A Study of Diffraction Effect on LCOS Microdisplay

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Abstract:

The measurement of diffraction of LCOS microdisplay with various pixel size, interpixel gap, pixel height and coatings demonstrates that pixel size is the leading factor for diffraction loss, while the role of varying pixel gap is less significant comparatively. One-dimensional diffraction simulation is found to be in good agreement with the measurement. Noticeable deviation occurs when pixel size is as small as 8um.

1. Introduction

Liquid Crystal on Silicon (LCOS) based microdisplays have found broad applications in projection displays and near-to-the-eye displays [1,2]. The demand for high-resolution microdisplays results in displays having smaller pixel sizes. However, as the pixel size decreases, several problems, such as lower aperture ratio, increased diffraction loss [5], and stronger fringe field [3-4] are introduced. As a result, the display will lose brightness and contrast. The study of diffraction related to pixel geometry is significant in the performance optimization of LCOS microdisplays. For example, varying ratios of pixel size and inter-pixel gap is one of the approaches to minimize fringing field effect, but it may increase diffraction effect and have negative impact on display performance. Therefore, there will be a trade off between the two effects in the performance optimization. Previous papers [5] mainly focused on simulation, but few report on experimental study of diffraction effect of microdisplay. In this paper, we perform diffraction measurement for LCOS microdisplay with various pixel size, inter-pixel gap, pixel height and coatings, and, consequently, study the dependence of diffraction on these pixel parameters. We use one-dimensional diffraction simulation to compare with measurement results.

2. Results

In the diffraction measurement, light from a HeNe laser (633nm) is incident on the LCOS panel, and the diffracted light is measured with a Goniometric Radiometer (Photon, Inc.), which is a real time angular scanning instrument capable of 2D intensity scanning. It provides a fast method to analyze data and visualize 2D intensity profile (figure 1).

We assume only the 0^{th} order diffraction is collected in the projection system, and the higher orders are diffraction loss. In the measurement, we use twist nematic mode LCOS panel with pixel sizes of 8um, 12um, and 12.9um, and pixel gaps of 0.5um, 0.55um, 0.6um, 0.72um and 0.8um. The sample is either a LC cell at an electrical off state or only the patterned backplane wafer.

To compare with the measurement, we also performed a simulation to calculate far field Fraunhofer diffraction. For simplicity, we use a one-dimensional approach.

In Figure 2 we compare the diffraction patterns for LC cells with 0.55um and 0.8um pixel gap, both with 12.9um pixel size. For 0.55um pixel gap, the diffracted light is mainly distributed on two perpendicular axes (Figure 2 (a)) that are parallel to pixel edges. Except for the dominant zero order diffraction, the intensity of higher orders are measured to be almost unchanged up to about 10^{th} order. For 0.8um pixel gap, the diffraction pattern, shown in Figure 2 (b), spreads out in all directions in the observation plane. Though the diffraction pattern looks quite different for pixel gaps of 0.55um and 0.8um, the diffraction loss for 0.8um pixel gap is only about 1.5% higher than that of 0.55um pixel gap. Figure 3 demonstrates the relationship of 0^{th} order diffraction and pixel gap. The simulation is in substantial agreement with measurement, with deviations of 0.7% at 0.55um pixel gap and 1.6% at 0.8um pixel gap. In this case our one-dimensional simulation is, though not accurate, sufficient to predict the diffraction.

