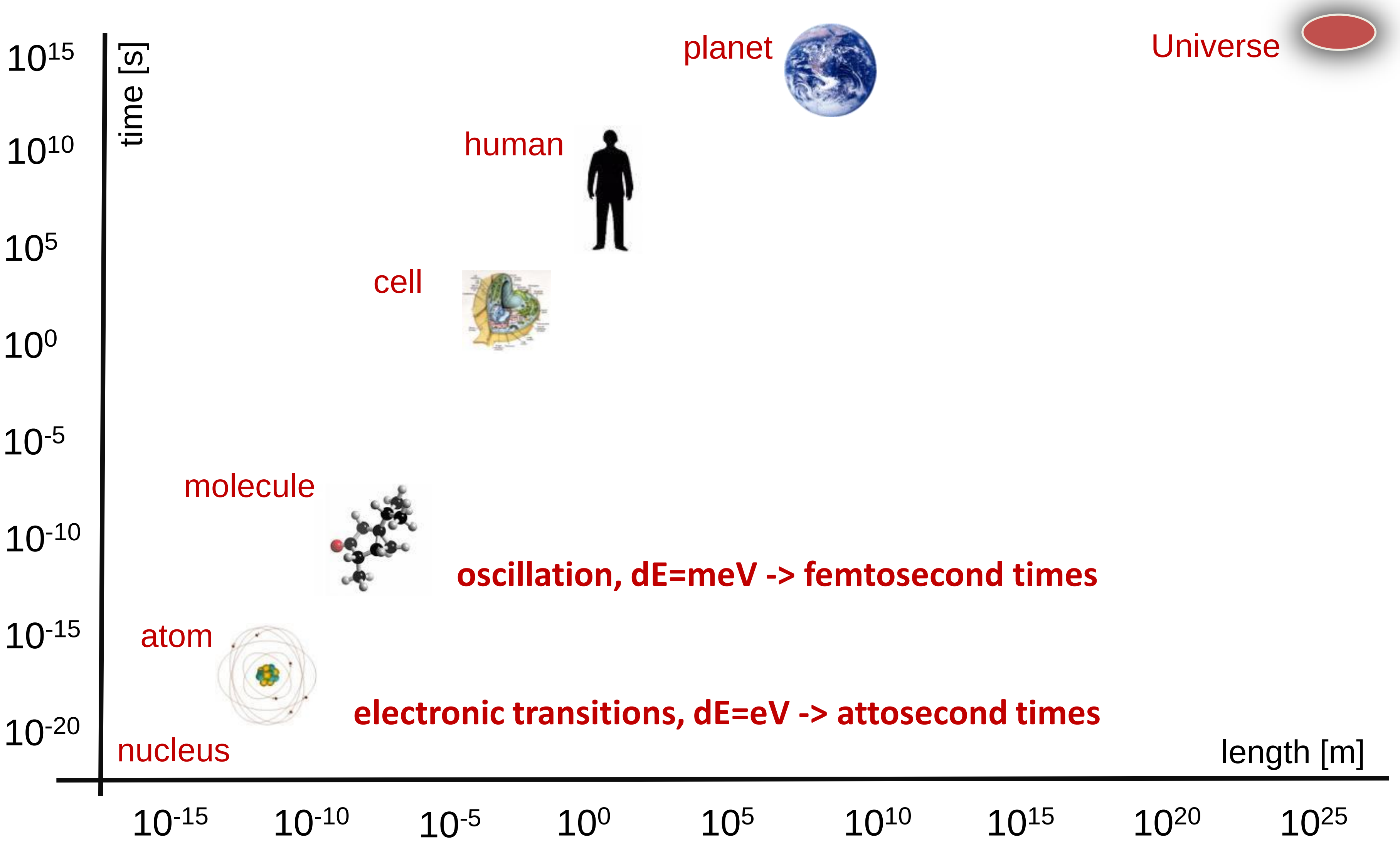
”There's Plenty of Room at the Bottom”

R. Feynman

Time and length scale in the (micro)world



The Nobel Prize in Chemistry 1967

Photo from the Nobel Foundation archive.

Manfred Eigen

Prize share: 1/2

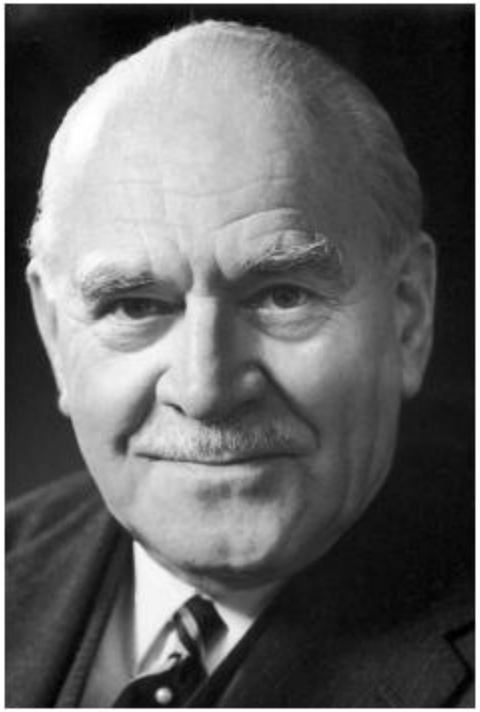


Photo from the Nobel Foundation archive.

Ronald George Wreyford Norrish

Prize share: 1/4

Photo from the Nobel Foundation archive.

George Porter

Prize share: 1/4

"for their studies of extremely fast chemical reactions, effected by disturbing the equilibrium by means of very short pulses of energy"

The Nobel Prize in Chemistry 1999

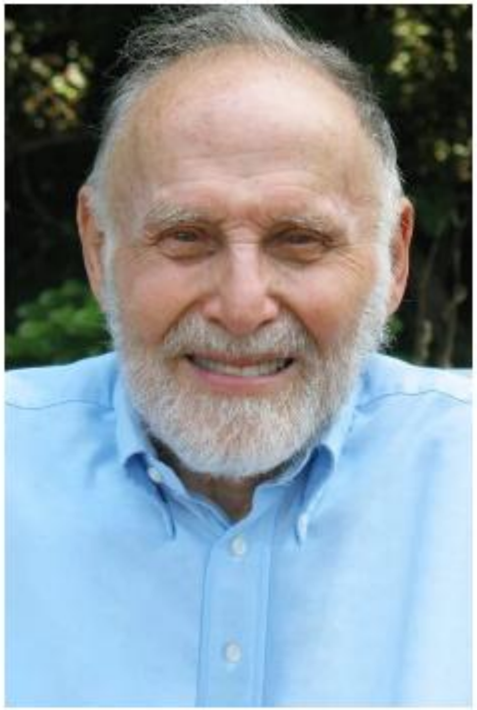
Photo from the Nobel Foundation archive.

