SUMMARY OF THESIS
CHAPTER - VIII
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8.1 Results and discussion

Building the optical systems that actually meet specifications requires more than knowledge of optics and the use of contemporary design codes. Excellence also comes with the kind of “street” knowledge, learned not from textbooks but from experience, mostly from failures. These hard-won lessons are colloquially here as “folk wisdom”. If considered during system conceptualization and design, these notes may improve efficiency, effectiveness, and ultimate performance. Finding solutions before serious consequence occurs make even difficult programmes proceed acceptably. To make an optical system requires detailed analysis followed by synthesis of the best ideas into a design to achieve acceptable performance.

The lens designer is to produce an optical system that is perfect from the geometrical viewpoint, but the designer is usually prevented from doing so by cost. The most economical materials available to the lens designer are glasses with a uniform index of refraction. Here, geometric optics is used to trace the rays through an optical system to determine the system’s performance before it is constructed. Ideally the optical system would collect light from an object point and focus it to an image point. In practice, the image point is blurred. The
design method based on genetic algorithm taking account of glass selection. Initially the Damped Least Square method (DLS) was considered. The modified lens design method based on the UNDX+MGG to search glasses of lens elements as well as the curvatures of surfaces and gaps between the surfaces by devising an encoding/decoding scheme. In this encoding/decoding scheme, only available glasses are used in evaluating lenses. Schott glass catalog was chosen in which BK7 found to be the best fit for our proposed optical system. The effectiveness of the extended UNDX+MGG is tested by applying it to conic interconnect lens system.

Optical design software is taken as tool to simulate design and analysis of conic microlens system. Initially the system settings were made based on the results obtained by genetic algorithms and system origin were initialized after repeated trial and error method, and correction were made for entrance and exit pupil positions. The X and Y position edge thickness were corrected for 0.764mm. Study on various glasses were systematically studied[1], Schott catalog was chosen and in which it is observed that the low cost and good performance for coupling application of conic interconnect lens can be done using BK7 glass[2]. The refractive index and other optical properties[3] were found to be good for the BK7 which can be tested for different conic constant values with various field angles. Other parameters such as working focal length, Paraxial working focal length, image space were fixed for achieving
better optical system were reported in Table 5.2. Lens data editor through which the information’s given to ZEMAX® which contains types of surface, thickness of surface, nature of glass, semi-diameter etc. The second surface conic constant was changed from 00 to -2.8 in steps of -0.4 applied, and the system performance had studied. Field angle variation from axial propagation i.e., 0 deg to 10 deg insteps of 2 degrees were done. The third order geometric aberration theory developed here is the only theory available at present for the aberration analysis and design of microlens lens with more then one surfaces and advanced types. Efforts have been directed to the analysis of individual aberrations of a conic interconnect lens systems.

The new parameters for calculation of third-order aberration coefficients (Seidel aberration coefficients) are introduced. The formulas for Seidel aberrations coefficients are linear in these new variables. From the Seidel third order aberration coefficients, the spherical aberration is found to be decreasing as it’s conic microlens of conic constant varies and it approaches zero value near to conic constant of -2.0. Initially when no conic constant was introduced into the system a maximum coefficient value of 0.31 is observed for spherical aberration while in the case of astigmatism and coma it is only 0.003. These facts suggest that spherical aberration is predominant in the case of interconnect lens system which get reduced upon changing the conic constant values.
It is interesting to note that, between the values of -2.0 to -2.4 the total aberration in this system approaches zero and again get raised up. Ray tracing provides spot diagrams that contains information on the resultant aberration of the system. However, it fails to give quantitative information on individual aberrations. From one geometrical point of view the calculation of moments in the distribution of points in the image, i.e., centre of mass, r.m.s. image radii of the spot diagrams is very important in the evaluation of optical systems and we used these to evaluate the spot diagrams corresponding to the different tilt angle conditions.

Increase in tilt angle results in slower increase in the r.m.s radii attributed to the increase in the astigmatism. The r.m.s radii of 57.769 µm is obtained for microlens of conic constant \( x = 0.0 \). Increase of tilt angle \( \theta \) (degree) at the maximum of 10 degree gives out 64.62 µm. however, when conic constant of \( x = -2.0 \) r.m.s radii of spot size reaches a minimum values of 2.04 µm corresponding to low aberration coefficient. The theoretical expression to analyze the point spread function (PSF) by using pupils function from Equation (6.42) in the presence of defocus aberration is derived for conic interconnect microlens system. There are two factors to be drawn from the Figure 6.6 of simulated PSF representations. The primary factor is that the maximum intensity drawn for a specific lens system and the width of the central maximum peak.
As expected, for conic constant values of -2.0 a sharp high intense single peak is observed. For example, for a conic constant of -2.0 the normalized intensity is observed to be high of 0.90 for zero field angles and a minimum of 0.05 is drawn for greater field angle of 10 degrees. This may be due to steady increase in astigmatism makes the rays to get defocus at the central maximum. The similar trend is observed for other conic constant values but the normalized intensity gets increased when we go from 0.0 to -1.6 and it attains a high intensity around -2.0 further change in conic values the peak retards. The intensity of peak for zero and two degrees is very nearer but when field angle further increased the intensity drop is higher. So, the incident wavelength incident on to the lens surface of field angle near to the optical axis of up to approximately 2 degree will be having good focusing ability. The width of the peak is observed to be approximately over the diameter of 10μm for a conic value of \( x = -2.0 \) found to a maximum of 15 μm at \( x = 0.0 \).

