Projection Technology for Future Airplane Cockpits

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ABSTRACT

A large single interactive display designed for the cockpits of future airplanes, as it was developed during the European Project ODICIS is presented. It is based on an array of several short throw wide angle projectors resulting in a seamlessly tiled display. The project results are discussed in this contribution.

1. INTRODUCTION

Airplane cockpits by nature contain a huge number of human-machine interfaces, both of the readout type as well as the input type. Concerning the readout devices, there has been an evolution in cockpit organization, starting from a large number of separate gauges, over a number of small (CRT-type) screens to a few large LCD displays nowadays. This is illustrated in figure 1.

If trends are to be detected in the use of displays in aircrafts, one can state them as follows:

- An increase of the size of the displays and further reducing of their number.
- The cockpit is treated as an integrated workspace, going towards a “paperless” cockpit.
- A rationalization of the needed equipment by reducing the number of dedicated input and output media and optimizing the usage of the available ones.

The research project ODICIS (or ‘One DIsplay for a Cockpit Interactive Solution’) aimed at developing a novel concept for an aircraft cockpit in which almost all indicators, navigation displays and controls are replaced by one single large touch-screen display.

2. CONCEPT

It is the view of the consortium that the next evolutionary step in cockpit design is to provide the crew with a large single multi-touch display that no longer is limited by the physical boundaries of adjacent displays. A single screen offers a more flexible design of the Human Machine Interface (HMI) and therefore improved opportunities for providing the right information at the right place depending on the phase of flight. Moreover, it offers optimized usage of the main instrument panel in terms of display space. A conceptual illustration of this system is shown in figure 2.

Fig. 1 Evolution of the human-machine interfaces in cockpits throughout the years.

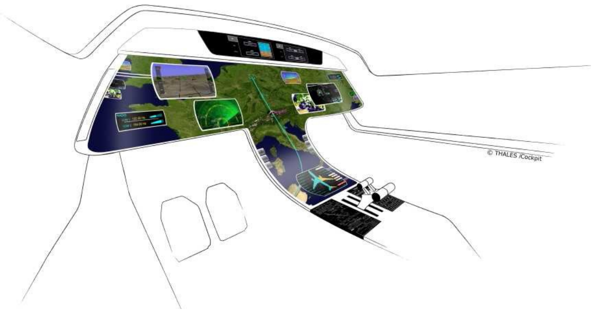

Fig. 2 Conceptual image of a single display interactive cockpit.

Such an approach has several advantages in different domains over using separate liquid crystal displays (LCDs) that are found in the modern aircraft cockpit.

From the technological side, a single cockpit display allows the realization of a common architecture that can be easily adapted to different airplane types, changing only the physical dimensions of the screen while using identical optical engines under the hood. This departs radically with the classical approach, where each display and gauge has to be refitted.

From the viewpoint of the man-machine interface, the elimination of the physical barriers between the different screens is very important, as it gives more freedom in the concept of the human interface. It would be possible to have a reconfigurable dashboard, where important elements can be placed in prominent view at will, as the situation requires. A combination with a display-wide touchscreen input device provides a complete, self-contained means of controlling the cockpit.

3. TECHNOLOGIES

3.1 Requirements

A crucial task is of course the selection of an appropriate technology to create the single display. Important factors are the compliance with the numerous avionics safety regulations and the need for short term availability, i.e. mature technologies are required. Apart from the avionics compliance, the following demands are set out for the display system:

- A large screen display with high information content density and superior image quality and the ability to accommodate curved surfaces with non-standard form factors
- A display that offers better features in terms of flexibility for showing user-defined cockpit configurations and also user interactivity.

Fig. 3 Color recombination unit with LCOS panels.

3.2 Candidates

Projection technology is the most natural candidate to achieve these goals. The technology is very versatile and adaptable. Resolution can be as desired without size constraints. Curved images are not a problem since only the screen has to be physically altered; keystone adjustment can be done electronically. Truly seamless tiling is possible using multiple projectors and has been demonstrated in simulation environments.

Rugged LCDs are of course also a possibility, but can only achieve non-seamless tiling; curved surfaces are possible but only at prohibitively large cost.

