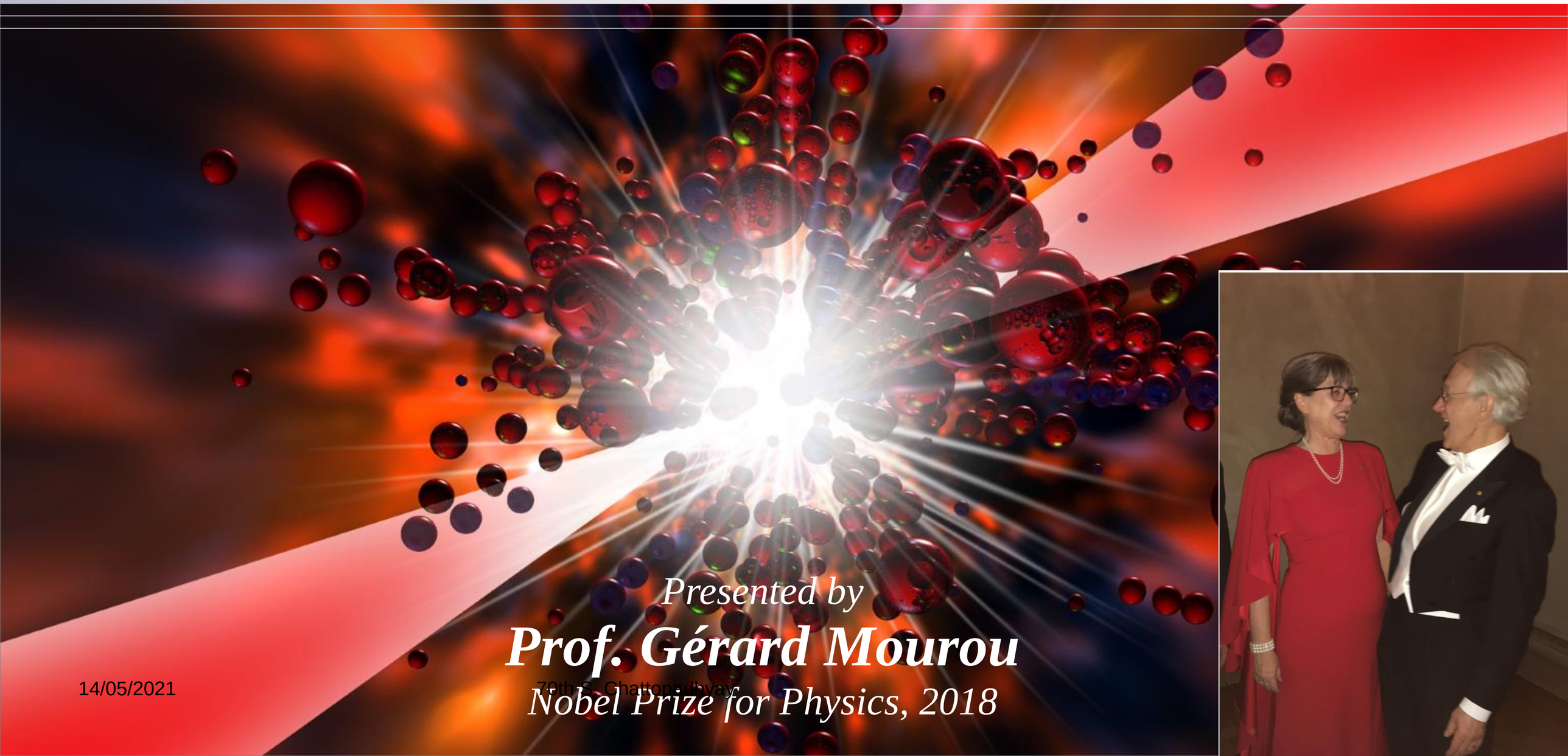
A PASSION FOR EXTREME LIGHT

In honour of the 70th BD of S. Chattopadhyay



Presented by

Prof. Gérard Mourou

Nobel Prize for Physics, 2018

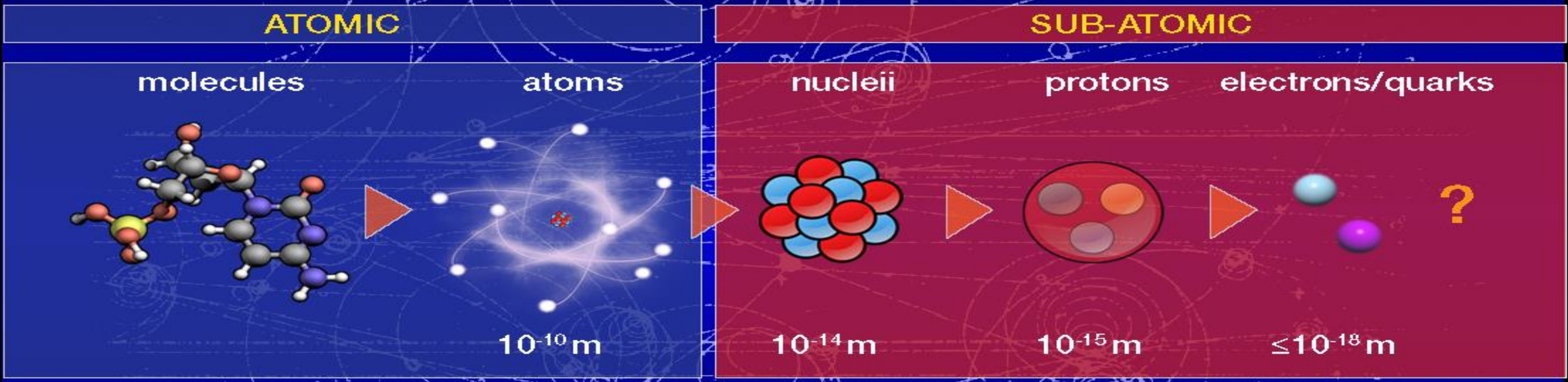
Extreme light Laser is capable to produce,

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

Laser Exploration : From Atomic to Sub-Atomic

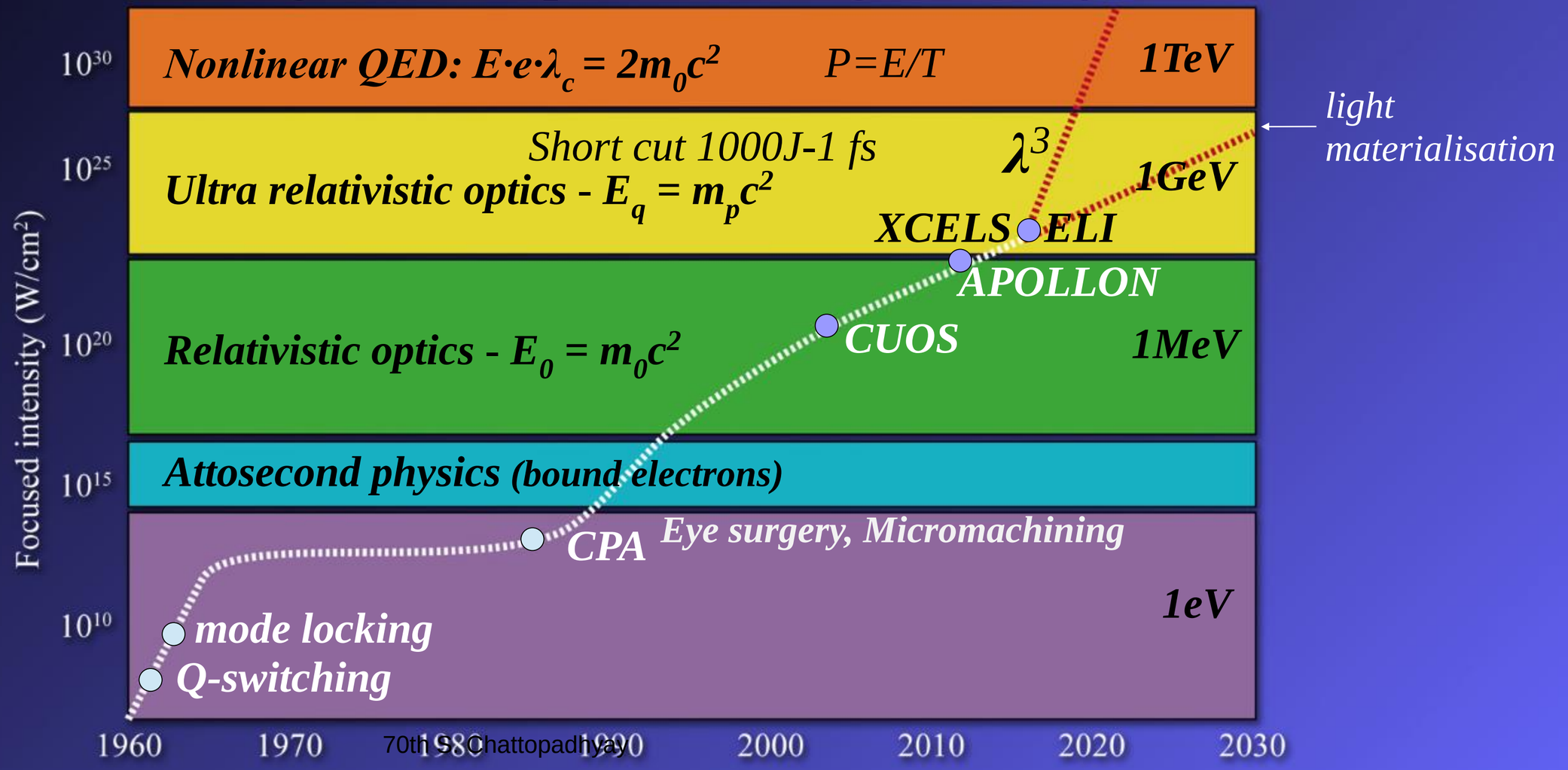
eV → TeV



A PASSION FOR EXTREME LIGHT

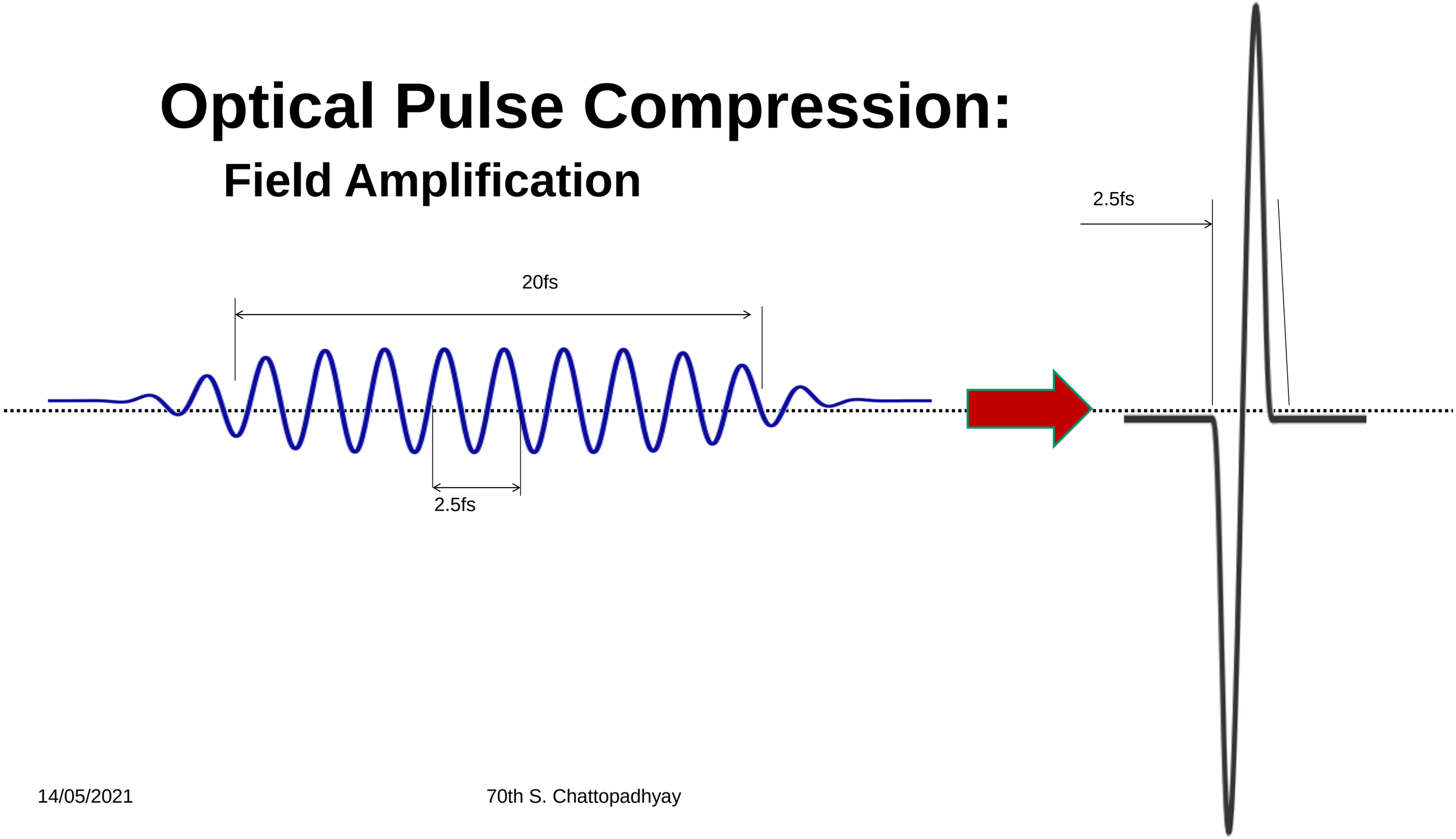
For the greatest benefit to human kind (Alfred Nobel)

