Нобелівська премія з фізики 2018

KUNGL.
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THE ROYAL SWEDISH ACADEMY OF SCIENCES

“for groundbreaking inventions in the field of laser physics”

Артур Ешкін
(Bell Laboratories,
Holmdel, NJ, USA)

“for the optical tweezers and their application to biological systems”

"за оптичний пінцет та його застосування до біологічних систем“

Жерар Муру
(École Polytechnique,
Palaiseau, France)

Донна Стрікленд
(University of Waterloo,
Waterloo,Canada)

“for their method of generating high-intensity, ultra-short optical pulses”

"за метод генерації високоенергетичних ультракоротких оптичних імпульсів“

Ashkin, Arthur A.

Born: 2 September 1922, New York, NY, USA

Affiliation at the time of the award:

Bell Laboratories, Holmdel, NJ, USA

Education
1947 - BS, Columbia University, New York
1952 - PhD, Cornell University, Ithaca (N.Y.).

Major Positions
1942 – 1946: Staff Member, Massachusetts Insititute of Technology (MIT)
Radiation Laboratory, Columbia University Satellite
1952-1963: Member, Technical Staff, Bell Telephone Laboratories, Murray Hill (N.J.);
1963-1987: Head, Department of Laser Science, Bell Telephone Laboratories;
1988-1992: Member, Bell Telephone Laboratories

Major Projects
nonlinear optics, optical fibers, parametric oscillators and parametric amplifiers, photorefraction, second harmonic generation, and non-linear optics in fibers

Awards

1984 Member, the National Academy of Engineering.

1996 Member, National Academy of Sciences.

2004 Awarded Harvey Prize, Technion (Israel Institute of Technology).

2009 Member, The Optical Society.

2018 Awarded Nobel Prize in Physics "for groundbreaking inventions in the field of laser physics…for the optical tweezers and their application to biological systems".

На фото: Ісадор Ашкеназі (зліва) – батько Артура Ешкіна, Київ, початок 20 століття
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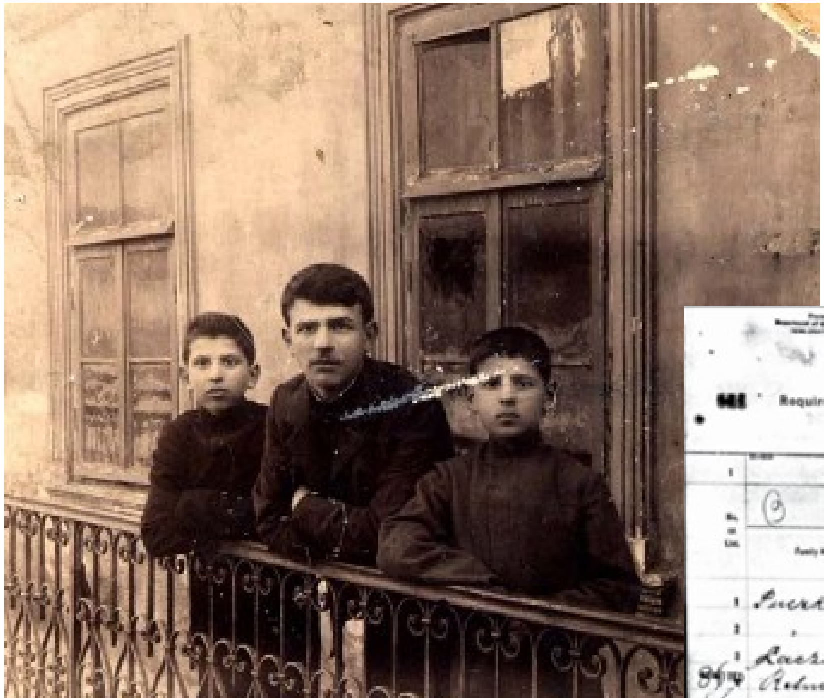
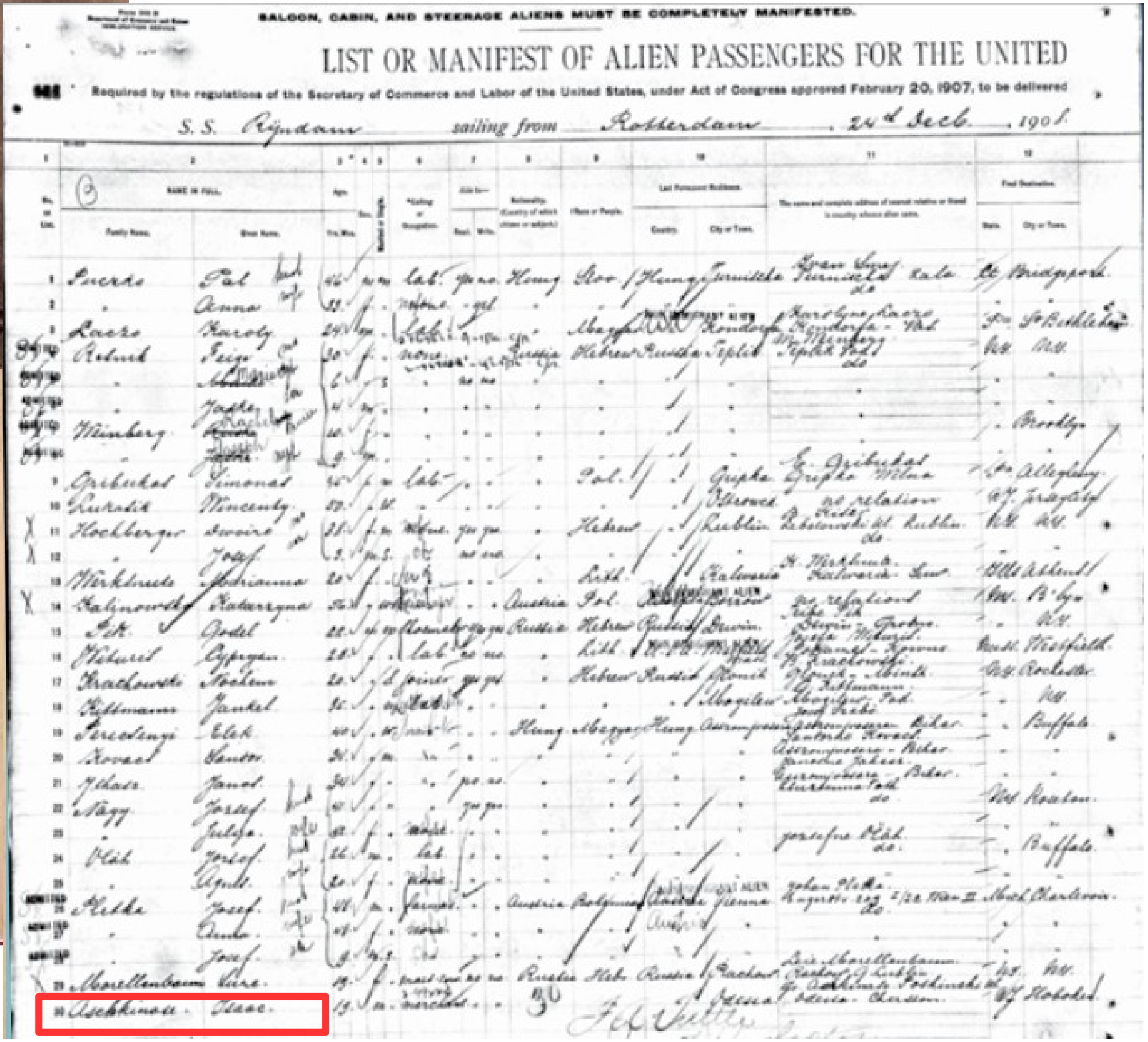




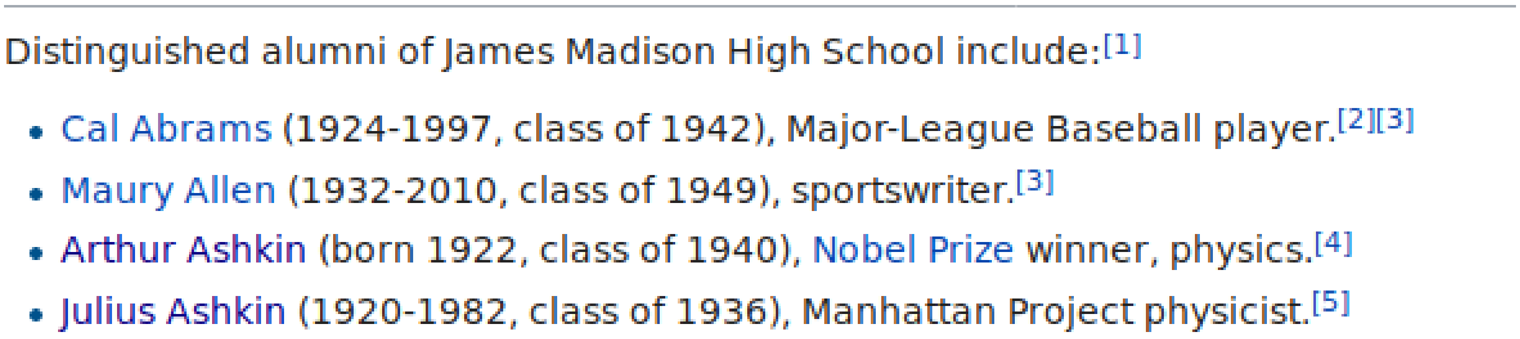
SALOON, CABIN, AND STEERAGE ALIENS MUST BE COMPLETELY MANIFESTED.

LIST OR MANIFEST OF ALIEN PASSENGERS FOR THE UNITED

Required by the regulations of the Secretary of Commerce and Labor of the United States, under Act of Congress approved February 20, 1907, to be delivered

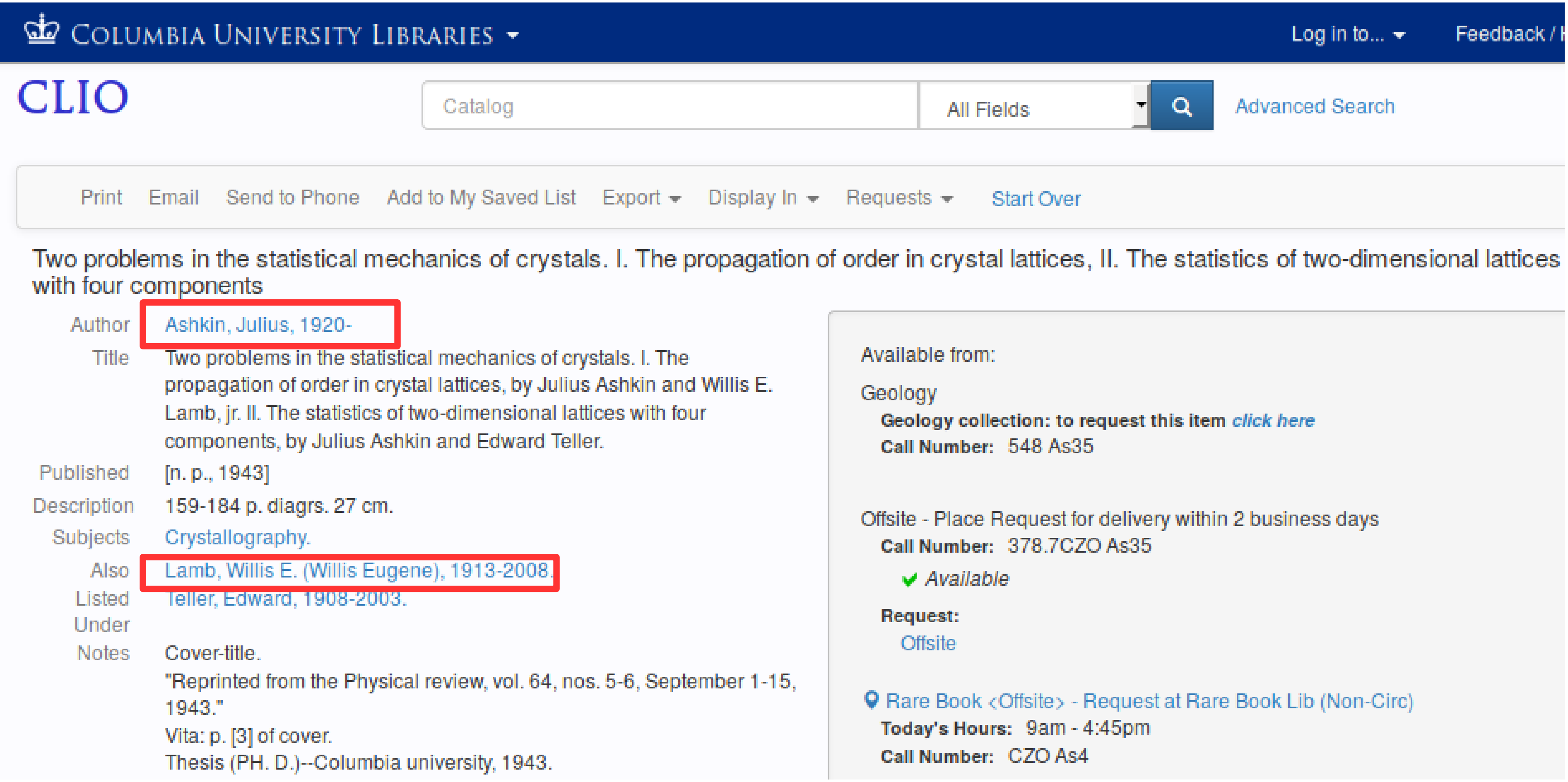
S.S. Rijndam sailing from Rotterdam, 24th Dec. 1908

Список пасажирів рейсу Роттердам – Нью-Йорк, 1908 р.



Distinguished alumni of James Madison High School include:[1]

- Cal Abrams (1924-1997, class of 1942), Major-League Baseball player.[2][3]
- Maury Allen (1932-2010, class of 1949), sportswriter.[3]
- Arthur Ashkin (born 1922, class of 1940), Nobel Prize winner, physics.[4]
- Julius Ashkin (1920-1982, class of 1936), Manhattan Project physicist.[5]



Two problems in the statistical mechanics of crystals. I. The propagation of order in crystal lattices, II. The statistics of two-dimensional lattices with four components

Author	Ashkin, Julius, 1920-
Title	Two problems in the statistical mechanics of crystals. I. The propagation of order in crystal lattices, by Julius Ashkin and Willis E. Lamb, jr. II. The statistics of two-dimensional lattices with four components, by Julius Ashkin and Edward Teller.
Published	[n. p., 1943]
Description	159-184 p. diagrs. 27 cm.
Subjects	Crystallography.
Also Listed Under	Lamb, Willis E. (Willis Eugene), 1913-2008. Teller, Edward, 1908-2003.
Notes	Cover-title. "Reprinted from the Physical review, vol. 64, nos. 5-6, September 1-15, 1943." Vita: p. [3] of cover. Thesis (PH. D.)--Columbia university, 1943.

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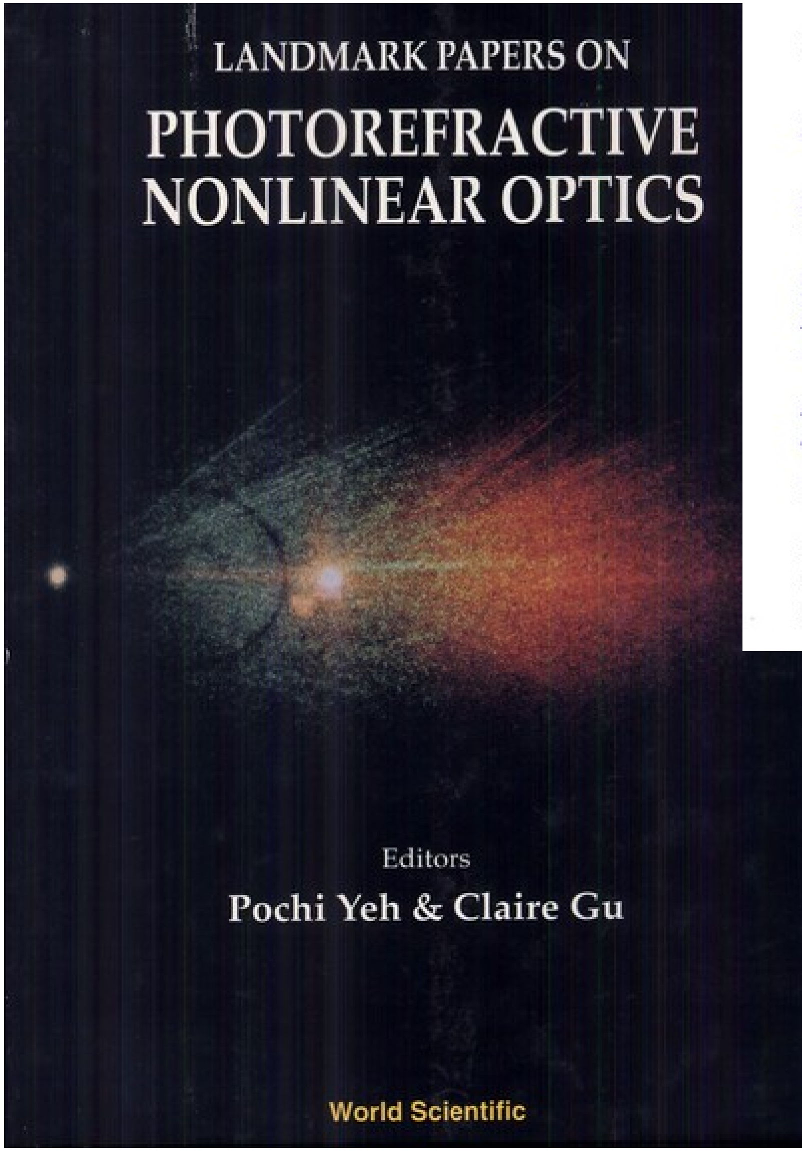


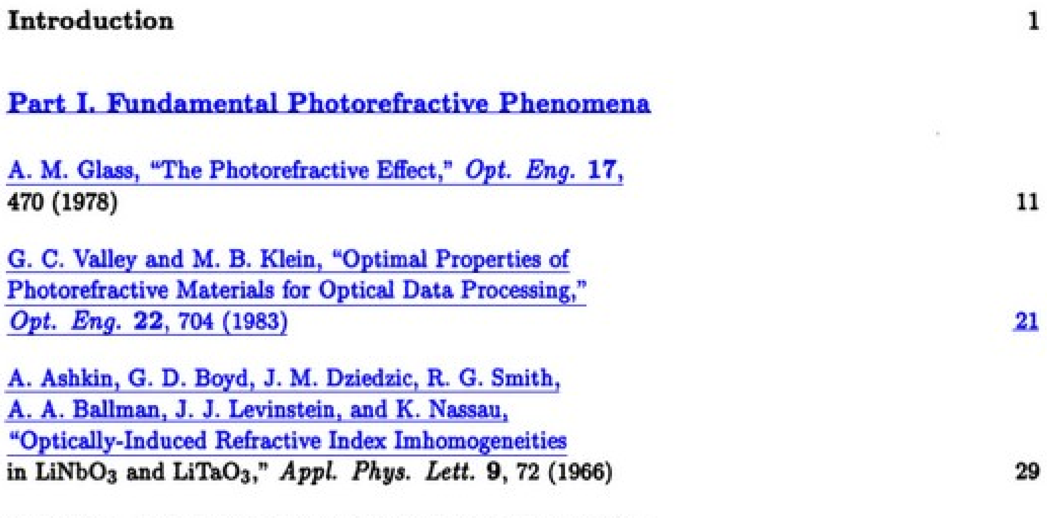
LANDMARK PAPERS ON

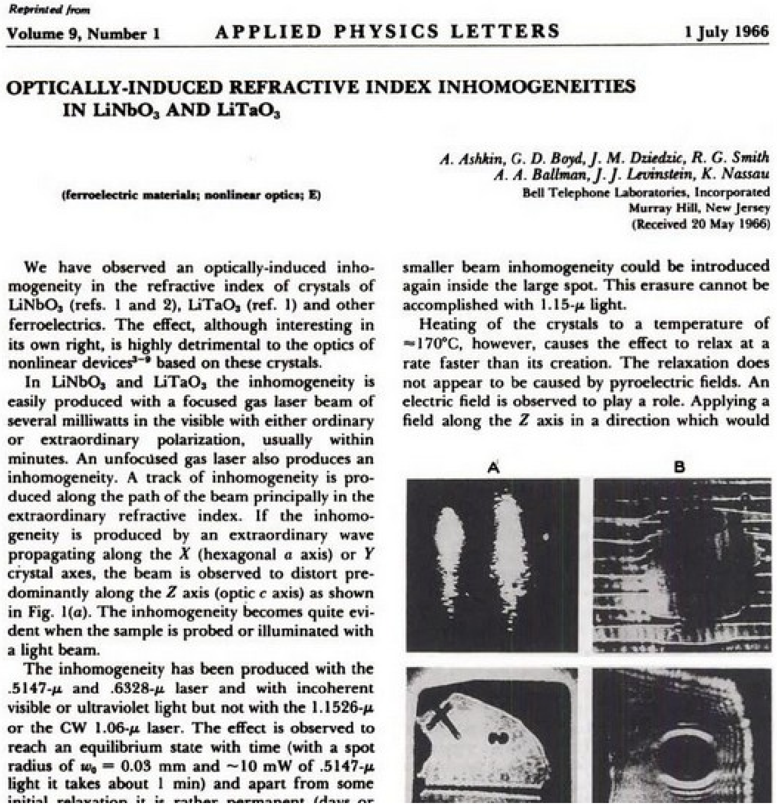
PHOTOREFRACTIVE NONLINEAR OPTICS

Editors

Pochi Yeh & Claire Gu

World Scientific





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Volume 9, Number 1 APPLIED PHYSICS LETTERS 1 July 1966

OPTICALLY-INDUCED REFRACTIVE INDEX INHOMOGENEITIES IN $LiNbO_3$ AND $LiTaO_3$

A. Ashkin, G. D. Boyd, J. M. Dziedzic, R. G. Smith
A. A. Ballman, J. J. Levinstein, K. Nassau
Bell Telephone Laboratories, Incorporated
Murray Hill, New Jersey

(Received 20 May 1966)

(ferroelectric materials; nonlinear optics; E)

We have observed an optically-induced inhomogeneity in the refractive index of crystals of $LiNbO_3$ (refs. 1 and 2), $LiTaO_3$ (ref. 1) and other ferroelectrics. The effect, although interesting in its own right, is highly detrimental to the optics of nonlinear devices[3-9] based on these crystals.

In $LiNbO_3$ and $LiTaO_3$ the inhomogeneity is easily produced with a focused gas laser beam of several milliwatts in the visible with either ordinary or extraordinary polarization, usually within minutes. An unfocused gas laser also produces an inhomogeneity. A track of inhomogeneity is produced along the path of the beam principally in the extraordinary refractive index. If the inhomogeneity is produced by an extraordinary wave propagating along the *X* (hexagonal *a* axis) or *Y* crystal axes, the beam is observed to distort predominantly along the *Z* axis (optic *c* axis) as shown in Fig. 1(*a*). The inhomogeneity becomes quite evident when the sample is probed or illuminated with a light beam.

