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COHERENT LIGHT METHODS FOR THE STUDY OF MECHANICAL VIBRATIONS

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Holographic Investigation of Loudspeakers

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Both time averaged and stroboscopic holography have been used for the study of vibrating loudspeaker cones. Ordinary stroboscopic holography is made difficult by random creeping which occurs in paper loudspeaker cones over a period of about ten minutes. Unfortunately a temperature and humidity controlled environment,which may have corrected this,was not available and so the setting of the correct stroboscopic phase with a live hologram eventually became impossible. To overcome this and other difficulties,such as the effects of amplifier hum and uncertainties about the cone rest position,the technique of scanned holography has been used.

To take a scanned hologram a disc with a number of radial slits is placed immediately in front of the photographic plate and both the reference and object beams pass through it to fall in partial registration on the plate. If one interslit distance is traced along the hologram by a given slit during one object cycle,and stationary and moving exposures are taken, then on reconstruction fringes corresponding to any phase of a vibration cycle may be seen on looking through the appropriate part of the hologram. There is therefore no longer any need for the strobe phase to have any definite angular relation with the object, though it must remain phase locked with it

The initial system still requires two exposures, however, and a second scanning method has been derived to overcome this. If <u>two</u> slits of the disc trace one interslit distance during one object cycle, on reconstruction fringe systems corresponding to differences between any two object cycle phases spaced 180° apart can be seen. Therefore the sensitivity is doubled and the need for a live hologram and a second exposure is removed.

An interesting phenomenon was discovered with this system: On moving the eye along the hologram the ordinary speaker fringe systems were seen to wax and wain as with the initial system, but also at certain object phases thicker dark fringes,unrelated in pattern, were seen to blank them out. these blanking fringes were phase related to the object vibrations as they too waxed and wained as the eye was moved along the hologram . Odd or even harmonics would not cause these fringes and neither would the presence of linear motion during the exposure. Finite exposure time has been shown to cause amplitude dependent changes in the brightness of the reconstruction,but these would follow the patterns formed by the ordinary fringes and to explain the effect observed the stroboscopic 'on time' would need to be much longer than that which was used.

Subharmonics offer a possible explanation. It is known that subharmonics exist in loudspeaker vibrations and the fact that speaker vibration amplitudes quadruple for a halving of the frequency for a given input allows subharmonics to show up in a hologram even if they do not contribute much to the actual sound radiation.Theory shows that the fringe function describing the subharmonic multiplies that due to the fundamental and so the subharmonic fringes will blank out the fundamental ones.If harmonics are shown to be present with this method it is possible to take a scanned hologram of the subharmonic alone with a different scanning system. As in the initial system one slit traces one interslit distance along the hologram during one object cycle - but this time the second exposure of the stationary object is not taken. There is therefore no amplitude difference resulting from either the fundamental or the (super)harmonics. The subharmonic however is sampled twice in its cycle, and these sample points are 180° apart (for the fundamental these points are 360° apart). Therefore the fringe systems seen for the first subharmonic are similar to those seen for the fundamental when using the second scanning system. Other scanning systems can be derived by both altering the scanning rates and the number of exposures taken. For instance by sampling four times in a fundamental cycle,the first harmonic could be regarded as the'fundamental'and the fundamental would take on the role of the'first subharmonic'. This and other scanning systems have not yet been investigated by the author.

The investigations of paper loudspeaker cones have shown that the fringe systems seen can be very complicated and as a result of this it can be quite difficult to obtain any useful data from them. Occasionally the systems resemble the symmetrical fringe systems seen on vibrating discs and the effects of lead-in wires have been well demonstrated, but the results on sandwich cones have had the greatest practical use to date. The response curve of a typical sandwich bass unit (made of expanded polystyrene between two thin aluminium skins) shows high Q high amplitude peaks in the break-up region which is several octaves above the equivalent region in paper cones. Holography has shown that all the break-up modes of the sandwich cones are axisymmetric in character. This behaviour would occur with all speaker cones, if their physical properties were uniform, since the conditions of excitation and support allow only for these modes to be excited. This is in fact the case with sandwich cones whose physical properties vary by a maximum of 10 percent over the area of the cone and it is not the case with paper cones whose properties may vary by over 100 percent from one small area of cone to another. Since holography has shown that all sandwich cones and modes have a common antinode at the surround and the voice coil we can take more effective steps to damp them out. By using a lossy coupling to attach a seismic mass to the voice coil, damping is applied in the most effective location possible and in fact all the modes can be damped out with only a slight sacrifice in sensitivity. In any case weighting rings attached to voice coils have been used for years as a kind of 'mechanical cross over system' and the lossy seismic mass may replace this , the overall effect then being merely the removal of the unwanted resonances.

The interpretation of loudspeaker fringe systems must be carried out bearing in mind the location of the coincidence critical frequency for the material of the cone. For sandwich cones this lies just below the first major break-up frequency and consequently this mode may radiate up to 12 db more than it would if the critical frequency fell above it. This in part explains the great height of the peaks in sandwich speaker units and the smaller height of the peaks in paper units where the critical frequency is supersonic. Experiments on brass plates have confirmed this step in radiation efficiency. The break-up modes of paper cones may indeed only radiate at boundaries and by scattering at inhomogeneities and so if they could be more uniformly made break-up modes would have less of an effect on their response curves.