6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions: modeling diffraction in the MCRT environment

Two diffraction models for use in the Monte-Carlo ray-trace (MCRT) environment have been described and tested: Model 1, a statistical approach, and Model 2, application of the modified Huygens-Fresnel principle. The derivation and application of these models, and the results that they predict are presented in detail in Chapter 4.0.

The concepts upon which Model 1, the statistical approach, is based were originally proposed by Heinisch and Chou in 1971. The details of the implementation of this model have evidently never been thoroughly documented in the public domain, so they were rediscovered and documented in this thesis. The statistical approach is useful for predicting diffraction in both the Fraunhofer and Fresnel regimes, but does not keep track of phase and thus cannot exactly predict the details, such as the secondary maxima of the expected diffraction patterns. Intensity distributions predicted by Model 1 are smooth curves, which approximate the diffraction patterns predicted by theory. The statistical approach was tested by applying it to a practical example involving the diffraction of radiant energy as it passes through the infinite-slit aperture of a cavity detector developed within the Thermal Radiation Group. This case involves the diffraction of energy along
the same coordinate direction due to the two edges of the slit, a situation not discussed in
the cited references. A study was conducted to determine the best approach to model this
type of situation and it was determined that the final angle of diffraction of an entering
energy bundle is best described by the algebraic sum of the angles of diffraction due to
each edge.

Model 2 involves the application of the Huygens-Fresnel principle, modified by a
correcting obliquity factor. This model is capable of predicting the diffraction pattern,
including the secondary maxima, for a limited range of Fraunhofer diffraction
configurations. A case study involving diffraction by an infinite slit was conducted to
determine the general range of applicability of this model. The results from this study
suggest that Model 2 will approximate the diffraction pattern of radiant energy entering
an aperture, including the secondary maxima, only if the ratio of the slit width to the
wavelength of the entering energy, \( \frac{a}{\lambda} \), is much less than one. Results indicate that as
long as \( \frac{a}{\lambda} \) exceeds one, the application of Model 2 will not lead to highly erroneous
results but the details of the secondary fringes may be lost. However, if \( \frac{a}{\lambda} \) is less than
one, Model 2 should not be applied as its underlying principles are no longer sound.

6.2 Conclusions: CERES follow-on instrument
A radiative model of the current CERES telescope was developed using a new Monte-
Carlo ray-trace environment being developed by a doctoral student in the Thermal
Radiation Group. This model was used to study the feasibility of partitioning the current
CERES telescope so that it serves multiple detectors. Also studied was the replacement
of the spherical mirrors currently used in CERES with hyperbolic mirrors in order to
achieve acceptable radiative throughput over a larger field of view.

The Optical Point Spread Function (OPSF) at a single detector placed on the CERES
optical axis was determined using this new radiative model. This result was used to
benchmark the new ray-trace environment and to validate the new code describing the
CERES instrument by comparing it to the OPSF previously obtained by members of the
TRG.
Results from this study indicate that the radiation throughput to two detectors placed in the CERES telescope is similar to that arriving at the single detector that lies on the optical axis in the current CERES instrument. However, if more than two detectors are placed into the telescope, the throughput drops off, resulting in an unacceptable OPSF at all but the central detector. It was also determined that hyperbolic mirrors do achieve acceptable radiative throughput over a larger field of view than do spherical mirrors, and their use is suggested if more than two detectors are to be placed in each telescope. These results are presented in Chapter 5.0.

**6.3 Potential future investigations of diffraction models**

Useful future work could involve the development of an approach to scale ray-trace results to match the analytical curve for the statistical method, as the current method involves simply scaling the results “by eye” until the area under the ray-trace curve appears to match that of the analytical curve. The model based upon the modified Huygens-Fresnel principle (Model 2), and the cause of the oscillating intensity pattern it predicts, should be further investigated. Other case studies similar to the one presented in Section 4.3.6 could be conducted to determine the generality of the restrictions placed on the applicability of this model. Another unexplored aspect of the diffraction of radiant energy by an aperture involves the behavior of radiation as it approaches an aperture (prior to entry through the aperture), and the possibility of backwards diffraction. The geometric theory of diffraction described in Chapter 3.0 does model both forward and backward diffraction of energy as it approaches an aperture, and may be capable of properly modeling this behavior.

**6.4 Potential future investigations of CERES follow-on instrument**

Future studies could involve the placement of the hyperbolic mirrors into an appropriately modified CERES telescope, and the determination of the resulting Optical Point Spread Function. The new MCRT environment could be used to study the effect of slight modifications of the interior telescope surfaces on the throughput to the detectors. Another potential study could involve a different detector arrangement within the telescope. For example, instead of inserting extra detectors in a row, the detectors could
be placed in some alternative arrangement, which provides an optimal throughput to all detectors.