The inhomogeneity has been produced with the .5147-μ and .6328-μ laser and with incoherent visible or ultraviolet light but not with the 1.1526-μ or the CW 1.06-μ laser. The effect is observed to reach an equilibrium state with time (with a spot radius of $w_0 = 0.03$ mm and ~10 mW of .5147-μ light it takes about 1 min) and apart from some initial relaxation it is rather permanent (days or

smaller beam inhomogeneity could be introduced again inside the large spot. This erasure cannot be accomplished with 1.15-μ light.

Heating of the crystals to a temperature of ≈170°C, however, causes the effect to relax at a rate faster than its creation. The relaxation does not appear to be caused by pyroelectric fields. An electric field is observed to play a role. Applying a field along the *Z* axis in a direction which would

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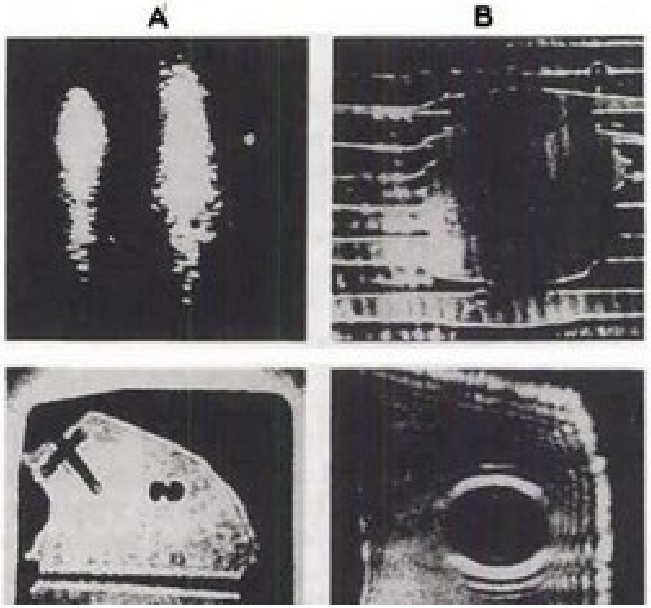

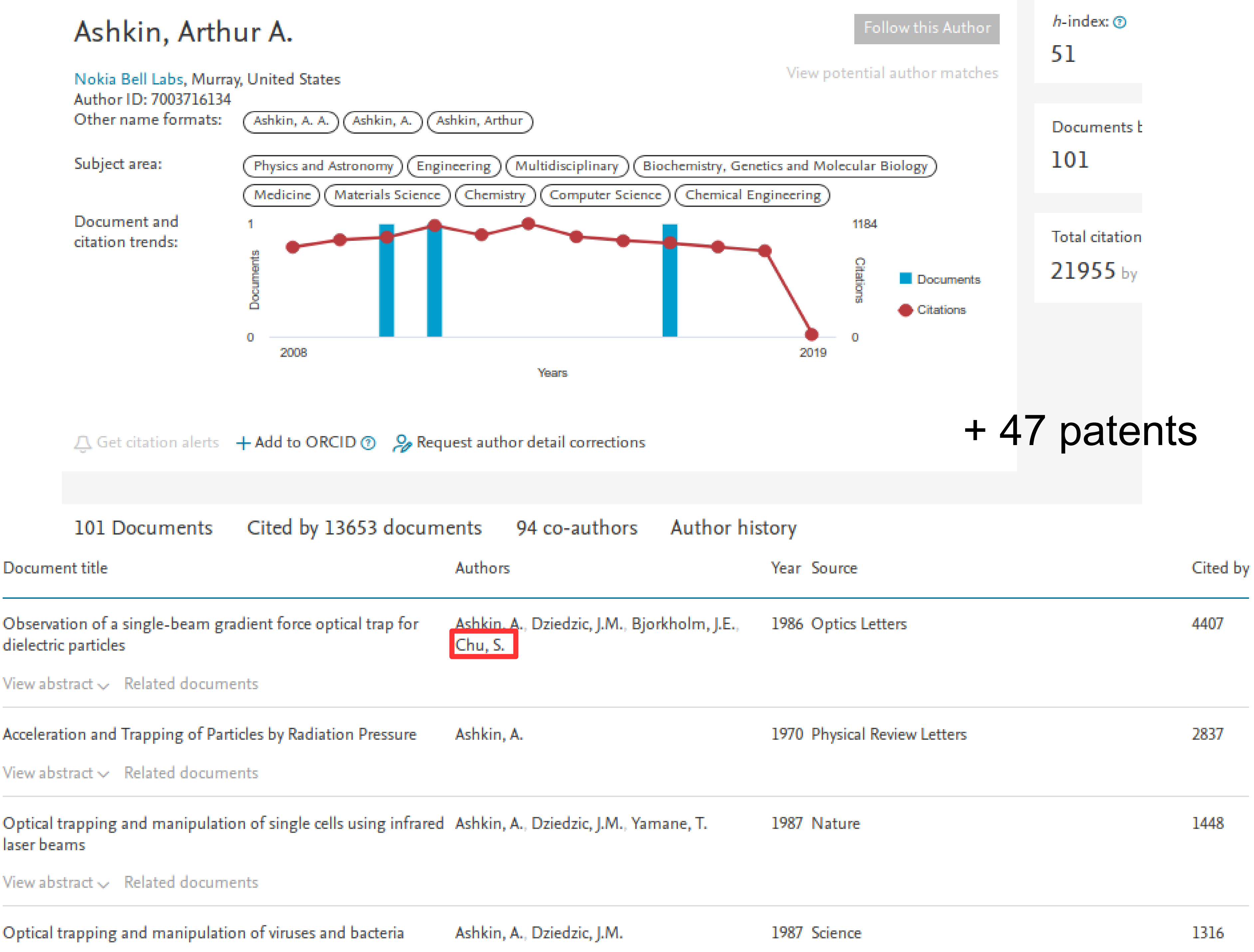

Ashkin, Arthur A.

Nokia Bell Labs, Murray, United States
Author ID: 7003716134
Other name formats: Ashkin, A. A. | Ashkin, A. | Ashkin, Arthur

Subject area: Physics and Astronomy | Engineering | Multidisciplinary | Biochemistry, Genetics and Molecular Biology | Medicine | Materials Science | Chemistry | Computer Science | Chemical Engineering

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Document title	Authors	Year	Source	Cited by
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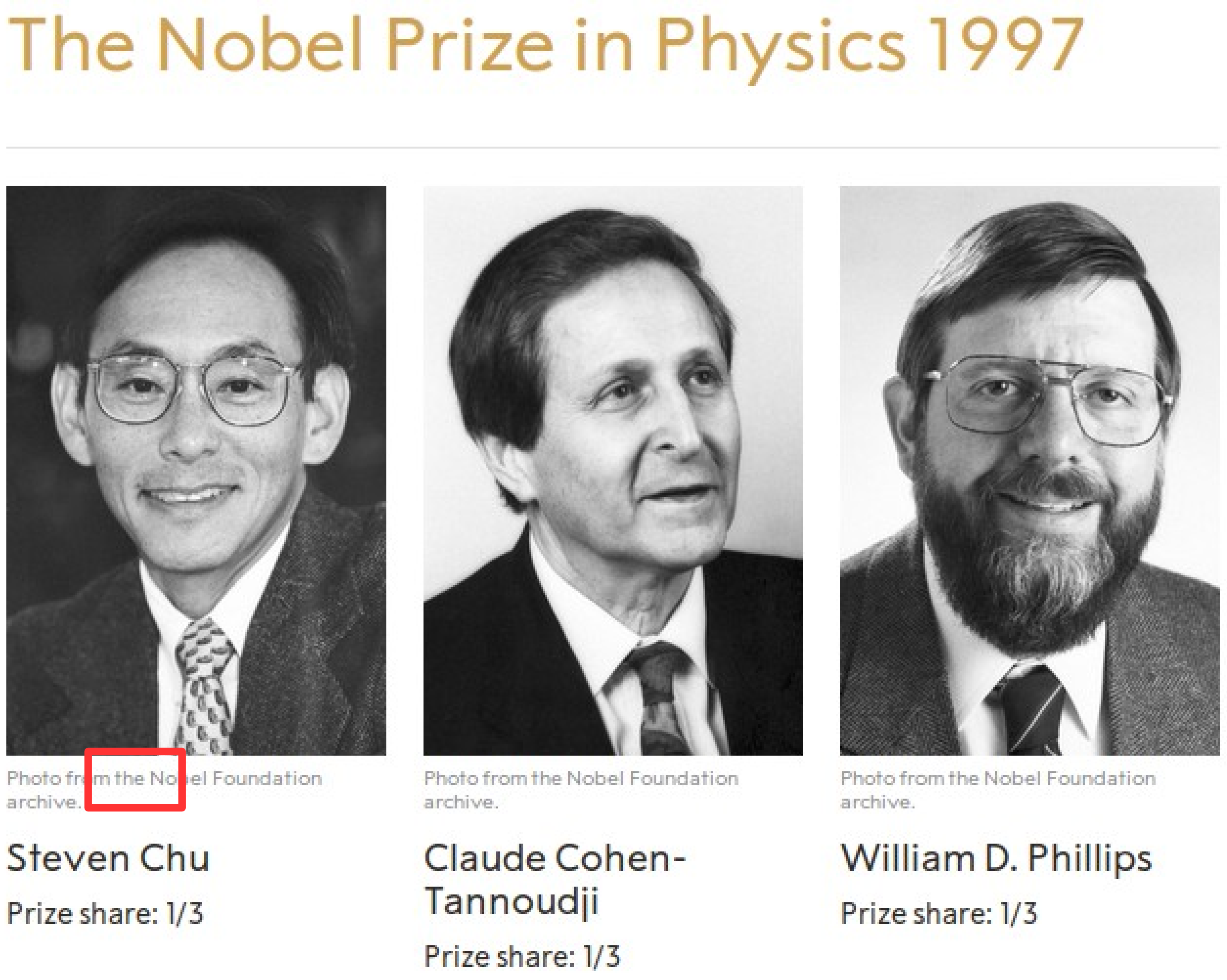
Acceleration and Trapping of Particles by Radiation Pressure	Ashkin, A.	1970	Physical Review Letters	2837
Optical trapping and manipulation of single cells using infrared laser beams	Ashkin, A., Dziedzic, J.M., Yamane, T.	1987	Nature	1448
Optical trapping and manipulation of viruses and bacteria	Ashkin, A., Dziedzic, J.M.	1987	Science	1316



The Nobel Prize in Physics 1997

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Steven Chu

Prize share: 1/3

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Claude Cohen-Tannoudji

Prize share: 1/3

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William D. Phillips

Prize share: 1/3

"for development of methods to cool and trap atoms with laser light."

MLA style: Steven Chu – Facts. NobelPrize.org. Nobel Media AB 2018. Tue. 20 Nov 2018. <https://www.nobelprize.org/prizes/physics/1997/chu/facts/>

VOLUME 55, NUMBER 1 PHYSICAL REVIEW LETTERS 1 JULY 1985

Three-Dimensional Viscous Confinement and Cooling of Atoms by Resonance Radiation Pressure

Steven Chu, L. Hollberg, J. E. Bjorkholm, Alex Cable, and A. Ashkin
AT&T Bell Laboratories, Holmdel, New Jersey 07733

(Received 25 April 1985)

We report the viscous confinement and cooling of neutral sodium atoms in three dimensions via the radiation pressure of counterpropagating laser beams. These atoms have a density of about $\sim 10^6$ cm^{-3} and a temperature of ~ 240 μK corresponding to a rms velocity of ~ 60 cm/sec. This temperature is approximately the quantum limit for this atomic transition. The decay time for half the atoms to escape a ~ 0.2-cm^3 confinement volume is ~ 0.1 sec.

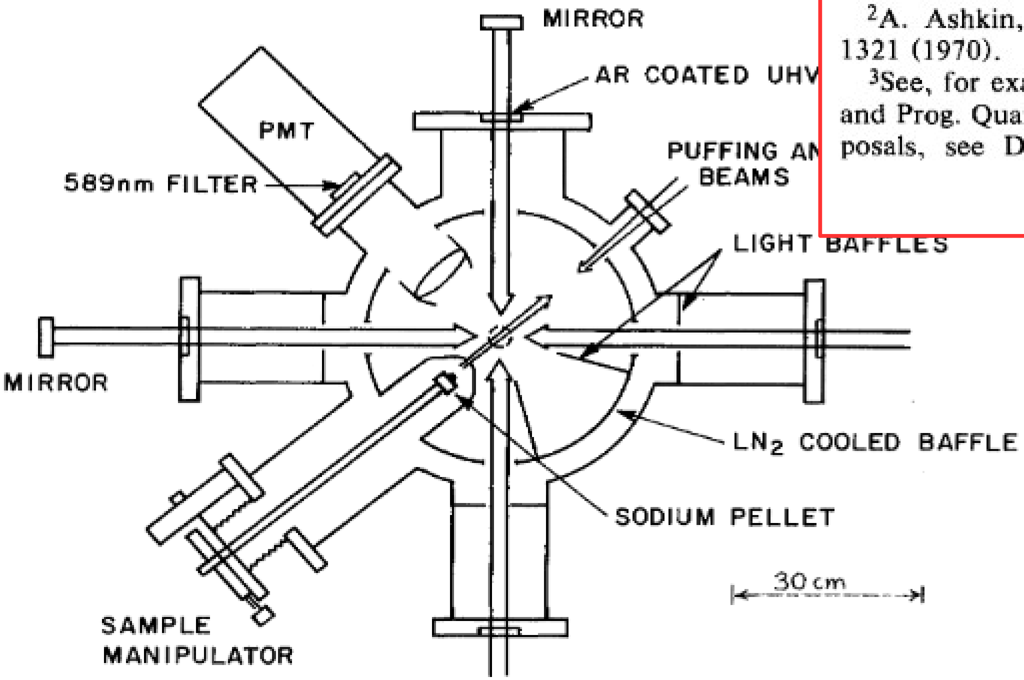

FIG. 1. Schematic of the vacuum chamber and intersecting laser beams and atomic beam. The vertical confining beam is indicated by the dashed circle. The "puffing" beam is from the pulsed YAlG laser.

[1] O. R. Frisch, Z. Phys. **86**, 42 (1933).

[2] A. Ashkin, Phys. Rev. Lett. **24**, 156 (1970), and **25**, 1321 (1970).

[3] See, for example, A. Ashkin, Science **210**, 1081 (1980), and Prog. Quantum Electron. **8**, 204 (1984); for recent proposals, see D. E. Pritchard, Phys. Rev. Lett. **51**, 1336

VOLUME 57, NUMBER 3 PHYSICAL REVIEW LETTERS 21 JULY 1986

Experimental Observation of Optically Trapped Atoms

Steven Chu, J. E. Bjorkholm, A. Ashkin, and A. Cable
AT&T Bell Laboratories, Holmdel, New Jersey 07733
(Received 14 April 1986)

We report the first observation of optically trapped atoms. Sodium atoms cooled below 10^{-3} K in "optical molasses" are captured by a dipole-force optical trap created by a single, strongly focused, Gaussian laser beam tuned several hundred gigahertz below the D_1 resonance transition. We estimate that about 500 atoms are confined in a volume of about $10^3\ \mu\text{m}^3$ at a density of $10^{11}-10^{12}$ cm^{-3}. Trap lifetimes are limited by background pressure to several seconds. The observed trapping behavior is in good quantitative agreement with theoretical expectations.

We report the optical trapping of neutral atoms by the forces of resonance-radiation pressure in a single-beam optical trap. At the time of the first demonstration of stable optical trapping and manipulation of small dielectric particles[1] it was predicted that similar effects were possible with atoms. Since then there have been extensive studies of the basic forces of laser light on neutral particles and atoms.[2-8] The trapping


(a) (b)

FIG. 2. (a) Photo showing the collimating nozzle, atomic beam, and atoms confined in OM. The distance from the nozzle to the OM region is 5 cm. (b) Photo taken after the atomic source and the slowing laser beam have been turned off, showing trapped atoms.

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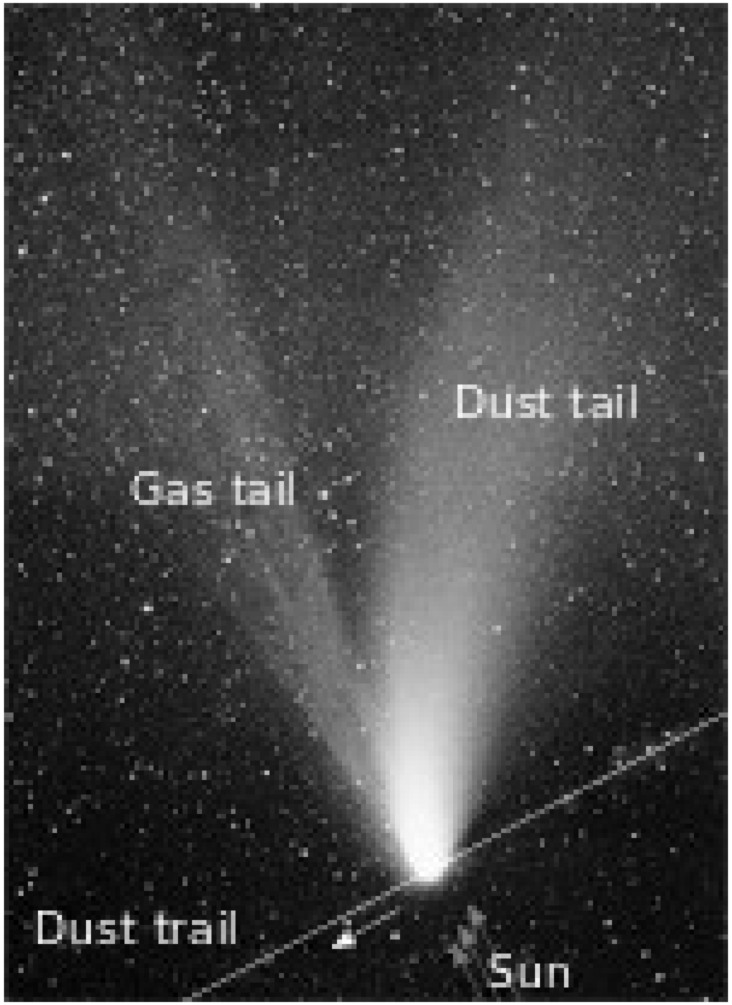
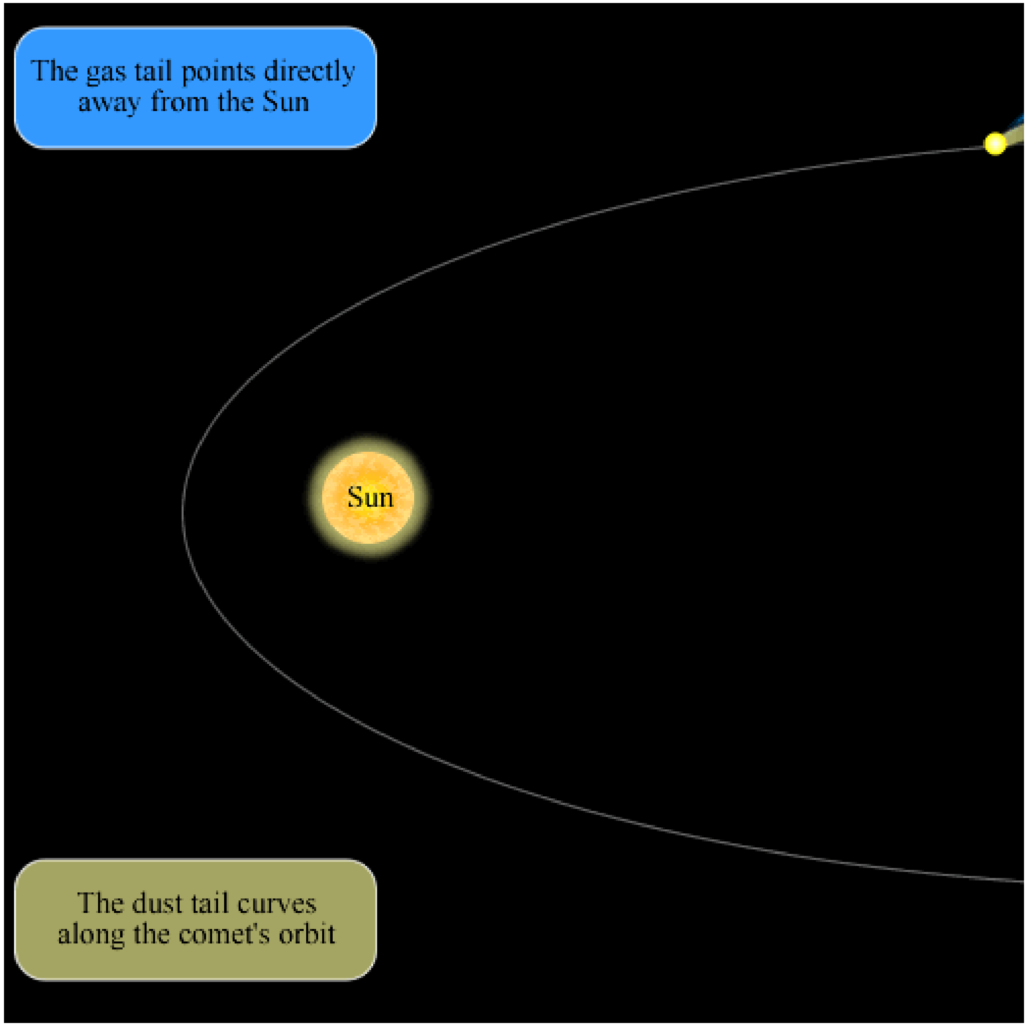
[1] A. Ashkin, Phys. Rev. Lett. **24**, 156 (1970).





