Different views

SIR—In his enthusiasm for ESO's adaptive optics prototype system (*Nature* **341**, 675; 1989), S. Dickman does not mention a basic physical constraint that severely restricts its use at visible wavelengths. This is the fact that the maximum diameter in which the wavefront from a star is not disturbed by turbulences in the Earth's atmosphere, that Fried's parameter r_0 shrinks considerably with the wavelength (r_0 is proportional to the wavelength's 6/5th power).

As J. M. Beckers and F. Merkle have clarified (ESO *Tech. Preprint.* No. 3, July 1989), "both the wavefront sensor and the adaptive mirror need to have sufficient spatial and temporal resolution to resolve the significant wavefront spatial and temporal variation. The former are of the magnitude of the Fried's parameter r_0. This parameter increases with wavelength from $r_0 = 10$ cm in the visible for 1 arcsec seeing to $r_0 = 60$ cm in the K band (2.2 μm) and $r_0 = 380$ cm at 10 μm. The durations of the temporal variations also increase proportional to the Fried's parameter so that the number of photons available for the wavefront sensing increases as the cube of this parameter."

That explains why the adaptive optics prototype system yielded perfect image improvement in the infrared beyond 3.5 μm, an acceptable image at 2.2 μm but hardly any image improvement at all at 1.2 μm. Its Shack–Hartmann-type wavefront sensor simply ran out of photons!

Fortunately, it is possible to obtain diffraction-limited images from the ground with only about one-thousandth of the photons needed by adaptive optics. In speckle imaging, thousands of distorted exposures are taken and the clear image is reconstructed afterwards. But as the efficiency of this technique grows sharply with smaller seeing disks, so-called 'partial adaptive optics' might be combined with it. Its real-time reconstruction of the wavefront is only partial, due to the photon shortage at short wavelengths, but it would still speed up interferometric applications. Thus, ESO has not "decided to rely on adaptive optics for the VLT", as Dickman writes — this will be just one of many optical concepts that will be tried.

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Thin-film fuel cells

SIR—Dyer's (C. K. Dyer, *Nature* **343**, 547; 1990) thin-film fuel cell presents two challenges to those involved in fuel-cell research. The first is to explain his observations in terms of known electrochemistry, and the second is to evaluate the technological potential of the device relative to present 'conventional' fuel cells.

A key element of Dyer's device seems to be the electrochemical response of a given electrode to a mixture of hydrogen (or another fuel) and oxygen. For example, the voltage is reversed in sign when nickel replaces platinum as the front electrode. This is probably because at the relevant experimental conditions the rate of oxygen reduction on nickel is higher than the rate of hydrogen oxidation, whereas the converse is true for platinum.

This suggests a possible mechanism for the behaviour of a cell with two Pt electrodes exposed to H_2/O_2 mixtures. That the back Pt electrode operates as the oxygen electrode could be due to the absence of mobile anions in the electrolytes used (pseudoboehmite or Nafion) and a partial oxide coverage on this electrode (formed during fabrication). The former could enhance the rate of O_2 reduction at the Pt electrode (which is inhibited by adsorbed anions); in the latter case, a monolayer of oxide on Pt is known to inhibit H_2 oxidation very effectively, while perhaps having a smaller effect on O_2 reduction. This explanation requires no new electrochemistry.

Irrespective of the exact mechanism, central to Dyer's device is the exposure of front and back electrodes to a mixture of fuel and oxidant, and the reliance on the relative kinetics of all possible processes at the electrode surfaces. There are potential problems with such an approach. A mixture of H_2 and O_2 in the ratios considered favourable (see Fig. 3 of ref. above) is explosive; at safer ratios, device performance would be limited by transport to the back electrode. Then there is the problem of fuel-oxidant recombination. Dyer states for one cell that fuel utilization is only 50 per cent because of recombination at the front electrode. This degree of fuel wastage is unacceptable for applications to electric vehicles. 'Conventional' fuel cells, which keep the fuel and oxidant separate, utilize nearly 100 per cent of the fuel.

Dyer emphasizes the advantage of the low operational temperatures of his device relative to high-temperature conventional fuel-cell technologies. This is somewhat misleading: low-temperature conventional fuel cells are now being developed, such as the polymer-electrolyte cell which operates best at just 80 °C.

I recognize that Dyer's paper is the first description of a new idea, but I feel that progress towards desirable fuel-cell applications such as electric vehicles is more likely to come from systems with separated fuel and oxygen streams.

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A recombination

SIR—I believe the segregation advantage proposed by Kirkpatrick and Jenkins[1] cannot play a major part in the maintenance of sexual reproduction. Parthenogenesis is generally achieved by the suppression of meiosis or pre-meiotic doubling[2]. In both cases, every daughter receives an exact copy of the mother's genome unless somatic recombination occurs.

Kirkpartick and Jenkins ignored the effect of somatic recombination, which can greatly reduce the time a locus is heterozygously fixed in the asexual population. If the combined rate of somatic gene conversion and crossing over at the four-strand stage in mitosis is equal to α events per individual per generation, then the equilibrium number of heterozygously fixed loci in the asexual population is:

$$\hat{n} = n_0 \times \mu/(\mu+\alpha)$$

where n_0 is equation 1 in ref. 1, the equilibrium number of heterozygously fixed loci in the absence of somatic recombination, and μ is the rate of nucleotide mutation per individual per generation.

Estimates of the rate of somatic recombination vary from 10^{-3} events per gamete in diptera[3] to 10^{-8} events per cell generation in yeast[4]. Studies of mosaicism in mice suggest that even in mammals somatic recombination is not uncommon[5]. Eighty per cent of somatic recombination events in yeast[4] and mammals[6] are gene conversions, and studies of mosaicism in diptera suggest that somatic recombination occurs at the four-strand stage[7] of mitosis.

It therefore seems likely that the rate of somatic recombination is orders of magnitude greater than the rate of nucleotide mutation, which is about 10^{-9} events per individual per year[8]. A 100-times difference would lead to an approximately 100-fold decrease in the number of heterozygously fixed loci, and a 100th root decrease in the advantage experienced by the sexual population. The number of potential advantageous mutations required to generate a segregation advantage may become unrealistically large or impose too much load on the sexual population.

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