INTELLIGENT OPTO SENSOR

Number 2

DESIGNER'S NOTEBOOK

SELFOC® Lens Arrays for Line Scanning Applications

Contributed by NSG America, Inc.

Design Problem What type of SELFOC Lens Array is best for a particular scanning application?

Solution A SELFOC® Lens Array (SLA) is a compact image transfer device that is ideal for use with Texas Advanced Optoelectronic Solutions linear sensor arrays. In scanning applications, the SLA is used to form a real, erect image directly onto the linear sensor array with unit magnification.

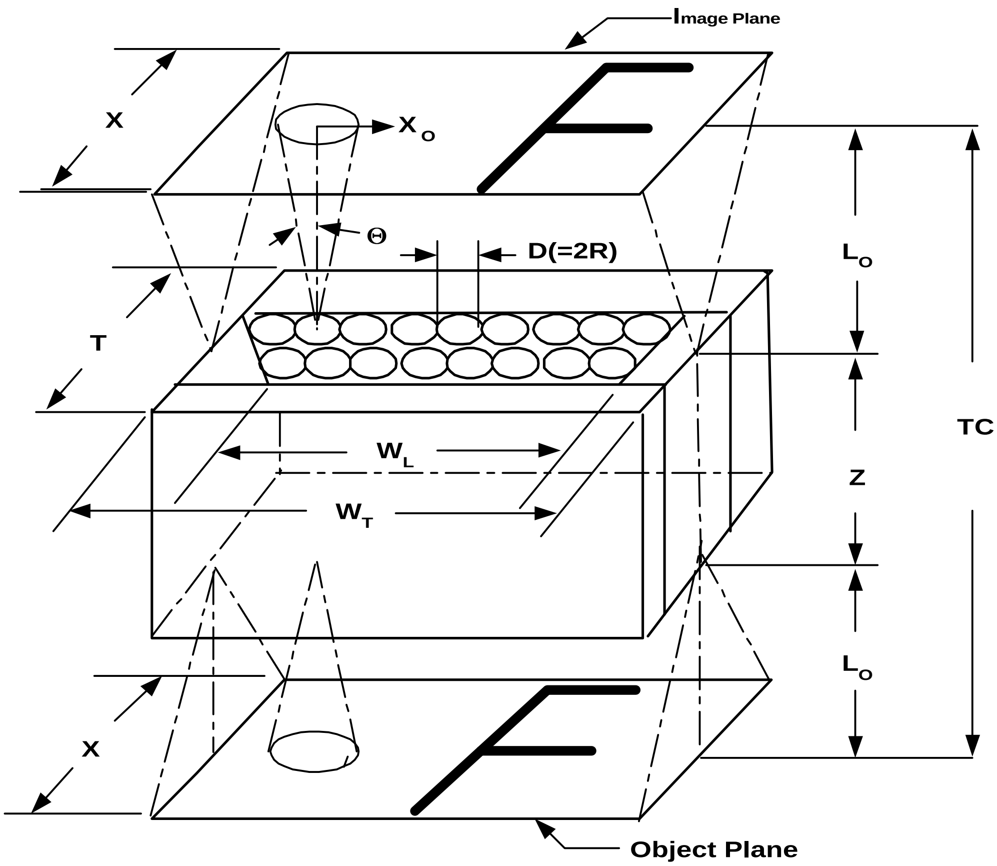

Figure 1: SLA Dimensional Parameters

An SLA is typically constructed from one or two rows of SELFOC gradient-index microlenses which are aligned and secured between two fiberglass-reinforced plates. These gradient-index (GRIN) microlenses are cylindrically shaped and have flat end surfaces. Their imaging ability is due to a graded refractive index which is formed by an ion-exchange process in the glass host material. The resulting index profile has a maximum at the center of the lens (on axis) and decreases quadratically towards the outer edge. This smoothly varying index of refraction causes incident rays of light to refract within the lens and converge towards a point of focus. When assembled in an array each microlens, or “lenslet”, forms its own image so that the images from adjacent lenslets overlap and form a continuous image across the width of the SLA.

Figure 1 illustrates the dimensional parameters used to select and specify an array. Notice that the heights, X, of the object and image planes are identical. This is because the SLA is a one-to-one image transfer device and, as such, it operates with unit magnification. The maximum height of this field that the SLA will “see” is determined by the numerical aperture of the individual lenslets and by the number of rows of lenslets in the array. For line scanning applications, the SLA’s field of view need not be large (perhaps 1 millimeter). For applications other than line scanning (eg., copiers, printers, etc.), it is necessary to determine the maximum height of the object field for your application, remembering that shorter field heights will generally result in greater depth of focus and higher resolution. The maximum object height currently viewable by a standard SLA is 7.8mm (SLA type 12B-495).