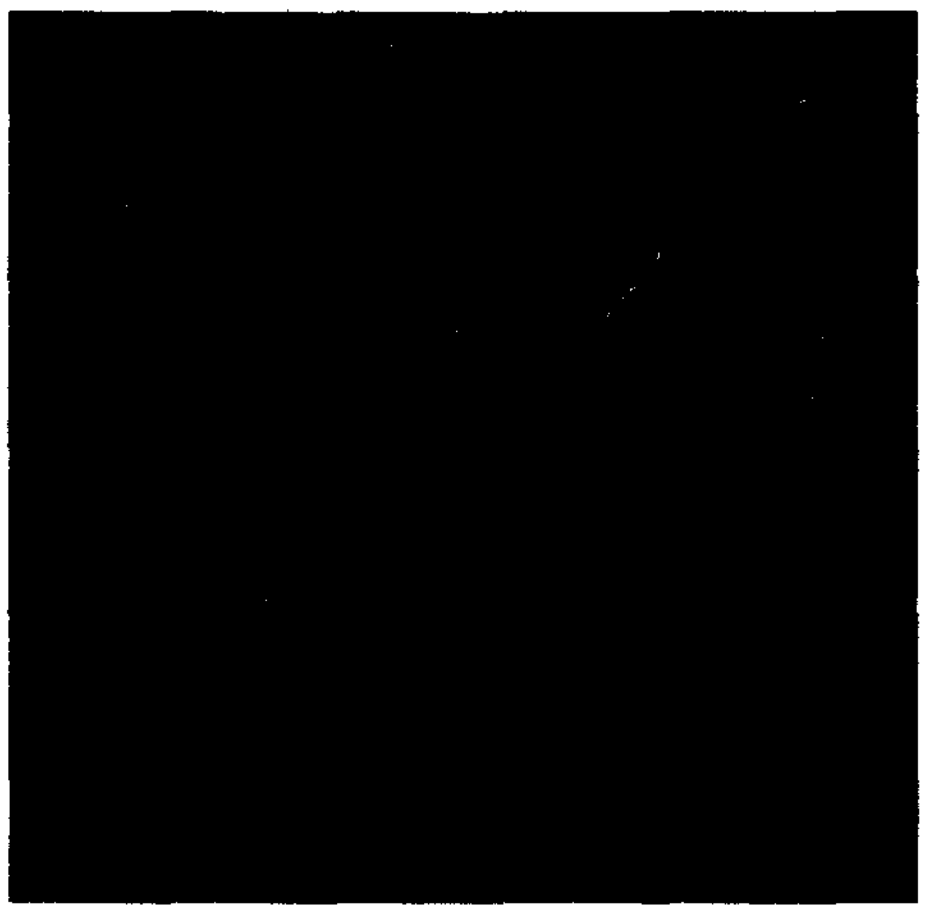


Figure 1. Diffraction distribution measured using Goniometric Radiometer.

