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# *Multi-Primary Projection Engines Comparative Analysis*

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## 1. General

Multi-primary technology enables a very efficient and cost effective method to enlarge color gamut and increase brightness of displays in general, and projection displays in particular. By proper adoption of the technology, a wide "cinema like" color gamut can be achieved, together with an overall large efficiency increase that, based on the configuration, can significantly increase lumens output. The main reason for this capability to simultaneously increase both color gamut and brightness, is that multi-primary technology enables very efficient use of the lamp spectrum to achieve both saturated color primaries and a well balanced white color.

This document presents a first order analysis of performance comparison between various HTPS and LCoS microdisplay based optical engines using single-, dual-, three-panel and four-panel configurations, both RGB and multi-primary. The calculations are based on some "generic" assumptions regarding the engine components and panels specifications. Exact analysis will depend on the precise characteristics of the components, the specific optical design of the different engines and engine specifications (gamut/brightness trade-off, white point).

It should be noted that for all the multi-primary configurations shown below Genoa has active patent applications. Two patents are already granted.

## 2. Calculation assumptions

- Lamp: 120W UHP, 1mm arc gap.
- Panels spectral efficiency: Genoa confidential data base of different components.
- Optical engine components: Genoa data base.

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## 3. Configurations

### 3.1. Single panel LCoS

For single panel LCoS, a "simple" color wheel type configuration is shown in figure 1. This configuration was tested extensively and successfully with many different optical engines, based on MDC LCoS panels. An earlier variation implemented by Philips (using a "drum" configuration) yielded excellent results that were published (M. S. Brennesholtz, S. C. McClain, S. Roth and D. Malka, A single Panel LCoS Engine with a Rotating Drum and a Wide Color Gamut, SID 2005 Digest of Technical Papers, paper 64.3 ).

Depending on requirements and system parameters, four- or five-primary configurations can be realized. The operation is sequential, and we assume (for four primaries) an overall 120Hz update rate – this translates to overall 480 primaries/second. It should be noted that in a perception test done by Philips Research together with Genoa, it was found that color breakup is significantly lower in multi-primary displays as compared with RGB displays. For example, the color breakup effect with a single panel 5-primary display operating at 85Hz was less than that of an RGB system operating at 120Hz (D. Eliav, E.H.A.Langendijk, S. Swinkels, I. Baruchi, Supression of Color Breakup in Color-Sequential Multi-Primary Projection Displays, SID 2005 Digest of Technical Papers, paper 47.3).

Thus, this configuration may be applicable with panels that have response times faster than ~1msec.

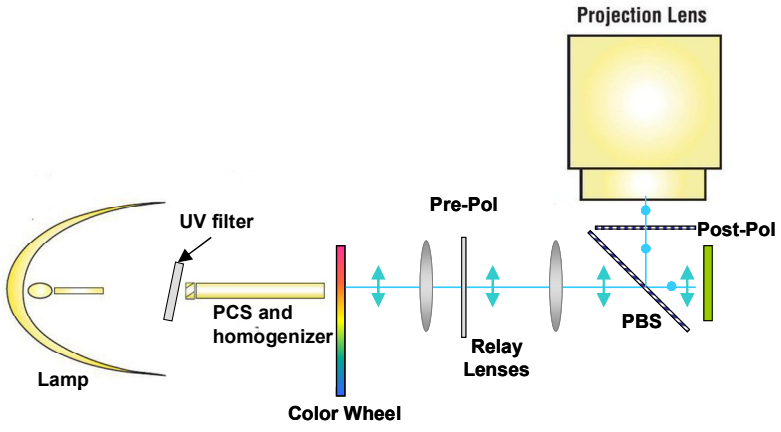


Figure 1. Single panel engine schematic configuration.

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### 3.2. Dual-panel LCoS

For dual-panel LCoS engines we assume the configuration shown in figure 2; many other configurations are feasible.