Extreme light roadmap and ultra high intensity shortcut

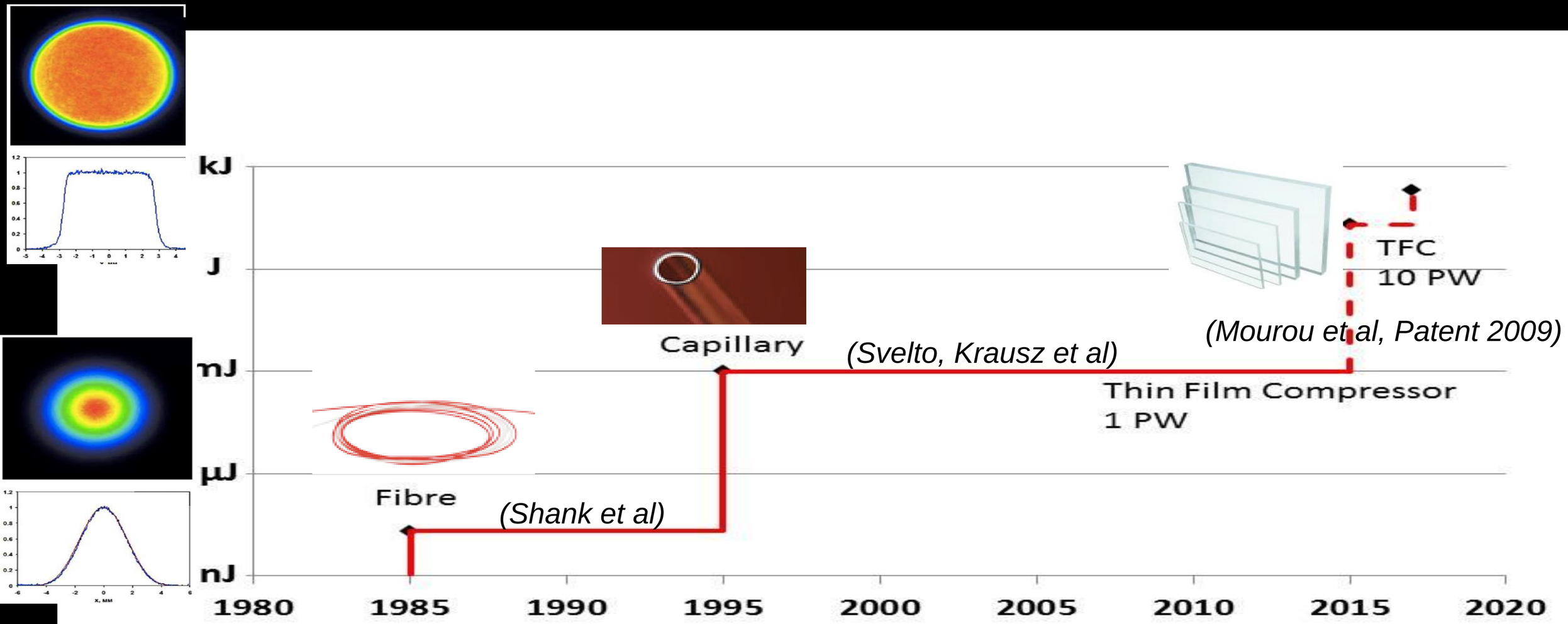


Optical Pulse Compression:

Field Amplification



Single Cycle Pulse Compression Pulse: History

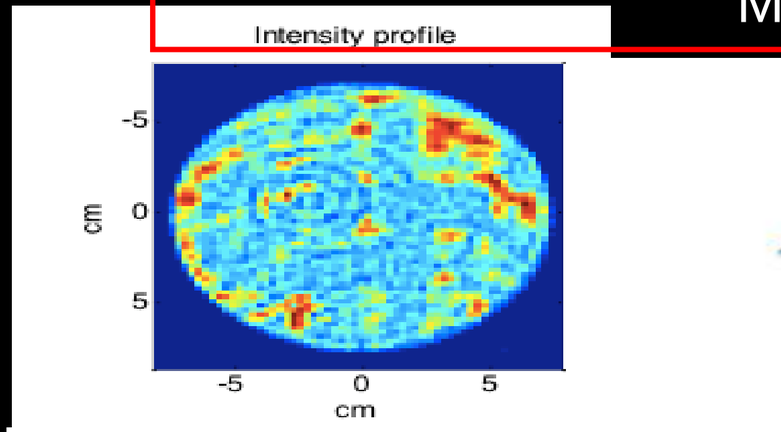


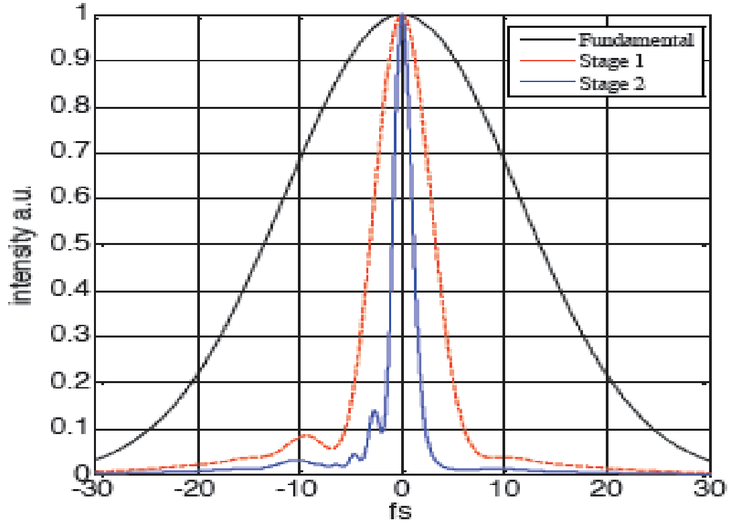
14/05/2021

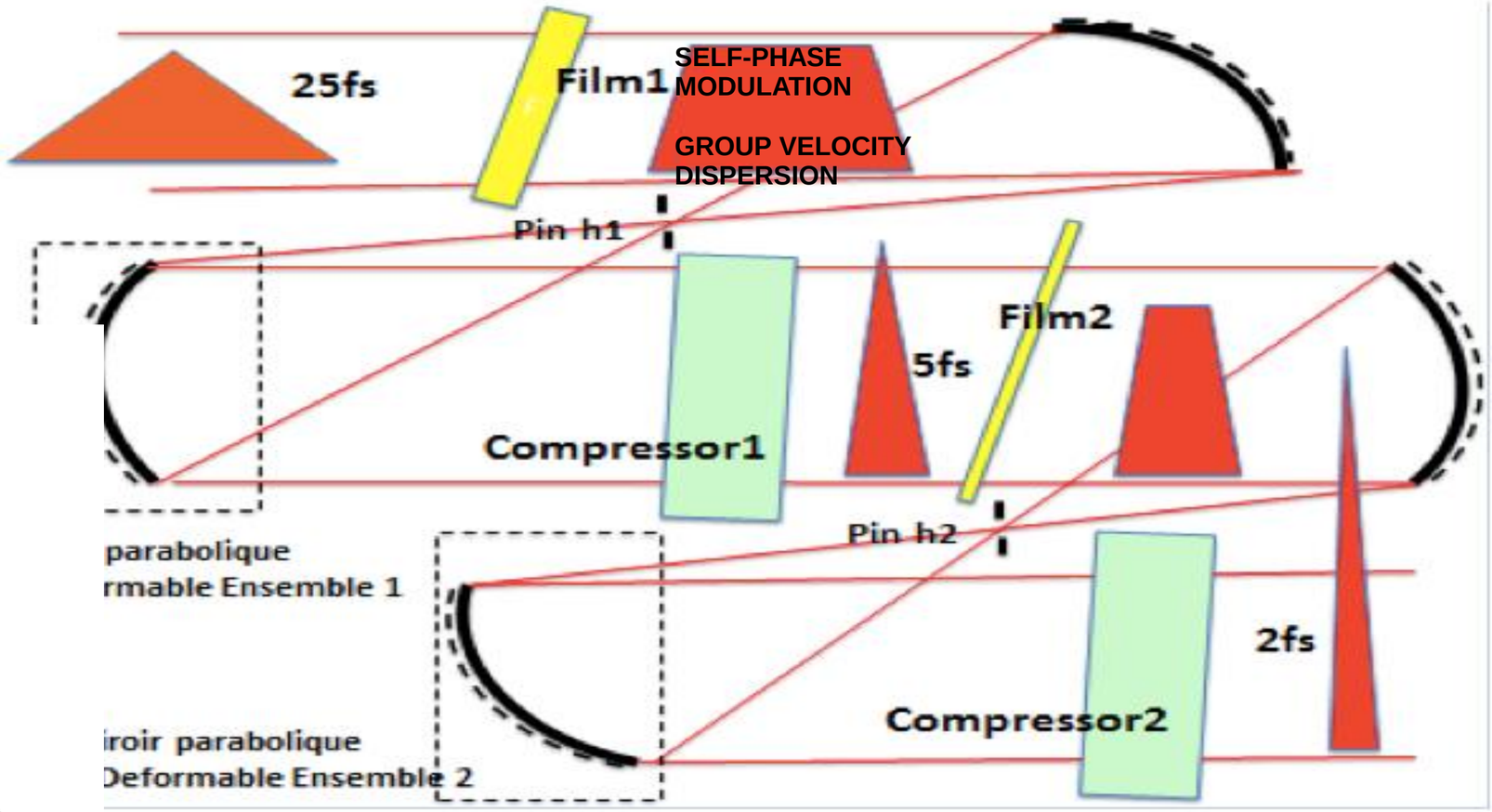
Gérard Mourou, Gilles Cheriaux, Christophe Radier,Device for generating a short duration laser pulse US 20110299152 A1

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)

