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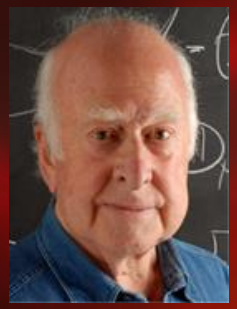
International Zeta-Exawatt Science Technology

IZEST Spring Meeting

Ecole Polytechnique
Palaiseau April 4 2017



"The discovery of this particle is potentially the beginning of another road, which is to explore what lies beyond the Standard Model"

- Peter Higgs

"I realized there would be many applications for the laser, but it never occurred to me that we'd get such power from it!"

- Charles Townes

Gérard Mourou,

International Year of Light 2015

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Preamble

- The laser is a photon source in the eV regime. As the intensity increases, it ‘’miraculously’’ morphes into a source of energetic particles, radiations (e, p, n, pion, muon, neutrino) and provide giant accelerating fields.
- Ultra high intensity laser can penetrate into the sub atomic world opening a vast offering of novel scientific and societal applications.
- Hence, our constant search for new paradigms leading to the highest peak power, average power, and efficiency.

Laser Exploration : From Atomic to Sub-Atomic

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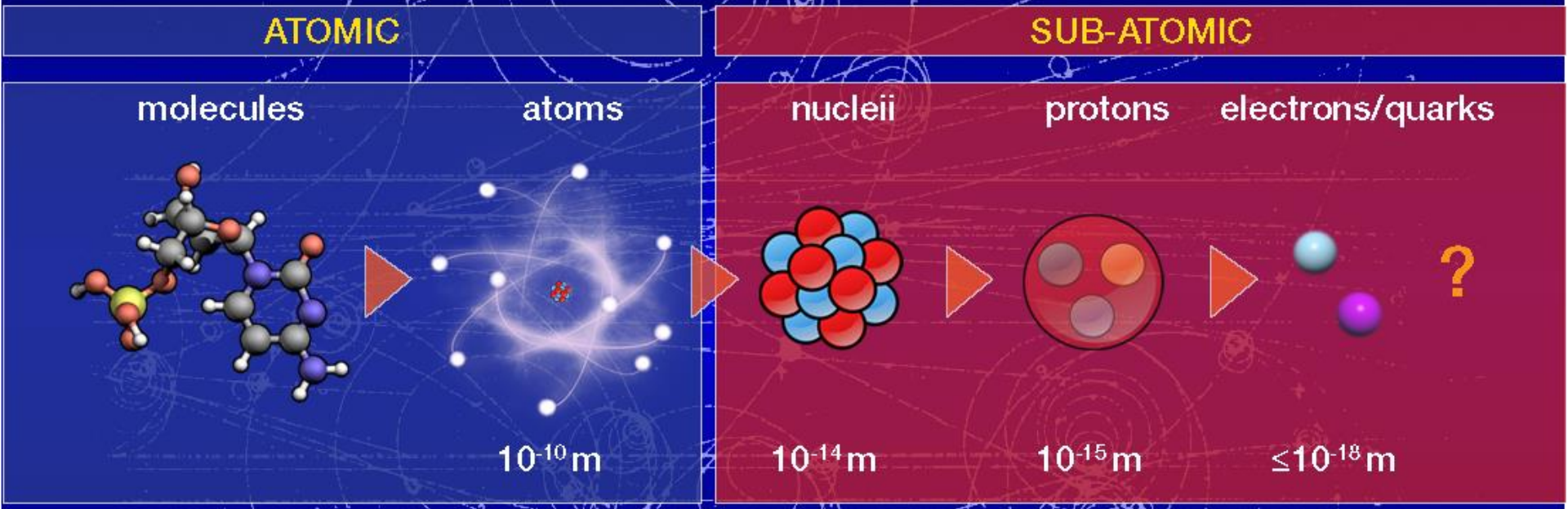
eV → TeV



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Extreme Light Petawatt in the World

