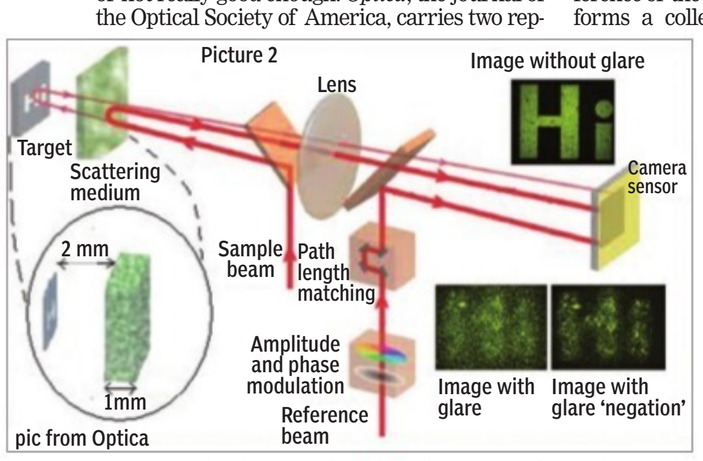
Spotting the glow through the glare

MORE WAYS HAVE BEEN FOUND TO MAKE OUT A DIM IMAGE OBSCURED BY THE BACKGROUND, WRITES **S ANANTHANARAYANAN**

The medium that lies between an object and the eye, or the camera, affects the light that comes from the object. This would blur the desired image, especially when it is feeble or small in size. Examples are when we try to view body tissue through a layer of skin, or when astronomers try to spot a tiny planet against the glare of the mother star, or even when driving through a fog.

A number of methods to either brighten the image or reduce the intensity of the light scattered by the medium have been developed. The emerging field is now known as "adaptive optics", but many methods are either impractical or not really good enough. *Optica*, the journal of the Optical Society of America, carries two reports — one by Anat Daniel, Liat Liberman and Yaron Silberberg of the Weizman Institute of Science, Israel; and the other by Edward Haojiang Zhou, Atsoushi Shibukawa, Joshua Brake, Haowen Ruan and Changhuei Yang from the California Institute of Technology — that describe more effective ways of neutralising the disturbance created by the intervening medium while viewing things.



The reason why images get obscured when light passes through a turbid medium is that the light wave emerging from an object is affected by tiny particles that are randomly distributed in the medium through which light passes. Each particle becomes a centre of scattering, or a fresh source of light waves, and the leading outline of the original wave gets distorted. The result is that the rods and cones in the eye, or the pixels in the camera, do not see the original light from the object and the image is obscured.

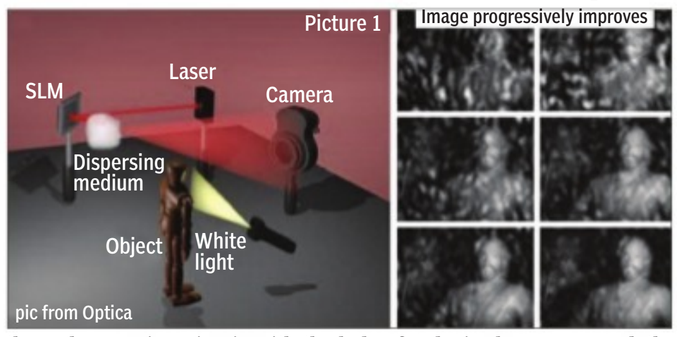
The method of the Weizman Institute group to deal with this problem is to turn around an earlier method where the light that illuminates an object was muddied by the dispersing medium even before it fell on the object. The returning light, which came from the object, was then viewed through the same medium so that the obscuring action was reversed! The light used for illumination was a laser beam that shone through the dispersing medium and the object was viewed with fluorescent light that the object emitted when illuminated.

When a laser beam, which is a train of light waves that are in step, or "coherent", passes through the scattering medium, there is interference of the sources of emerging light, and this forms a collection of dark and bright spots known as *speckle*. The distribution of the speckle, however, is not random as it arises from specific scattering centres and retains the information in the original beam as well as the structure of the scattering centres. Slightly changing the angle of the beam, hence, only makes small changes in the speckle pattern as the distribution of the scattering centres is unchanged.

