PASSION LUMIÈRE EXTRÊME

Pour le benefice de la science et de la société

Presented by

Prof. Gérard Mourou

Nobel Prize for Physics, 2018

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

A PASSION FOR EXTREME LIGHT

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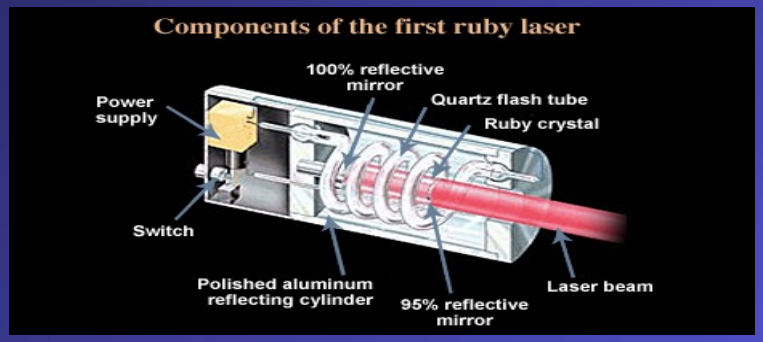
Theodore Maiman

16 May 1960, Malibu Californie,



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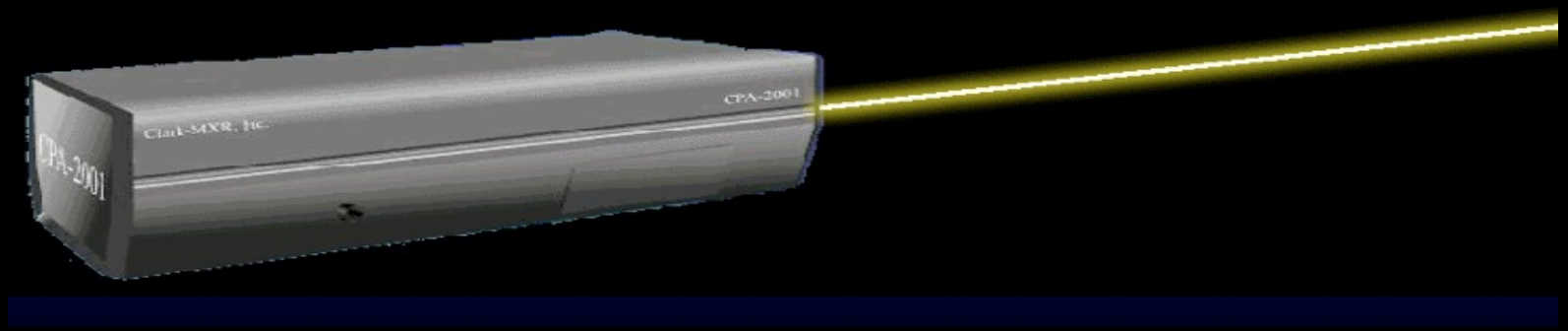
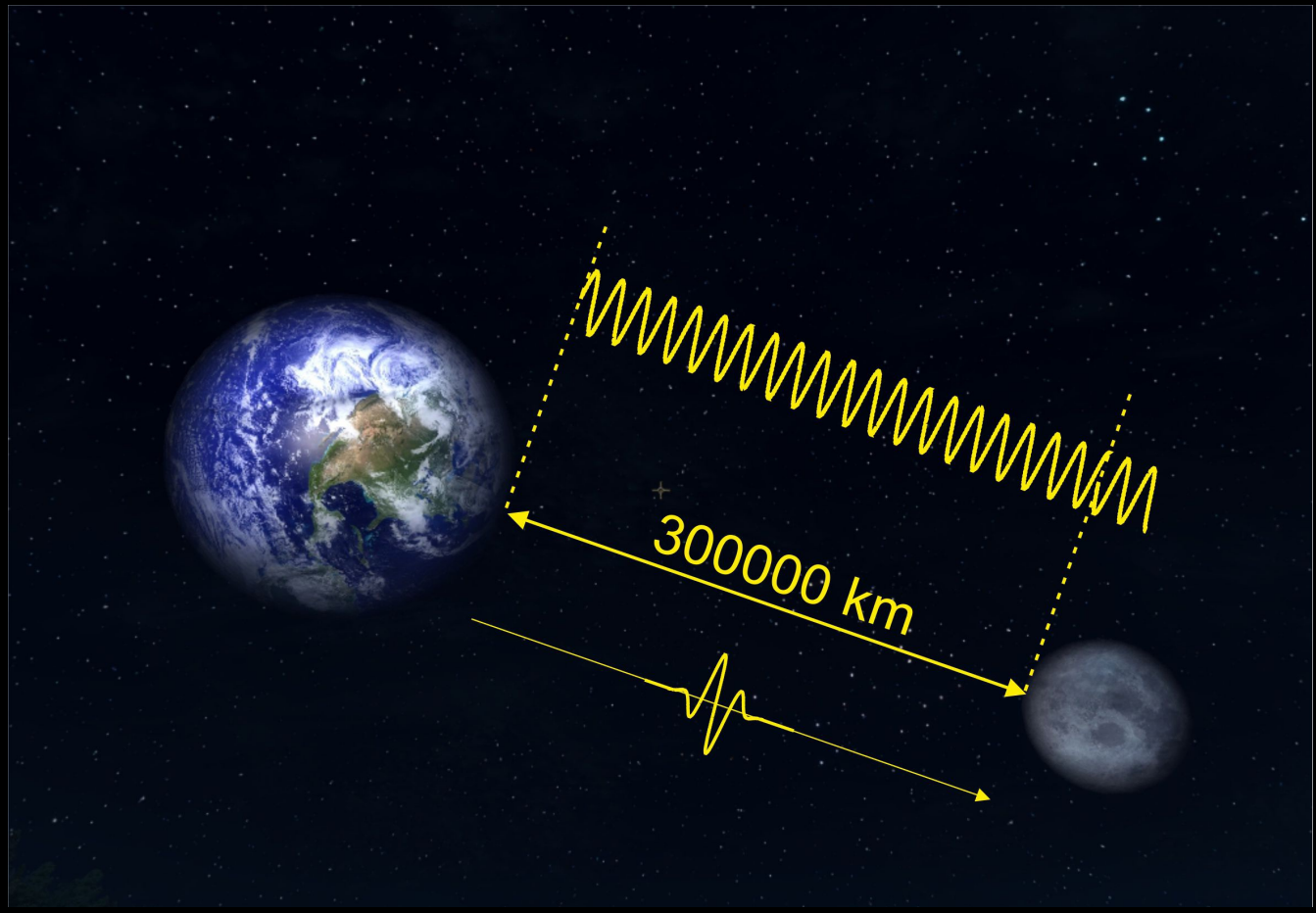
THIS IS A LASER!




300000 km

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Slowing down atoms

2018

1960

1eV

Theodore Maiman

(July 11, 1927 – May 5, 2007)

A PASSION FOR EXTREME LIGHT

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Quantum Optics

μeV - neV

Slowing down atoms to cm/s

2018

1960

1eV

Theodore Maiman

(July 11, 1927 – May 5, 2007)

Accelerating particles to C

2018

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

*

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

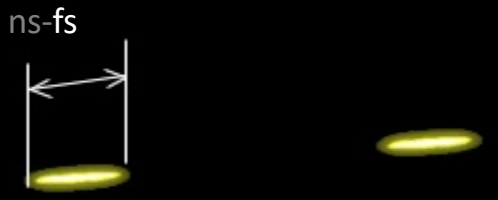
A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

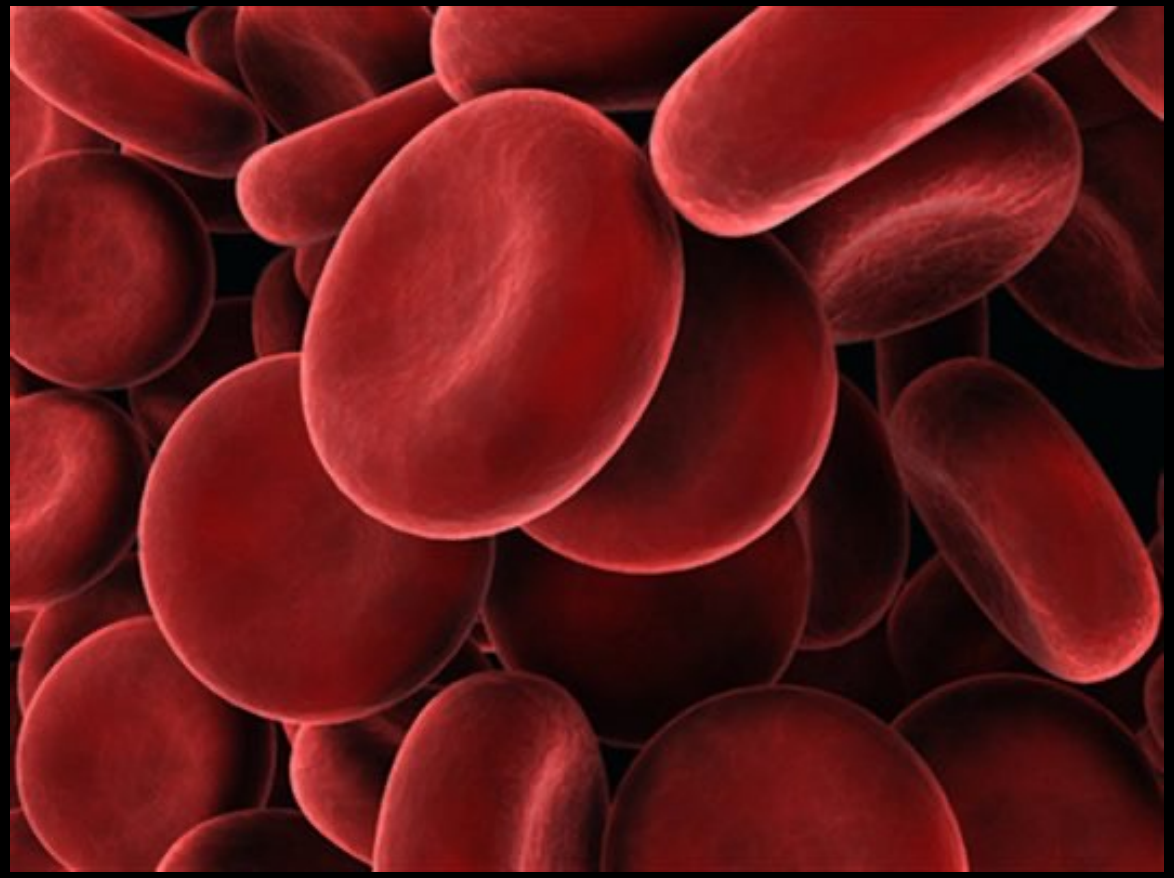
Extreme light is capable of generating the largest fields, largest accelerations, the largest temperatures and the largest pressures

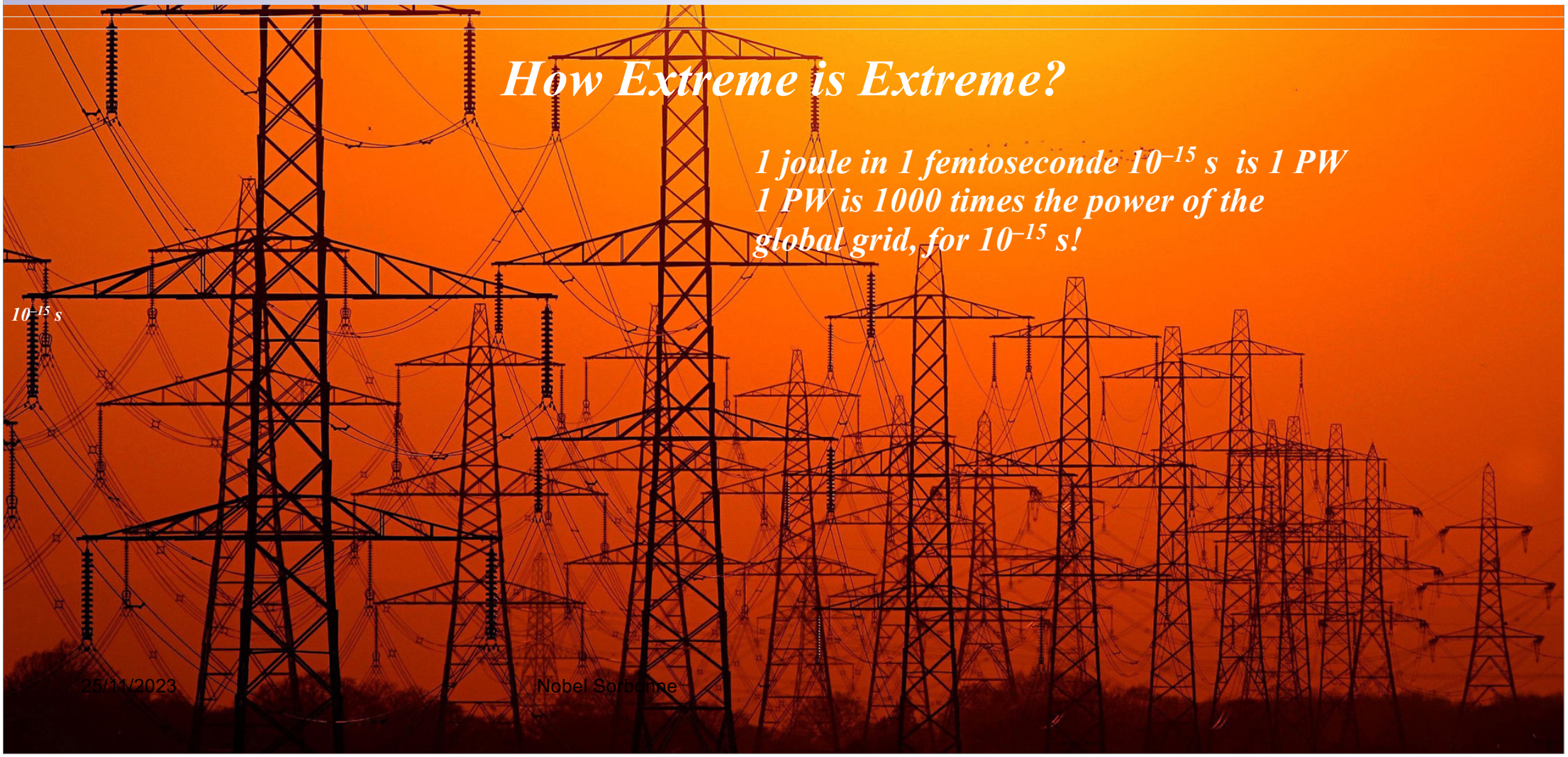
It carries the best hopes and opportunities for the future of science and society

Laser can emits very short bursts of light



Red Blood Cell: 10 fs





How Extreme is Extreme?

1 joule in 1 femtoseconde 10^{-15} s is 1 PW
1 PW is 1000 times the power of the global grid, for 10^{-15} s!

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!