Ahmed H. Zewail

Prize share: 1/1

”for his studies of the transition states of chemical reactions using femtosecond spectroscopy”

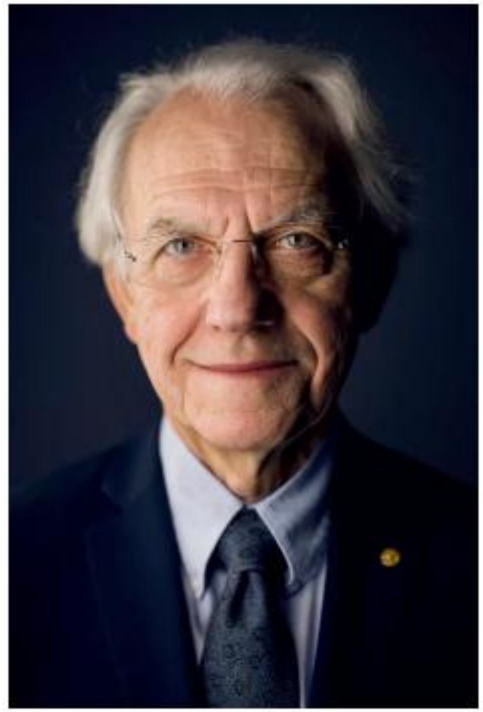
The Nobel Prize in Physics 2018



© Arthur Ashkin

Arthur Ashkin

Prize share: 1/2



© Nobel Media AB. Photo: A. Mahmoud

Gérard Mourou

Prize share: 1/4

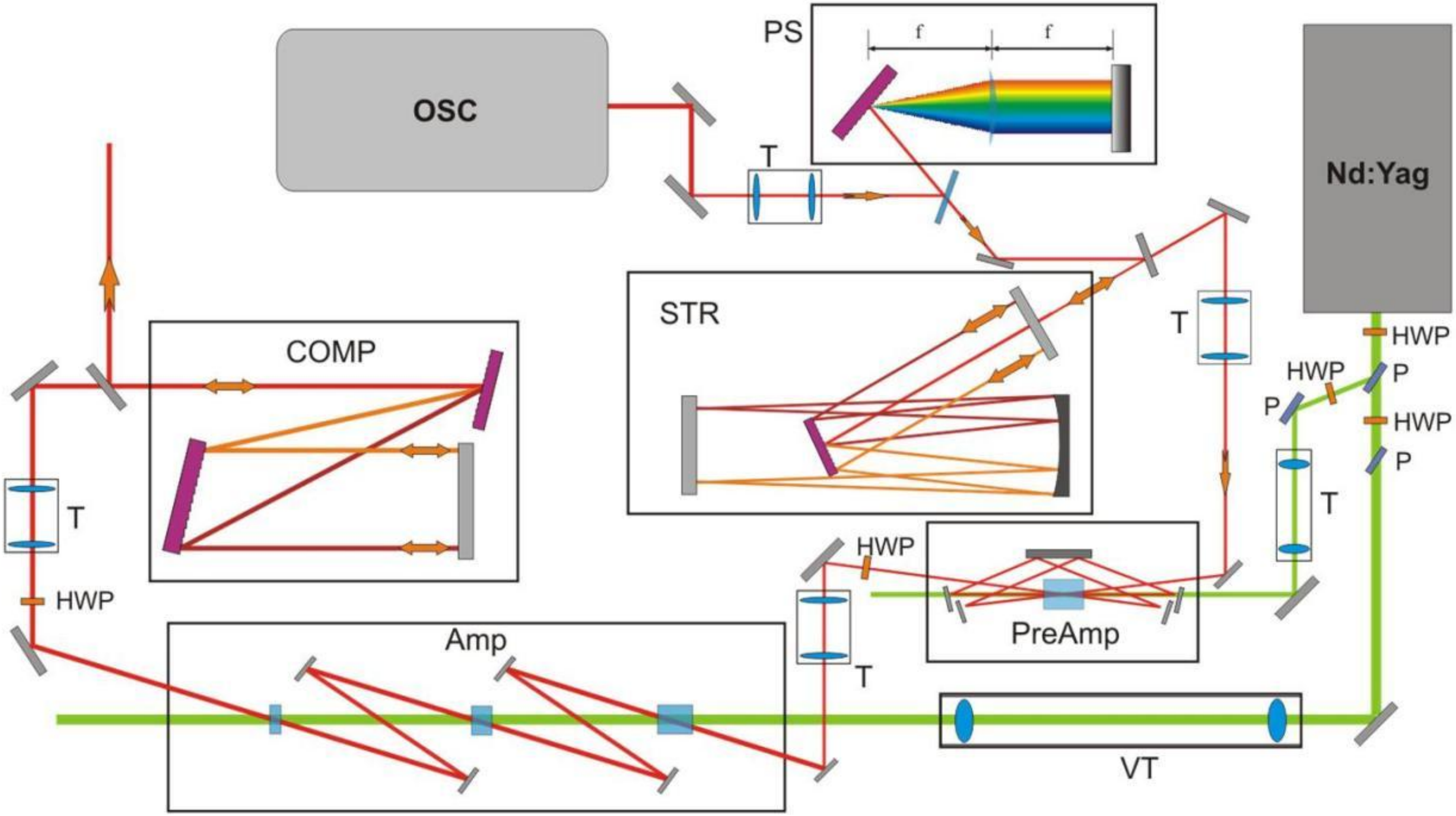
© Nobel Media AB. Photo: A. Mahmoud

Donna Strickland

Prize share: 1/4

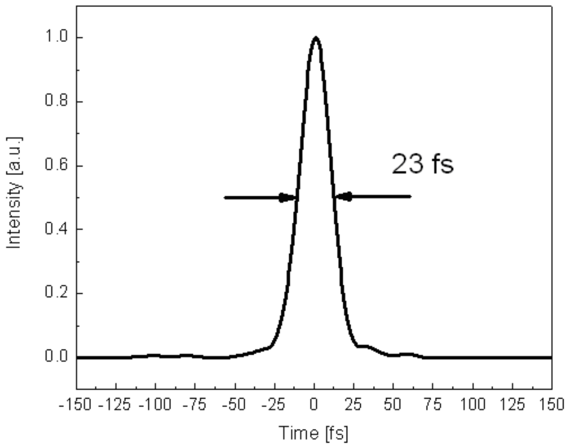
“for their method of generating high-intensity, ultra-short optical pulses”

