A Technology Roadmap for Developing Large Capacity Electronic Display Fabrics

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ABSTRACT

Continuing interest in developing large area, high-resolution immersive display environments has led to an on-going technology roadmap study. This paper discusses the results of this effort, including a review of the market opportunity and timing, the architecture characteristics of Electronic Display Fabric (EDF), the technology considerations and challenges, and the primary and enabling technology candidates. Results of early R&D efforts are summarized.

BACKGROUND & MARKET OPPORTUNITY

Large conformal display fabrics have been with us for thousands of years in the form of woven and printed cloth. Although the materials and methods of manufacture have changed and "frame formation" times have shortened, the addressability generally remains "one display frame" per lifetime of the fabric. In recent years, market futurists and technology developers have begun to describe applications for large, conformal fabrics that are electronically addressable, i.e. the designs and colors can be changed on demand. Following are several examples:

- Addressable wall coverings, i.e. electronic wall paper and digital advertising
- Lightweight, highly mobile immersive displays for simulation and gaming
- Lightweight, foldable/rollable displays for mapping and planning applications
- Displays with flexible screen shape and size, i.e. no format restrictions
- Clothing that can change color and design
- Displays which conform to a variety of shapes, i.e. a blanket or draping
- Fabrics that not only function as displays but include a variety of sensors

One particularly important market opportunity for EDF is in the development of consumer and professional level immersive display systems. Although there has long been a strong desire to develop fully immersive display environments, earlier attempts have resulted in very expensive, fixed site facilities which are used as large audience venues, as in the case of Cinerama™ [1] and IMAX™[2], or are dedicated to specialized needs such as flight simulators and virtual reality CAVE[3] environments in research laboratories.

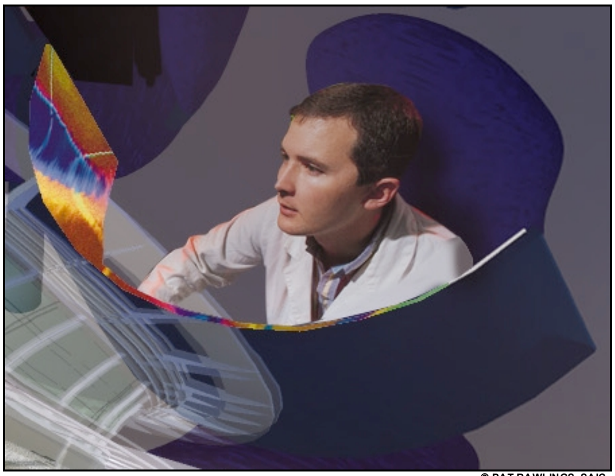

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Fig. 1 Immersive System Concept
A Conformal Emissive Surface Imaging Fabric Application.

The development of low cost, highly efficient EDF could provide the basis for highly mobile, immersive displays in individual consumer and business products as illustrated in Figures 1 & 2, as well as in professional applications such as that shown in Figure 3.

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Fig. 2 Immersive Family Room
A "Common View" display for interactive family entertainment.

To understand both the time frame and the investment needed to bring low cost, high performance EDF to reality, Information Technology, Ltd., with additional support from SAIC[4] and the US Government, initiated a technology roadmap study. This study has been underway for several years and is expected to continue into the foreseeable future.

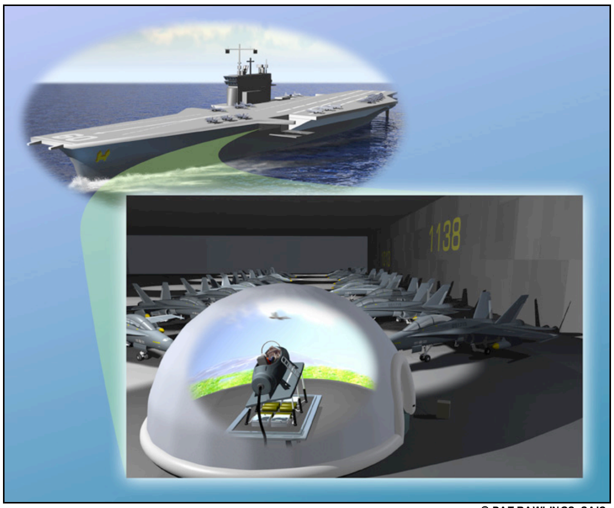

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Fig. 3 Mobile Immersive Display Environments

A Lightweight, mobile flight simulator facility.