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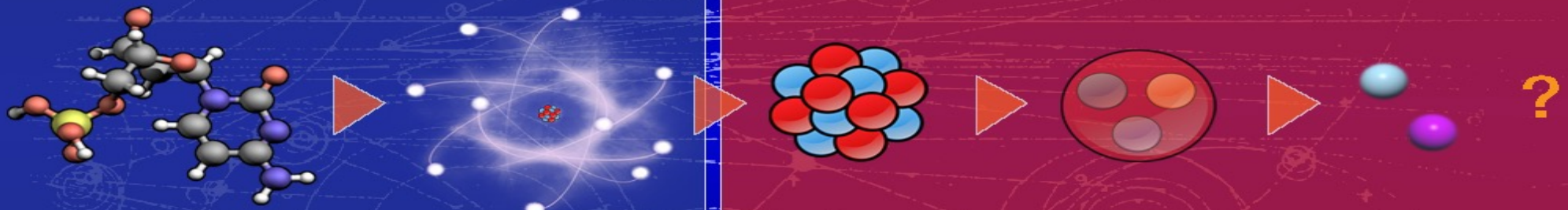
Laser Exploration : From Atomic to Sub-Atomic

eV → TeV

ATOMIC		SUB-ATOMIC		
molecules	atoms	nucleii	protons	electrons/quarks
	10^{-10} m	10^{-14} m	10^{-15} m	$\leq 10^{-18}$ m



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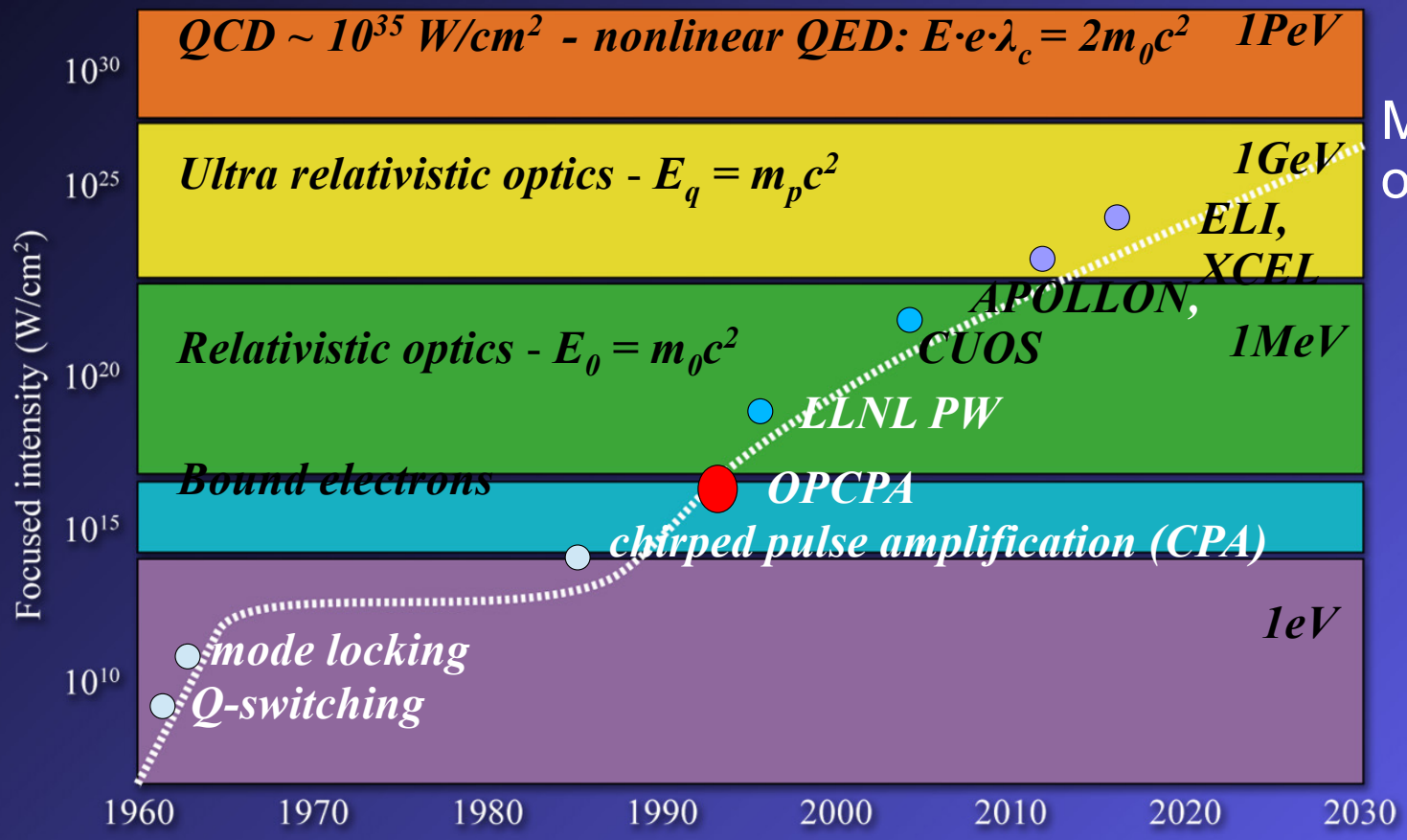
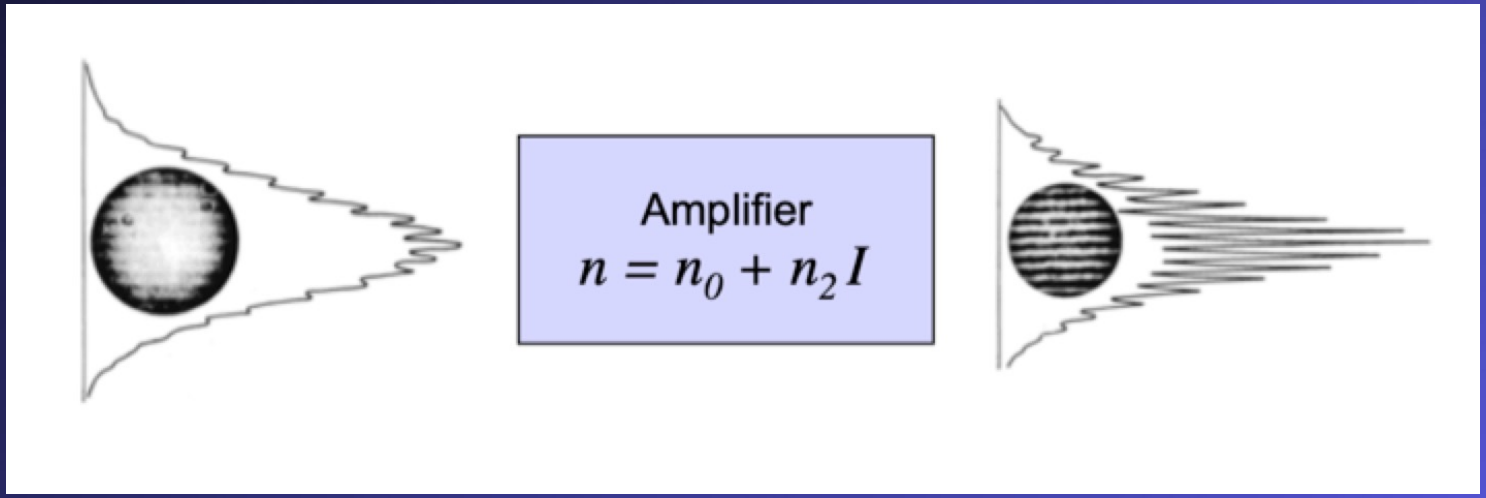
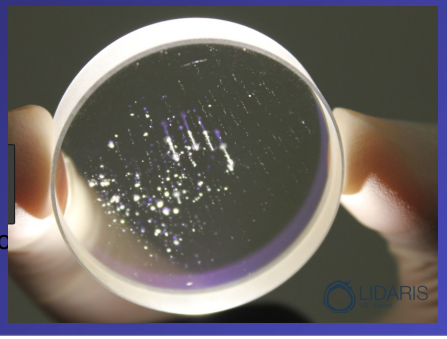
Extreme light ultra high intensity roadmap



Materialization of Light

Filament -Induced by Nonlinear Effect

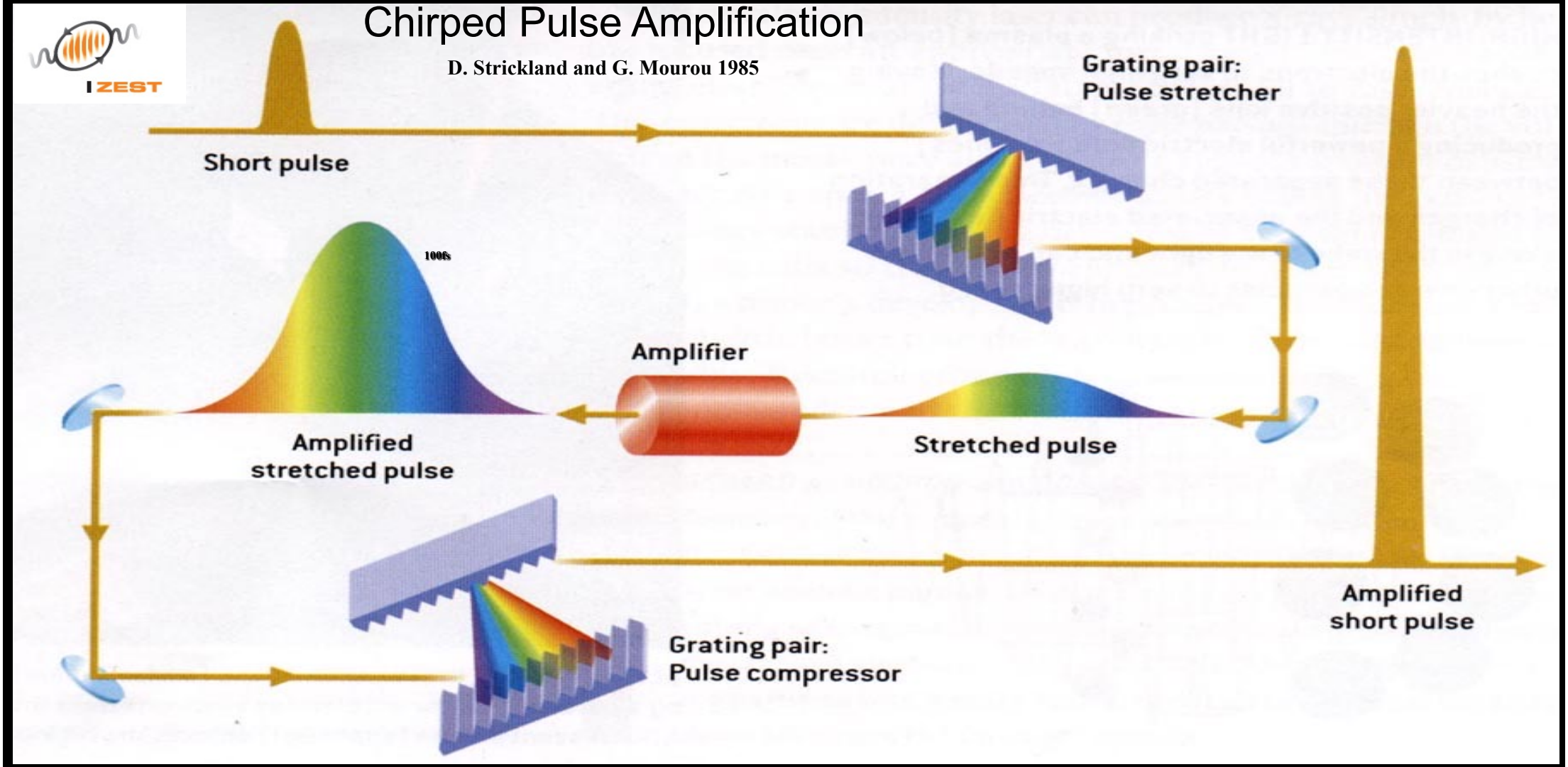




Naissance de la CPA (Chirped Pulse Amplification)

Chirped Pulse Amplification

D. Strickland and G. Mourou 1985



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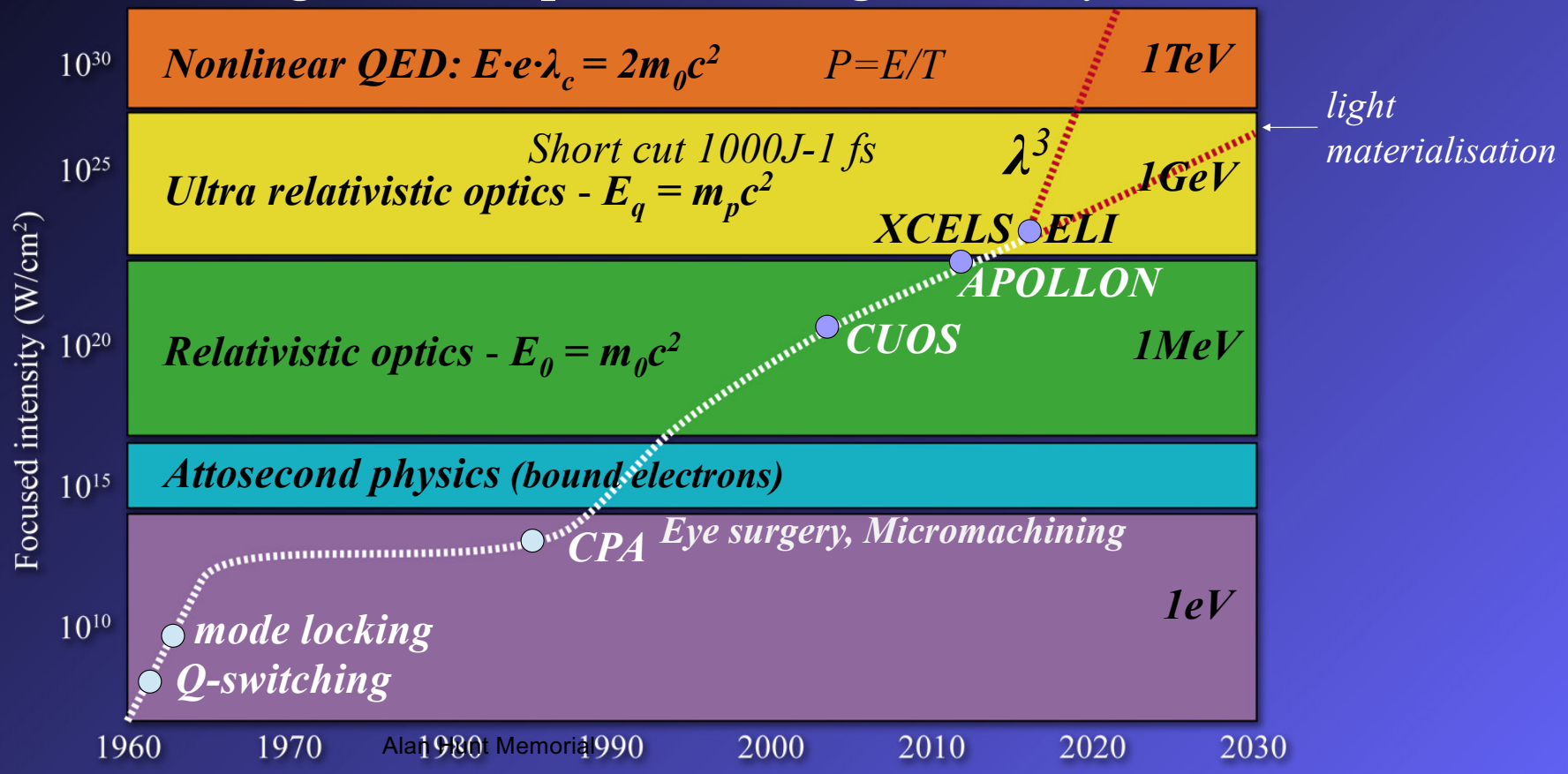
Extreme light roadmap and ultra high intensity shortcut



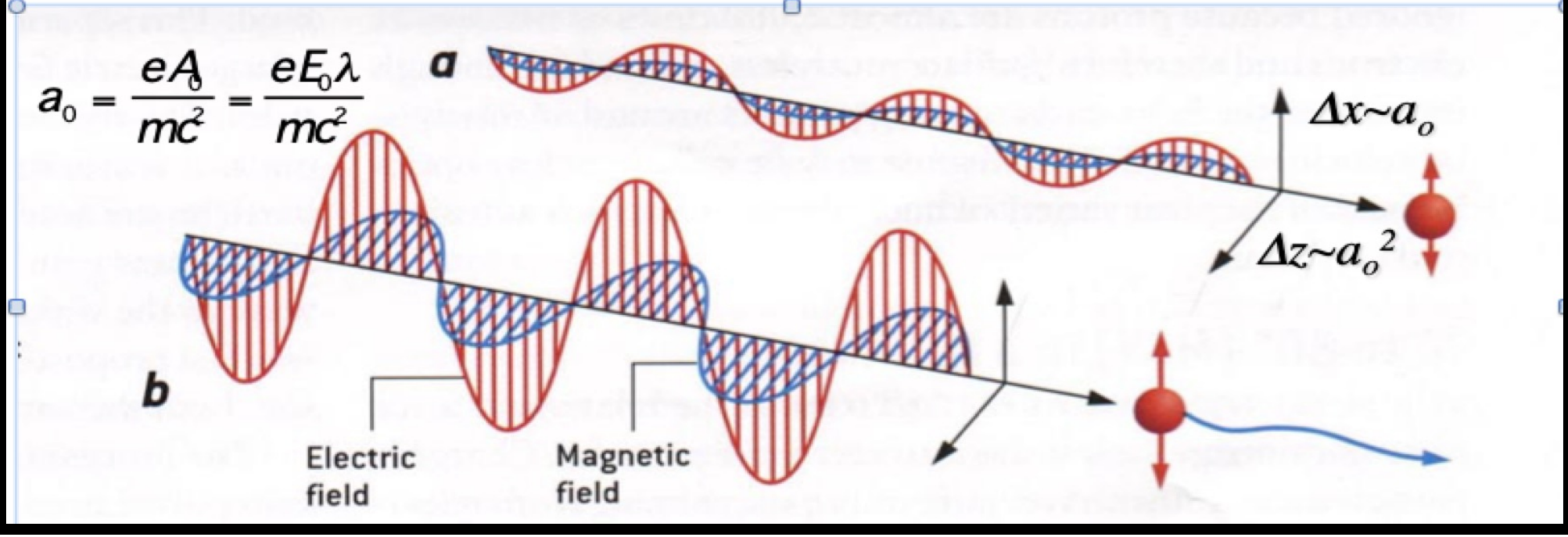
Relativistic Optics

$$\vec{F} = q\left(\vec{E} + \left(\frac{\vec{v}}{c} \wedge \vec{B}\right)\right)$$

