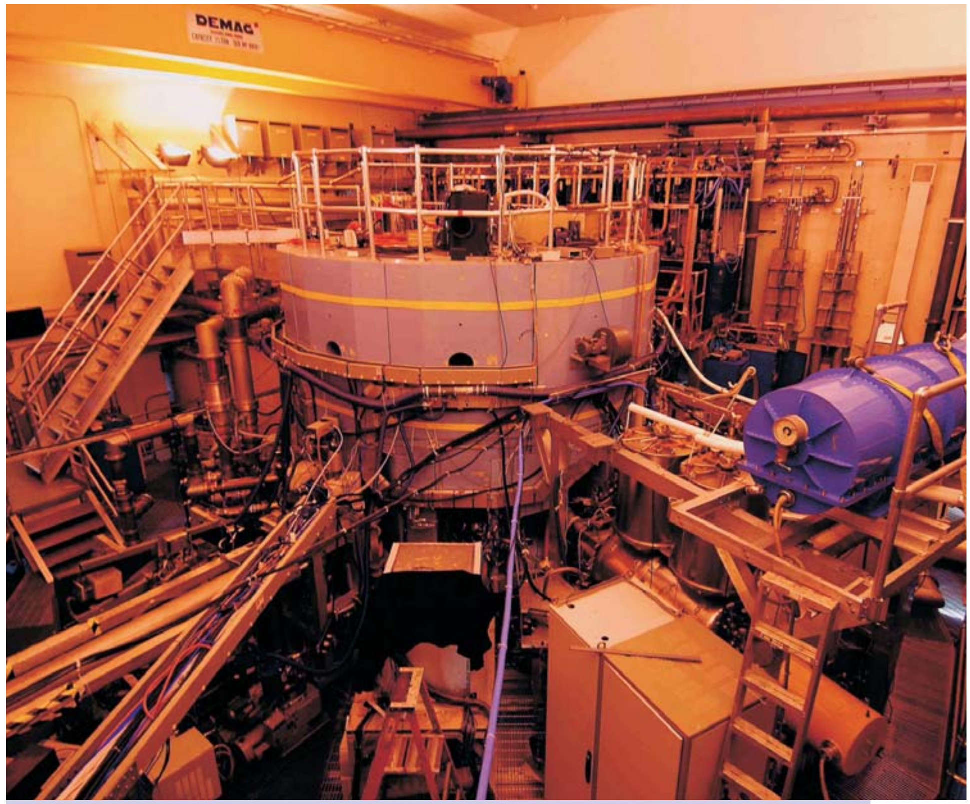
(~100 MHz), electron cyclotron (~100 GHz), and an intermediate frequency called the lower hybrid band (~5 GHz).

Once the 200-MK fusion temperature is reached, energetic byproducts of fusion act as heat sources. In the case of D–T fuel, 3.5-MeV alpha particles heat the plasma, whereas the other byproduct, 14-MeV neutrons, escapes. If the neutrons are caught in a blanket, their energy can ultimately be converted to electrical energy using a conventional steam-powered generator. Steep gradients in the plasma's pressure and density provide enough free energy to drive as much as 80% of the plasma current; microwaves of particle beams can provide the remaining 20%.

No tokamak has ever reached the so-called burning plasma regime, in which the plasma heats itself. Scaling laws derived from past and present tokamaks imply that an ITER-sized device will reach the burning plasma regime. But to sustain that regime—and maybe just to attain it—plasma instabilities must be suppressed. That's where rotation might come into play.



The fusion chamber at MIT's Alcator tokamak is located inside the gray, hot-tub-shaped, concrete-clad structure.

Ion cyclotron mode conversion

Rotating a plasma is akin to stirring soup: You need a spoon and energy. Lin, Rice, and their colleagues seeded their deuterium fuel with a small admixture of helium-3 ions to serve as a spoon. For the stirring energy, they used radio waves tuned to the helium ions' cyclotron resonance, which, for Alcator's 5-tesla magnetic field, is around 50 MHz.

