A PASSION FOR EXTREME LIGHT

Ampère et l'Electro dynamisme, Lyon le 5 octobre 2022

Presented by

Prof. Gérard Mourou

Nobel Prize for Physics, 2018

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

Theodore Maiman

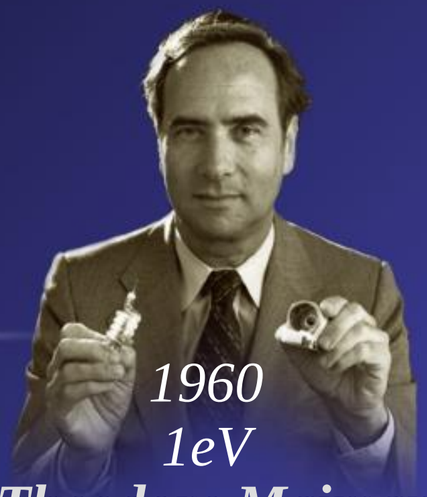
(July 11, 1927 – May 5, 2007)

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

Slowing down atoms

2018



1960

1eV

Theodore Maiman

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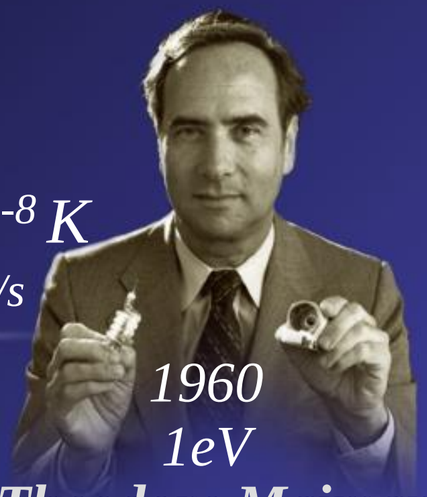
Quantum Optics

μeV – peV Temp.= 10 $^{-8}$ K

K Slowing down atoms to cm/s

2018



1960

1eV

Theodore Maiman

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Atomic Molecular Optics

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

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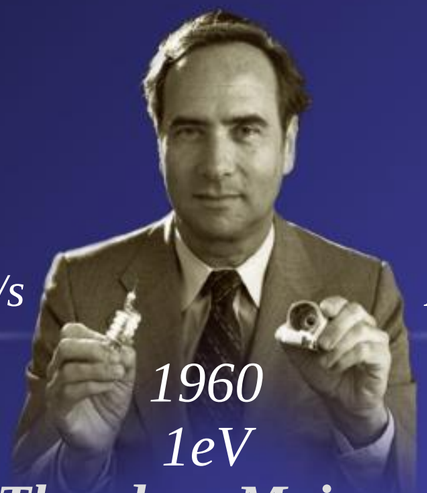
Quantum Optics

μeV - neV

Slowing down atoms to cm/s

2018



1960

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Accelerating particles to C

2018

Atomic Molecular Optics

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A PASSION FOR EXTREME LIGHT

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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***
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**** chemistry***

Relativistic and Ultra-relativistic Optics

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

Chirped Pulse Amplification (CPA)

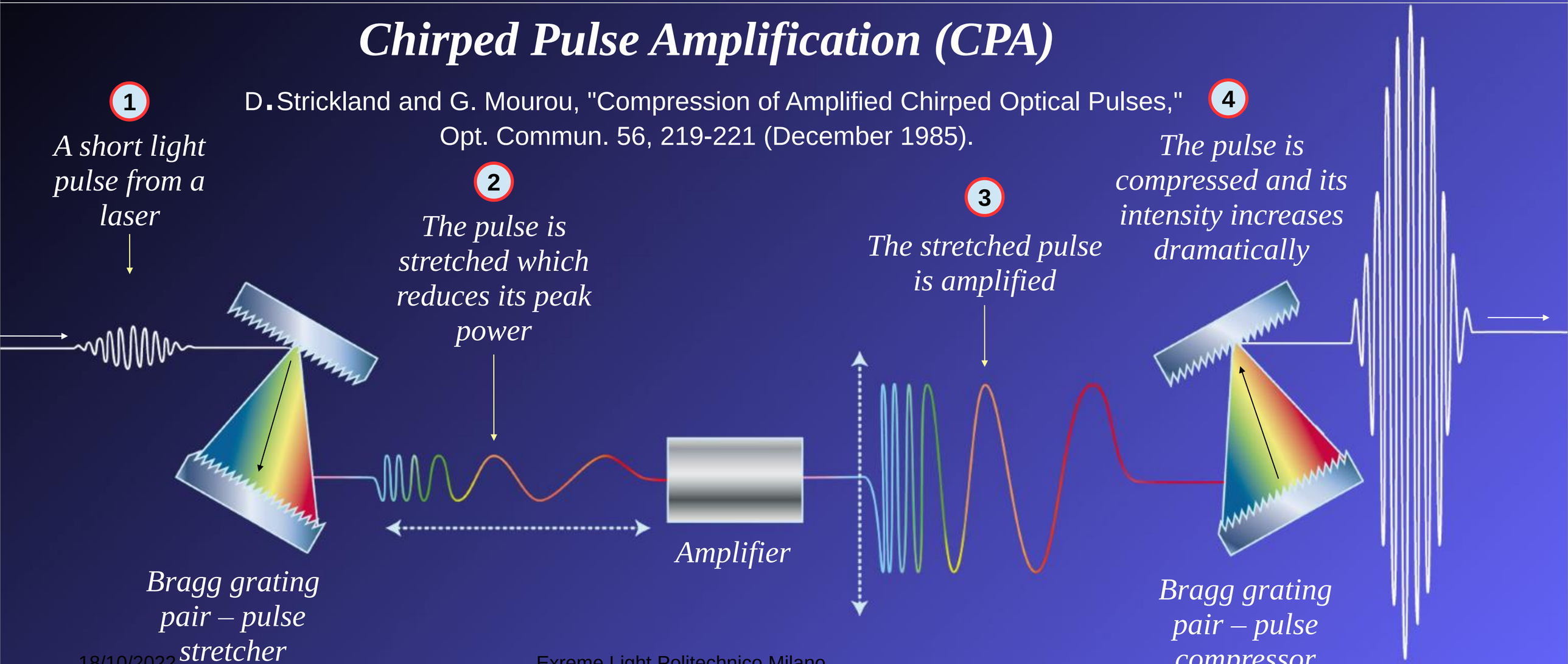
D. Strickland and G. Mourou, "Compression of Amplified Chirped Optical Pulses," Opt. Commun. 56, 219-221 (December 1985).

