VNIVERSITAS STVDII SALAMANTINI

Coherent X-Ray Pulse Generation
based on
High Order Harmonics of an Optical Laser.

coherence

coherence

Universidad de Salamanca

Luis Roso

Grupo de Optica El Fotón Charro

Coherence vs brilliance

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Coherence		Brilliance
X ray laser →	Sorry, Not yet ready	← Synchrotron

$$\gamma_{12}(\tau) = \frac{\langle E_1(t) E_2(t-\tau) \rangle}{\sqrt{\langle |E_1|^2 \rangle \langle |E_2|^2 \rangle}}$$

Correlation
of the fluctuations
in two points.

Arbitrary separation

Spatial coherence $\gamma_{12}(0)$

Temporal coherence $\gamma_{11}(\tau)$

X ray lasers

laser = coherent

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Radiofrequency
Microwaves
IR lasers
visible
UV lasers Excimer lasers
X ray lasers …

Harder to get coherence as frequency increases

Several experimental scenarios: Free electron lasers
High order hamonics

Outline

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The tool: CPA Ti:Sa laser

The fields: Record man-made electric fields

The applications:

Generation of coherent VUV radiation
soft X rays

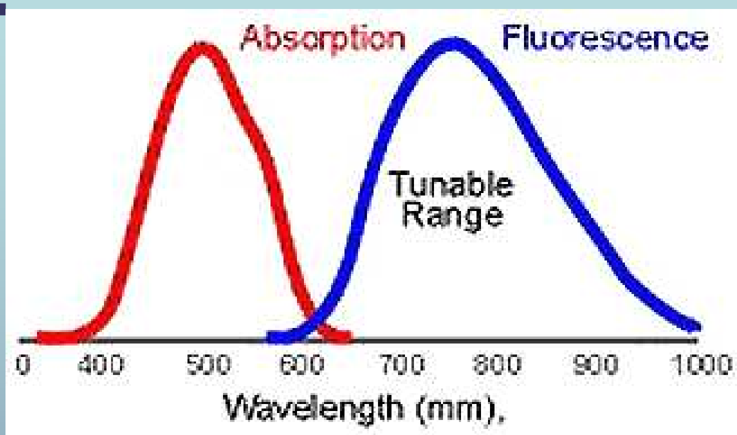
Direct radiation from atoms

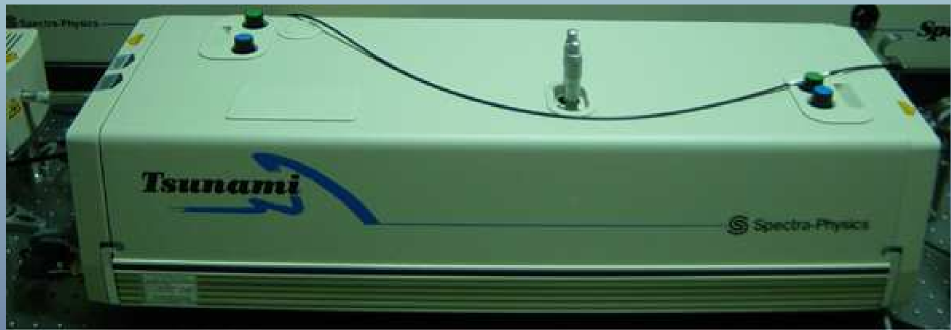
Indirect effects in plasmas

Short electron bunches

Femtosecond lasers

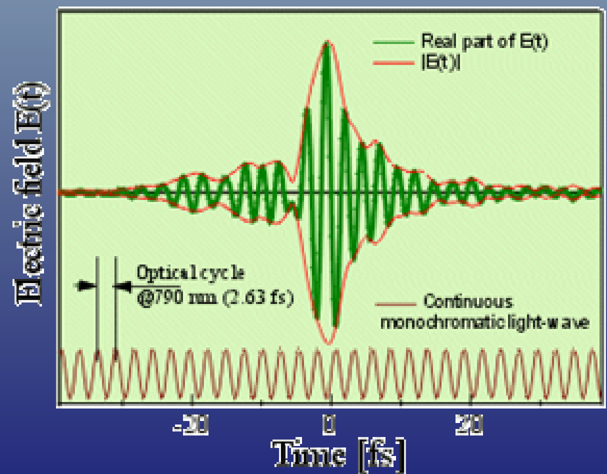
Pushing mode-locking to the limit
Short pulse length implies a material able to lase in a very broad band



