Harnessing atoms and molecules with metrological sources

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Interrogation and manipulation of atomic and molecular transitions for challenging experiments put increasingly demanding constraints on sources, detectors and techniques. Continuous coverage of extreme spectral regions, tight control of phase and frequency fluctuations as well as implementation of ultra-low noise techniques, can disclose new horizons for frontier research. I will give an overview of recent results aiming at a study of new comb-based coherent sources extending at longer wavelengths, down to the THz range, and spectroscopic techniques, obtained at INO-CNR and LENS, with present and perspective applications to molecules and atoms [1,2,3,4].

References:

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[3] L. Consolino et al., "Phase-locking to a free-space terahertz comb for metrological-grade terahertz lasers", Nature Communications, **3**, Article number: 1040 (DOI: 10.1038/ncomms2048) (2012).

[4] I. Galli et al., "Comb-assisted subkilohertz linewidth quantum cascade laser for high-precision mid-infrared spectroscopy", Applied Physics Letters **102**, 121117 (2013).

Biography

Paolo De Natale graduated in Physics (cum laude) at Federico II University, Naples, Italy. He joined the European Laboratory for Nonlinear Spectroscopy (LENS) in 1988 and, since 1996, he has been staff scientist at Istituto Nazionale di Ottica (INO)-CNR (formerly INOA) which, at the time of writing, he directs.

His research activity has always been focused on atomic, molecular and optical physics. Pioneering results included tests of theories, measurements of fundamental constants, using state-of-the-art spectroscopic techniques and originally developed coherent sources, often harnessing nonlinear optical phenomena. He has often carried on research in quite unexplored spectral regions, like infrared and far-infrared (THz), for the lack of suitable sources. Another part of PDN research has been devoted to the study and design of novel optoelectronic

devices, especially based on ferroelectric crystals. To trigger such multidisciplinary research, PDN summoned a group combining unusual skills in spectroscopy, interferometric diagnostics, mastering of nonlinear sources and techniques, that enabled quick achievement of unique results. Such activity is still ongoing in the Napoli section of the Istituto Nazionale di Ottica-CNR (formerly INOA), producing internationally recognized breakthrough results.

The most recent best results to which PDN has given significant contributions include the first fiber-based mid-IR generation of a frequency comb as well as demonstration of its suitability for frequency metrology; pioneering work on sub-Doppler molecular spectroscopy with an absolute frequency scale in the IR, using coherent sources based on difference frequency generation with smart phase-locks; use of optical frequency-comb synthesizers for building highly coherent mid-IR radiation sources; development of a novel spectroscopic technique (SCAR), based on saturated absorption cavity ring-down, overcoming background-related sensitivity limits of standard cavity ring-down; pioneering work on the intrinsic noise properties of Quantum Cascade Lasers; discovery of the intrinsic sensitivity limits of fiber-based optical sensors; molecular gas sensing at parts per quadrillion, achieving the highest sensitivity (i.e. minimum detectable gas pressure) ever observed in a spectroscopic experiment on a gas of simple molecules, taking to detection of radiocarbon-dioxide ($^{14}CO_2$) below its natural abundance.

Paolo De Natale has authored more than 200 papers, has edited 10 books and special journal issues and holds six patents.