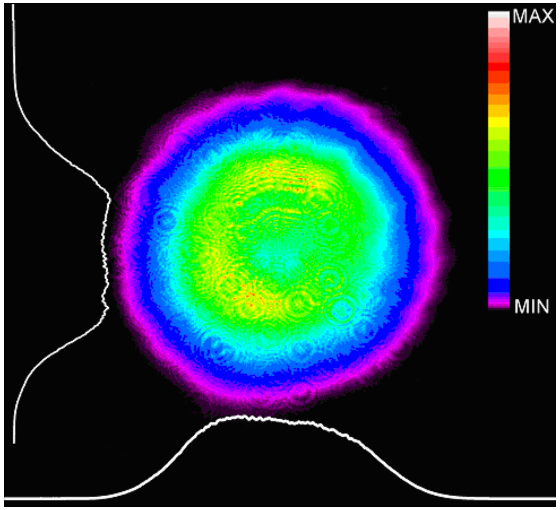
High powers in the lab

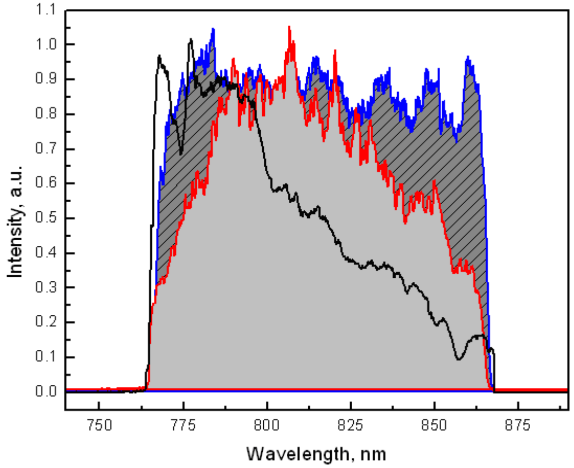


TTT-class (Table Top Terawatt)
10 Hz Optical Parametric Chirped Pulse Amplifier (OPCPA)
in the Laser Center of the Institute of Physical Chemistry, Warsaw
(Wnuk, Stepanenko, Radzewicz)

High powers in the lab







Output beam parameters:
- pulse energy: 49 mJ
- pulse duration: 23 fs
- total gain: 36 M
- stability: 2% RMS
- repetition rate: 10Hz
- pulse contrast: 10^{-8}

What is progress?

1967	**10^{-6} s**	**0.6 GW**	**Stockholm**
2017	**10^{-14} s**	**2 TW**	**the world**

Installed power capacity

Poland	0.05 TW
Germany	0.2 TW
USA	1.3 TW
China	2.4 TW
global	8.5 TW

The Nobel Prize in Physics 2023

Ill. Niklas Elmehed © Nobel Prize Outreach

Pierre Agostini

Prize share: 1/3

Ill. Niklas Elmehed © Nobel Prize Outreach

Ferenc Krausz

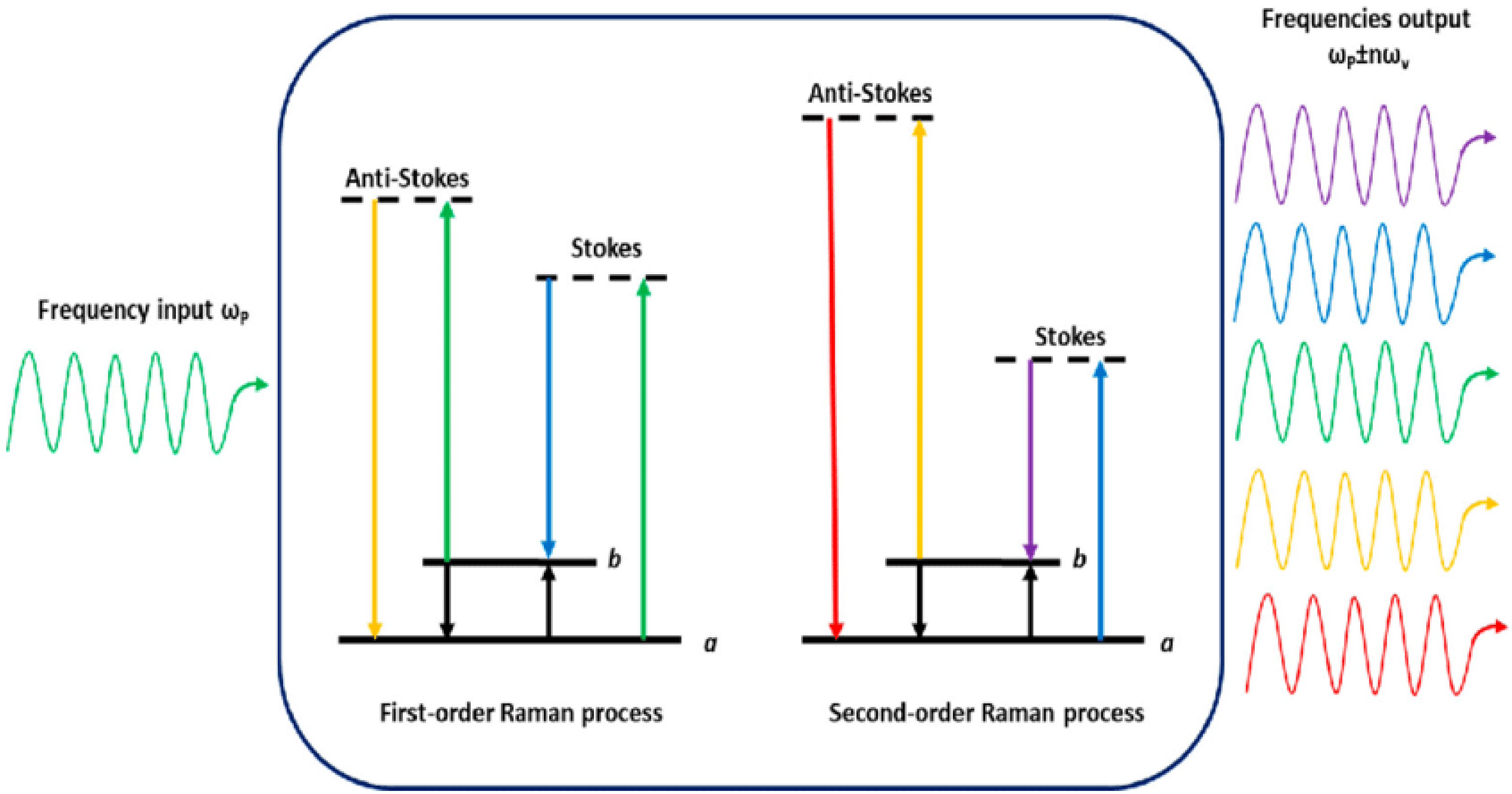
Prize share: 1/3

Ill. Niklas Elmehed © Nobel Prize Outreach

Anne L'Huillier

Prize share: 1/3

"for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter"