ARCHITECTURE CONCEPTS AND OPERATIONAL CHARACTERISTICS

Today, there is a large and fast-moving investment in the development of flexible display technologies based upon organic light emitting materials and flexible LCD/backlight assemblies. Most of these initiatives are based on conventional semiconductor 2D wafer fabrication principles and therefore are expected (1) to be limited in size; (2) to be restricted to "edge connected" drive schemes; and (3) to exhibit conventional levels of electrical and optical efficiency.

Our assessment is that these initiatives will not lend themselves to the rapid development of large area, low power fabrics in the size range of 10 square meters or 100 square feet.

The current development activities are expected to provide a substitution technology into conventional small area flat panel applications such as cell phones, PDAs, laptops, monitors and televisions. In these applications, the "flexible" characteristic will be used to achieve conformal (non-planer) shapes but are not expected to mature into the concept of a foldable-rollable "display blanket".

Our technology roadmap study has concentrated on evaluating alternative advanced technologies and fabrication methods which could be developed to support the manufacture of large area, high resolution fabrics similar to the way carpeting, wallpaper or projection screens are currently produced.

The desired key characteristics of such an EDF material are listed below:

- Lightweight, rugged and highly flexible, i.e. foldable, rollable, drapable
- Arbitrary sizing, i.e. not restricted to media industry shapes and sizes
- Energy efficient
- Highly redundant so that damage to one area does not fail the entire display
- Self-addressing and/or remotely addressable
- Operable under a wide range of lighting conditions
- Support integrated sensor arrays

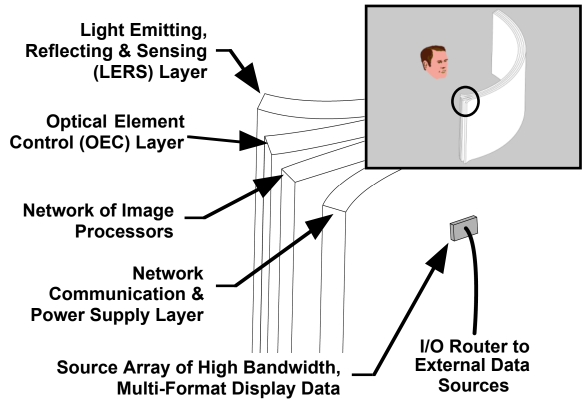

Fig. 4 Layering Detail

Electronically Addressable Imaging Fabric.

Figure 4 illustrates the architectural concepts associated with our approach to developing an EDF. An electronically addressed display fabric can be viewed as a material consisting of a number of functional layers. The layers closest to the viewer consist of light emitting elements and the drive electronics specific to the technology selected.

The next layers aggregate the light emitting/electronic drive elements into arrays and control these arrays in a manner similar to that used for a conventional display. The next layers provide a redundant network of power and data that are distributed to the arrays in a philosophy analogous to that used with the Internet.

In this manner a large fabric could be manufactured with a great deal of freedom from format constraints. In this scheme we anticipate the development of chemically and electrically isolated emitting/electronic elements that can be supported in a flexible substrate and where the electrical connections to each element are made with via's similar to the manner used to make connections in a multi-layer PC board, i.e. Z-direction connectivity.

