Frequency Combs and Dual-Comb Interferometry

Optical frequency combs have revolutionized time and frequency metrology by providing rulers in frequency space that measure large optical frequency differences and/or straightforwardly link microwave and optical frequencies. Such combs enable precision laser spectroscopy, tests of fundamental physics and provide the long-missing clockwork mechanism for optical clocks. Today, table-top instruments have become commercially available and much of the efforts have shifted towards accessing new spectral territories, miniaturizing the devices with integrated optics and exploring new parameter ranges. Frequency combs have become key to research areas such as attosecond science, molecular spectroscopy, calibration of astronomical spectrographs, ranging or low-noise microwave generation. Intriguing new applications continue to emerge, including dense optical data transmission, quantum technologies, photonic processors for optical neural networks, three-dimensional imaging and biological sensing.

One of the most successful uses of frequency combs beyond their original purpose has been dual-comb interferometry. An interferometer can be formed using two frequency combs of slightly different line spacing. Dual-comb interferometers without moving parts are fundamentally different from any other type of interferometers: they perform direct frequency measurements, without geometric limitations to resolution. They outperform state-of-the-art devices in an increasing number of fields including spectroscopy and holography, offering unique features such as frequency measurements, accuracy, precision, speed.

This lecture will provide an introduction to the concepts behind optical frequency combs, it will outline the latest exciting developments on frequency combs and their applications and will survey techniques of dual-comb interferometry, in particular for spectroscopy.

Lecturer: Nathalie Picqué is a research group leader at the Max-Planck Institute of Quantum Optics (Garching, Germany). She was previously a tenured research scientist with the Centre National de la Recherche Scientifique (CNRS) at Orsay (France). She received her doctoral degree in Physics from Université Paris-Saclay (France) in 1998. Her research interests are in the areas of optics and molecular physics, more particularly in interferometry, precision spectroscopy and laser technology. Her research focuses on exploring new ideas that involve laser frequency combs and on applying these novel concepts to metrology, molecular spectroscopy, holography and chip-scale sensing. A 2019 Optica fellow, Nathalie Picqué has received several awards, including the 2007 Bronze Medal of the CNRS, the 2013 Coblentz award in Molecular Spectroscopy, the 2021 Gentner-Kastler Prize in Physics, a 2021 European Research Council Advanced Grant, the 2022 Helmholtz Prize in Metrology and the 2022 Breakthrough in Physical Sciences of the Falling-Walls Foundation. Further details at http://www.frequency-comb.eu