7.1: An Image Quality Wire-Grid Polarizing Beam Splitter

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Abstract
MOXTEK[1] introduces a flat ProFlux™ wire-grid polarizing beam splitter for use in projection systems where preservation of image quality is required upon reflection at the PBS. This paper discusses advantages obtainable when using the ProFlux™ flat PBS in projection display architectures, and reasons for these advantages. Specifically, these advantages include high system contrast, simplified designs with various LCOS panels, and inherent high durability.

1. Introduction
A couple of years ago, MOXTEK introduced its ProFlux™ wire-grid polarizer for use in Liquid Crystal projection displays. These polarizers have boasted high durability as well as high performance and purity of the resultant polarization state.

More recently, we introduced a version of ProFlux™ optimized for use as a polarizing beam splitter (PBS), including an optically flat PBS for applications that reflect an image. Performance of the ProFlux™ PBS will be discussed in this paper, from throughput and contrast to polarization purity and its interaction with liquid crystal panels that make it a nearly ideal polarizer for liquid crystal projection applications.

2. Projection System Contrast
Many people have reported contrast exceeding 15,000:1 when used in a configuration as in Figure 1 that transmits light through the PBS, reflects from a mirror [with quarter-wave plate (QWP) to produce the bright state], and then reflects from the PBS onto a detector. Contrast values exceeding 2000:1 have been reported in a similar configuration when using an LCOS panel instead of the mirror-QWP.

These results are much higher than have been reported with conventional PBS solutions or even with other newer devices, and merit some explanation. An understanding of the reasons behind this high performance may provide some insight into how using the ProFlux™ PBS and polarizers in projection displays may enable high performance systems with a variety of LC panels and simpler system designs.

2.1 Test System Configuration
Layout of the test system is shown in Figure 1. Three separate measurements are made to demonstrate the performance characteristics of the ProFlux™ PBS. Measurement 1 (bright state) is taken with the quarter-wave plate (QWP) oriented to rotate the polarization so that it reflects from the PBS and exits to the screen (detector in this case). This measurement yields greater than 80% throughput, including transmission through the PBS and reflection off the PBS. Measurement 2 (dark state with QWP) is taken with the QWP oriented such that polarization is not rotated, yielding a dark state at the screen. This measurement gives a contrast of greater than 2000:1. The third measurement (dark state without QWP) – the measurement of greatest interest – removes the QWP altogether, also yielding a dark state at the screen. Surprisingly, this measurement yields a contrast exceeding 15,000:1 at the screen.

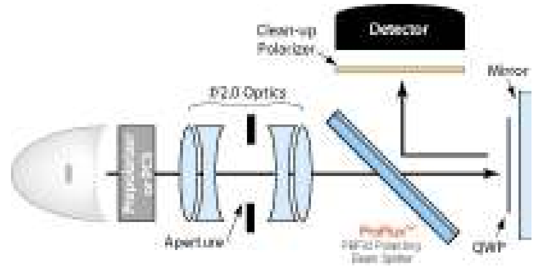

Figure 1

System layout for measurement of contrast and throughput.

2.2 Test Results
The natural question arises: why such a difference in the dark state with and without the QWP, and what is its significance?

The answer to this question will give insight into why ProFlux™ is able to provide such high contrast in this architecture, and why it enables higher performance from a number of LCOS panels previously thought unable to provide such performance.

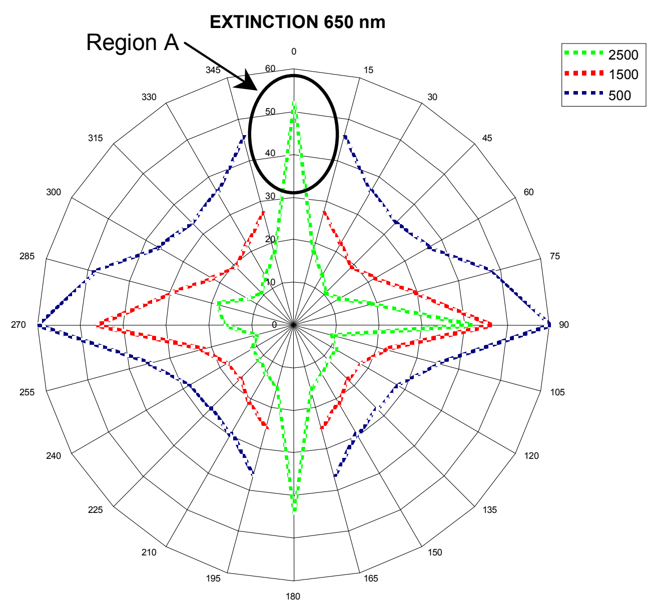

Figure 2

Polar plot: isocontrast curves for a typical wire-grid polarizer.