Thin Film Pulse Compression

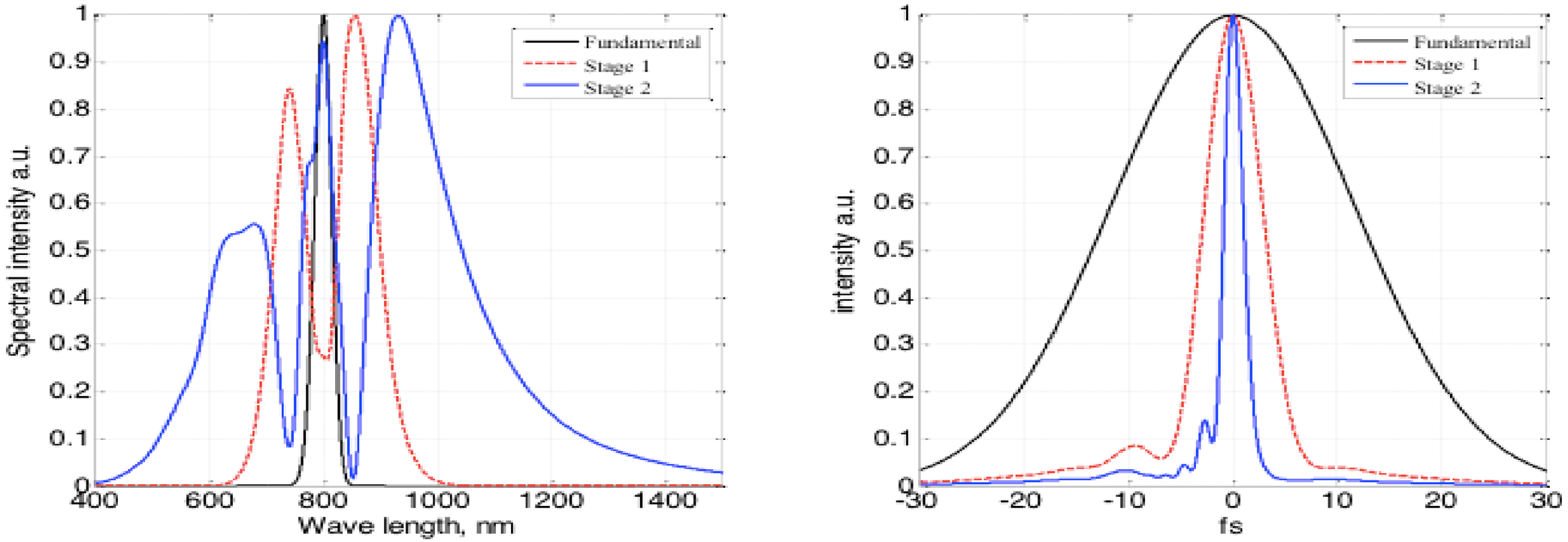
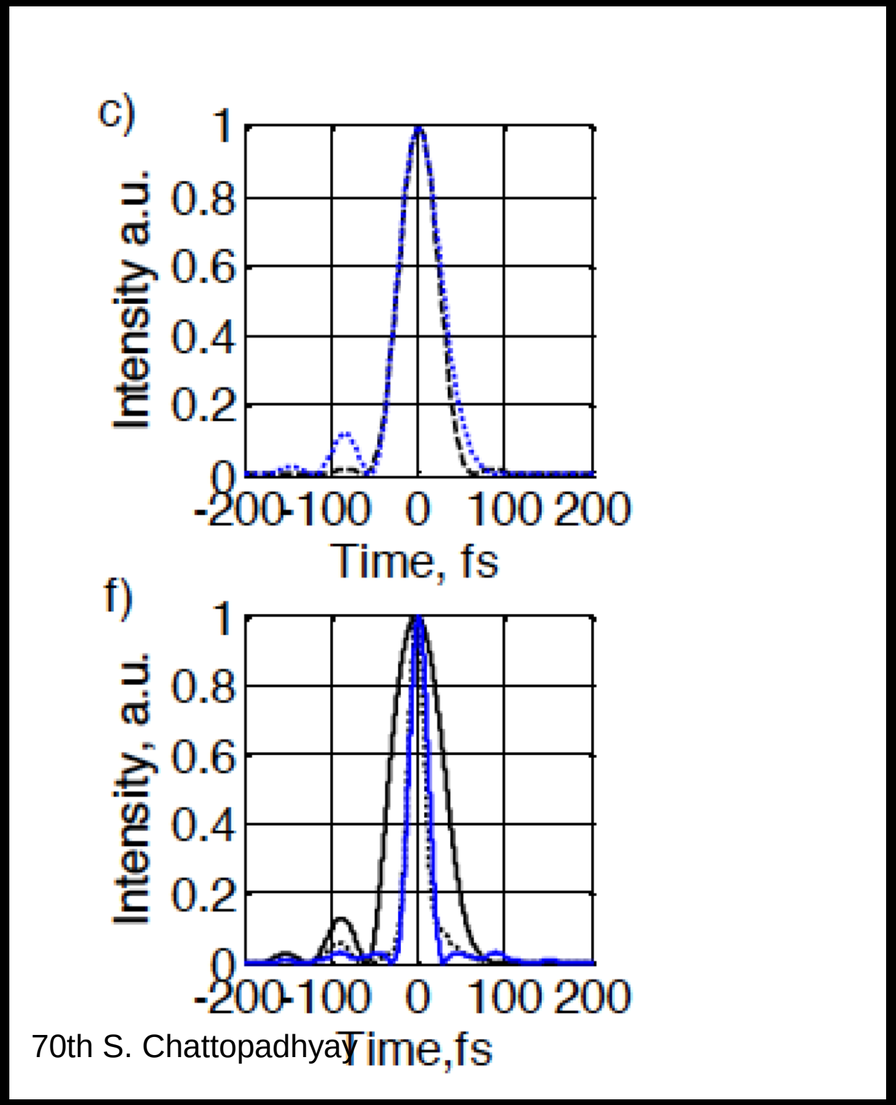


Fig. 4 shows the successive spectra and pulse durations corresponding to the laser out put, after the first stage and second stage. After the first stage the pulse 6.4fs, after the second stage the pulse is shrunk to 2.1fs

Pulse Compression on PEARL

Pulse Duration In
75 fs

Pulse Duration out
15 fs
Compression 5

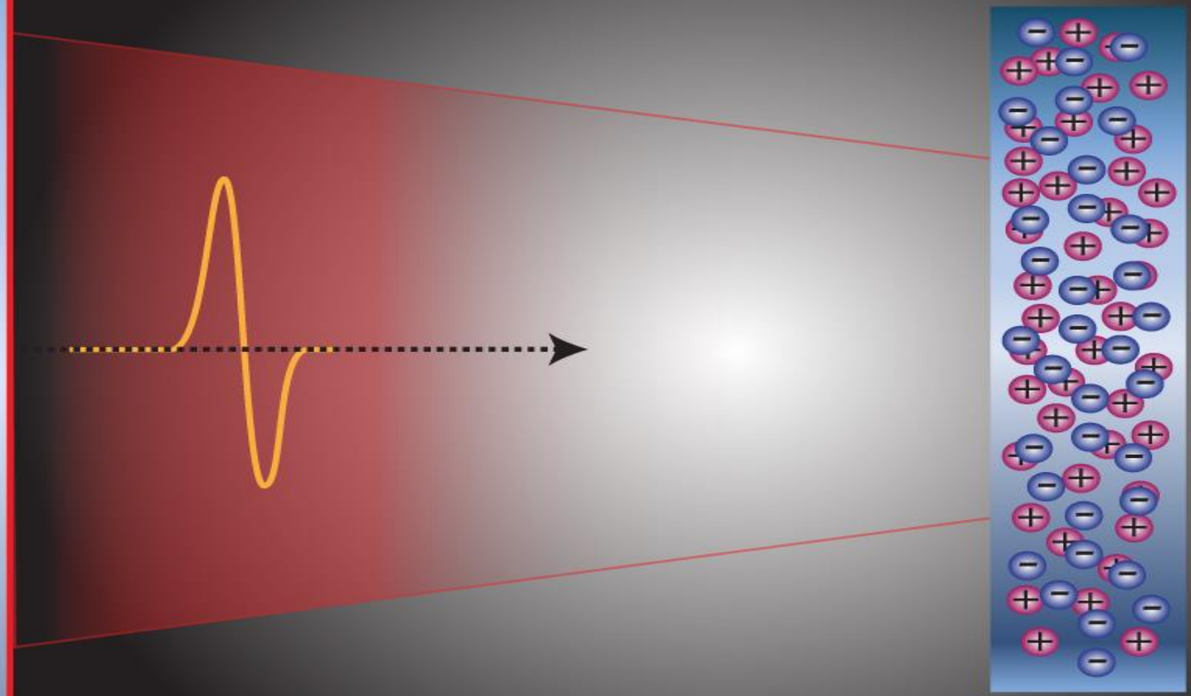


Relativistic Compression
Scalable Isolated Attosecond Pulses

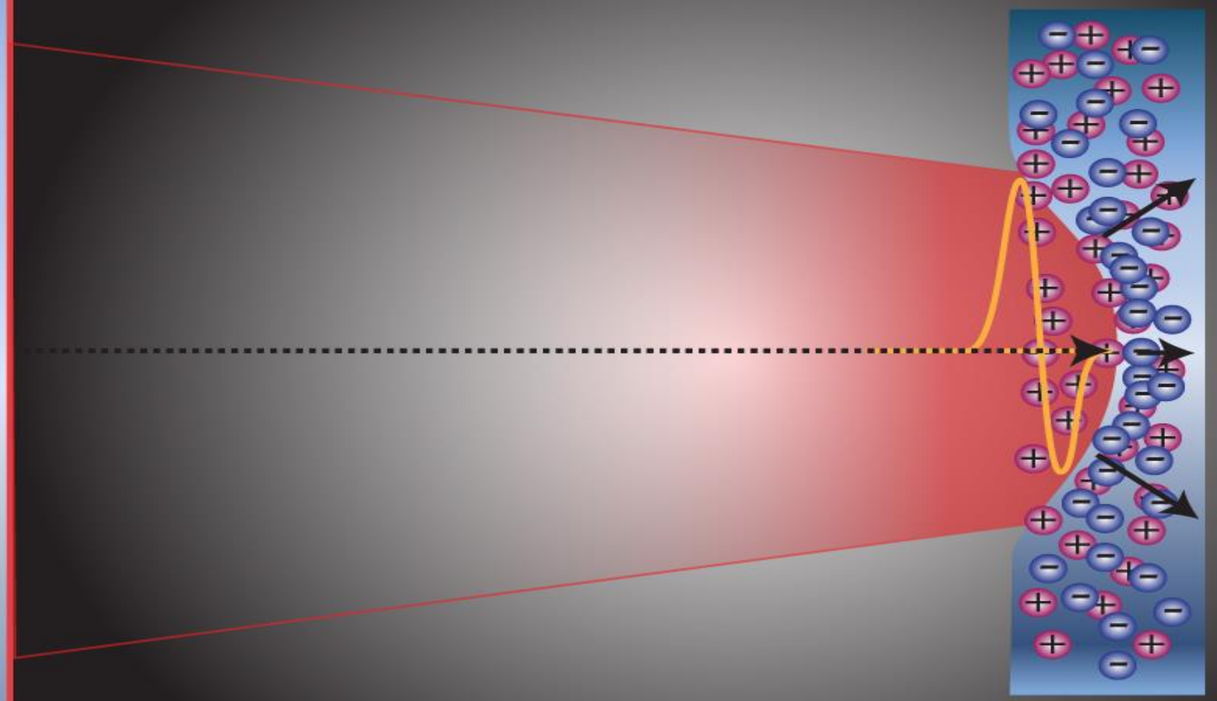
N. M. Naumova, J. A. Nees, I. V. Sokolov, B. Hou, and G. A. Mourou,