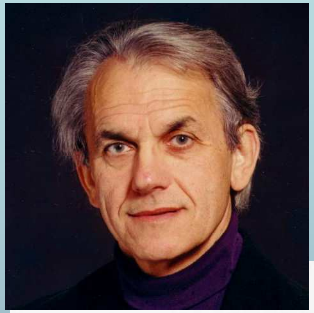


Titanium-Sapphire laser

790 nm wavelength
correspond to 2.6 fs period

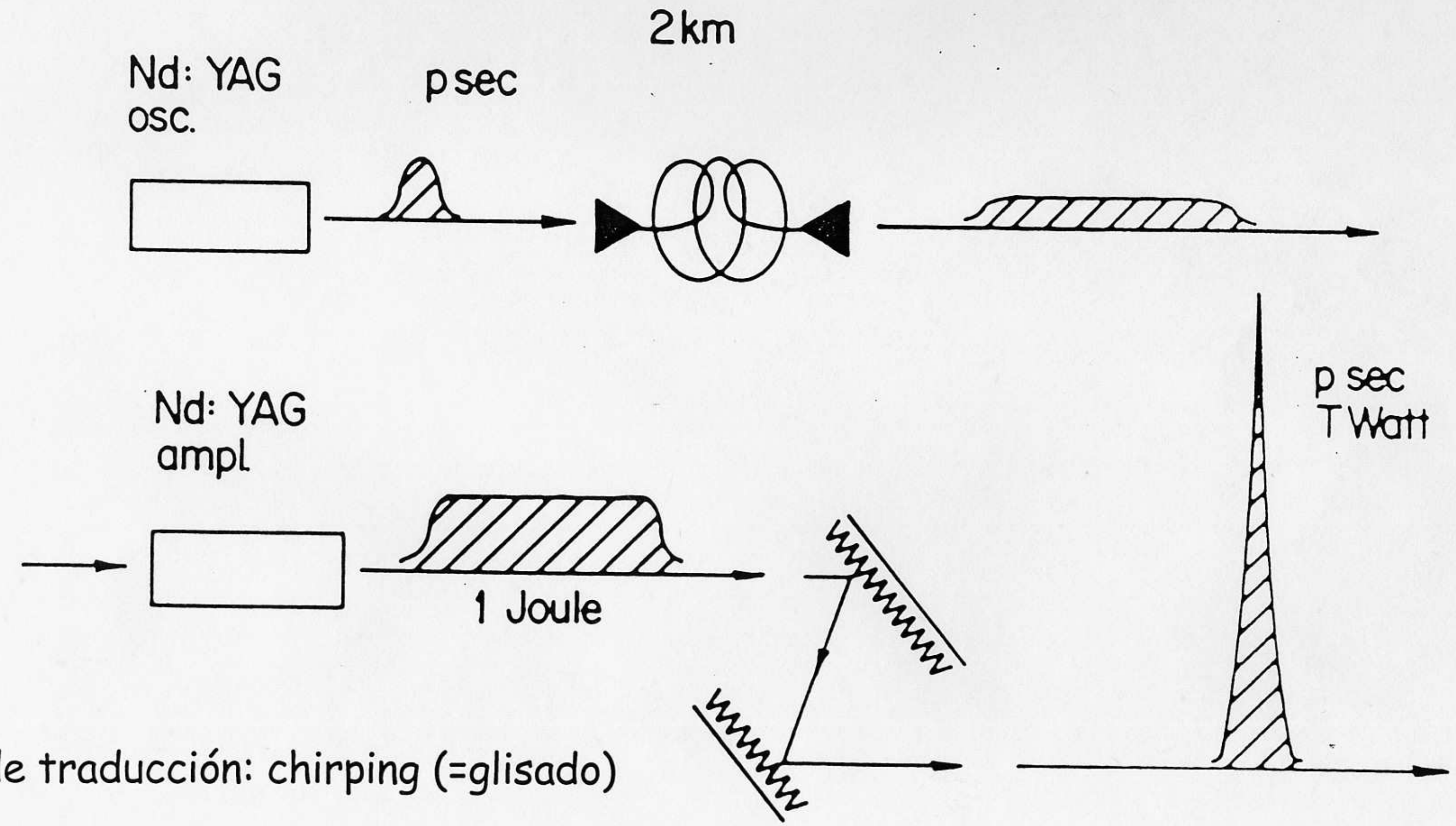


What about intensity?



G Mourou, Rochester, 1985: **Stretch, amplify and compress**

Chirped pulse amplification



Un problema de traducción: chirping (=glisado)

It involves chirped pulses, ...