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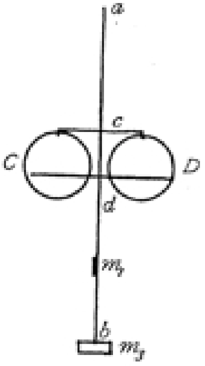
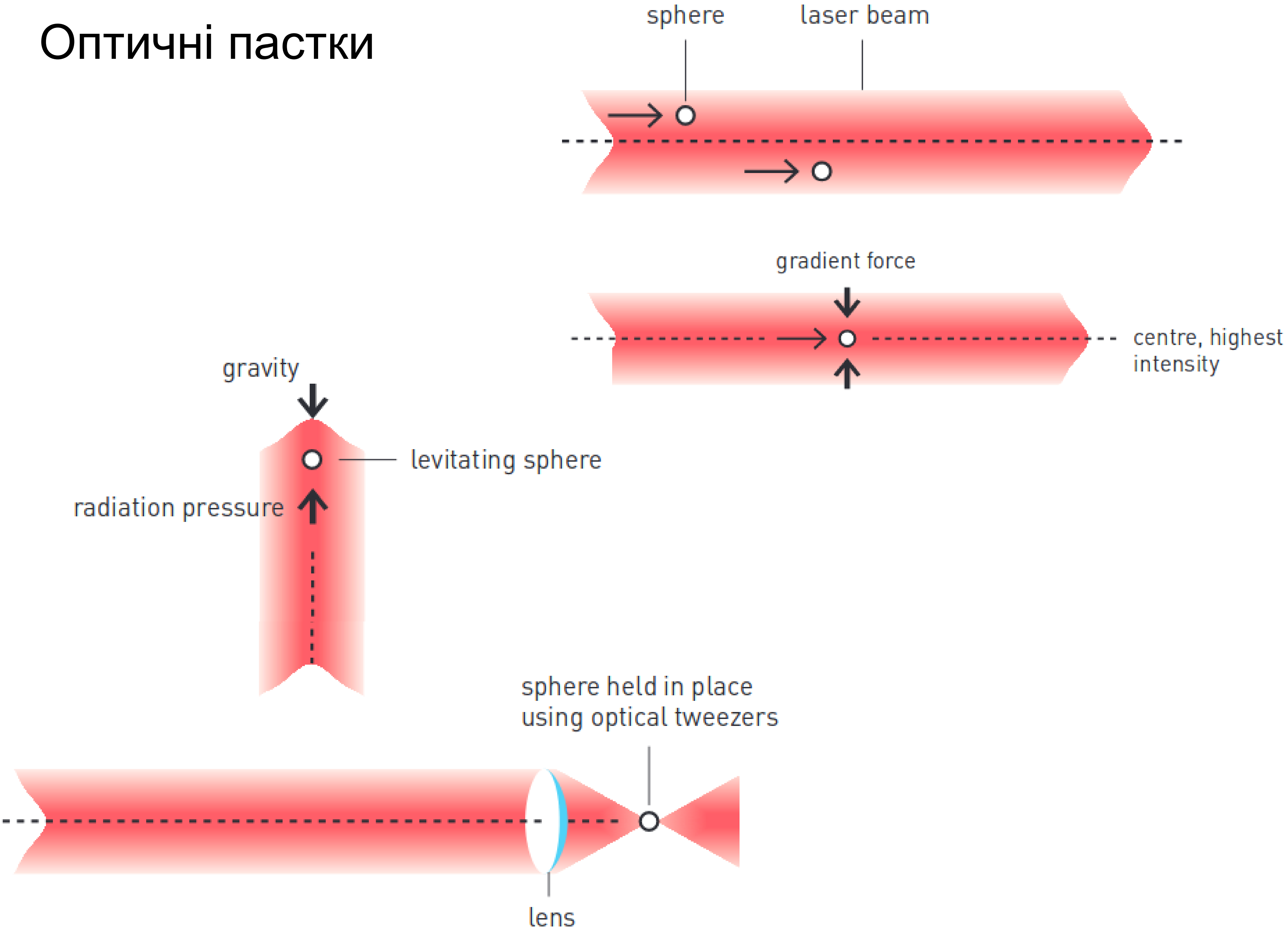


Nichols, E. F., and Hull, G. F., A preliminary communication on the pressure of heat and light radiation, Phys. Rev. 13, 307 (1901); The Pressure Due to Radiation. (Second Paper.), Phys. Rev. 17, 26 (1903)

Lebedev, P., Untersuchungen uber die Druckkrafte des Lichtes, Ann. Phys. (Leipzig) 6, 433 (1901)

www.dartmouth.edu/~pressureoflight/history/history1.html

Оптичні пастки



VOLUME 24, NUMBER 4 PHYSICAL REVIEW LETTERS 26 JANUARY 1970

ACCELERATION AND TRAPPING OF PARTICLES BY RADIATION PRESSURE

A. Ashkin
Bell Telephone Laboratories, Holmdel, New Jersey 07733

(Received 3 December 1969)

Micron-sized particles have been accelerated and trapped in stable optical potential wells using only the force of radiation pressure from a continuous laser. It is hypothesized that similar accelerations and trapping are possible with atoms and molecules using laser light tuned to specific optical transitions. The implications for isotope separation and other applications of physical interest are discussed.

This Letter reports the first observation of acceleration of freely suspended particles by the forces of radiation pressure from cw visible laser light. The experiments, performed on micron-sized particles in liquids and gas, have yielded new insights into the nature of radiation pressure and have led to the discovery of stable optical potential wells in which particles were trapped by radiation pressure alone. The ideas can be extended to atoms and molecules where one can predict that radiation pressure from tunable lasers will selectively accelerate, trap, or separate the atoms or molecules of gases because of their large effective cross sections at specific resonances. The author's interest in radiation pressure from lasers stems from a realization of the large magnitude of the force.

spheres[6] of 0.59-, 1.31-, and 2.68-μm diam freely suspended in water. A TEM_{00}-mode beam of an argon laser of radius $w_0 = 6.2$ μm and $\lambda = 0.5145$ μm was focused horizontally through a glass cell 120 μm thick and manipulated to focus on single particles. See Fig. 1(a). Results were observed with a microscope. If a beam with milliwatts of power hits a 2.68-μm sphere off center, the sphere is simultaneously drawn in to the beam axis and accelerated in the direction of the light. It moves with a limiting velocity of microns per second until it hits the front surface of the glass cell where it remains trapped in the beam. If the beam is blocked, the sphere wanders off by Brownian motion. Similar effects occur with the other sphere sizes but more power is required for comparable velocities. When

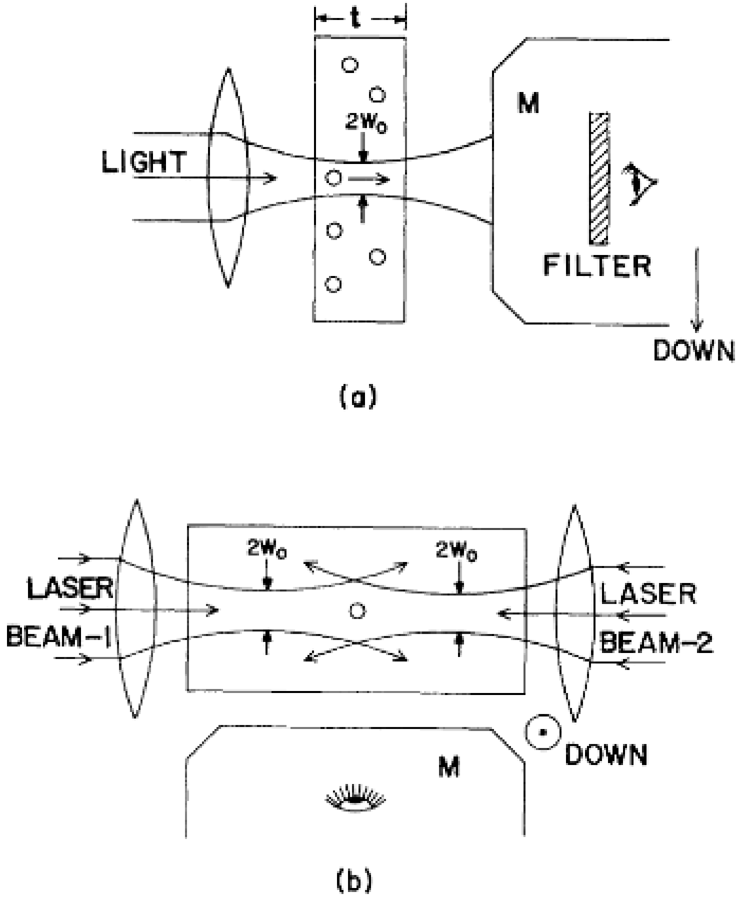


FIG. 1. (a) Geometry of glass cell, $t = 120\ \mu\text{m}$, for observing micron particle motions in a focused laser beam with a microscope M. (b) The trapping of a high-index particle in a stable optical well. Note position of the TEM_{00}-mode beam waists.

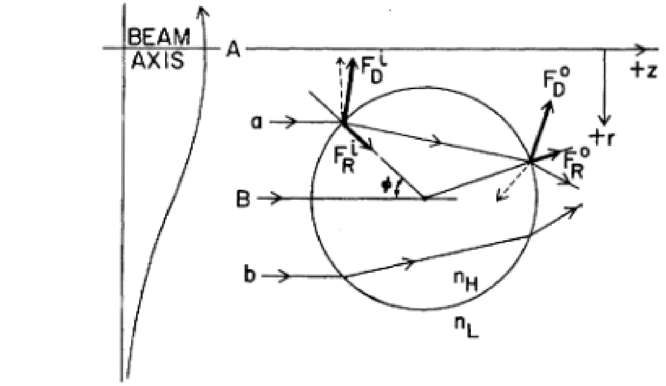


FIG. 2. A dielectric sphere situated off the axis A of a TEM_{00}-mode beam and a pair of symmetric rays a and b. The forces due to a are shown for $n_H > n_L$. The sphere moves toward $+z$ and $-r$.

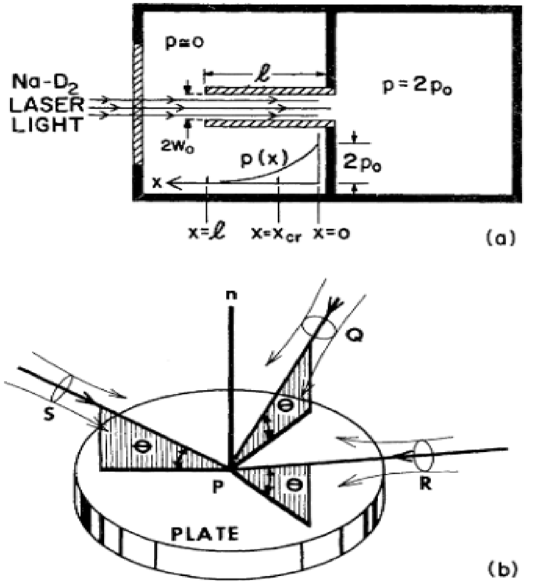
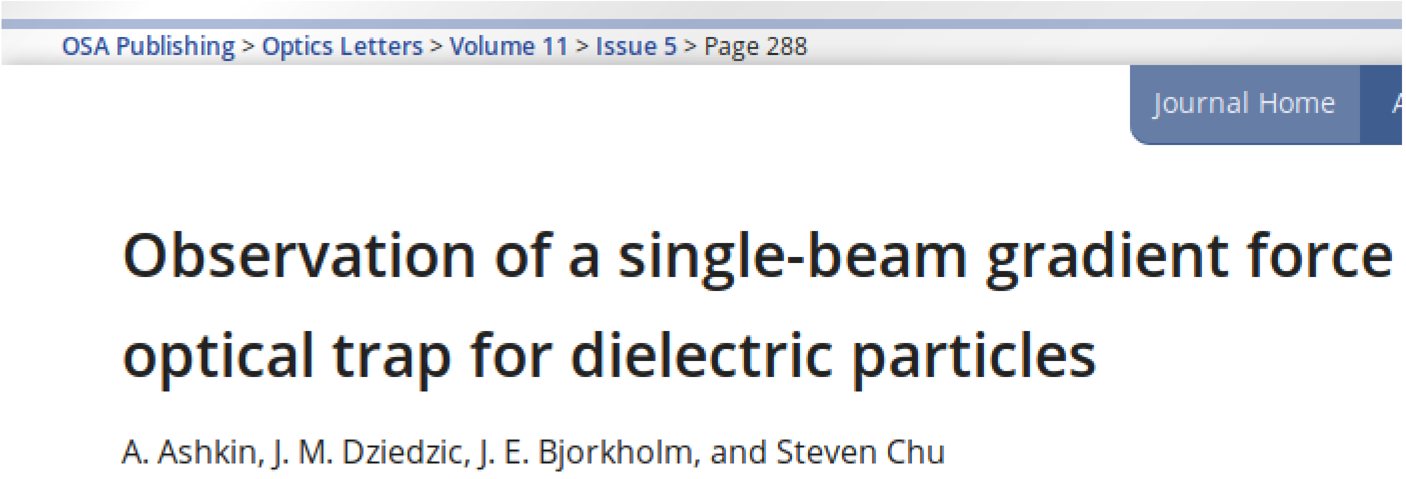
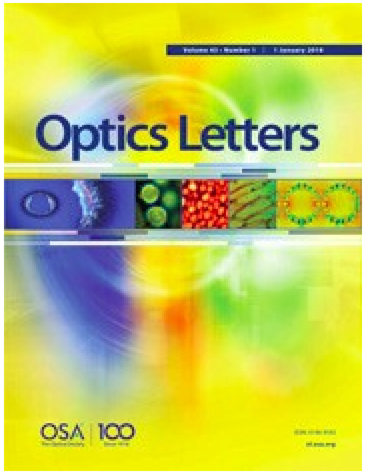


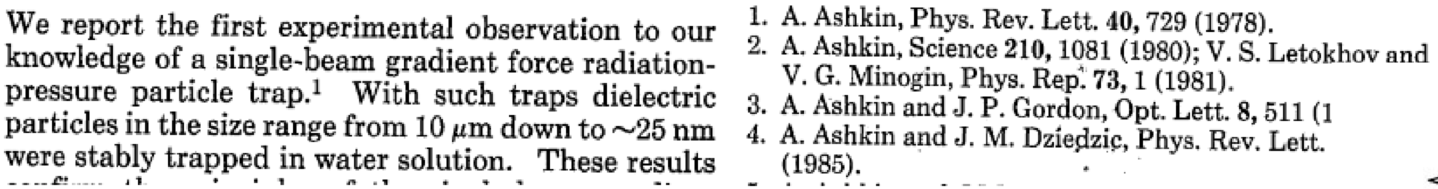
FIG. 3. (a) Schematic optical gas pump and graph of Na pressure $p(x)$. (b) Geometry of gas confinement about point P of a plane surface.


OSA Publishing > Optics Letters > Volume 11 > Issue 5 > Page 288

Observation of a single-beam gradient force optical trap for dielectric particles

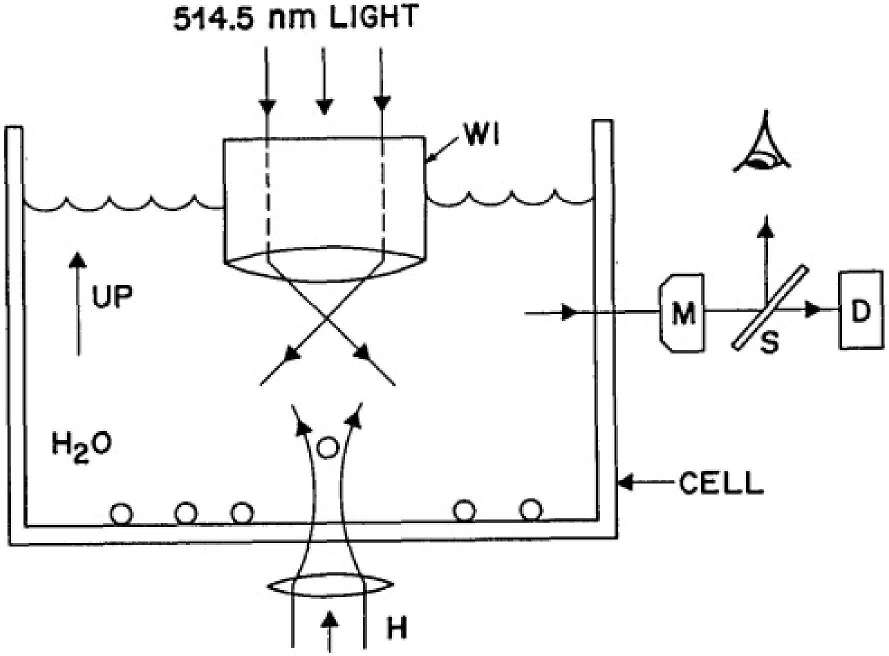
A. Ashkin, J. M. Dziedzic, J. E. Bjorkholm, and Steven Chu

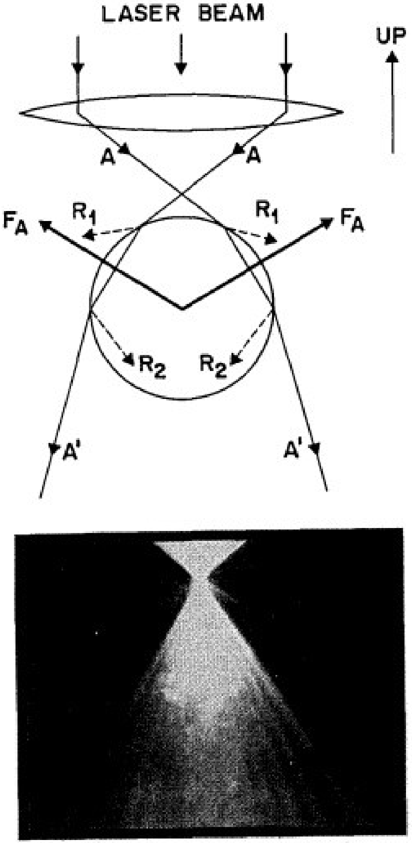



We report the first experimental observation to our knowledge of a single-beam gradient force radiation-pressure particle trap.[1] With such traps dielectric particles in the size range from 10 μm down to ~25 nm were stably trapped in water solution. These results

1. A. Ashkin, Phys. Rev. Lett. **40**, 729 (1978).
2. A. Ashkin, Science **210**, 1081 (1980); V. S. Letokhov and V. G. Minogin, Phys. Rep. **73**, 1 (1981).
3. A. Ashkin and J. P. Gordon, Opt. Lett. **8**, 511 (1
4. A. Ashkin and J. M. Dziedzic, Phys. Rev. Lett. (1985).

Optics Letters Vol. 11, Issue 5, pp. 288-290 (1986) • https://doi.org/10.1364/OL.11.000288





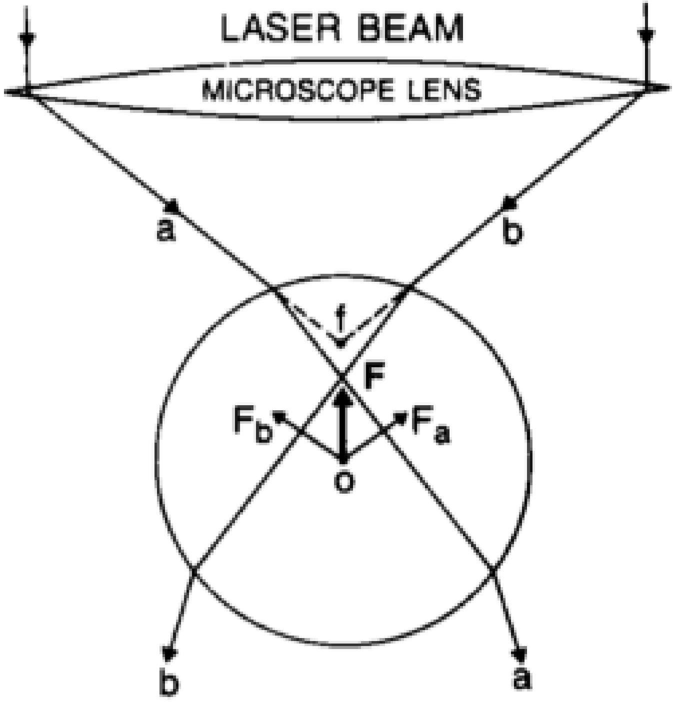


Figure 1: *Qualitative ray optics description of the restoring backward force in an optical tweezers trap, for a dielectric sphere that is located below the focus* **f** *and assumed to be large compared with the wavelength of the light. Rays of light carry momentum and are bent by refraction when passing the dielectric sphere. By conservation of momentum and Newton's second law, the momentum change of the refracted rays results in an oppositely directed force*

June 1979 / Vol. 4, No. 6 / OPTICS LETTERS 161

Cooling and trapping of atoms by resonance radiation pressure

A. Ashkin and J. P. Gordon

Bell Laboratories, Holmdel, New Jersey 07733

Received February 16, 1979

The combined use of trapping and cooling laser beams for optical trapping and cooling of neutral atoms by the forces of resonance radiation pressure is examined. Calculations show that atoms can be held in traps as deep as 10^{-4} eV at temperatures of $\sim 10^{-3}$ K, close to the minimum set by quantum fluctuations. Spatial confinement of atoms to a region a fraction of a wavelength in length should be possible.

Recently a new method was proposed for optically trapping and cooling neutral atoms based on resonance radiation pressure forces.[1] The technique is potentially useful for high-resolution spectroscopy and novel experiments on a few or even possibly single atoms. The

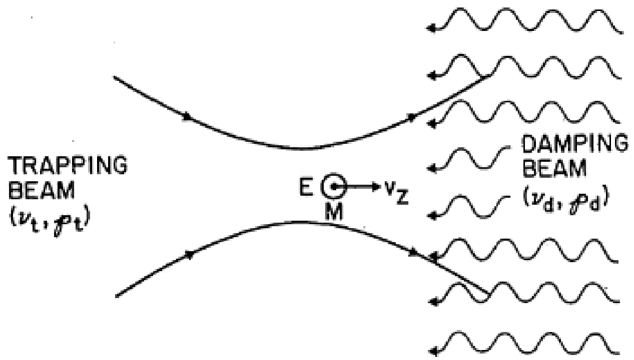
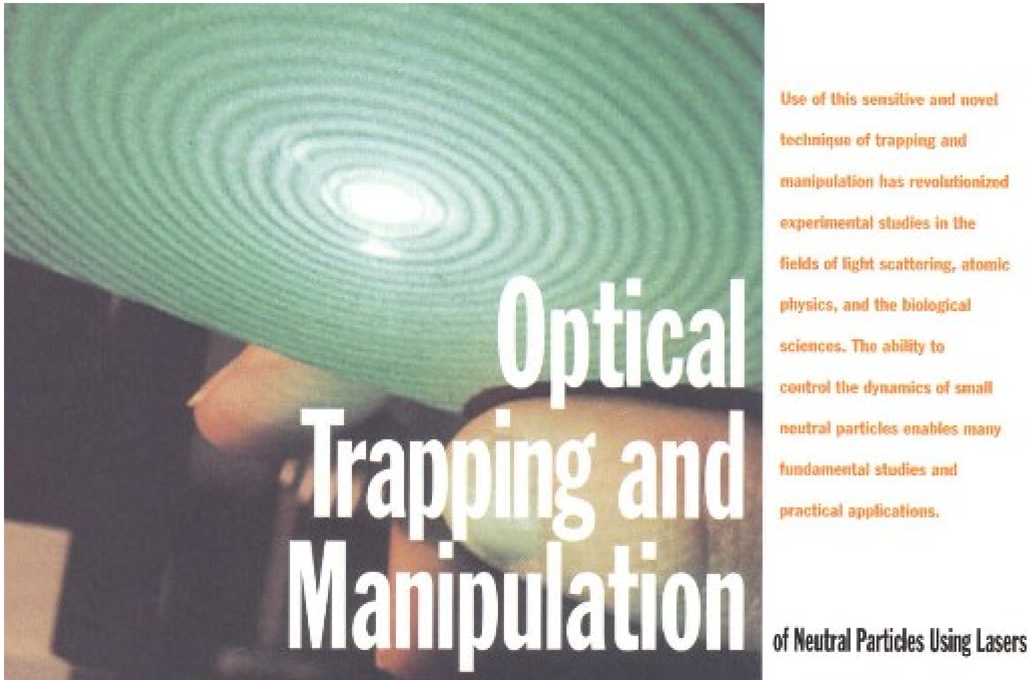


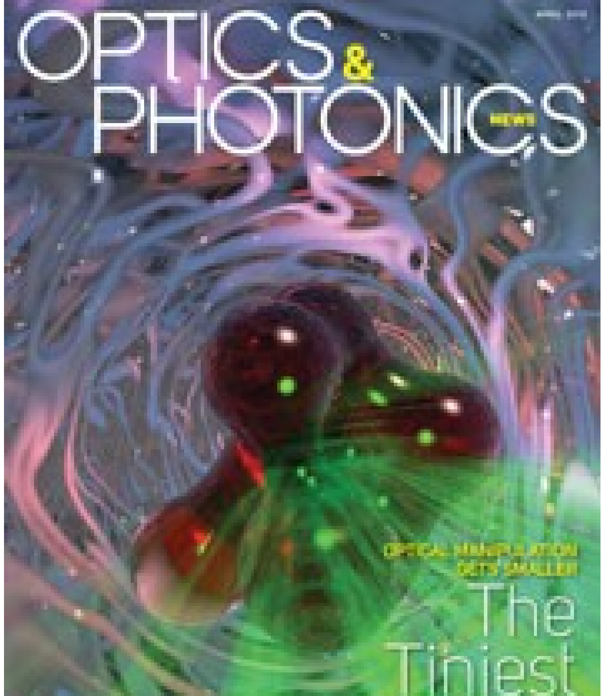
Fig. 1. Atom of mass M and velocity v_z located at the equilibrium point E of a Gaussian-beam trap with a plane-wave damping beam. The axial location of E depends on the magnitudes of p_t and p_d.