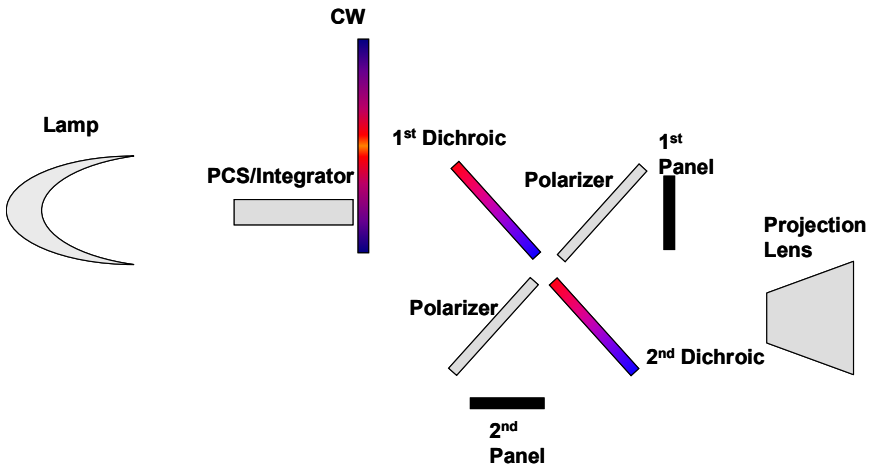


Figure 2. Dual-panel engine schematic configuration.

This configuration can be operated with both four and five primaries. For a schematic of the spectral properties of the dichroic mirrors and color wheels – see figure 3.

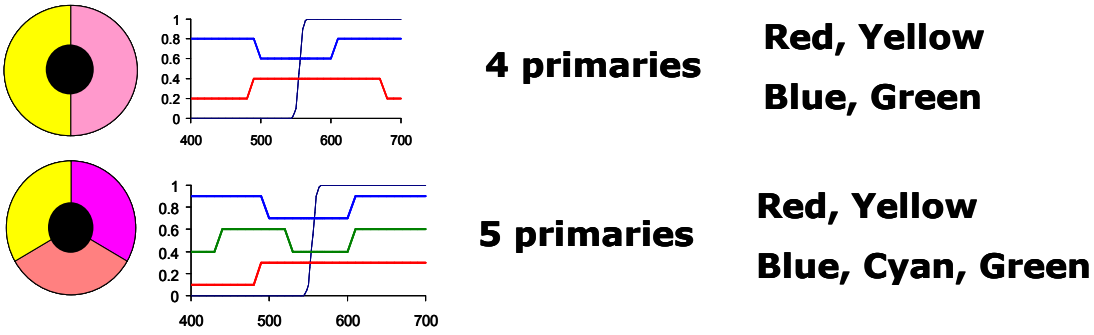


Figure 3. Schematics of dichroic mirror and color wheel spectral properties.

The dual panel LCoS configuration was also tested successfully, with good results. Operation rate of dual-panel engines can be lower, since color breakup with dual panel is lower. However, since operation lower than 120Hz was not tested, we propose that initially we do not operate at lower repetition rates. Therefore, an

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approximately 1 millisecond response time is desirable. 2-2.5 milliseconds response time may cause some performance (brightness) degradation, however, this configuration may be still very attractive.

### 3.3. Four-panel LCoS

For four-panel LCoS operation, we assume a ColorQuad type configuration – see figure 4. However, different configurations, based on a variety of basic engine schematics is also possible. Basic design considerations of this configuration were also published ( M. G. Robinson, J. Chen, G. D. Sharp, M. Cheng, S. Roth and M. Ben Chorin, Four-Panel LCoS Video Projection System, EuroDisplay 2005 Digest of Technical Papers, paper 9.3).

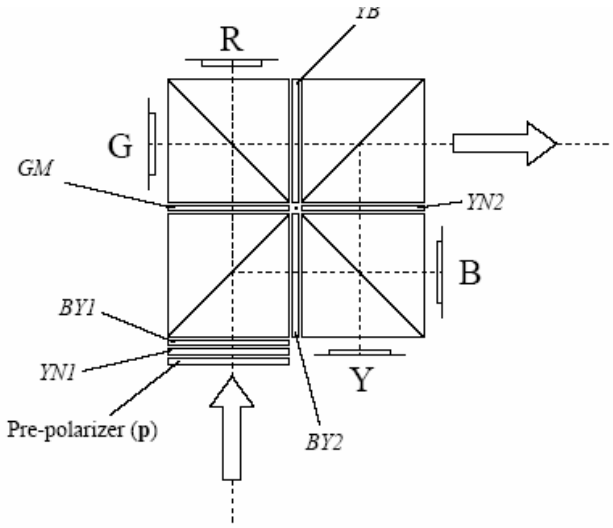


Figure 4. Schematics of ColorQuad based four-panel LCoS engine

### 3.4. Four-panel HTPS

Genoa has developed and constructed two four-panel HTPS projectors, based on the modification of existing Sony Cineza VPL-HS20 projectors (S. Roth and W. Caldwell, Four Primary Color Projection Display, SID 2005 Digest of Technical Papers, paper 64.4). These projectors were demonstrated numerous times on many occasions, including demonstrations at CES and SID, and demonstrations to many projectors manufacturers. The image quality of the projectors was found to be significantly superior as compared to any existing RGB projector.

