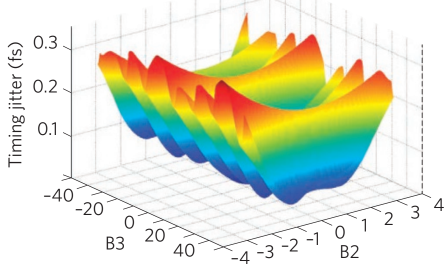
METROLOGY

Timing is everything

Light Sci. Appl. **6,** e16187 (2017)



A kilometre-scale synchronous network linking optical and microwave devices with attosecond precision has been developed by a team of scientists from the Center for Free-Electron Laser Science in Hamburg, Germany and Massachusetts Institute of Technology (MIT) in the USA. Such networks will prove useful for X-ray science experiments relying on free-electron lasers (FELs) that require attosecond-level synchronization of optical and microwave signals across large distances, and may also benefit applications in geodesy, long-baseline interferometry and multi-telescope arrays. By mitigating the effects of optical fibre nonlinearity and sources of noise the team achieved stabilization of a 4.7-km-long fibre network with a timing jitter of just 580 attoseconds (root mean square) for over 40 hours. A complete laser-microwave network operated with a timing jitter of 950 attoseconds over a period of 18 hours. The ability to control the timing of FELs with this level of precision will be useful to make atomic and molecular movies at the attosecond timescale, thus aiding investigations in biology, drug development, materials science and fundamental physics. *OG*

SPECTROSCOPY

Probing antimatter

Nature **541,** 506–510 (2017)

The apparent imbalance of matter and antimatter in the Universe is one of the great remaining mysteries in physics. One possible explanation, not yet proven, is the existence of a small asymmetry between the behaviour of atoms and their anti-atoms. Hydrogen is probably the most studied atom in the periodic table. However, the optical spectrum of antihydrogen, consisting of an antiproton and a positron, has not been measured and the pressing question is will it be identical to that of hydrogen? Now, a group of researchers from 12 different countries has answered the question by optically driving the 1S–2S transition in magnetically trapped antihydrogen using the ALPHA-2 set-up at CERN. A cylindrical volume (44 mm diameter, 280 mm length) of anti-atoms was illuminated by 150 mW of ultraviolet light at a wavelength of 243 nm. The apparatus includes a Fabry–Pérot cavity to enhance the interaction time between antihydrogen atoms and ultraviolet photons. Counterpropagating photons excite the 1S–2S transition at a frequency that is approximately independent of the Doppler effect; the cavity transmission is monitored by a photodiode. The frequency of the transition observed for antihydrogen is the same, within the limits of experimental uncertainty, as that of hydrogen. These results are in agreement with the CPT (charge conjugation, parity reversal and time reversal) theorem, which requires the symmetry of the two spectra. *DP*

INTEGRATED CIRCUITS

Chip-scale frequency synthesizer

Opt. Express **25,** 681–695 (2017)

Reducing the size of optical frequency synthesizers (OFSs) to the chip scale is technically challenging. Optical frequency comb (OFC) generators are a key element of OFSs, and microresonator-based OFCs lend themselves to on-chip integration. However, even these generators require pump laser powers in the hundred milliwatt range, thus hampering the successful thermal management of integrated OFSs. Now, Shamsul Arafin and co-workers from the USA have demonstrated a chip-scale OFS based on an optical heterodyne phase-locked loop. Light emitted from a semiconductor distributed feedback laser with an output power of 20 mW was sent to a high-*Q* MgF_2 whispering-gallery-mode resonator to generate an optical frequency comb spanning the 1,535–1,575 nm range. The comb lines were used as the reference for the heterodyne optical phase-locked loop, where the latter consisted of a photonic integrated circuit, an electronic integrated circuit and a loop filter. Arbitrary frequency synthesis between the comb lines was demonstrated by tuning the radio frequency offset source, and better than 100 Hz tuning resolution within an accuracy of 5 Hz was achieved. *NH*

X-RAY SCIENCE

Unexpected diffraction

Phys. Rev. Lett. **118,** 024801 (2017)

Conventional diffraction theory breaks down at sufficiently high X-ray intensities, such as that achieved with the latest generation of X-ray lasers (XFELs), and in this regime it is possible for an X-ray diffraction pattern to be self-focused beyond the diffraction limit. That's the conclusion of a theoretical study conducted by Joachim Stöhr from the SLAC National Accelerator Laboratory in the USA. Stöhr considered the case of a source formed from a thin film within a circular aperture. When illuminated at high intensities such that spontaneous scattering from the film is replaced by stimulated scattering, the resulting diffraction pattern is no longer the expected Airy pattern. Instead, the stimulated pattern corresponds to the square of the Airy pattern, where the central peak has a reduced width and the outer Airy rings effectively disappear. The new pattern results from the interaction of cloned photon pairs created by stimulated emission. *OG*

OPTICAL IMAGING

Light scattering on tape

Sci. Adv. **3,** e1601814 (2017)

Ultrafast two-dimensional imaging of dynamic phenomena in real time should ideally achieve a picosecond-level exposure time per frame while avoiding temporal and spatial scanning. Now, Jinyang Liang and collaborators have successfully recorded light-scattering dynamics in the form of a photonic Mach cone with a single camera exposure at a rate of 100 billion frames per second. The team used a lossless-encoding compressed ultrafast photography (LLE-CUP) system designed to acquire three 'views' of the observed scattering phenomenon, two of which capture the crucial temporal information as they originate from spatially encoded beams that are temporally sheared inside a streak camera. To produce the photonic Mach cone, a 'source tunnel' medium with refractive index n_s scattered a visible picosecond laser beam, creating wavefronts that propagated in two bordering 'display panels' with refractive index n_d. For $n_s < n_d$, the secondary light sources produced by the scattering events in the source tunnel advanced faster than the light in the display panels, leading to an instantaneous scattered light distribution with a distinctive Mach cone structure. *GD*

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Corrected after print: 14 March 2017