1. A. Ashkin, Phys. Rev. Lett. 40, 729 (1978).



Optical Trapping and Manipulation of Neutral Particles Using Lasers

Use of this sensitive and novel technique of trapping and manipulation has revolutionized experimental studies in the fields of light scattering, atomic physics, and the biological sciences. The ability to control the dynamics of small neutral particles enables many fundamental studies and practical applications.



OPTICS & PHOTONICS NEWS

OPTICAL MANIPULATION GETS SMALLER

The Tiniest

OSA Publishing > Optics and Photonics News > Volume 10 > Issue 5 > Page 41

Optical Trapping and Manipulation of Neutral Particles Using Lasers

A. Ashkin

Optics and Photonics News Vol. 10, Issue 5, pp. 41- (1999) • https://doi.org/10.1364/OPN.10.5.000041

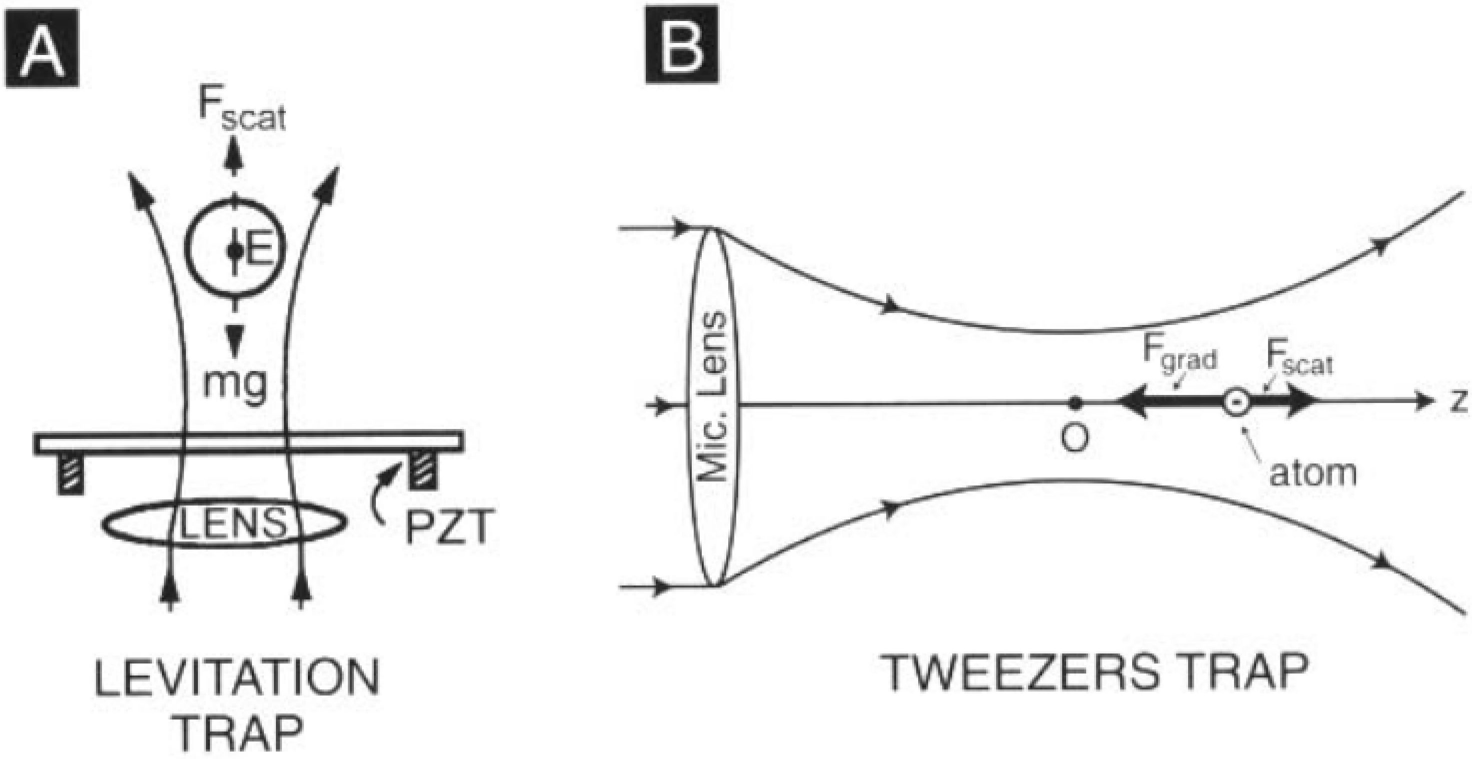


Figure 2. (A) Geometry of levitation trap. (B) Tweezer trap for atoms. $F_{grad} > F_{scat}$ giving a net backward restoring force toward E.

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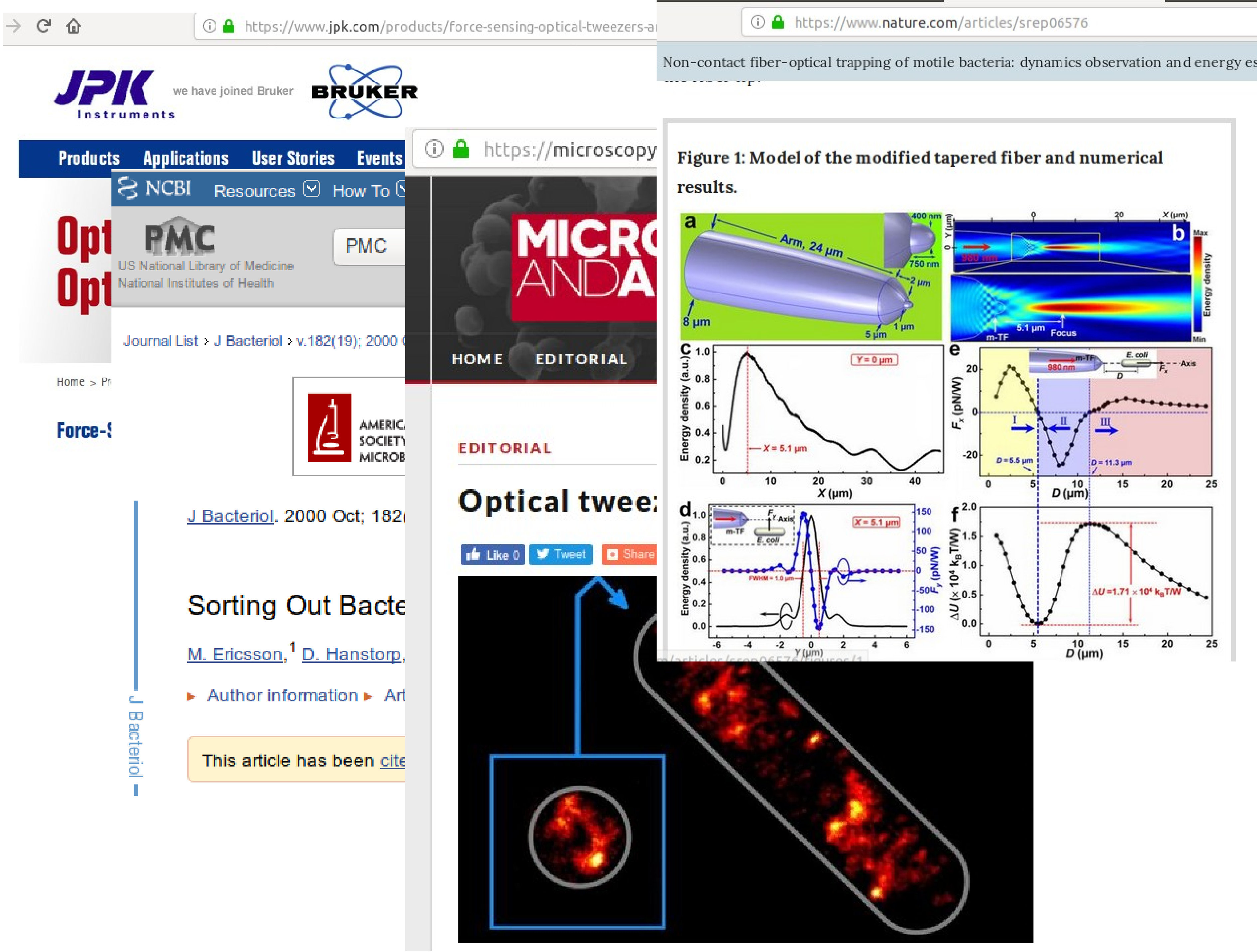

https://www.jpk.com/products/force-sensing-optical-tweezers-a

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M. Ericsson,[1] D. Hanstorp,

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Optical twee

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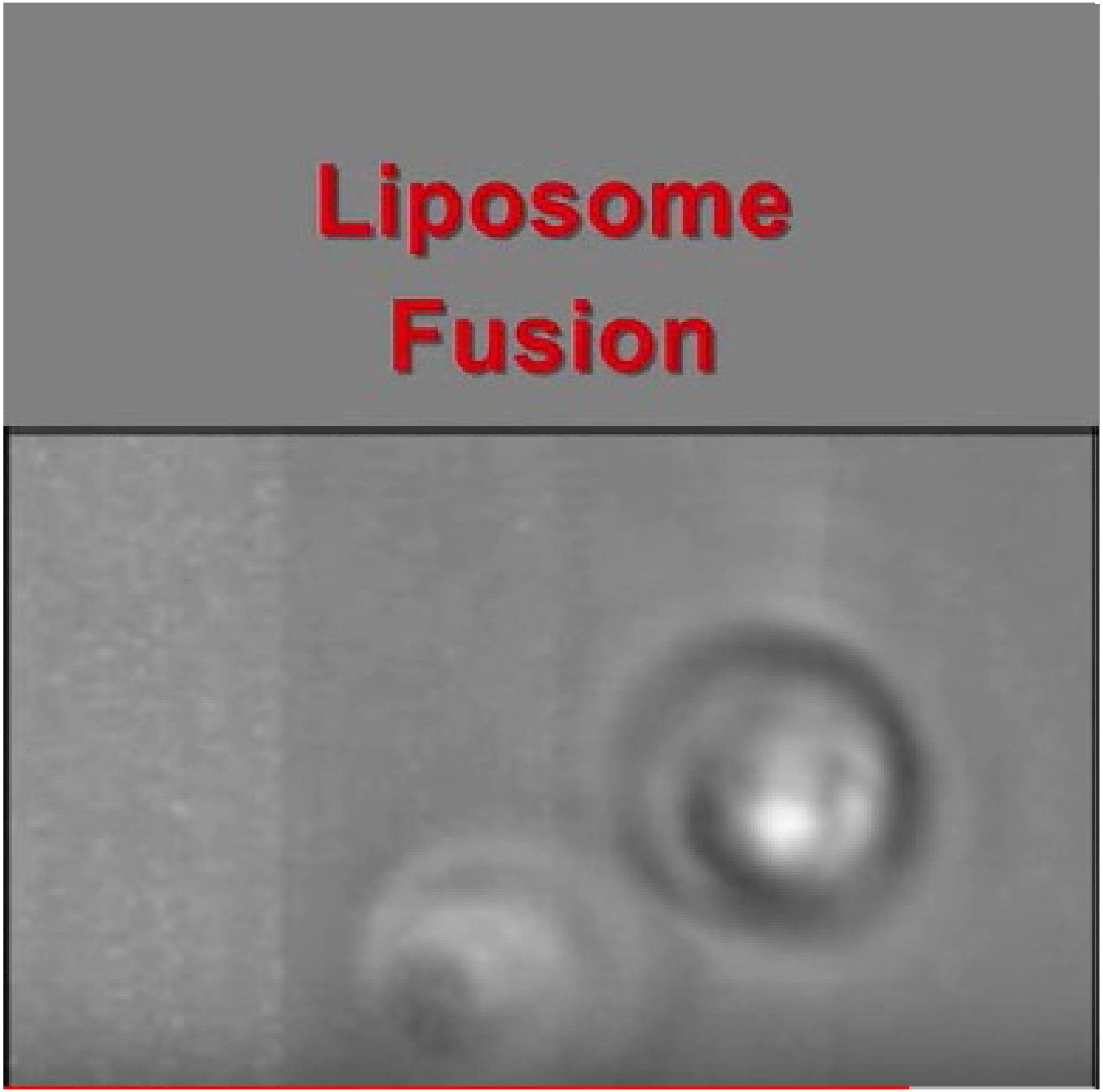
Non-contact fiber-optical trapping of motile bacteria: dynamics observation and energy es

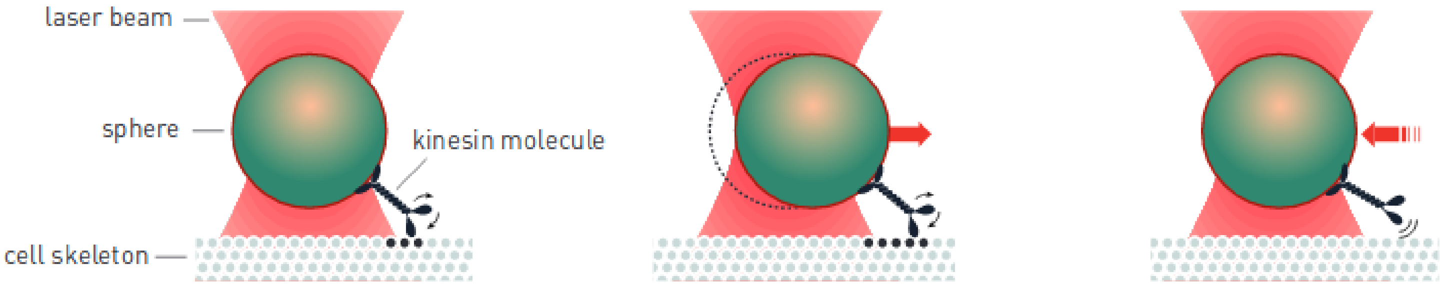
Figure 1: Model of the modified tapered fiber and numerical results.



https://www.youtube.com/watch?v=xmUHwHoVBIY

A motor molecule walks inside the light trap

Молекулярний мотор



1 The kinesin molecule attaches to a small sphere held by the optical tweezers.

2 Kinesin marches away along the cell skeleton. It pulls the sphere, making it possible to measure the kinesin's stepwise motion.

3 Finally, the motor molecule can no longer withstand the force of the light trap and the sphere is forced back to the centre of the beam.

©Johan Jarnestad/The Royal Swedish Academy of Sciences

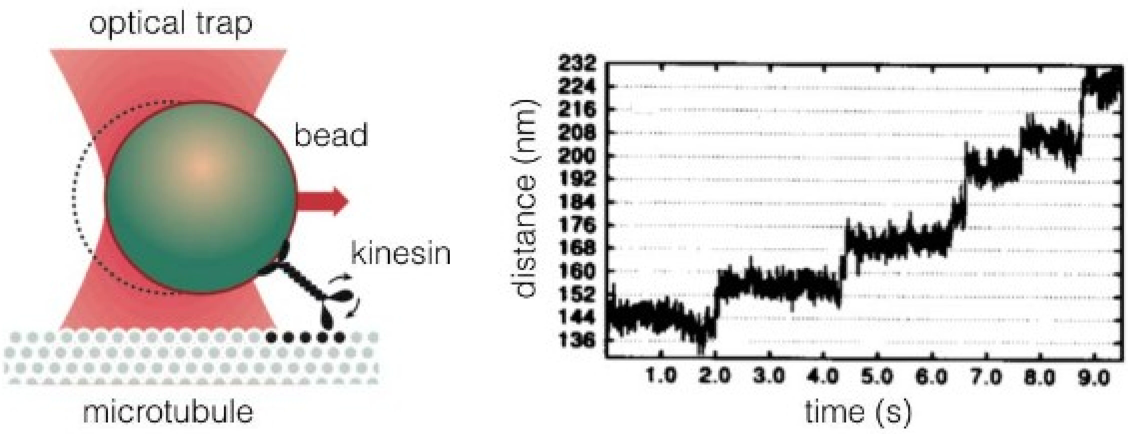
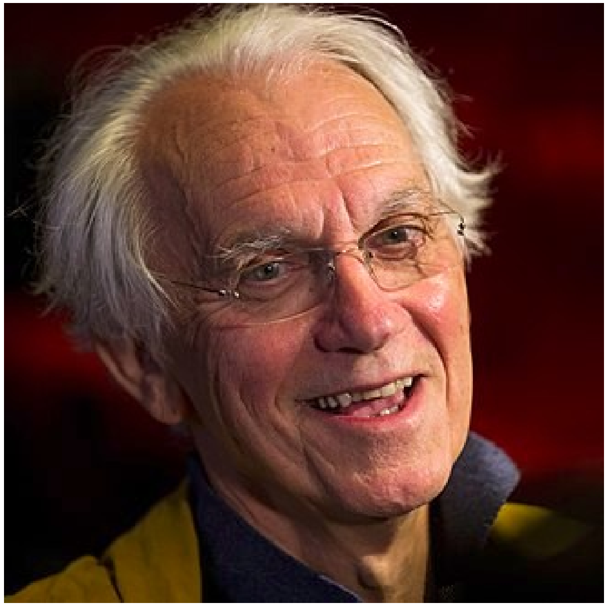


Figure 2: *(Left) Sketch of the kinesin-microtubule system studied with optical tweezers in reference [39]. An optically trapped bead carries a single kinesin molecule that walks along an immobilized microtubule filament. (Right) Displacement versus time graph for a bead, which shows that the kinesin molecule executes a walk, pulling the bead forward in a stepwise manner.*

www.nobelprize.org/uploads/2018/10/advanced-physicsprize2018.pdf



Mourou, Gérard A.

Born: 22 June 1944, Albertville, France

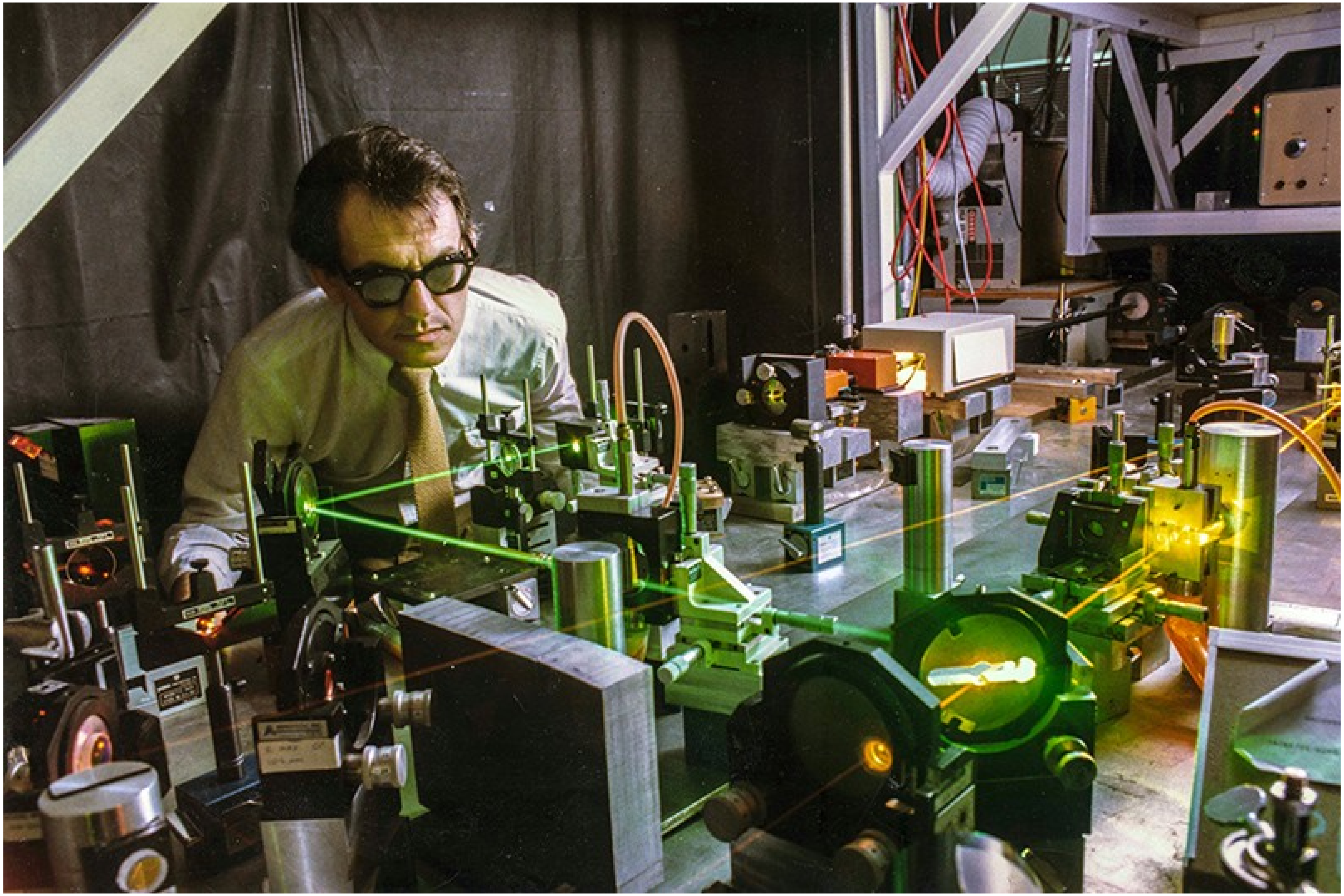
Affiliation at the time of the award: École Polytechnique, Palaiseau, France; University of Michigan, Ann Arbor, MI, USA

Academic Positions

professor and member of Haut Collège at the École Polytechnique and
A. D. Moore Distinguished University Professor Emeritus
1973 University of Rochester, Laboratory for Laser Energetics
1988 Mourou joined the University of Michigan at Ann Arbor
1991 he founded U-M’s Center for Ultrafast Optical Science
2008 Director of the Laboratory of Applied Optics at the École Polytechnique until
2005 to 2009 director of the Laboratoire d'Optique Appliquée at the ENSTA

Education

Ph.D. Pierre and Marie Curie University 1973
University of Grenoble, license de Physique(1967),
Universite Paris VI,Thèse de 3è Mecycle (1970)