OLED displays are very promising with regards to curvature and odd form factors, but a lot of limitations are still present. The maturity of the technology is however far too low for avionics use, while brightness is still not high enough and the lifetime issue still remains.

Consequently, the project endeavored to use projection technology to achieve the goals of the single display interactive cockpit.

The ODICIS project has now been finished and the technological results are reported in this contribution.

4. PROTOTYPE

The projection system is built around LCOS microdisplays. LCOS panels provide higher light throughput than similar transmissive devices and are available at very high resolution. The fact that they have no moving parts is a valuable asset in the vibration-rich airplane environment. They also eliminate the risk for any color artifacts known from moving mirror devices.

Highest light throughput and color fidelity is obtained by using a three channel color recombination architecture. Since the color recombination optics are already very developed, existing commercial optical cores can even be used (see figure 3).

Although the highest brightness values and efficiency is still obtained with conventional arc lamps, these have been proven to be not suitable for use in airplanes. The risk for explosion and fire and the relatively low lifetime pose a serious reliability issue.

The only reliable light source is thus an LED based system. Advanced high-brightness projection LED make it possible to meet the high demands on brightness, imposed by the screen legibility requirement in direct sunlight while still conforming to the etendue restrictions imposed by the LCOS. A custom illumination optics system, (e.g. the light pipe in figure 4) was designed to meet the specifications. Figure 5 shows the expected brightness on the screen as calculated for the envisioned complete system.

Reliability over a long lifetime is also a key factor for a crucial component as a cockpit display. The LED's main failure and degradation mechanism is related to junction temperature excursions, so an adequate cooling system that is by itself very robust has been developed. The ODICIS display is a typical example of a high-end application where the sturdiness of LCOS microdisplays and LEDs are essential.

One of the most serious demands posed on the projection system, is the very short throw distance of only about 25 cm. Hence, a dedicated short throw ultra wide angle projection lens was designed to accommodate for this short range projection while keeping a small footprint (Figure 6).

To deal with the curviness of the screen and the special form factor (i.e. T-shape), the display area is split up in five projection areas, each with their own projector unit. The individual projection images are then tiled using blending techniques to form one seamless display. Figure 7 shows the final arrangement of the projectors to form the cockpit display.

In order to maintain a high contrast ratio even at high levels of ambient light, a black-matrix screen (see figure 8), such as 3M's Vikuiti is used. However, such screens only work well if a well-collimated incident beam is provided. Therefore, a combination of linear Fresnel lenses was added to the screen to ensure a highly uniform brightness level and guaranteeing the possibility of seamless tiling.

Interactivity is added by integrating touch detection over the entire screen surface using optical detection methods.

Figure 9 shows the complete prototype as it was built and made its first public appearance on the Paris International Airshow in April 2012.

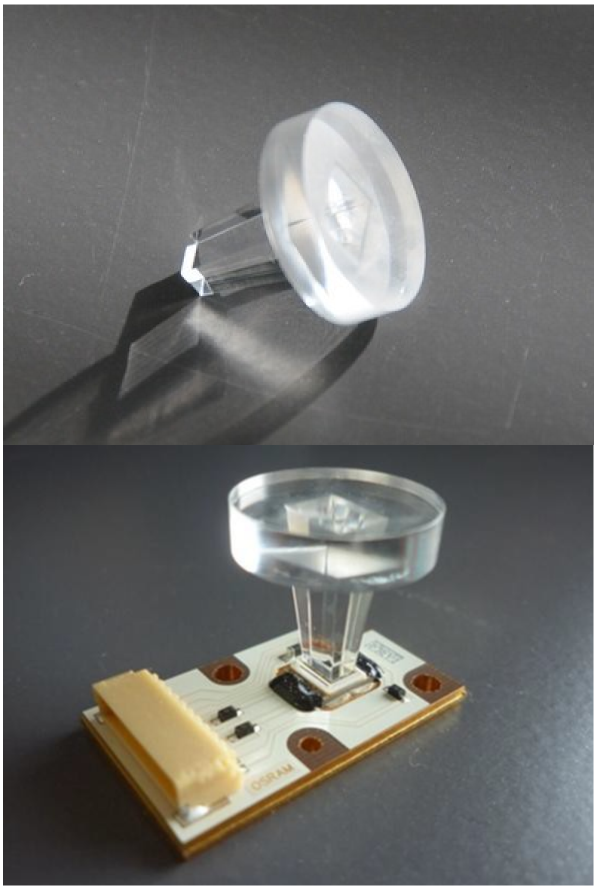

Fig. 4 Light pipe design to transform the LED output into a rectangle suitable to illuminate the LCOS panel.