a) Classical optics $v<<c$, $a_0<<1$, $a_0>>a_0^2$

b) Relativistic optics $v\sim c$, $a_0>>1$, $a_0<<a_0^2$

$$a_0 = \frac{eA_0}{mc^2} = \frac{eE_0\lambda}{mc^2}$$



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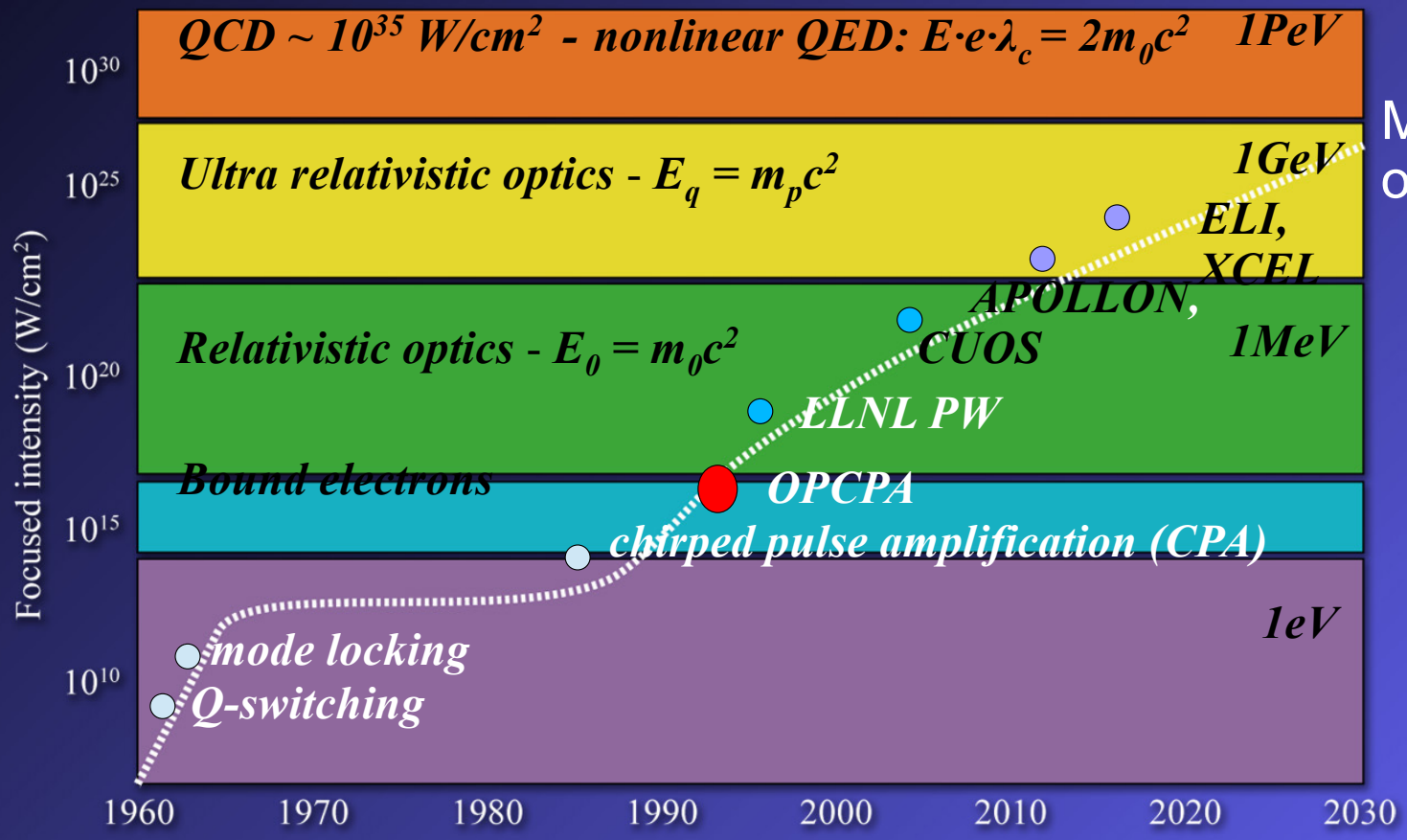
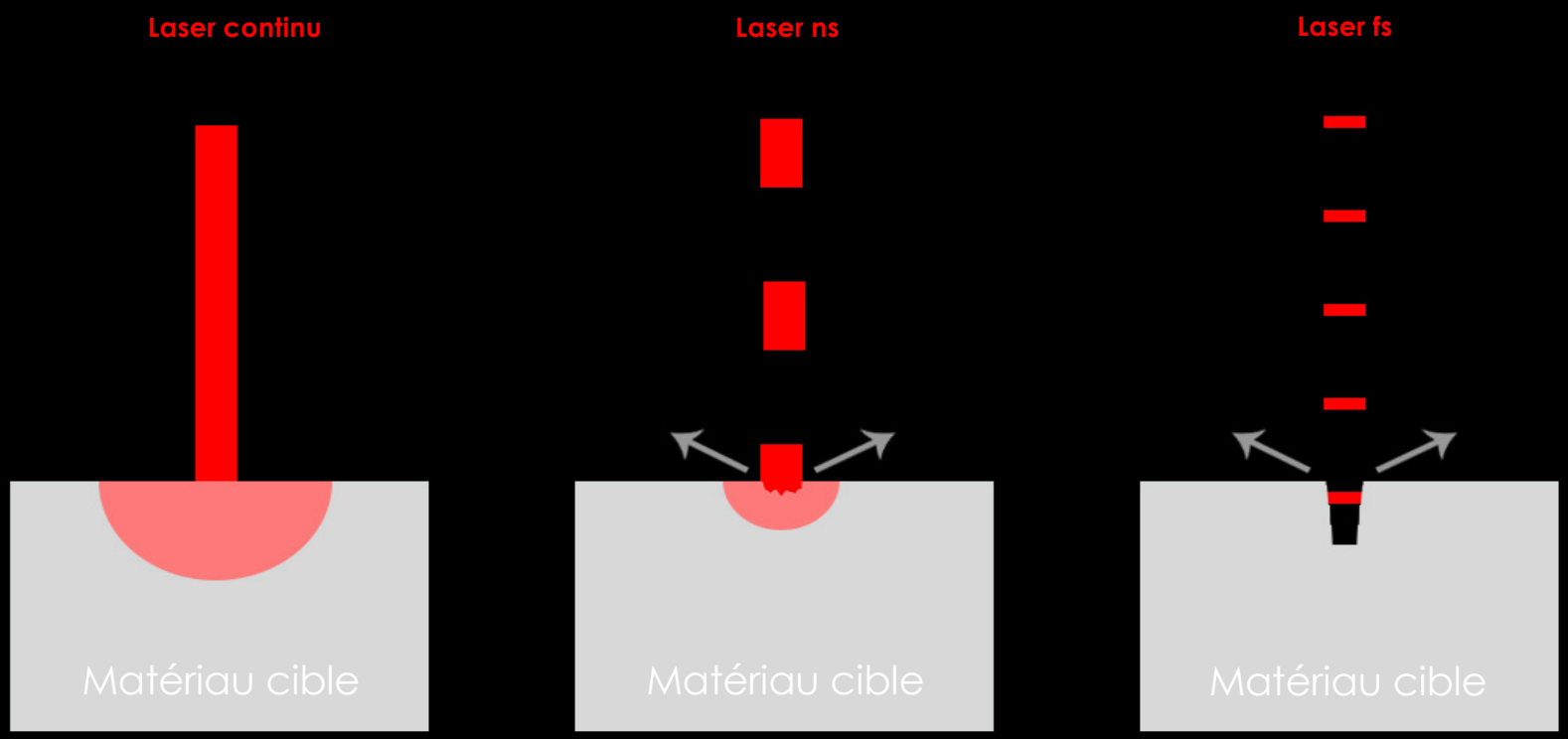
Extreme light ultra high intensity roadmap



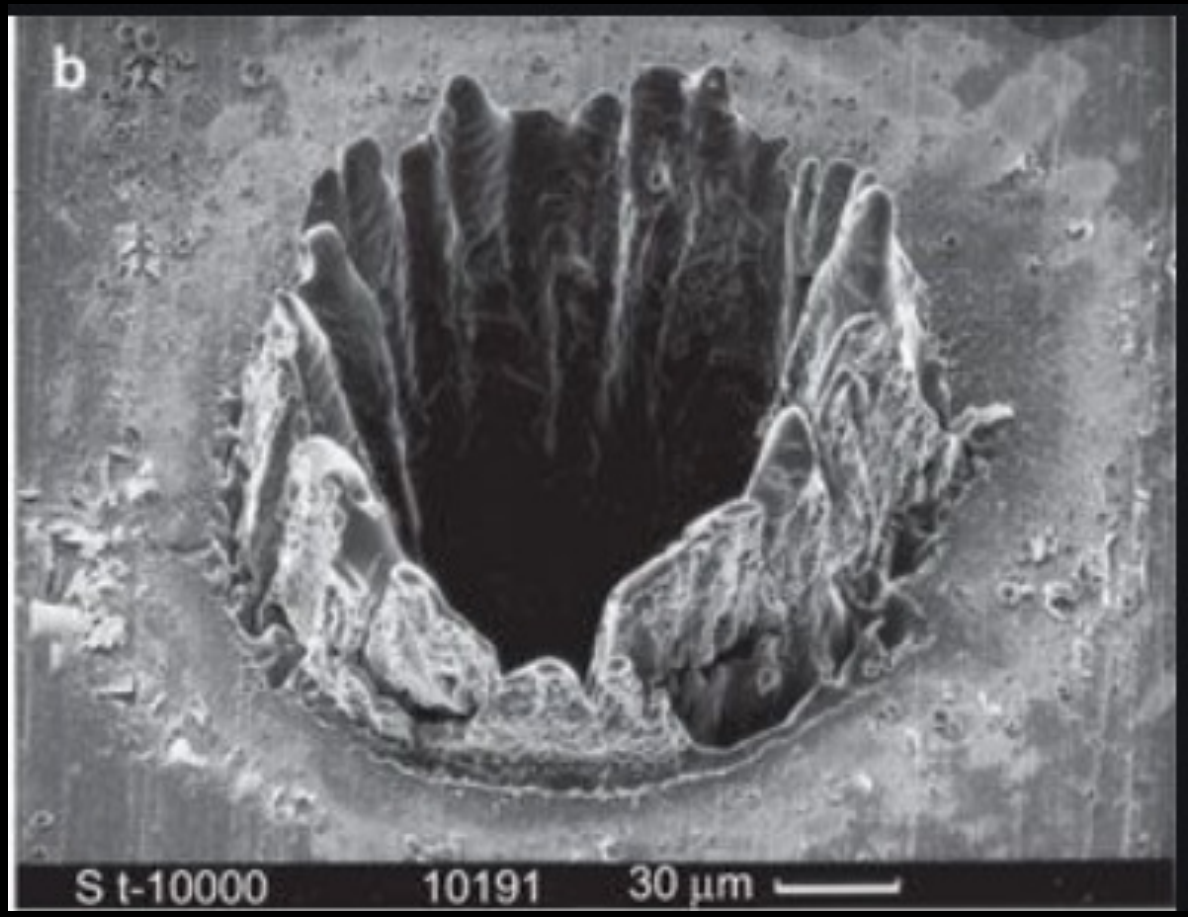
Materialization of Light

Micromachining



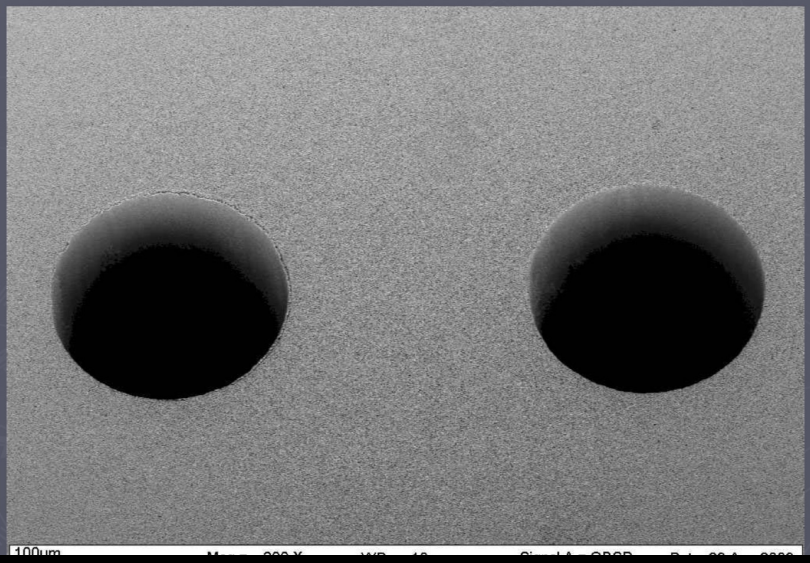
Un intérêt des lasers femto-secondes :
creuser la matière sans l'endommager

