Penetrating the fog

Free-space laser communication is an economically attractive way to get high-bandwidth signals the "last mile" to individual homes because it does not require laying millions of miles of fiber. However, laser signals cannot penetrate heavy rain or dense fog, and because the beams are scattered, multiple path lengths totally blur the signal modulation. Similar problems limit other laser-signal applications, such as range finding and laser-infrared-radar detection of pollutants.

One possibility for overcoming this scattering is to send signals through fog by using high-intensity ultrashort pulses. A research group at the Laboratory of Molecular and Ionic Spectroscopy (LASIM) at Université Claude Bernard (Lyon, France) has demonstrated that the stable light filaments generated by such pulses can maintain themselves and overcome heavy scattering through a substantial fog (*Appl. Phys. Lett.* **2003**, *83*, 213).

The filaments are created because the light pulses, which have a power of more than 3 GW (7-mJ, 120-fs pulses), change the refractive index of the air though which they pass and create a strong focusing effect. This focusing further intensifies the light, breaking the beam up into filaments about 150 μm in diameter and hundreds of meters long. At a critical intensity, around 10^{14} W/cm^2, the filaments start to form ions from the air by multiple photon absorption. This phenomenon counters the decrease in refractive index and starts to defocus the filament. The balance between the focusing and defocusing maintains the stability of the filaments as they travel.

The French team studied the filaments as they interacted with an artificial fog of droplets from 30 to 100 μm in diameter, which is smaller than the filaments. They found that the filaments lost energy when scattered by the droplets but regained it almost immediately by drawing energy from the bath of unfilamented photons in the broader laser beam. As long as the surrounding beam had enough energy, the filament was almost unaffected by the fog and could carry a signal. The experiments showed that the filament could penetrate a cloud with an optical thickness of 1.2, typical of many real clouds; but in thicker ones, too much energy was lost to sustain the filaments.

Université Lyon 3/DAVM/Alexis Gratié

On a foggy night outside Lyon, France, when regular laser beams would be scattered, stable filaments of 400-mJ, 100-fs laser pulses are detected by a cloud chamber over a distance of 50 m.

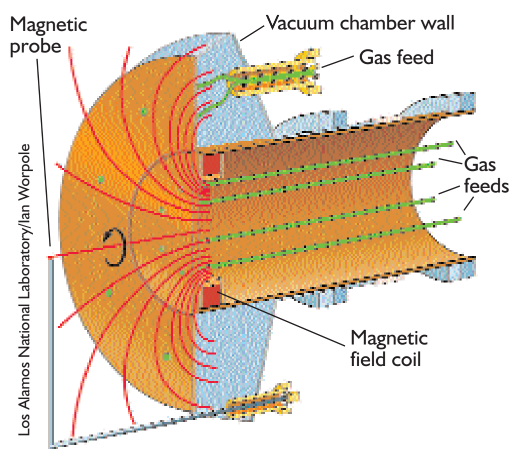
"We are not sure that the filaments could get through heavy rain because in this case, the droplets are larger than the filaments and might block them entirely," says Jean-Pierre Wolf, a leader of the research team. The next step is to test the approach using a more powerful system—the Teramobile, a joint French–German femtosecond–terawatt Ti:sapphire laser, which produces 400-mJ, 80-fs pulses. These experiments will be done with actual clouds.

Plasma self-organization

Researchers working on controlled thermonuclear fusion have tried for 30 years to confine hot plasmas with external magnetic fields, mostly using the tokamak device. The plasmas, however, tend to wriggle out of the confining fields before much fusion energy can be produced.

Another approach to fusion seeks to harness the plasma's own magnetic fields, produced by its currents, to confine it. This effort—which uses devices such as the reversed-field pinch, the spheromak, and the dense-plasma focus—attempts to induce the plasma to self-organize into structures called toroidal vortices, which resemble fat smoke rings. Because the Lorentz force on a charged particle depends on its motion perpendicular to the magnetic field, if the current and magnetic field are always parallel, there is no force on the particle. Thus, toroidal vortices (also called plasmoids or spheromaks) are force-free configurations in which the direction of the current flow and the magnetic field are everywhere identical. Physicists have long known that these structures have the least energy possible for the current carried, so they are intrinsically quite stable.

"Although we know how stable they are, and we know generally how to produce



Los Alamos National Laboratory/Ian Worpole

A high-speed multiple-frame CCD camera reveals images of the formation and helical instability of a collimated plasma injected into a vacuum chamber by this planar magnetized coaxial gun.