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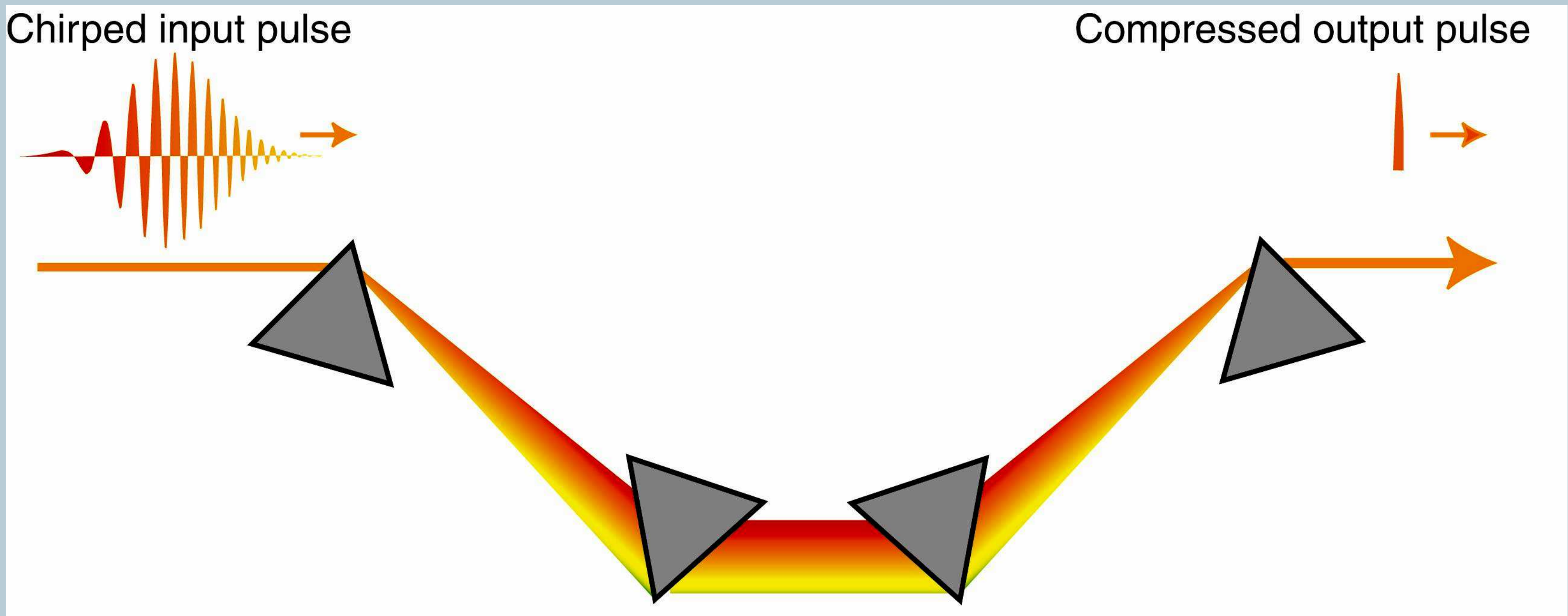
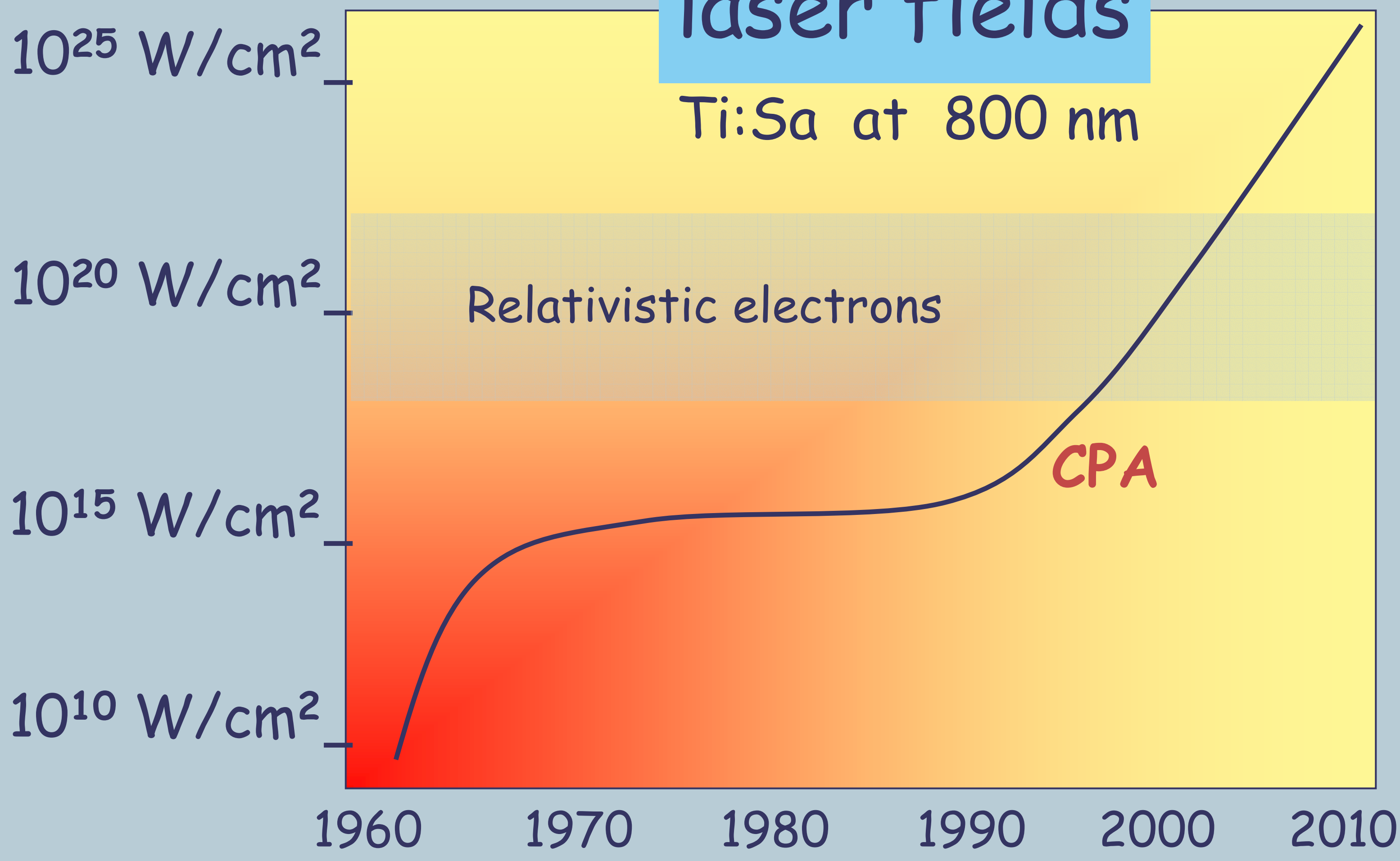


A quantum free particle ($m \neq 0$) is a chirped wave

laser fields



Intensity	10^{17} W/cm^2	10^{21} W/cm^2
Electric field	10^{12} V/m	10^{14} V/m
	spain	world

The laser system at Salamanca

Central wavelength 790 nm

100 fs pulses   50 mJ   0.5 Terawatt

Intensity 10^{17} W/cm2

Electric field amplitude 10^{12} V/m

ULTRAHIGH-INTENSITY LASERS: PHYSICS OF THE EXTREME ON A TABLETOP

By stretching, amplifying and then compressing laser pulses, one can reach petawatt powers, gigagauss magnetic fields, terabar light pressures and 10^{22} m/s^2 electron accelerations.