Drilling with ns, 10^{-9}s pulse

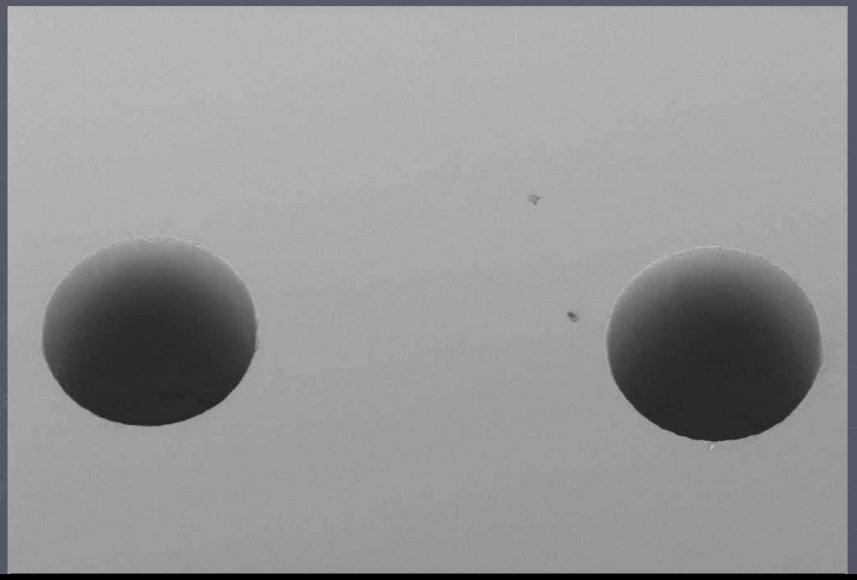


Drilling with 100fs pulse

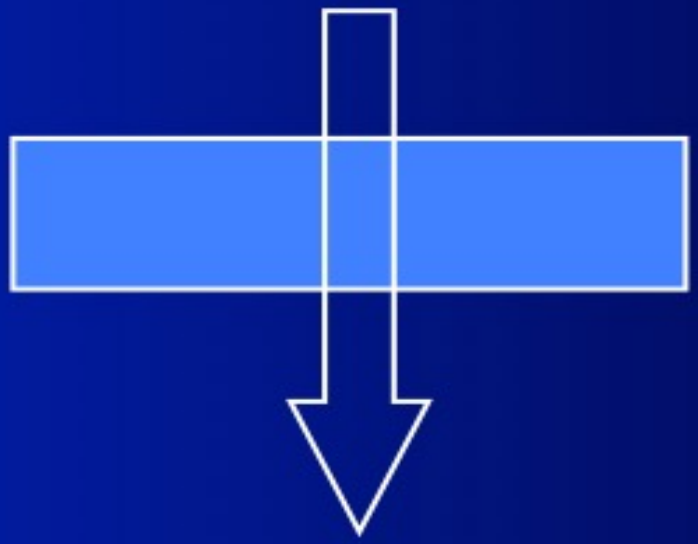
400 µ Ø holes in ceramic

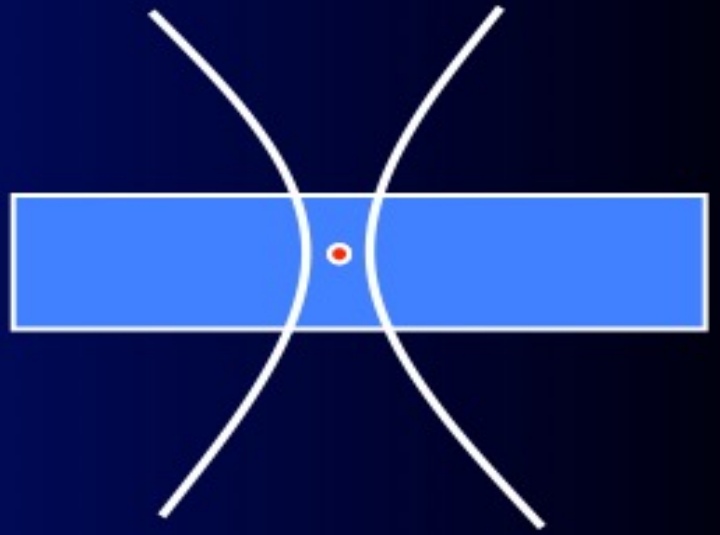


400µ Ø holes in glass



Femtosecond





Precise Sub-Surface Effects

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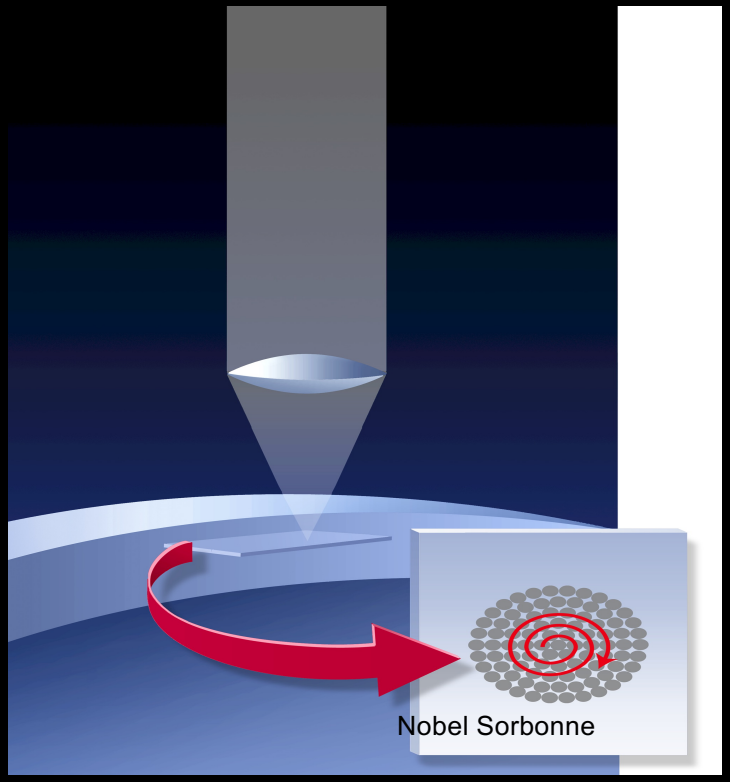
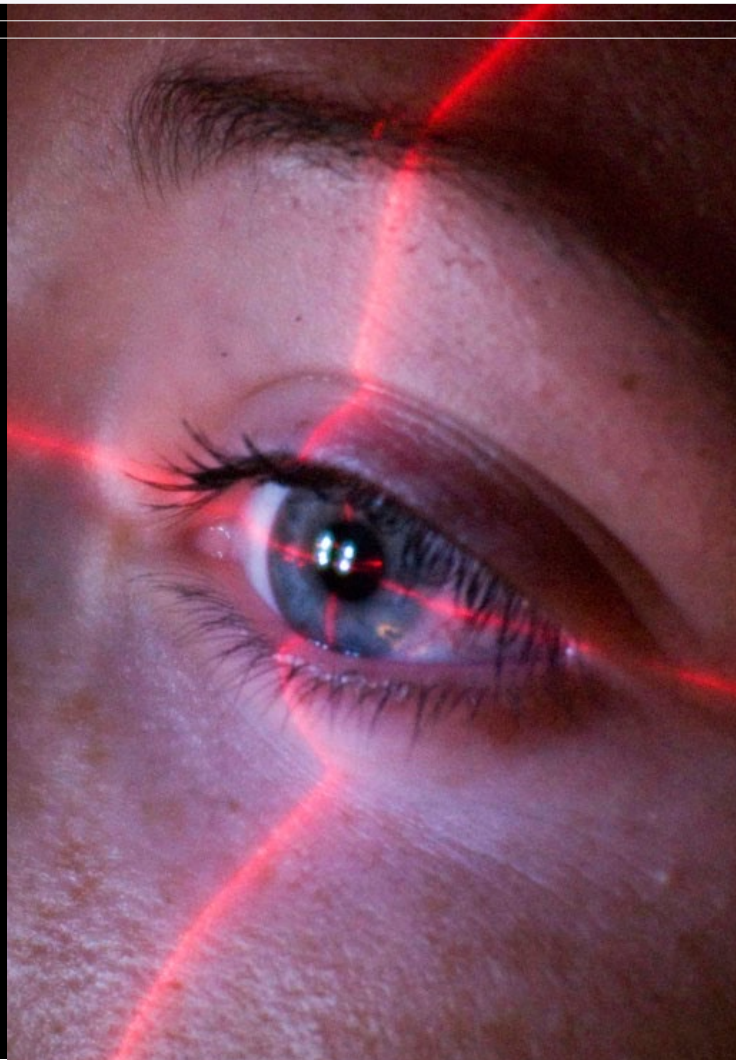
CPA femtosecond lasers revolutionised ophthalmology
24 million eye operations since 2001!





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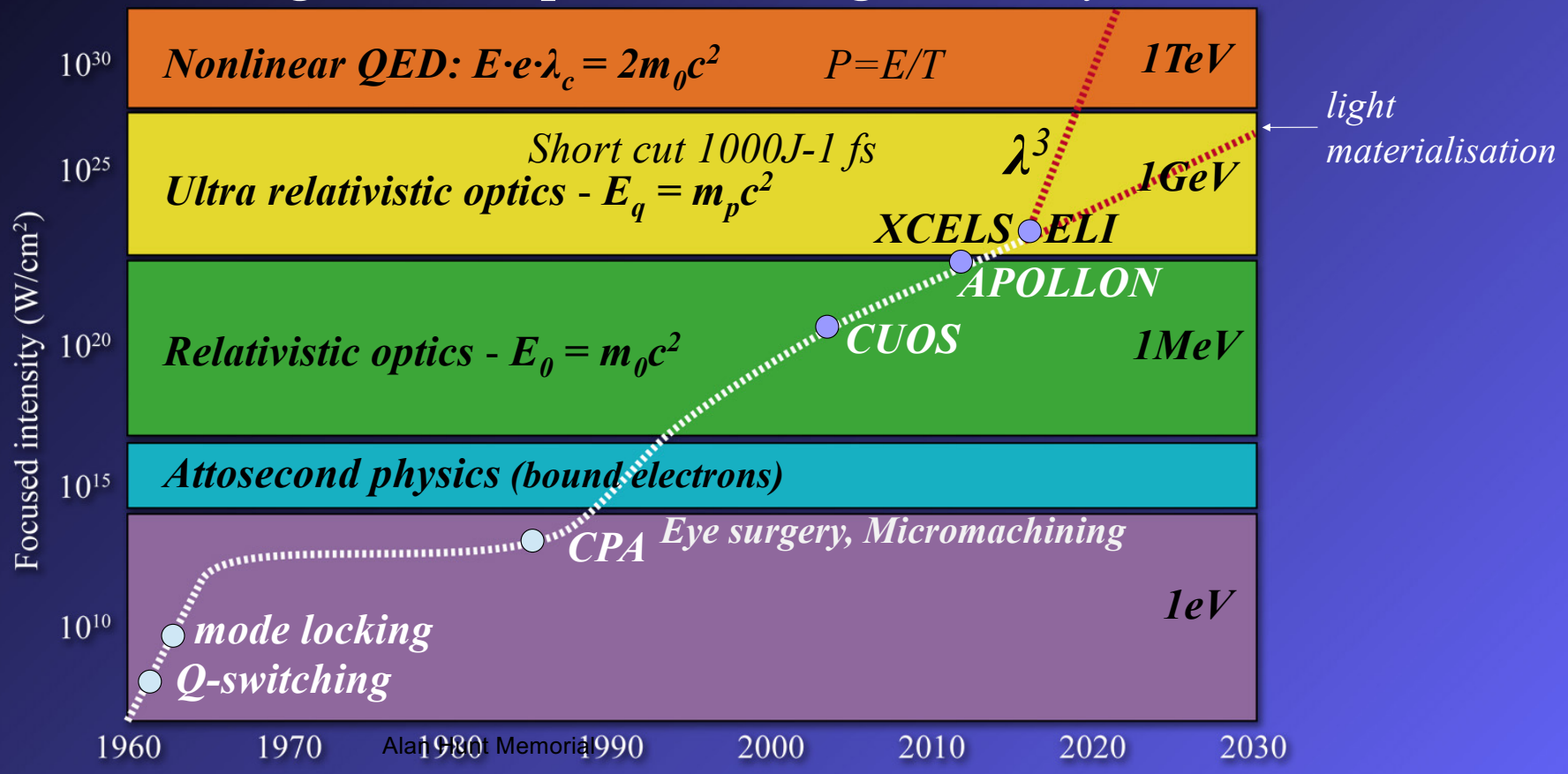
Extreme light roadmap and ultra high intensity shortcut



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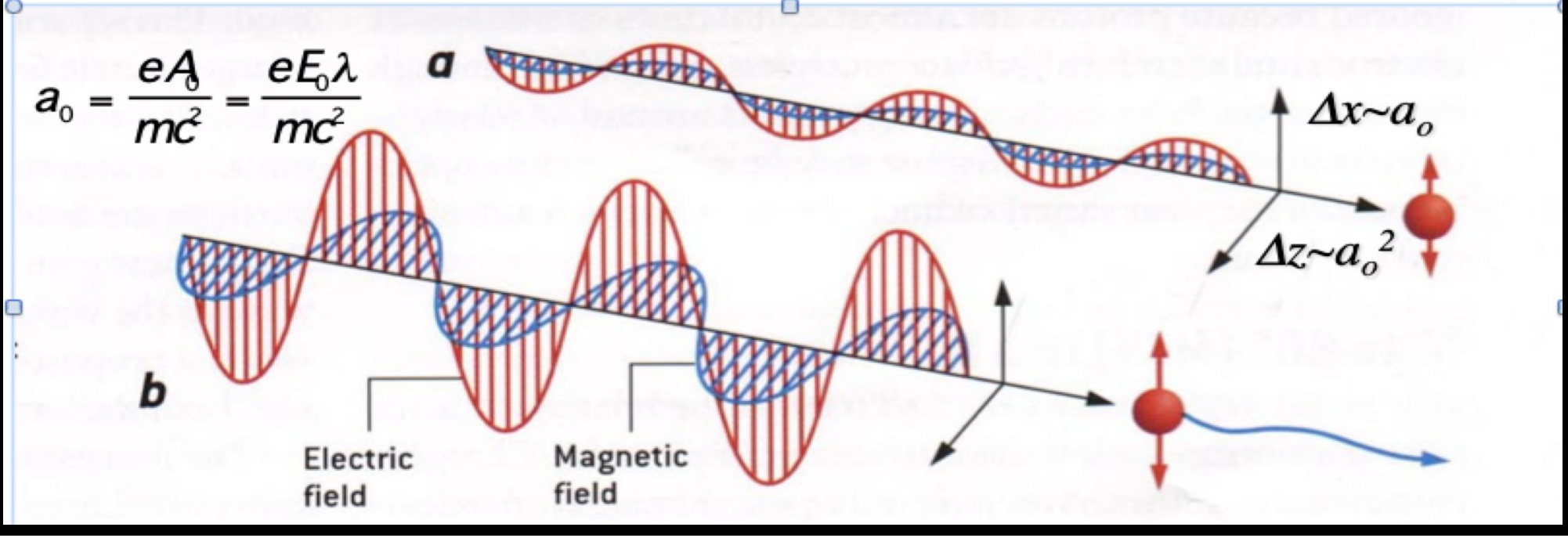

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Giant wakefield acceleration in gas and solid

Tajima et Dawson (1979)

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

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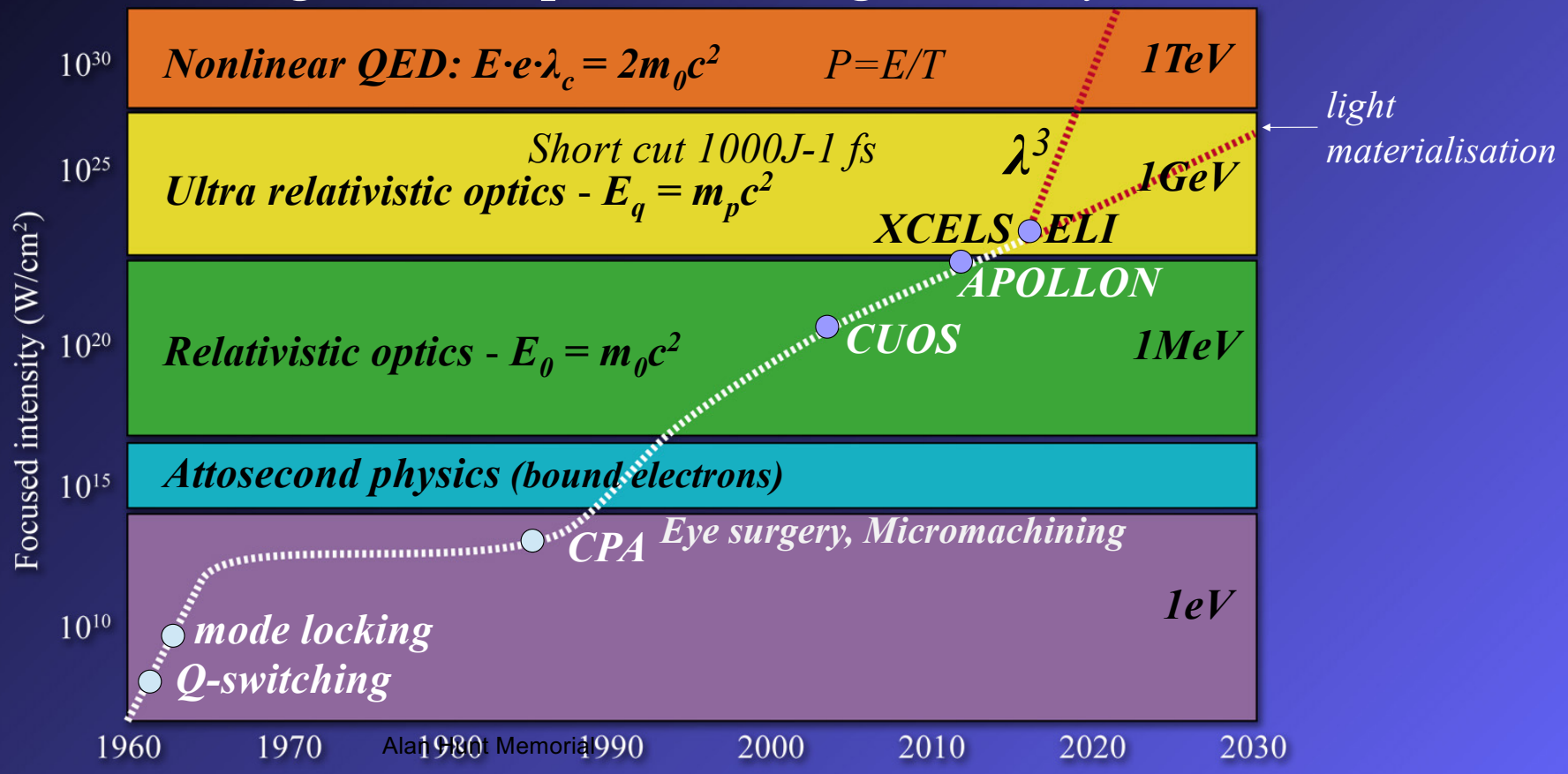
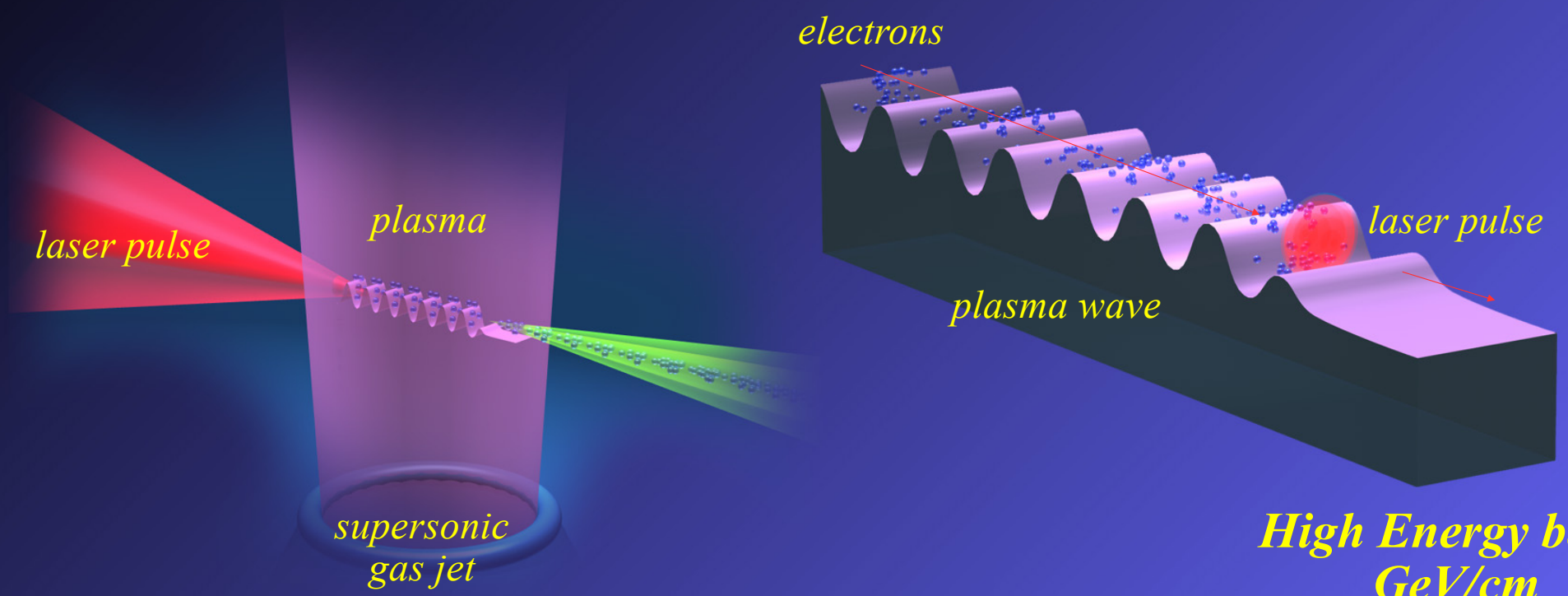