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

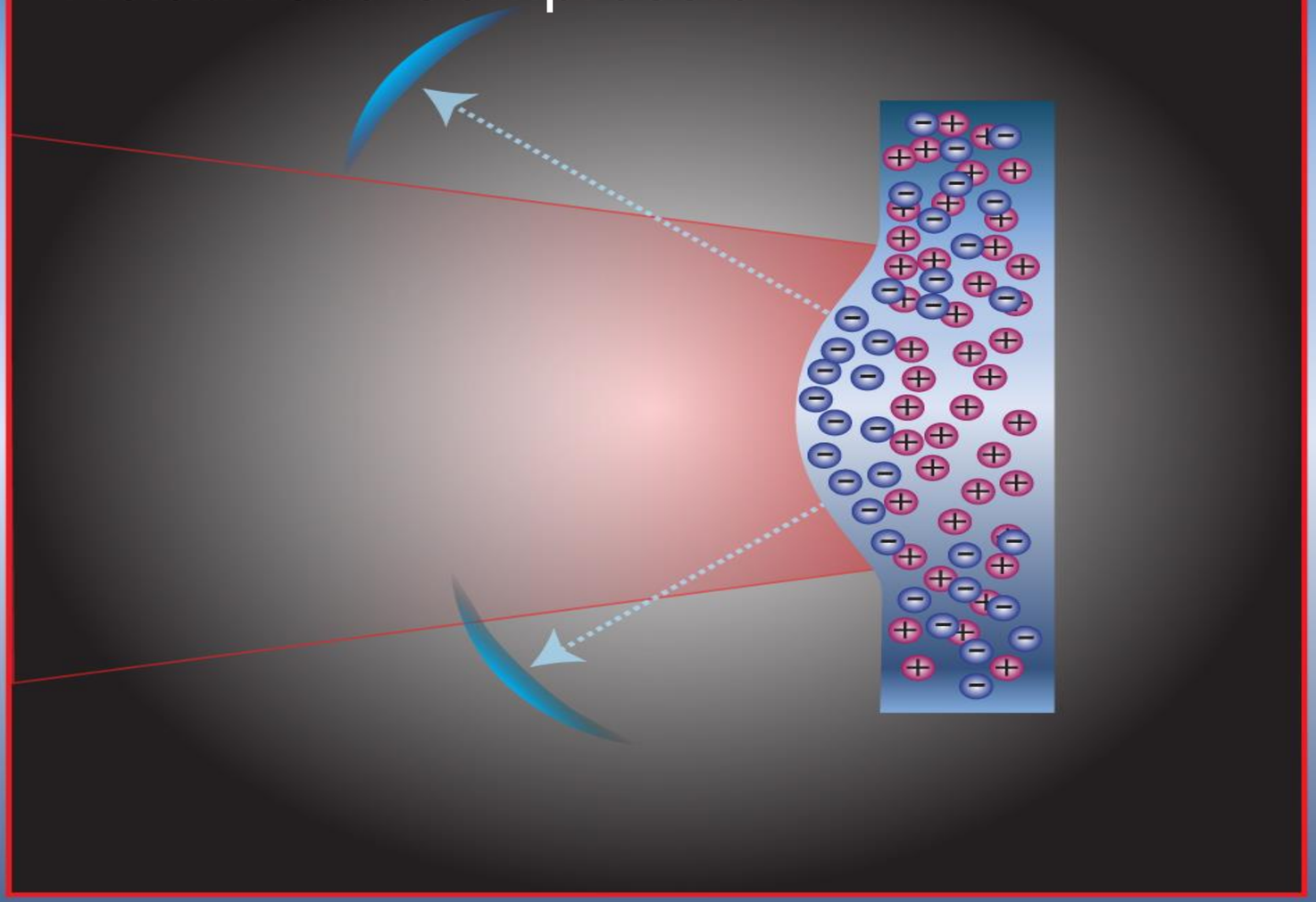
Relativistic Compression



Relativistic Compression

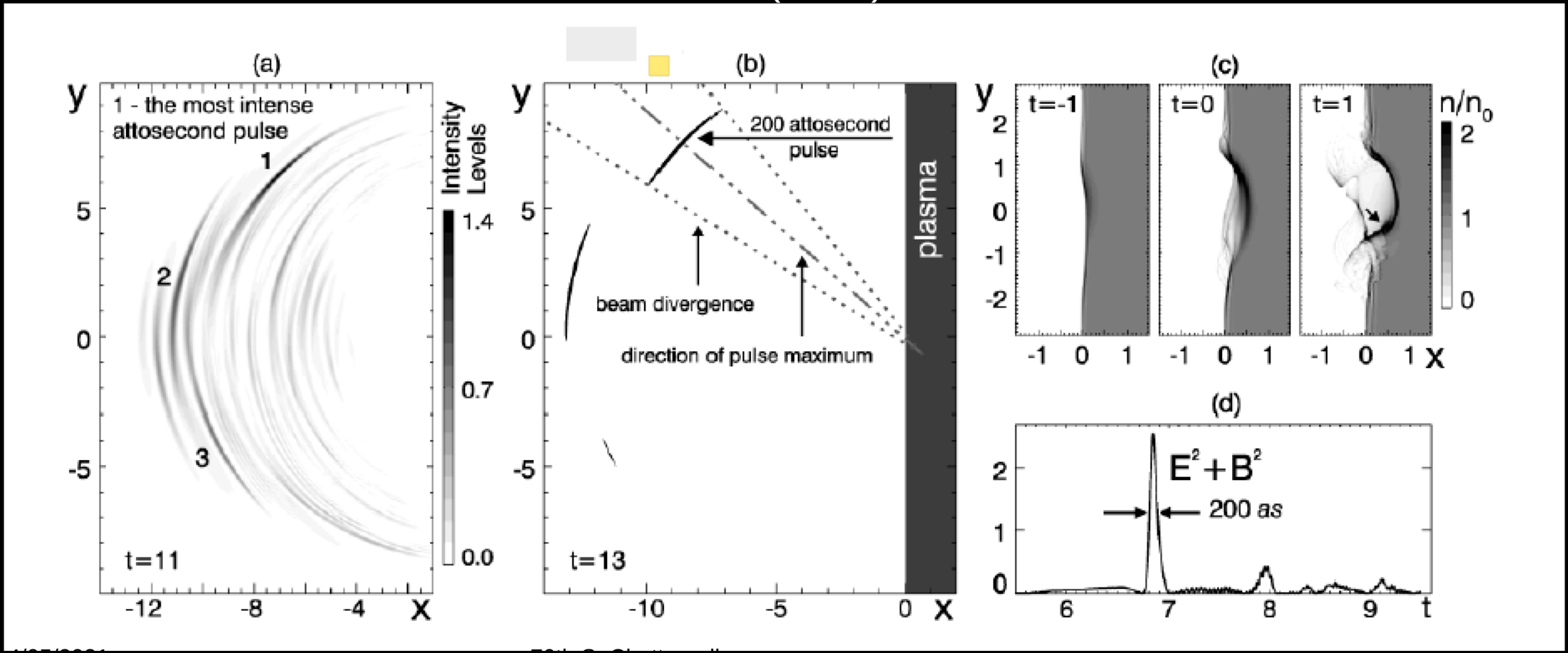


Relativistic Compression



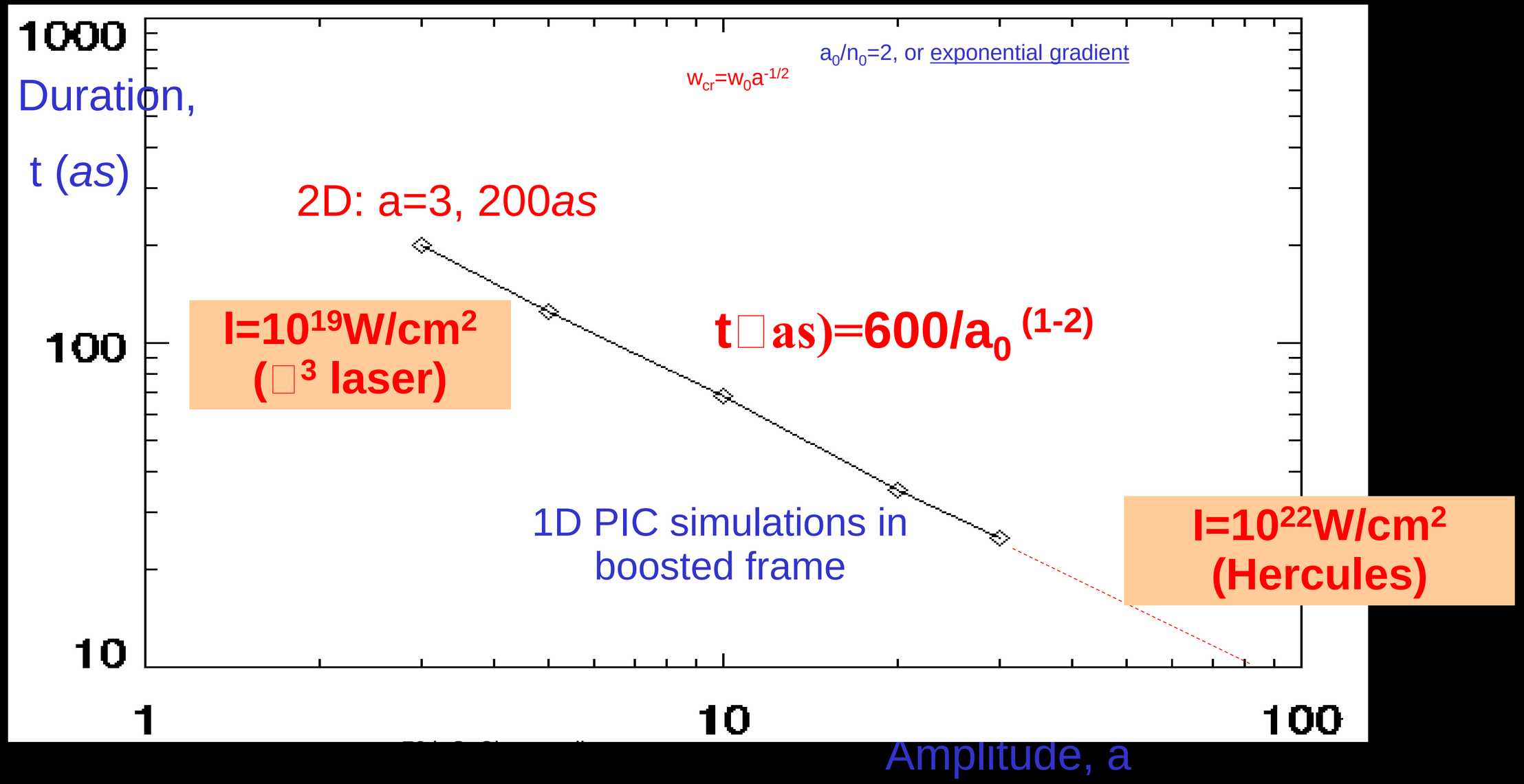
Relativistic Compression

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).



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).