Gérard A. Mourou, Christopher P. J. Barty and Michael D. Perry

Over the past ten years, laser intensities have increased by more than four orders of magnitude[1] to reach enormous intensities of 10^{20} W/cm^2. The field strength at these intensities is on the order of a teravolt per centimeter, or a hundred times the Coulombic field binding the ground state electron in the hydrogen atom. The electrons driven by such a field are relativistic, with an oscillatory energy of 10 MeV. At these intensities, the light pressure, $P = I/c$, is extreme, on the order of giga- to terabars. The laser interacting with matter—solid, gas, plasma—generates high-order harmonics of the incident beam up to the 3 nm wavelength range, energetic ions or electrons with mega-electron-volt energies (figure 1), gigagauss magnetic fields and violent accelerations of 10^{21} g (g is Earth's gravity). Finally, the interaction of an ultraintense beam with superrelativistic

time-resolved x-ray experiments in the femtosecond range, or at the Stanford Linear Accelerator Center (SLAC) to test nonlinear quantum electrodynamics by the interaction of the high-intensity pulses with super-relativistic electrons.

Some of the new tabletop-laser principles have been implemented on existing large laser systems built for laser fusion. Lawrence Livermore National Laboratory, Los Alamos National Laboratory, the Commissariat à l'Energie Atomique (CEA) in Paris, the Rutherford Appleton Laboratory in the UK and the Institute of Laser Engineering in Osaka, Japan, have all added subpicosecond pulse capabilities to their nanosecond lasers, pushing their peak power by three orders of magnitude from 1 terawatt to 100–1000 TW.

Figure 2 presents the focused intensity of lasers as a

Harmonic generation

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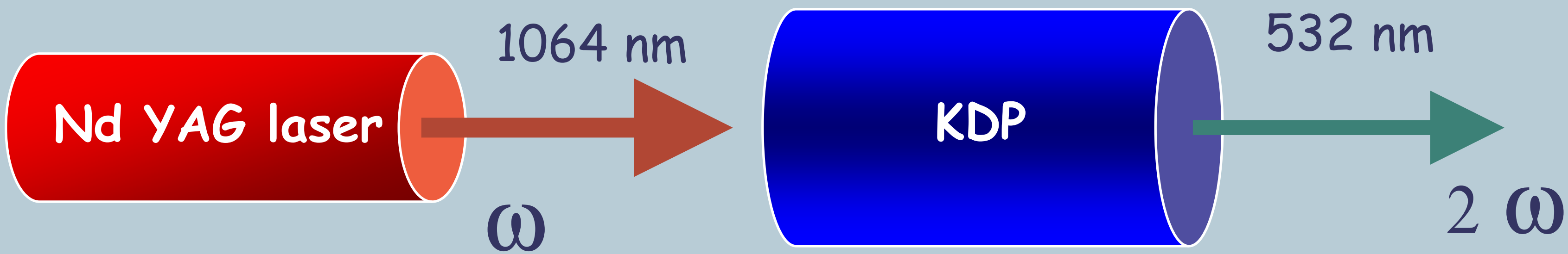
Ordinary nonlinear optics

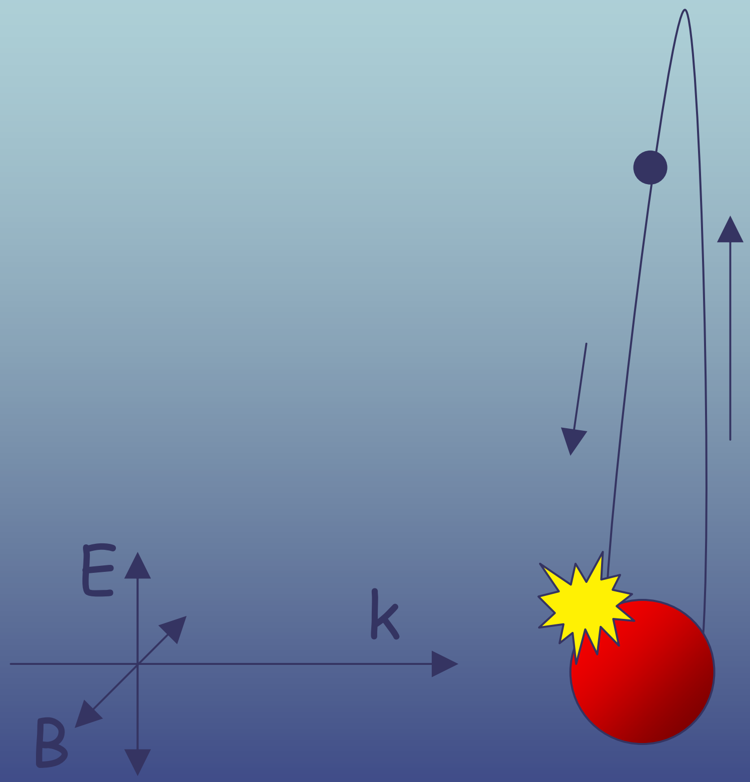
Second harmonic generation is a standard technique now