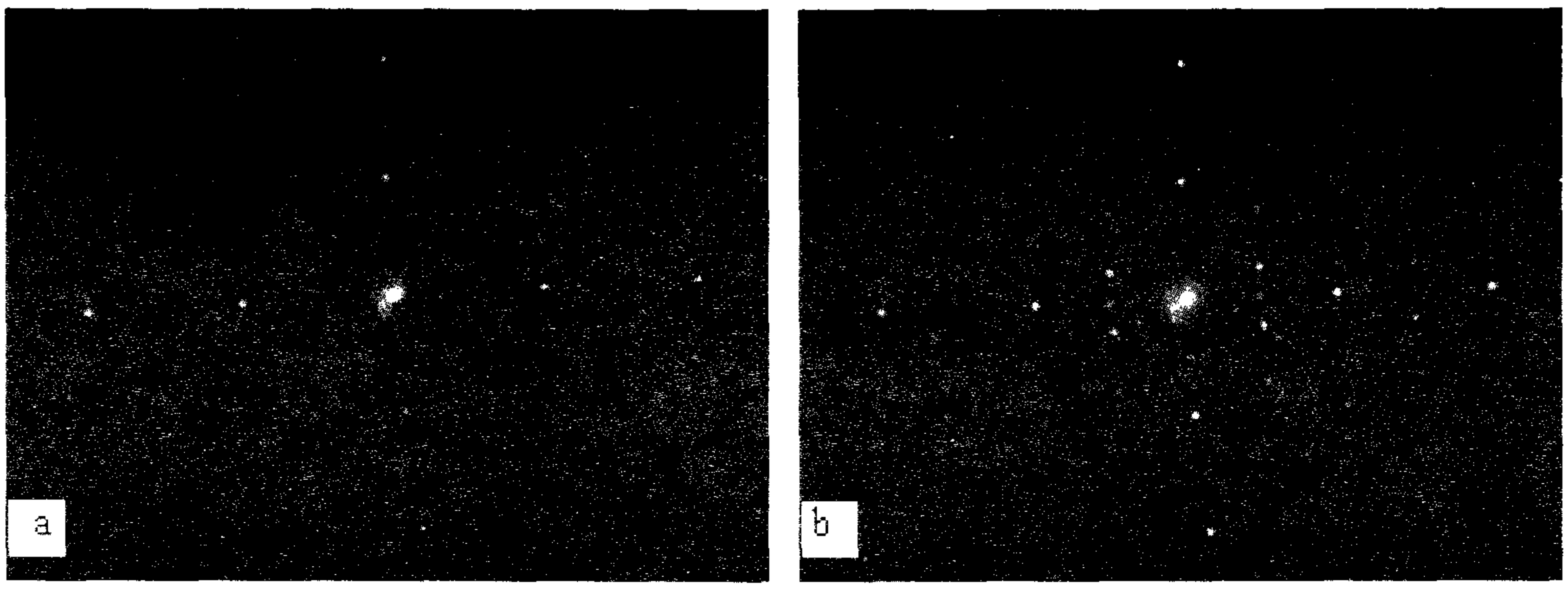
