Reprinted from **APPLIED OPTICS**, Vol. 8, page 2146, October 1969
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Measurement of Diffraction Loss in a Solid State Laser

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Received 29 May 1969.

The measurement of oscillation losses in solid state lasers has long been used as a method of evaluating the quality of the laser material.[1-9] Most of these active loss measurements provide a measure of the total cavity loss, from which other losses such as mirror reflectivity losses must be subtracted to give a figure for the *internal loss* of the laser material. Diffraction losses are also present but the question of their exact contribution to the total cavity loss is frequently ignored. This is because material distortions and filamentary oscillation can make prediction of diffraction loss rather uncertain unless lengthy calculations are made, taking account of the distortions which prevail in each particular laser system.[10,11]

However, Aagard[3] showed experimentally that there was a considerable difference in total cavity loss for two ruby rods, one having plane parallel faces, the other having confocal faces. He ascribed this to a difference in diffraction loss since the rods were cut from the same boule, but the possibility of a genuine difference in material quality was not entirely eliminated. This indicates the importance of making a precise determination of the contribution from diffraction loss since otherwise the measurement of losses of the same material in different laser systems may give ambiguous results. Diffraction losses in a gas laser have been measured previously[12] but we believe this is the first report of such a measurement in a solid state laser.

The laser material investigated was Nd^{3+}:$CaWO_4$, (1 at. % Nd^{3+}), cut in the form of a rod 5 cm long, 6 mm in diameter, and of 0° orientation. Total cavity losses were measured using the technique of Findlay and Clay.[7] Two types of cavity have been used (i) a plane parallel cavity and (ii) a cavity consisting of a plane mirror and a 2 m concave mirror. A circular aperture was placed adjacent to the curved mirror and centered on the cavity axis. Since the aperture size, mirror separation, and mirror curvatures were known, the diffraction losses of the TEM_{00} mode in the empty cavity could be found from the calculations of Li (see Fig. 1).[13]

When the aperture was removed it was found that within experimental error the total cavity loss was the same for either cavity (10 ± 1% per single pass), and independent of mirror separation over the range 40–110 cm, whereas similar measurements in this laboratory on Verneuil ruby have shown an increase in loss with increasing mirror separation. This result suggested that the diffraction losses produced by this $CaWO_4$ rod were negligible in the unapertured cavity. To give further confidence to this conclusion the total losses of the curved mirror cavity were measured for a range of aperture sizes and mirror separations. The increase in total cavity loss from the loss of the unapertured cavity was compared with the diffraction loss of the TEM_{00} mode predicted by Li and excellent agreement was found (see Fig. 1). These results indicate that over the area of the TEM_{00} mode (~1 mm in diameter) distortions were not important in producing losses and most of the measured loss is probably due to scattering from small foreign particles.[14]

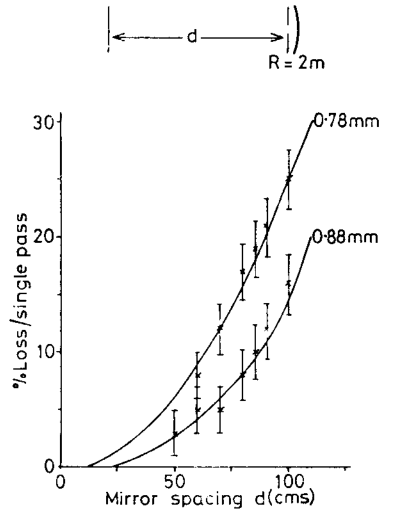

Fig. 1. Solid lines indicate diffraction losses per single pass of the TEM_{00} mode as computed by Li[13] for circular apertures of radius 0.88 mm and 0.78 mm at a wavelength of 1.06 μ. The crosses indicate the measured increase in loss per single pass over the unapertured cavity.

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