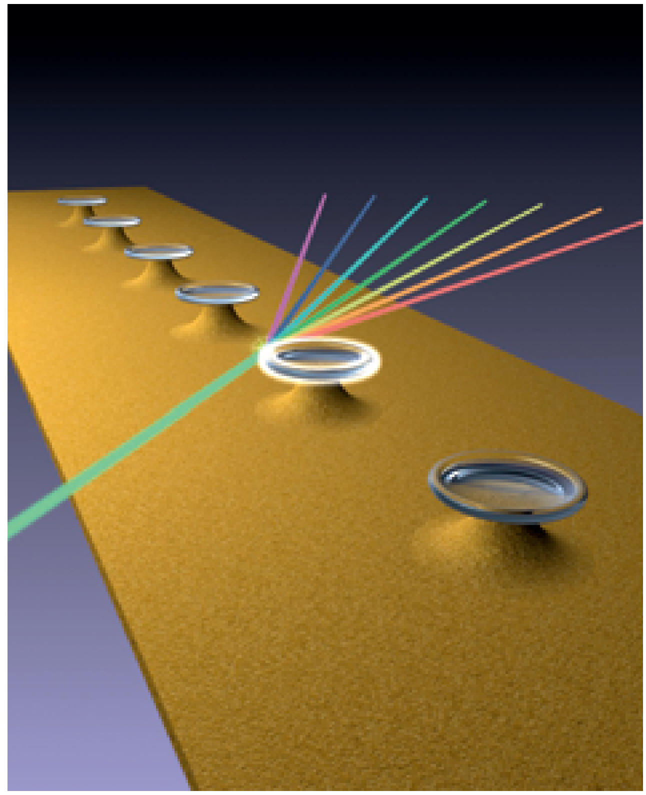
OPTICS

Light Ruler on a Silicon Chip

It may soon be possible to measure light frequencies with extremely high precision on a microchip. Using a ring-shaped resonator that is not even as thick as a strand of hair, scientists at the Max Planck Institute for Quantum Optics in Garching have now created, on a microchip, the frequency comb that allows measurements of this kind to be made. In 2005, Theodor Hänsch from the Max Planck Institute in Garching received the Nobel Prize for developing the frequency comb. Now that the frequency comb has become much more compact, it opens up new technological possibilities for time measurement and data transfer. (NATURE, December 20, 2007)



A microresonator breaks monochromatic light into a frequency comb.

A frequency comb is a kind of ruler that allows light frequencies to be measured with great precision. It is created in a laser that emits very short pulses by coupling its resonance frequencies with each other. This, in turn, creates laser light containing up to 100,000 very closely spaced spectral lines whose frequency separation is always identical and very precisely known – thus the name "comb". Overlaying this frequency comb with another laser beam of an unknown frequency creates a beat like that of two tones with almost exactly the same pitch. This beat allows the unknown frequency to be determined with a precision never before achieved. The device that produces a frequency comb of this type has thus far consisted of several separate components and is larger than a desktop computer.

Now, Tobias Kippenberg's Independent Junior Research Group and Ronald Holzwarth from Menlo Systems, which markets the frequency technology worldwide, have created a frequency comb in a ring-shaped glass resonator with a diameter of only 75 micrometers on a silicon chip. Light can be coupled into the resonator by passing a laser beam close by in a glass nanofiber. Pascal Del'Haye created the microresonators in Professor Jörg Kotthaus' clean room at Ludwig Maximilian University in Munich, and proved the comb lines' equidistance in precision measurements.

The microresonators can store light for a relatively long time. This can lead to extremely high light intensities – that is, photon density – and gives rise to the Kerr effect. In this process, two new photons are created from two photons, light particles or quanta of identical energy. One of these new photons has more and the other less energy than one of the original photons. The new photons interact with the original photons and, in turn, produce yet other frequencies. A wide spectrum of frequencies results from this cascade: a frequency comb. "This is a completely new creation process," says Tobias Kippenberg.

In the future, this new type of frequency comb could be used to construct ultra-precise clocks. And applications in optical telecommunications are also possible: whereas the lines are extremely dense and very dim in the traditional frequency comb, the approximately 130 spectral lines of the monolithic frequency combs are separated by around 400 gigahertz and generate output on the order of a milliwatt. This almost exactly meets the requirements for the carrier of the data channels in optical telecommunications using glass fiber. Until now, each frequency channel has needed its own generator with its own laser. Now, it would be possible to define multiple data channels with a frequency comb generated on a microchip. "However, before the frequency comb can be used for any practical applications, we still need to work out a few technical details," says Tobias Kippenberg.

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