1 *A short light pulse from a laser*

2 *The pulse is stretched which reduces its peak power*

3 *The stretched pulse is amplified*

4 *The pulse is compressed and its intensity increases dramatically*



Bragg grating pair – pulse stretcher

Amplifier

Bragg grating pair – pulse compressor

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

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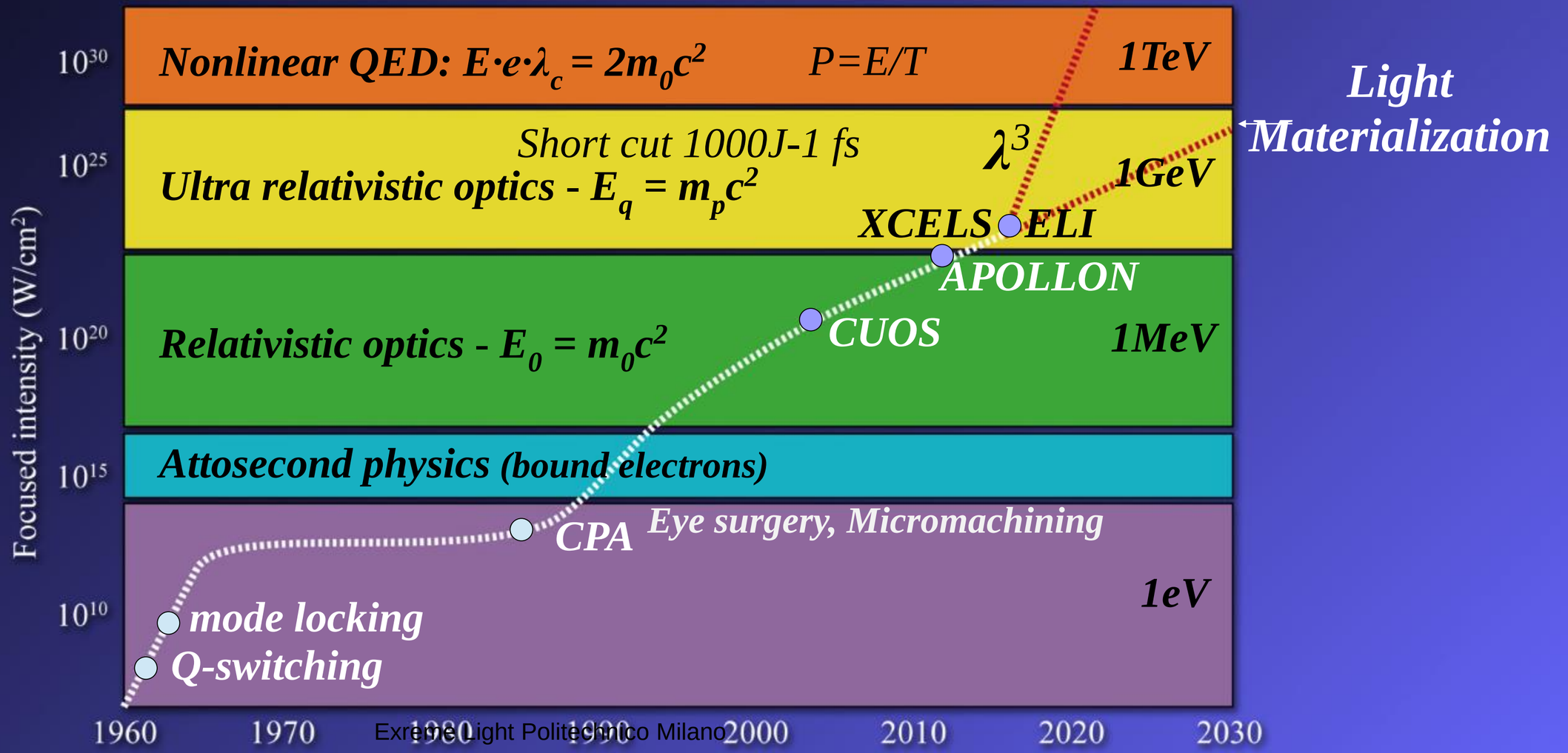
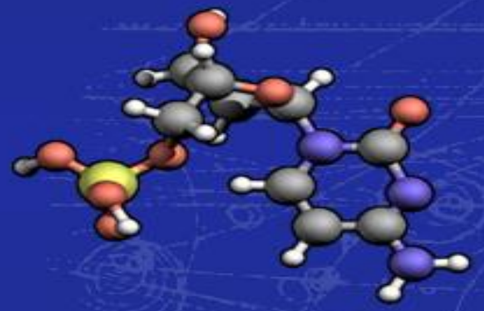
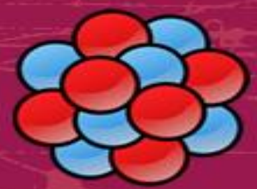
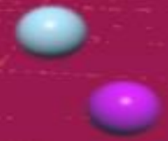
Extreme light roadmap and ultra high intensity shortcut



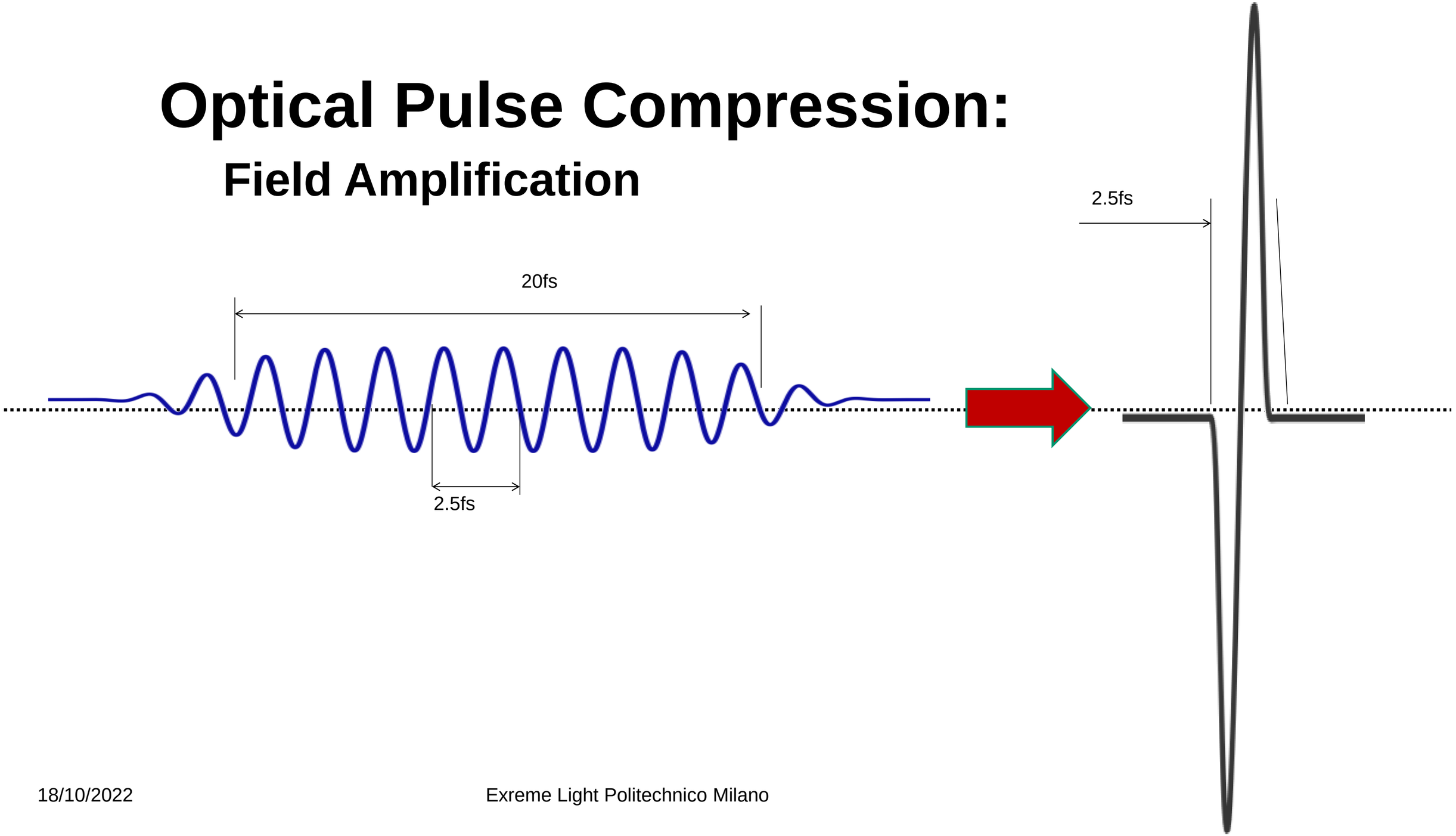
Laser Exploration : From Atomic to Sub-Atomic

eV → TeV

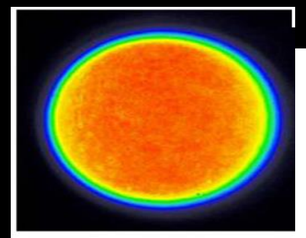
ATOMIC		SUB-ATOMIC		
molecules	atoms	nucleii	protons	electrons/quarks
				 ?
10^{-10} m		10^{-14} m	10^{-15} m	$\leq 10^{-18}$ m

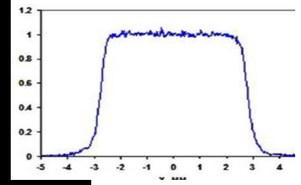
Optical Pulse Compression:

