Extreme light for molecules at the extremes

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Interrogation and manipulation of molecules is a challenging task, when sensitivities beyond parts per trillion or accuracies for frequency measurements approaching the uncertainty of primary frequency standards are requested. It indeed requires an overall rethinking of radiation sources, spectroscopic techniques and molecular samples preparation. Compared to atoms, difficulties are increased by the weaker absorption line-strengths, as well as by the need to cover the huge 2-1000 micron wavelength interval, where fundamental ro-vibrational bands of molecules are found, by appropriate photonic tools and spectroscopic techniques. To make matters worse, cryogenic cooling is often required to suppress the strong background radiation noise from which this spectral range suffers. However, a tremendous progress in photonics and spectroscopy, as well as in molecular sample preparation, is revolutionizing the scenario [1]. In the last twenty years, the main game changers on the photonics side have been frequency comb synthesizers [2-3], quantum cascade lasers [4-5] and quasi-phase-matching schemes for nonlinear generation of coherent radiation [6]. For spectroscopy, extension to the infrared and THz range of precision frequency measurements, beyond 10^{-11}, and the achievement of sensitivities better than 1 part-per-trillion are providing novel, powerful physical probes and new areas of application for sensing [7]. On the side of molecular samples, a key role is played by the emerging technologies for the production of cold and ultra-cold stable molecules, including buffer-gas cooling and magneto-optical trapping [8-11].

Several examples showing significant, often ground-breaking, results in the areas cited above will be discussed, together with perspectives in these areas.

References

[1] P. Maddaloni, M. Bellini, and P. De Natale, *Laser-based Measurements for Time and Frequency Domain Applications. A Handbook*, Series in Optics and Optoelectronics, Taylor&Francis Group 2013.
[2] T. Udem, R. Holzwarth, and T. W. Hänsch, Nature **416,** 233 (2002).
[3] S. Bartalini, L. Consolino, P. Cancio, P. De Natale, P. Bartolini, A. Taschin, M. De Pas, H. Beere, D. Ritchie, M. S. Vitiello, and R. Torre, Phys. Rev. X **4**, 021006 (2014).
[4] J. Faist, *Quantum Cascade Lasers*, Oxford University Press 2013.
[5] F. Cappelli, G. Campo, I. Galli, G. Giusfredi, S. Bartalini, D. Mazzotti, P. Cancio, S. Borri, B. Hinkov, J. Faist, and P. De Natale, Laser Photon. Rev. **10**, 623 (2016).
[6] G. Insero, C. Clivati, D. D'Ambrosio, P. De Natale, G. Santambrogio, P. G. Schunemann, J.-J. Zondy, and S. Borri, Opt. Lett. **41**, 5114 (2016).
[7] I. Galli, S. Bartalini, R. Ballerini, M. Barucci, P. Cancio, M. De Pas, G. Giusfredi, D. Mazzotti, N. Akikusa, and P. De Natale, Optica **3**, 385 (2016).
[8] L. Santamaria, V. Di Sarno, P. De Natale, M. De Rosa, M. Inguscio, S. Mosca, I. Ricciardi, D. Calonico, F. Levi, and P. Maddaloni, Phys. Chem. Chem. Phys. **18**, 16715 (2016).
[9] G. Insero, S. Borri, D. Calonico, P. Cancio Pastor, C. Clivati, D. D'Ambrosio, P. De Natale, M. Inguscio, F. Levi, and G. Santambrogio, Sci. Rep. **7**, 12780 (2017).
[10] S. Truppe, H. J. Williams, M. Hambach, L. Caldwell, N. J. Fitch, E. A. Hinds, B. E. Sauer, and M. R. Tarbutt, Nature Phys. **13**, 1173 (2017).
[11] L. Anderegg, B. L. Augenbraun, E. Chae, B. Hemmerling, N. R. Hutzler, A. Ravi, A. Collopy, J. Ye, W. Ketterle, and J. M. Doyle, Phys. Rev. Lett. **119**, 103201 (2017).

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What happens at the molecular level when the polarised light passes through the molecule? Ad by Fashinza. Production, without the stress!Â When plane polarised light pass through a molecule, the electromagnetic waves (of molecule and light) interact with each other. By virtue of this interaction, the plane of vibration of polarised light is tilted and we term it as optical rotation. Now, for a molecule which is not chiral (that which posses plane of symmetry), the optical rotation of one half of molecule is opposite of the other half. Therefore, the two effects cancel each other. Hence show no optical rotation. Office of Science. Science Up-Close: Blasting Molecules with Extreme X-Rays. December 6, 2018. Office of Science. Science Up-Close: Blasting Molecules with Extreme X-Rays. Image courtesy of DESY/Science Communication Lab.Â To dig into the issue, they shot the most powerful X-ray laser in the world â€" located at the Department of Energy (DOE) Office of Science's Linac Coherent Light Source (LCLS) â€" at a series of atoms and molecules. Can We Trust What We See? Scientists regularly use X-ray light sources to take pictures and videos of biological and chemical processes and objects. For example, a recent study at the LCLS looked at how antibiotics and the parts of the body that produce proteins interact . Extremely small objects and incredibly fast processes now appear in a new light. Not only physics, but also chemistry, biology and medicine have gained precision instruments for use in basic research and practical applications. Arthur Ashkin invented optical tweezers that grab particles, atoms and molecules with their laser beam fingers.Â Finally, the motor molecule can no longer withstand the force of the light trap and the sphere is forced back to the centre of the beam. Figure 2. The optical tweezers map the molecular motor kinesin as it walks along the cell skeleton. From science fiction to practical applications.Â He initiated and led the early development of Extreme Light Infrastructure (ELI). Three sites â€“ in the Czech Republic, Hungary and Romania â€“ will be complete in a few yearsâ€™ time.