Gérard Mourou, in a 1987 photograph from the Laboratory for Laser Energetics. Mourou’s work at Rochester has helped shape the direction of research in high-powered lasers. (University of Rochester photo)

www.rochester.edu/newscenter/rochesters-breakthrough-in-laser-science-earns-nobel-prize-340302/

Awards

- Chevalier de la Legion d’ Honneur 2012
- Recipient of the 2009 Charles H. Townes Award from the Optical Society of America
- Recipient of the 2007 Grand Prix Carnot from the French National Academy
- Recipient of the 2005 of the Physics of Quantum Electronics Lamb Medal
- Recipient of the 2004 Chaire d’ Excellence from the French Ministry of Research
- Recipient of the 2004 Quantum Electronic Award from IEEE-LEOS
- Recipient of the 2002 Russel Award from the University of Michigan (Highest Honor fro
the University)
- Recipient of the 1999 D. Sarnoff Award from IEEE
- Recipient of the 1997 H. Edgerton Award from the SPIE
- Recipient of the 1995 R. W. Wood Prize, from the OSA

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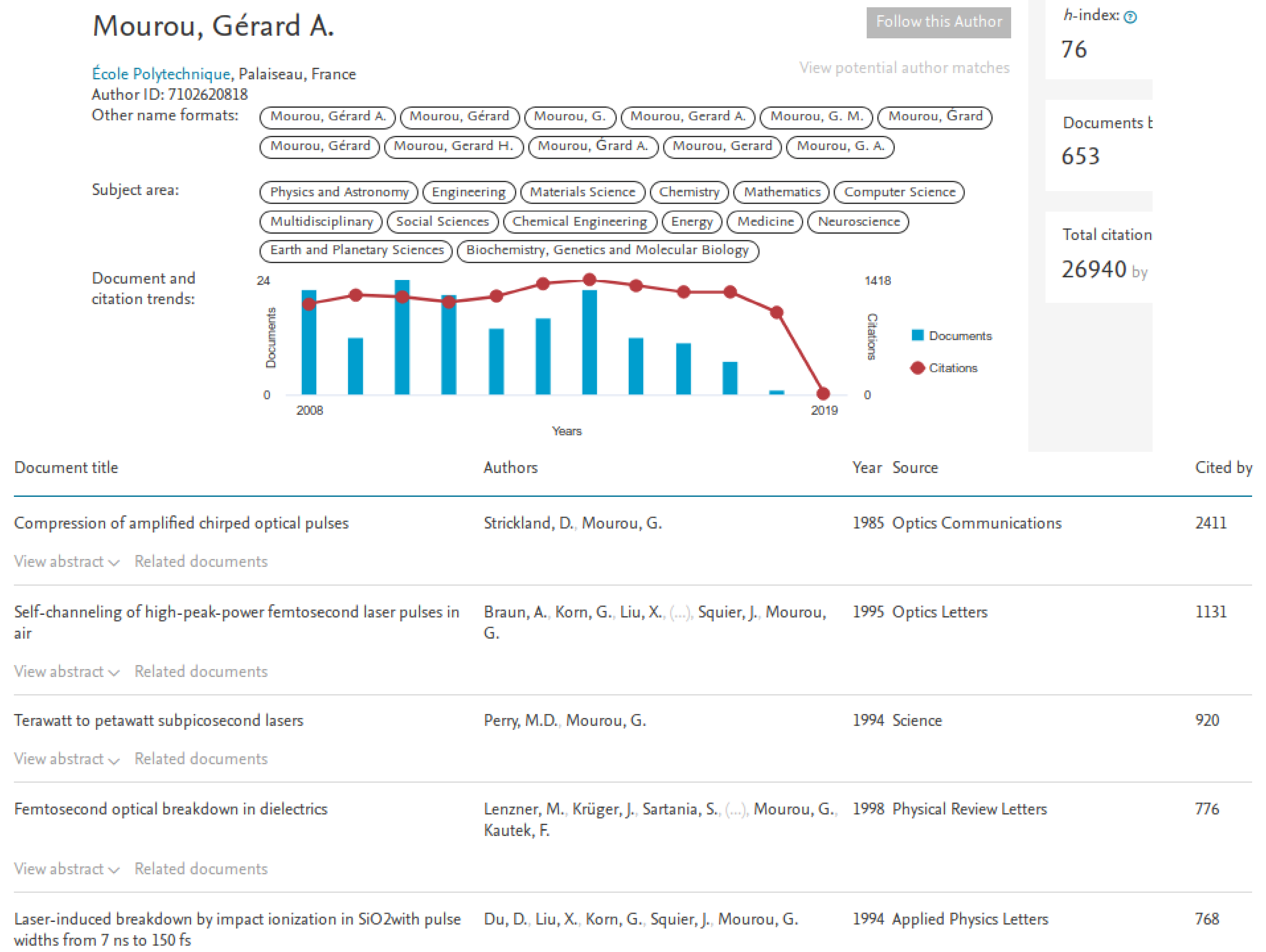
CENTER FOR ULTRAFAST OPTICAL SCIENCE



Mourou, Gérard A.

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École Polytechnique, Palaiseau, France
Author ID: 7102620818

Other name formats: Mourou, Gérard A. | Mourou, Gérard | Mourou, G. | Mourou, Gerard A. | Mourou, G. M. | Mourou, Ǵrard | Mourou, Gérard | Mourou, Gerard H. | Mourou, Ǵrard A. | Mourou, Gerard | Mourou, G. A.

Subject area: Physics and Astronomy | Engineering | Materials Science | Chemistry | Mathematics | Computer Science | Multidisciplinary | Social Sciences | Chemical Engineering | Energy | Medicine | Neuroscience | Earth and Planetary Sciences | Biochemistry, Genetics and Molecular Biology

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Document title	Authors	Year	Source	Cited by
Compression of amplified chirped optical pulses View abstract Related documents	Strickland, D., Mourou, G.	1985	Optics Communications	2411
Self-channeling of high-peak-power femtosecond laser pulses in air View abstract Related documents	Braun, A., Korn, G., Liu, X., (...), Squier, J., Mourou, G.	1995	Optics Letters	1131
Terawatt to petawatt subpicosecond lasers View abstract Related documents	Perry, M.D., Mourou, G.	1994	Science	920
Femtosecond optical breakdown in dielectrics View abstract Related documents	Lenzner, M., Krüger, J., Sartania, S., (...), Mourou, G., Kautek, F.	1998	Physical Review Letters	776
Laser-induced breakdown by impact ionization in SiO2with pulse widths from 7 ns to 150 fs	Du, D., Liu, X., Korn, G., Squier, J., Mourou, G.	1994	Applied Physics Letters	768

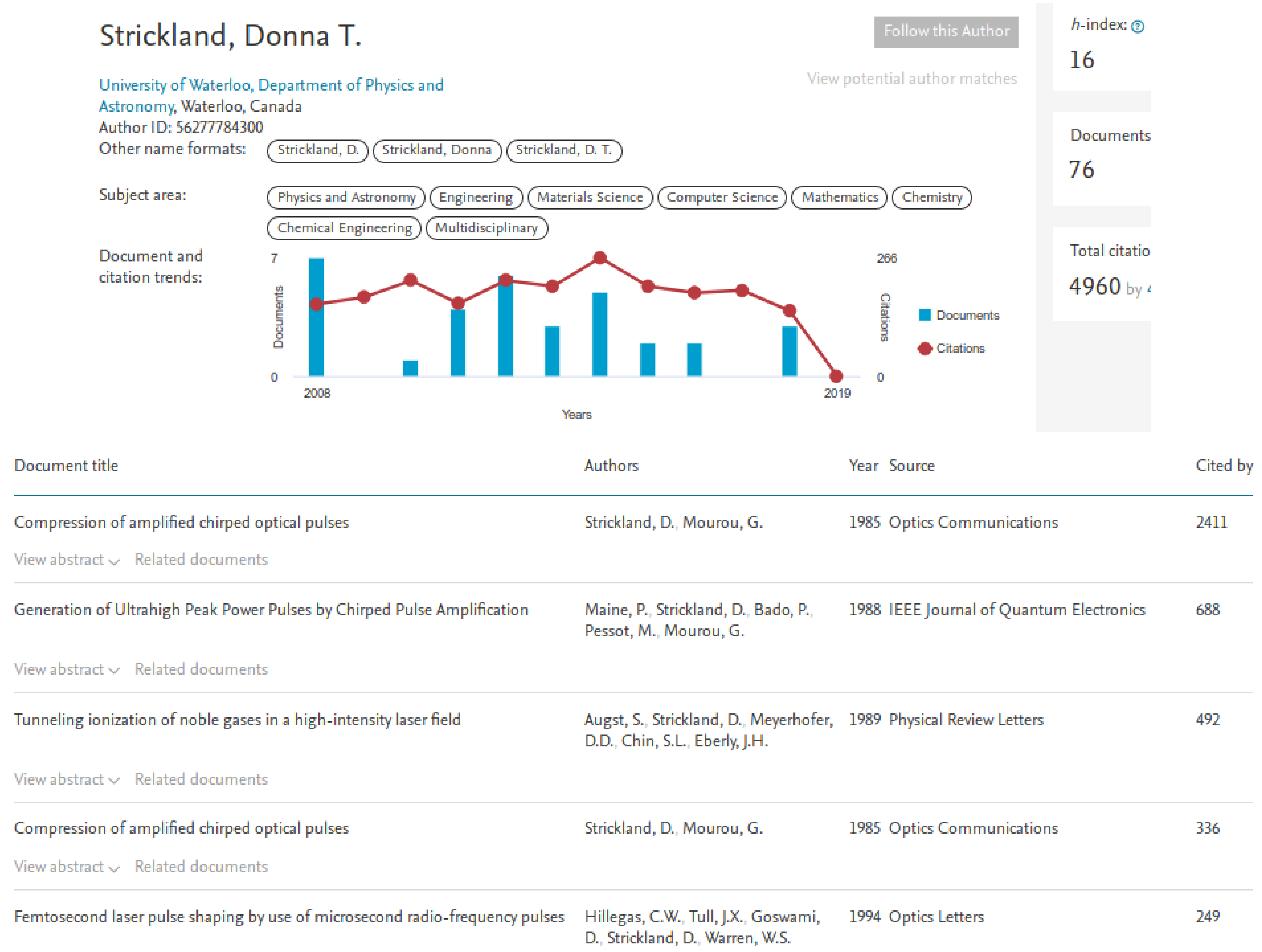
Strickland, Donna T.

Born: 27 May 1959, Guelph, Canada

Present Position
University of Waterloo, Department of Physics and Astronomy, Waterloo, Canada

Career
Research associate at the National Research Council of Canada 1988 to 1991
Laser division of Lawrence Livermore National Laboratory 1991 to 1992
Princeton University's Advanced Technology Center for Photonics and Opto-electronic Materials 1992 to 1997
University of Waterloo in 1997 — present

Education
B.Eng. - McMaster University 1981
Ph.D. (Physics) - University of Rochester 1989



Strickland, Donna T.

University of Waterloo, Department of Physics and Astronomy, Waterloo, Canada
Author ID: 56277784300
Other name formats: Strickland, D. | Strickland, Donna | Strickland, D. T.

Subject area: Physics and Astronomy | Engineering | Materials Science | Computer Science | Mathematics | Chemistry | Chemical Engineering | Multidisciplinary

Document and citation trends:

h-index: 16

Documents 76

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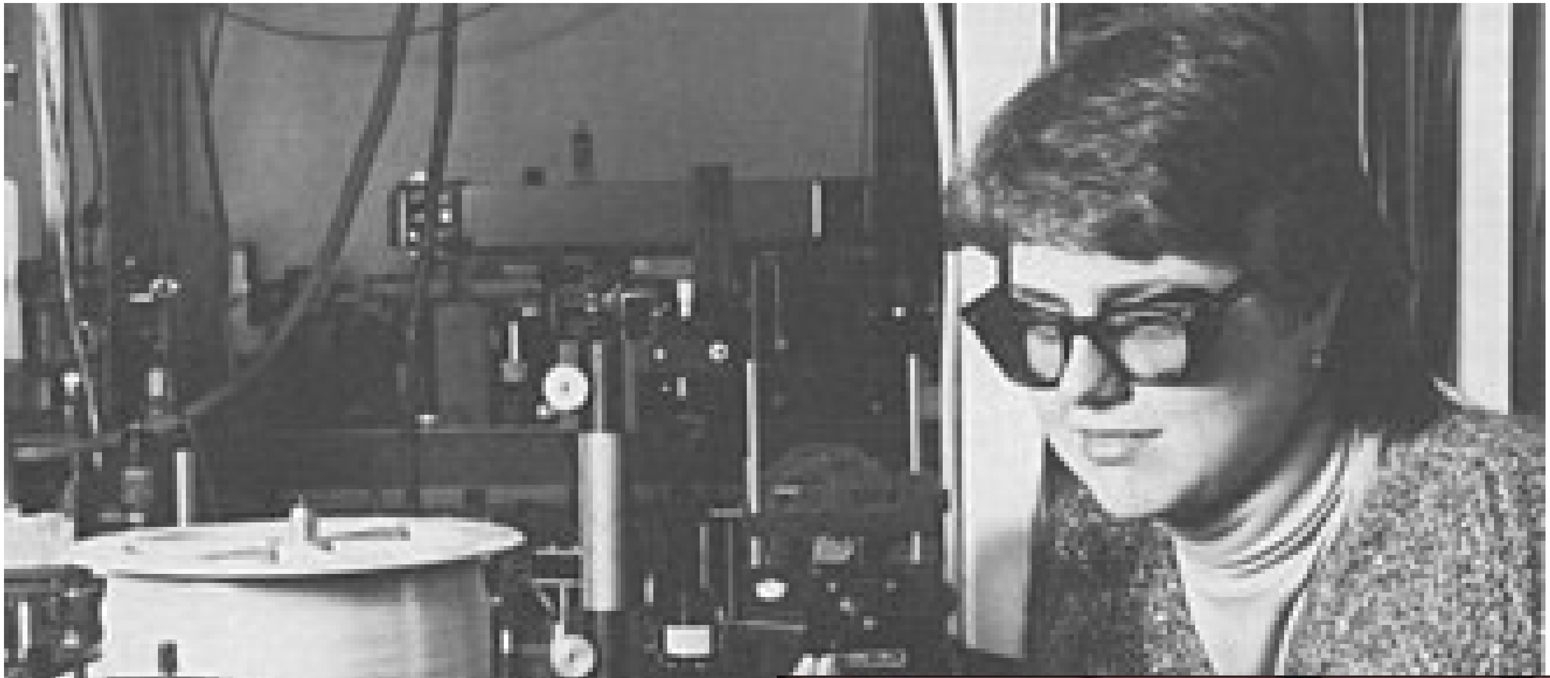
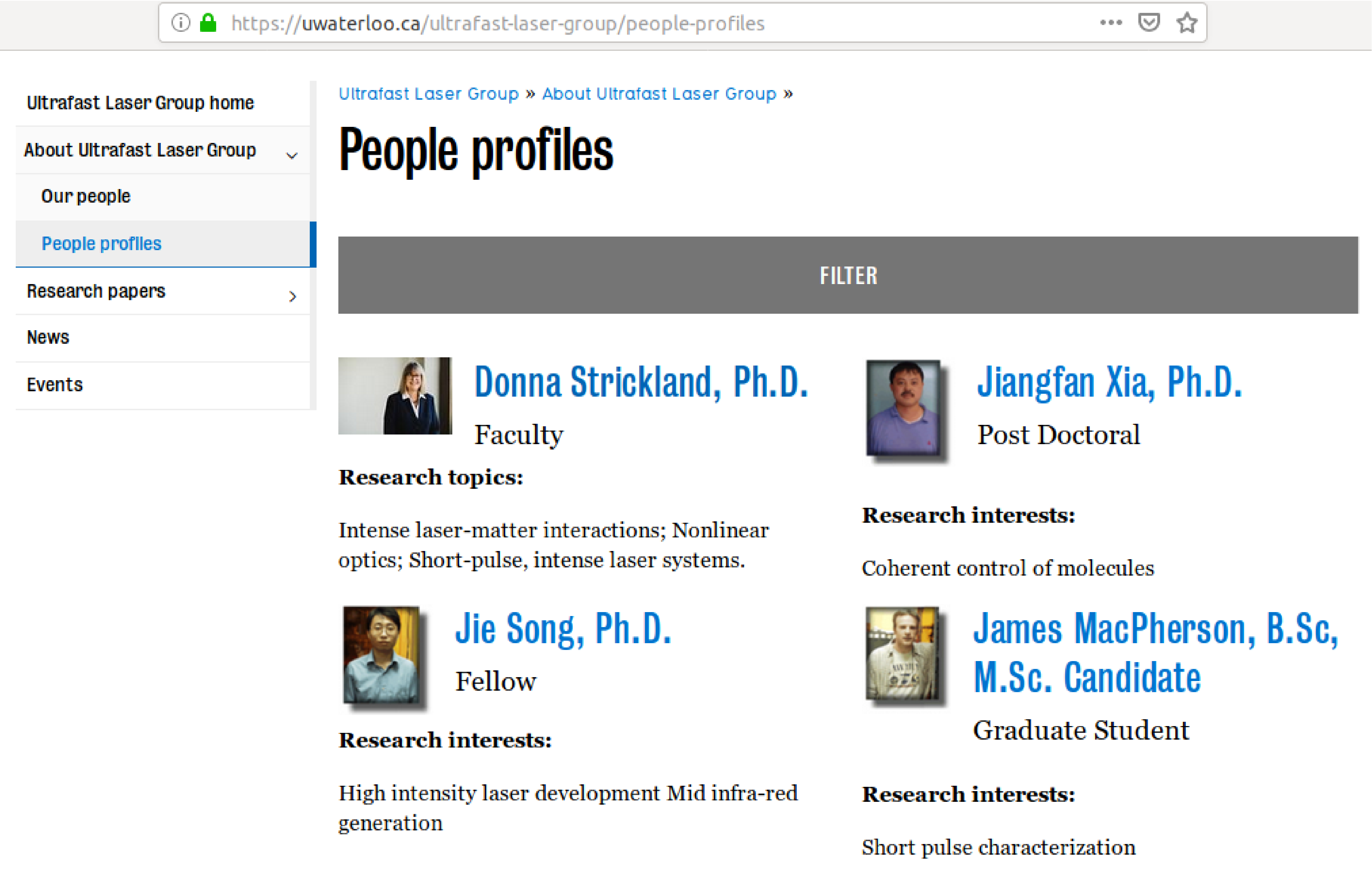
Document title	Authors	Year	Source	Cited by
Compression of amplified chirped optical pulses	Strickland, D., Mourou, G.	1985	Optics Communications	2411
Generation of Ultrahigh Peak Power Pulses by Chirped Pulse Amplification	Maine, P., Strickland, D., Bado, P., Pessot, M., Mourou, G.	1988	IEEE Journal of Quantum Electronics	688
Tunneling ionization of noble gases in a high-intensity laser field	Augst, S., Strickland, D., Meyerhofer, D.D., Chin, S.L., Eberly, J.H.	1989	Physical Review Letters	492
Compression of amplified chirped optical pulses	Strickland, D., Mourou, G.	1985	Optics Communications	336
Femtosecond laser pulse shaping by use of microsecond radio-frequency pulses	Hillegas, C.W., Tull, J.X., Goswami, D., Strickland, D., Warren, W.S.	1994	Optics Letters	249



Strickland aligning an optical fiber during her gradua
Group at the University of Rochester, 1985



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FILTER

Donna Strickland, Ph.D.

Faculty

Research topics:

Intense laser-matter interactions; Nonlinear optics; Short-pulse, intense laser systems.

Jiangfan Xia, Ph.D.

Post Doctoral

Research interests:

Coherent control of molecules

Jie Song, Ph.D.

Fellow

Research interests:

High intensity laser development Mid infra-red generation

James MacPherson, B.Sc, M.Sc. Candidate

Graduate Student

Research interests:

Short pulse characterization

$$\nu_i(t) = \nu_0 + \frac{b}{\pi} t$$

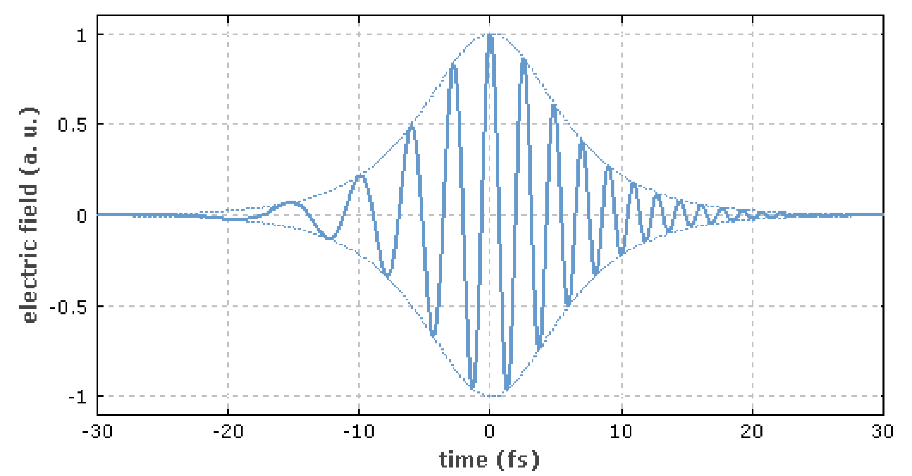


Figure 1: Electric field of a strongly up-chirped pulse, where the instantaneous frequency grows with time.

www.rp-photonics.com/chirp.html

Volume 56, number 3 OPTICS COMMUNICATIONS 1 December 1985

COMPRESSION OF AMPLIFIED CHIRPED OPTICAL PULSES ☆

Donna STRICKLAND and Gerard MOUROU

Laboratory for Laser Energetics, University of Rochester, 250 East River Road, Rochester, NY 14623-1299, USA

Received 5 July 1985

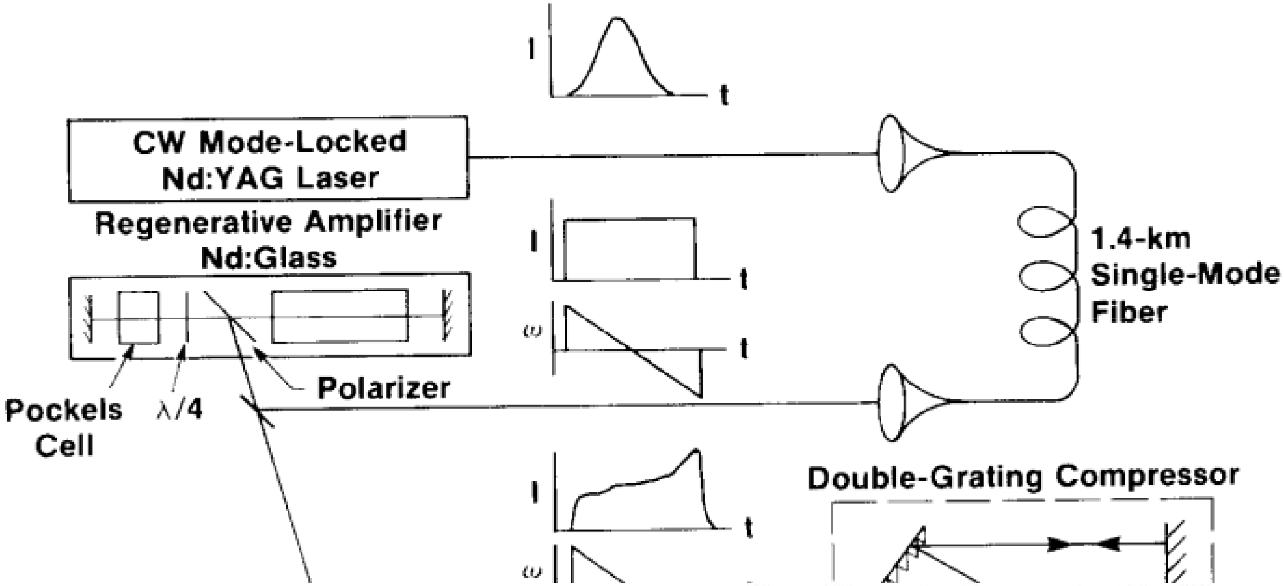
We have demonstrated the amplification and subsequent recompression of optical chirped pulses. A system which produces 1.06 μm laser pulses with pulse widths of 2 ps and energies at the millijoule level is presented.