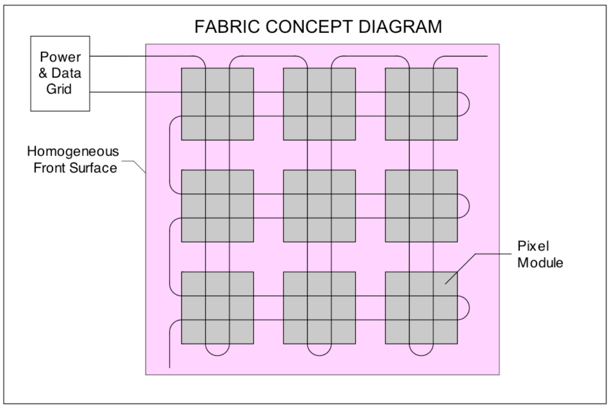

Fig. 5 Fabric Concept Diagram
A fabric consisting of a 3x3 array of pixel modules on a woven power and data communication network mesh (back side view).

Z-direction or Z-axis connectivity is the necessary construct that will allow the elimination of tiling artifacts. These artifacts plague all conventional approaches to realizing large area, high-resolution display walls.

TECHNOLOGY CONSIDERATIONS AND CHALLENGES

The purpose of the study has been to review a broad portfolio of advanced materials, nanotechnologies and microfabrication methods and to identify those which may form the basis for the development of isolated, smart pixels that can be aggregated into a fabric backplane and managed as a network of display areas. Figure 5 illustrates the concept of an array of sub-displays and Figure 6 shows how the elements of a sub-display might be arranged in the laminates of the fabric.

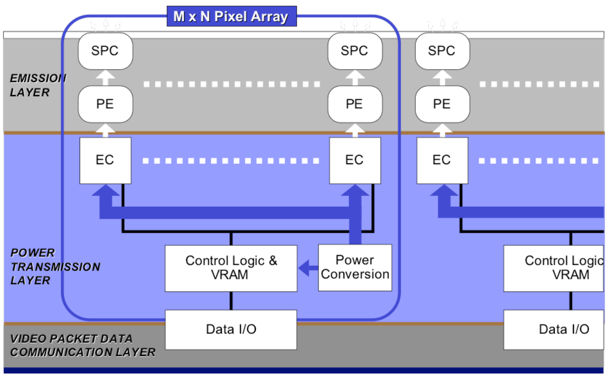

Fig. 6 Intelligent Emissive Pixel Array
Functional Block Diagram describing Z-Direction Connectivity into the Communication Layer.

In an addressable display fabric each pixel will consist of some number of subpixels and sensor elements. For example in conventional displays, each pixel contains three subpixels: red, green and blue. Advanced fabrics may contain different pixel/sensor counts. In Figure 6, each subpixel is represented by the three symbols, SPC, PE and EC. The PE represents the Primary Emission material, the SPC represents the Secondary Photon Conversion material, and EC represents the Emitter Control and power conversion functions.

As an example to clarify this notion, consider the case of plasma display subpixels. The PE is a gas discharge that emits UV photons; the SPC is a phosphor that down-converts the UV to visible R, G or B; and the EC is the insulating envelope that contains the gas and draws power from the electronic waveforms supplied to the element through an array of conductors.

In the case of a large area display fabric that might contain 20-30 Megapixels or more, the entire fabric may be made up of smaller arrays of MxN isolated pixels. These sub-arrays might then be laminated into a distributed power and high bandwidth video packet data layer and managed as a network of cooperating displays. The sizing of the sub-array will be determined by a variety of factors including total subpixel count, sub-array processor bandwidth, and energy budgets. The viewer would see a homogeneous display fabric surface and would not be visually aware of the matrix arrangement. The power and data network layer may also serve as the primary structural element of the fabric.

PRIMARY AND ENABLING TECHNOLOGY CANDIDATES

To identify and evaluate primary and enabling technology candidates, we divided the approaches into two major categories: those consisting of addressable emissive elements and those consisting of addressable transmissive elements. The table below lists the candidates in each of the categories.