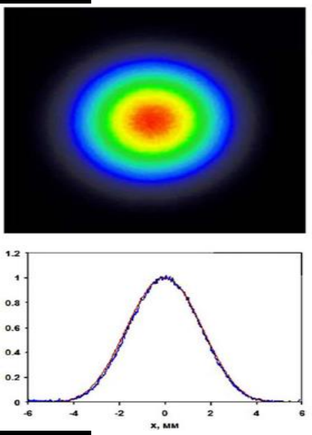
Field Amplification

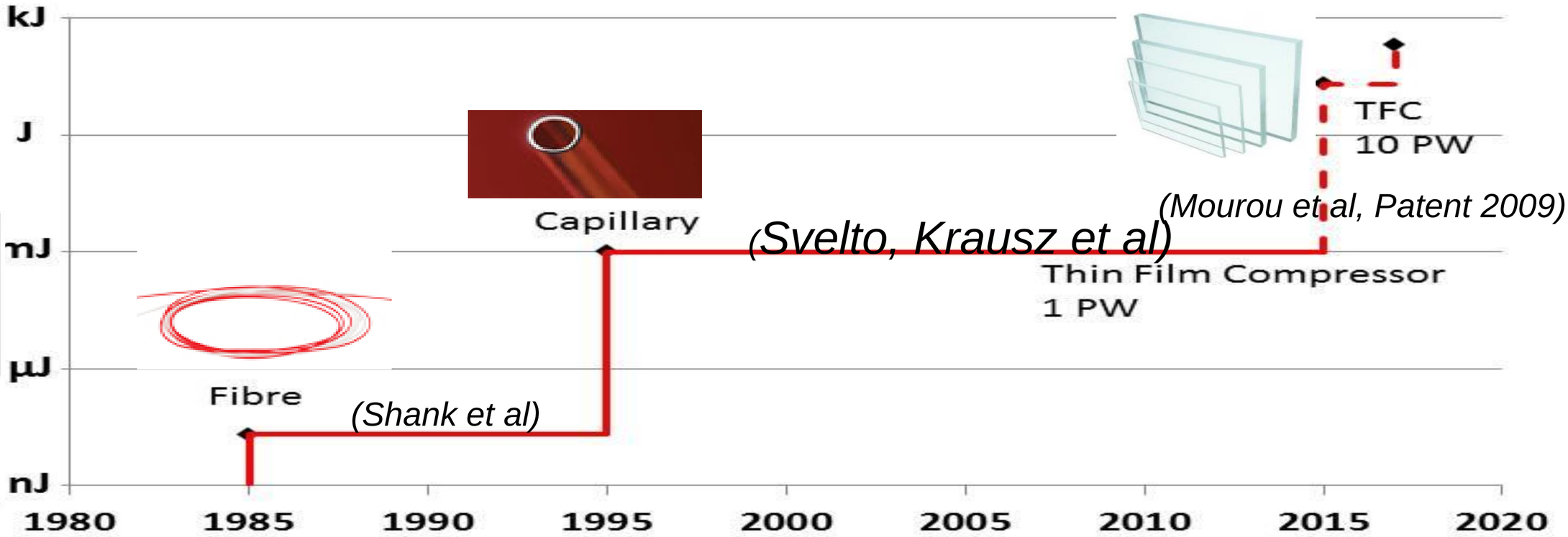


Single Cycle Pulse Compression Pulse History







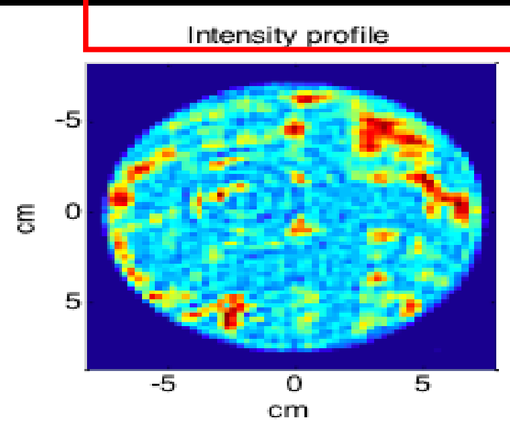


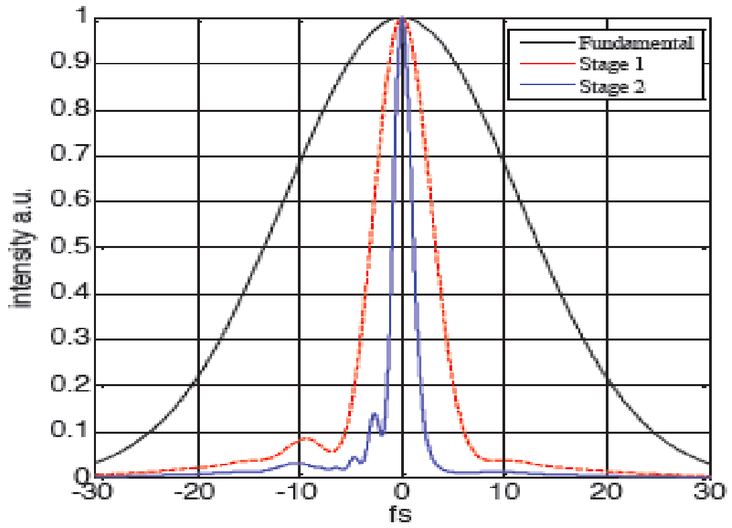
18/10/2022

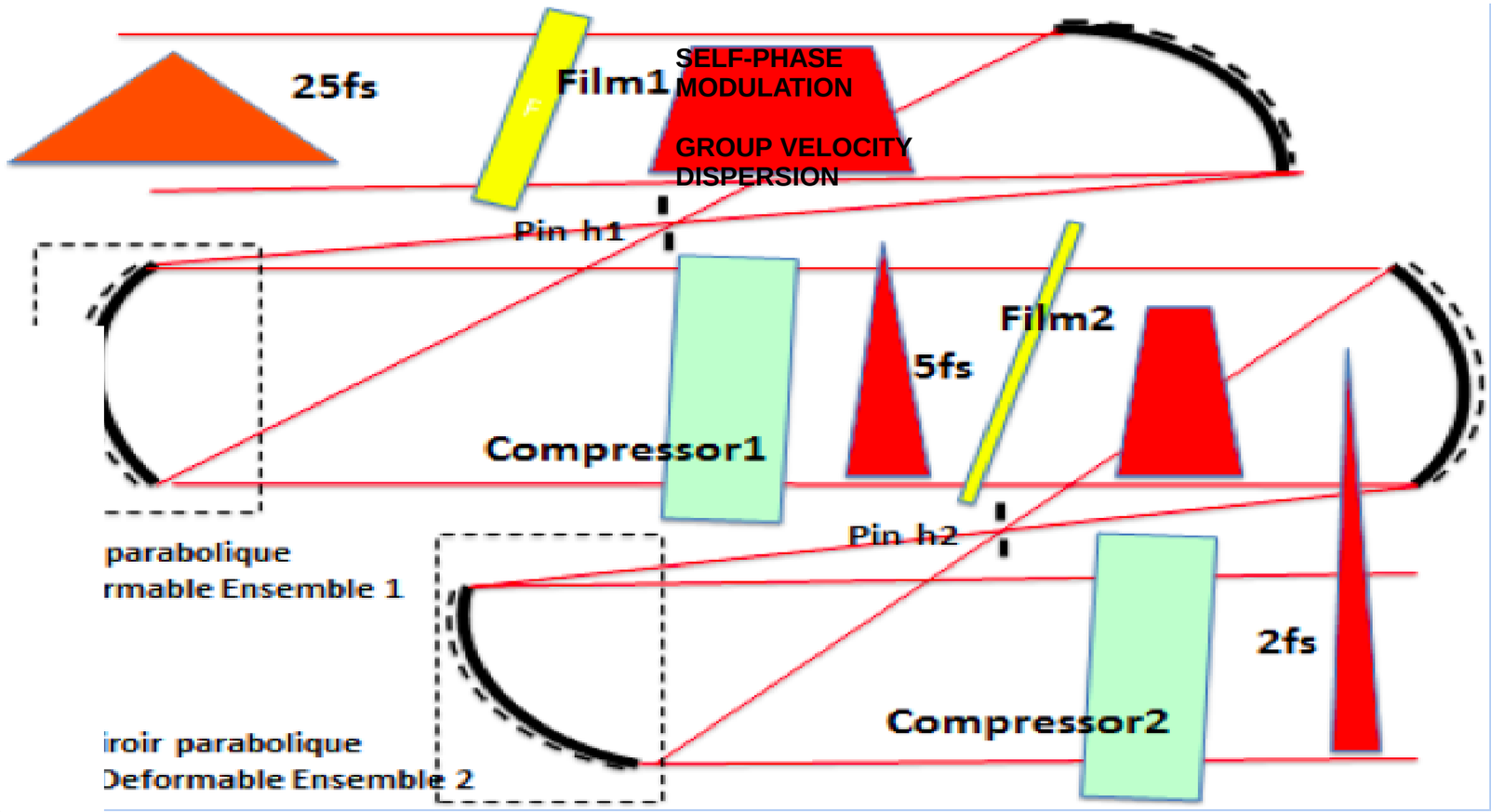
Gérard Mourou, Gilles Cheriaux, Christophe Radier,Device for generating a short duration laser pulse US 20110299152 A1

Thin Film Compressor to Single Cycle (TFC)