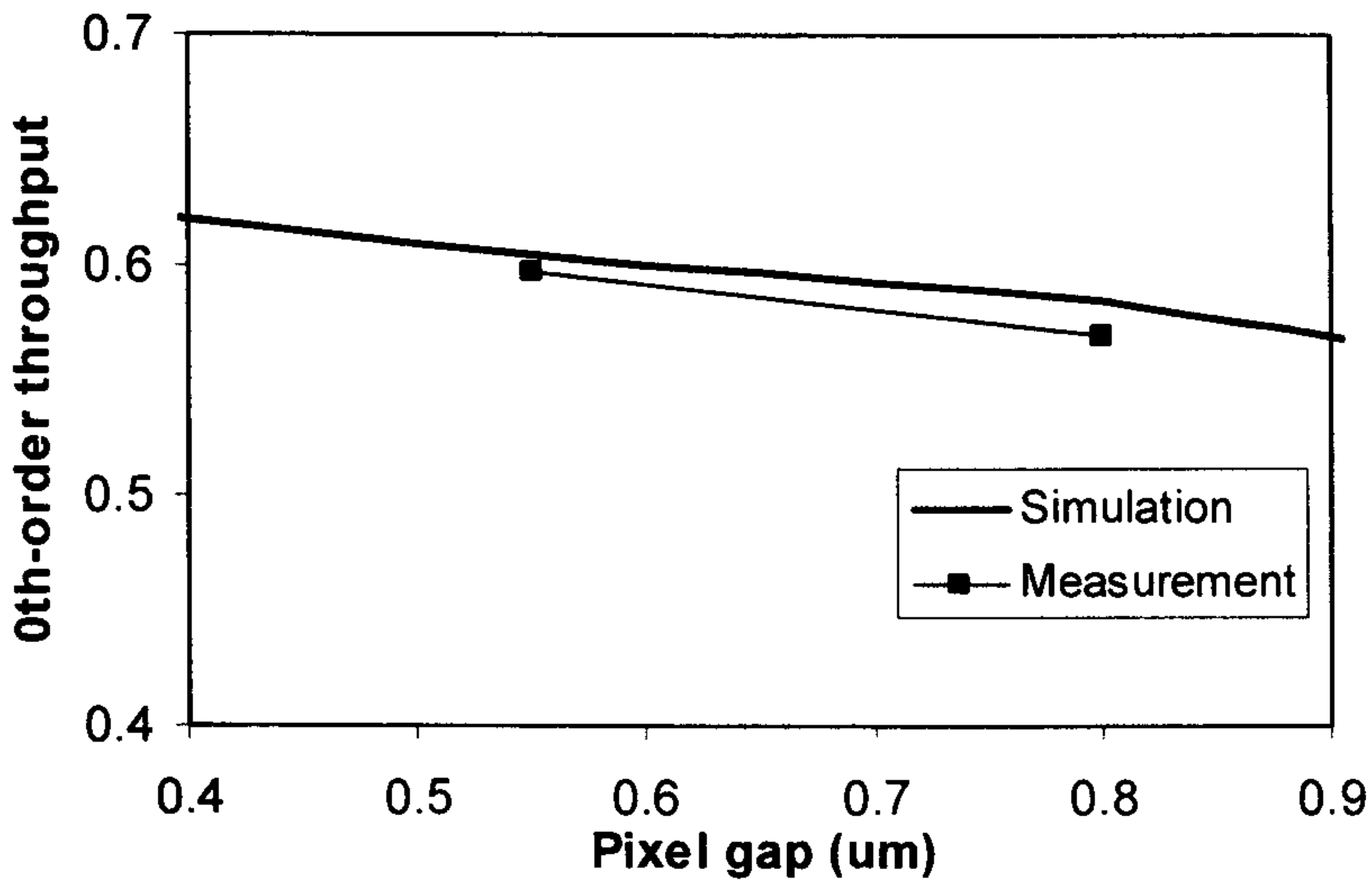