Giant wakefield acceleration

Tajima et Dawson (1979)



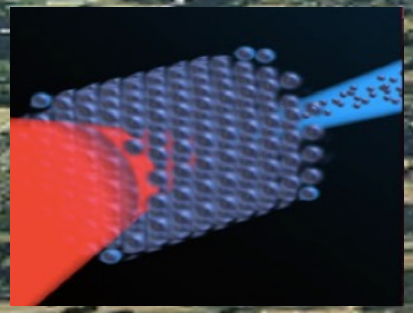
High Energy beam
GeV/cm

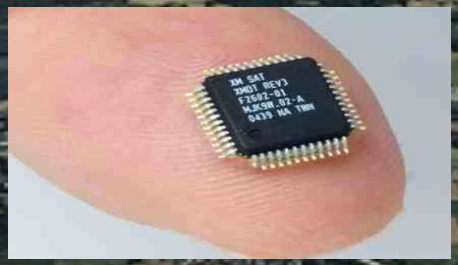
Synchrotron SOLEIL 3GeV

Outlook for Laser-Particle acceleration TeV

Microwave cavity

Laser wakefield X-ray, 1cm





Laser wakefield Visible 100m

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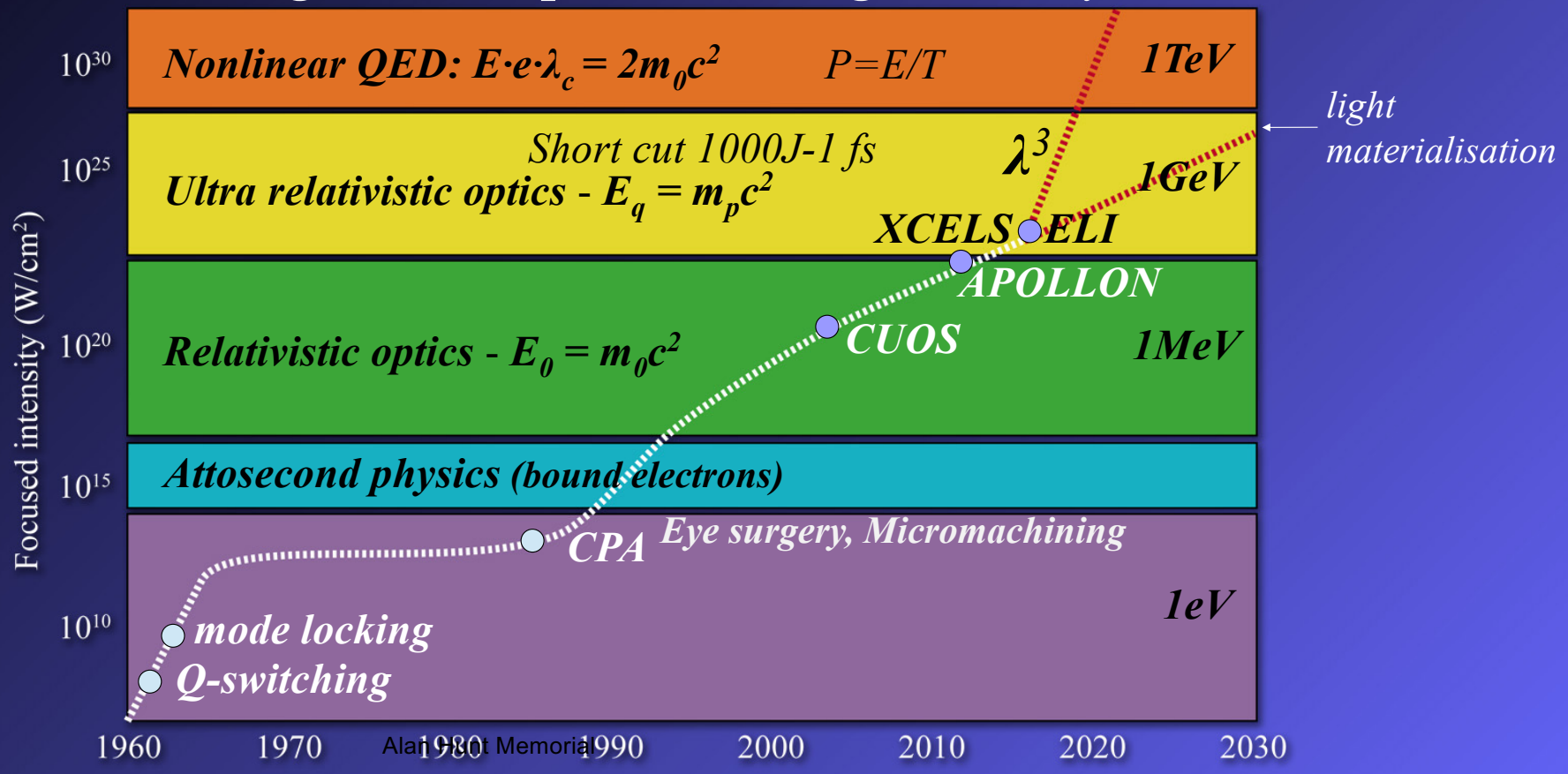
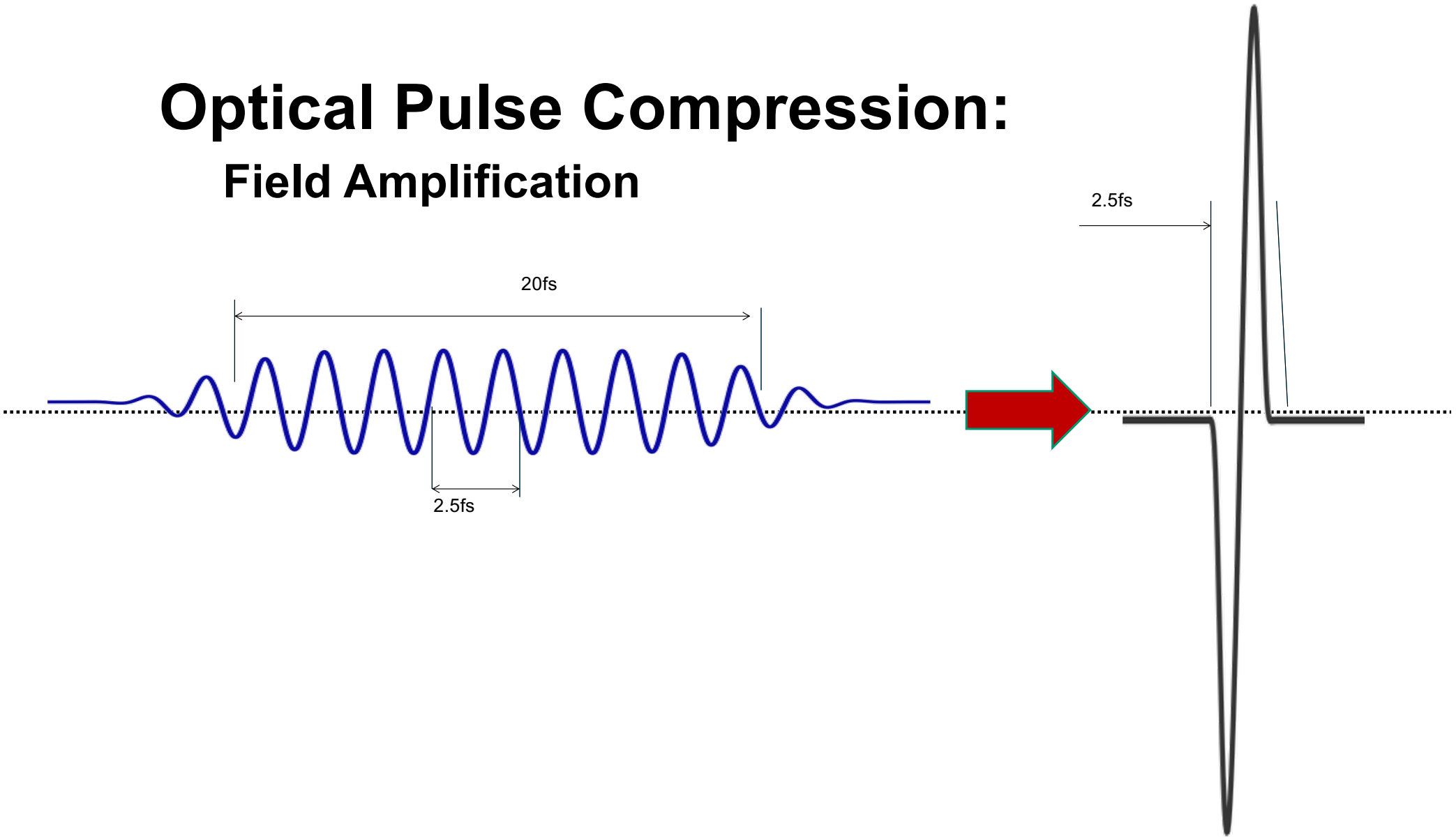
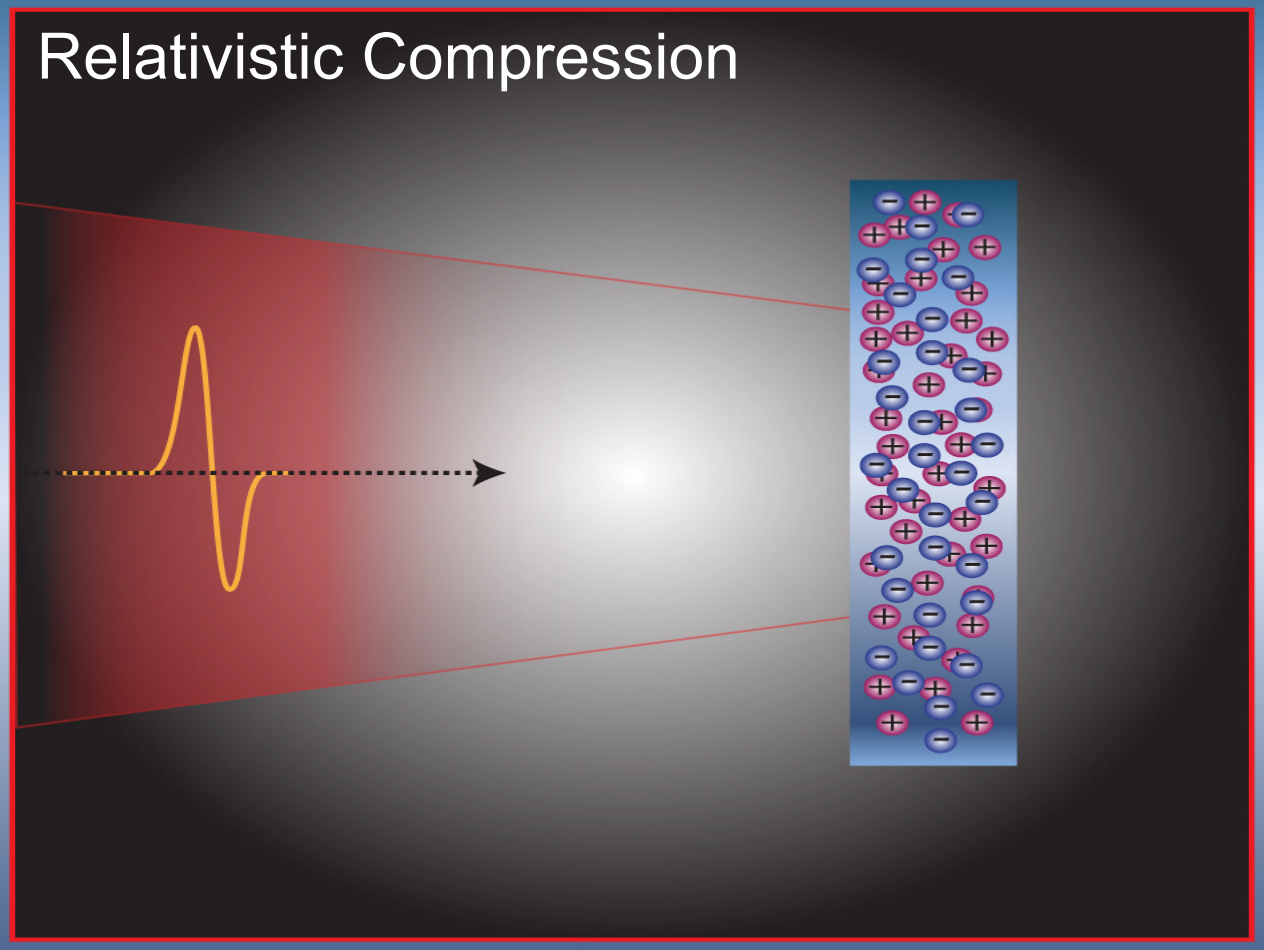


Optical Pulse Compression:

