Utilization of HID Illumination in Medical Diagnostics and Treatment

Charles N. Stewart, Douglas M. Rutan, William H. Lagerway
Welch Allyn, 4619 Jordan Road, Skaneateles Falls, NY 13153, USA

Medical diagnosticians rely on suitable illumination, including adequate illumination levels and faithful color rendition. Recent advances in CCD technology and high efficiency lighting have permitted non-invasive diagnostics and minimally invasive surgery employing fiber optic lighting coupled with distal mounted CCD imagers. These technologies result in both less expensive procedures and better medical outcomes.

We present the results of a design of a lighting system that was developed to provide optimum illumination for medical and industrial endoscopes. Through Monte Carlo ray tracing techniques[1] based on experimental measurements of luminance through 4π steradians we have successfully modelled the lamp's light output. By optimizing the lamp, reflector, and the optical system, we have been able to develop a system that provides the physician with 5500K illumination with very good color rendition and optical system efficacies well above halogen and many HID alternatives. This high efficacy results in smaller system size and lower weight, which allows battery operation where necessary, as well as consuming less electrical power.

A key factor in the efficiency of illumination systems for endoscopes is the collection efficiency of the lamp and fiber optic system. This efficiency is controlled by several factors: inherent efficiency of the lamp in lumens per watt (lpw); source size (*i.e.*, arc gap or filament size); luminance of the source, which is related to the lamp efficiency and the source size; magnification of the reflector; numerical aperture of the fiber optic bundle; and size of the fiber optic bundle.

Fiber optic bundles used for medical diagnostics must be as small as possible, consistent with adequate illumination; generally the bundle size is in the range of 1.0 to 5.0 mm. The arc tube used in this study has an arc gap of 1.2 mm; it is desired, therefore, that the optical system magnification be no more than four. The arc tube output, of course, should be as large as possible, compatible with a short arc gap and a long lifetime. Fortuitously, the design of an elliptical reflector with a magnification of four results in a numerical aperture of approximately 0.7, which provides wide angle illumination to the working area.

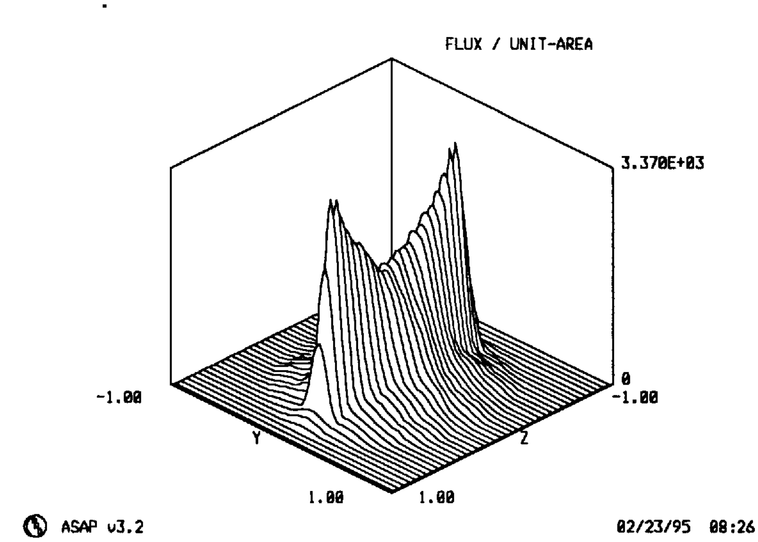

Figure 1. Model results for luminance of the arc.

In this work we measured the luminance of the arc tube as a function of angle for three burning orientations. We were then able to construct a model of the arc that gave an excellent representation of the projected arc intensity, as shown in Figure 1.

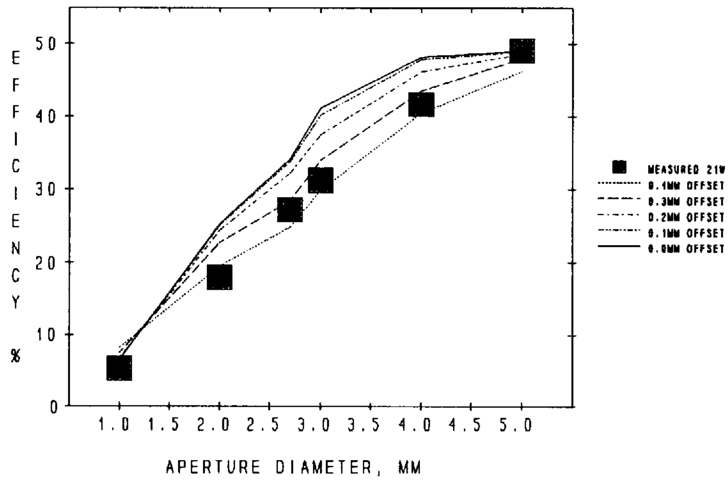

Figure 2. Comparison of model results with measurement for insertion efficiency into apertures.

This model was used to predict the quantity of light projected into an aperture at the focal length (f_2) of the elliptical reflector. The agreement between model and measurement was excellent when the axial position of the arc tube was treated as an adjustable parameter. Even when the axial position was fixed at the first focus of the reflector (f_1) the agreement was very good. Model and measurement are shown in Figure 2.

Combining the several parts of the optical system and comparing to other lighting system alternatives, as shown in Figure 3, we find that the combination of the arc tube's high efficacy (60 lpw), the collection efficiency of the reflector (>60%), and the low magnification of the reflector (4.0) gives an extremely efficacious lighting system. System efficacy is approximately 30 lpw for 5.0 mm bundles; comparable systems range from 5 to 15 lpw. The system performs particularly well in comparison to halogen lamps because of their lower lamp efficacy, larger source size, and higher magnification.

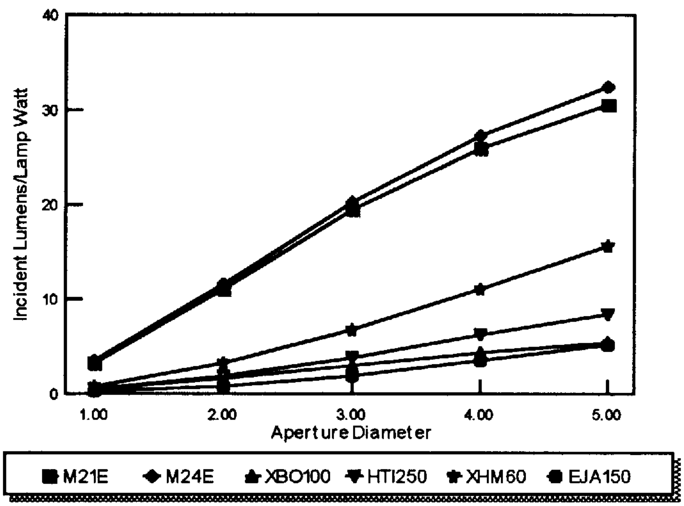

Figure 3. Measured efficacy as a function of aperture diameter for several sources.

In summary, we have found that a combination of measurements and optical modelling shows that a compact arc source can be designed into an optical system to give system efficacies of 30 lpw into 5.0 mm fiber optic bundles while maintaining excellent color rendition. Additionally, the low input wattage of the system allows light weight, portable systems to be designed for the medical practitioner or the industrial technician - a capability not previously achievable in high brightness systems.

1. Advanced Systems Analysis Program (ASAP), Breault Research, Tucson, AZ.