Mourou, G. Cheriaux, C. Radier Patent 2009







A.A. Voronin, A.M. Zheltikov, T. Ditmire, B. Rus and G. Korn Optics. Com. 2011

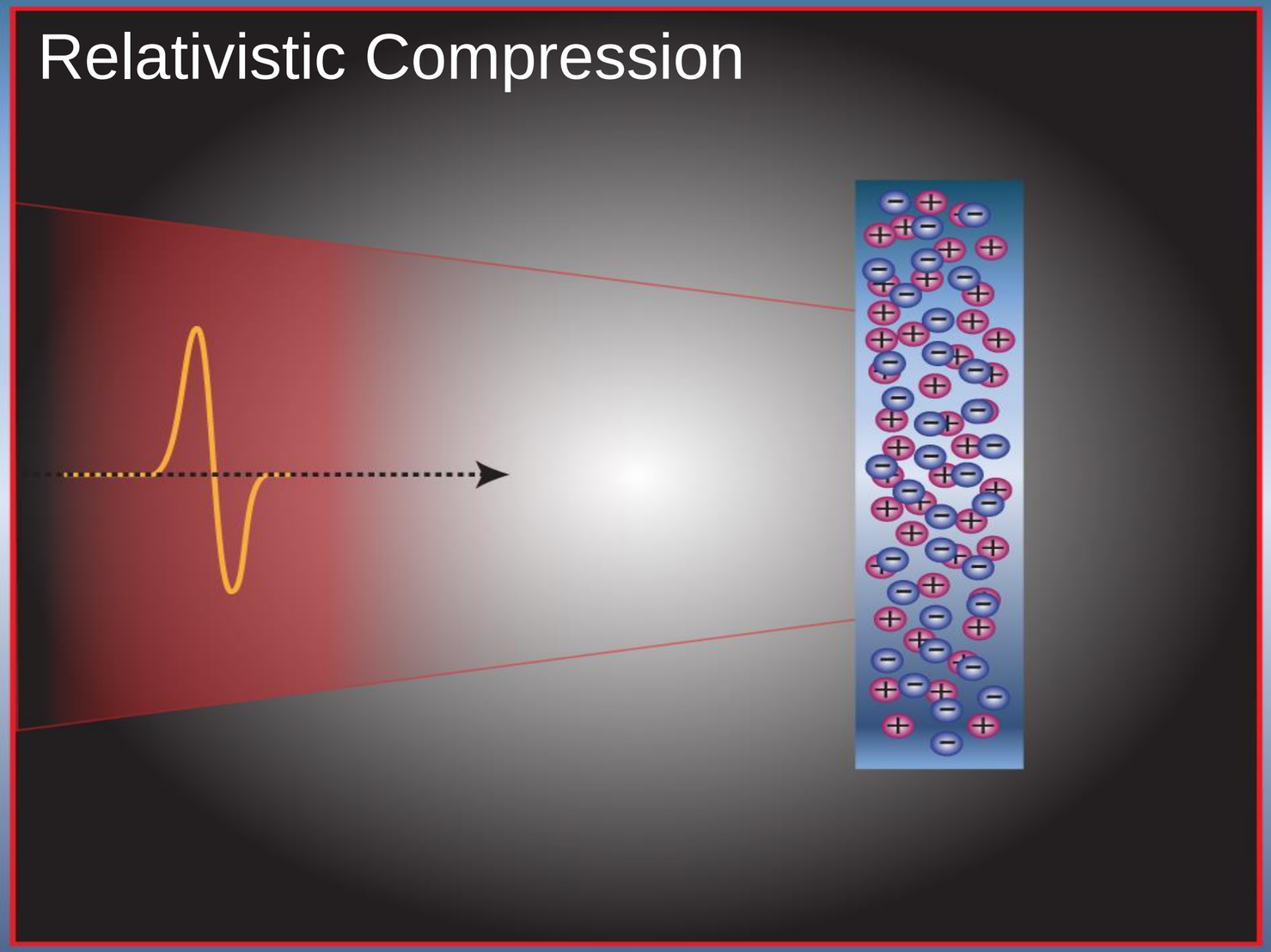
G. Mourou, S. Mironov, E. Khazanov and A. Sergeev, Single cycle Physics , Eur. Phys. J. Special Topics, 223, 1181(2014)

Relativistic Compression
Scalable Isolated Attosecond Pulses

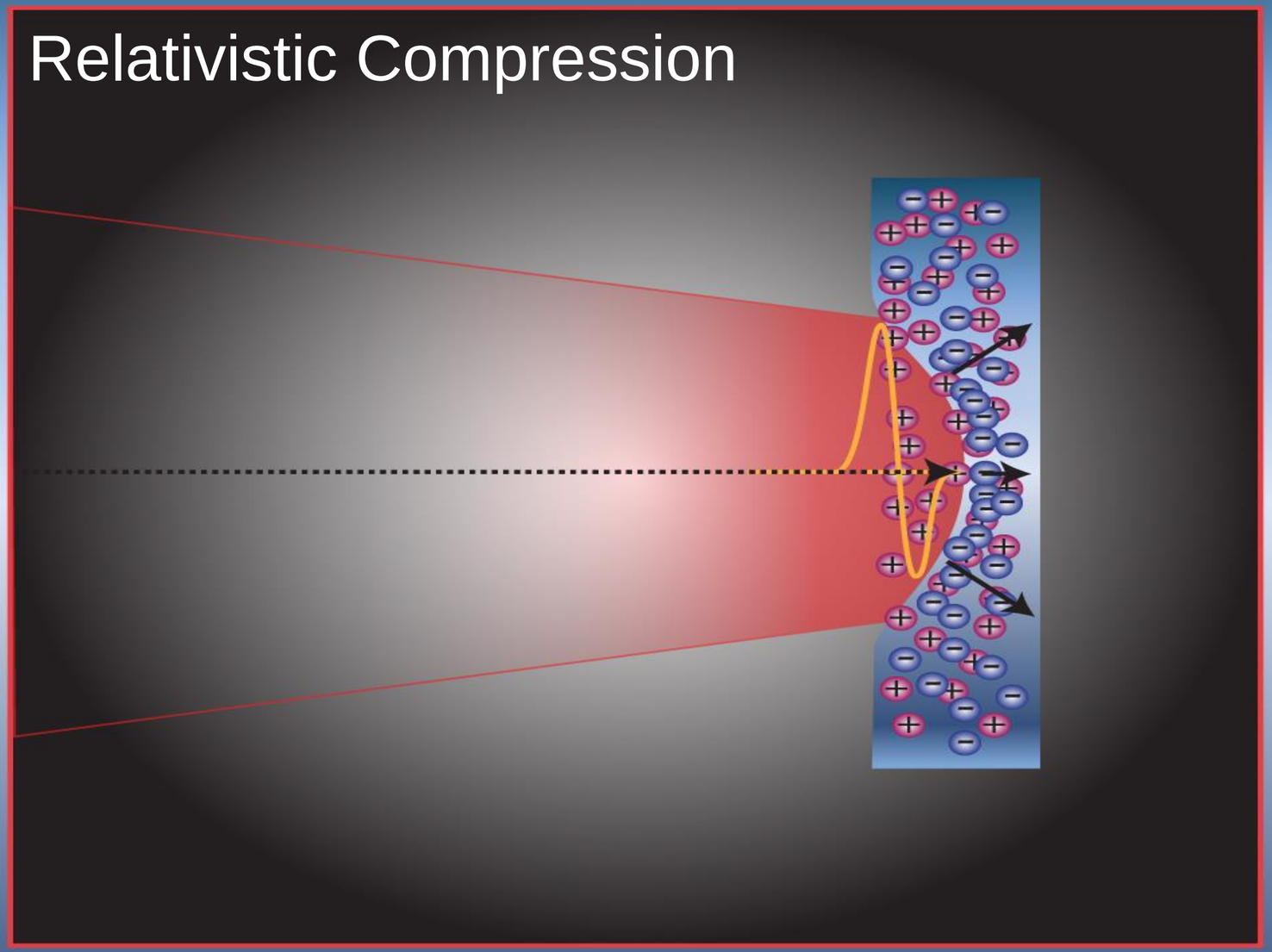
N. M. Naumova, J. A. Nees, I. V. Sokolov, B. Hou, and G. A. Mourou,

Relativistic generation
of Isolated attosecond Pulses in a λ^3 Focal Volume, Phys. Rev. Lett. 92, 063902-1 (2004).

