The kob antelopes show altruistic behaviour in that individual males do not pursue females into neighbours' territories, victors of border disputes do not inflict serious wounds on losers, and individuals expose themselves in a conspicuous manner to predators inviting attack from a 'safe' distance. The latter behaviour has been investigated in detail by Smythe (*Am. Nat.*, **104**, 491; 1974).

Thus the courtship customs and social behaviour of each lek seem effectively to prevent matings outside the lek. Such matings are rare and their illegitimate offspring rarely survive. Social behaviour therefore maintains the genetic heterogeneity of the population by preserving the differences between leks. This ensures that there is sufficient genetic scope for evolution if conditions change, a mechanism which is probably especially important for the preservation of alleles with a small selective advantage (Wright in *The Evolution of Life*, edit. by S. Tax, 429, University of Chicago Press; 1960). A solution also exists in this successful species population to the problem of maintaining a certain amount of gene flow—every so often temporary leks are formed, lasting one to five years, after which time animals return to their original lek.

# Phonon transmission

*from P. V. E. McClintock*

THE transmission coefficient of phonons travelling from a silicon crystal into superfluid helium exhibits a maximum when the phonon energy corresponds to a temperature of about 5 K, according to a thermal pulse experiment by Swanenburg and Wolter of the Philips Research Laboratories at Eindhoven described in a recent issue of *Physical Review Letters* (**33**, 882; 1974).

The thermal energy in a crystal at low temperatures takes the form of quantised lattice vibrations known as phonons, which behave much like a gas of free particles each travelling at the velocity of sound. At any given temperature $T$ the average energy of the phonons present is $\sim kT$ where $k$ is Boltzmann's constant, so that an increase of $T$ not only causes an increase in the phonon density, but also brings about an increase of their average energy.

It has long been known that, when heat passes from one material to another, there is a discontinuity in temperature at the junction. The phenomenon can be understood in terms of an acoustic mismatch theory: just as in the case of light which undergoes partial reflection when incident on the interface between two media in which its velocity is different, so also are phonons partially reflected if the velocity of sound differs in the two materials, thus affecting the transmission of thermal energy between them.

The velocity of sound in liquid helium is about an order of magnitude smaller than in most solids, so that there is a correspondingly large temperature discontinuity when heat passes between liquid helium and a solid, describable in terms of a thermal boundary resistance called after Kapitza, the Russian physicist who discovered the effect. For $T<1$ K values of the Kapitza resistance measured in equilibrium heat flow experiments are in reasonable agreement with those predicted by an acoustic mismatch model. When $1<T<2$ K, however, the Kapitza resistance falls below the predicted values by an order of magnitude or more, an effect which is still not understood and which Swanenburg and Wolter have sought to investigate by means of their heat pulse technique.

Their experimental arrangement consisted of a very high quality silicon crystal, one face of which was in contact with liquid helium and the opposite face of which was in vacuum. A thin resistive metal film heater was deposited on the latter face. By applying an electrical pulse to the heater, high energy phonons could be generated, all of which necessarily passed into the silicon. A certain proportion of the phonons incident on the silicon–helium interface travelled on into the helium where they generated a pulse of the thermal wave mode known as second sound, which could be detected by a bolometer positioned a few millimetres away. The size of the bolometer signal was proportional to the energy flux entering the liquid. Because of the thermal discontinuity between them it was possible to heat the metal film to a very much higher temperature than that of the crystal. Thus it was possible to transmit phonons of energies equivalent to as much as 34 K into the crystal at 1.8 K, and then to investigate what proportion of these high energy phonons was transmitted into the liquid helium, which also remained at 1.8 K.

Unexpectedly, the authors found that although the transmission coeffiecient increased as the average phonon energy rose from 2 to 5 K, it then passed through a maximum and subsequently decreased as the energy was raised further. They describe a number of detailed checks, involving the use of heaters with different surface areas, which they have carried out in order to ensure that the change in the bolometer signal was really due to changes in the phonon transmission coefficient at the interface, and was not an artefact arising from some frequency dependent process in the crystal: they conclude that the phenomenon is genuine.

A new theory of the Kapitza resistance is therefore required which can not only explain why the transmission of thermal energy across a solid–liquid helium interface is anomalously enhanced above 1 K, but which is also able to account for Swanenburg and Wolter's conclusion that the responsible mechanism decreases in efficiency as $T$ is raised above 5 K.

# High speed colour schlieren photography

*from J. Kim Vandiver*

THE cover picture of the bullet and candle is a colour schlieren photograph. It exploits techniques that were first used by August Toepler in 1864, and later by Schardin, who developed the first colour system in 1934. Though many improvements were made, until 1971 all colour methods gave only one-dimensional information about the density gradients in the test section. In 1971 a technique was described (Strong and Settles, *Scient. Am.*, **225**; May 1971) which simplified the equipment and made possible colour photographs with fully two-dimensional density gradient information. These optical refinements were combined with a sub-microsecond light source and triggering device to photograph a variety of transient events.

Refraction occurs when light encounters a region of non-uniform index of refraction. The refraction will be toward the region of increasing index in proportion to the gradient of the index perpendicular to the direction of travel. Natural events that cause changes in the pressure, density or temperature in the media around them ultimately alter the refractive index. Schlieren techniques discriminate light that has been refracted by a physical event from the remainder of the light in the test section. Once isolated, this light is focused by the camera into an image of the original disturbance.

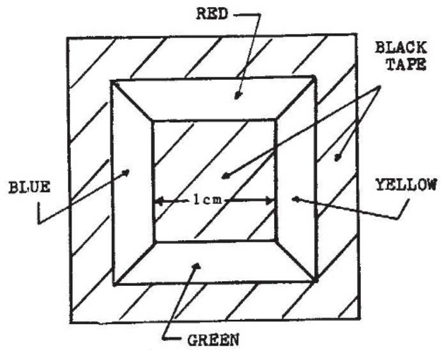


**Fig. 1** Source filter