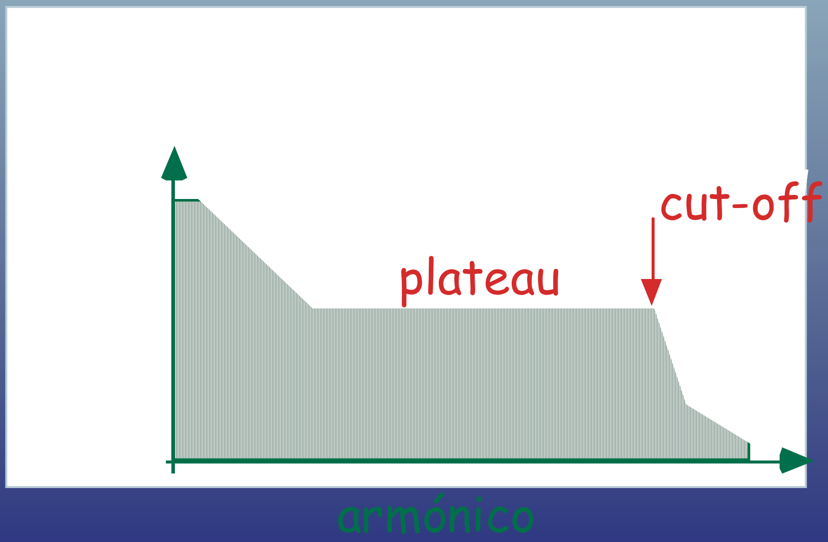


Low order nonlinear effects
N Bloembergen

High-order harmonics

Harmonic 100 of
Ti:Sa laser is 8 nm
X ray laser





Extremely short pulses

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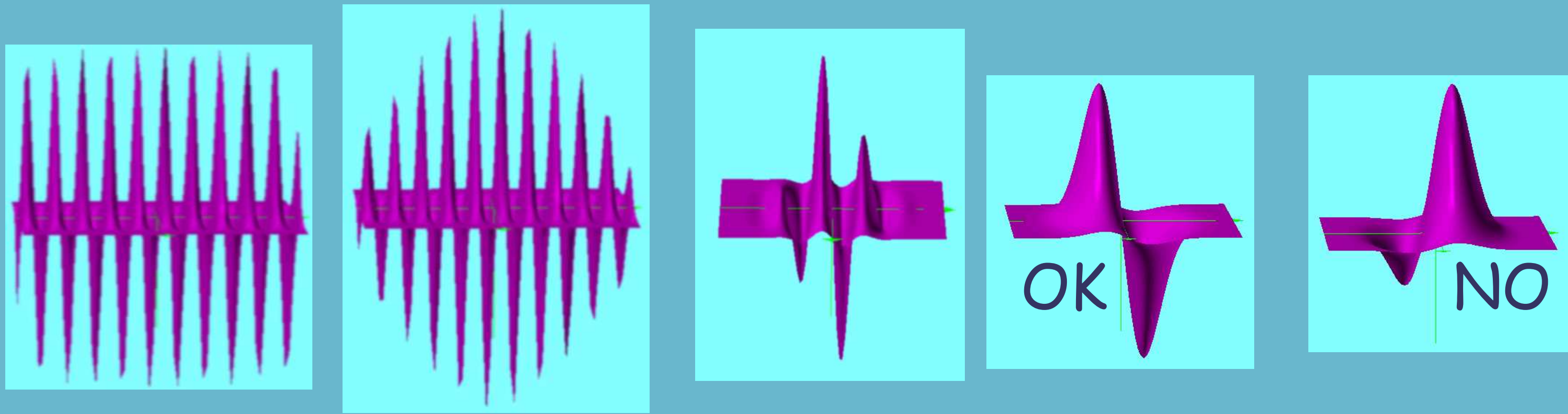
790 nm wavelength correspond to 2.6 fs period



$\langle E(t) \rangle = 0$ … if electromagnetic wave
no DC component

High order harmonics are
even shorter: attosecond pulses
2003 record about 100 attoseconds