A schematic layout of the optical engine is shown in figure 5. It should be noted that this layout was chosen mainly since we wanted to use as many as possible existing components, but other schematics can be readily adopted.

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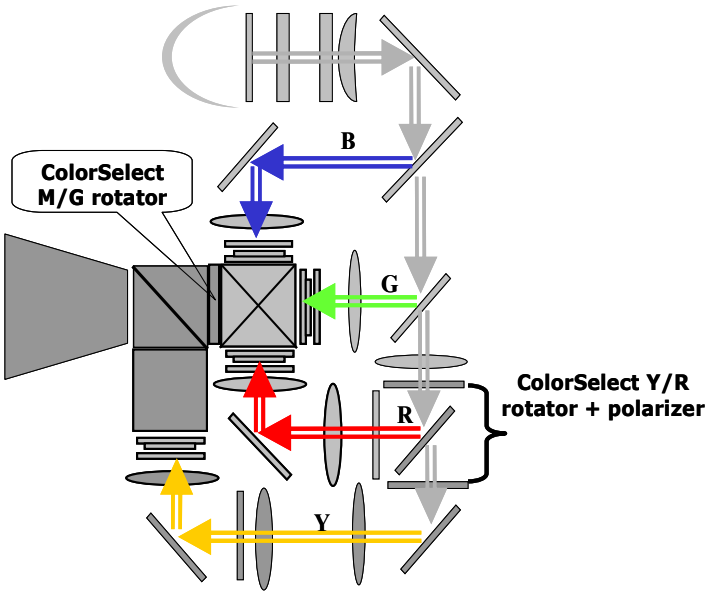


Figure 5. Schematics of the four-panel HTPS projector.

## 4. Performance estimation

In table 1 we show the estimated performance (output brightness and color gamut) of the different configurations. The brightness levels are shown as two options:

- Option a: relative values when compared to an RGB single panel display
- Option b: absolute lumens output, based on our assumptions.

However, the values in the table should serve only as indication - actual performance will be of course strongly dependent on actual engine parameters.

In the gamut terminology, “Moderate” gamut corresponds approximately to REC-709, “Large” gamut corresponds to 80-90% NTSC and “Very Large” gamut to >100% NTSC. In this document we do not distinguish between three- and four-panel LCoS and HTPS performance, however, in a more accurate calculation the different panel types will obviously lead to different performance levels.

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| No. | Number and type of panel | Primaries | Relative brightness | Estimated brightness (lumens) (*) | Color Gamut |
|---|---|---|---|---|---|
| 1 | One LCoS | 3: RGB | 1 | 140 - 170 | Moderate |
| 2 | One LCoS | 4: RGBY<br>5: RGBCY | 1.35 | 190-230 (**) | Large |
| 3 | Two LCoS | 4: RGBY<br>5: RGBCY | 2.5 | 350 - 430 | Very large |
| 4 | Three LCoS/HTPS | 3: RGB | 2.2 (***) | 310 - 390 | Moderate |
| 5 | Four LCoS/HTPS | 4: RGBY | 4.0 | 600 - 750 | Very large |

* - Brightness for balanced, D65 white output
** - This result is based on a "color wheel" configuration; the Philips "drum configuration" enables ~10-20% more output.
*** - The reason for the relatively low output of a 3-panel display is that white point correction requires significant reduction of the green and blue intensities.

Table 1. Initial performance estimation of the different types of multi-primary projection displays.

## 5. Analysis

Multi-primary displays enable very high color gamut and bright displays. The above results are only indicative, based on some assumptions on engine and components data; in reality the data can be different. However, the general trend is obvious. Multi-primary LCoS displays have a significant advantage over RGB displays.

In RPTV applications, multi-primary single-panel display is probably enough for screen sizes up to ~50". Multi-primary dual-panel will allow screen sizes of up to ~65". The best solution for high brightness, large gamut and large screen displays is achieved by using four-primary four-panel engines.