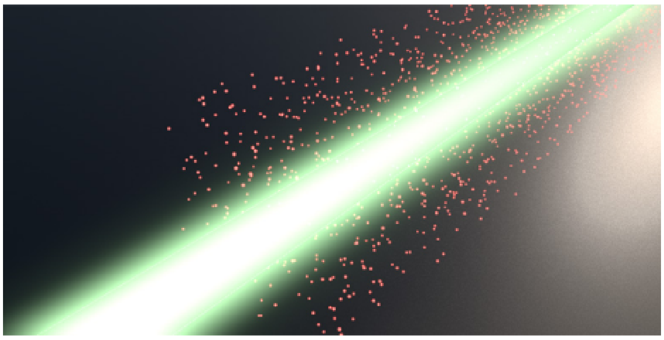
One laser is enough

12 May 2017, by Oliver Morsch



Pulsed lasers: the key to analysing gases quickly and precisely. Credit: ETH Zurich/Sandro Link

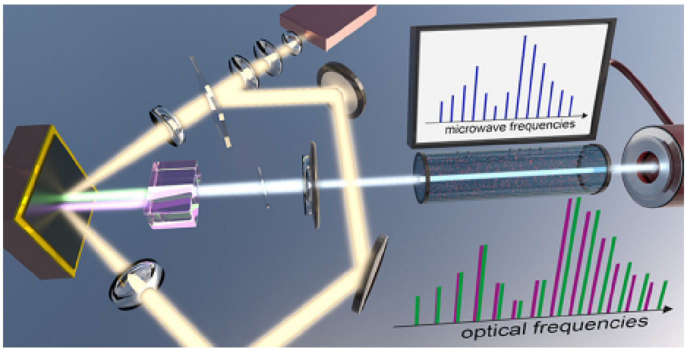
Gases in the environment can be spectroscopically probed fast and precisely using so-called dual frequency combs. Researchers at ETH have now developed a method by which such frequency combs can be created much more simply and cheaply than before.

In contrast to the light emitted by a simple lamp, laser light has a very precisely defined frequency. This makes it ideally suited to spectroscopic investigations, in which the properties of substances are determined on the basis of the frequencies at which they absorb light. A complete spectroscopic analysis typically requires a little patience, as the frequency of the laser has to be gradually changed ("scanned") in order to obtain a full spectrogram. A group of physicists at ETH in Zurich led by Ursula Keller at the Institute for Quantum Electronics have now demonstrated a seminal method that could lead to simpler and faster spectroscopic investigations in the future. For that purpose, they developed a novel technique for creating so-called dual frequency combs. The results have now been published in the scientific journal *Science*.

A ruler made of light

Whereas a normal laser emits light at one frequency, a frequency comb features a large number of frequencies at a constant distance from one another – just like the marks on a ruler. This is made possible by using lasers that create extremely short periodic light pulses. Such pulse trains have a comb-like frequency spectrum, which can be broadened further using particular optical materials. In 2005 the Nobel Prize was awarded for laser-based precision spectroscopy including the optical frequency comb technique, to which Ursula Keller in collaboration with Harald Telle from PTB Braunschweig invented the key enabling technology for the stabilization of the comb in 1999.

In principle one could probe a substance simultaneously with many frequencies using such a frequency comb. In ordinary spectroscopy a part of the laser light is sent through the material to be studied, and the other part is used as a reference. The frequency of the laser is now steadily scanned, and at the same time the absorption of the laser light by the substance is measured relative to the reference beam using two photodetectors. From this frequency scan the characteristic spectrogram of the substance is obtained. Unfortunately, this procedure cannot be applied straightforwardly to a frequency comb. The different frequencies simultaneously contained in the comb would certainly be absorbed differently. The photodetector, however, would not be able to tell them apart. To do so, it would have to directly record the individual, superposed oscillations of the light, which, however, is impossible in practice because of their high frequency of several hundred Terahertz (a thousand billion oscillations per second).



The new method uses a single laser that emits two beams of differing pulse periods. Sending both beams through the sample material creates a beat frequency that can be measured using conventional electronics. Credit: ETH Zurich/Sandro Link

The piano tuner's trick

The technique developed by Keller and her co-workers "translates" these fast and not directly measureable oscillations into much slower ones that can be easily detected with conventional electronics. This procedure relies on a trick that is used in a similar form by piano tuners. In order to obtain an equal tuning of the different chords of the same tone a piano tuner uses the beat produced by the superposition of two different frequencies. The beat pulsates at a speed that corresponds to the difference of the two superposed frequencies.

The researchers at ETH use a very similar method in which they create a second frequency comb, whose frequencies have a slightly different spacing than those of the first one. This creates pairs of frequencies, each of which results in a slightly different beat frequency. These beat frequencies are now in the Megahertz regime and can be easily measured using photodetectors.

Two frequency combs for the price of one

This kind of dual-comb spectroscopy has been around for a few years, but the technique now developed at ETH makes it considerably simpler and less expensive, as Sandro Link, PhD student and first author of the paper, explains: "The real novelty is that we create the two frequency combs with just one laser instead of two, which would have to be painstakingly stabilized with respect to each other." The trick they use consists in a birefringent crystal that is inserted into a laser, which causes the light to travel slightly different distances according to its polarisation (i.e., the direction of oscillation of the electromagnetic wave). As a consequence, the two laser beams thus produced have slightly different pulse periods, which in turn leads to frequency combs with different frequency spacings. As the two frequency combs are created by the same laser, stabilizing them against each other becomes redundant.

A number of possible applications of the new technology present themselves. Since it allows one to produce a complete spectrogram in less than a thousandth of a second, it is ideally suited to measuring the concentration of substances in the environment or in the exhausts of factories. Fast flowing gases in petrochemical settings could also be analysed quickly, for example to monitor and control production processes.

More information: S. M. Link et al. Dual-comb spectroscopy of water vapor with a free-running semiconductor disk laser, *Science* (2017). DOI: 10.1126/science.aam7424

Provided by ETH Zurich

APA citation: One laser is enough (2017, May 12) retrieved 18 June 2019 from https://phys.org/news/2017-05-laser.html