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

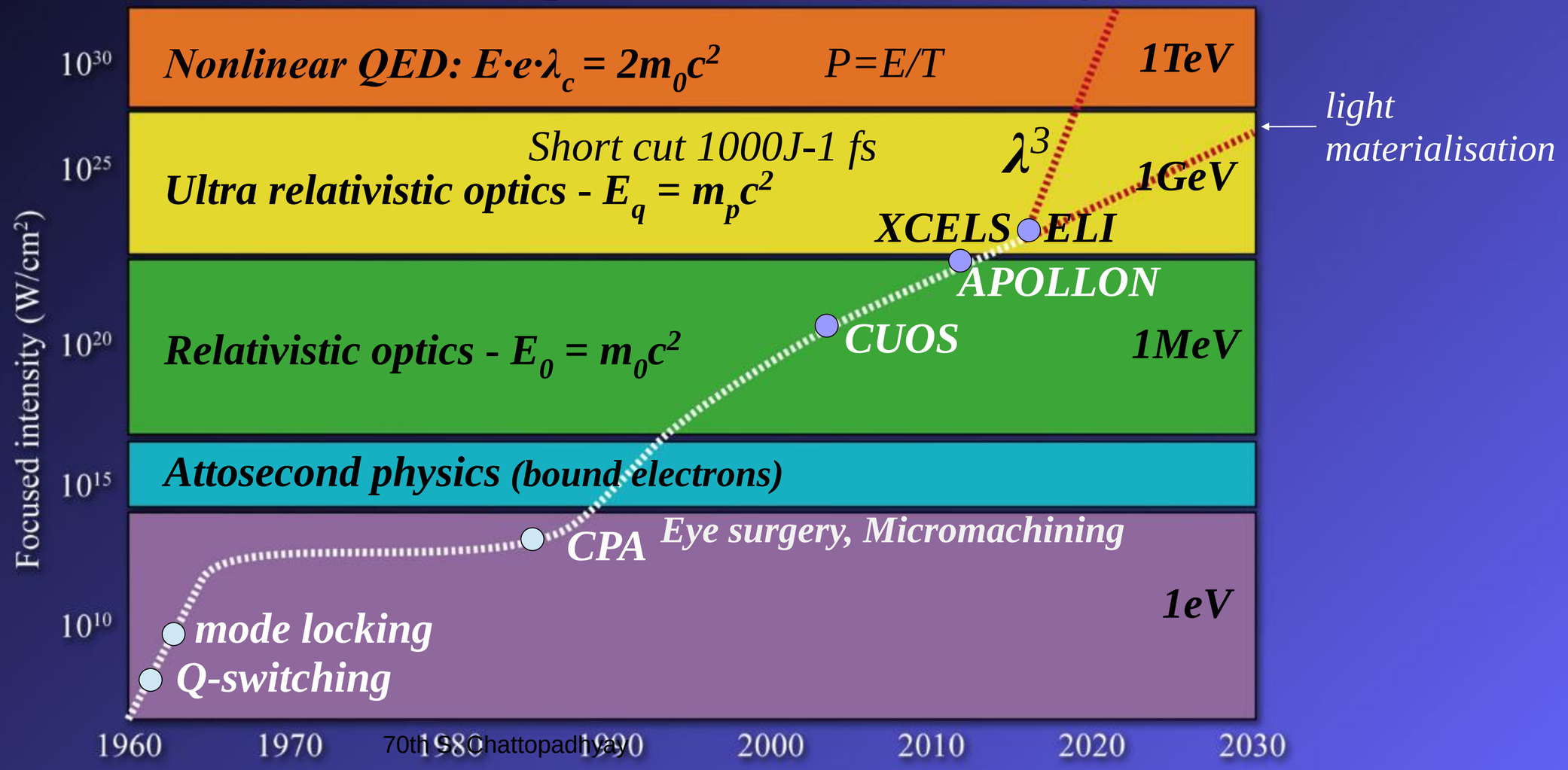
3. 1Zw over λ^2 spot size is 10^{29} W/cm^2 Schwinger Intensity:

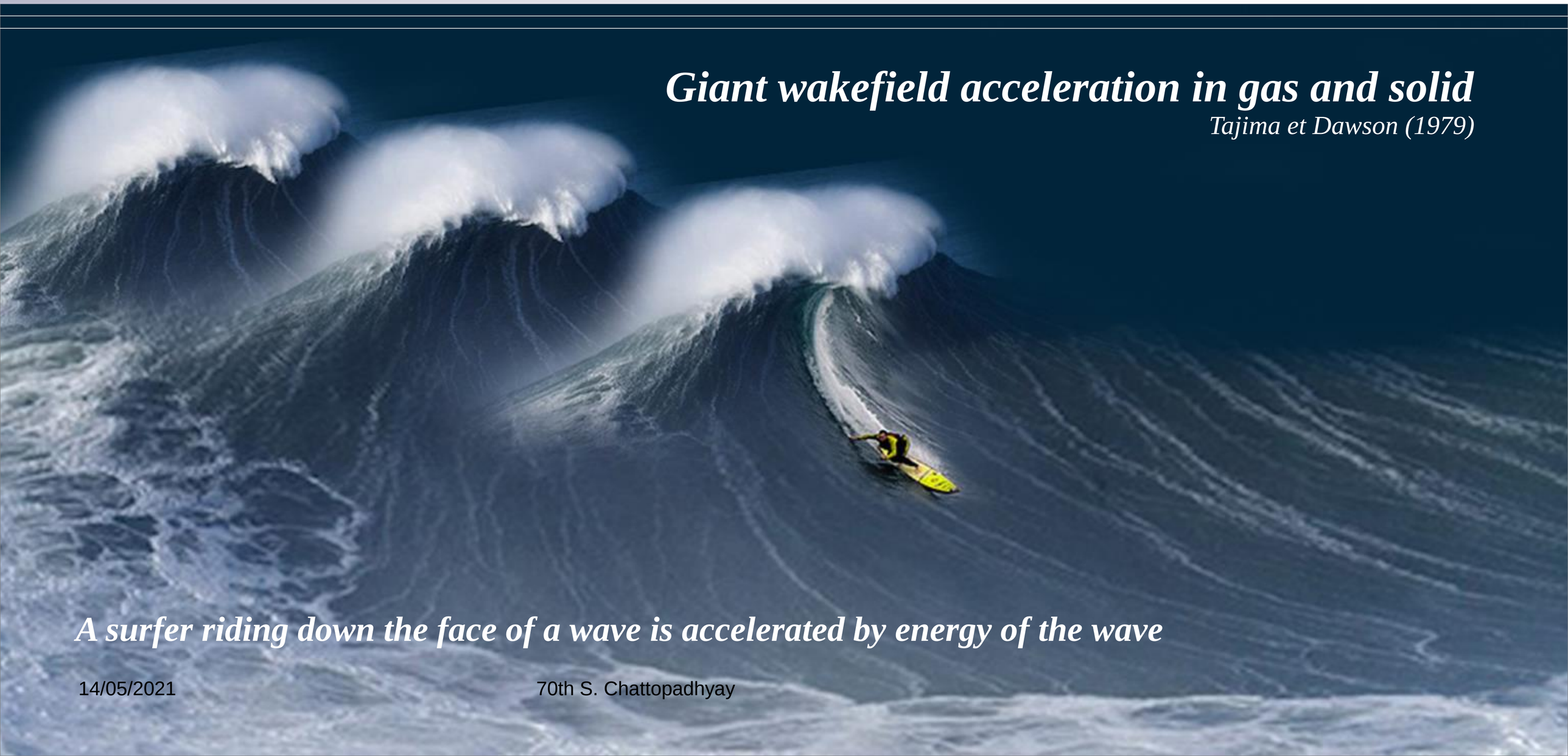
Light Turns into Matter and Antimatter

A PASSION FOR EXTREME LIGHT

For the greatest benefit to human kind (Alfred Nobel)

Extreme light roadmap and ultra high intensity shortcut





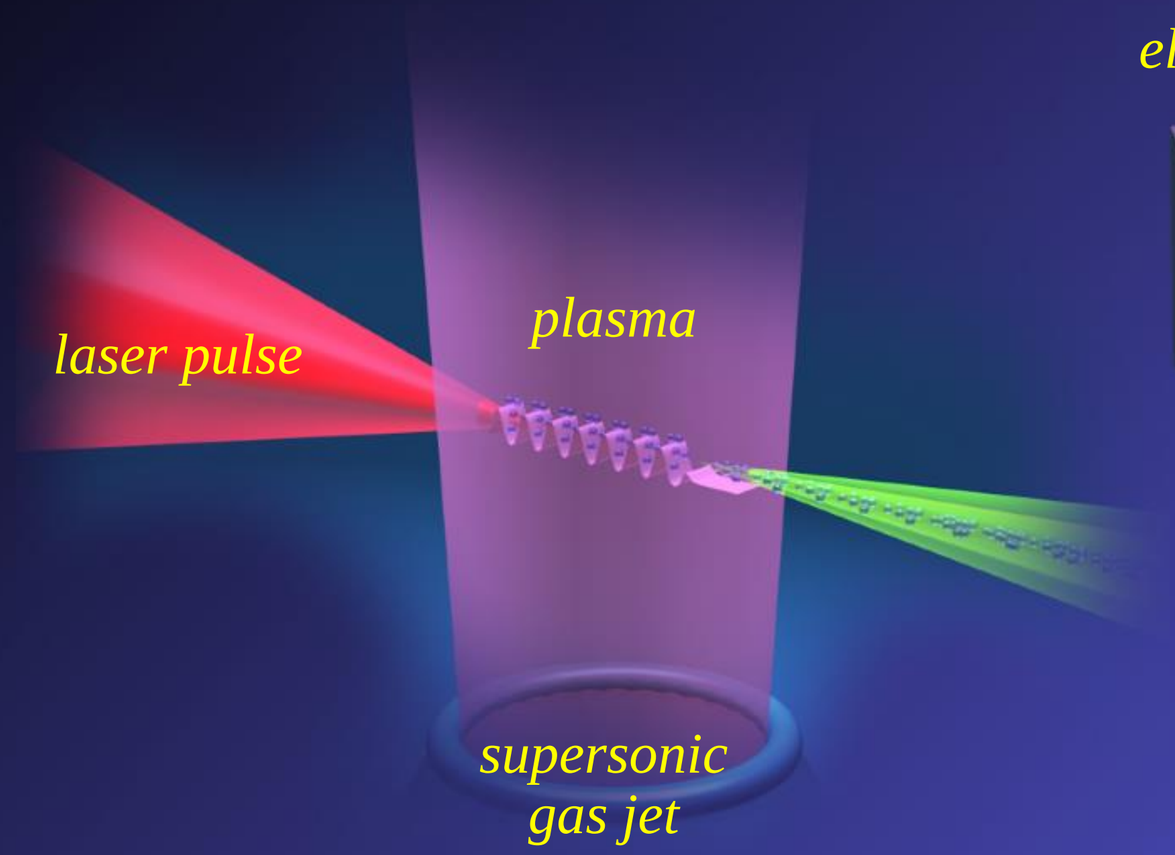
Giant wakefield acceleration in gas and solid

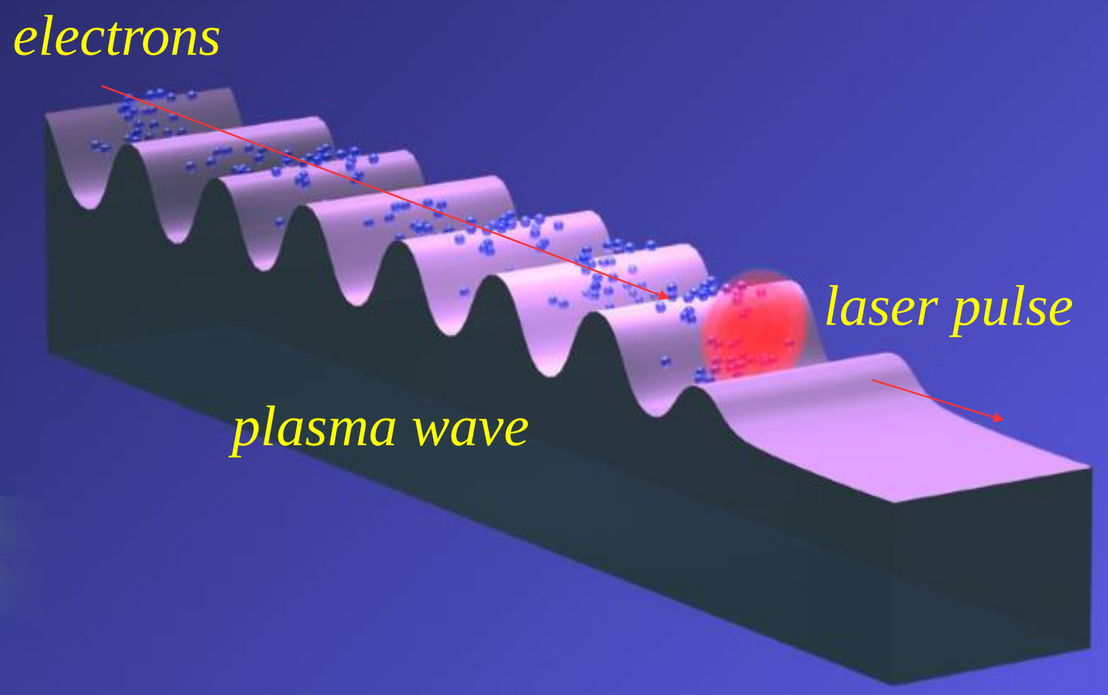
Tajima et Dawson (1979)