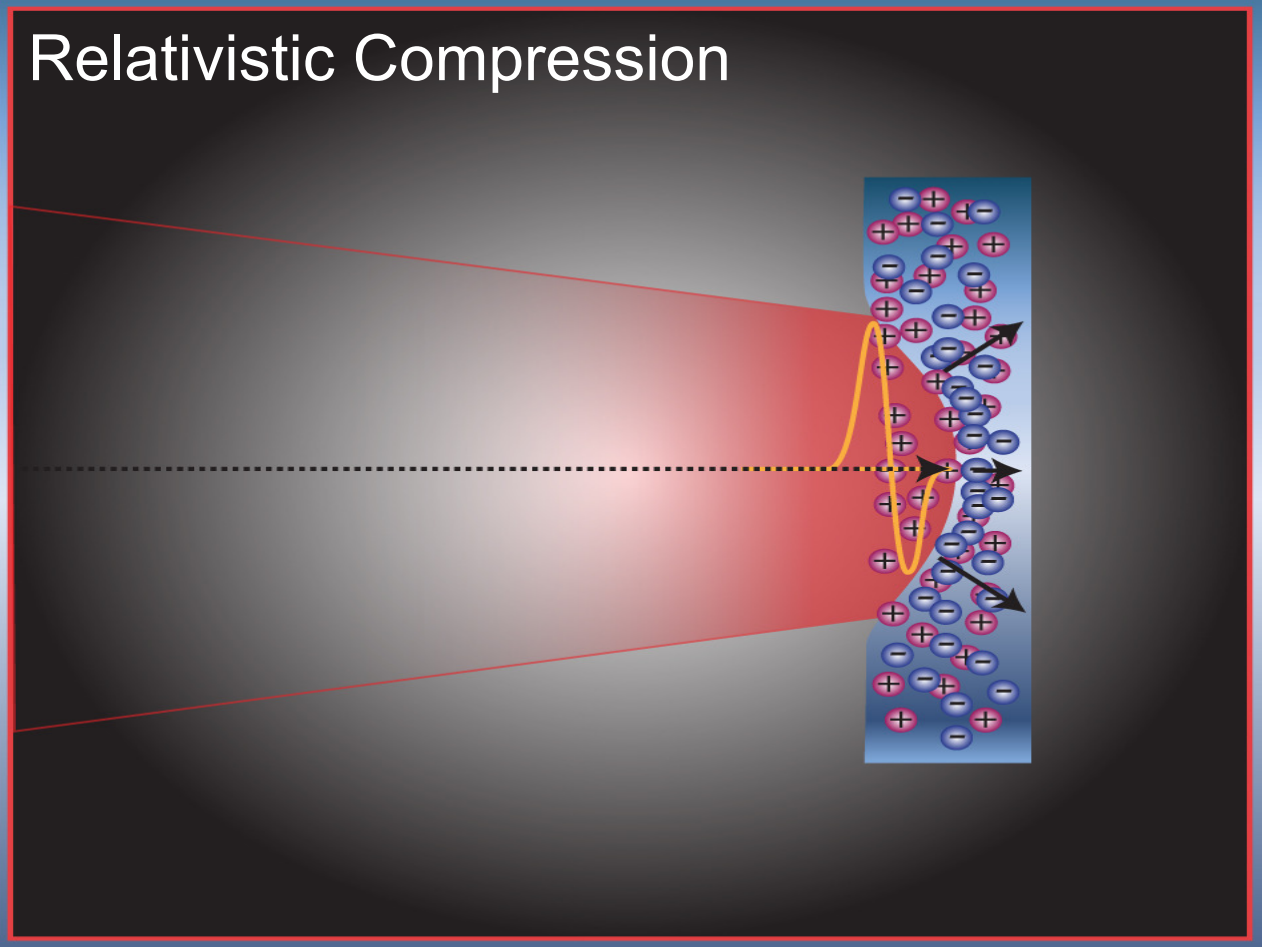
Field Amplification



Relativistic Compression



Relativistic Compression



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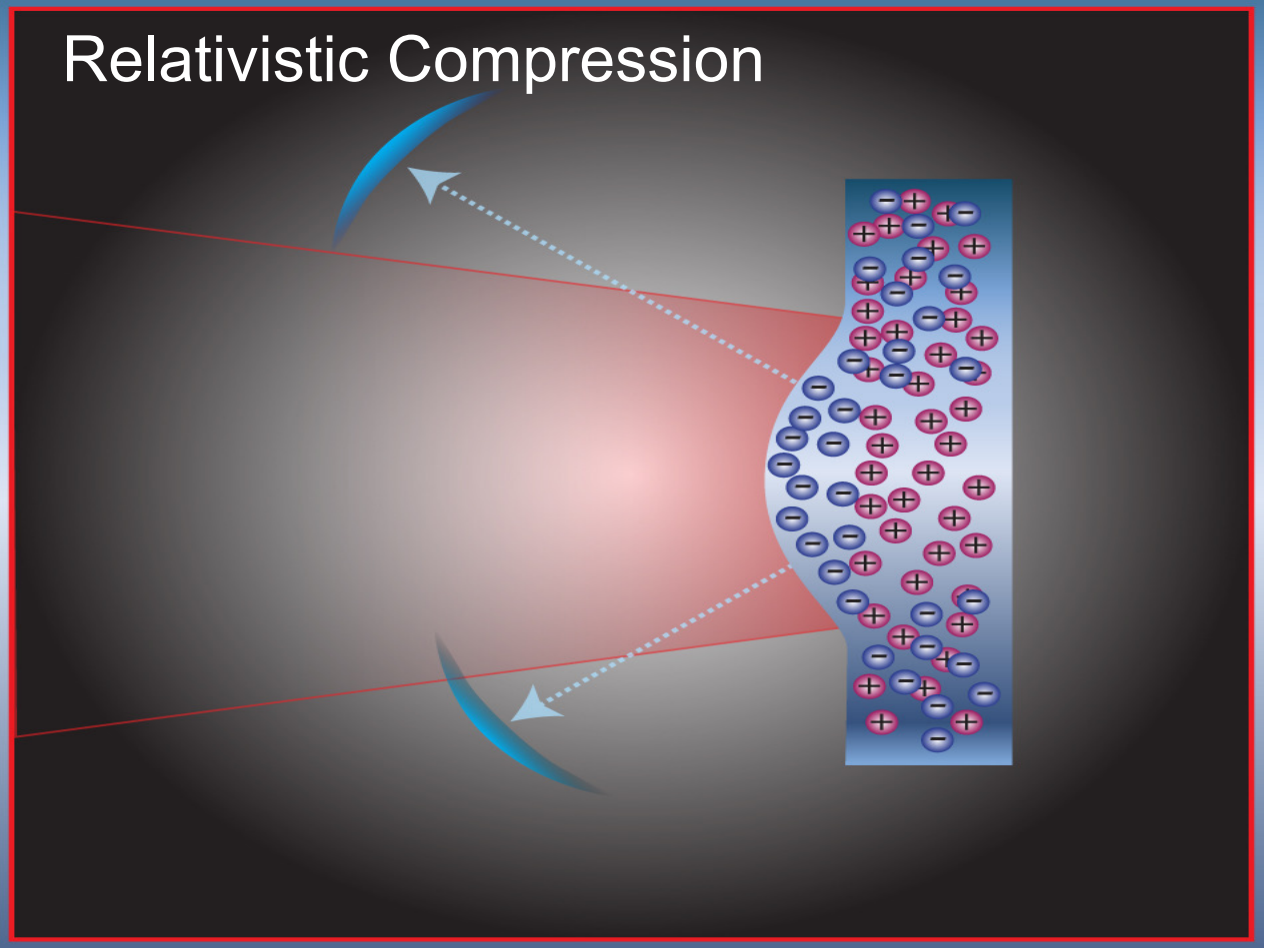

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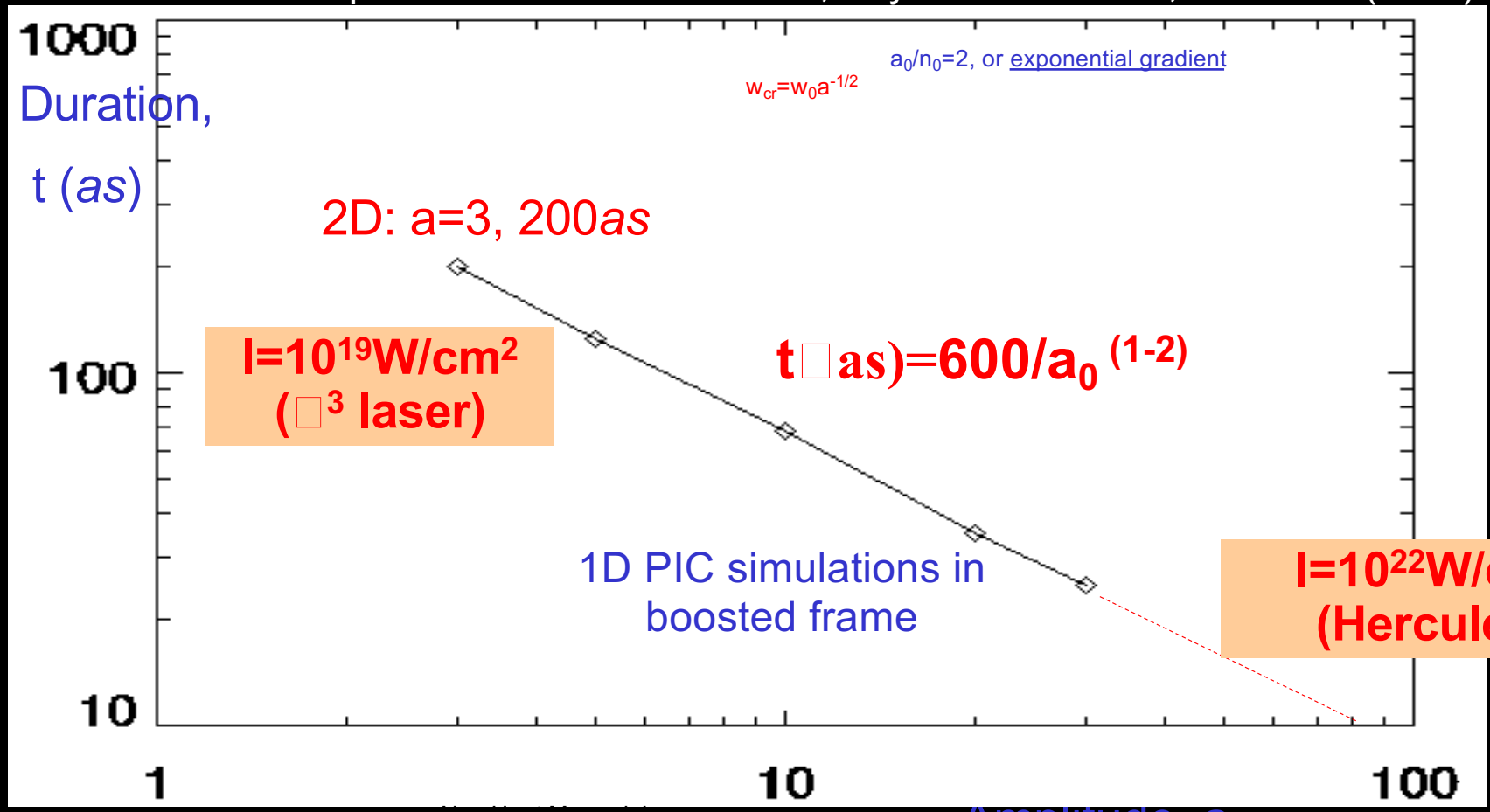
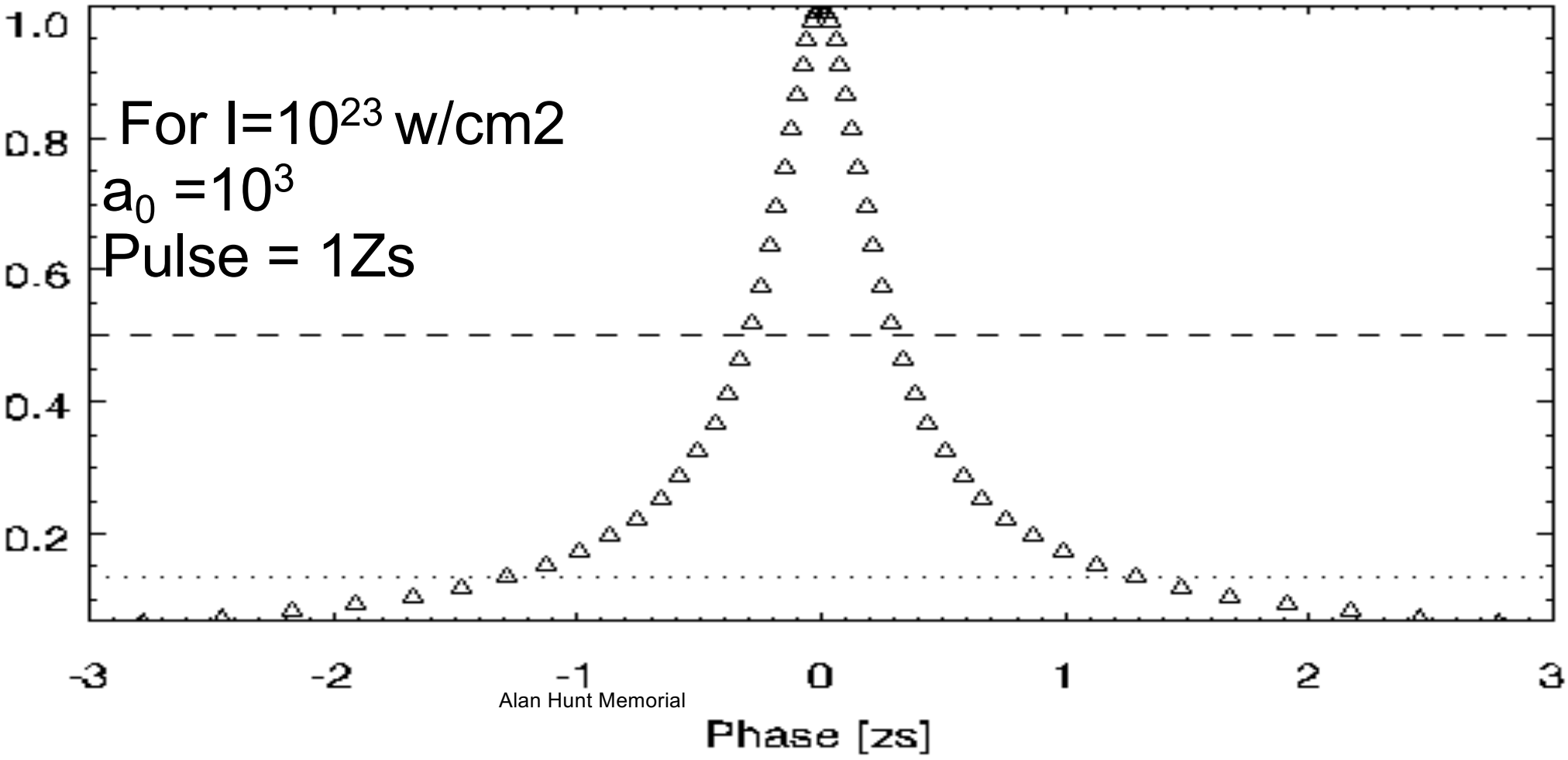
Scalable Isolated Attosecond Pulses

N. M. Naumova, J. A. Nees, I. V. Sokolov, B. Hou, and G. A. Mourou, Relativistic generation of isolated attosecond pulses in a λ^3 focal volume, Phys. Rev. Lett. 92, 063902-1 (2004).



Zeptosecond pulses, (N. Naumova, I. Sokolov, G. Mourou)
(Preliminary Result)



But a zeptosecond pulse is also:

1. 1J in a Zs (10^{-21}s) is a Zettawatt Zw (10^{21}W)
2. A Zs (10^{-21}s) is a 1MeV Coherent Gamma- Ray

   Giant Laser Acceleration in solid: TeV/cm (CERN on a Dime) towards ZeV
3. 1Zw over λ^2 spot size is 10^{29} W/cm^2 Schwinger Intensity:

   Light Turns into Matter and Antimatter

Extreme Light for Cosmology

Particle Acceleration Application

1. *Black Hole Analog*
2. *Medical*
3. *Environment*
4. *Spatial*

Cosmos on a Table
Lorentz Invariance

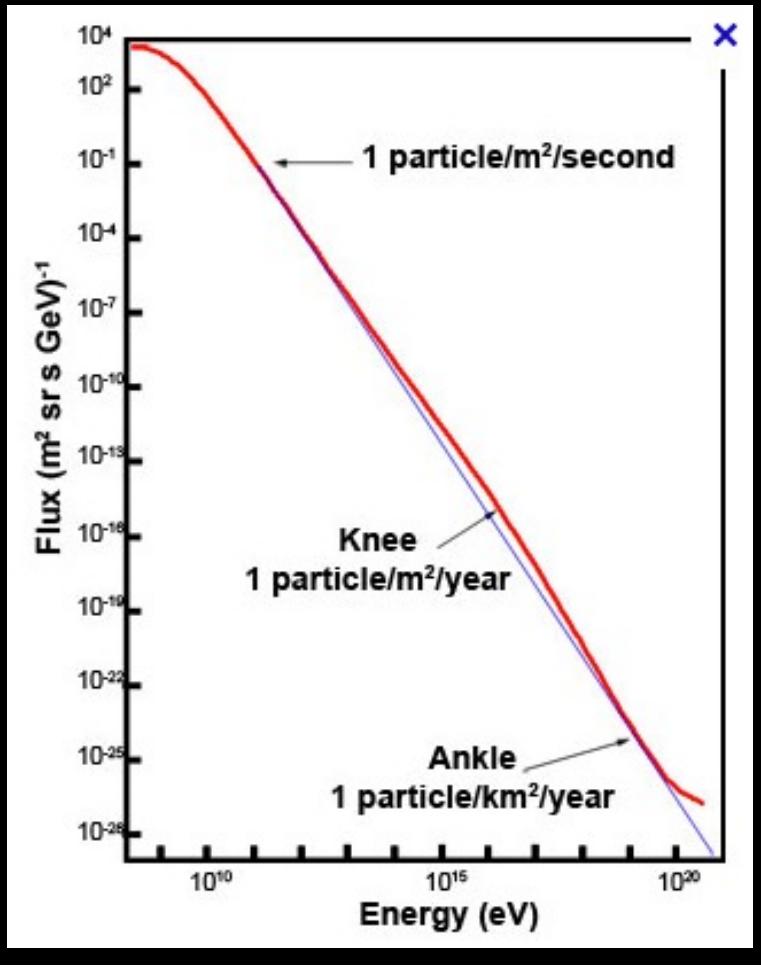
Light Dispersion
From quantum Vacuum

Gamma Ray Burst
mn Duration

1billion years,

,
10mn spread

Cosmic Ray Spectrum



Principe du Trou Noir Analogue

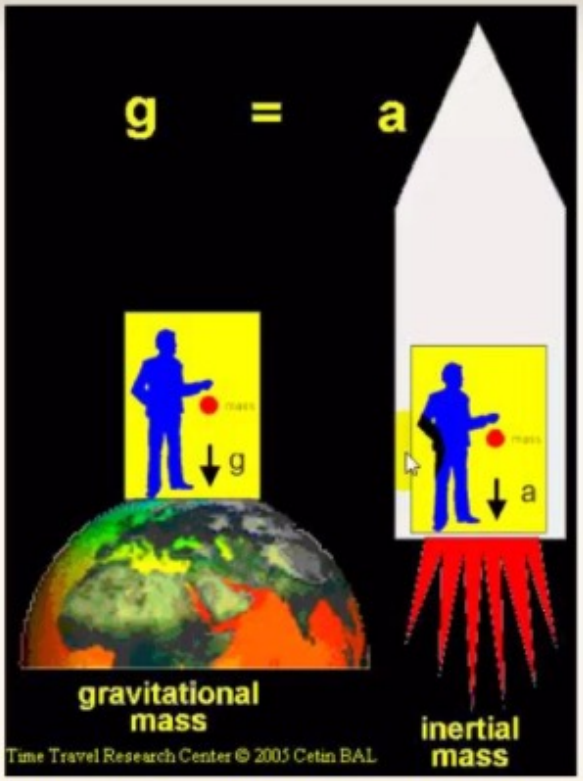
General Relativity

Principle of equivalence:

There is no experiment that will discern the difference between the **effect of gravity** and the **effect of acceleration**.

Or…

Gravitational mass and **inertial mass** are equivalent.



