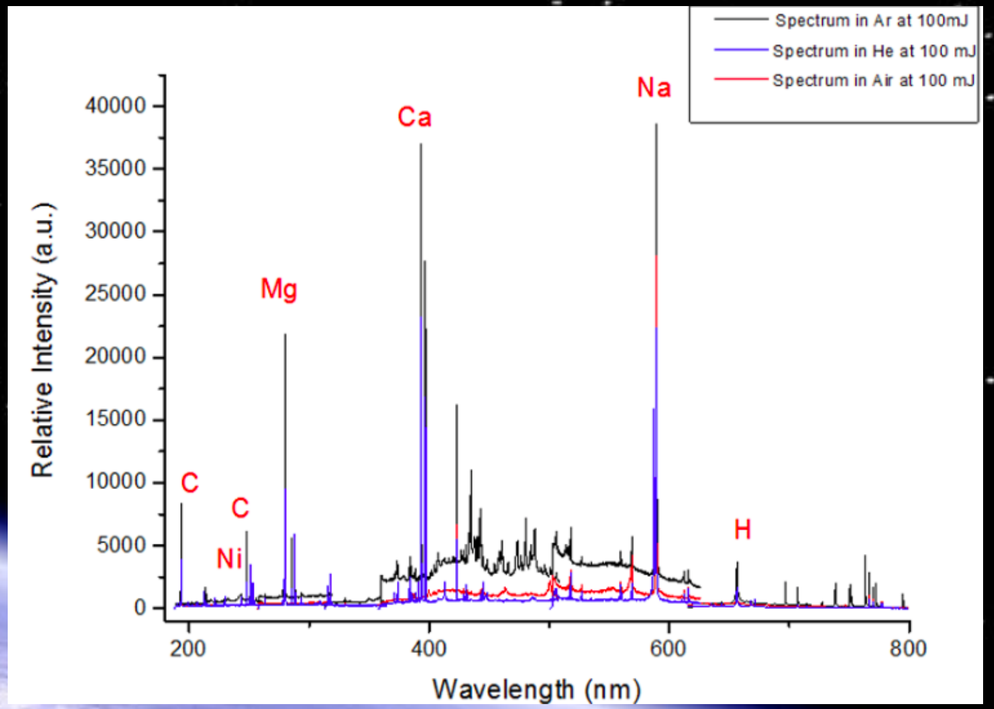
# *Space Debris*

*Millions of orbital debris are cluttering  space*



# Debris identification: Laser Induced Breakdown Spectroscopy

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UNIVERSITÉ PARIS-SACLAY

***In conclusion, extreme light is capable of generating the largest fields, largest accelerations, the largest temperatures and the largest pressures***

***It carries the best hopes and opportunities for the future of science and society***

# *The best is yet to come!*


gettyimages
JONATHAN NACKSTRAND
1071247972

# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

# *A PASSION FOR EXTREME LIGHT*

*For the greatest benefit to human kind (Alfred Nobel)*

# *Outlook for Laser-Particle acceleration TeV*