A. V. Sokolov et al. PRL 85, 562 (2000)

J. Phys. B: At. Mol. Opt. Phys. 21 (1988) L31–L35. Printed in the UK

LETTER TO THE EDITOR

Multiple-harmonic conversion of 1064 nm radiation in rare gases

M Ferray, A L'Huillier, X F Li, L A Lompré, G Mainfray and C Manus
Service de Physique des Atomes et des Surfaces, 91191 Gif sur Yvette, Cédex, France

Received 2 November 1987

Abstract. We report the observation of very-high-order odd harmonics of Nd:YAG laser radiation in rare gases at an intensity of about 10^{13} W cm^{-2}. Harmonic light as high as the 33rd harmonic in the XUV range (32.2 nm) is generated in argon. The key point is that the harmonic intensity falls slowly beyond the fifth harmonic as the order increases. Finally, a UV continuum, beginning at 350 nm and extending down towards the short wavelength region is apparent in xenon.

Surpising:
- high efficiency
- narrow cone of emission
- constant intesity of harmonics

Possible application:
compact source
for XUV spectroscopy

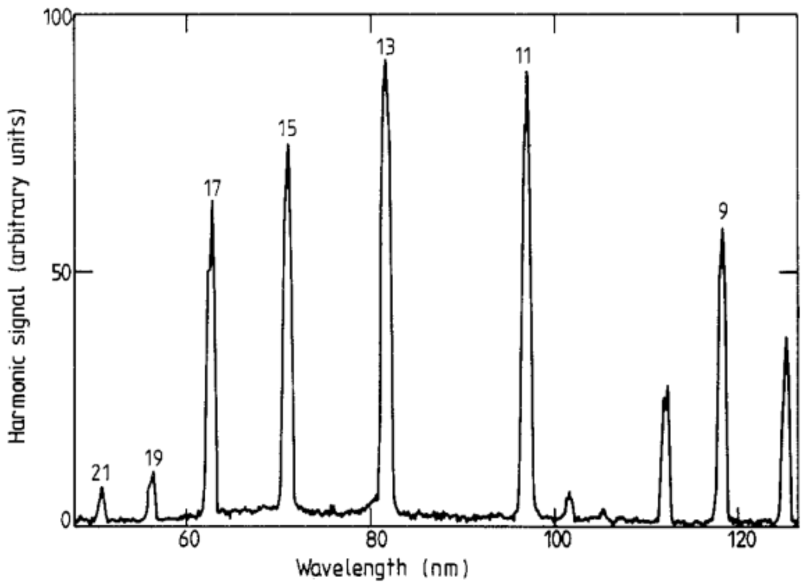
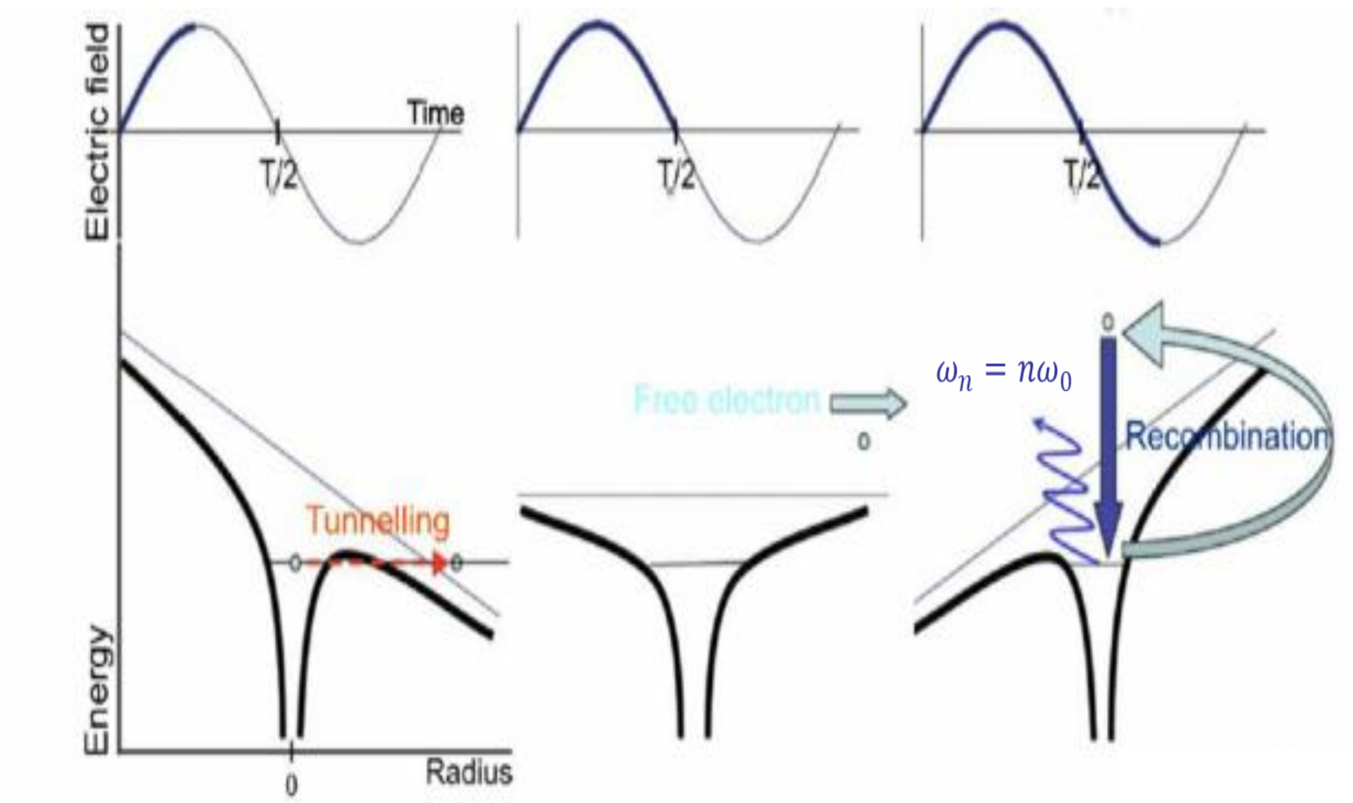


Figure 1. Harmonic spectrum obtained using a Xe gas jet showing all odd harmonics between 9 and 21. The peaks at 101, 112 and 125 nm are the second diffracted orders of the 21st, 19th and 17th harmonics respectively. The laser intensity was approximately 3×10^{13} W cm^{-2} and the Xe pressure at the focal point was about 10 Torr.

