Generalized confocal imaging system

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The classical 4-f imaging setup is widely used in optical interconnects because it offers telecentricity and good imaging performance for extended fields. As shown in Fig. 1, one important feature of this setup is that all the object distance d_1, the image distance d_2 and the focal length f are the same. However, design restrictions in practical setups often do not allow one to choose the parameters d_1, d_2 and f in this way. This is particularly the case for planar-integrated free-space optical interconnects [1]. To overcome this disadvantage and to provide additional design freedom, we propose here a generalized confocal imaging system, shown in Fig. 2.

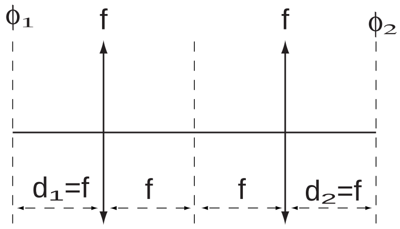

Fig. 1

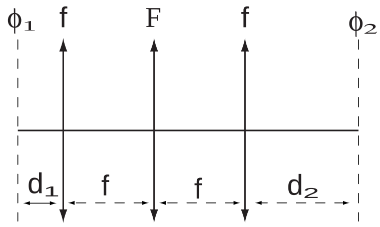

Fig. 2

According to matrix optics, the total matrix M between the object plane and the imaging plane in Fig. 2 can be determined to be

$$M = \begin{bmatrix} -1 & 2f - d_1 - d_2 - \frac{f^2}{F} \\ 0 & -1 \end{bmatrix}. \tag{1}$$

On the other hand, according to the Collins' diffraction integral [2], one knows that the complex amplitude distribution $\phi_2(x_2,y_2)$ at the imaging plane has a simple relation $\phi_2(x_2,y_2)=\phi_1(x_1,y_1)$ with the complex amplitude distribution $\phi_1(x_1,y_1)$ at the object plane, when A=D=-1 and B=C=0, where A, B, C, D are the four matrix elements of the ABCD matrix. From Eq. (1) one can find that the three conditions A=-1, D=-1 and C=0 is always satisfied for the structure of Fig. 2. The fourth relation B=0 holds when

$$d_1 + d_2 + \frac{f^2}{F} = 2f \tag{2}$$

Eq. (2) is the imaging condition for the setup of Fig. 2. In particuar, the classical 4-f setup corresponds to the case of $F=\infty$ and $d_1=d_2=f$. Because the two f lenses still have a common focal plane and the added F lens is just located at this plane, we name this setup the generalized confocal imaging system.

Compared with the conventional 4-f setup, the main advantage of this setup is that the object distance d_1 and the image distance d_2 can be almost artitrarily chosen. This advantage is especially suitable for planar-integrated micro-optical system [1], for which the object distance d_1 are often different from the imaging distance d_2.

[1] J. Jahns, "Planar packaging of free-space optical interconnects", Proc. IEEE **82** (1994) 1623-1631.

[2] S. A. Collins, "Lens-system diffraction integral written in terms of matrix optics", J. Opt. Soc. Am. **60** (1970) 1168-1177.