Relativistic effects

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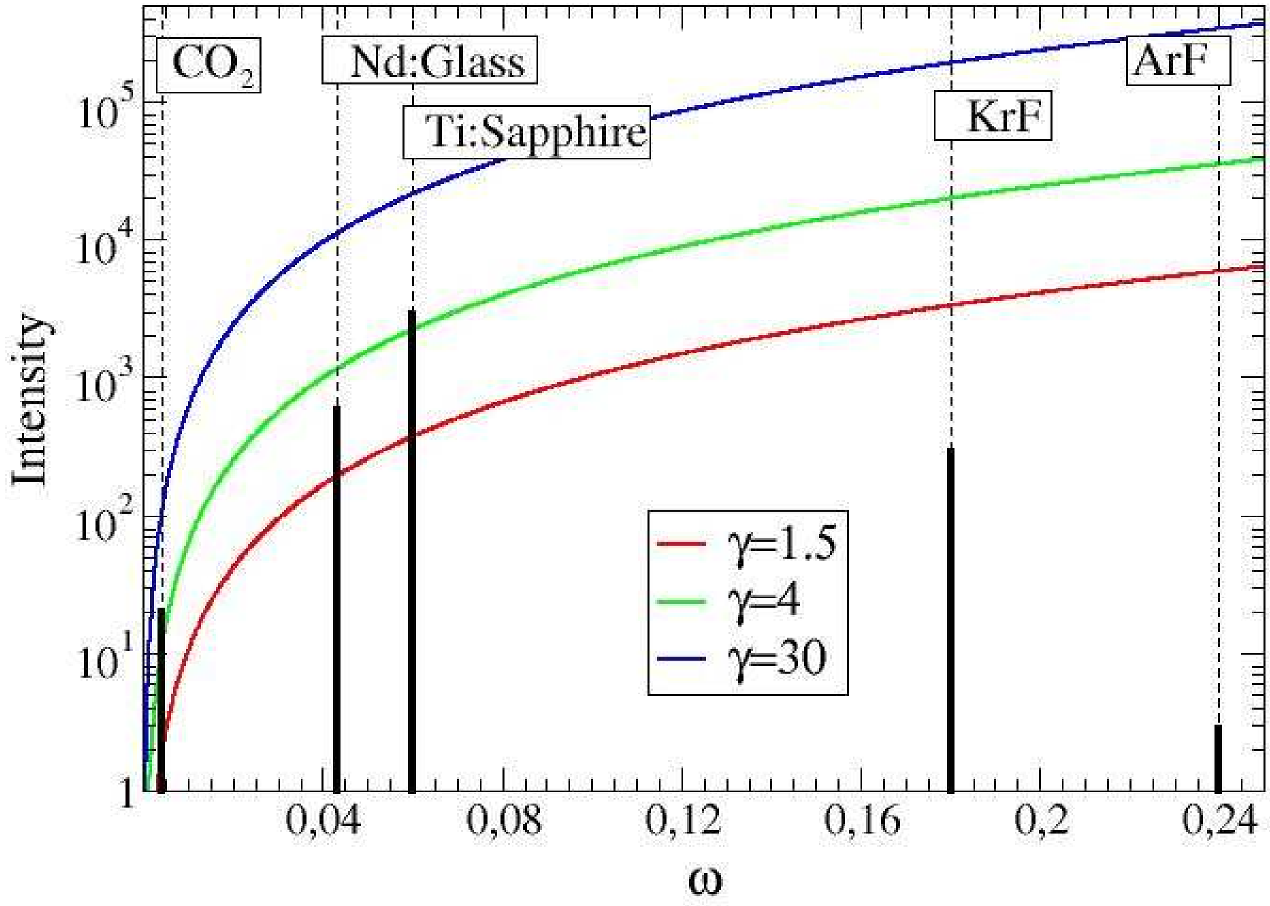

Relativistic effects

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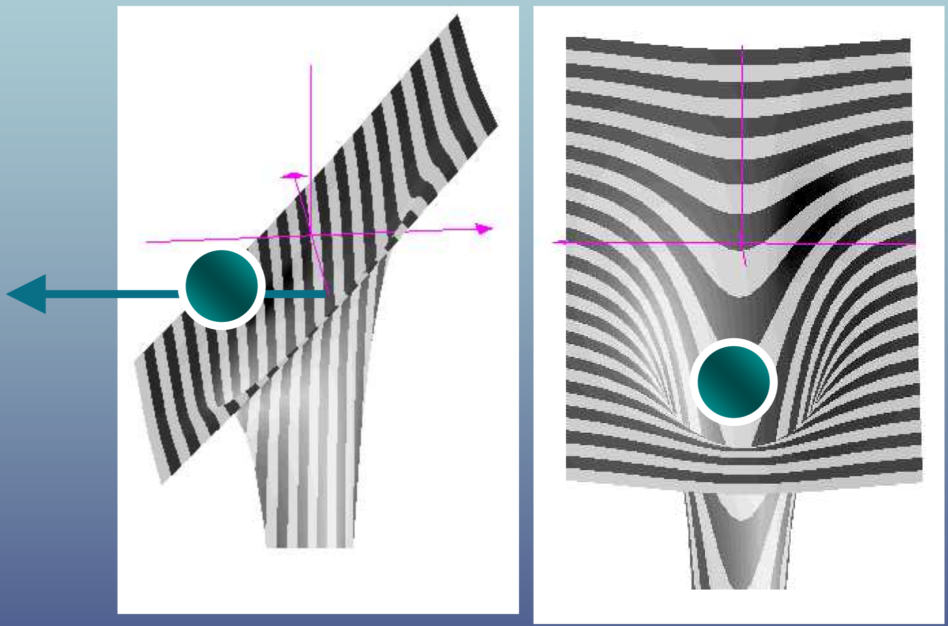
At 800 nm and for intensities beyond 10^{18} W/cm2 electrons are promoted to relativistic speeds.



Over the barrier ionization
In a few femtoseconds

10 MeV electrons are now "normal"

Direct acceleration

Indirect Acceleration

What is a synchrotron?