Now when the fluorescent light from the object, in the experiment described, returns through the scattering medium, it meets the same scattering points as the illuminating beam and the effect of the scattering can be taken to have been "undone". The image created, however, is still only a pattern of dark and bright spots, or the "speckle". To retrieve the desired image, the angle of the illumination is varied and the resulting speckle pattern recorded a large number of times. This data, with the help of an approximate shape of the object, yields a slightly better picture of the object. This slightly better shape then leads to an even better shape, and so on, till an acceptable image is constructed.

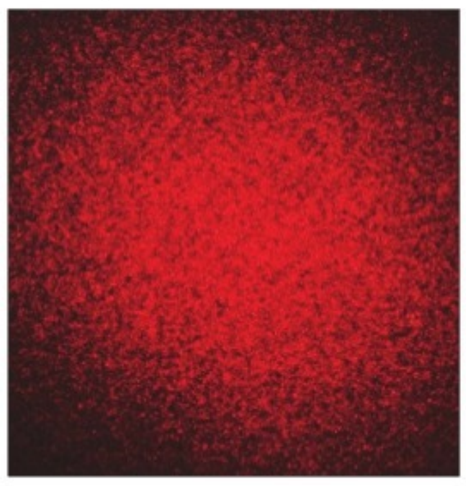
Wavefront shaping

In place of reversing the change of the wavefront, what the Weizman Institute group has done is to engineer the wavefront of the original light even before it enters the scattering medium. The engineering is with the help of a device known as a *Spatial Light Modulator* — a matrix or criss-cross of optical elements, like liquid crystal light sources, which alter the intensity or the phase of light waves over an area. Even a transparency in a slide projector is an SLM as it blocks or allows light at different points. For our purpose, however, we need to modify the action of each element, and an electronic array of elements that can be controlled is what is used.



When the scattering medium is lit by a laser beam, without any action of the SLM, it shows, as expected, a pattern of speckles. But now, if the SLM starts modifying the wavefront that falls on the disperser, there would be an increase or decrease of the speckle effect and the SLM can be tuned to get rid of most of the speckle.

In the actual trial, the object to be viewed was illuminated by a dim, white light source, as shown in Picture 1, and glare was created by shining laser light through the passive SLM and then the dispersing medium. As a result of the glare, the image of the object could hardly be made out. When the SLM was worked, however, and the level of speckle reduced, it was seen that the image of the object got progressively clearer! The trial, hence, demonstrates that it is possible to reduce scattering by modifying the wavefront of light to compensate for a dispersing medium.



A laser beam scattered by a plastic surface.

A real application would differ from this trial, as the object to be viewed would not be lit by a separate source but by the same source that causes the glare. The method, hence, would not work in the case of a static object being viewed. In a real application, however, as in say blood corpuscles in a vein or a satellite around a distant star, the objects being viewed are not static but in motion. The action of the SLM would, hence, only reduce the scattering from the static surroundings of the blood corpuscles or from the star and not the light from the actual objects to be viewed.

Reducing backscatter

Another source of obscuring images is because of the reflection, or backscatter, of light before it falls on the object. Even if the distortion of the reflected light from the object is reduced, the camera may not be able to resolve the dim image against the glare of backscatter. The California Institute of Technology group reports a successful technique of identifying the real image signal at each pixel of the camera by blacking out the glare signal with the help of a reference laser.

The arrangement is shown in Picture 2. The illuminating tool is a laser beam that goes partly through the diffusing medium to reach the object and is partly reflected back as glare. The light that reaches the camera is, thus, the part reflected by the object and the part reflected back by the medium. And then there is the reference beam, which is derived from the same laser and whose path length is adjusted to be equal to that of the glare illumination. The light that falls on each pixel of the camera thus consists of the real image signal plus the backscattered signal plus the reference signal.

The way the real signal is fished out of this is by rapidly changing the reference signal through a spectrum of phase and intensity values. At the point, during this process, when the reference signal value is equal and opposite to the glare value and hence cancels out the glare, the total value is the least and equal to the real signal. This process repeated at high speed over each pixel of the field and the real glare-free image is computed from the least intensity at each cycle. Better image quality is possible if the steps through which the reference beam is varied are closer together, which is easier if the object imaged is static.

The trial of this process, reported in the paper, improved the image of an object placed two millimetres behind a one millimetre thick screen that had particles with a diameter of three microns. While the technique is promising for microscopy, the researchers are examining ways to use it in astronomy to see objects behind the opaque atmosphere of Venus, for example.