Figure 2. Diffraction pattern of cells with 12.9um pixel size and (a) 0.55um pixel gap. (b) 0.8um pixel gap, respectively

We investigated the dependence of pixel size on diffraction by measuring samples of LC cells with 8um, and 12um pixel sizes, all having the same pixel gap of 0.5um. These samples show lower non-diffraction loss than those used in the pixel gap experiment. The simulation shows (Figure 4) that in this region (8um-12um), 0^{th}-order throughput changes rapidly with pixel size, from 66% at 12um to 57% at 8um, a 9% decrease. Pixel size is the dominant factor for diffraction loss. The measurement results agree well with the simulation.
We compared diffraction experimentally using cells filled with liquid crystal and backplane wafers only, respectively. The comparison shows that the 0^{th} order throughput of the LC cell is less than that of the backplane. The difference is chiefly due to losses other than diffraction.

We also study the relation of less diffraction loss with reflection enhancement layer on Al. The average loss difference of with and without reflection enhancement layer decreases with pixel gap. (Table 1)

Our study also show that diffraction loss increases with Al thickness by 1%~3% for thickness of 2000A, 3000A, and 4000A.



;ure 3. Pixel gap dependence of 0^{th}-order throughput for LC cell with pixel size of 12.9um.

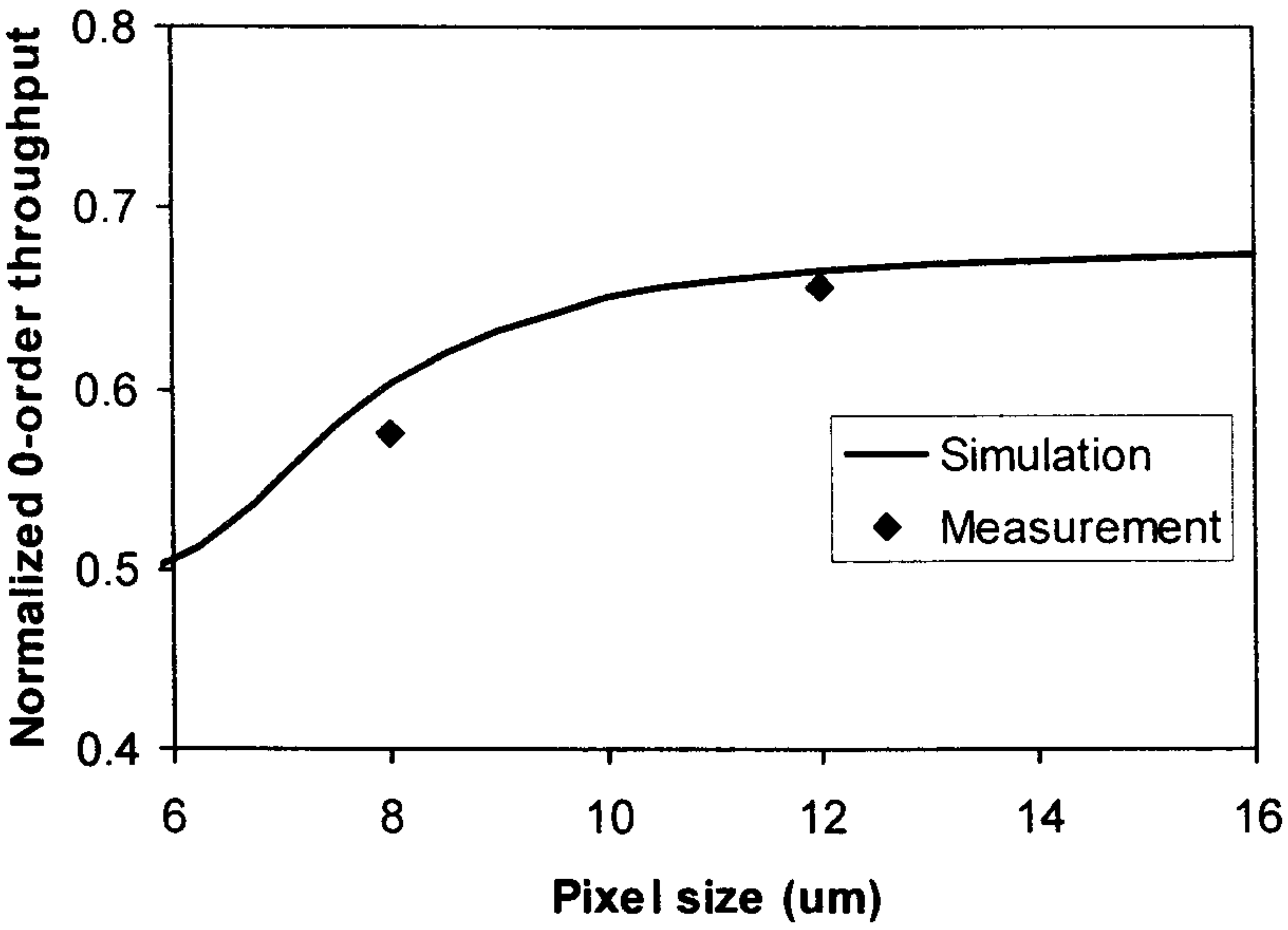


Figure 4. Pixel size dependence of 0^{th}-order throughput for LC cell with pixel gap of 0.5um.

Table 1. Diffraction loss difference for with and without reflection enhancement coatings

Pixel gap (um)	0.5	0.6	0.72
Diffraction loss difference (%)	1.97	1.0	0.3

3. Impact

The results from our diffraction study are significant in the performance optimization of LCOS microdisplays. The study shows that pixel size plays a more important role in diffraction than the pixel gap currently used in LCOS. The diffraction loss for LC cells with 8um pixel size is about 9% larger than that of 12um pixel size. There is only 1.5% diffraction loss difference for a pixel gap of 0.55um and 0.8um. The coating and pixel height also play an important role in reducing diffraction loss. The 1-D simulation provides a fast and economical approach for the optimization of pixel geometry.

4. References

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