Because of their significantly different mass-to-charge ratio, the $^3He^{2+}$ ions can be in resonance with the waves when the majority D^+ are not. And because the magnetic field has a gradient, the frequency of the radiation can be adjusted to resonate with $^3He^{2+}$ ions at specific locations in the plasma.

The ability to target the radiation is crucial. Where the waves' momentum ends up and whether it's dissipated before it can rotate the plasma depend on which of several magnetohydrodynamic processes the waves trigger. And that depends on local conditions. The theoretical picture is incomplete, but the MIT researchers believe their input waves are converted into another type of wave that entrains the $^3He^{2+}$ ions, which then impart some of their momentum to the D^+ ions.

Another minority species, argon, provides the diagnostic for measuring flow. Under the temperatures and pressure that prevail in Alcator, argon is stripped of all but one or two of its electrons. The spectra of hydrogen- and helium-like Ar ions are characterized so well that departures from their rest-frame values serve as accurate Doppler probes of motion. Line widths probe temperature.

The MIT team tested a range of minority concentrations and found that a 10% admixture of ^3He provides the biggest rotational boost—from 10 km/s to 70 km/s using 3 MW of VHF power.

Proving that rotation does indeed suppress turbulence requires probing the velocity field on small scales. That goal awaits future experiments, but the MIT team did find indirect evidence. In general, turbulence mixes momenta and flattens gradients. Line widths indicate that the temperature gradient of the optimally seeded plasma was steeper than that of an otherwise similar plasma.

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Reference

1. Y. Lin et al., *Phys. Plasmas* **16**, 056102 (2009).

physics update — **These items, with supplementary material, first appeared at http://www.physicstoday.org.**

Statistically speaking, Indus script is a language. The Indus Valley civilization, in what is now eastern Pakistan and northwestern India, flourished circa 2500–1900 BCE. To this day its writing, as in the figure, has not been deciphered. Indeed, scholars are unsure if the Indus script represents a language. Other, superficially similar ancient texts are thought to be either rigidly prescribed strings, such as a hierarchical list of deities, or nonlinguistic strings in which order is unimportant. Now computer scientist Rajesh Rao (University of Washington) and colleagues from several Indian institutions have studied the correlations of neighboring tokens (symbols or words) with a statistical tool—the conditional entropy—that reliably distinguishes natural languages from token strings in which the ordering is rigid or unimportant. The Indus script, they conclude, has the structure of a language. Like the conventional entropy, the conditional entropy involves the logarithm of a probability—in this case the conditional probability that a specified token appears, given its immediate antecedent. Rao and colleagues identified the *N* most common tokens in the Indus script, various languages, and nonlinguistic systems and plotted the conditional entropy against *N*. The curves for the Indus system and the natural languages bunched together and were clearly distinct from those corresponding to rigid or unimportant orderings. And the conditional entropy of the Indus system seemed especially closely related to Old Tamil, consistent with the conclusions of scholars who have analyzed the Indus script with more conventional means. (R. P. N. Rao et al., *Science*, 2009, doi:10.1126/science.1170391.) —SKB

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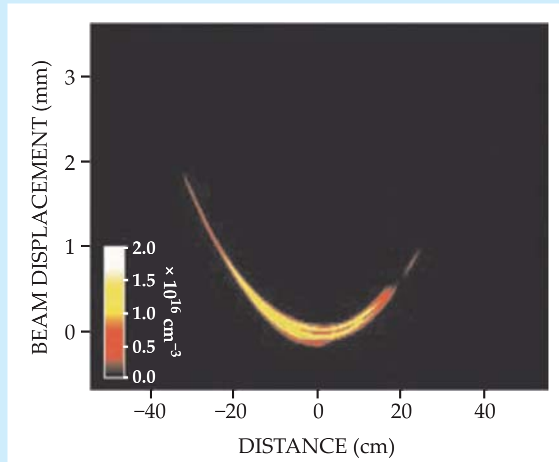
Probing elasticity in diseased tissue. The unusual stiffness or sponginess of dead and decaying biological tissue is readily apparent to the human touch. However, early detection of such mechanical property changes in a tissue's extracellular matrix could signal the onset of disease. To measure the elasticity of tissue in living patients, needle-based indentation methods are more direct and less expensive alternatives to MRI, ultrasound, and electrical impedance. Such a probe has recently been developed by University of California, Santa Barbara, physicist Paul Hansma and his collaborators. The handheld tissue diagnostic instrument (TDI) consists of a stainless steel probe—175 µm to 1 mm in diameter depending on the tissue sample—that longitudinally oscillates at 4 Hz in a needle-thin stationary sheath. The force from the magnetically controlled oscillation of the probe produces a corresponding displacement in the tissue. The tissue's elastic modulus, or stiffness, is proportional to the slope of the force–displacement curve, and energy dissipation in the tissue is proportional to the area under that curve. The researchers measured, with millimeter spatial resolution, healthy and diseased tissue samples ranging in elastic moduli from around 1 kPa to 12 GPa. Among them were mouse breast tissue, which hardens when it becomes tumorous, and human tooth dentin (see schematic), which softens and decays when infection sets in. The researchers say the instrument could be used in the future to simultaneously test and biopsy a tumor or, if the probe is coated with antibodies, to measure single-molecule interaction forces. (P. Hansma et al., *Rev. Sci. Instrum.*, in press.) —JNAM