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

Giant wakefield acceleration

Tajima et Dawson (1979)





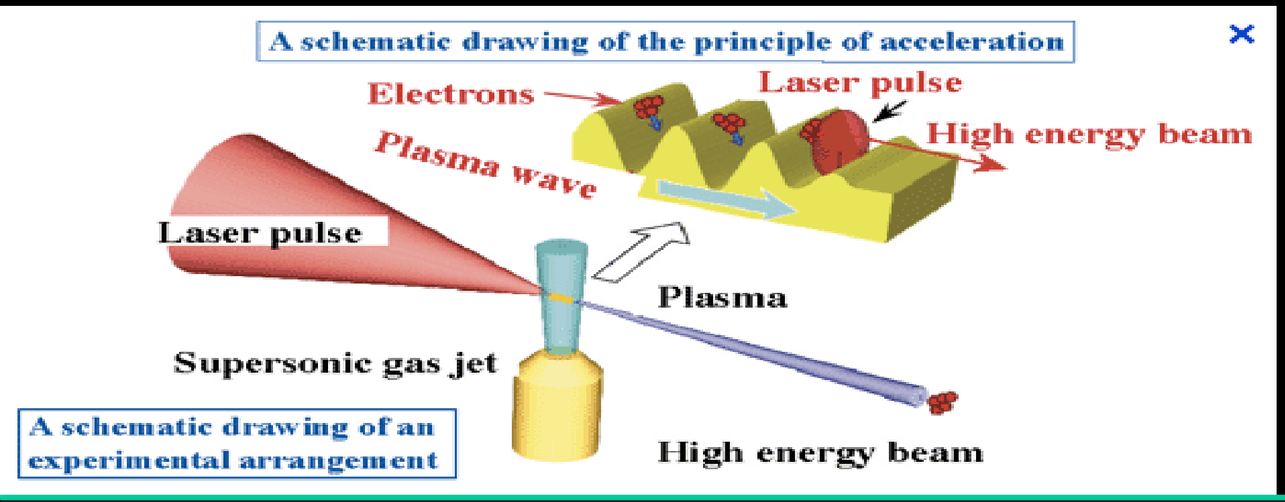
High Energy beam
GeV/cm

Synchrotron SOLEIL 3GeV

S

Giant Wake Field Acceleration in Gas and Solid

Femtosecond Visible Light Driver in Gas ***Tajima et Dawson 1979***



Plasma Acceleration Energy Gain

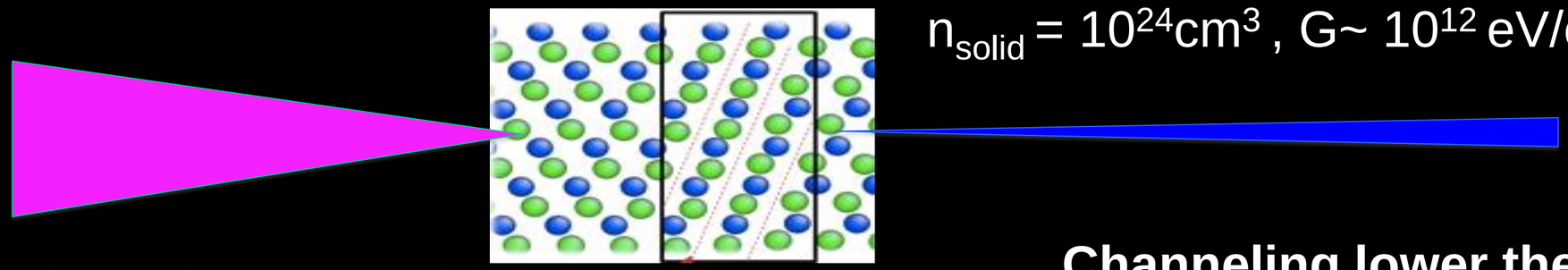
$G \alpha n^{1/2}$ eV/cm

1eV light $n_c \sim 10^{21} cm^{-3}$

$n_{gas} = 10^{18} cm^{-3}$, $G \sim 10^{9}$, GeV/cm

Atto-zepto, X-ray Driver, Solid, ***Tajima et Cavenago 1987***

$n_{solid} = 10^{24} cm^{3}$, $G \sim 10^{12}$ eV/cm, TeVcm



Drive pulse X-Ray, 600zs
+ as electron pulse

Channeling lower the emittance
Valid for electron, muons, heavy ions

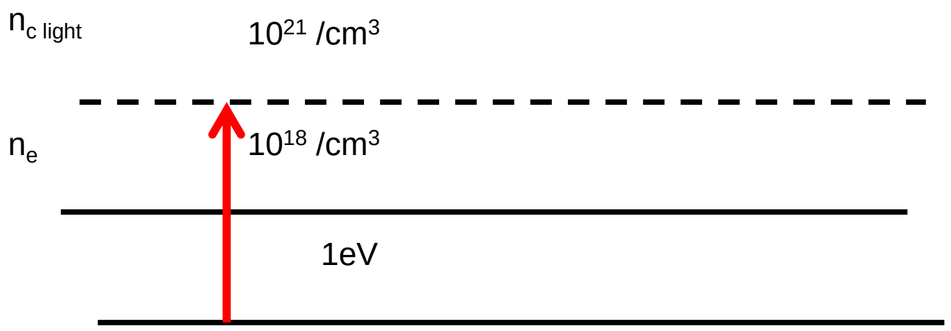
Laser-Wake-Field Acceleration
Gas/Light vs Solid/ X-Ray