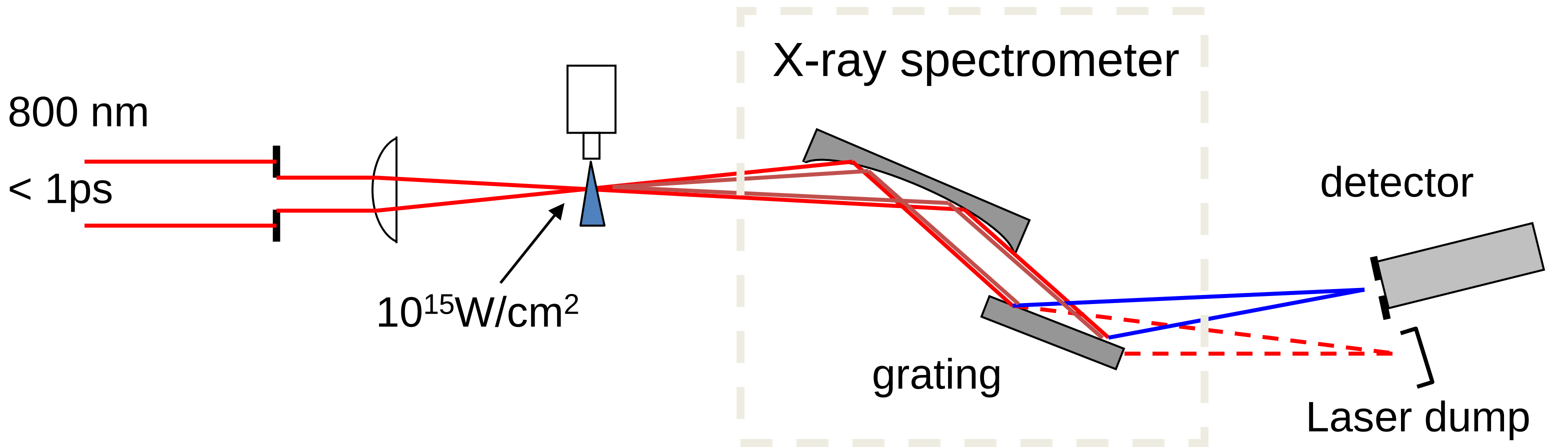
Generating high harmonics – 3-stage model

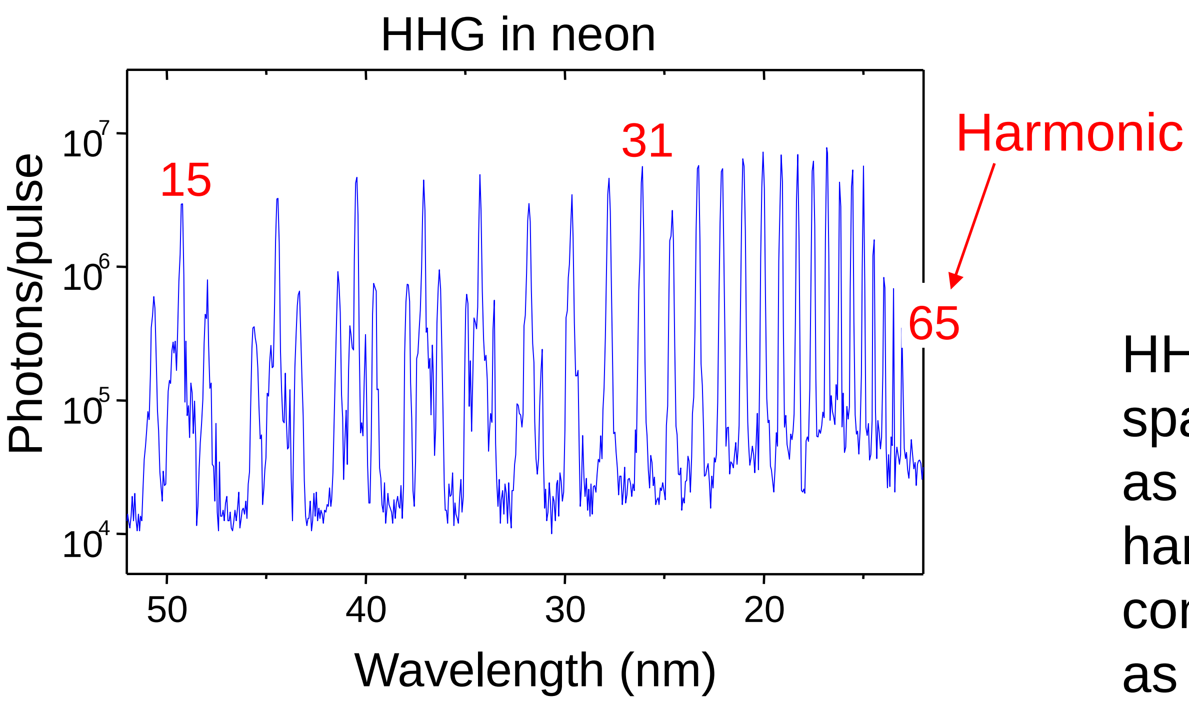
$I \sim 10^{15}\,\frac{\mathrm{W}}{\mathrm{cm}^2}$ **1 V/Å**



J.L. Krause, K.J. Schafer, K.C. Kulander, PRL **68**, 3535 (1992)
K.J. Schafer, B. Yang, L.F. DiMauro, K.C. Kulander PRL **70**, 1599 (1993)
M. Lewenstein, et al., Phys. Rev. **A. 49**, 2117-2132 (1994).