The onset of self-focusing of intense light pulses limits the amplification of ultra-short laser pulses. A similar problem arises in radar because of the need for short, yet energetic pulses, without having circuits capable of handling the required peak powers. The solution for radar transmission is to stretch the pulse by passing it through a positively dispersive delay line before amplifying and transmitting the pulse. The echo is compressed to its original pulse shape by a negatively dispersive delay line [1].

We wish to report here a system which transposes the technique employed in radar to the optical regime, and that in principle should be capable of producing short ($\lesssim$1 ps) pulses with energies at the Joule level. A long pulse is deliberately produced by stretching a

pulse would be free from gain saturation effects, because the frequency varies along the pulsewidth and each frequency component sees gain independently.

A schematic diagram of the amplifier and compression system is shown in fig. 1. A CW mode-locked, Nd : YAG laser (Spectra-Physics Series 3000) is used to produce 150 ps pulses at an 82 MHz repetition rate. Five watts of average power are coupled into 1.4 km of single-mode non-polarization-preserving optical fiber. The fiber (Corning Experimental SMF/DS$^{\text{TM}}$) has a core diameter of 9 μm. The average power at the output of the fiber is 2.3 W. The pulses have a rectangular pulseshape with a pulse width of approximately 300 ps, as can be seen from the autocorrelation trace in fig. 2. The bandwidth of the pulses is



therefore the losses in the fiber are immaterial. The

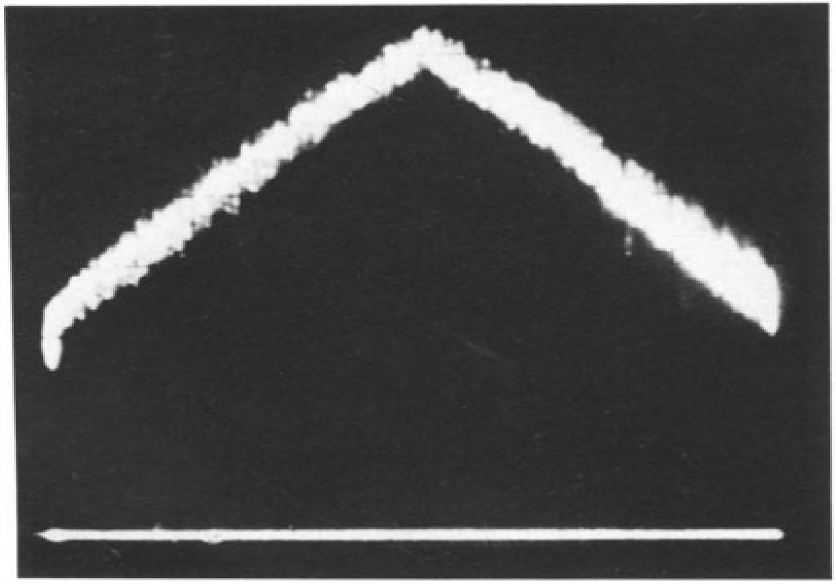


Fig. 2. Autocorrelation of stretched pulse at output of fiber. The pulse is rectangular in shape with a 300 ps pulsewidth.

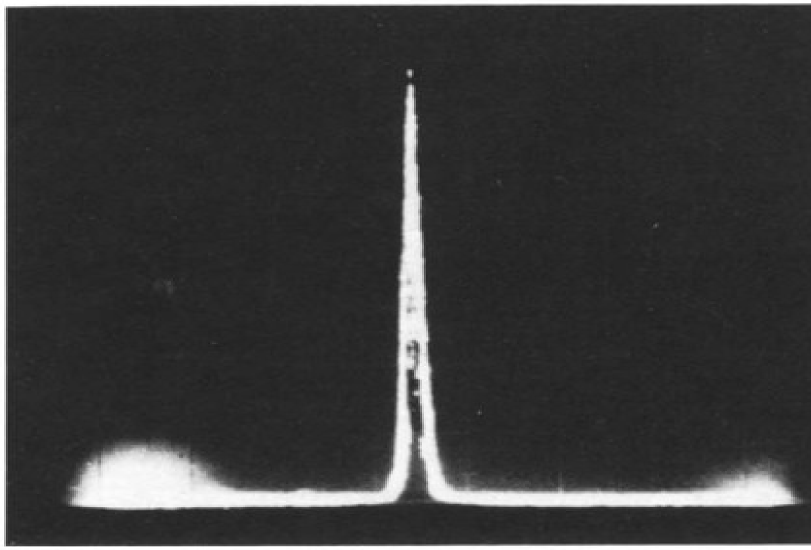
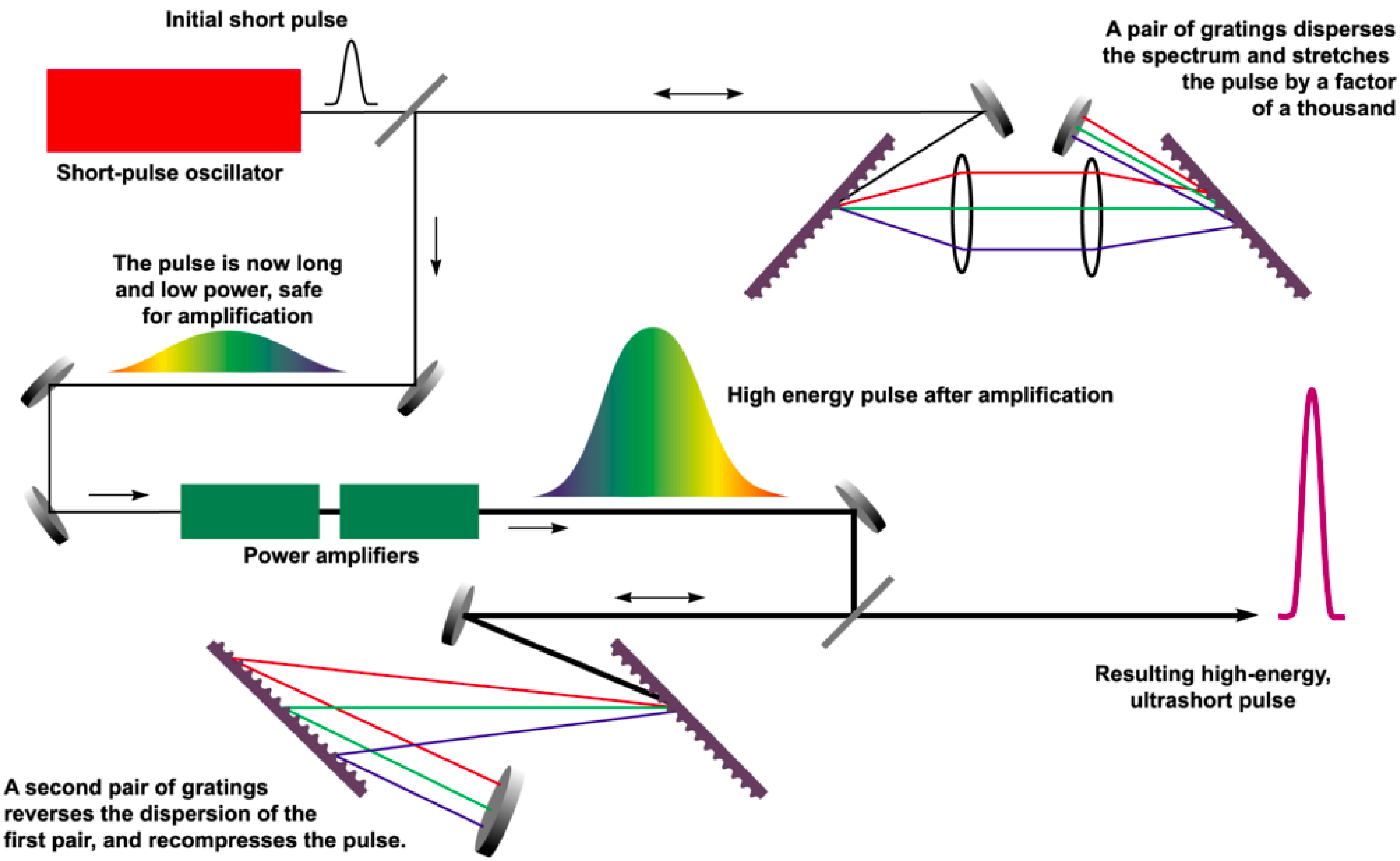
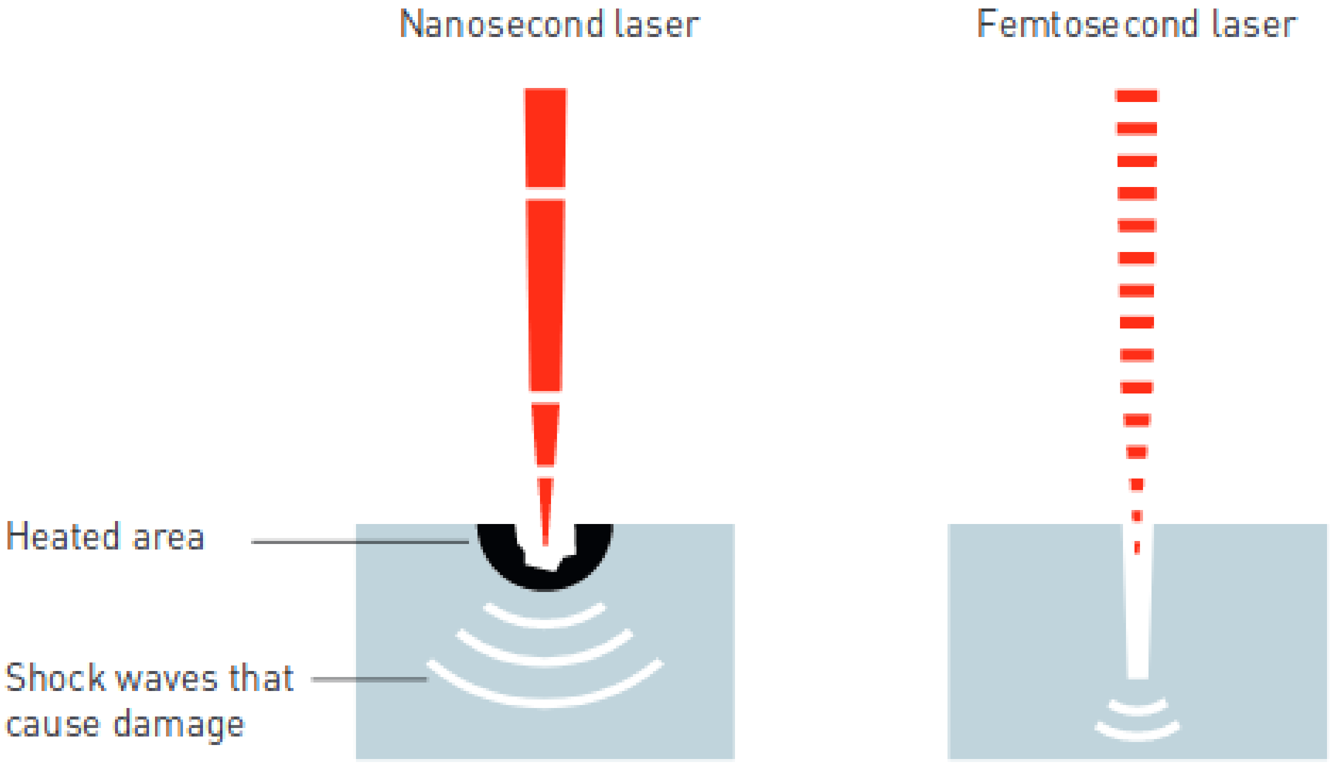


Fig. 3. Autocorrelation of 1.5 ps compressed pulse.

Chirped pulse amplification



https://en.wikipedia.org/wiki/Chirped_pulse_amplification



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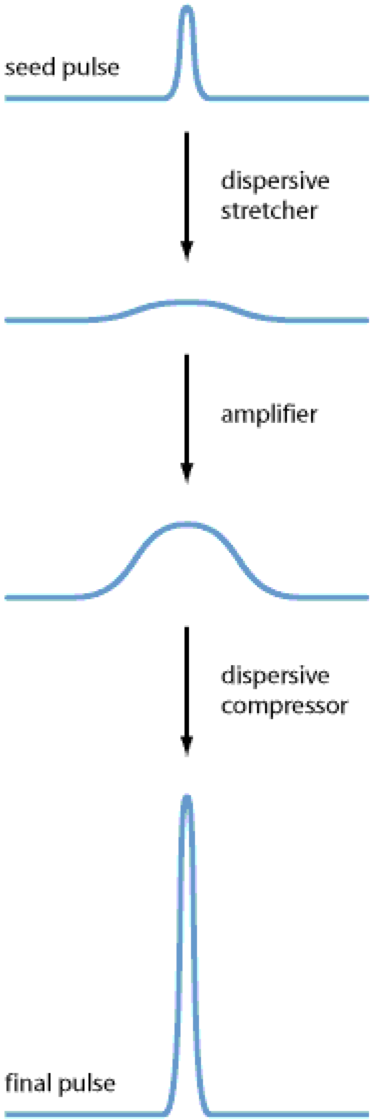

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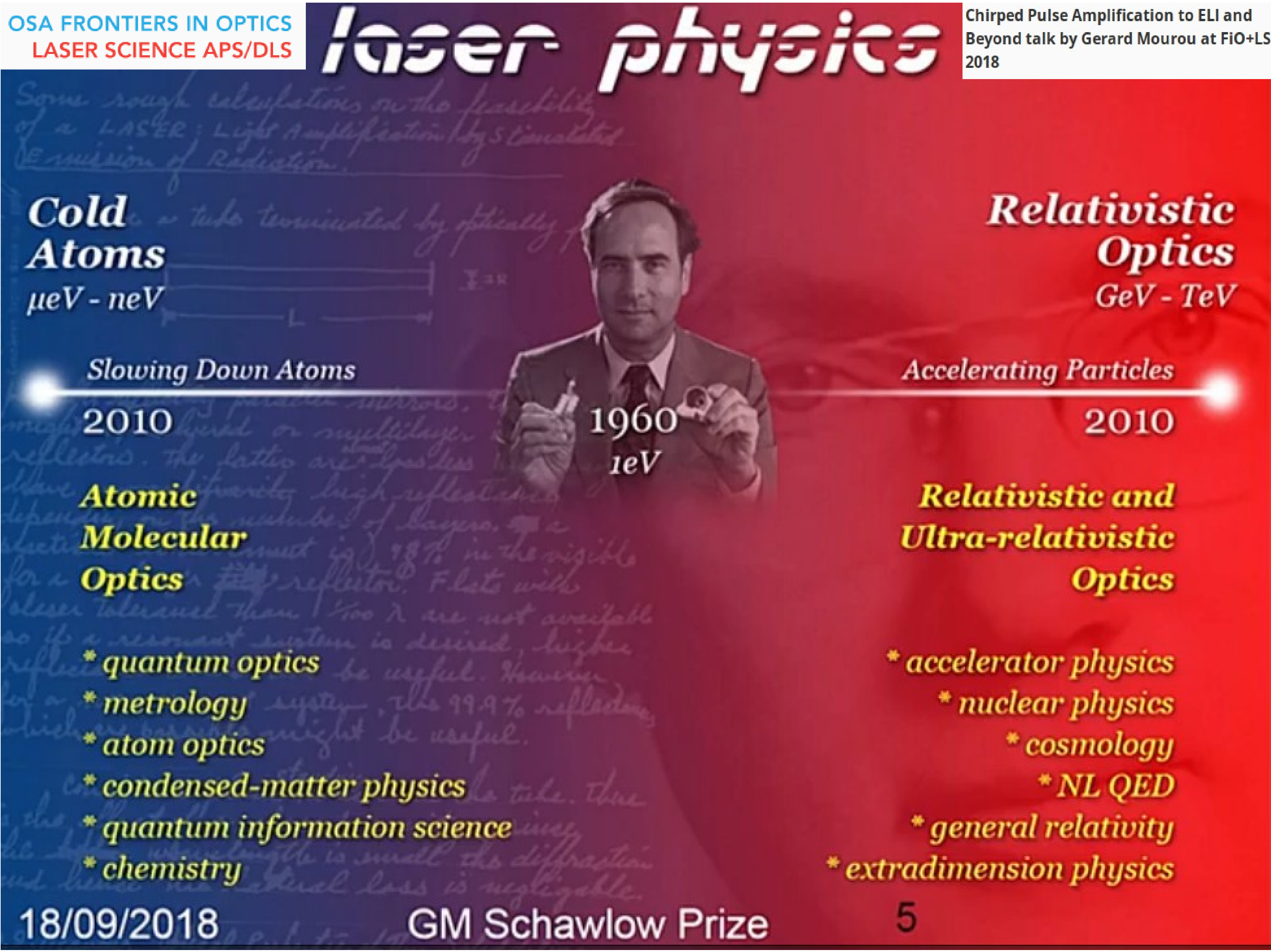


laser physics

Cold Atoms
μeV - neV

Relativistic Optics
GeV - TeV

Slowing Down Atoms — *Accelerating Particles*

2010 — 1960 *1eV* — 2010

Atomic Molecular Optics

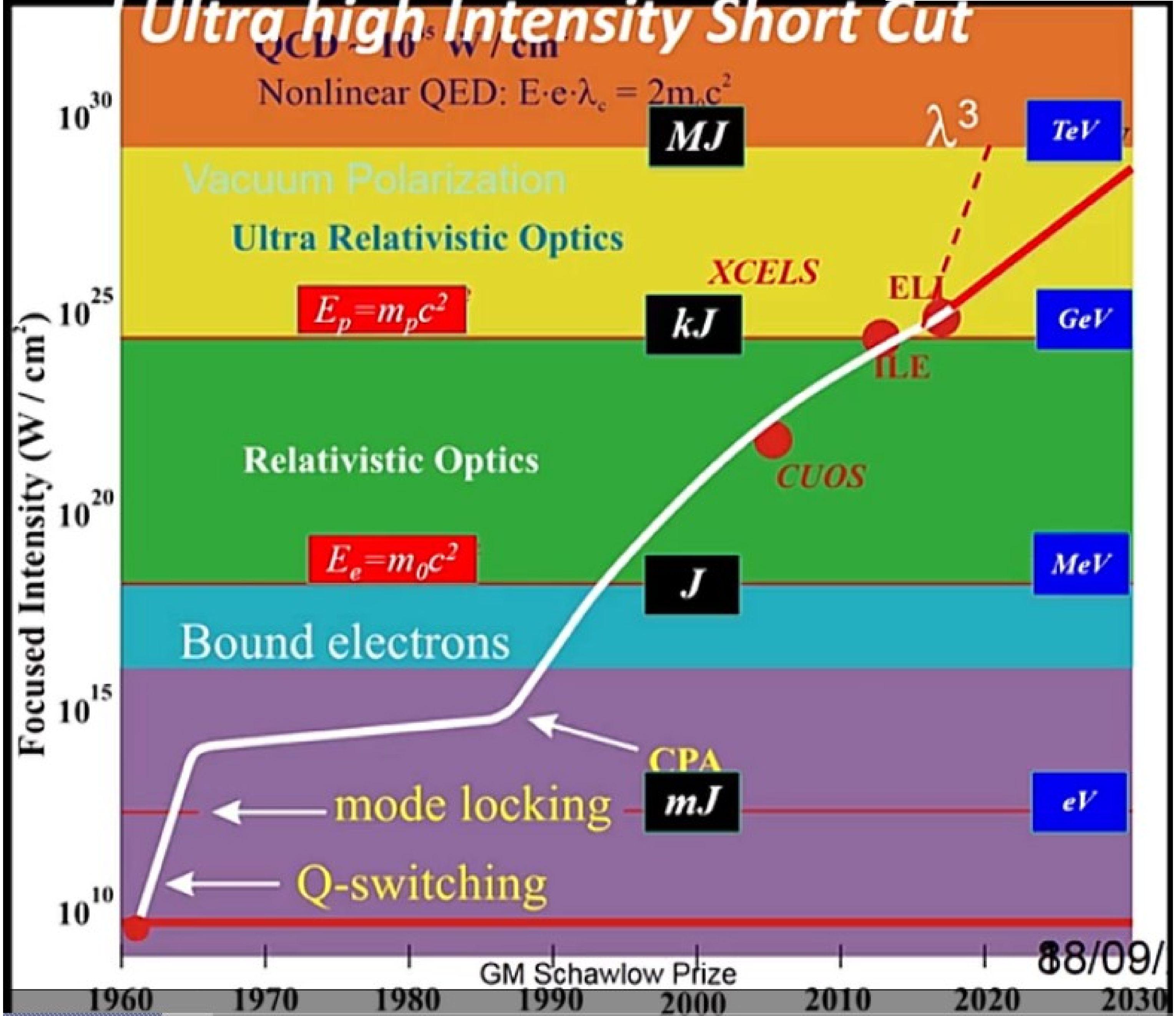
- *quantum optics*
- *metrology*
- *atom optics*
- *condensed-matter physics*
- *quantum information science*
- *chemistry*

Relativistic and Ultra-relativistic Optics

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

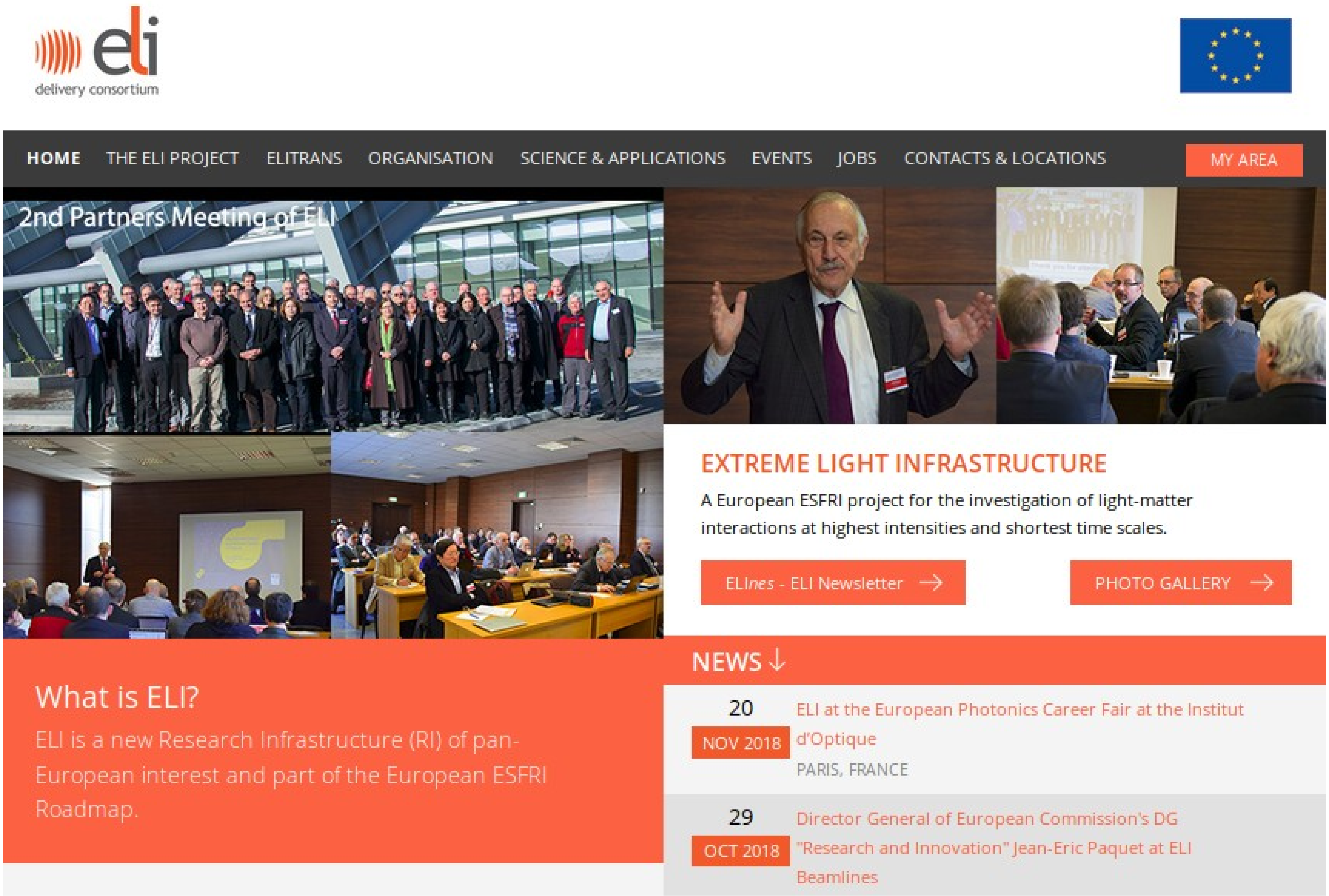
Extreme Light Road Map / Ultra high Intensity Short Cut

Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018



Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018

Extreme Light Petawatt in the World



EXTREME LIGHT INFRASTRUCTURE

A European ESFRI project for the investigation of light-matter interactions at highest intensities and shortest time scales.

