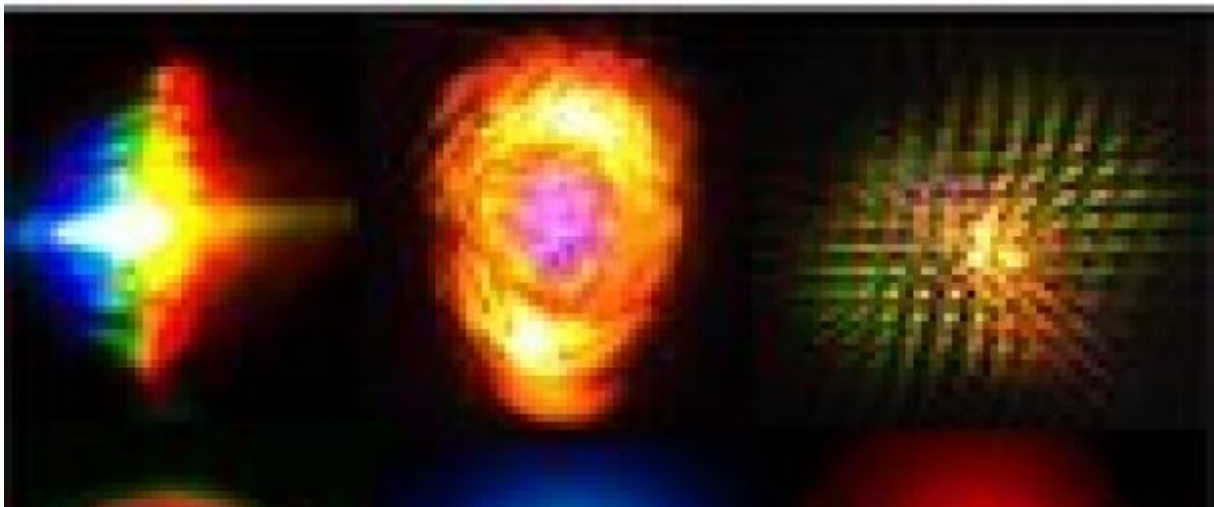


FRANCISCO SILVA

Advisor: Jose Berges



PhD Thesis Defense FRANCISCO JOSE MAIA DA SILVA 'Generation of intense few-cycle waveform-controlled electric fields: from the mid-IR to soft-Xrays'

FRANCISCO JOSE MAIA DA SILVA

February 29, 2016

Monday February 29, 10:00. ICFO Auditorium

FRANCISCO JOSE MAIA DA SILVA

Devising new tools that expand our capabilities to sense and manipulate the world enables much of the scientific and technological progress around us. For example, light is increasingly more important as a tool for humanity. Not all light is equal, however - the light that we normally interact on a daily basis (e.g. the sun), despite its serene and directional appearance, exists in a state of ever changing disorder. What one would perceive as a smooth beam of white light is actually an ever changing pattern of colours. However, As the scale over which the colour changes is spatially too small and temporarily too rapid to be

resolved by the human eye we perceive it as a smooth white beam. This lack of a clear spatio-temporal structure in naturally occurring light - coherence - limits what can be done with it.

If one were to overlap all the frequencies in a temporally coherent beam of light, one could generate an extremely short and powerful pulse. For example, by compressing in time all the colours in sunlight one would generate a light pulse with just a few femtoseconds duration. If such pulse would have a very modest energy (e.g., a Joule), it would have a peak power approaching the PetaWatt - several orders of magnitude more than the total energy production on earth at a given time. When focused on a minuscule spot, the electric field oscillations of this wave would have amplitudes greatly surpassing the electric fields that bind electrons to atoms, or even atoms together in molecules. This implies that by focusing these pulses into matter one can destroy chemical bonds, free the electrons from the influence of the atom's nucleus and even further accelerate these particles away from the interaction region. It follows that with the correct electric field shape, one could control and manipulate matter in new and interesting ways.

In this thesis we have dedicated ourselves to the creation and characterisation of intense, few-cycle pulsed sources of light, using several different approaches.

In this thesis a light source with more than 3 octaves (450-4500 nm) has been developed through filamentation of intense mid-IR pulses in solids. This source has high repetition rate (100 kHz), high spectral density and absolute carrier-envelope phase stability. Additionally, numerical simulations suggest that the nonlinear propagation dynamics induce self-compression, possibly leading to single-cycle pulses.

The scaling of strong field processes such as electron acceleration highly depends on the period or wavelength of the driving electrical field. This has implications for High harmonic generation (HHG) - the longer the wavelength of this field, the higher the energy of the generated photons. In this thesis we have built a high energy pulsed parametric light source at 2100 nm, a wavelength that enables one to generate soft-x-ray photons with energies exceeding 300 eV through phase-matched HHG - and further demonstrated HHG cutoff extension up to 190 eV in Argon, when compared to HHG from 800 nm pulses.

When doing HHG, in order to restrict the soft-X-ray emission to a single isolated attosecond pulse one needs to employ a gating technique. In this thesis we have extended the attosecond lighthouse technique up to the Water window (284-543 eV) which is of fundamental interest to study biological processes with unprecedented spatio-temporal resolution and elemental specificity.

The routine generation and characterisation of pulses in the single-cycle regime has historically been a challenge. As such sources invariably require extreme nonlinear spectral broadening, the optimisation of the output pulse has always been a limitation. In this thesis we extend the dispersion-scan technique to the single-cycle regime and demonstrate its use as a straightforward way to compress, characterise and phase-stabilise 3.2 fs pulses with >50 GW peak power. We illustrate the steps done to optimise this source to reach the single-cycle regime.

Monday February 29, 10:00. ICFO Auditorium

Thesis Advisor: Prof. Dr. Jens Biegert