Un laser of 10^{22} W/cm ^{2}

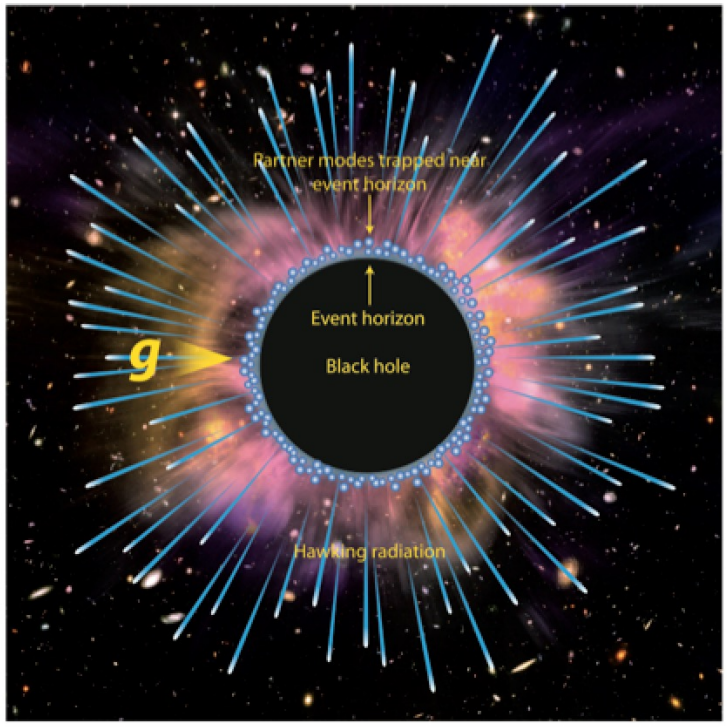
Egal BH10000 soleils

Flying plasma mirror as an analog black hole

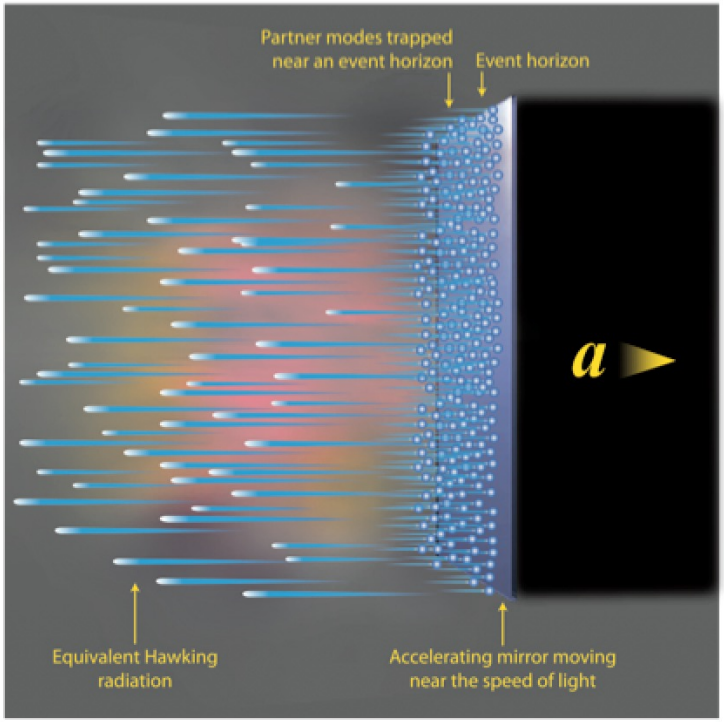
P Chen, G Mourou, "Accelerating plasma mirrors to investigate black hole information loss Paradox", Phys. Rev. Lett. 118, 045001 (2017).

SIMULATING A BLACK HOLE ON A TABLE

New black hole simulator may shed more light on a contradiction in fundamental physics



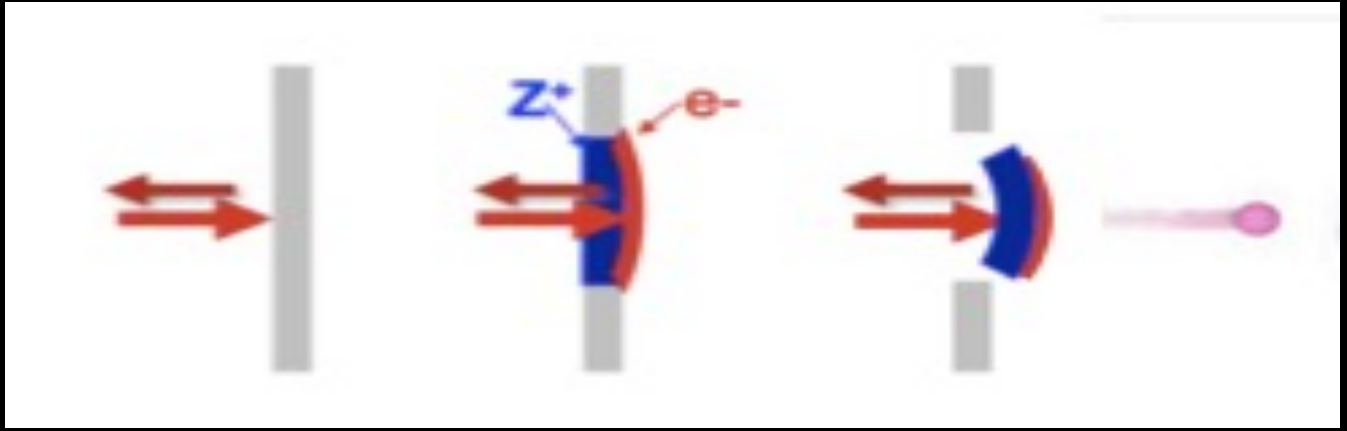
Black hole Hawking evaporation



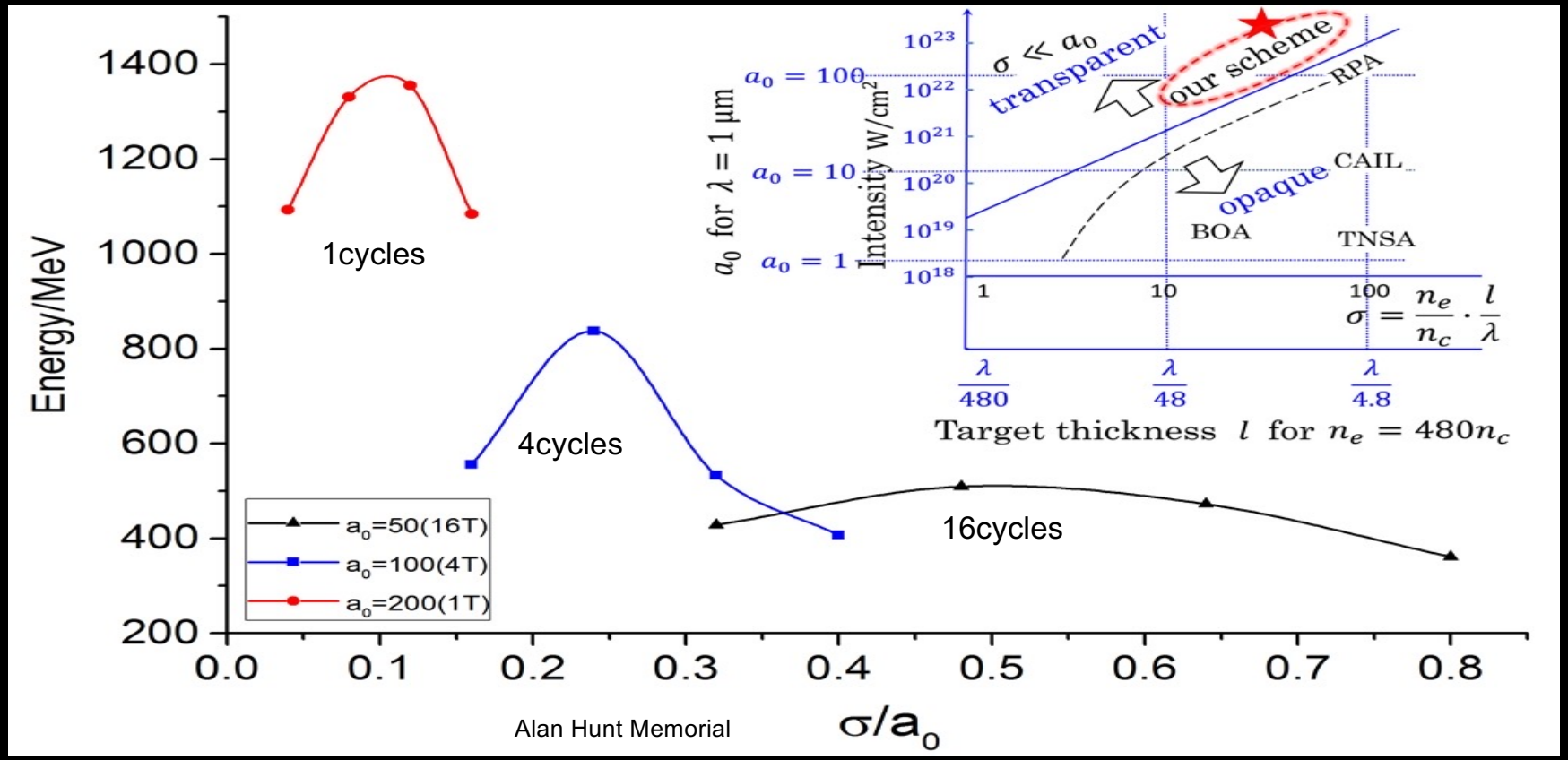
Accelerating mirror as an analog black hole

Low Hanging Fruit: High Energy Proton Generation

GeV Proton Generation



Applications of Single Cycle to Proton Generation vs a_0



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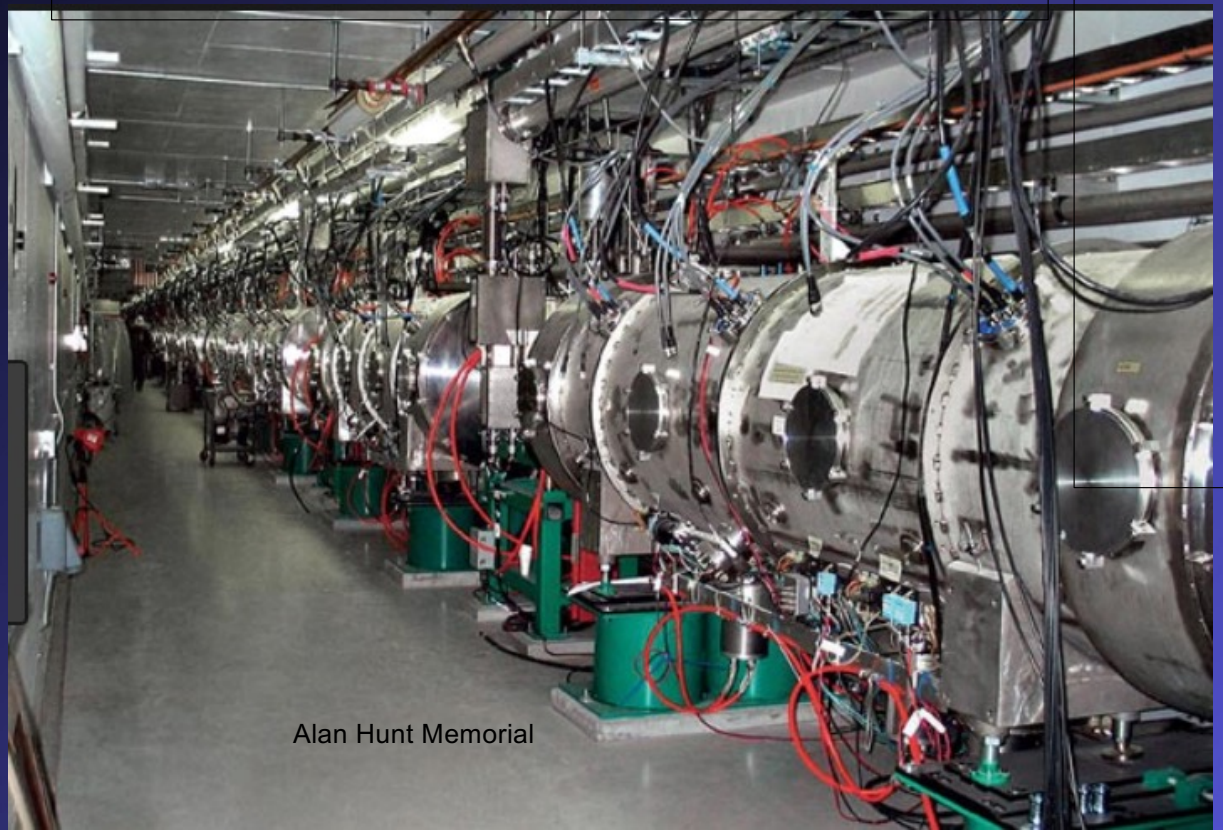
RELATIVISTIC PROTON ACCELERATOR for TRANSMUTATION

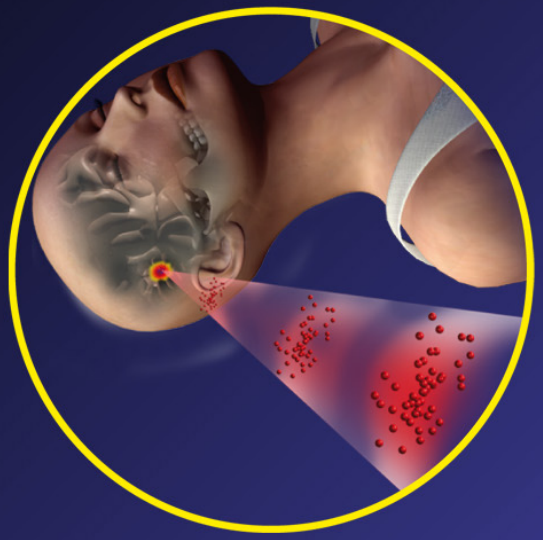


Alan Hunt Memorial

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

CPA Mitigating Nuclear waste

ENVIRONMENT:

EXPLORING AVENUES FOR CLEAN NUCLEAR ENERGY PRODUCTION

1. Energy production: fostering the Thorium cycle.

2. Transmutation of nuclear waste/ Burning the minor actinides produced in the uranium during energy production.

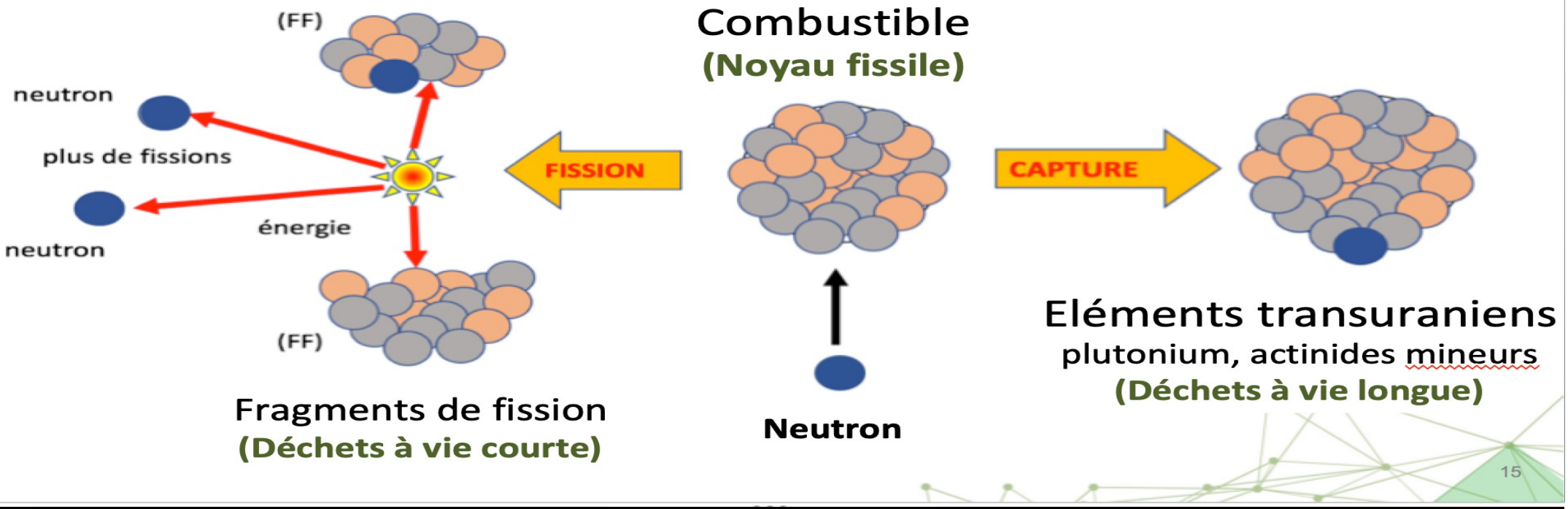
Why Considering Nuclear and Thorium?