Addressable Primary Energy Emitters (APEE)
- Gas Discharge (PDP)
- Semiconductor Junctions (LED & LET)
- Field Emission Devices (FED)
- Electroluminescent Devices (EL)

Gated Area Energy Emitters (GAEE)
- Liquid Crystal Devices (LCD)
- MEMS Light Valves

Figures 7 and 8 illustrate the schematic approach used for evaluating each of the candidate technologies and their respective "electrical power-to-light" conversion efficiencies. In addition to evaluating the primary energy approaches, we are also surveying the associated advances in enabling technologies that include secondary photon conversion materials, flexible conductor and backplane materials, microfabrication approaches, and self-organizing display architecture concepts.

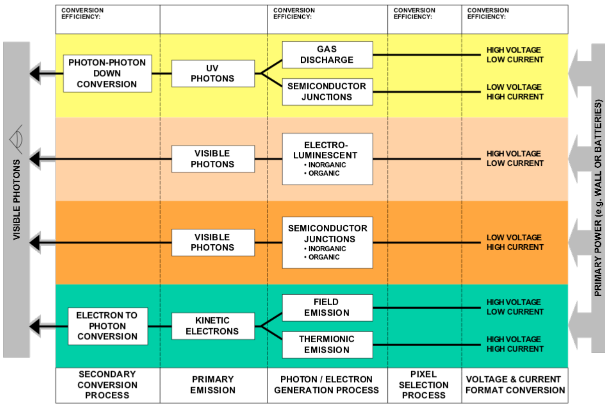

Fig. 7 APEE Pixel Arrays
Energy Conversion Chain For APEE Pixel Arrays.

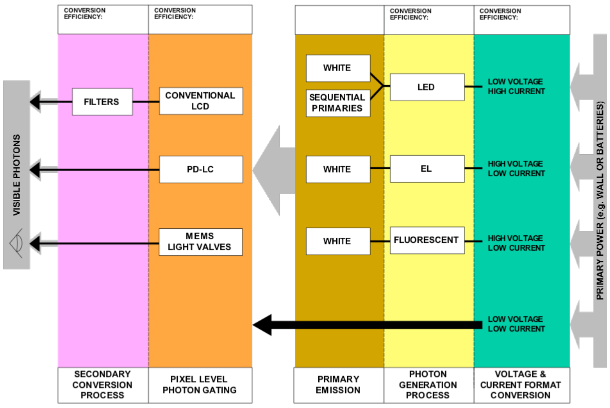

Fig. 8 GAEE Pixel Arrays
Energy Conversion Chain For GAEE Pixel Arrays.

EARLY RESULTS

The study has identified and is evaluating a number of industry and university research and development projects where the objectives are consistent with those described above. In the APEE/PDP category, exciting work is going on at Fujitsu Laboratories Ltd.[5] and Imaging Systems Technology[6]. In the APEE/LED&LET category we are evaluating both the encapsulation of OLED materials by a number of companies and the advanced architecture concepts of Color Kinetics, Inc.[7]. The work at MIT, NanoSys, Inc. and InnovaLight, Inc. in the area of quantum-dot and silicon nanocrystals suggest that major advances in the luminous efficiency of secondary photon conversion materials may become available in the near future. In general, we see exciting advances in all areas related to the EDF concept.

SUMMARY

In the future, the display market will not be restricted to small (2-inch to 70-inch diagonal), rigid displays conforming to the conventional media formats of 4:3 and 2:1. Digital advertising, immersive family rooms, and conference rooms with interactive walls will require Electronic Display Fabric (EDF). It will be purchased in rolls and applied when and where large area, high-resolution display surfaces are required. To help accelerate this vision, we plan to continue our EDF technology roadmap study and invite additional participation from both industry and the university community [8].

We close with a quote from the book titled, "Beyond Calculation: The Next Fifty Years of Computing", by Gordon Bell and James N. Gray:

"Two forces drive the evolution of computer technology: the discovery of new materials and phenomena and advances in fabrication technology. These advances enable new architectures and new applications. Each advance touches a wider audience, raises aspirations for the next evolutionary step, and stimulates the discovery of new applications that drive the next innovative cycle."

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