They set the field's horizon

Extreme Light Infrastructure - ELI

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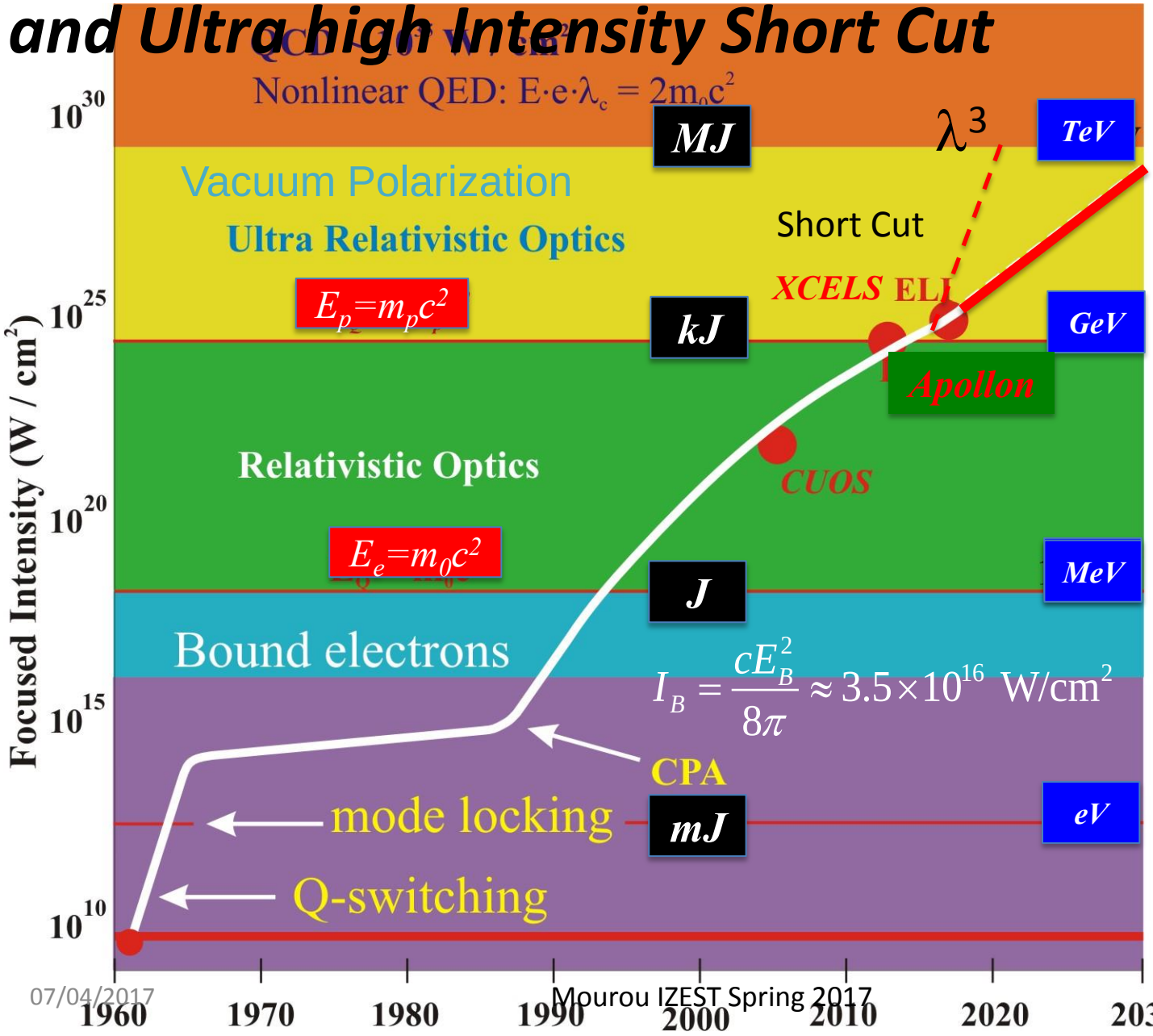
The Largest Civilian Laser Infrastructure
Initiated and Coordinated(PP) by, G. Mourou (EP)
ELI (Delivery Consortium) W. Sandners

Czech Republic

Hungary

Romania

Extreme Light Road Map and Ultra high Intensity Short Cut



$$I_B = \frac{cE_B^2}{8\pi} \approx 3.5\times10^{16}\ \mathrm{W/cm^2}$$

1EW
1Joule in
1 attosec

Or

1000J
1 fs

IZEST Disruptive Technology

- Peak power Pulse compression to single cycle
- Efficient Relativistic Proton Generation
- Laser Wake Field Acceleration and High peak power in the x-ray regime
- High Average Power Paradigm (MW) XCAN

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IZEST Disruptive Technology Applications