1 GW Power Plant
producing 8 Billion kWh /year

Coal = 100 Trains
3M Tons Coal
1km3 of CO2

300 Tons Uranium
0 liter C02

1 Ton Thorium
0 liter C02

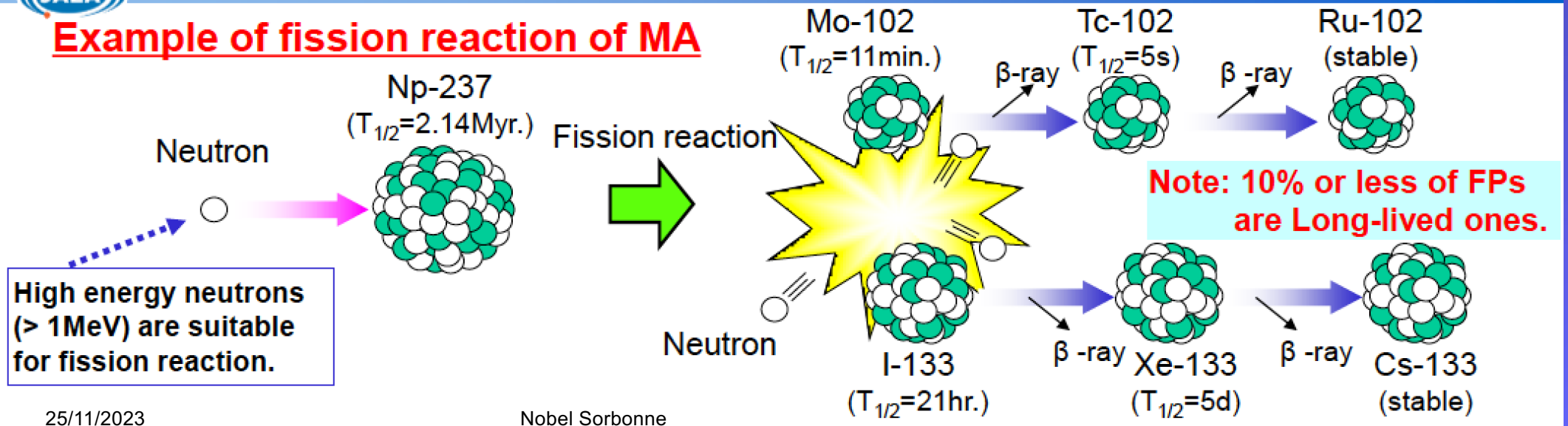

(FF)
neutron
plus de fissions
énergie
neutron
(FF)
Fragments de fission
(Déchets à vie courte)
FISSION
Combustible
(Noyau fissile)
Neutron
CAPTURE
Eléments transuraniens
plutonium, actinides mineurs
(Déchets à vie longue)

NUCLEAR TRANSMUTATION CONCEPT

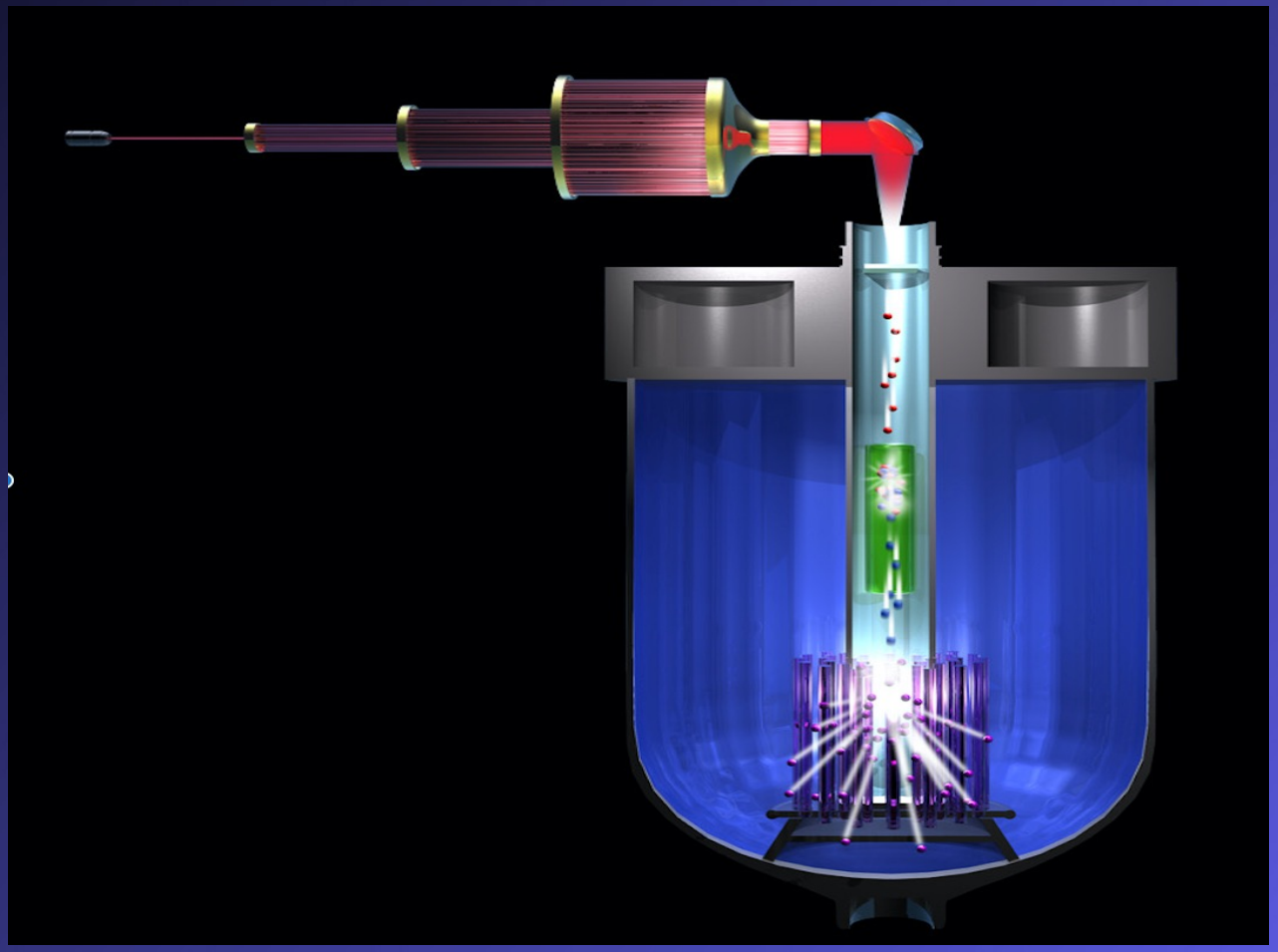
How to Transmute MA and LLFP

JAEA

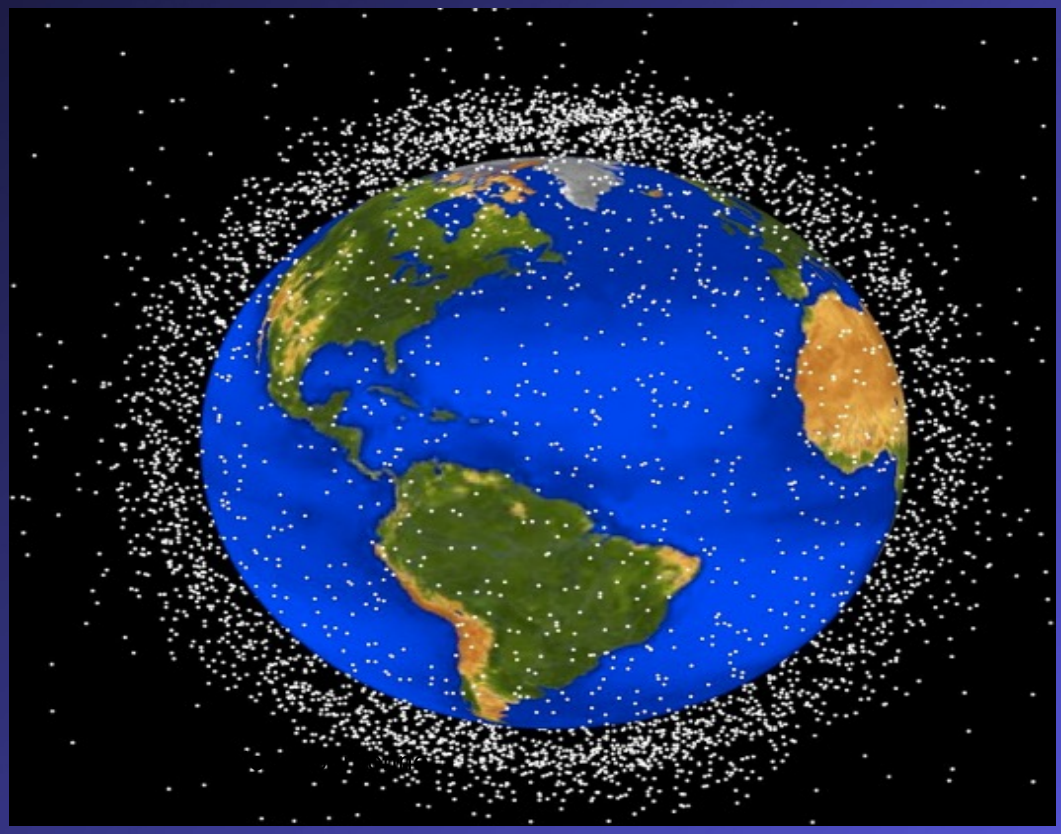
Example of fission reaction of MA



Accelerator-Driven-Subcritical Reactor



Millions of orbital debris are cluttering space



A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

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

How much is that?

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

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)


IOANNES XXIII PONT MAX

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

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Nobel Ceremony


KUNGL.
VETENSKAPS-
AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES
"...har till uppgift att främja vetenskaperna och stärka deras inflytande i samhället."
"...has as its aim to promote the sciences and strengthen their influence in society."
KUNGL.
VETENSKAPS-
AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

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

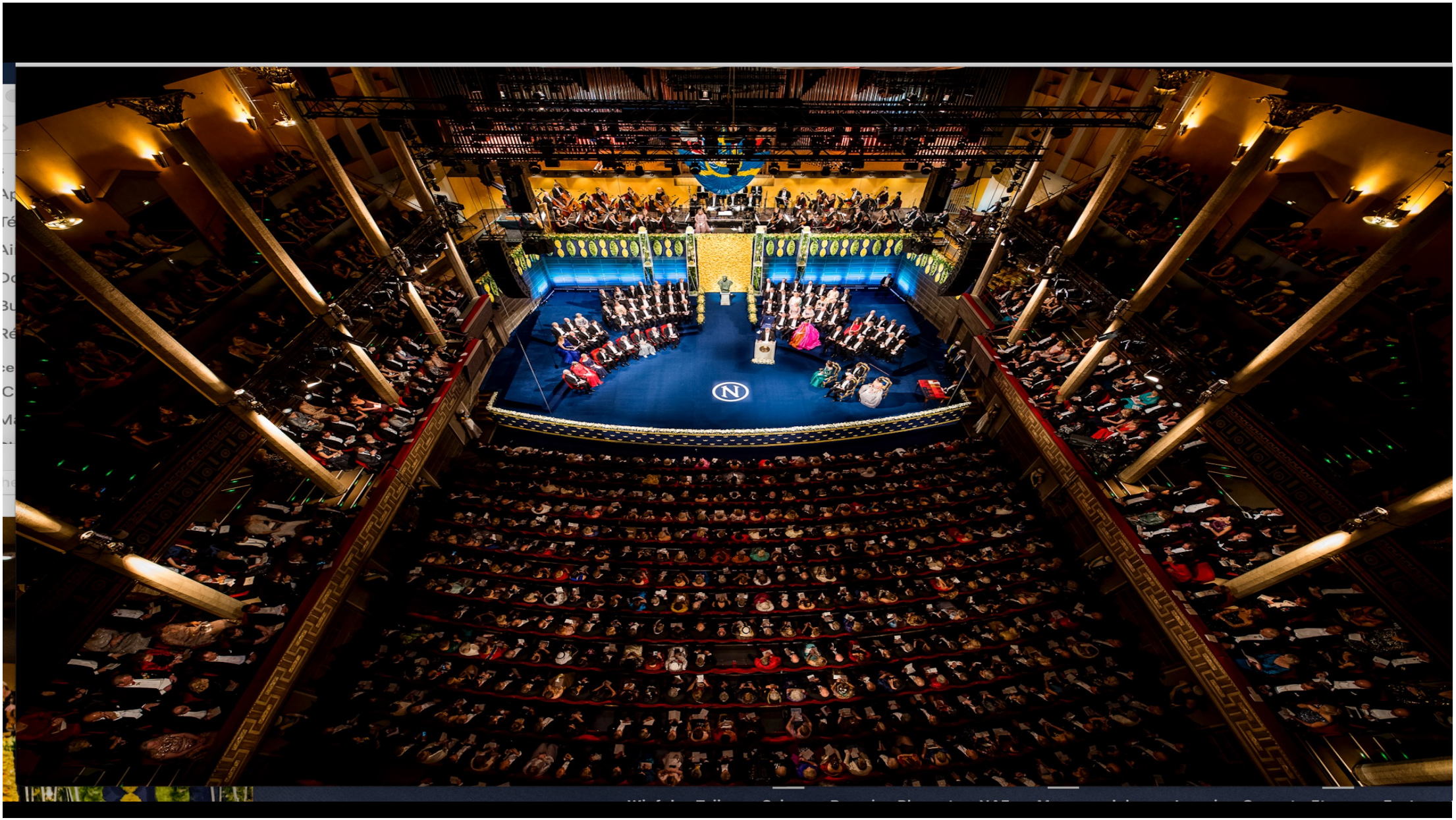
04/0[illegible]7

Trondheim University

IZEST
International Zeta-Exawatt Science Technology

International Year of Light 2015


Nobel Taipei



A PASSION FOR EXTREME LIGHT

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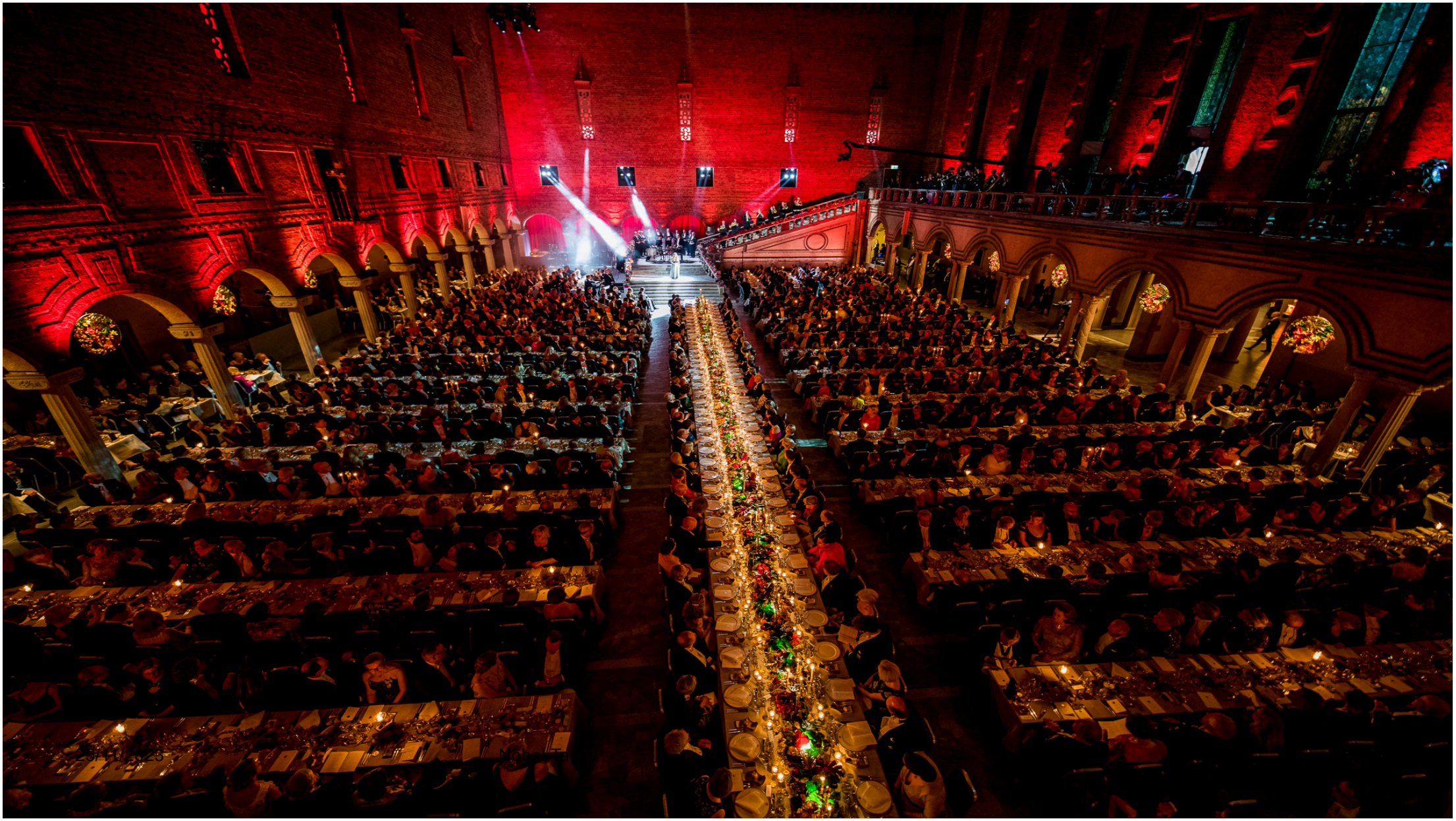
25/11/2023

Nobel Taipei



25/11/2023 Nobel Taipei

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A PASSION FOR EXTREME LIGHT

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Extreme light roadmap and ultra high intensity shortcut