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MYSTERY OF THE 'GHOST TREES'

SARAH KAPLAN STUMBLES ACROSS THE ALBINO REDWOOD THAT HAS STUMPED RESEARCHERS FOR MORE THAN A CENTURY

The redwood appears like a phantom, as if from thin air. What looked like a trick of the light a moment ago materialises into a trunk, branches, needles — a tree, roughly the height of a man, with delicate leaves the colour of bone. It is an albino redwood, the "ghost": of California's coastal forests. "I like that metaphor a lot," says biologist Zane Moore as he grasps a branch of the unusual conifer and holds it up to the light.

Brilliant October sunshine filters through the high forest canopy where the silver-green needles of healthy trees soak up rays and turn them into fuel. But the albino tree lacks chlorophyll and is incapable of the one thing all trees must do to live. "It shouldn't be here. It should be dead, but it's not,"

A branch of an albino redwood at Henry Cowell Redwoods State Park.

says Moore. "Just like a ghost."

The mystery of the albino redwood has stumped researchers for more than a century. The trees are so improbable that those who haven't seen them up close sometimes question whether they can exist at all. But Moore is convinced this ghost story has a scientific solution — one that should change how we view not just the albino trees but also the entire forest. He's a doctoral student at the University of California in Davis with a professorial manner and an easy smile. He's been visiting Henry Cowell Redwoods State Park, an old-growth redwood grove near Santa Cruz, since he was a child, and spotted his first albino redwood here at 16.

For the trees' own protection, staff at the park typically don't tell visitors how to find them. "Trees can be loved to death," says Dave Kuty. "They're not like animals. They can't run away." He's the unofficial caretaker of Henry Cowell's 11 albinos and he alone knows where each one hides. Some look like haphazardly spray-painted bushes, while others resemble the artificial white trees sold around Christmas. Still others are little more than single, luminous branches high up in the canopy, barely discernible in the shifting morning sun.

As a teenager in 2010, Moore heard Kuty give an interview to a local radio station about the redwoods and he set out to track one down for himself. That quest won Moore membership into the loose group of botanists, park rangers and enthusiasts devoted to understanding the enigmatic trees. Now he is among the foremost experts on the albino redwoods of the Santa Cruz mountains. And he's only 22.

It helps that hardly anyone else has studied them. Albinos are exceedingly rare — there are only 406 in existence, by Moore's latest count. And redwoods as a species are notoriously complex. Their genomes have 32 billion base pairs to humans' 3.2 billion, and they carry six copies of each chromosome instead of two. No one has successfully sequenced the redwood genome, making it impossible to pinpoint the mutation that causes their albinism.

Redwoods can also clone themselves, further complicating scientists' understanding of them. Vast rings of related plants communicate via their roots, and during the hard months of winter and early spring they'll distribute nutrients evenly among themselves. Scientists have spilled dye onto trees at one end of a grove and traced it through the root network all the way to the other side. "Most people, when they come to the redwood, they look up at the canopy," Kuty says. "But down is where the action is."

This collaboration lasts only until summer comes. Then every tree, sprout and branch must fend for itself. Those that can't photosynthesise enough sugar are cut off from the shared root system and discarded during what's known as the autumn "needle drop". That shedding process is taking place at Henry Cowell. Bits of branches drift hundreds of feet down from the canopy, buffeted by a soft breeze. The air carries the scent of wood smoke and the spicy aroma of crushed leaves. The redwoods' great age and immense height — coast redwoods, *Sequoia sempervirens*, are the tallest organisms on the planet and live as long as 2,500 years — give the forest a cathedral-like quality.

But Moore looks down as he explains how albino redwoods take advantage of their shared root system by siphoning off sugars produced by their healthy neighbours. "A lot of people thought they were parasites," he says. "They even called them 'vampire trees'." But that interpretation never made sense to him. If redwoods were so ruthless about sloughing off unproductive branches, it seemed unlikely that they would tolerate a parasite year after year. "Redwood trees are smarter than that," he says. He looks around at the towering green trees that surround — and presumably, sustain — the small albino. "Why, why, why?"