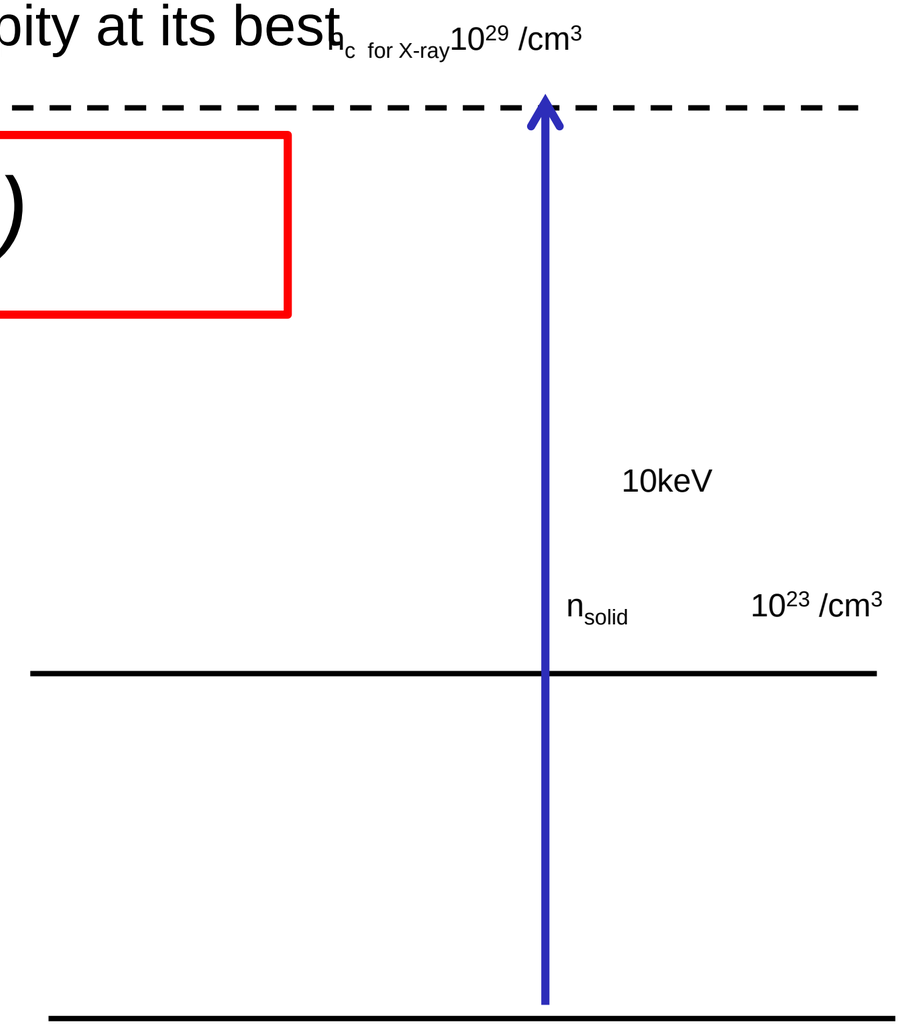
Serendipity at its best

$$\boxed{\textit{Energy Gain} \quad E = a_0^2 m_o c^2 (n_c / n_e)}$$

In the visible $n_c = 10^{21}/cm^3$ Low gaz density

In the X-ray, $n_c = 10^{29}/cm^3$ Solid density

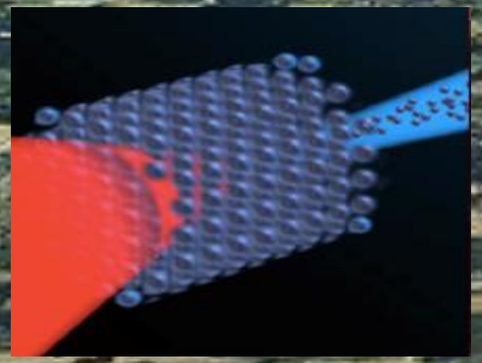




Outlook for Laser-Particle acceleration TeV

Microwave cavity

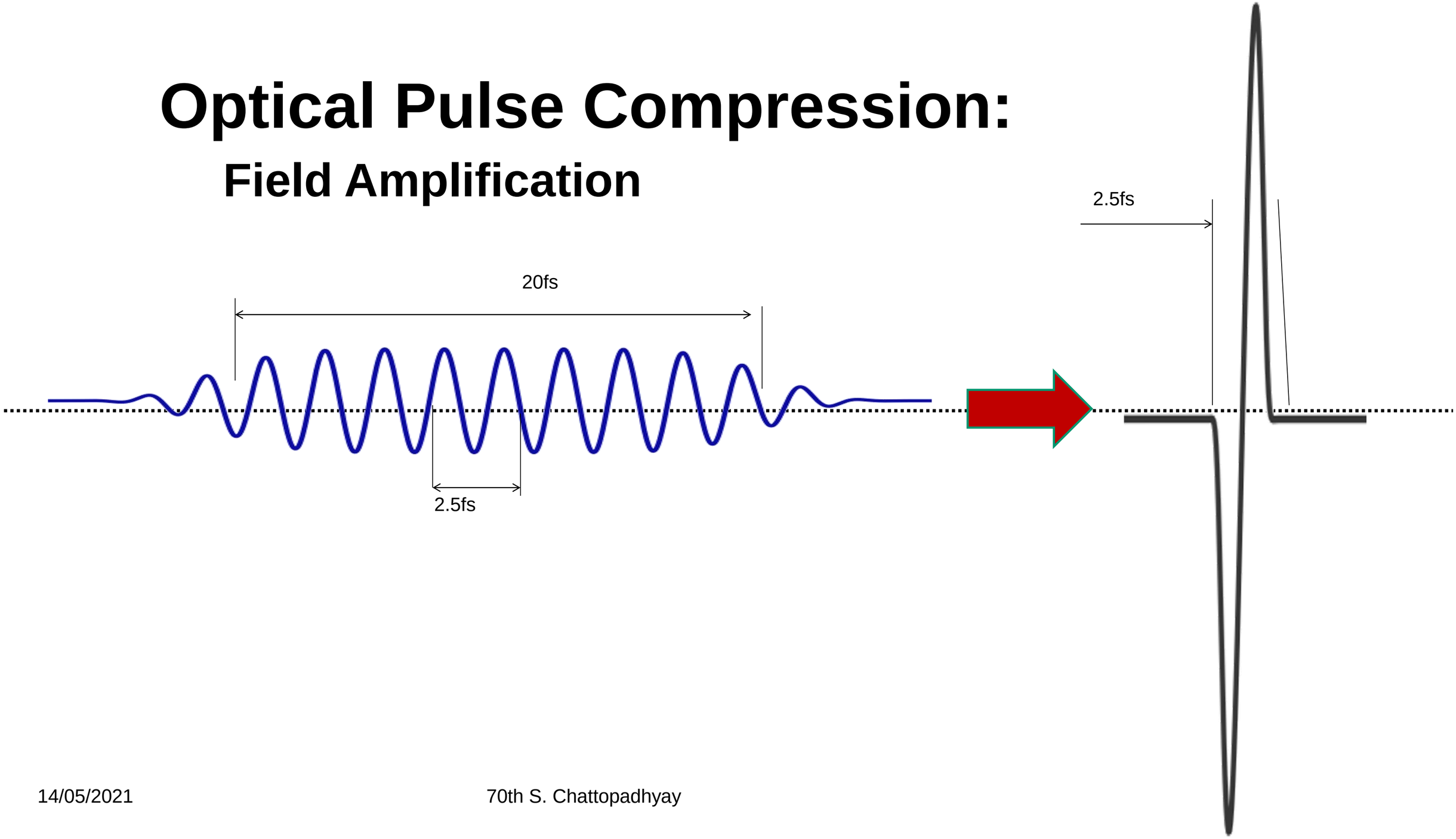
Laser wakefield X-ray, 1cm



Laser wakefield Visible 100m

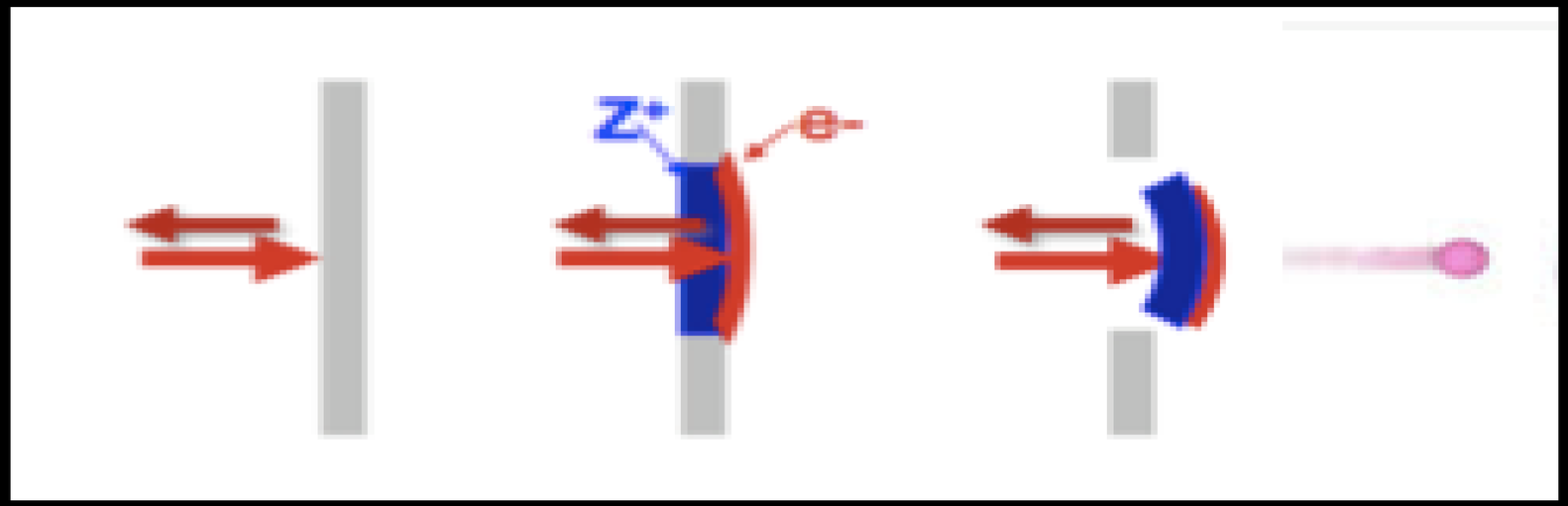
Optical Pulse Compression:

Field Amplification

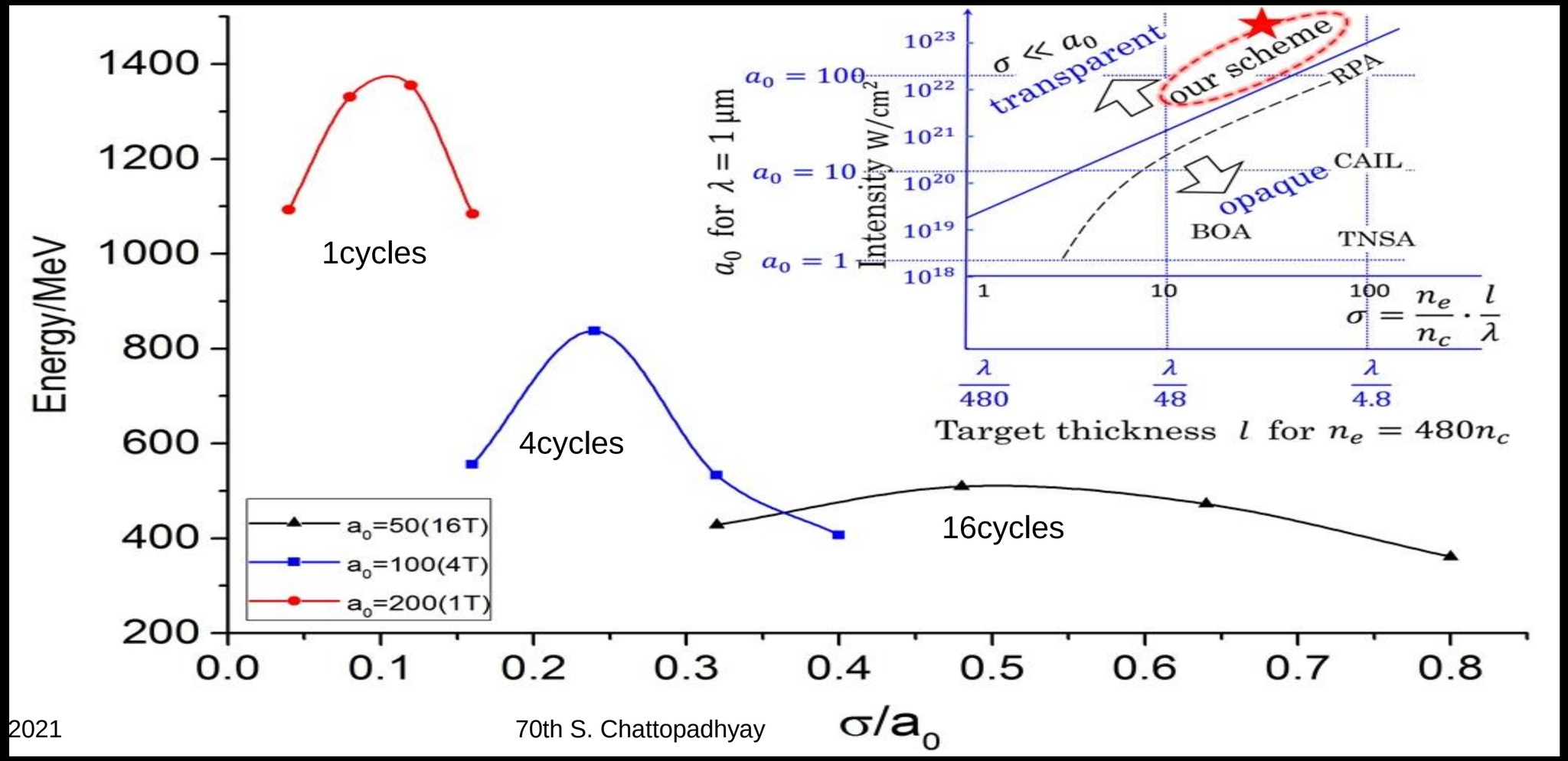


Low Hanging Fruit: High Energy Proton Generation

GeV Proton Generation

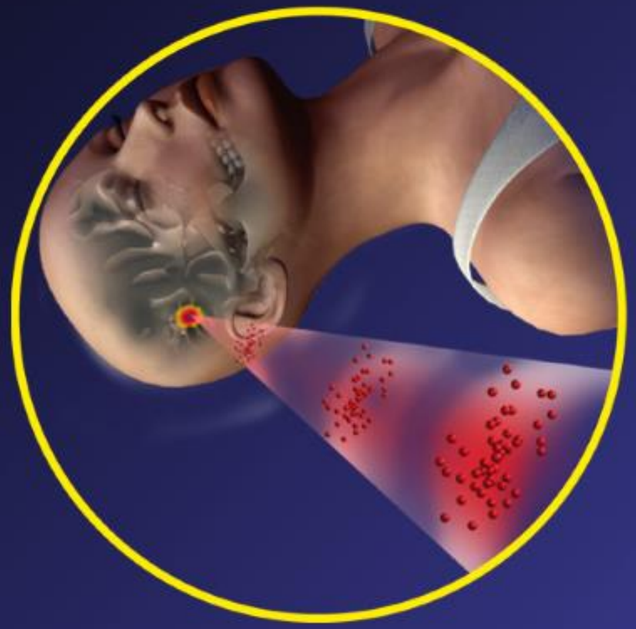


Applications of Single Cycle to Proton Generation vs a_0



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

ENVIRONMENT:

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 and Thorium?

