# THE TWO-DIMENSIONAL VIRTUAL SOURCE METHOD

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The theoretical determination of eigenmodes of hard-aperture unstable-cavity lasers is a demanding computational problem. Much research has therefore been devoted to the development of approximate semi-analytical methods (SAMs) which can circumvent the need for large-scale numerical calculations. Moreover, while standard (Fox-Li) computational approaches only yield lowest-loss modes, SAMs also have the potential to predict the entire spectrum of eigenmodes and their associated eigenvalues. To date, SAMs have only been developed for systems which have essentially one transverse coordinate (such as square or circular geometries). However, the computer modelling of systems with two fully-independent transverse coordinates can be an exceptionally resource-hungry task. The need for SAMs that can be applied to such configurations is thus ever more pressing.

In this presentation, we report our generalisations of the most commonly-used SAM, the Virtual Source Method [1]. This method may be summarised as follows. The unstable cavity is firstly unfolded into a series of effective apertures. One then considers a distant plane-wave and its subsequent diffraction through this sequence of elements; at each aperture, the diffraction pattern is decomposed into an undiffracted plane-wave component and edge-waves. Finally, the lowest-loss and higher-order eigenmodes are built up from weighted sums of a single plane-wave term and the spatially-inhomogeneous diffractive waves.

While many recent experiments have used unstable cavities of relatively low Fresnel number, most SAMs assume that this parameter is large. We have thus also tested the accuracy of the Virtual Source Method is this regime [2]. It was found that surprisingly accurate predictions of the lowest-loss modes were made for Fresnel numbers as low as unity, but that results for the higher-order modes were unreliable. The source of the problem in the higher-order mode calculations has now been identified and we have developed a further modification of the method which addresses this aspect. In doing so, we have also generalised the Virtual Source Method to deal with *two-dimensional apertures of arbitrary shape*.

Results will be presented, for a variety of transverse geometries, in a highly-graphical format that gives a physical picture of the underlying mathematics and which justifies the assumptions invoked.

## References

[1] WH Southwell, J Opt Soc Am A **3** (1986) 1885
[2] GS McDonald, GHC New and JP Woerdman, "Excess noise in low Fresnel number unstable resonators", to appear in Opt Comm