Moore and a colleague, arborist Tom Stapleton, set out to document the locations of every known albino redwood. Their map revealed that white trees tended to grow where the conditions become less favourable — a hint that environmental pressure might allow the mutants to thrive. Next, Moore sought help from his fellow redwood fans up and down the California coast, soliciting clippings from both albino trees and their healthy hosts. He found that the albino needles were saturated with what should have been a deadly cocktail of cadmium, copper and nickel. On average, white needles contained twice as many parts per million of these noxious heavy metals as their green fellows; some had enough metals to kill them 10 times over. Moore thinks faulty stomata — the pores through which plants exhale water — are responsible: plants that lose liquid faster must also drink more, meaning that the albinos have twice as much metal-laden water running through their systems.

Moore studies the most-poisoned albino tree he has found; it has more than 10 times the healthy levels of nickel in its leaves. His theory — which he presented at a redwood conference last month and hopes to publish next year — is that albino redwoods are in a symbiotic relationship with their healthy brethren. They may act as a reservoir for poison in exchange for the sugar they need to survive. He acknowledges he needs to study the phenomenon further. His next experiment will involve dousing lab-grown green and white redwoods with nickel to see whether the plants with an albino partner stay healthier. He also wants to test whether the heavy metals in albino trees stay bound up in the plants or eventually leak back into the soil. If his theory does turn out to be valid, he can envision a day when albino redwoods are planted in polluted areas to help make the soil safer for other trees.

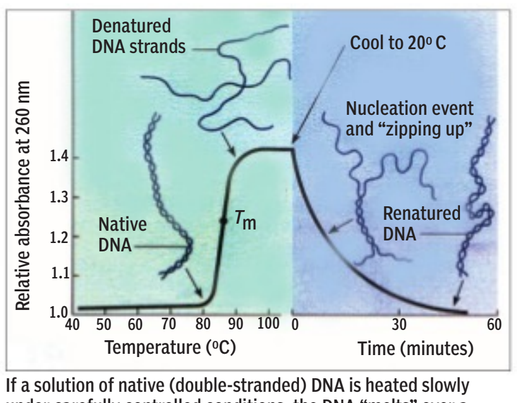
THE WASHINGTON POST

Detecting sequences

TAPAN KUMAR MAITRA EXPLAINS HOW THE TWO STRANDS OF A DNA DOUBLE HELIX CAN BE SEPARATED AND REJOINED

Because the two strands of the DNA double helix are bound together by relatively weak, non-covalent bonds, they can be readily separated from each other under appropriate conditions. Strand separation is an integral part of both DNA replication and RNA synthesis and it can also be induced experimentally, resulting in DNA denaturation; the reverse process, which re-establishes a double helix from separated DNA strands, is called DNA renaturation.

One way to denature DNA in the laboratory is to raise its temperature. If this is done slowly, the DNA retains its double-stranded, or native, state until a critical temperature is reached, at which point the duplex rapidly denatures, or "melts", into its component strands. The melting process is easy to monitor because double-stranded and single-stranded DNA differ in their light-absorbing properties. All DNA absorbs ultraviolet light, with an absorption maximum around 260 nm. When the temperature of a DNA solution is slowly raised, the absorbance at 260 nm remains constant until the double helix begins to melt into its component strands. As the strands separate, the absorbance of the solution increases rapidly because of the higher intrinsic absorption of single-stranded DNA.



If a solution of native (double-stranded) DNA is heated slowly under carefully controlled conditions, the DNA "melts" over a narrow temperature range, with an increase in absorbance at 260 nm. When the solution is allowed to cool, the separated DNA strands reassociate with kinetics that depend on the initial concentration. Complementary strands collide randomly in the nucleation event, followed by a rapid "zipping up" of adjacent nucleotide pairs. The reassociation requires varying amounts of time, depending on both the DNA concentration in the solution and the length of the DNA strands.

The temperature at which one-half of the absorbance change has been achieved is called the DNA melting temperature (T_m). The value of the melting temperature reflects how tightly the DNA double helix is held together. For example, GC base pairs, held together by three hydrogen bonds, are more resistant to separation than AT base pairs, which have only two. The melting temperature therefore increases in direct proportion to the relative number of GC base pairs in the DNA. Likewise, DNA molecules in which the two strands of the double helix are properly base-paired at each position will melt at higher temperatures than DNA in which the two strands are not perfectly complementary.

