Acceptance speech

20 June 2023

Paul Corkum, awardee in the Basic Sciences category (15th edition)

It is a great honor to be awarded the BBVA Foundation award together with my colleagues, Professor Anne L'Huillier and Professor Ferenc Krausz.

The first laser operated in 1960 and immediately a few forward-looking scientists knew that optics would never be the same. Among them was Professor Bloembergen. He began developing what we now refer to as nonlinear optics. The nonlinearity in Professor Bloembergen's case was the nonlinear motion of the electron within the atom. He published his famous papers on nonlinear optics in 1962. He was awarded the Nobel Prize for Physics in 1981.

Professor Bloembergen's nonlinear optics was very influential, powering such important advances as quantum optics, optical communications, and countless scientific studies. It was not that unbound states were unknown. Since the first days of quantum mechanics, we understood single photon ionization. In fact, Einstein's Nobel Prize was given for precisely that: the photoelectric effect. But photoionization was linear and therefore, simple.

Professor Keldysh was also influenced by the development of the laser. Professor Keldysh derived the boundary that separated ionization as tunneling from ionization as a weak effect. One might think that these pioneers captured everything there was to say about how high-intensity light interacts with matter.

Influenced by Professor Keldysh, I began to look at ionization through a plasma physics lens. That is, what happens to the electron if Keldysh was correct about tunnelling. For one thing, atoms are transformed into ions, so a plasma is formed from a neutral gas. What was less obvious was that the plasma characteristics could be very different depending on parameters such as the light's polarization. I, as an experimentalist, could easily vary the polarization. I also found that, within a cycle, the electron could return to its place of birth.

At first, I thought that the returning electron was interesting, but not very important. Of course, I was wrong. The returning electron was a generalization of Bloembergen's nonlinear optics to include unbound electrons. Once I realized this, using the recollision electron, I predicted the characteristic of the nonlinear radiation that was generated, showing that it could stretch to X-ray wavelengths. I also immediately knew how recolliding electrons could be used to make attosecond pulses, and how these pulses could be measured.

I published the more general model for atoms, now often termed the three-step model, in 1993. It concentrated on the returning electron and provided a mental image to which all scientists could relate.

By now recollision (as it is called) is found in almost all transparent materials when they are irradiated by intense light.

In subsequent years, powered by recollision, we have decreased the minimum duration of light flashes by a factor of 100; performed the fastest controlled measurements ever made; extended the spectral reach of conventional lasers by a factor of about 100, and all of this while providing a more complete picture of the nonlinear response of materials to intense light.

I would like to end by acknowledging the contribution of Canada's National Research Council from the very beginning of attosecond science to the present time. I would also like to acknowledge other Canadian and U.S. institutions for their contribution. They include the Natural Science and Engineering Research Council, the Canada Research Chairs program, and the Canada Foundation for Innovation (whose president, Dr. O'Reilly Runte, has come to Spain to help celebrate the occasion). Reaching beyond Canada, my research was supported by the U.S. Air Force Office of Scientific Research, and the U.S. Army Research Office. All these institutions helped build a strong and creative group of students and postdocs.

Before concluding I must thank my wife Nadja, who has also come to Bilbao for the awards ceremony. Over many years she has given warm support for my obsession with physics.