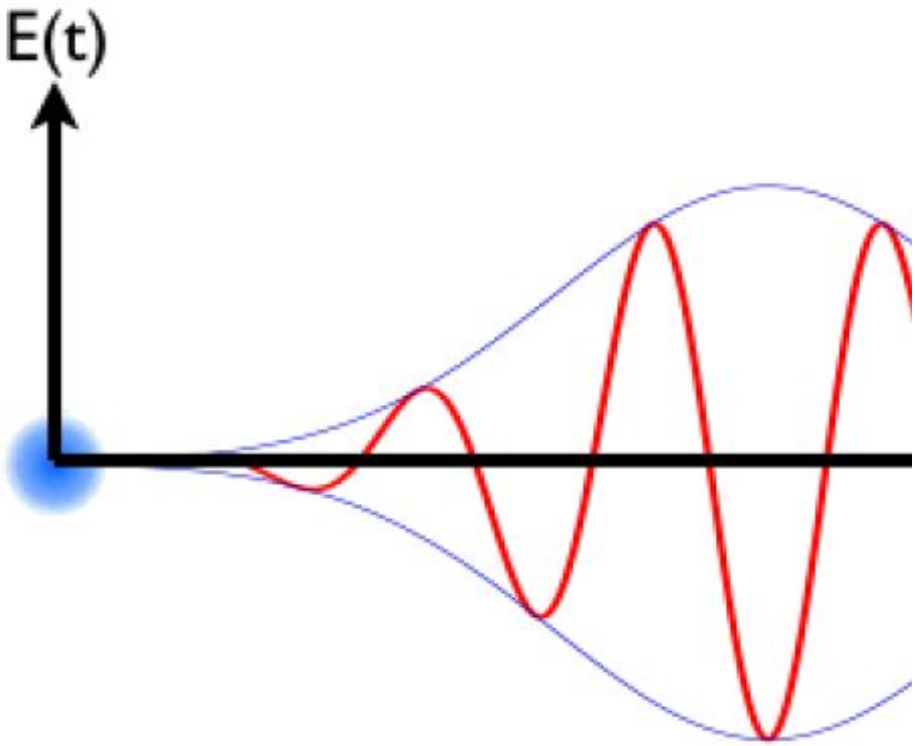


One of the most cited papers in PRA

In its 50th anniversary, PRA highlights the 1994 paper authored by Prof. Lewenstein as one of the highest impact studies ever published in the history of the journal.

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In the past four decades, astounding advances have been made in the field of laser technologies and the understanding of light-matter interactions in the non-linear regime. Thanks to this, scientists have been able to conceive extremely complex experiments to achieve, for example, femtosecond light-pulses in the visible and infrared range and accomplish crucial milestones such as using a molecule's own electrons to image its structure, to see how it rearranges, vibrates or dissociates during a chemical reaction.

On the occasion of the 50th anniversary, the March issue of the journal Physical Review A, published by the American Physical Society, is issuing a special edition, highlighting the papers that have had the highest impacts in the history of the journal. The study authored by ICREA Prof. at ICFO Maciej Lewenstein, Ph. Balcou, M. Yu Ivanov, A. L'Huillier and P.B. Corkum, entitled i¿½Theory of high-harmonic generation by low-frequency laser fieldsi?

½, published in 1994, has been selected as one of these outstanding studies, with over 800 citations according to Google Scholar.

On the occasion of the 25th anniversary of this important paper, an extensive review entitled i¿½Symphony on Strong Field Approximationi¿½ and written by the ICFO researchers K sra Amini, Alexandre Dauphin, Antonio Picon, Emilio Pisanty and Noslen Suarez, led by the I REA Professors at ICFO Maciej Lewenstein and Jens Biegert, and in collaboration wit an international team of researchers including Marcelo Ciappina and Andrew Maxwell, gives the historical background, current status as well as future prospects of this important theoret cal tool of matter physics for intense laser.

It all began in the 60s and 70s, when many experiments observed perturbative harmonic generation in solid and gas samples. Theories were cooked up but never robust and solid enough to really explain why and how this phenomenon occurred. After years of research, in the early 90s, researchers Paul Corkum and Ken Kulander proposed a theory coined as the **"simple man's model",** which used classical and quantum arguments to give an elegant explanation of the physics involved in such processes. The simple man's model, also known as the three-step or recollision model, meant a major breakthrough in the field.

The physics behind the simple man's model is as follows: Firstly, an electron can tunnel through the potential energy barrier that binds it to its atom or molecule, a process considered i¿½quantumi¿½; secondly, the emitted electron can be accelerated by the st ong oscillating electric field of the laser as a i¿½classicali¿½ particle; and thirdly, in certain occasions, the accelerated electron can return back to the nucleus of the ionized atom or molecule where it can:

recombine with the nucleus, releasing its excess energy gained in the laser field as extreme ultraviolet or X-ray photons through high harmonics of the driving laser (called high harmonic generation - HHG),

elastically rescatter against the nuclear cores of atoms in the structure, with structural information embedded in the electron's momentum distribution (called laser-induced electron diffraction - LIED),

inelastically rescatter against the ionic target, leading to the emission of a second electron from the parent ion, creating a doubly charged ion (called non-sequential multi-electron ionization - NSMI).

Now, even though the simple man's model was consistent with experimental results, it only provided a classical picture of the underlying quantum processes. Thus, a fully quantum extended version of the theory was developed by the work of Lewenstein, L'Huillier and Corkum, who found a quasi-classical solution to the harmonic generation in a low frequency high-intensive regime. This quantum version of the "simple man's model" was called i¿½Strong Field Approximation (SFA)i¿½. Based on Feynman path integral formulatio of quantum mechanics, the theory takes into account effects such as the quasi-classical mo ion of electrons along complex trajectories, including tunneling and recombination/rescater ing effects, quantum interference of various complex electron trajectories, or quantum diffu ion of the electronic wave packet.

The scientific legacy of Lewenstein and his collaborators has been such that the theory was named the **i¿½Lewenstein modeli¿½** and, since the 1990s, almost all experimental research groups working in the field of Quantum Physics have been conducting experiments related to HHG, LIED and NSMI in strong fields.

Illustration Caption: Illustration of three-step model. An electron (green) from a hydrogen atom's s-orbital (blue) is: (i) emitted by strong-field tunnel ionization above its ionization threshold (grey dotted); (ii) accelerated and returned by the oscillating laser field (orange trajectory); (iii) before recombining with the target ion to release the energy gained in the field as an attosecond burst of high-order harmonics of the driving laser field. Animation credit: Jens Biegert/ICFO.