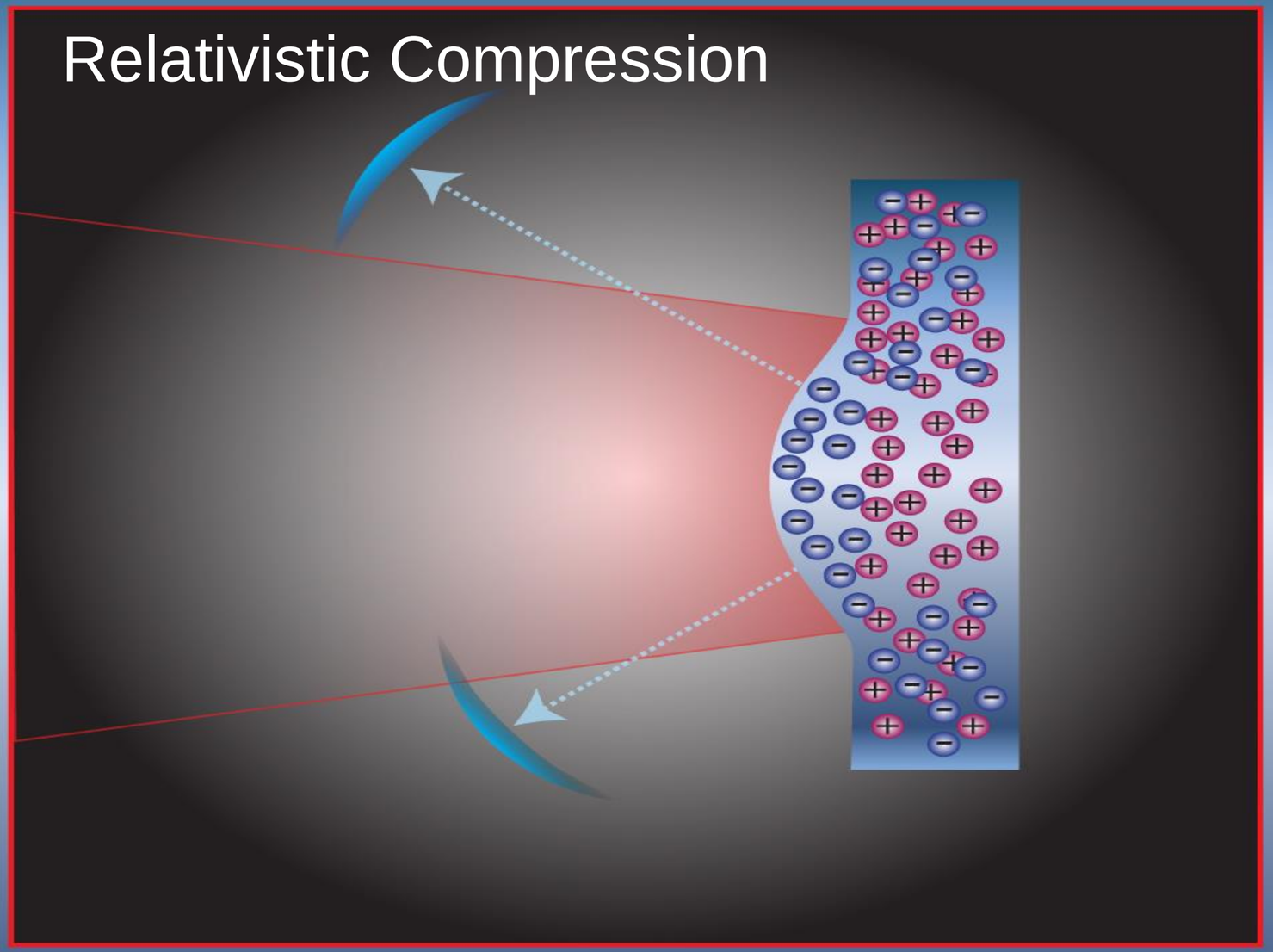
Relativistic Compression



Relativistic Compression



Relativistic Compression



Relativistic Compression