Laser and Particle Accelerator for High Energy Acceleration

- Laser Wake field acceleration T. Tajima
- Laser/particle accelerator for Future High Energy physics M. Spiro
- Gamma-Gamma Collider Roy Aleksan
- Future Circular Collider(FCC) Bernhard Holzer
- Status of AWAKE and Futures perspectives Allen Christ. Caldwell
- Results and Outlook from FACET Spencer Gessner
- Eupraxia Overview Massimo Ferrario

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IZEST Disruptive Technology Applications

High Energy Pulse compression: route to Atto/zeptosec. -

-Relativistic Intensity 1kHz-mJ R. Lopez-Martens

- High Energy Pulse in the lamda-cubed Regime J. Wheeler

- High Energy pulse compression at ELI-Beam line G. Korn

- The Apollon Laser P. Audebert

High Average power and High Peak Power Laser

- High Average and High Peak power at ALPS K. Osway

- XCAN Laser for subatomic Applications Ihsan Fsaifes

- High Peak Power Systems C. Simon Boisson

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IZEST Disruptive Technology Applications

Fondamental Physics

-Black hole and the Inormation Theory Paradox P. Chen

Societal Applications

-Laser Mitigation of Orbital Debris T. Ebisuzaki

-ADS and Nuclear Transmutation S. Gales

-Design of medical isotope production A. Cucoanes
Using Laser induced proton Beam

Summary

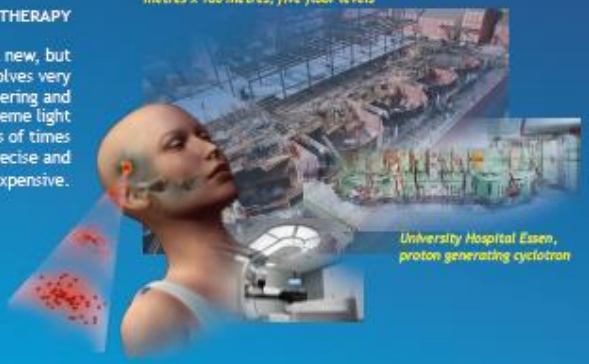
Extreme Light Societal Applications

The most recent development in extreme light laser technologies, such as UV generation, x-ray generation and proton acceleration, open the way to the incredible potential of high-tech applications development; a "blue sky" of innovation in a completely new market, especially in medical fields. These are some examples :

1 PROTON THERAPY

Proton therapy is not new, but present technology involves very large scale engineering and construction. Extreme light technology will be tens of times more compact, more precise and less expensive.

Maryland Proton Treatment Center, 2015 - 350 metres x 180 metres, five floor levels



University Hospital Essen, proton generating cyclotron

2 NUCLEAR DIAGNOSTICS

A biologically active molecule called fluorodeoxyglucose and a positron emitting radionuclide are injected into a patient about 45 minutes before the scan.

This produces gamma emissions which are detected by the scanner

Medical scanners, such as positron emission tomography (PET), depend upon a radioactive isotope being injected into a patient. Although this presents no great risk, the isotope can only be produced in a nuclear reactor. It takes time to get it to a clinic, so the radioactive content has to be much higher to compensate.

Extreme laser proton acceleration means that isotopes could be produced in the clinic instead of a distant nuclear reactor.

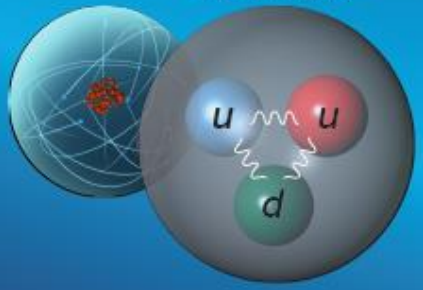
The pellets are about the size of a grain of rice and because they are directly implanted to the tumour the risk of damage to healthy tissue is greatly reduced

3 NUCLEAR THERAPY

Radionuclides are also used to treat patients directly, often by implanting tiny radioactive pellets directly into a tumour. Again, the only available radioactive source at present is a nuclear reactor, and so the potential application of extreme laser proton acceleration is an attractive proposition.

THE MAGICAL PROTON

A proton is a sub particle within an atom. It has a negative charge and is made up of six smaller pieces: 2 up quarks, 1 down quark and 3 gluons, which stick the quarks together.



4 NUCLEAR WASTE DISPOSAL

Extreme laser proton acceleration may also provide a means to transmutate dangerous nuclear waste into something relatively harmless and much shorter lived.

The staggering cost of collecting and disposing of toxic nuclear waste makes this application very exciting.