Denatured DNA can be renatured by lowering the temperature to permit hydrogen bonds between the two strands to re-establish. The ability to renature nucleic acids has a variety of important scientific applications. Most importantly, it forms the basis for nucleic acid hybridisation, a family of procedures for identifying nucleic acids based on the ability of single-stranded chains with complementary base sequences to bind, or *hybridise,* to each other.

Nucleic acid hybridisation can be applied to DNA-DNA, DNA-RNA and even RNA-RNA interactions. In DNA-DNA hybridisation, for example, the DNA being examined is denatured and then incubated with a purified, single-stranded radioactive DNA fragment called a probe, whose sequence is complementary to the base sequence one is trying to detect.

Nucleic acid sequences do not need to be perfectly complementary to be able to hybridise. Changing the temperature, salt concentration and pH used during hybridisation can permit pairing to take place between sequences exhibiting numerous mismatched bases. Under such conditions, it is possible to detect DNA sequences that are related to one another but not identical. This approach is useful for identifying families of related genes, both within a given type of organism and among different kinds of organisms.

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PLUS POINTS

Insight on marijuana

The remains of a man who died 2,400-2,800 years ago when he was about 35 were found wrapped in 13 plants in the Jiayi cemetery at Turpan in north-west China. Archaeologists said the plants, which were up to about a metre long, appeared to have been arranged as a "burial shroud".

Writing in the journal *Economic Botany*, archaeologist Dr Hongen Jiang of the Graduate University of Chinese Academy of Sciences in Beijing and colleagues described the discovery as "extraordinary". They said, "Research discussed in this paper describes 13 nearly whole plants of cannabis that appear to have been locally produced and purposefully arranged and used as a burial shroud which was placed upon a male corpse. This unique discovery provides new insight into the ritualistic use of cannabis in prehistoric central Eurasia."

The *National Geographic* magazine reported the tomb added to growing archaeological evidence that cannabis was "very popular" in the Eurasian steppe during pre-history. The burial is associated with the Subeixi culture, also known as the Gushi Kingdom, which existed between 3,000-2,000 years ago in the area. Turpan's oasis in the surrounding desert made it an important stop-off on the Silk Road linking China to the West.

IAN JOHNSTON/THE INDEPENDENT

Lionfish invasion

The population of Cuji fish (*Haemulon aurolineatum*), native to the southeastern coast of the USA, has dropped by 45 per cent since 1990 — a time that coincides with the start of an invasion by lionfish

(*Pterois antennata*), which originate from the Indian Ocean and western Pacific. The estimate was made in a study published in the *Scientific Reports* journal (31 August). It states that this invasion is an "unprecedented" hazard for biodiversity and fisheries in the USA, the Caribbean and the Gulf of Mexico.

Although the study only includes impacts on Cuji fish, the authors believe it is likely that the lionfish invasion had similar impacts on other fish species, some of which could be economically significant. They compared different areas of the Atlantic Ocean, from the US states of North Carolina to Florida, during the lionfish invasion (1990-2014).

Data on the abundance of fish species were obtained through systems typically used for monitoring fishing resources, which use similar methodologies to gather biological information. The abundance of each species was measured with the use of traps installed 15-200 metres deep. This method also allowed the researchers to obtain relevant information about the environment, such as depth, date, time, location and water temperature. The traps were equipped with video cameras to support the abundance estimates of native species and lionfish.

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Wooing pollinators

Flowers are known to employ all manner of trickery to attract pollinators, from taking the shape of an insect mate to emitting wafts of rotting flesh. A South African flower (*Ceropegia sandersonii*) lures in its main pollinators, *Desmometopa* flies, with the scent of a fresh meal. It produces a cocktail of chemicals that mimics those released by a wounded honey bee (*Apis mellifera*), drawing flies into a pollen-coated chamber. The discovery was described in *Current Biology* (6 October).

Desmometopa flies specialise in

stealing food from spiders. They follow the alarm chemicals that honey bees release when under attack from a spider or other predator and make an easy meal out of the debilitated prey. Researchers studying the umbrella-shaped flowers of *C. sandersonii* noticed that almost all of its pollinators were those thieving flies. They suspected the flowers were exploiting the flies' feeding habits, study co-author Stefan Dötterl of the University of Salzburg, Austria, told *New Scientist*.

C. sandersonii are fairly common, Dötterl said. "Some people have (the flower) in their living rooms but just don't know that it's such a special plant," he said.

THE SCIENTIST