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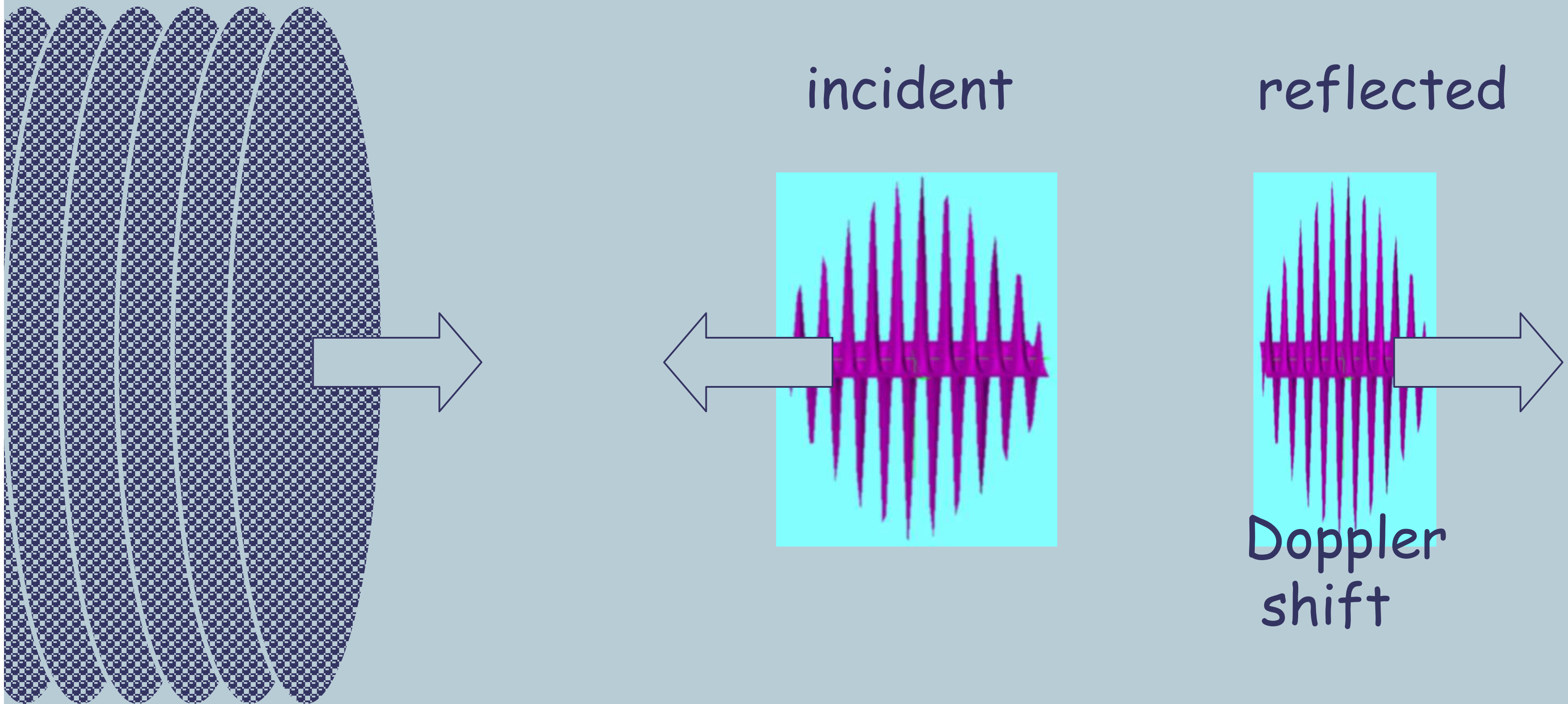
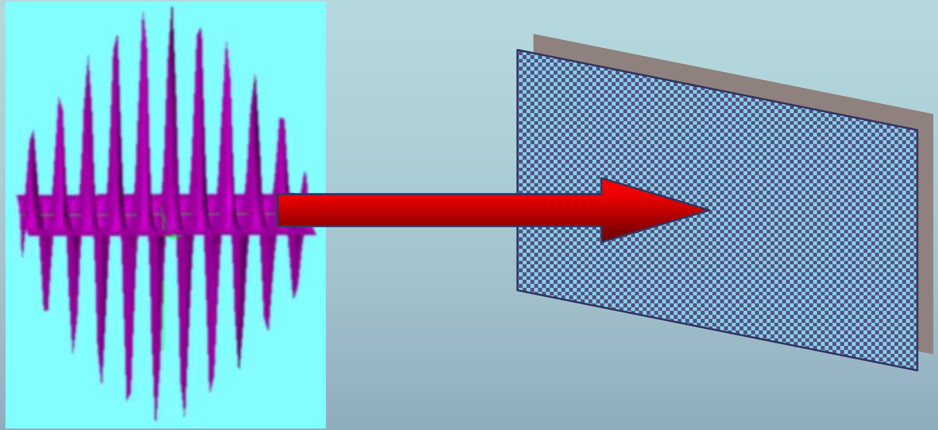
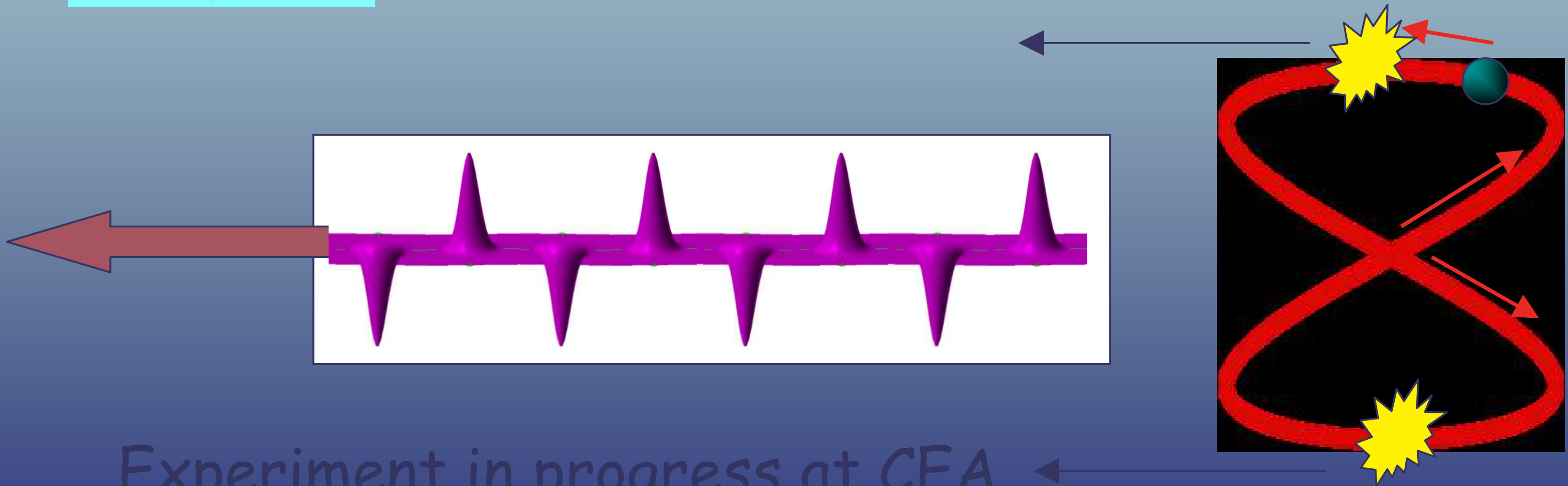
For my a synchrotron is a relativistically moving mirror, a bunch of electrons moving close to the speed of light