	Blue	Green	Red	White
light flux	50	735	312	
x	0.12	0.2	0.68	
y	0.03	0.7	0.32	
illumination sys. Efficiency	54.20%	55.60%	54.50%	
Dichroics trans/reflectivity	97.00%	94.09%	94.09%	
Polarizer transmission	45.00%	45.00%	45.00%	
Polarization separation & combination	72.90%	72.90%	72.90%	
LCoS reflectivity	70.00%	70.00%	70.00%	
Lens transmissivity	90.00%	92.00%	95.00%	
Fresnel lenses transmissivity	84.93%	84.93%	84.93%	
Screen Transmissivity	50.00%	50.00%	50.00%	
Total optical efficiency	4.61%	4.69%	4.75%	
light output	2.31	34.5	14.82	**51.63** lm
Surface	0.078	0.078	0.078	
Screen gain	2.28	2.28	2.28	
Brightness	21.53	321.96	138.33	**481.82** cd/m²

Fig. 5 Estimation of the brightness on the screen.

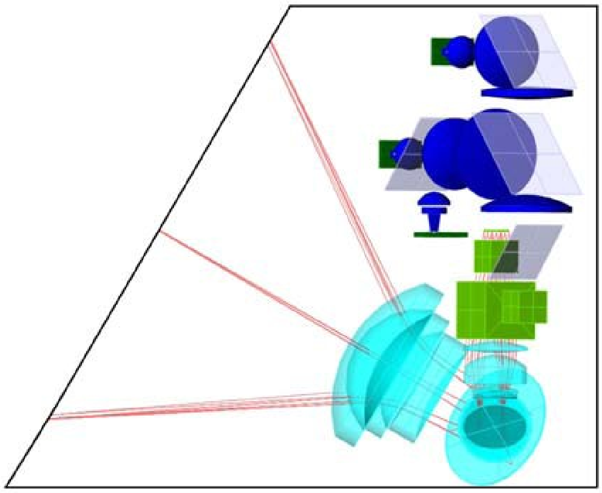

Fig. 6 Design of the short throw ultra wide angle projector.

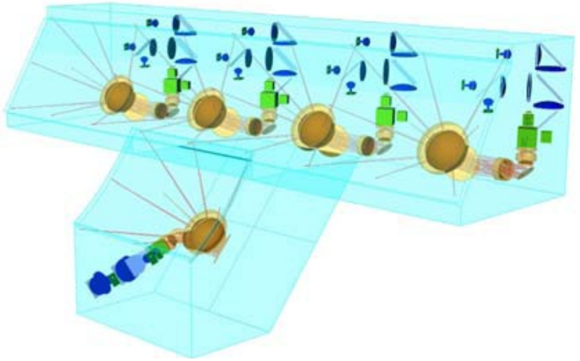

Fig. 7 Arrangement of five wide angle projectors that make up the single display in the cockpit.

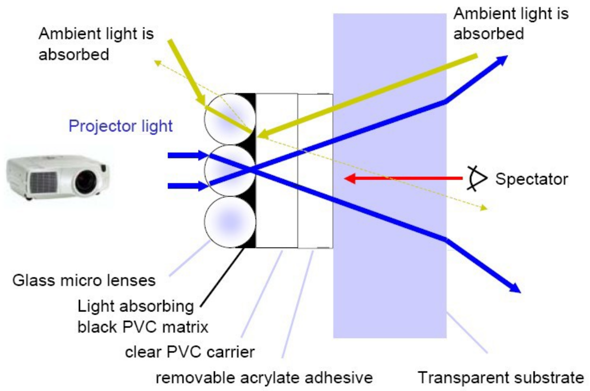

Fig. 8 Black matrix screen working principle.

Fig. 9 The final prototype at work.