Polygon Modes of Unstable-Cavity Lasers

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Hermite-Gaussian modes have formed the basis for the analysis and understanding of *stable*-cavity lasers for many decades. These modes tend to be highly paraxial and have low round-trip loss but often do not exploit the full volume of the gain medium. On the other hand, *unstable*-cavity lasers utilise diverging light wavefronts for high gain extraction, leading to strong periodic aperturing effects and high-loss modes. The transverse structure of these modes is determined, to a large extent, by the detailed symmetry of the aperturing element, resulting in mode patterns which are radically different from those of conventional stable-cavity lasers. However, to date, only strip-type and circular transverse geometries have been considered, since then the problem reduces to one-dimension. We have undertaken the first investigations of the transverse modes of unstable-cavity lasers with truly two-dimensional aperture symmetries. Our studies have concentrated on cavities with triangular apertures and work is currently underway on the generalisation of these results to encompass N-sided polygon and variable-angled rhombus symmetries. A full update of results from experimental, semi-analytical and numerical work will be presented.

In our experimental investigations, we have used a miniature unstable-resonator HeXe laser operating on the high gain $3.51\mu m$ Xe transition [1]. A short laser cavity, having a large free-spectral range and well-spaced transverse modes, is used to facilitate spectral selection of individual fundamental and higher-order modal patterns. The near-field mode patterns at the position of the aperture are imaged onto an infra-red camera. Figure 1 shows some of the mode patterns for a resonator with *triangular* aperturing symmetry.

Our semi-analytical work is based on a virtual-source approach in which the unstable-cavity is unfolded into a sequence of effective apertures. While Fresnel diffraction patterns for square and circular apertures are well-documented, there appears to be no published work for apertures with non-orthogonal edges. However, the results of a little-known study by Newton of diffraction at a thin wedge aperture (his "2-Knife Experiment" [2]) prove to have profound relevance to the low Fresnel number regime of the more general problems addressed here. New results on Fresnel diffraction at polygon apertures, which lie at the heart of our semi-analytical work, will be summarised. Finally, data from full-blown numerical simulation of each of the cavity geometries (incorporating non-orthogonal beam propagation methods) will be compared with our semi-analytical and experimental results.

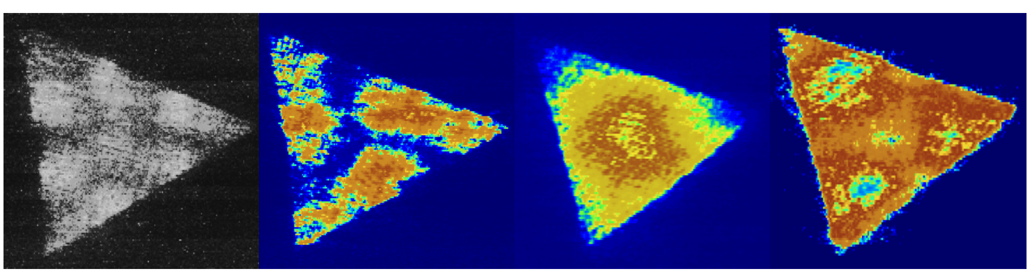

Figure 1: Experimental mode profiles for a low Fresnel number unstable-cavity laser which incorporates triangular aperturing. Analysis and simulation predict a range of hexagonal, triangular and single spot modes.

[1] M.A van Eijkelenborg, Å.M. Lindberg, M.S. Thijssen and J.P. Woerdman, Phys. Rev. Lett. **77**, 3414 (1996).

[2] Sir Isaac Newton, Opticks, Fourth Edition, London, 1730 (reprinted by Dover, New York, 1952).