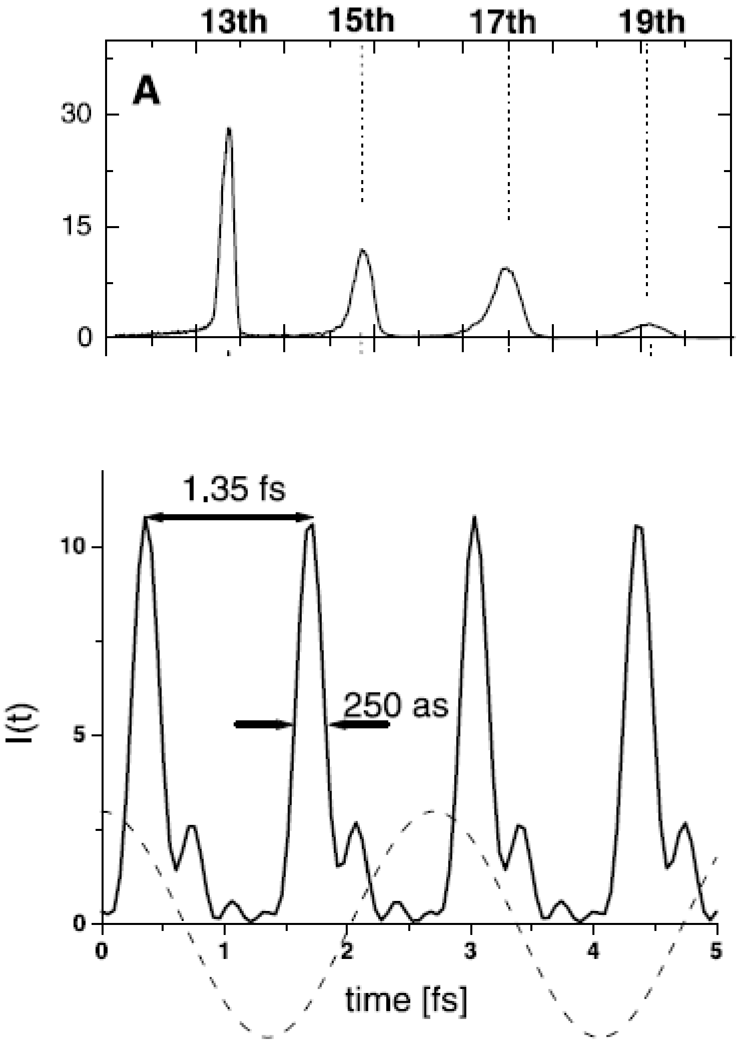
High Harmonic Generation in a gas

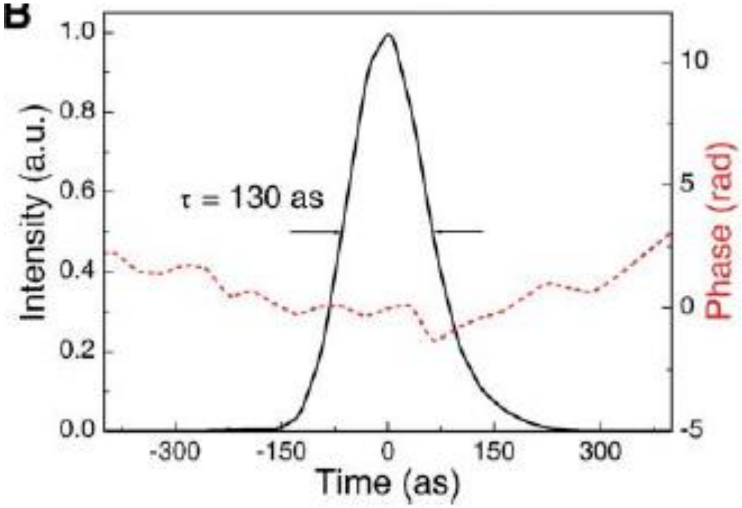




HHG produces equally spaced harmonics out to as much as the 300th harmonic, potentially compressible to pulses as short as 10 as