The focal shift can be considered in terms of the optical transfer function (OTF). It is interesting to note that the second moment of intensity has a special significance in terms of the Fourier transform of the intensity, which is formally identical with the OTF. The Fourier integral is applied on to the OTF to get modulation transfer function(MTF) which is studied in terms of spatial frequency. The MTF study on our microlens system begins with characterizing the lens by encircled energy distribution which gives the quantum intensity of light beam from which OTF is obtained. The normalized encircled energy is
obtained a maximum value of 0.82 for a conic constant of -2.0 and field angle of 0 degrees. This shows that maximum light energy passes across the lens. When field angle get increased it drops to 0.53 shows that some part of energy is lost during this transmission as given in Table 6.6. The decreasing trends is observed when calculation was done for x values of 0.0, -0.4 etc., and the theoretical results were quit agrees with simulation findings reported in Figure 6.5. There is large variation in normalized encircled energy values were observed for increasing field angle may due to diffraction effect. The maximum and minimum encircled energy are taken from which MTF was calculated theoretically and the results were compared with the simulation findings.

When the field angle of 0 and 2 degrees the normalized optical transfer function maximum for lower cut-off frequency due to existence of minimum aberrations which is also gets agrees with PSF calculations. Lower the cut-off frequency give aberration free image quality which can be achieved by sending the incident ray to the angle very close to the optical axis of the optical system. the field angles of 4, 6 and 8 degrees has still higher cut-off frequency and further 10 degree has very high cut-off frequency confirms larger aberration coefficient which is also reported in spot diagram of section 6.3. The Zernike theory of diffraction integrals was intended to produce analytical results that, with the computational means of that time, led to a good approximation for the intensity distribution in or close to the focal plane.
The series representations of Zernike coefficients yield a flexible means to compute 3rd order Seidel aberration coefficients such as spherical aberrations, astigmatism and coma which predominantly affect the conic interconnect lens system. The numerical values drawn from Zernike coefficients corresponds to 3rd order Seidel aberration were tabulated in Table 6.7, 6.8 and 6.9 for spherical, astigmatism and coma respectively. The maximum aberration coefficient 0.328 was found for 0 field angle of conic constant 0.0. When field angle get increased spherical aberration increases but not at the greater level due to increase in astigmatism observed in Figure 6.11.

The same linearity observed in spot diagram results. The magnitude of astigmatism and coma were small compared with spherical aberration coefficients which closely aggress with Seidel coefficient results reported in Figure (6.1). The Zernike coefficient which represents the 3rd order Seidel aberration reaches lesser value in between conic constant values of -2.0 to -2.4. at nearer to conic constant of -2.25 almost all the 3rd order Seidel coefficients lies near to 0.0 gives out better performance of conic interconnect lens system near 0 field angle. High coupling efficiency and large misalignment tolerances are two important optical requirements of packaging a laser diode for various applications in optical fiber communications. High coupling efficiency implies an increase of the repeaters spacing, and may lead to cost saving. For Butt coupling, the coupling efficiency is very small, typically about 10 %, due to mode mismatch between laser diode and single mode fiber. To enhance
coupling efficiency, the small laser waists must be somehow transformed to match the large fiber waist by for example, utilizing lens system. Many kinds of lens system have been proposed to couple light from a laser diode laser diode to a single mode fiber. The analysis of keeping the conic microlens at the tip of SMF fiber and it is coupled with laser diode to enhance the coupling efficiency of the system. The analytical model for measuring the coupling efficiency using conic microlens in LD-SMF interconnects shown in Figure 7.1. The theoretical and simulation using ZEMAX® results taking into account the effect of multiple reflection reveals that contribute to an interference phenomenon, which causes a variation in the power coupled to the SMF. The maximum coupling efficiency, taking into account of multiple reflections is 70.15% with the optimum distance between laser diode and fiber facets. The incident ray that falls on the oblique section does not contribute multiple reflection, due to divergence of the reflected light, but the transmitted power would be reduced due to Fresnel reflection at an oblique angle. One of the ways to reduce multiple reflection, and thus power variation is to have angled, hyperbolic or hemispherical facets instead of flat sections, as in butt coupling on the fiber tip[4], this is besides coating the lens surface with AR coating. The power variation is also seen to always be larger near to the laser facet and reduced as the fiber moves away from the laser facet. This is due to the laser beam, which diverges as it propagates further away from the laser facets[5].
The coupling efficiency obtained from the ABCD analysis method was compared with the reported values shown in Figure 7.2 and in Table 7.2 & 7.3. The working distance is kept constant of 5 $\mu m$ and the thickness of lens varies by changing $a$, $b$ of the fiber regions the variation of coupling efficiency is shown in Figure 7.3. When the thickness of the lens decreases the coupling efficiency increases as predicted. The numerical reported values closely aggress with the theoretical model[6]. In all the cases the multiple refraction effect is ignored.
8.2 References