Throwing light for a curve. Ultrashort, ultraintense laser pulses undergo competing interactions: The nonlinear Kerr effect self-focuses the beam, while multiphoton ionization generates a plasma that defocuses the beam and prevents it from collapsing. The result is a self-channeled, nondiffracting beam with a tight core, termed a filament, consisting of the intense laser field and the generated plasma (see PHYSICS TODAY, August 2001, page 17). Filaments are self-healing and emit broadband light in the forward direction, properties that yield a variety of applications, including remote atmospheric sensing and spectroscopy. Recent work by Pavel Polynkin (University of Arizona), Demetrios Christodoulides (University of Central Florida), and colleagues has put a new twist on the filaments. Unlike earlier studies, which relied on Gaussian or other axially symmetric beam profiles, Polynkin and company used axially asymmetric beams: With a phase modulator, they shaped the transverse profile of their femtosecond pulses into the form of a two-dimensional Airy function. The resulting beams remained diffraction free, but their peak intensities followed a parabolic trajectory reminiscent of projectile motion. (Momentum was still conserved, however, thanks to the momentum of the other parts of the beam.) The figure shows the calculated plasma density that accompanies a 5-mJ Airy beam as its peak traces its parabolic path. The curvature could be controlled experimentally by changing the focal lengths of the lenses used. The forward emission from curved laser filaments could find use as a broadband, wide-angle illumination source for remote sensing and for laser-induced breakdown spectroscopy. (P. Polynkin et al., *Science* **324**, 229, 2009.) —RJF



Sequencing neurotoxic peptides. The venoms from spiders, scorpions, some marine snails, and certain other animals immobilize victims by blocking ion channels that control nerve cells. The bioactive molecules in the venoms are incredibly diverse—cone snails alone produce more than 50 000 distinct peptide venoms—and researchers hope to mine them for potential pharmaceuticals that, say, kill pain or unblock diseased ion channels. Knowing the amino acid sequences would help in that effort. Researchers typically turn to mass spectrometry, in which the peptides are fragmented and the amino acid sequence deduced, usually in combination with searching a protein database. Unfortunately, the organisms do not have sequenced genomes, so the amino acid sequence has to be determined from mass spectrometry alone. Such de novo sequencing has been hampered by an inability to produce sufficient fragmentation. Now, Beatrix Ueberheide, David Fenyö, and Brian Chait of the Rockefeller University and Paul Alewood of the University of Queensland have devised a method to solve that problem. They realized that a simple chemical trick—the conversion of cysteine, an abundant amino acid in peptide venoms, to a lysine-like charged residue—would put the molecules in a highly positive charged state. The peptides could then be more efficiently fragmented using a technique known as electron transfer dissociation and thereby give rise to a rich mass spectrum. As proof of principle, the team reconstructed the complete sequence for 31 distinct peptide toxins using just 7% of the venom from the gland of a single cone snail. (B. M. Ueberheide et al., *Proc. Natl. Acad. Sci. USA* **106**, 6910, 2009.) —RMW ■