Glassy state good for lasers?

from our Solid State Physics Correspondent

LASER beams are often of such high intensity that the electric component of the electromagnetic wave reaches the level of the breakdown field for the medium through which it is travelling. In solids, local fractures and other damage are seen at a level of about 10^8 V m^{-1} and in gases, plasma discharges are formed. The instantaneous field at which this takes place in solids is called the intrinsic optical damage field (the word 'intrinsic' is necessary because in solids there are other damage phenomena which are not intrinsic to the material and which are apparently caused by increased energy deposition in small imperfections in the transparent materials; these effects may occur at much lower light intensities than the electrical breakdown).

The intrinsic breakdown is interesting both from the fundamental and from the practical point of view. Electron avalanching is almost certainly the mechanism by which damage occurs and the processes by which hot electrons impart energy to a solid lattice is of great interest at present. Also, in the bid to make more and more powerful lasers, materials with the highest possible tolerance to the extremely high frequency electric fields present in the light pulse have to be found or fashioned; of special interest, of course, are the optically transparent glasses, mainly amorphous compounds with a wide band gap such as that possessed by many oxides. Here, the question of electron transport in a disordered lattice presents a double problem; first, because the theory of high field transport in any material with a wide band gap is not yet well developed and, second, because the theory of carrier scattering in disordered systems is more complex than that in crystalline lattices and is also in an embryonic state; some courageous attempts at predicting breakdown from data on lattice vibrational modes in an amorphous dielectric have, however, been made, with fair success (Lynch, *J. appl. Phys.*, **43**, 3274; 1972).

Thus the need for utilitarian data on the behaviour of glass optical elements in laser systems leads into a distinctly challenging area of research and leaves one to sink or swim, and perhaps to grasp at straws of data as they come past. Such a straw, perhaps, is a first report of a comparison of intrinsic damage fields in some glasses, some polycrystalline solids and some comparable single-crystal materials by Fradin and Bass, of Raytheon Research and the University of Southern California, respectively (*Appl. Phys. Lett.*, **23**, 604; 1973).

The comparisons are between quartz and fused silica, polycrystalline and single-crystal potassium chloride and a germanate glass and its crystalline form. First, the fused silica did not show breakdown until a light intensity of 108 GW cm^{-2} was reached, five times that at which crystalline quartz broke down. This factor of five in intensity corresponds to a factor of 2.2 in the relative damage fields. By contrast, polycrystalline potassium chloride broke down at about the same intensity as its single-crystal form (about 8 GW cm^{-2}). Thus, both types of silica seem to be very good laser materials but, what is more, a large improvement seems to be gained by virtue of the microscopic disorder of the amorphous form. The disorder in this material is on the scale of a few lattice constants, taking the form of a dispersion of bond angles in an otherwise continuous and compositionally ordered network. The polycrystalline potassium chloride, of course, is disordered but is made up of crystallites which are many hundreds of lattice constants in size. Thus, grain boundaries do not seem to interfere with the progress of the gross damage effects (fractures and so on), which are the indicators of when the intrinsic damage fields are reached, but microscopic disorder apparently damps the breakdown effect quite drastically.

Although this is only a straw in the wind, a set of data for only one amorphous/crystalline pair, it is tempting to grasp at it and say, as the authors do, that the disordered network is more efficient at extracting energy from the electrons before they reach the energy necessary for impact ionisation: that is, it is more difficult to heat the electron distribution in the disordered material. This is, however, equivalent to saying that the electron mobility in amorphous silica at high fields is considerably lower than that for the crystalline form; this is unlikely, since Hughes has found that, for fields up to 10^7 V m^{-1} (though impurity content caused some variation) the electron mobility and lifetime in synthetic fused silica was generally higher than for pure crystalline quartz. (See, for example, *Nature*, **246**, 190; 1973). Nevertheless, the study of high field breakdown in solids induced by a laser, when carried further, may well prove quite a versatile and useful method for investigating the transfer of energy from hot electrons to their solid host medium, with unique possibilities for the localisation and shortening of duration of the accelerating fields.

Singing muscles in a katydid

from our
Insect Physiology Correspondent

INSECTS are commonly regarded as cold blooded, or poikilothermic—their temperature agreeing with that of the environment. But it was well known to Newport, writing in Todd's *Cyclopaedia* in 1838, that the honeybee without visibly moving increases its body temperature well above that of its surroundings; and it is now known that this change is accompanied by action potentials in the thoracic muscles without vibration. It has been known since Girard in the middle of the last century that hawk moths increase their thoracic temperature by as much as 10° C by vibrating their wings. Such a rise in temperature increases the efficiency and frequency of wing muscle contraction. Recourse was had to this effect in trying to explain the very high rates of contraction and relaxation in the flight muscles of insects, which far exceed those of vertebrates. The rate of wing beat in the humming bird is 30–50 cycles per second: the blowfly will beat its wings at 150 cycles per second, a rate too rapid to be explained by a rise in temperature alone.

It was suggested that these wing muscles were operating in a state of incomplete tetanus. But the explanation was ultimately found by Pringle who showed that these high rates of oscillation are myogenic: the rapid contraction of one set of muscles is induced by the stretching brought about by their antagonists; whereas shortening of the muscles leads to a rapid relaxation of tension. This same mechanism can explain the high rate of vibration in the timbal muscles of cicadas which may go up to 4,500 Hz.

It has now been shown by Josephson (*J. exp. Biol.*, **59**, 781; 1973) that in the singing katydids *Neoconocephalus* and *Eoconocephalus*, relatively high rates of sound pulses, rising to about 200 Hz, generated by rubbing the wings together, are controlled by synchronous, or neurogenic, muscles in which each contraction is initiated by a nerve impulse. The high rates of contraction are dependent on two factors: a rise in temperature to about 36° C (12° C above ambient temperature) in the thoracic muscles, and a consequent persistence of an unfused tetanus in the muscles at rates of 160 Hz or more.

This mechanism is expensive in energy, for each muscle must contract while its antagonist is still contracting, and the songs may continue for several hours on end. But the heat produced is necessary to maintain the required temperature; and the author suggests that the mechanism may have evolved as the result of sexual selection—the females opting for the males with the highest pulse frequencies in their song.