MMI coupler has been shown to improve the power balance in simulations. The imbalance of the symmetrical MMI was calculated to be 0.02 dB while the original design was calculated to be 0.1 dB according to the simulation data. A third prototype has already been designed and the mask has been received. Fabrication will begin as soon as possible.

A second design improvement that may be pursued involves replacing the output 2x2 coupler with a 2x4 coupler. With the 2x2 MMI coupler, outputs 1 and 2 are complements of one another, i.e., when output 1 is maximum output 2 is a minimum. Hence, one channel becomes somewhat redundant. The only advantage of having access to both outputs is that the total power can be calculated and used as a normalization for both outputs. Implementing the normalization technique would reduce the effect of the varying input power caused by the input fibre moving from heating of the optical adhesive. If a two-in-four-out output coupler were used, then quadrature, or phase, information could be obtained. Each output experiences 4-beam interference. The result is that the MZ intensity transfer function at each output is shifted by 90°, relative to adjacent output channels (see Figure 4.3).

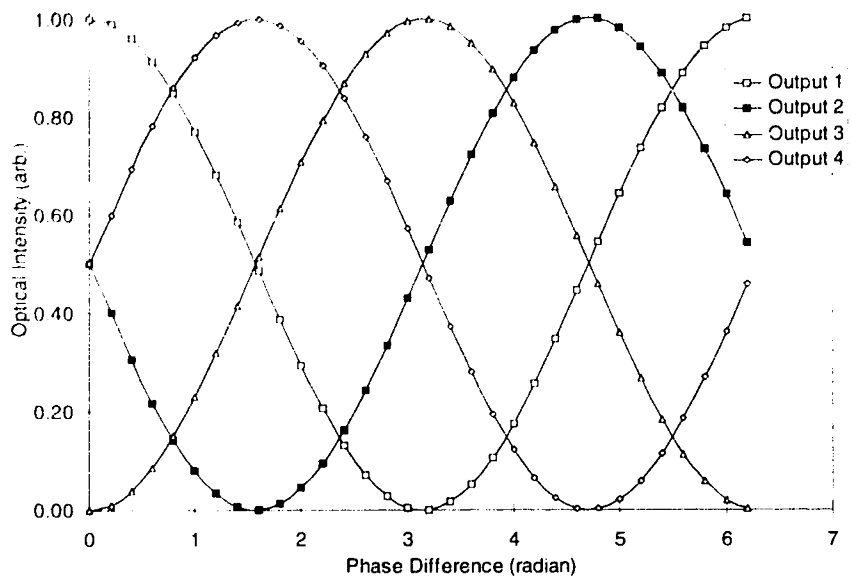


**Figure 4.3** Intensity at the output of a 2x4 MMI coupler.

Acquiring the phase information is important; to extend the optical dynamic range of the sensor. With this phase information it is possible to eliminate phase ambiguity. For this reason, prototypes I and II can only operate over *one half* of a MZ period. If a 2x4 coupler was used, then the phase at any point could be determined. Not only could the sensor operate over a complete period, but fringe or peak counting could be used. Fringe counting is difficult, requires extra computation and calibration problems can occur if the sensor is not initialized properly. Even if the fringe counting is not used, using a 2x4 coupler will increase the dynamic range of the device by a factor of two. The tradeoff requires only a moderate design change and the added difficulty of attaching five fibres rather than three.

In this chapter some of problems, such as poor response time and fibre to waveguide coupling, have been discussed. Comparisons between the modeled results and experimental results were attainable only for the optical model. The heat transfer and microwave interaction models require precise knowledge of certain material properties, such as thermal conductivity, microwave loss factor, and others. Furthermore, knowledge of these properties as a function of temperature must also be obtained before suitable predictions are possible. Future designs that incorporate symmetrical input couplers and 2x4 output couplers will most certainly improve the overall performance of the sensor.

# 5. CONCLUSION

The design and fabrication of an integrated optic microwave power sensor has been presented. It has been demonstrated that the sensor is capable of responding to low (25 W) and very high power levels (>900 W), resulting in a large dynamic range and high sensitivity. The sensor is capable of measuring microwave power at a point in space which facilitates the determination of the power distribution inside a microwave cavity. Also, successful integration of well balanced multimode interference couplers has resulted in the ability to integrate a Mach-Zehnder interferometer and a susceptor into a single device.

Although the work in this thesis has carried the project from the design stage to the fabrication and testing stages, further work is necessary before a practical product is available. Specifically, the connection between the optical fibres and the sensor waveguides is cumbersome and unreliable. Measures can be taken to reduce the effects of dynamic coupling variations between the waveguide and fibres, and will likely include signal processing. The best direction to pursue, however, is to investigate better methods of coupling the fibres to the waveguides, because it is this link which is the most vulnerable in the sensing system.

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# APPENDIX I

Additional calculations for a mirrored image about the x-axis in an MMI

The field distribution as a function of x and $z=L_{s,p}$ in the MMI is given by:

$$\Phi(x, L_{s,p}) = A\sum_{v=0}^{N-1} c_v \sin\left(\frac{\pi x(v+1)}{W}\right) e^{j\pi v(v+2)\frac{s}{p}} \quad (A.1)$$

If $\sin(x) = \dfrac{e^{jx} - e^{-jx}}{j2}$ and s=p=1, then

$$\Phi(x, L_{1,1}) = \frac{A}{j2}\sum_{v=0}^{N-1} c_v \left\{ e^{\frac{j\pi x(v+1)}{W}} - e^{-\frac{j\pi x(v+1)}{W}} \right\} e^{j\pi v(v+2)} \quad (A.2)$$

$$\Phi(x, L_{1,1}) = \frac{A}{j2}\sum_{v=0}^{N-1} c_v \left\{ e^{j\pi\left[\frac{x(v+1)+v(v+2)W}{W}\right]} - e^{j\pi\left[\frac{x(v+1)-v(v+2)W}{W}\right]} \right\} \quad (A.3)$$

$$\Phi(x, L_{1,1}) = \frac{A}{j2}\sum_{v=0}^{N-1} c_v \left\{ e^{-j\pi\left[\frac{x(v+1)(W-x)}{W}\right]} e^{-j\pi(v^2+3v+1)} - e^{j\pi\left[\frac{x(v+1)(W-x)}{W}\right]} e^{j\pi(v^2+3v+1)} \right\} \quad (A.4)$$

$$\Phi(x, L_{1,1}) = A\sum_{v=0}^{N-1} c_v \sin\left(\frac{(v+1)(W-x)}{W}\right) \quad (A.5)$$

The following equation describes an image of the input field that has been mirrored about the x-axis.

$$\Phi(x, L_{1,1}) = A\sum_{v=0}^{N-1} c_v \Phi(W-x) \quad (A.6)$$