X rays from plasmas



Plasma mirror
(relativistically moving)



Experiment in progress at CEA
… controlled generation
… explosive generation … nuclear fusion

Peak brilliance

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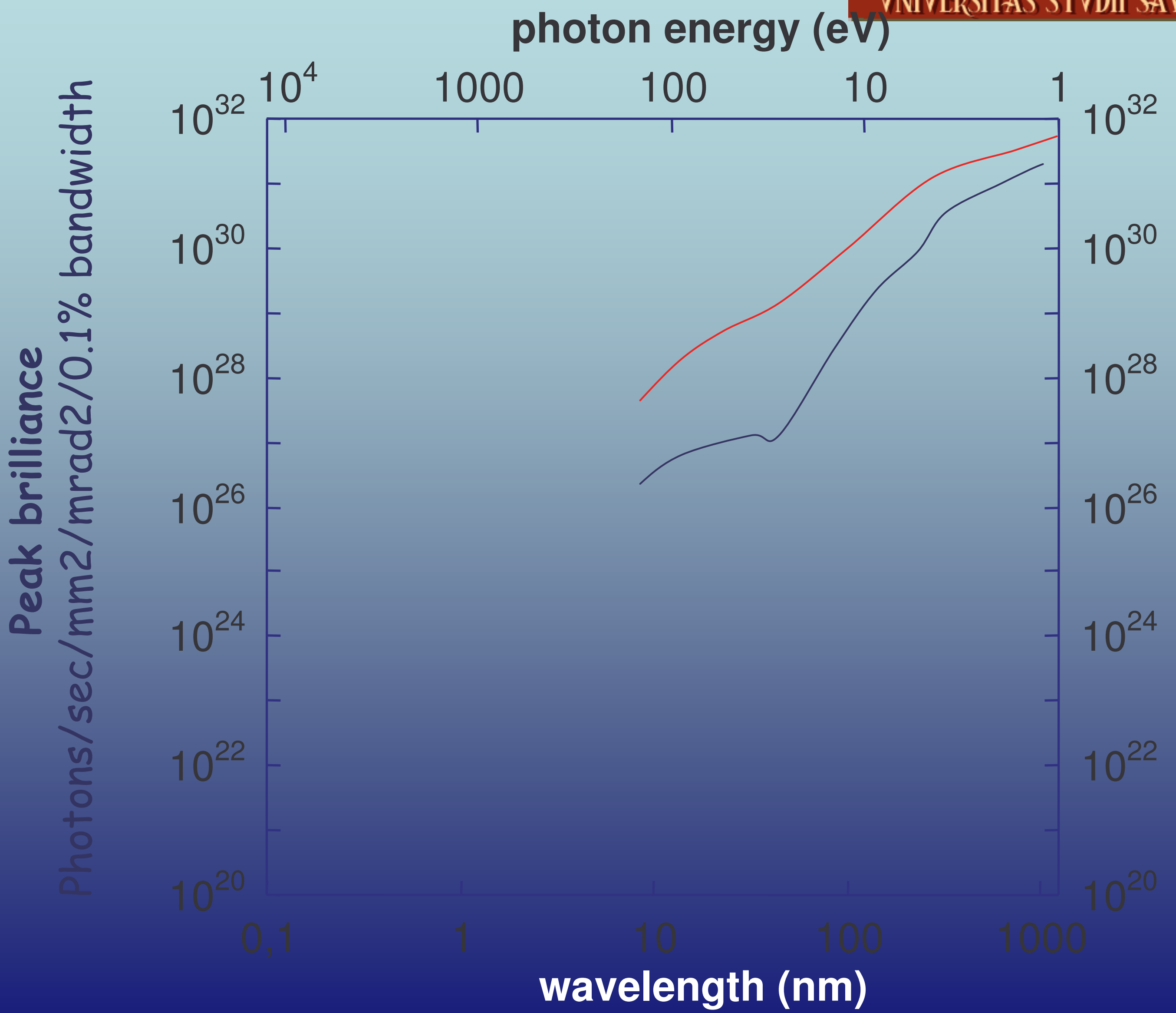

Conclusions

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CPA Femtosecond laser pulses provide monster electric fields over very short times in a controlled way.

Applications in

- High order harmonic generation
- Acceleration of electrons
- Generation of ultrashort bunches

Several possible ways to combine such lasers with synchrotrons