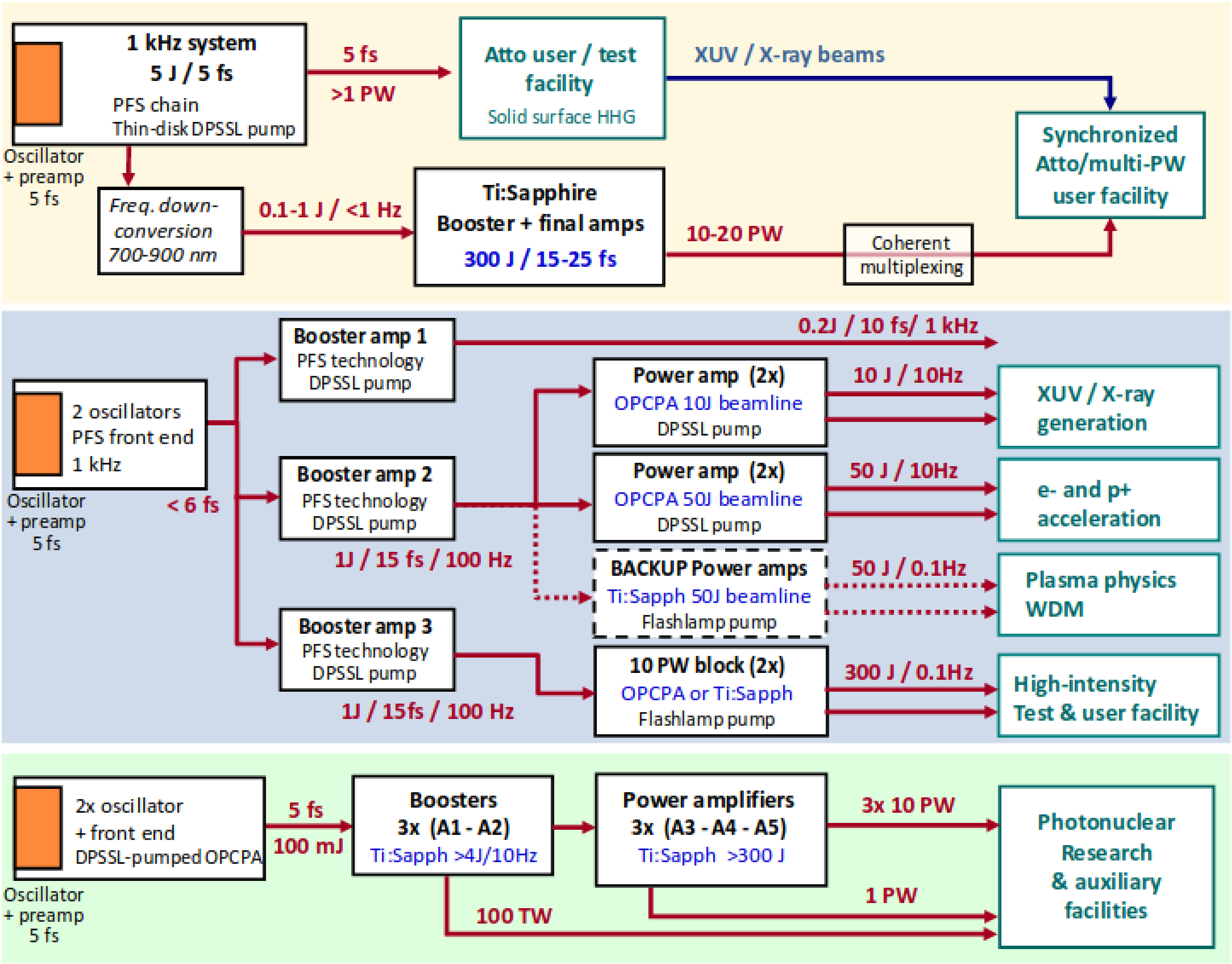
What is ELI?

ELI is a new Research Infrastructure (RI) of pan-European interest and part of the European ESFRI Roadmap.

20 NOV 2018 ELI at the European Photonics Career Fair at the Institut d'Optique
PARIS, FRANCE

29 OCT 2018 Director General of European Commission's DG "Research and Innovation" Jean-Eric Paquet at ELI Beamlines

eli-laser.eu



1 kHz system
5 J / 5 fs
PFS chain
Thin-disk DPSSL pump
Oscillator
+ preamp
5 fs
5 fs
>1 PW
Atto user / test facility
Solid surface HHG
XUV / X-ray beams
Synchronized Atto/multi-PW user facility
Freq. down-conversion 700-900 nm
0.1-1 J / <1 Hz
Ti:Sapphire
Booster + final amps
300 J / 15-25 fs
10-20 PW
Coherent multiplexing

0.2J / 10 fs/ 1 kHz
Booster amp 1
PFS technology
DPSSL pump
2 oscillators
PFS front end
1 kHz
Oscillator
+ preamp
5 fs
< 6 fs
Booster amp 2
PFS technology
DPSSL pump
1J / 15 fs / 100 Hz
Booster amp 3
PFS technology
DPSSL pump
1J / 15fs / 100 Hz
Power amp (2x)
OPCPA 10J beamline
DPSSL pump
10 J / 10Hz
XUV / X-ray generation
Power amp (2x)
OPCPA 50J beamline
DPSSL pump
50 J / 10Hz
e- and p+ acceleration
BACKUP Power amps
Ti:Sapph 50J beamline
Flashlamp pump
50 J / 0.1Hz
Plasma physics
WDM
10 PW block (2x)
OPCPA or Ti:Sapph
Flashlamp pump
300 J / 0.1Hz
High-intensity
Test & user facility

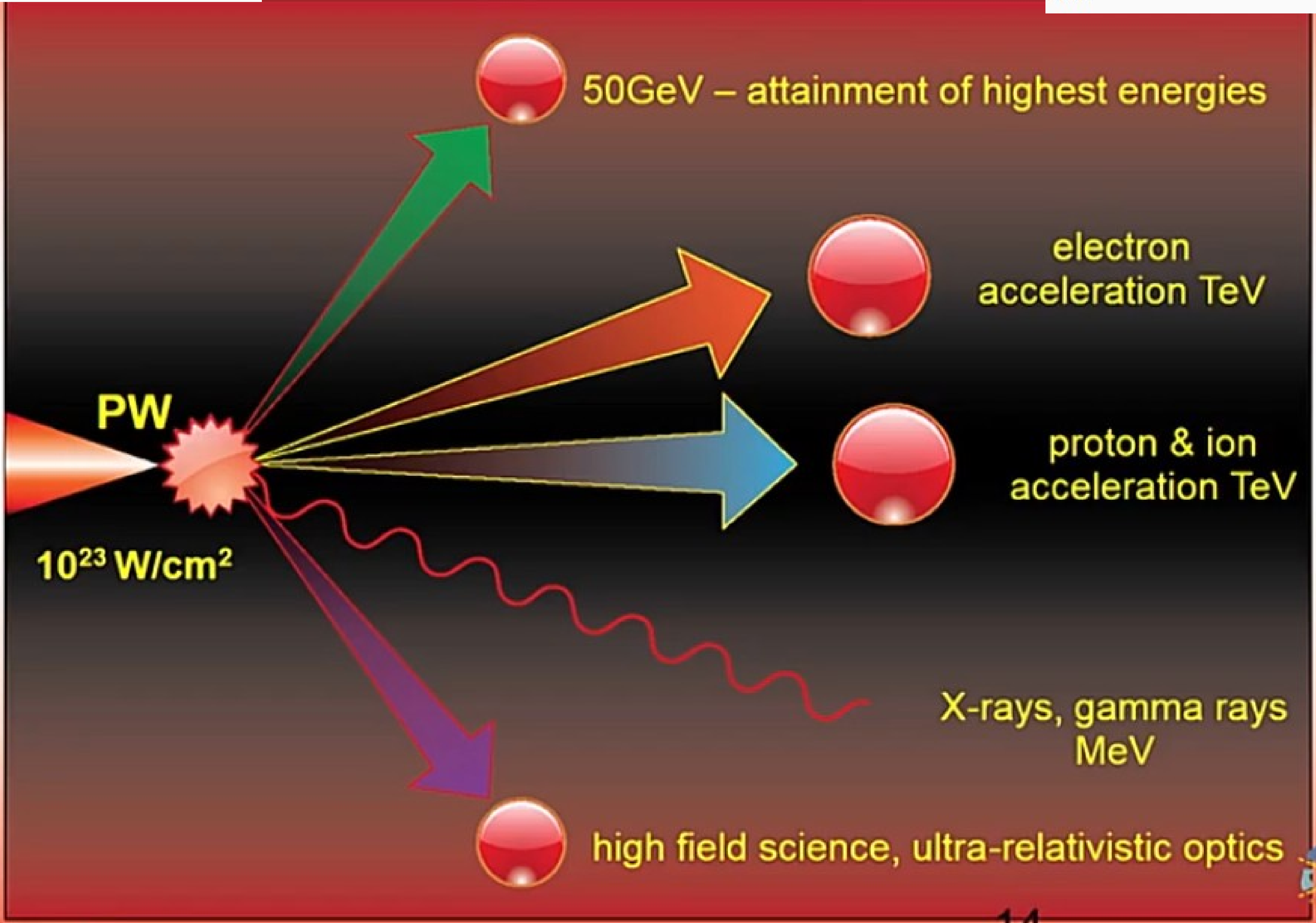
2x oscillator
+ front end
DPSSL-pumped OPCPA
Oscillator
+ preamp
5 fs
5 fs
100 mJ
Boosters
3x (A1 - A2)
Ti:Sapph >4J/10Hz
100 TW
Power amplifiers
3x (A3 - A4 - A5)
Ti:Sapph >300 J
3x 10 PW
1 PW
Photonuclear Research & auxiliary facilities

Schemes of the plannedELIlaser facilities: Top:Attosecond facility, middle:beam-line facility, bottom:photonuclear facility.

https://www.osapublishing.org/DirectPDFAccess/16A0B496-E90D-0E1D-E82AC9BB8D354AAB_201105/CLEO-2010-JThG2.pdf?da=1&id=201105&uri=CLEO-2010-JThG2&seq=0&mobile=no

Extreme Light: Universal Source of Radiations and Particles

Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018



PW

10^{23} W/cm²

50GeV – attainment of highest energies

electron acceleration TeV

proton & ion acceleration TeV

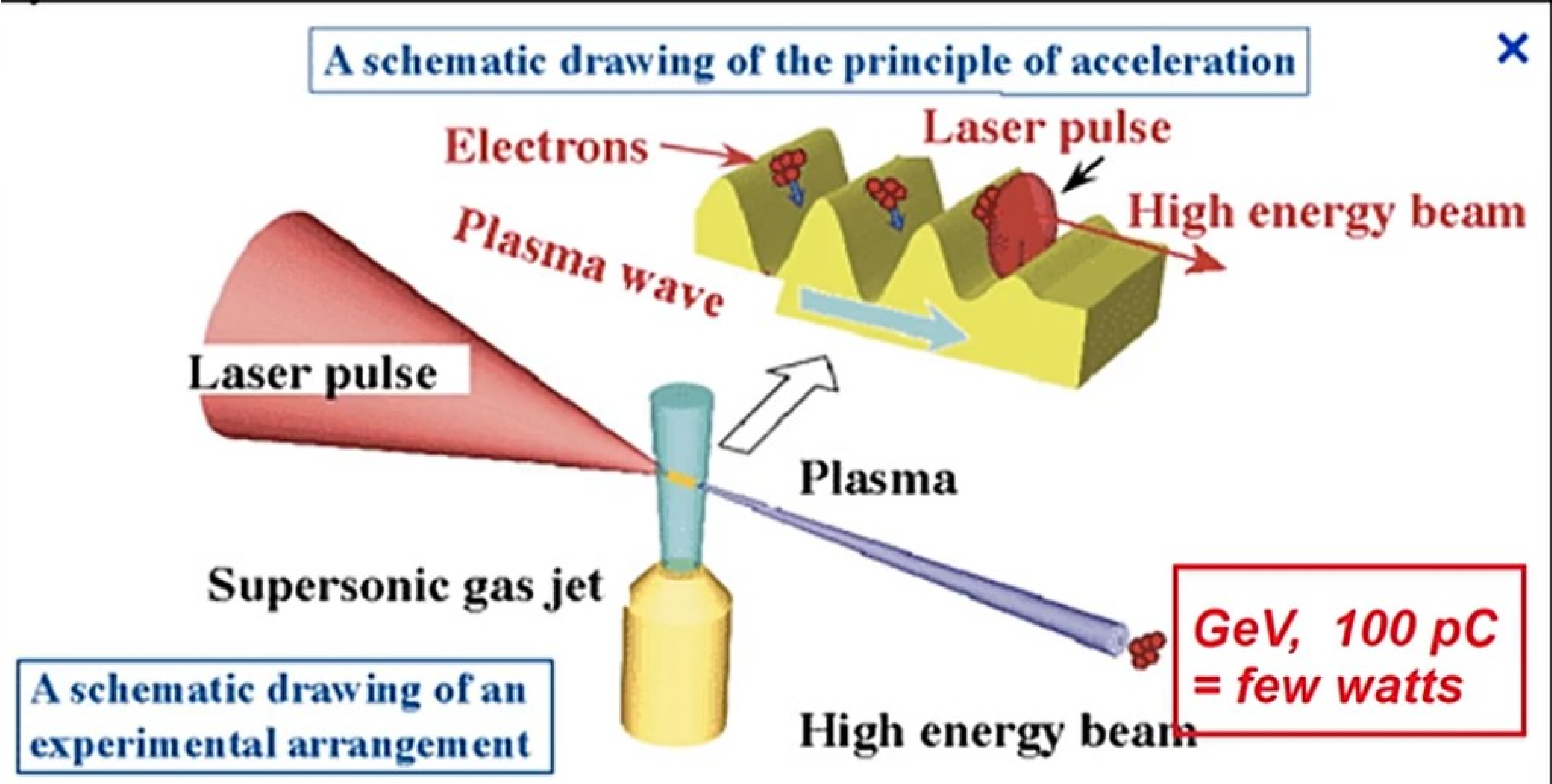
X-rays, gamma rays MeV

high field science, ultra-relativistic optics

Laser Wakefield Acceleration

T.Tajima and J. Dawson1989

GeV/cm gradient W. Leemans 2014



GeV, 100 pC = few watts

Single Cycle Pulse Compression Pulse: History

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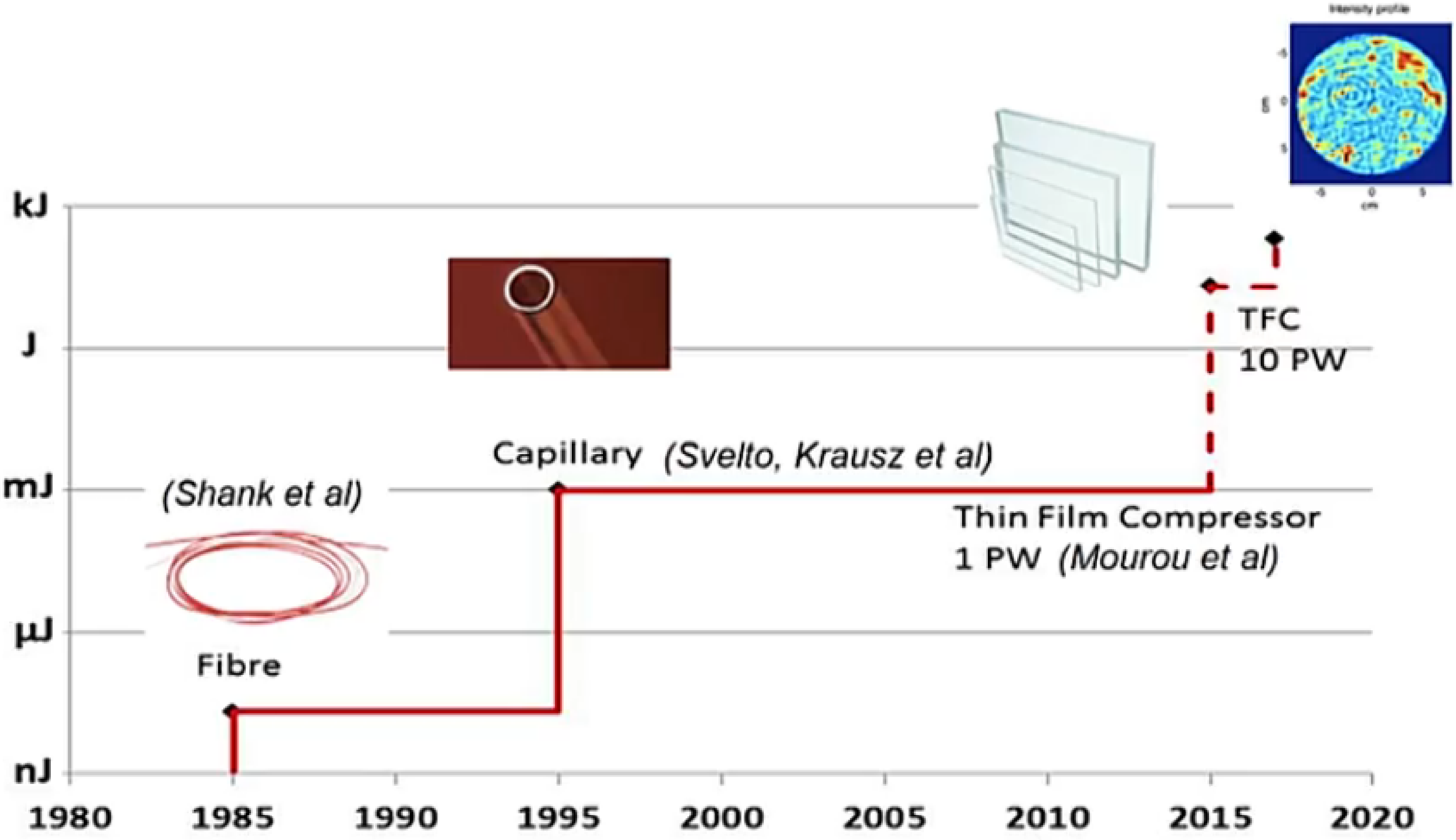
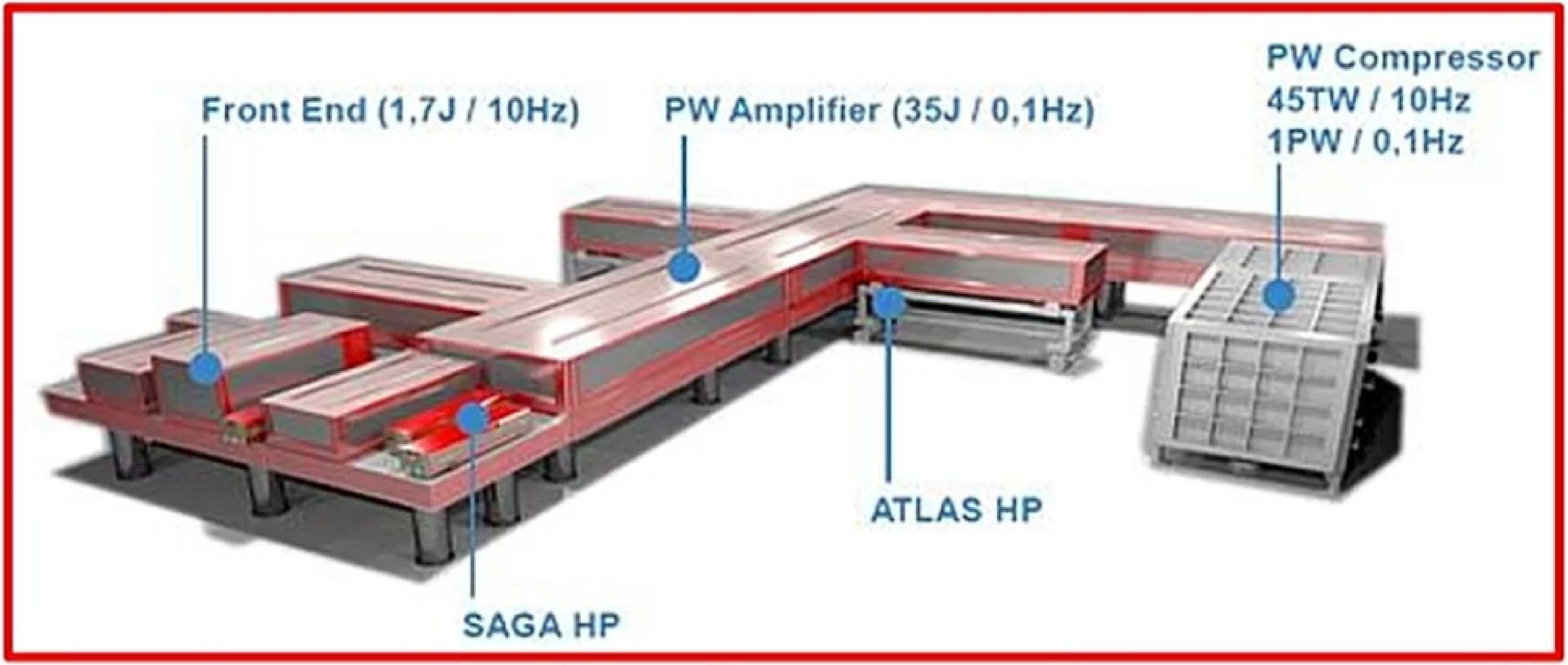