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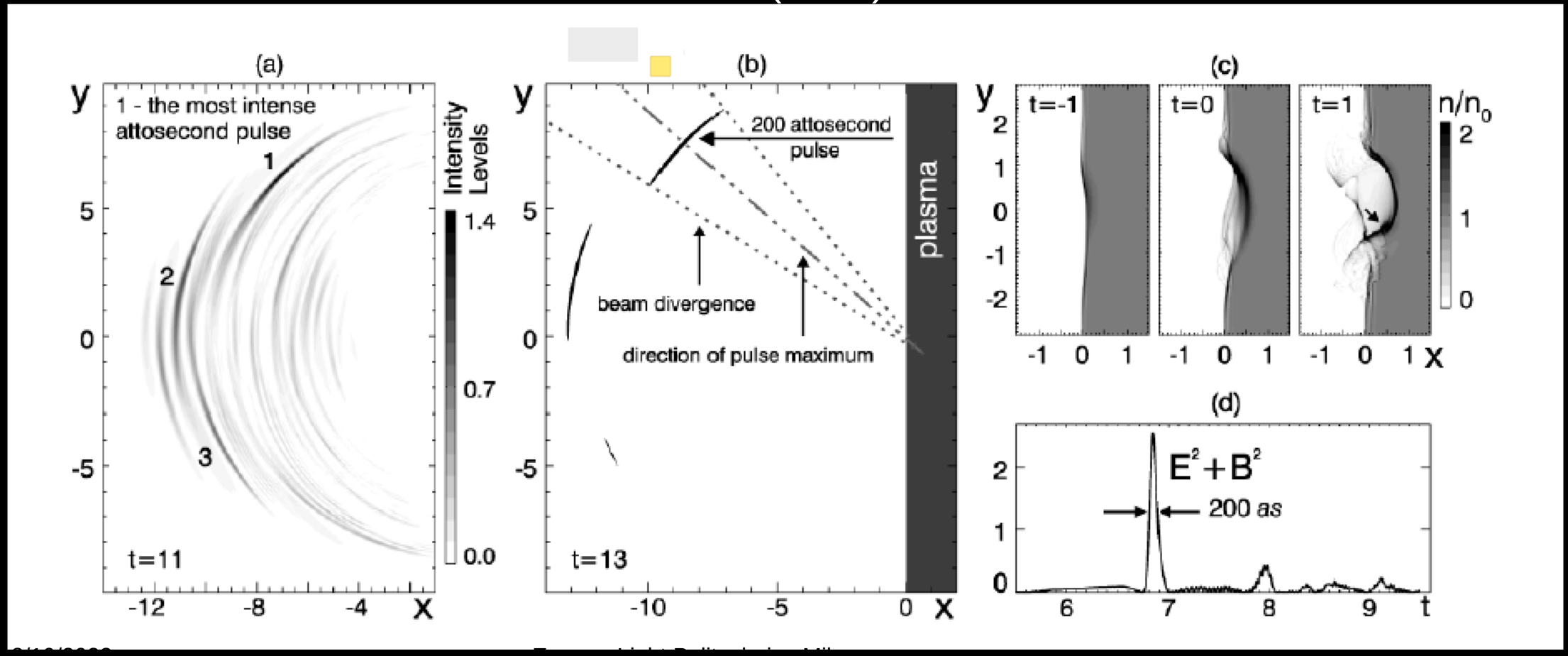
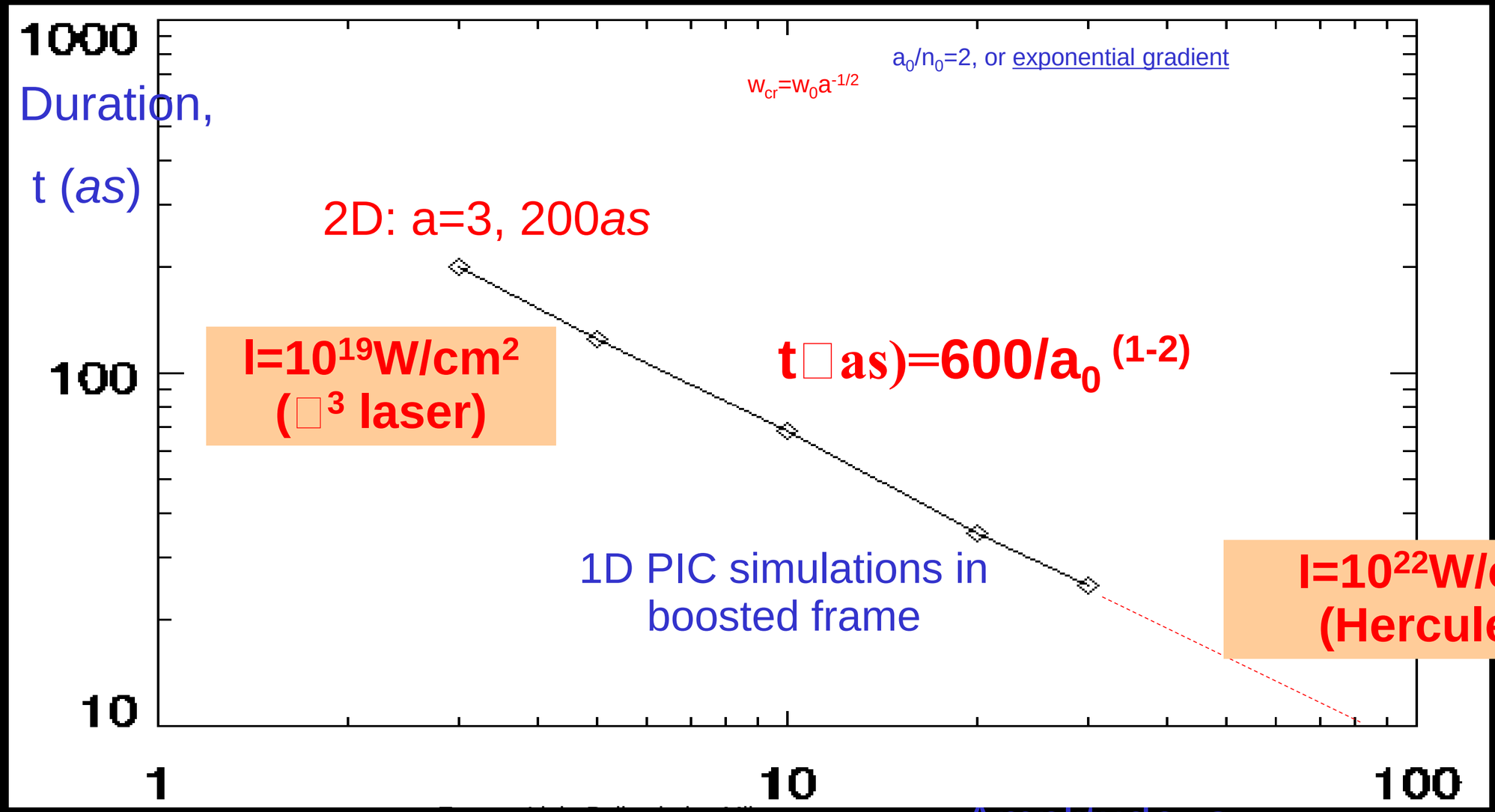
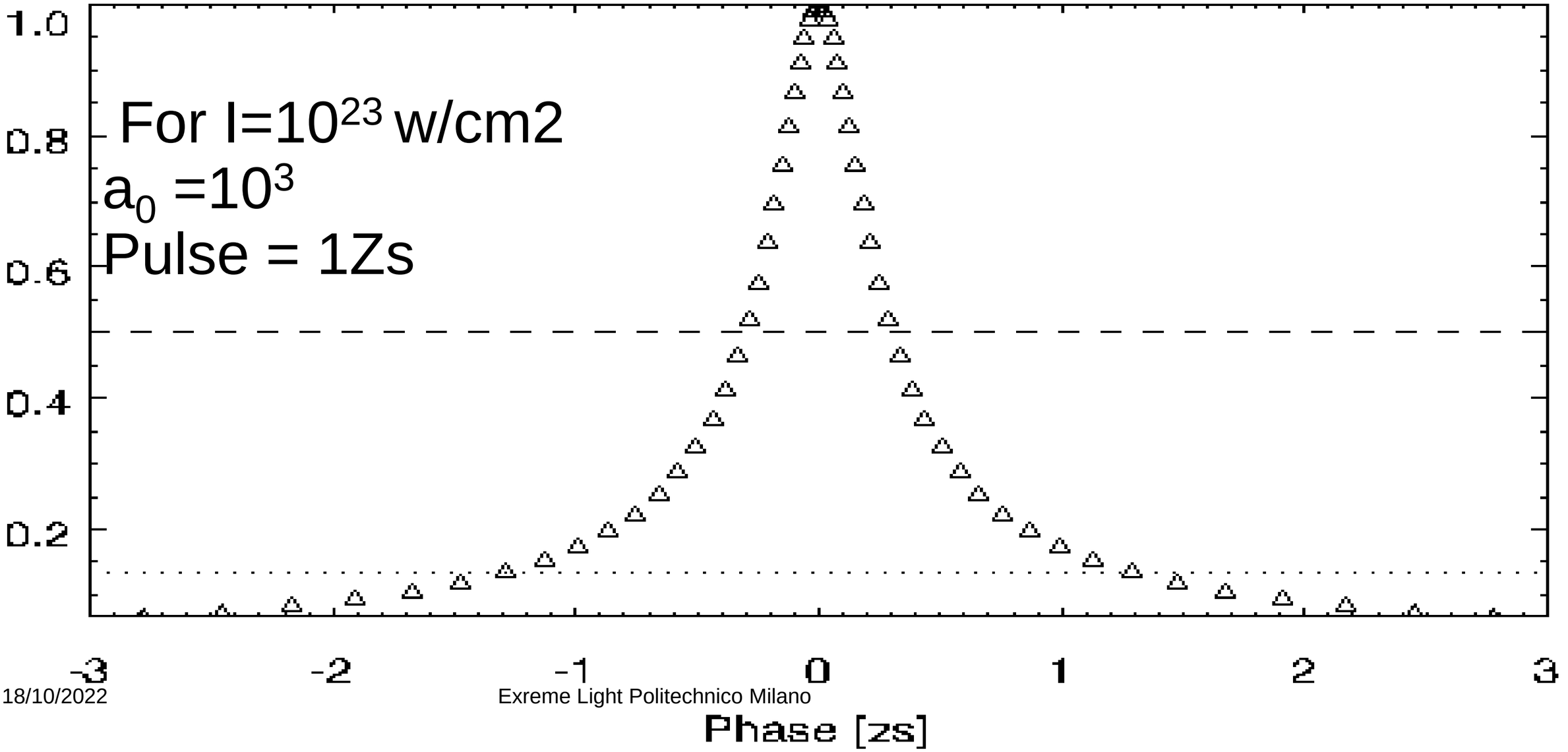