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ISSN/0003-0966X/03/3403-0694-$1.00+.00 © 2003 SID

When a wire-grid polarizer is viewed through an analyzer, the phenomenon known as a Maltese cross is seen, as suggested by the isocontrast curves shown in Figure 2. When a wire-grid PBS is viewed at 45 degrees, as indicated by Region A in Figure 2 for an f/2.0 cone, there are regions of lower contrast at the top and bottom of the screen caused by slight rotation of the polarization vector for the skew rays.

This nonuniformity in contrast does not show up in a system configuration because upon return from the LCOS, the PBS reflection creates a similar but opposite rotation, essentially correcting the polarization aberration, and producing a very dark and uniform dark state. The PBS is, then, self-compensating in this configuration, an apparently unique behavior.

3. Discussion and Conclusions

The results obtained when the above optical systems are tested indicate that the polarization behavior of the wire-grid polarizer is very different from the common MacNeille cube beam splitter or other similar polarizing beam splitters. In particular, one is led to the conclusion that wire-grid beam splitters do not require a QWP in order to obtain high contrast in an LCOS-based projection system. In fact, the introduction of a QWP in this system creates undesirable changes in the polarization state and will reduce contrast and image uniformity. What is desired, instead, is that the LCOS panel have the characteristics of a simple mirror when the panel is switched to the dark state in order to obtain high contrast and outstanding dark state uniformity.

We believe there are a number of ways to achieve this high level of performance from an LCOS panel. One obvious method is to apply trim retarders to correct the LCOS panel dark state for residual birefringence. We understand that impressive contrast improvement has been shown using this approach, and we believe there are ways to improve the panels themselves to achieve improved contrast without the use of trim retarders.

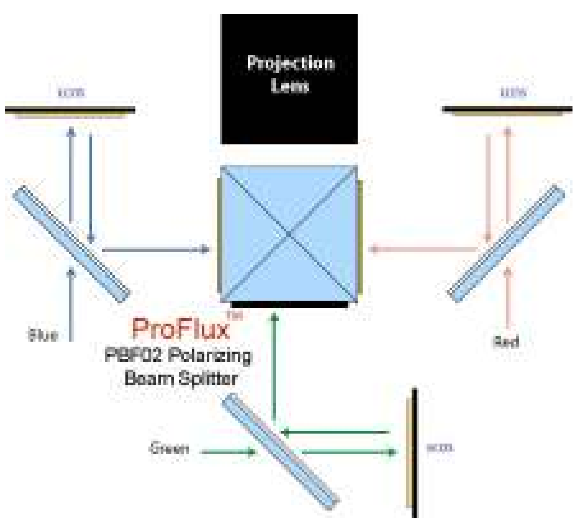

Figure 3

A three-panel LCOS-ProFlux™ architecture.

The combination of the ProFlux™ PBS and an LCOS panel designed for near-zero retardance in the dark state as outlined above provides the foundation for a family of high-performance LCOS engines. This foundation architecture has an obvious application in a single-panel LCOS system, but can easily be applied to two- and three-panel architectures by combining it with various color recombination schemes.

A recently published patent filing by Kodak[1] proposes one possible LCOS architecture built around the common X-cube color combiner and three LCOS- ProFlux beam splitter assemblies. This architecture is outlined in Figure 3. We expect to see other two- and three-panel architectures developed by following this approach.

In addition, we expect that variations on these layouts will surface around HTPS panel architectures that are designed to take advantage of the ProFlux™ PBS. One such system is shown in Figure 4.

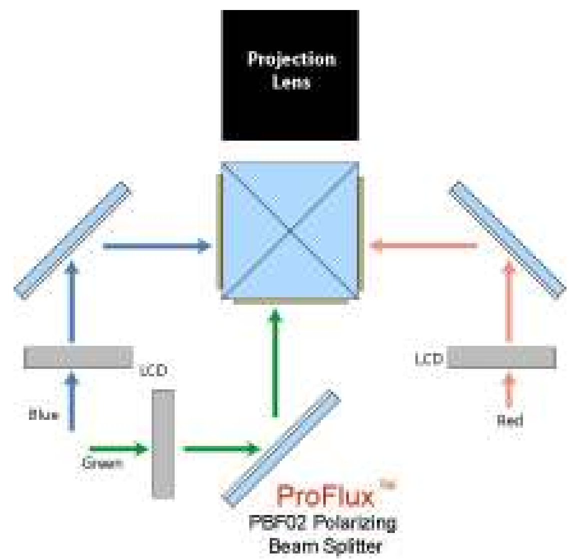

Figure 4

A three-panel HTPS-ProFlux™ architecture.

While this design does not have the same dual path at the PBS as the LCOS system (that is, transmission-panel rotation-reflection), we expect that new system designs using ProFlux™ and HTPS panels will improve the performance of the traditional HTPS architecture, while providing improved durability and contrast.

4. Acknowledgements

We would like to thank Chanda Walker of Houston Research and Consulting for her help with concepts and measurements presented in this paper.

5. References

[1] Kurtz, et al, *Digital Cinema Projector*, US Patent Application Publication, US2002/0171809A1.