blue light luminous intensity greater than 1 cd in 1994[11]. These LEDs, which were almost 250 times brighter than their SiC-based predecessors, were subsequently successfully commercialized. This remarkable achievement is due to the breakthroughs by Akasaki and Amano and the further improvements and modifications essential for commercial viability made by Nakamura.

The work on GaN LEDs also naturally led the Japanese trio to investigate GaN-based LDs. Optically pumped stimulated emission[12] and pulse current injected stimulated emission[13], both at room temperature, were reported by Akasaki and Amano for the first time in 1990 and 1995, respectively. Nakamura eventually realized continuous-wave operation of a blue-violet InGaN-based laser diode in 1996[14] and in 1999, the GaN-based LD become commercially available.

The invention of bright blue LEDs has brought remarkable benefits to our daily life, such as bright, efficient traffic signals, large and clear full-colour displays and, most importantly, a new form of high-efficiency white light, by combining blue LEDs with a yellow phosphor. Such white LEDs now commonly provide backlight in mobile phones, PCs and TVs, saving a huge amount of energy worldwide.

The development of energy-saving LED-based white light sources is arguably as important as Edison's invention of the incandescent lamp more than 130 years ago. Group III nitride semiconductors, including AlN, GaN, InN and associated alloys, provide emission spanning from the ultraviolet to the infrared. AlN-based ultraviolet LEDs or LDs are expected to be useful for biological sensing, medical treatment, sterilization and ultra-high density data storage. Due to their high saturation velocity and large breakdown voltage, group III nitride semiconductors can be used not only for photonics but also for high-power electronics. The nitride-based blue LED invented by Isamu Akasaki, Hiroshi Amano and Shuji Nakamura will undoubtedly have a profound impact on our future in the areas of energy, communication, information technology, medicine and biology. ❐

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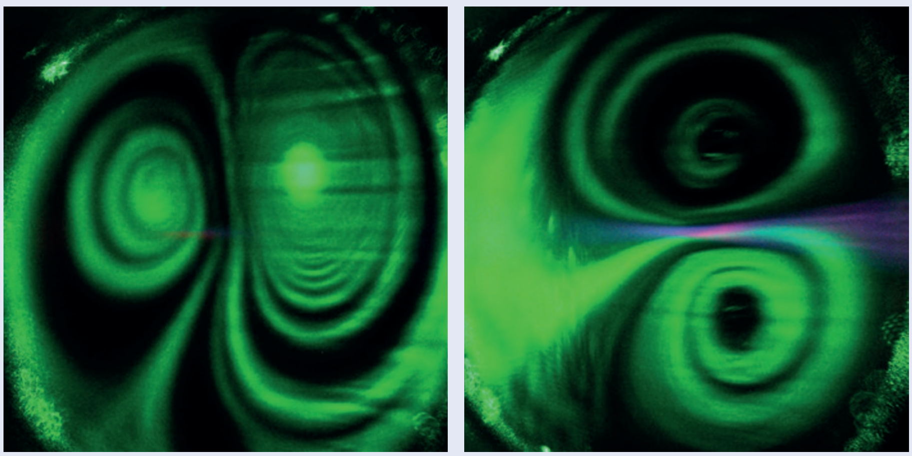
ULTRASHORT PHOTONICS

Filament vortices

Laser filaments — thin 'strands' of laser-induced plasma that form in the atmosphere — can induce air vortices in their wake, report researchers in the USA (*Opt. Express* **22,** 26098–26102; 2014). Such filaments form when the peak power of femtosecond laser pulses is sufficient to ionize the air and create a plasma. When the plasma's defocusing effects are compensated by self-focusing due to the nonlinear optical Kerr effect, the result is a natural 'self-channelling' of the laser light and the generation of spatially confined laser filaments.

Anton Ryabtsev and co-workers from Michigan State University have now observed that these filaments can create vortices in dry air. The team created filaments by focusing laser pulses with a duration of 40 femtoseconds (with an energy of 0.7 mJ and a repetition rate of 1 kHz) from an 800 nm regenerative amplifier into a hollow glass tube (4 or 14 mm in diameter). A green light sheet formed by a 532 nm laser diode was then used to image a cross section of the tube. To visualize the air flow in the tube, a small amount of butanol was sprayed nearby to act as a distribution of small scattering particles. The scatter of the green laser light was then imaged by a digital camera.



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The results show that, following the generation of a laser filament, pairs of vortices form in its wake. The precise number and location of the vortices depends on the position of the filament relative to the central axis of the tube. When the laser is blocked or no filament is formed, no motion of the air is observed.

The researchers believe that the vortices are formed due to filament-induced heating of the air and resulting convection currents. Indeed, experiments with a resistance wire placed at the location of the filament indicate very similar air-flow patterns and rotation speeds when the temperature of the wire reaches 150 °C. It is known that the temperature at the core of laser-induced plasmas can reach 3,000–5,000 K.

The findings suggest that filaments can offer a means for affecting fluid flow dynamics in the air and that such effects need to be taken into account when performing filament-based experiments, especially molecular tagging velocimetry.

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