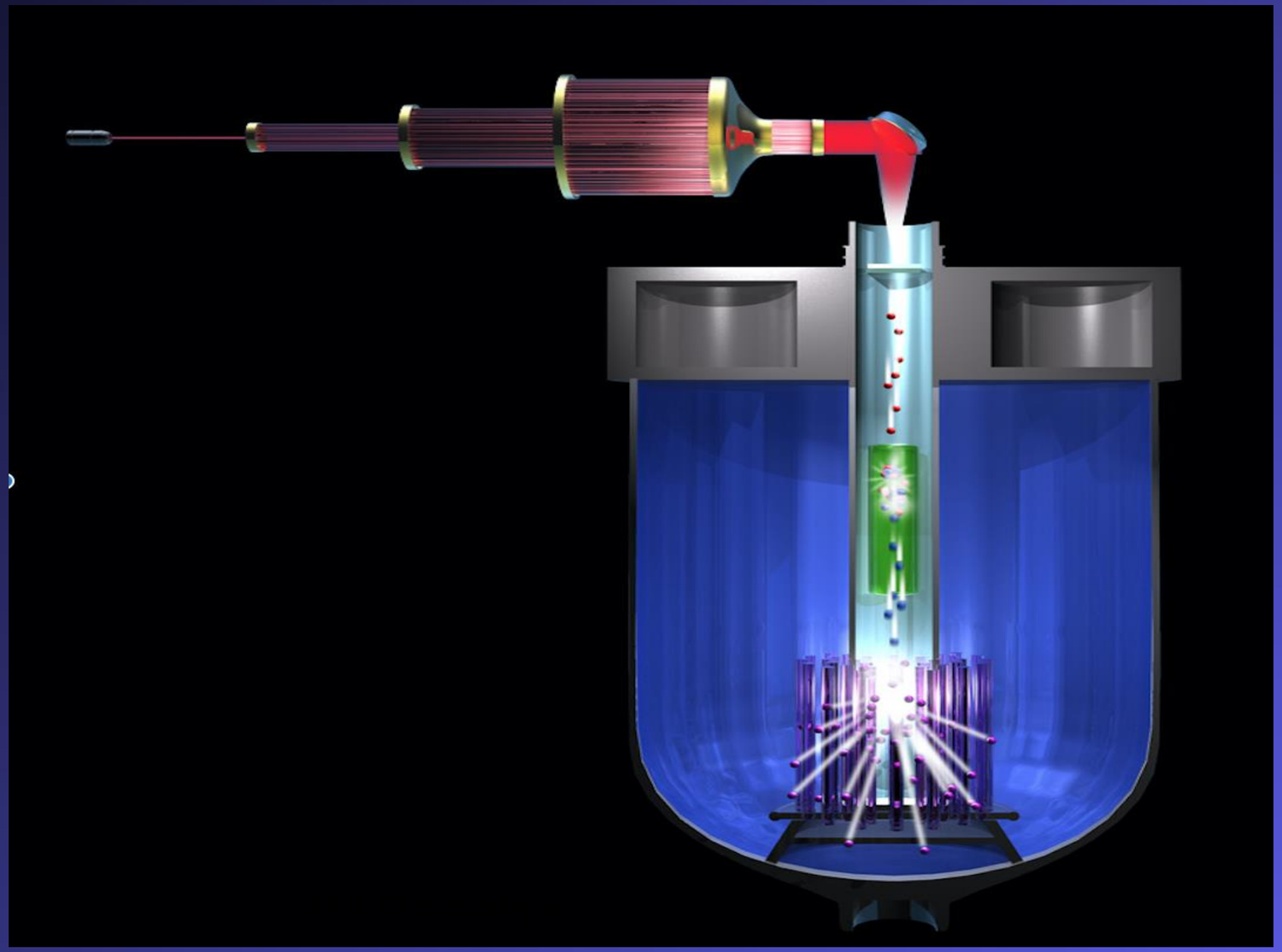
1 GW Power Plant
producing 8 Billion kWh /year

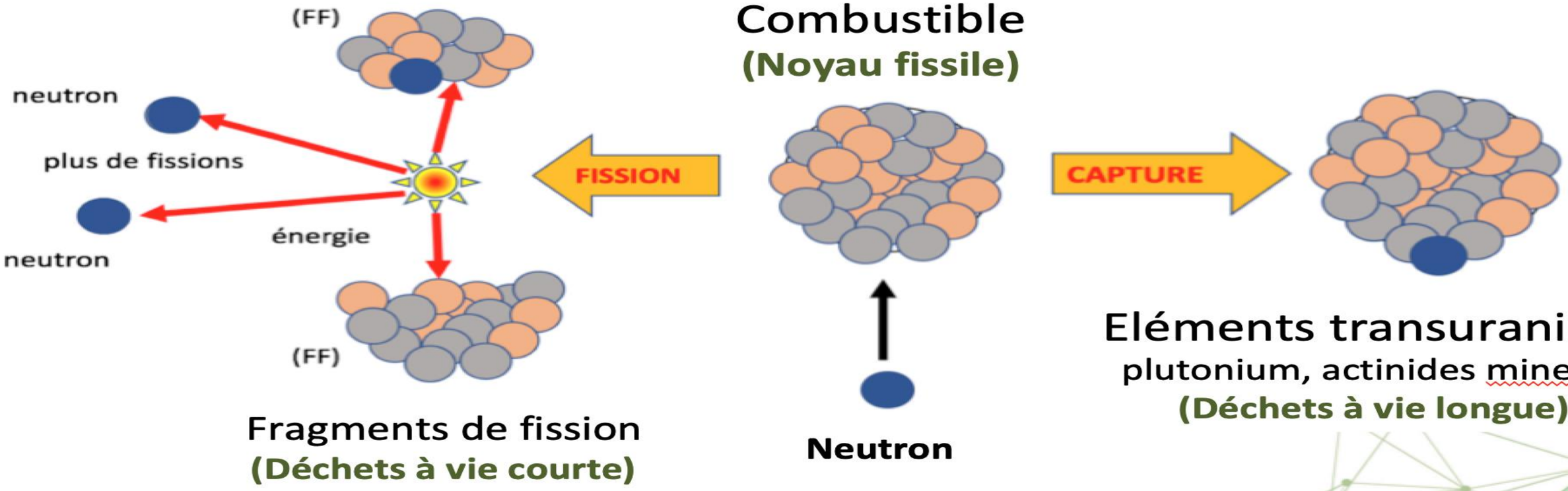
Coal = 100 Trains
3M Tons Coal
1km3 of CO2

300 Tons Uranium
0 liter C02

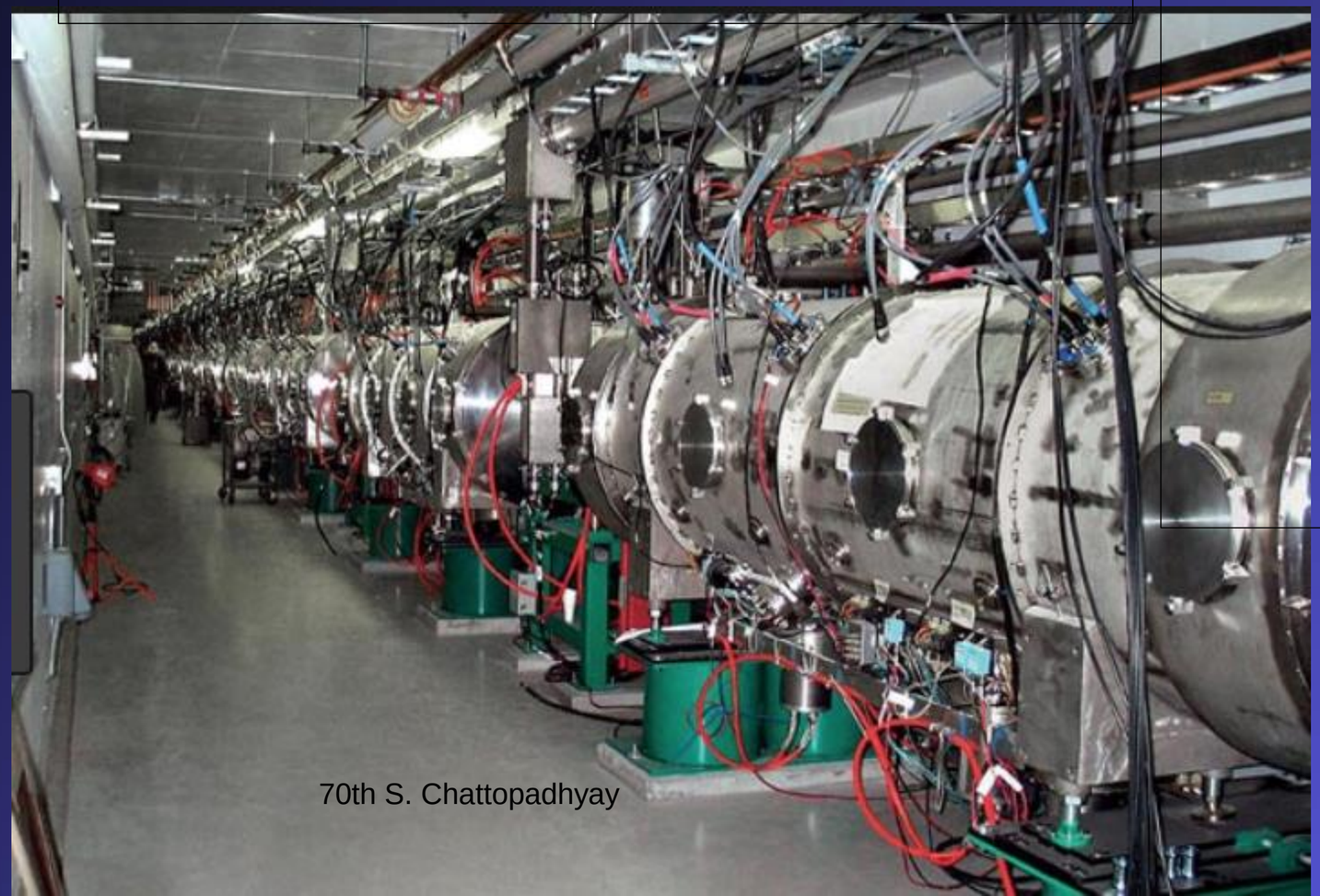
1 Ton Thorium
0 liter C02

Accelerator-Driven-Subcritical Reactor



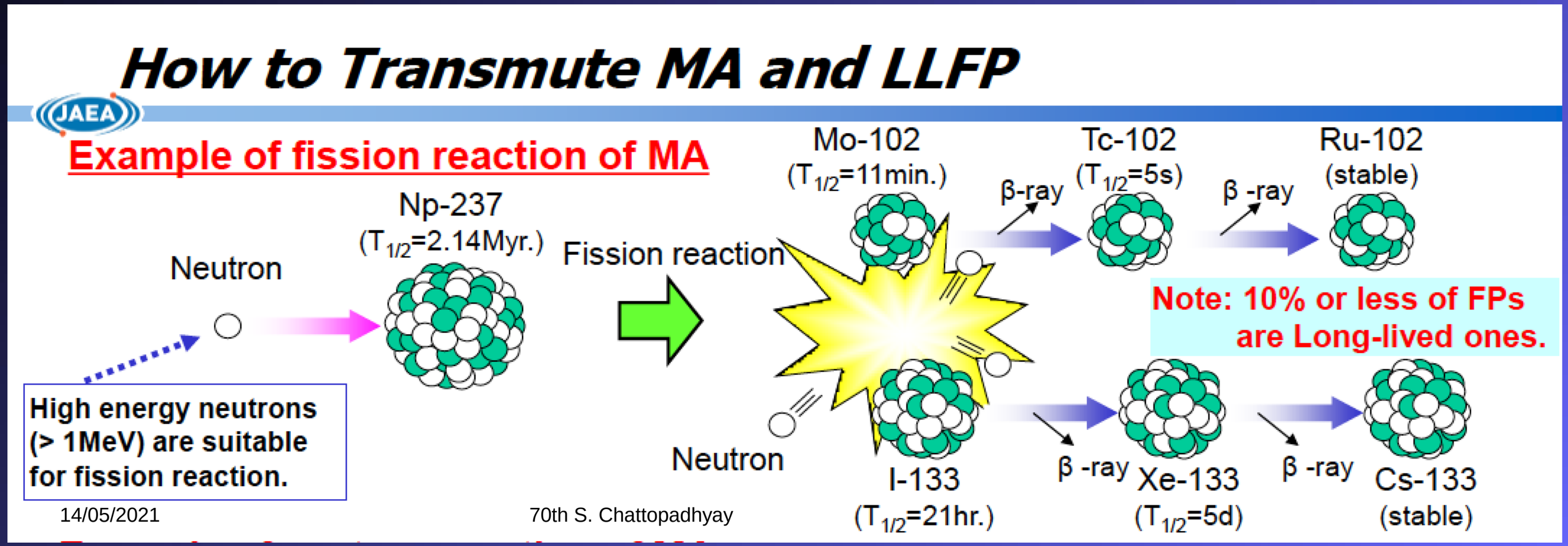

(FF)
neutron
plus de fissions
neutron
énergie
(FF)
Fragments de fission
(Déchets à vie courte)
FISSION
Combustible
(Noyau fissile)
Neutron
CAPTURE
Eléments transuraniens
plutonium, actinides mineurs
(Déchets à vie longue)

RELATIVISTIC PROTON ACCELERATOR for TRANSMUTATION



Projet MYRRHA

NUCLEAR TRANSMUTATION CONCEPT



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!

Dear Swapan I wish you a Great 70th Birthday!

Your Friend Gérard Mourou