Another aspect of the SLA’s one-to-one imaging ability is conjugate symmetry. Referring again to Figure 1, the working distance L0 is shown to be identical on each side of the lens (object distance = image distance). By adding the working distances to the lenslet length (Z) we obtain the Total Conjugate, or “TC”, of the optical system (TC=Z+2L0). The TC represents the total separation of the object and image planes and is a key identifier in the specification of an SLA. A wide range of TCs are available, from 9.1mm (SLA-20D) to 74mm (SLA-06A), with different TCs being suitable for different applications. In a contact image sensor (CIS), for example, the SLA-20D is extremely convenient because it allows the SLA and the sensor array to be packaged together in a very small unit. For other types of imaging applications, longer TCs may be needed due to mechanical constraints or optical requirements. As with the field height specification, there are trade-offs between TC and depth of focus. The positioning of a “short-TC” lens may be more critical than for a lens with a longer total conjugate.

Once the total conjugate and the field height requirements are known for your optical system, the choice of an appropriate SLA becomes much clearer. The table in the appendix gives a complete list of the standard SLA types and their major optical parameters. The numeral in the SLA type code corresponds roughly to the acceptance angle of the lenslets in the array. For example, in an SLA type 09A, each lenslet has an acceptance angle of about 9 degrees (ie., a lenslet will accept light from a 9-degree cone). The letter in the type designation is a code corresponding to the lenslet diameter. Type “A” lenslets are the largest (about 1.1mm), while type “D” are the smallest (0.56mm). Larger lenslet diameters result in a more massive lens array and provide a larger viewing angle for field scanning applications.

It is important to remember that the optical properties of an SLA depend upon the wavelength at which it is used. For example, the values of the total conjugate and the working distance are specified for a particular wavelength as indicated in the appendix. But if the SLA is used at a different wavelength, a positioning adjustment will be required to achieve the best performance. The general rule is that longer wavelengths require larger working distances and result in greater total conjugates.

Finally, we must determine the width of the entire lens array. Recall that an SLA creates a continuous image from the overlapping images formed by adjacent groups of lenslets. A large amount of overlap will result in better image uniformity, higher brightness, and greater resolution. Consider, however, the lenslets lying at the ends of the array. Because the degree of overlap is small at the edges of the SLA, the image quality at the extremities will be correspondingly lower than at the center. For this reason it is necessary to oversize the SLA width such that this "edge effect" does not appear in the transmitted image. The following equation shows how to calculate the SLA lens width W_L for a particular image width W_i:

$$W_L = W_i + 2[X0-(D/2)]$$

X0 is the view radius of a lenslet and D is the lenslet diameter. The values of X0 and D are tabulated in the appendix for each SLA type. Table 1 lists the required W_L of common SLA types for use with TAOS linear arrays.

In most SLA products there is a small section at each end of the SLA which contains no lenslets. The total SLA width W_T may, therefore, be larger than the width of the active lens portion W_L. See Figure 1 for an illustration.

For order placements and technical inquiries, a unique coding system is used to specify SELFOC Lens Arrays. The part code is composed of essential identifying information in the following order: SLA type, total conjugate, wavelength, number of rows, and array size. Here is an example of a typical SLA part code:

SLA-12A-380-570-2-226/256

The above code indicates an SLA type 12A with a 38.0mm total conjugate at a wavelength of 570nm and containing 2 rows of lenslets. The final section of the code represents W_L/W_T. In this case the lenslet array is 226mm wide and the total unit is 256mm wide. If special positioning notches, grooves, or holes are required in the SLA, the coding information for these features is included at the very end of the part code.

To place an order for a SELFOC Lens Array, or to receive more information about SELFOC products, contact an applications engineer at NSG America Inc. There are two regional sales offices in the United States to assist you.