Scalable Isolated Attosecond Pulses

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

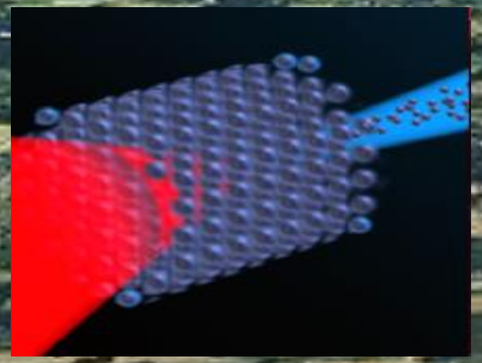
Synchrotron SOLEIL 3GeV

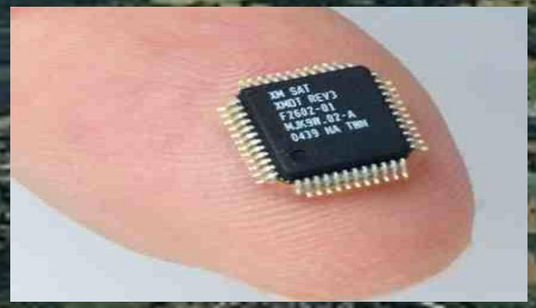
S

Outlook for Laser-Particle acceleration TeV

Microwave cavity

Laser wakefield X-ray, 1cm

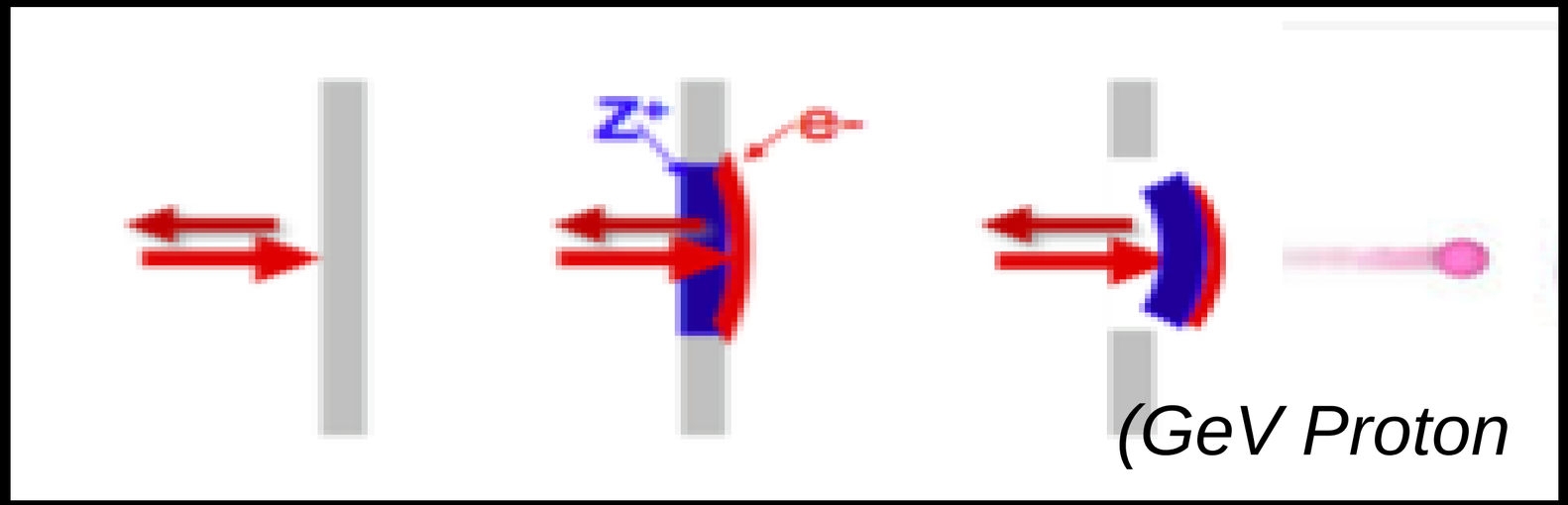




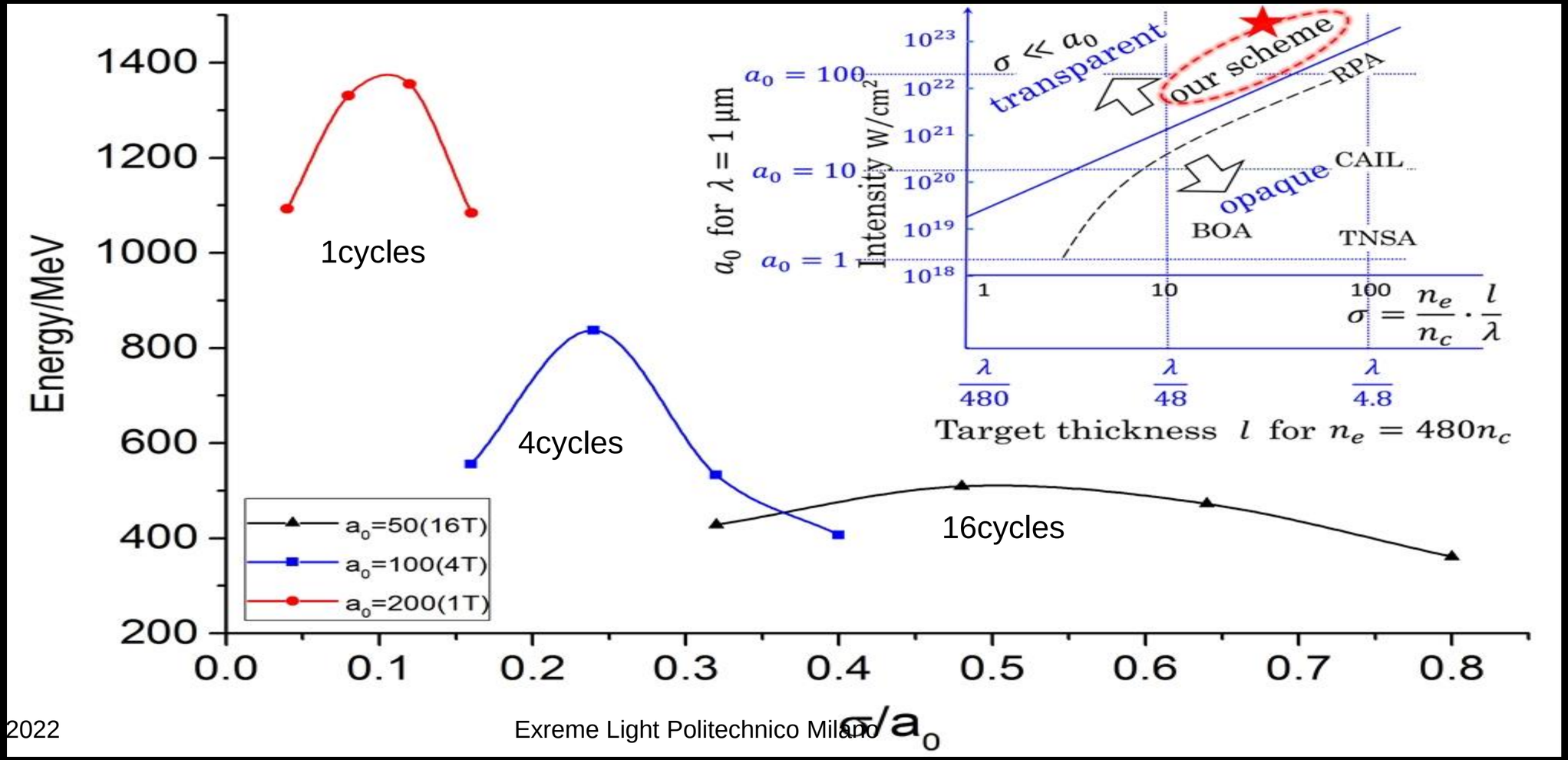
Laser wakefield Visible 100m

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

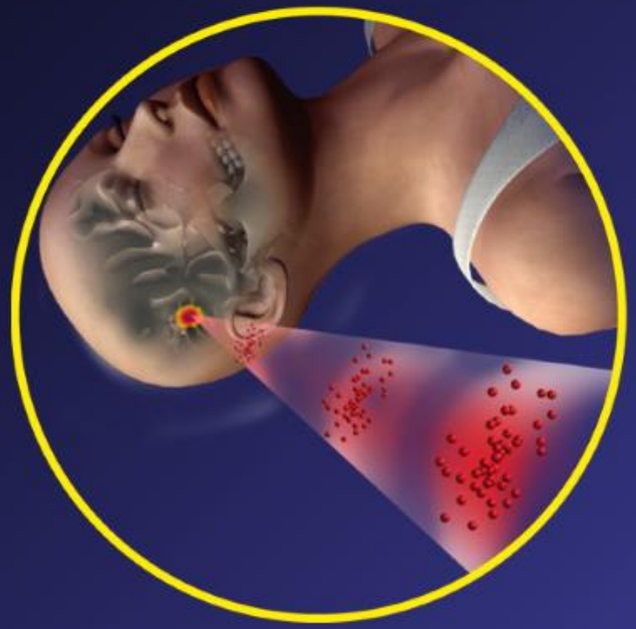
Exreme Light Politechnico Milano

Projet MYRRHA

18/10/2022

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

Extreme Light for Clean Nuclear Energy

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.

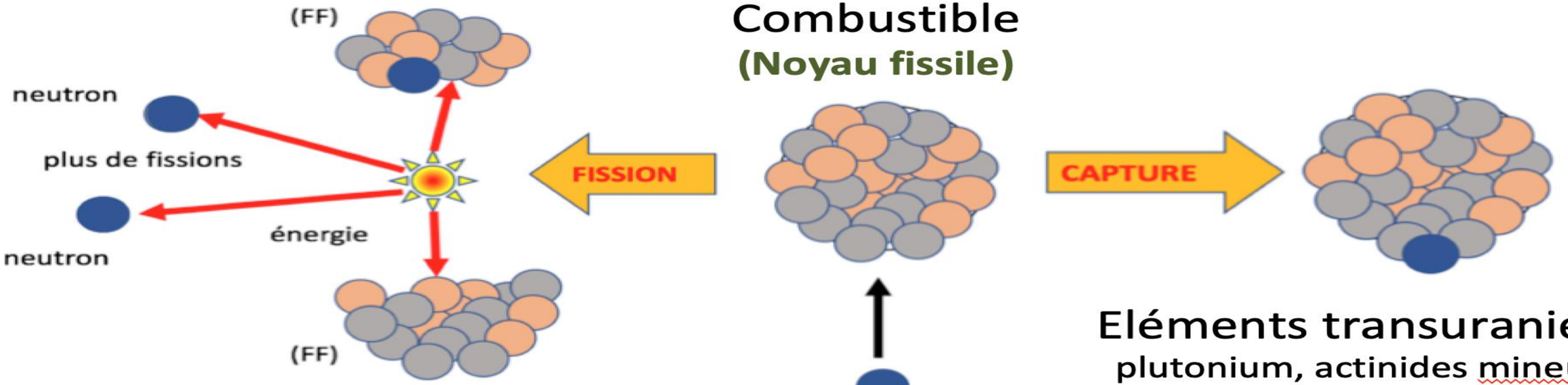
Why Considering Nuclear Energy?

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

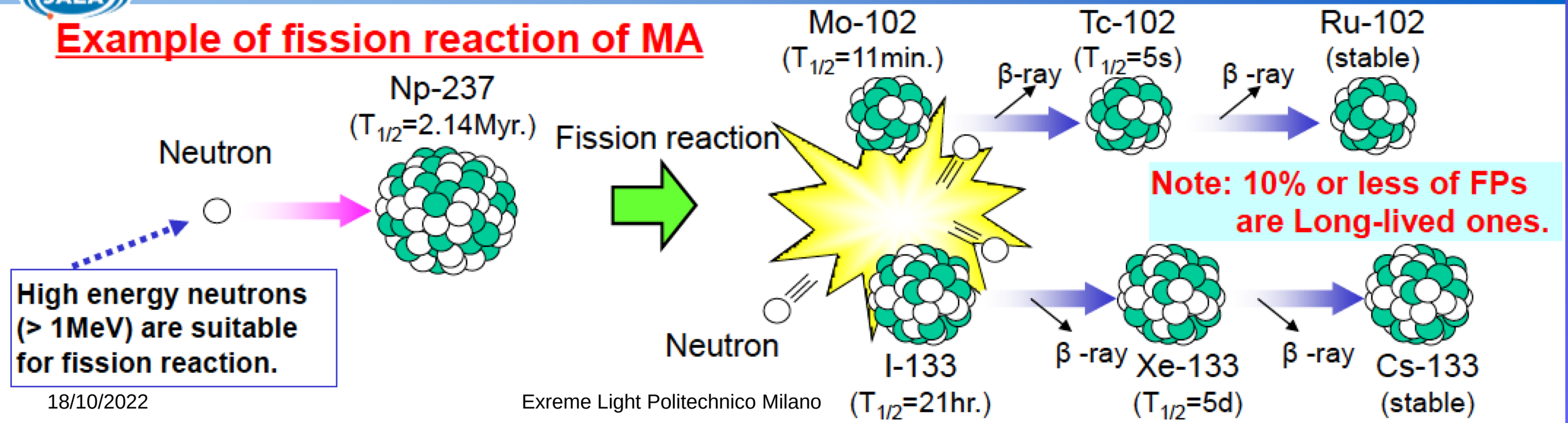

(FF)
neutron
plus de fissions
énergie
neutron
(FF)
FISSION
Combustible
(Noyau fissile)
CAPTURE
Fragments de fission
(Déchets à vie courte)
Neutron
Eléments transuraniens
plutonium, actinides mineurs
(Déchets à vie longue)