Attosecond pulses – from pulse trains to a single pulse

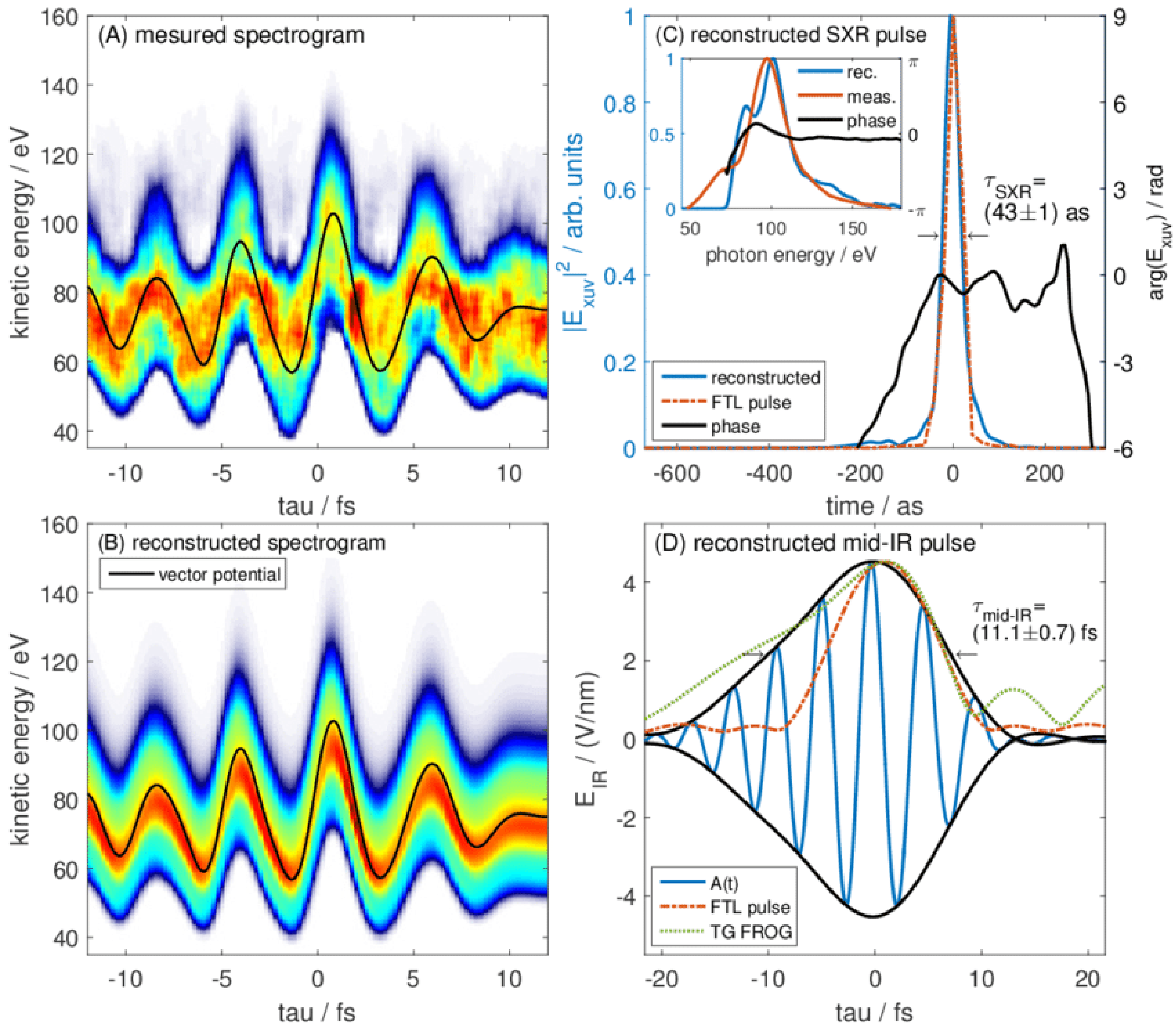




Two methods:
-spectral filtering
- polarization gating

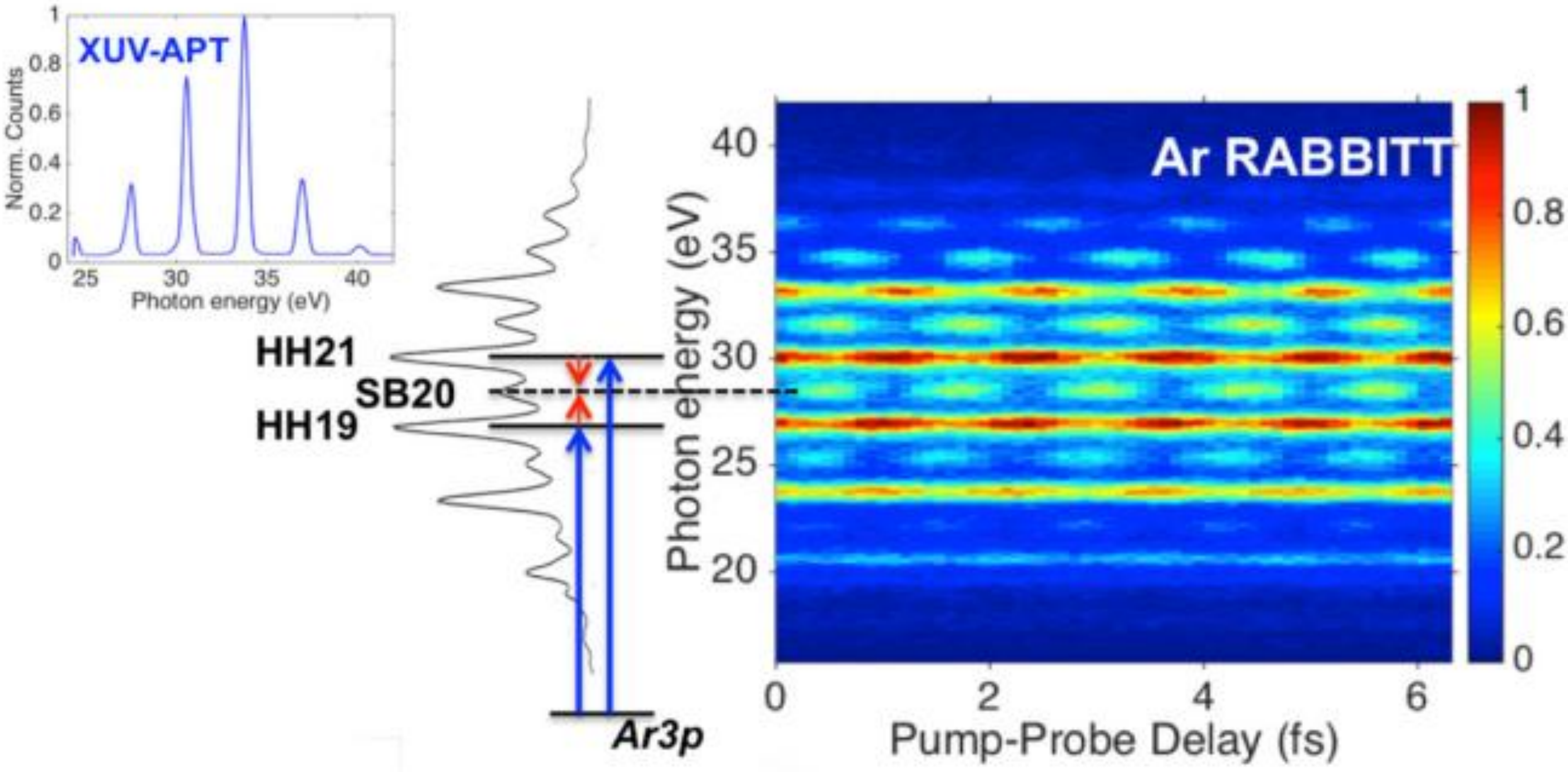
G. Sansone et al., Science 314, 443 (2006)

Attosecond pulses – recent results



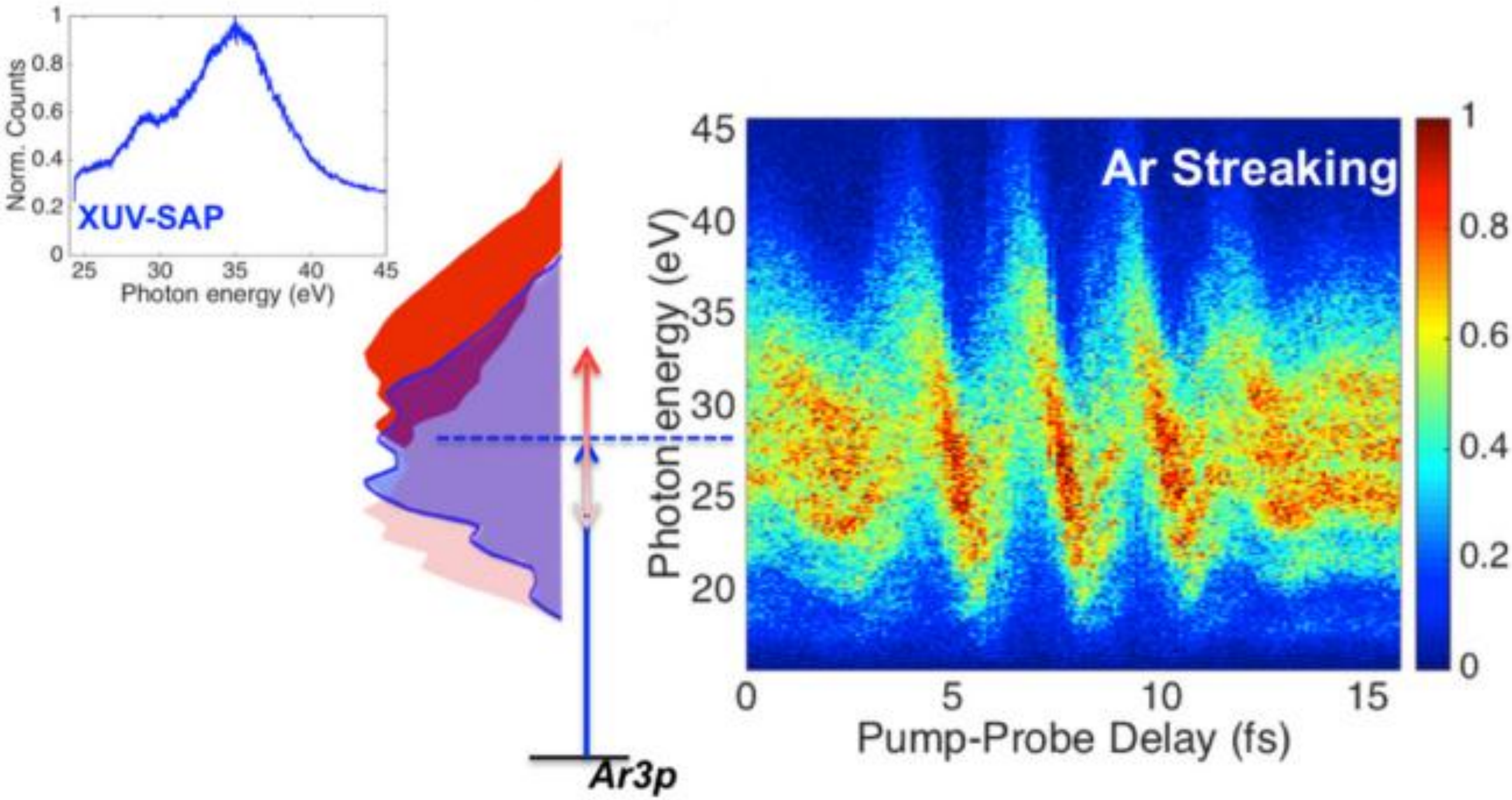
T. Gaumnitz, et al., Opt. Express 25, 27506 (2017)