DANGEROUS AND EXPENSIVE!

In February, 2013, the UK government estimated that the total lifetime cost of removing all radioactive nuclear waste from the Sellafield nuclear waste facility and burying it in Cumbria would cost over €90 billion!

Protons are accelerated into the waste container

They slam into a Pb-Bi liquid which produces an avalanche of neutrons

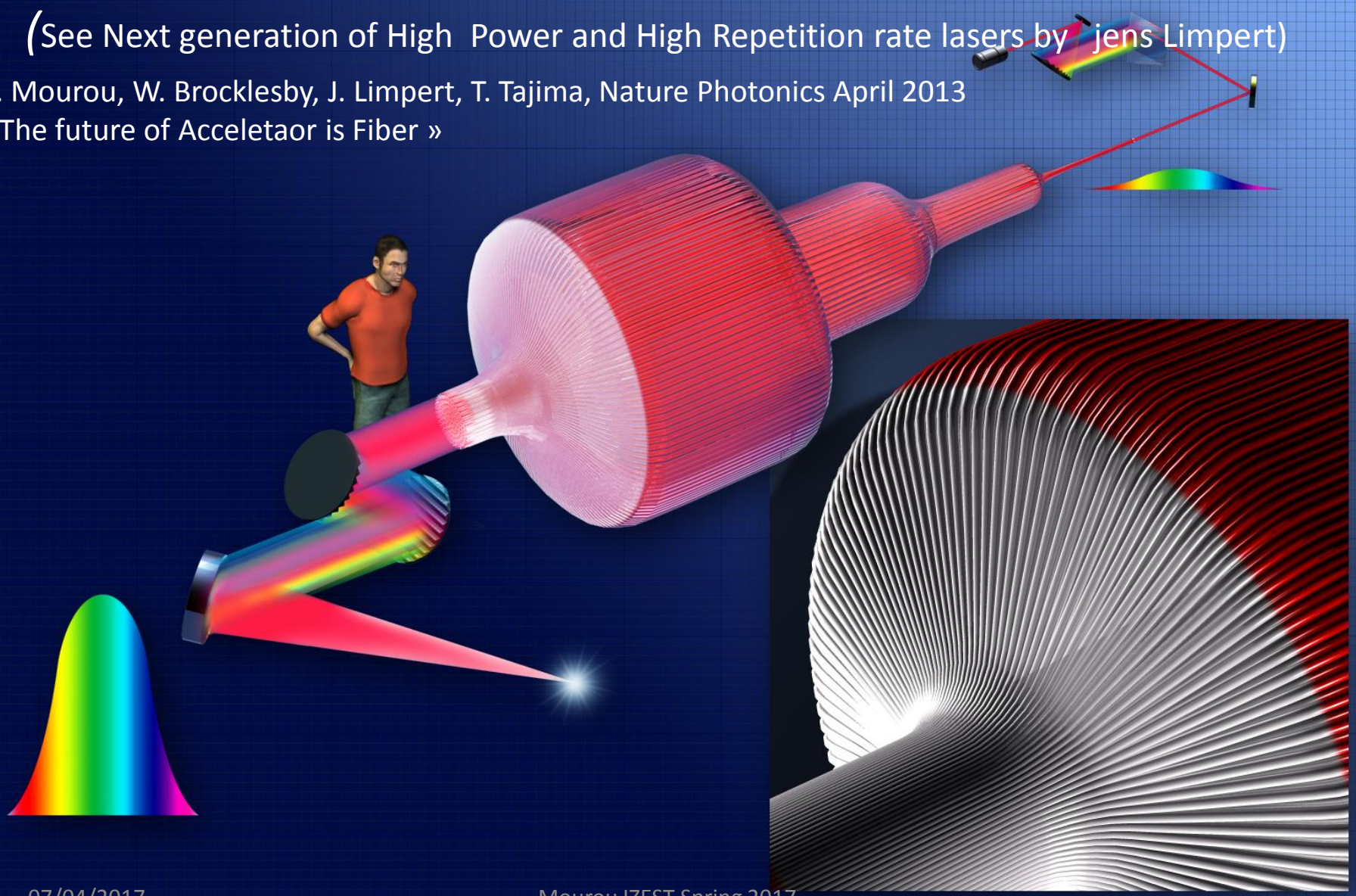
When the neutrons collide with the waste the atomic structure collapses and it is transmutated

ICAN (European Project)