Eastern Regional Office	Western Regional Office
28 Worlds Fair Drive	19200 Von Karman Avenue, Suite 400
Somerset, NJ 08873	Irvine, CA 92715
tel 908-469-9650	tel 714-261-6212
fax 908-469-9654	fax 714-261-6704

Table 1. Required width of common SLA types for use with TAOS Linear Arrays

			* Minimum Lens Array Width W_L (mm)				
Linear Sensor Array	Sensor Resolution (LP/mm)	Active Width (mm)	SLA-04D TC 49.0	SLA-06A TC 64.0	SLA-12A TC 43.0	SLA-20A TC 18.0	SLA-20D TC 9.1
TSL201	3.9	8.13	12	15	17	15	13
TSL202	3.9	16.26	21	23	25	23	21
TSL208	3.9	65.02	69	72	74	72	70
TSL1401	7.9	8.13	12	15	17	15	13
TSL1301 / TSL2301	5.9	8.64	13	16	18	16	13
TSL1402	7.9	16.26	21	23	25	23	21

Appendix - Mechanical and Optical Parameters of SLA

SLA Type	No. of Rows	TC (mm)	D (mm)	Z (mm)	L_0 (mm)	X_0 (mm)	X (mm)	MTF@6LP/mm (%)		DOF* (mm)	Wavelength (nm)
								Avg.	Min.		
04D	2	49.0	0.563	23.4 ± 1.5	12.8	0.90	2.29	60	35	±1.3	570
06A	2	74.0	1.070	28.21 ± 1.3	22.90	2.46	5.85	45	25	±0.8	510
	2	70.0		28.56 ± 1.3	20.72	2.23	5.39	48	28		510
	2	64.0		29.25 ± 1.3	17.38	1.90	4.73	50	30		510
09A	2	54.0	1.045	19.85 ± 1.3	17.05	2.62	6.14	53	28	±0.6	510
	2	48.0		20.40 ± 1.3	13.80	2.14	5.18	55	30		510/570
	2	40.0		21.71 ± 1.6	9.15	1.47	3.84	60	40		570
	1	58.0		19.60 ± 0.5	19.20	2.94	5.88	50	25		510
12A	2	43.0	1.085	15.12 ± 0.7	13.94	2.90	6.74	60	30	±0.4	510
	2	38.0		15.50 ± 0.7	11.25	2.36	5.66	65	40		570
	2	32.0		16.32 ± 0.7	7.84	1.69	4.32	70	50		570
	1	44.2		15.05 ± 0.4	14.58	3.02	6.04	60	30		510
12A (HR)	2	43.2	1.085	15.13 ± 0.7	14.04	2.90	6.74	70	45	±0.45	660
	2	43.0		15.13 ± 0.7	13.94	2.89	6.72	70	45		570
	2	32.1		16.32 ± 0.7	7.89	1.69	4.32	73	50		660
	2	32.0		16.32 ± 0.7	7.84	1.69	4.32	73	50		570
12B	2	25.6	0.895	13.57 ± 0.4	6.02	1.32	3.41	70	50	±0.4	660
	2	25.5		13.57 ± 0.4	5.97	1.31	3.40	60	50		570
	1	49.5		11.90 ± 0.3	18.80	3.91	7.82	50	30		510
	1	40.6		12.16 ± 0.3	14.22	2.97	5.94	65	35		510
12D	1	33.4	0.563	7.86 ± 0.2	12.77	2.43	4.86	55	30	±0.4	545
	1	18.3		8.71 ± 0.2	4.80	0.97	1.94	70	55		570
15B	2	22.25	0.860	11.74 ± 0.45	5.26	1.27	3.28	60	45	±0.35	740
	2	22.2		11.74 ± 0.45	5.23	1.27	3.28	60	45		660
	2	22.0		11.74 ± 0.45	5.13	1.25	3.24	60	45		570
20A	2	18.7	1.115	8.41 ± 0.5	5.15	2.11	5.19	50	35	±0.3	740
	2	18.0		8.41 ± 0.5	4.80	2.00	4.97	50	35		660
	2	16.9		8.42 ± 0.5	4.24	1.82	4.61	50	35		570
	1	17.6		8.30 ± 0.4	4.65	1.98	3.96	50	35		570
20B	2	15.1	0.912	6.89 ± 0.4	4.10	1.70	4.18	55	45	±0.3	740
	2	14.6		6.89 ± 0.4	3.86	1.62	4.03	55	45		660
	2	13.8		6.89 ± 0.4	3.46	1.48	3.75	55	45		570
	1	14.4		6.79 ± 0.33	3.81	1.62	3.24	55	45		570
20D	1	9.1	0.563	4.30 ± 0.05	2.40	0.98	1.96	60	50	±0.3	570

* DOF is based on 10% MTF @ 6LP/mm and is for reference only, not inspected.

** Consult **SELFOC® Lens Array Reference Book** for complete design and application data.