Reconstruction of attosecond beating by interference of two-photon transitions (RABBIT)



L. Cattaneo, J. Vos, M. Lucchini, L. Gallmann, C. Cirelli, and U. Keller, Opt. Express 24, 29060 (2016)

Attosecond streaking



L. Cattaneo, J. Vos, M. Lucchini, L. Gallmann, C. Cirelli, and U. Keller, Opt. Express 24, 29060 (2016)

PHYSICAL REVIEW A VOLUME 49, NUMBER 3 MARCH 1994

Theory of high-harmonic generation by low-frequency laser fields

M. Lewenstein,[1,*] Ph. Balcou,[2] M. Yu. Ivanov,[3,†] Anne L'Huillier,[2,4] and P. B. Corkum[3]
[1]*Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, Colorado 80309-0440*
[2] *Service des Photons, Atomes et Molécules, Centre d'Etudes de Saclay, 91191 Gif sur Yvette, France*
[3]*National Research Council of Canada, M-23A, Ottawa, Ontario, Canada K1A OR6*
[4]*Lawrence Livermore National Laboratory, L-443, P.O. Box 5508, Livermore, California 94550*
(Received 19 August 1993)

PHYSICAL REVIEW A VOLUME 53, NUMBER 3 MARCH 1996

Theory of high-order harmonic generation by an elliptically polarized laser field

Philippe Antoine,[1,2] Anne L'Huillier,[1,3] Maciej Lewenstein,[1,4] Pascal Salières,[1] and Bertrand Carré[1]
[1]*Commissariat à l'Energie Atomique, DSM/DRECAM/SPAM, Centre d'Etudes de Saclay, 91191 Gif-sur-Yvette, France*
[2]*Laboratoire de Physique Atomique et Moléculaire, Université Catholique de Louvain, Chemin du Cyclotron, 2 B-1348 Louvain-la-Neuve, Belgique*
[3]*Department of Physics, Lund Institute of Technology, S-221 00 Lund, Sweden*
[4]*Centrum Fizyki Teoretycznej, Polska Akademia Nauk, 02-668 Warsaw, Poland*
(Received 10 August 1995)

VOLUME 77, NUMBER 7 PHYSICAL REVIEW LETTERS 12 AUGUST 1996

Attosecond Pulse Trains Using High–Order Harmonics

Philippe Antoine,[1,3] Anne L'Huillier,[2] and Maciej Lewenstein[1]
[1]*Commissariat à l'Energie Atomique, DSM/DRECAM/SPAM, Centre d'Etudes de Saclay, 91191 Gif-sur-Yvette, France*
[2]*Department of Physics, Lund Institute of Technology, S-221 00 Lund, Sweden*
[3]*Laboratoire de Physique Atomique et Moléculaire, Chemin du Cyclotron, Université Catholique de Louvain, 2 B-1348 Louvain-la-Neuve, Belgium*
(Received 8 March 1996)

We demonstrate that high-order harmonics generated by an atom in intense laser field form trains of ultrashort pulses corresponding to different trajectories of electrons that tunnel out of the atom and recombine. Propagation in an atomic jet allows us to select one of these trajectories, leading to a train of pulses of extremely short duration. [S0031-9007(96)00866-6]

PACS numbers: 32.80.Rm, 42.65.Ky

A. Zeilinger - Radek Łapkiewicz

ARTICLE

Received 24 Feb 2014 | Accepted 25 Jun 2014 | Published 30 Jul 2014

DOI: 10.1038/ncomms5502

Interface between path and orbital angular momentum entanglement for high-dimensional photonic quantum information

Robert Fickler[1,2], Radek Lapkiewicz[1,2], Marcus Huber[3,4], Martin P.J. Lavery[5], Miles J. Padgett[5] & Anton Zeilinger[1,2]

LETTER

doi:10.1038/nature13586

Quantum imaging with undetected photons

Gabriela Barreto Lemos[1,2], Victoria Borish[1,3], Garrett D. Cole[2,3], Sven Ramelow[1,3]†, Radek Lapkiewicz[1,3] & Anton Zeilinger[1,2,3]

F. Krausz - Paweł Wnuk
- Maciej Kowalczyk

Check for updates

nature photonics

ARTICLES

https://doi.org/10.1038/s41566-022-01001-2

Check for updates

OPEN

Single-cycle infrared waveform control

Philipp Steinleitner[1,6], Nathalie Nagl[1,2,6] ✉, Maciej Kowalczyk[1,2,3,6] ✉, Jinwei Zhang[1,4], Vladimir Pervak[2], Christina Hofer[1,2,3], Arkadiusz Hudzikowski[5], Jarosław Sotor[5], Alexander Weigel[1,3], Ferenc Krausz[1,2,3] and Ka Fai Mak[1] ✉

Research Article Vol. 10, No. 6 / June 2023 / *Optica* 801

OPTICA

Ultra-CEP-stable single-cycle pulses at 2.2 μm

Maciej Kowalczyk,[1,2,3,†] Nathalie Nagl,[1,3,5,†] Philipp Steinleitner,[3,6,†] Nicholas Karpowicz,[3] Vladimir Pervak,[1] Aleksander Głuszek,[4] Arkadiusz Hudzikowski,[4] Ferenc Krausz,[1,2,3] Ka Fai Mak,[3] and Alexander Weigel[2,3,*]