G Mourou, S. Mironov, Single cycle thin film compressor opening the door to Zeptosecond-Exawatt Physics ,Eur. Phys(2014)

Petawatt Laser Provides A 10-1000J Flat Top



Zeptosecond pulses, (N. Naumova, I. Sokolov, G. Mourou)
(Simulation Results)

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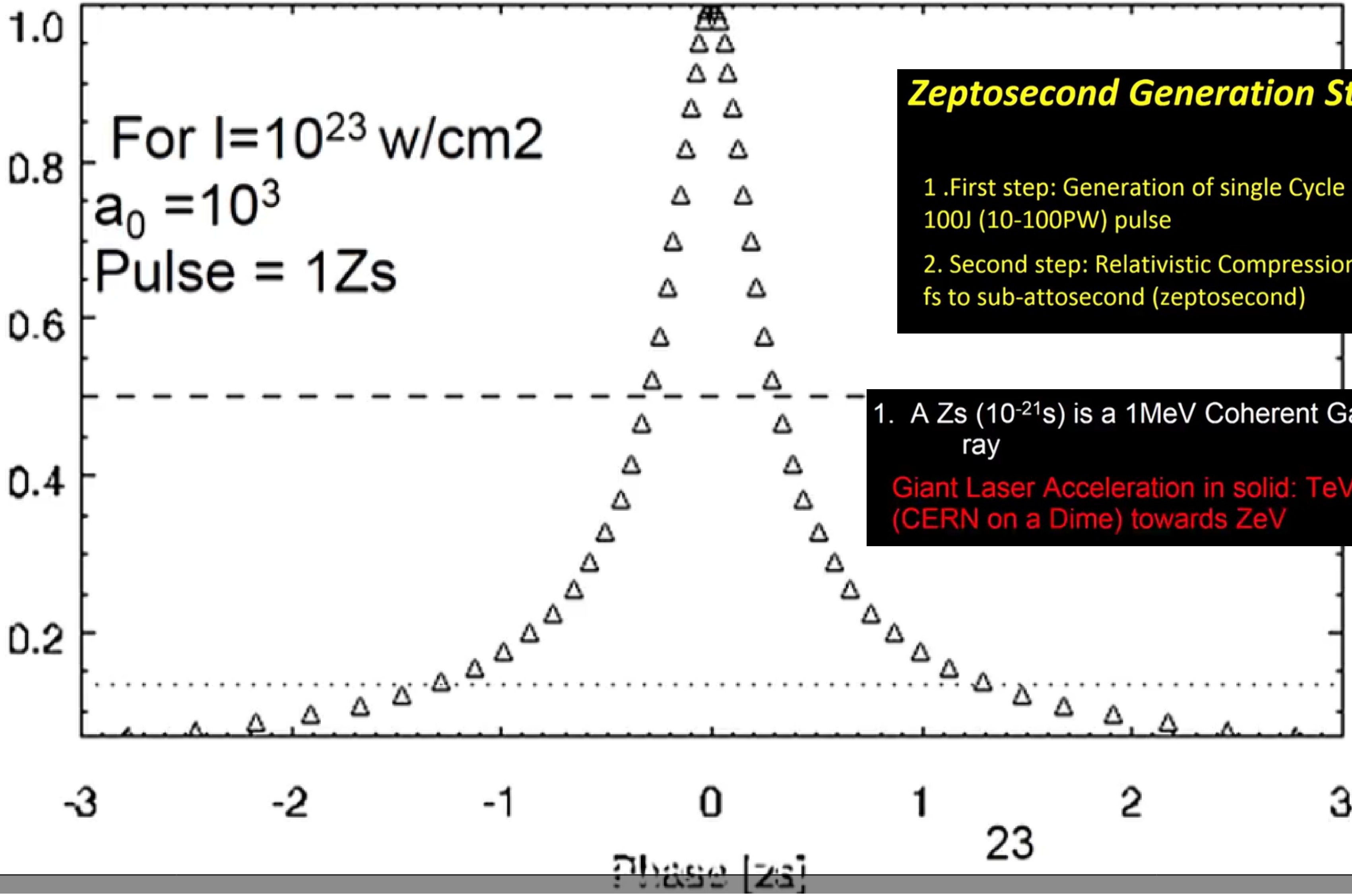
LASER SCIENCE APS/DLS

Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018



For $I=10^{23}$ w/cm2
$a_0 = 10^3$
Pulse = 1Zs

Zeptosecond Generation Steps

1 .First step: Generation of single Cycle 10-100J (10-100PW) pulse

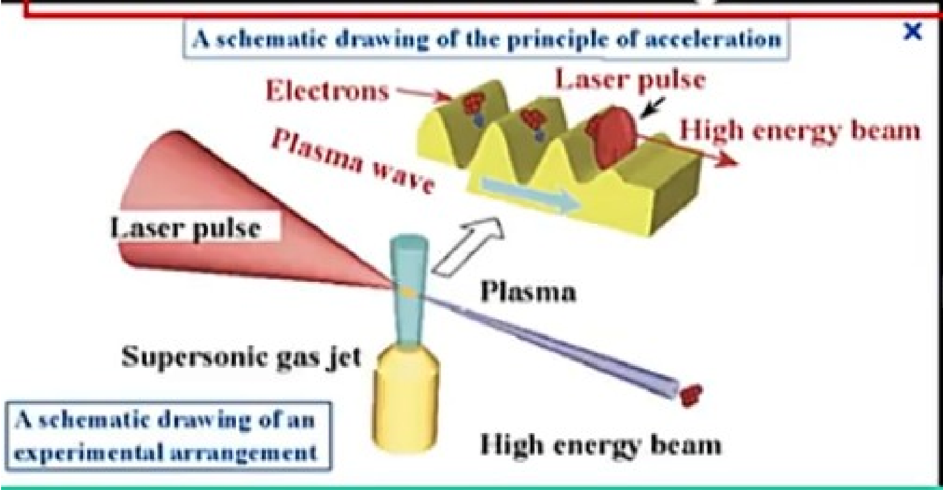
2. Second step: Relativistic Compression from fs to sub-attosecond (zeptosecond)

1. A Zs (10^{-21}s) is a 1MeV Coherent Gamma-ray

Giant Laser Acceleration in solid: TeV/cm (CERN on a Dime) towards ZeV

X-Ray Pulse
Laser Wake Field in Solid: Giant Acceleration

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

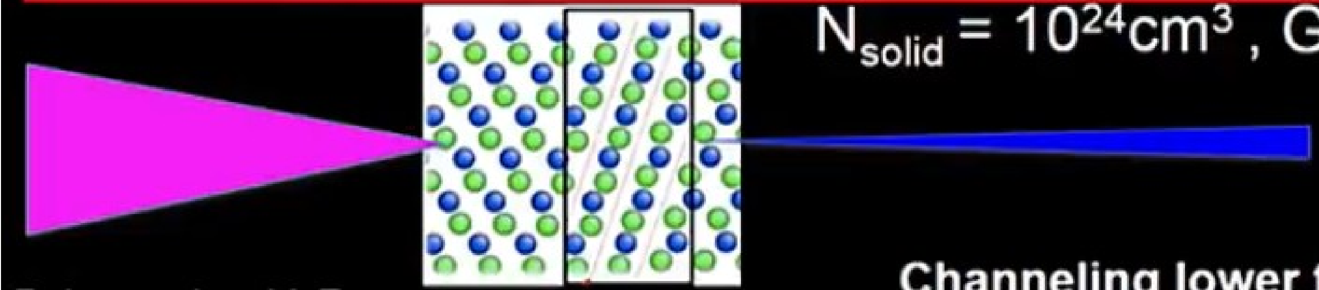


Plasma Acceleration Energy Gain

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

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

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



$N_{solid} = 10^{24}cm^{3}$, $G \sim 10^{12}$ eV/cm.
TeV/cm

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

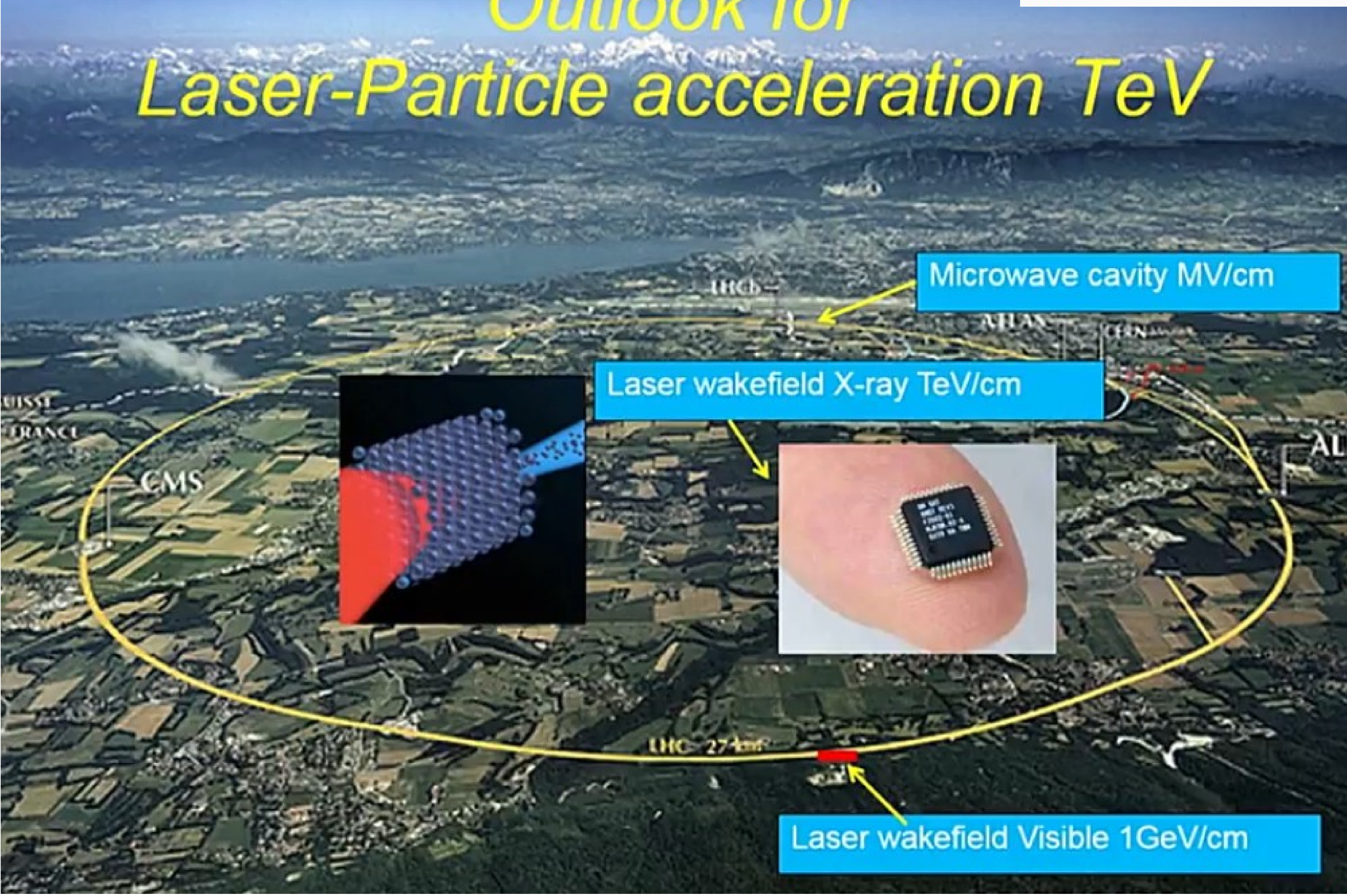
Channeling lower the emittance
Valid for electron, muons, heavy ions

GM Schawlow Prize

OSA FRONTIERS IN OPTICS
LASER SCIENCE APS/DLS

Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018

Outlook for Laser-Particle acceleration TeV

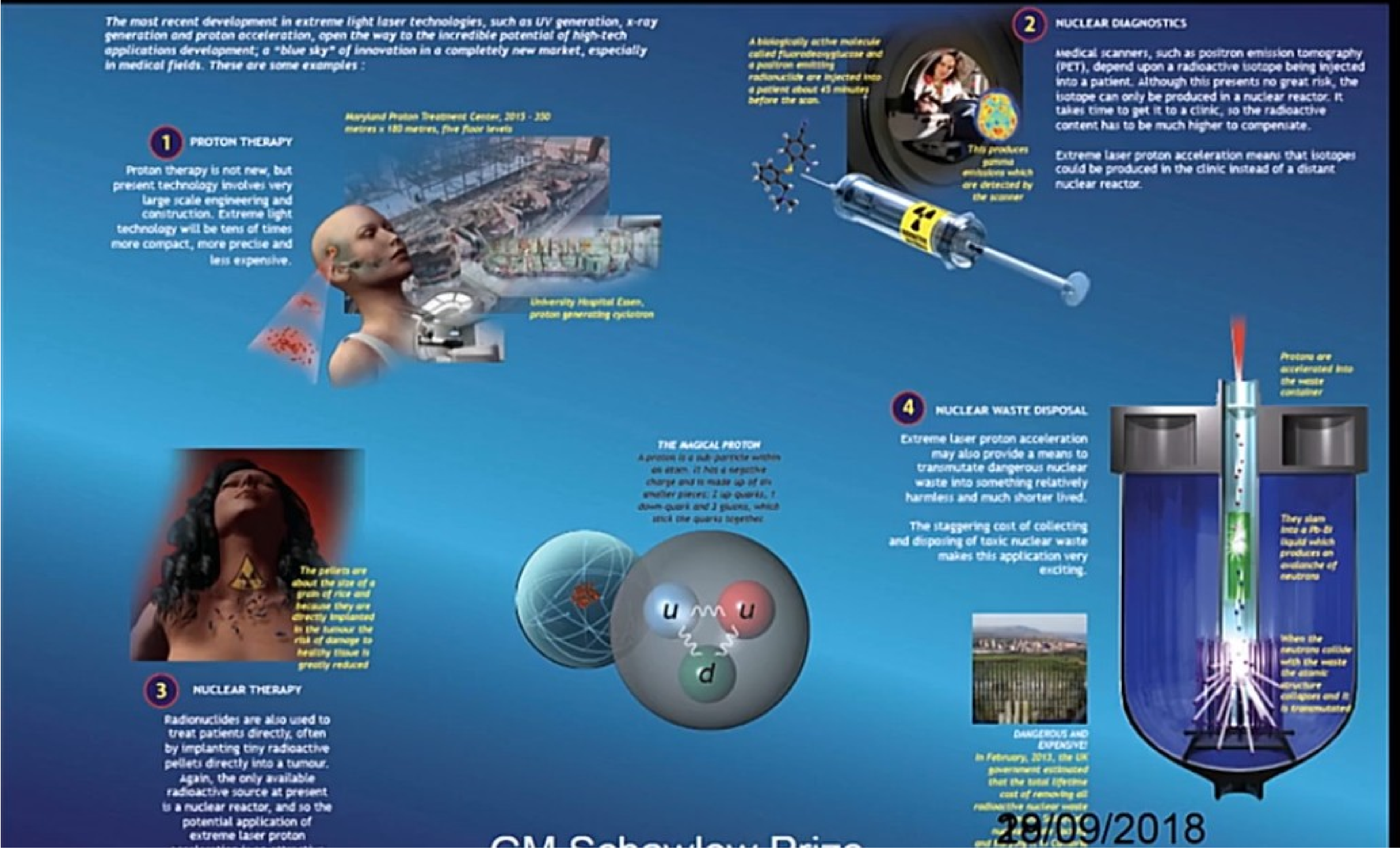


Microwave cavity MV/cm

Laser wakefield X-ray TeV/cm

Laser wakefield Visible 1GeV/cm

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 in 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

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

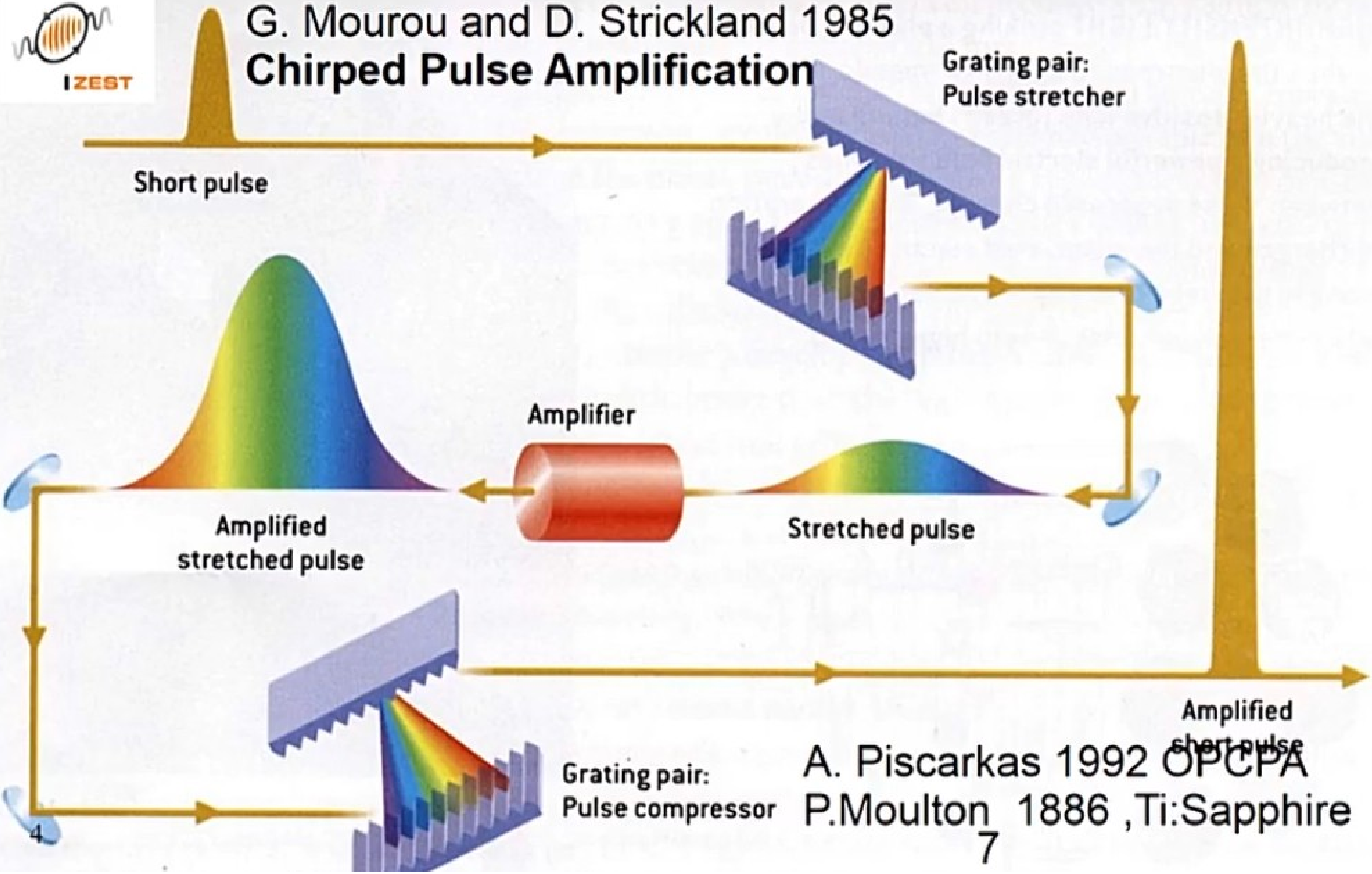
Protons are accelerated into the waste container

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

G. Mourou and D. Strickland 1985

Chirped Pulse Amplification



A. Piscarkas 1992 OPCPA
P.Moulton 1886 ,Ti:Sapphire

OSA FRONTIERS IN OPTICS
LASER SCIENCE APS/DLS

Quantum Communication and Networking talk by Prem Kumar at FiO+LS 2018

Chirped Pulse Amplification to ELI and Beyond talk by Gerard Mourou at FiO+LS 2018

Scott McEldowney - From VR and AR to "Mixed Reality" - FiO 2017 Visionary Speaker

Michael Godwin: "Digital Lighting Trends in Automotive Applications: : Bits, Bytes and Photons" - FiO 2017 Visionary Speaker

Marc Taubenblatt: "Optical Interconnects in Large Scale Computing System… What's Next" - FiO 2017 Visionary Speaker

Jungsang Kim: "Quantum Computing using Trapped Atomic Ions" - FiO 2017 Visionary Speaker

Identifying the Necessary Performance Requirements

Range
>200m @ 10% reflectivity

Frame Rate
~10/second

Resolution
>1 million+ pts/sec

Eye Safety
FDA/IEC Class 1

Weather agnostic
Rain/Fog/Snow

Limited Interference
Direct sunlight/other LIDAR

Scalable Architecture
Elegant design

Production timeframe
Minimal assembly time

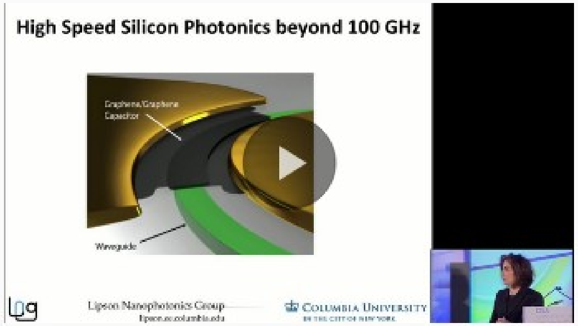
Supply Chain Security
JIT, exclusive/dedicated channels

Exportability
DOC certification -EAR99

Robustness
>100,000 hours / auto grade

Cost
Reduced BoM, economies of scale

Building the Vision for Autonomous Mobility



High Speed Silicon Photonics beyond 100 GHz

FiO/LS 2016 Plenary - JTh1A.1 - Next Generation Silicon Photonics

On the Creation of Realistic Virtual Experiences

By Nala Rogers | Posted: 20 September 2018

https://www.frontiersinoptics.com/home/media-center/fio-ls-video-library/

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JAMES MADISON HIGH SCHOOL

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The Optical Society

IOP A website from the Institute of Physics

physicsworld.com

ÉCOLE POLYTECHNIQUE
UNIVERSITÉ PARIS-SACLAY

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