CAN Coherent Amplification Network

(See Next generation of High Power and High Repetition rate lasers by jens Limpert)

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



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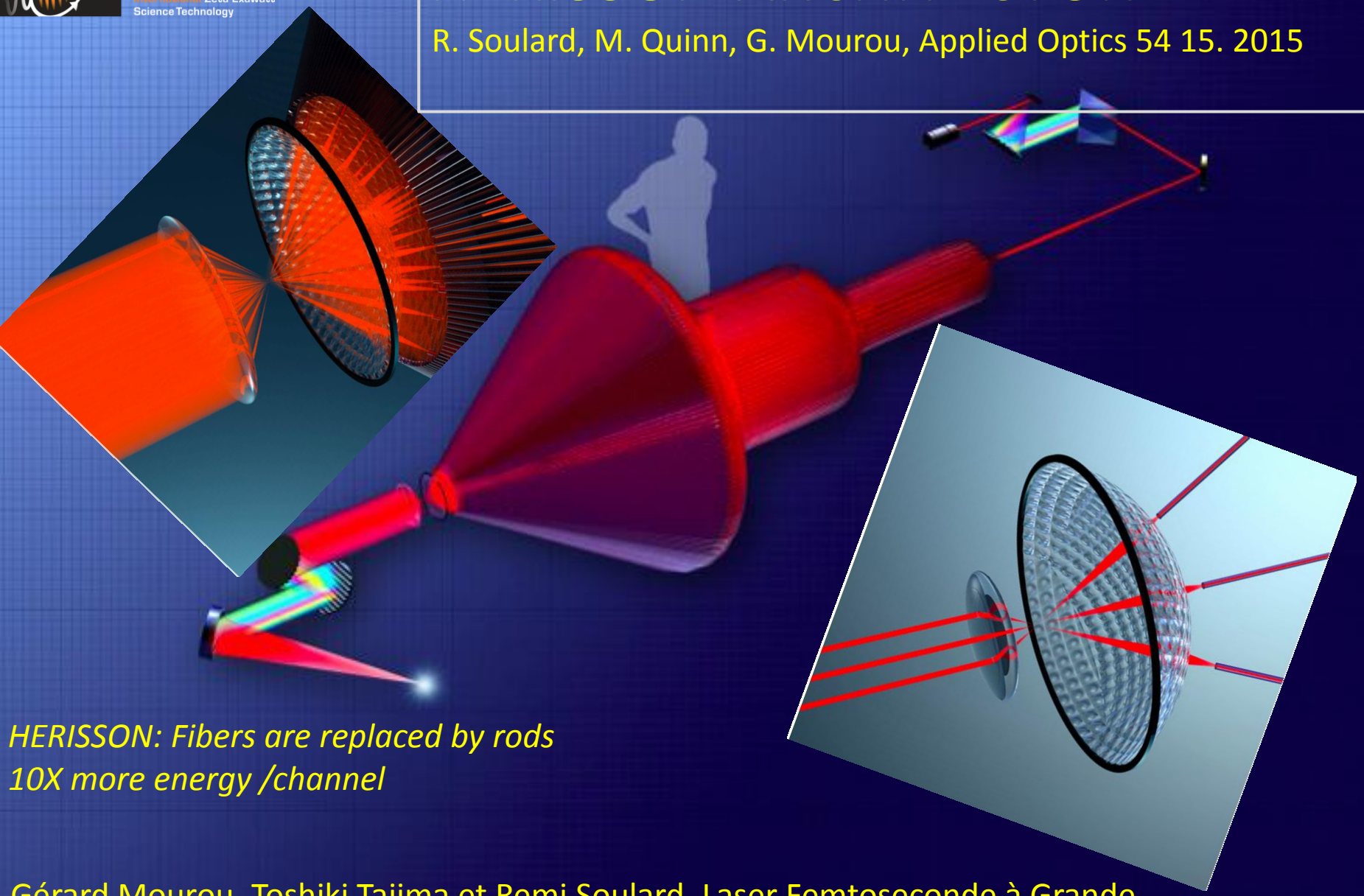
HERISSON ARCHITECTURE

R. Soulard, M. Quinn, G. Mourou, Applied Optics 54 15. 2015



HERISSON: Fibers are replaced by rods
10X more energy /channel

Gérard Mourou, Toshiki Tajima et Remi Soulard, Laser Femtoseconde à Grande puissance Impulsionnelle Patent EP 218267FR