NUCLEAR TRANSMUTATION CONCEPT

How to Transmute MA and LLFP

JAEA

Example of fission reaction of MA



Space Debris

Millions of orbital debris are cluttering space

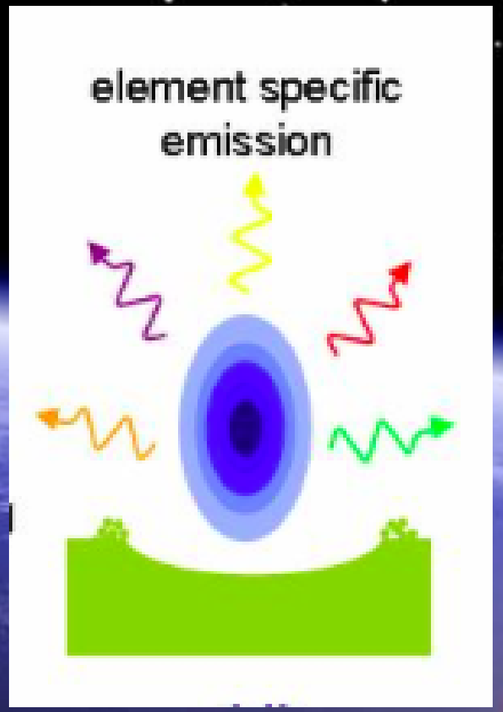
SPACE DEBRIS - A state of emergency!

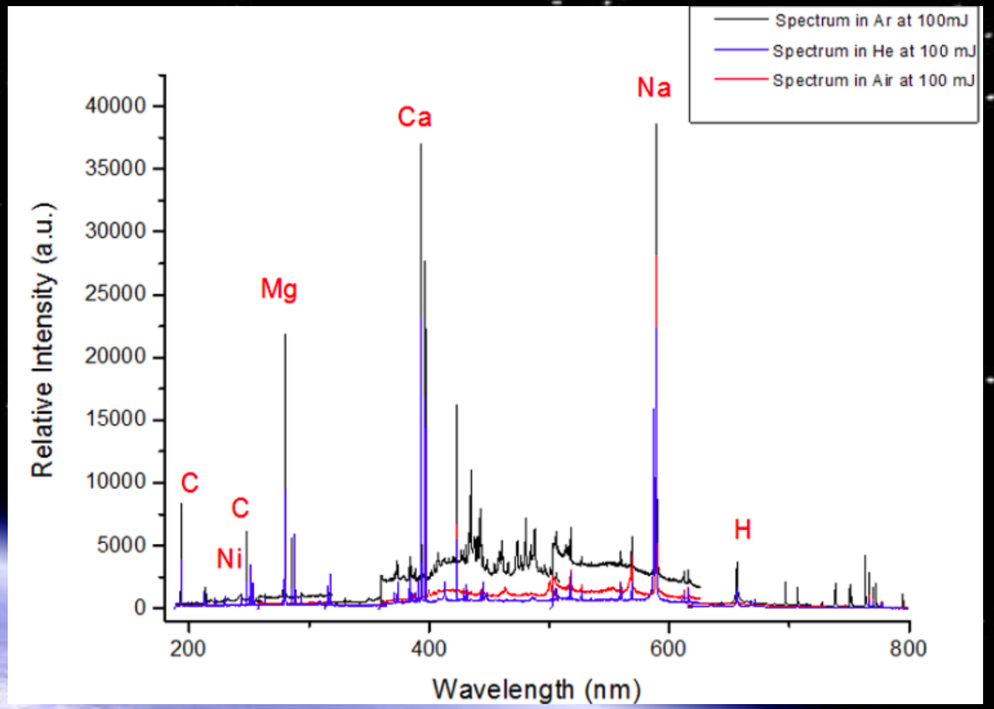
4x 7,000 tons = **28,000 tons!!!**

How much is that?

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

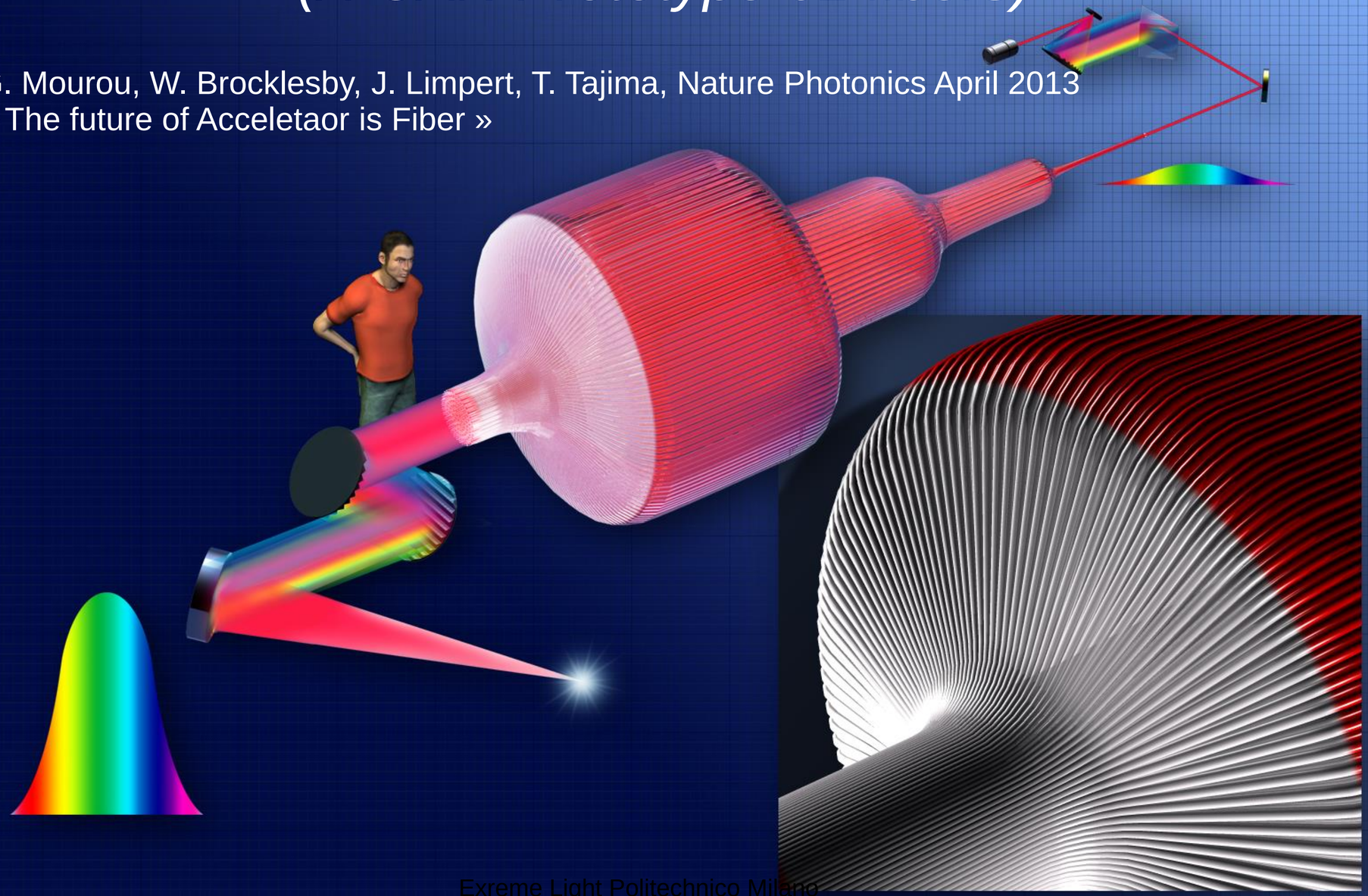
Debris identification: Laser Induced Breakdown Spectroscopy





CAN Coherent Amplification Network (X-CAN Prototype 61 fibers)

G. Mourou, W. Brocklesby, J. Limpert, T. Tajima, Nature Photonics April 2013
« The future of Acceletaor is Fiber »



Extreme Light for Planet Stewardship
Anciclica Laudato si

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!