ColorLink, Inc.

LCOS Technology Expands Potential of Color Imaging and Display

As computer and communication devices have miniaturized, a key problem has been capturing and displaying high-quality and high-resolution color images. In 1995, ColorLink, Inc., was created to develop a tunable optical filter technology that would be compatible with a decreased display size while increasing the brightness and clarity of the image. They believed that the next generation of consumer televisions, monitors, and business projectors would be based on liquid crystal on silicon (LCOS) technology. To further its research and development efforts and to demonstrate a proof of concept for tunable filters, ColorLink needed an injection of capital. The company was unable to attract any venture capital funding, however, because its proposed research was considered too high risk and too long term. ColorLink received an Advanced Technology Program (ATP) award in 1997 and by the end of its three-year ATP project, the company had developed several components that support image capture and display applications. Over the course of the project, ColorLink shifted focus from miniature displays to the more promising application of projection displays. As a result of the technology developed during this project, ColorLink has formed partnerships with a Japanese material supplier, to decrease manufacturing costs and improve its U.S. product line, and with Thomson RCA.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 96-01-0263 were collected during October - December 2001.

Existing Technologies Limit Evolution of Image Devices

Most digital color cameras and color displays capture or create the appearance of a color image by spatially separating the individual colors. In a typical color display, each color pixel (i.e., the basic unit of the composition of an image on a television screen, computer monitor, or similar display) is actually a combination of three monochrome pixels, each assigned a different primary color (red, green, or blue; commonly referred to as “RGB”). Although this technique has been effective for the last 30 years, it has become an inhibitor as display devices such as compact personal digital assistant (PDA) devices, web-enabled cellular phones, and compact flat-screen televisions become smaller and users demand higher resolutions.

ColorLink Proposes Color Sequential Imaging

In 1995, Dr. Kristina Johnson and Dr. Gary Sharp incorporated ColorLink with the goal of developing a tunable optical filter technology that would increase capture and projection display color quality. Previous approaches to color sequential imaging used RGB color wheels or inefficient color shutters to achieve color, but neither of these could achieve the desired size and resolution. The problem with color shutter technology at that time was its use of highly absorptive, poor-quality dye color polarizers. The key distinguishing feature of the ColorLink polarizer is that the separation of primary and complementary color is achieved through a loss-less transformation using a stack of optically transparent retarder films, known as a retarder stack.

ColorLink proposed, in its ATP application to introduce a new paradigm in high-resolution display and imaging by developing the underlying technologies for a high-efficiency, solid-state, electro-optic tunable filter for color sequential imaging. In color sequential imaging, which encodes color in time and not space, the complete color image is displayed as a rapidly changing sequence of primary RGB monochrome images. A switchable color filter selects which color is displayed in each image (red, green, or blue). Since every pixel in the display contributes to every primary image, a color sequential imaging display can have at least three times the resolution of an equivalent display that uses spatial separation. ColorLink's approach would employ color sequential imaging to capture or display information with the highest color quality, resolution, and brightness.

ColorLink's Innovation Has Potential Economic Benefits

If ColorLink's technology proved successful, it would advance the state-of-the-art in projection display and image capture from the pixilated, slow-moving color switches to smaller high-resolution displays with increased switching times. This could dramatically improve the quality in the highly competitive miniature display market and lead to a decrease in cost to consumers. Also, ColorLink's project had the potential to significantly impact the electronic display and digital imaging markets, which, according to the Optoelectronics Industry Development Association, were predicted to exceed $20 billion by 2001.

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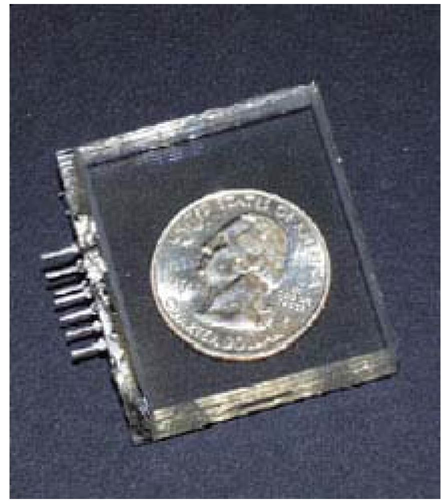
ColorLink Forms Partnerships and Finds Funding

ColorLink partnered with Polaroid Corporation and Kent State University's Liquid Crystal Institute to assist in the development of the color sequential imaging technology; later in the project, the company also added MicroContinuum, Inc., as a subcontractor. ColorLink had also attracted the interest of the industry's largest players.



ColorLink's color switch uses color sequential imaging to capture or display information with the highest color quality, resolution, and brightness.

The company's early-stage funding from "friends and family" disappeared quickly, however, and as a small company, ColorLink did not have the financial resources to support the development of the technology on its own. Moreover, the proposed research was too long term to attract the interest of venture capitalists. In 1997, ColorLink received an award of approximately $1.8 million from ATP to pursue research and development of its color sequential imaging technology. Its proposed tunable color filter was highly innovative, but needed significant improvements before it would become commercially viable. At that time, Japan and other countries dominated flat-panel display technology overseas, with the United States' world market share at less than 5 percent. The proposed technological developments could give the United States a greater share in at least part of this important and growing market.

Goals Defined for Color Sequential Imaging Project

ColorLink pursued three major technical goals in the color sequential imaging project: 1) maximizing the filter optical efficiency, 2) developing a new class of fast-switching nematic liquid crystals with switching times below one millisecond, and 3) fabricating liquid crystal devices on plastic. The purpose of the company's first objective was to produce the very brightest color-filter technology for integration into direct views and displays. At the time, there was not a high-quality method to colorize monochrome display systems. Their second objective focused on developing a new class of fast-switching nematics (relating to a liquid crystal phase in which the molecules are oriented in loose parallel lines) to optimize the duty cycle of the filter. Their third objective was important in producing a lightweight, compact tunable filter technology for application in displays for portable computing and communication devices.

ColorLink Refocuses on Projection Displays

In order to serve the growing projection display market, ColorLink began to shift its focus from developing a core technology to developing components for applications and, eventually, to system development of projection displays and digital imagery.

Over the course of the project, ColorLink realized that the most promising application stemming from the system development efforts was in projection displays, rather than digital imaging. To expand into this market, ColorLink sought a partnership to enhance its manufacturing operations. In 2000, before the ATP project ended, the company used internal resources to complete a joint venture agreement with material supplier Arisawa of Japan to form ColorLink Japan, Ltd.

To serve the growing projection display market, ColorLink began to shift its focus to system development of projection displays and digital imagery.

ColorLink believed that the next generation of consumer televisions, monitors, and business projectors would be based on liquid crystal on silicon (LCOS) technology. These displays are liquid crystal films that are sandwiched between an integrated circuit chip and a transparent window.

At the time, there were inefficiencies in the technology and widespread acceptance had been slow. One challenge with the LCOS technology involved a lack of color management, as poor color brightness and contrast were evident. ColorLink felt that it could modify its filter technology to further the development of LCOS technology and thus began a testbed program.

The goal of the program was to optimize the component technology and the color management architecture until the company was able to achieve the required performance on a system level. The feedback from the testbed produced many changes to the retarder stack designs and architecture, ultimately allowing ColorLink to identify the best use of its technology.

Subcontractors Provide Insight and Expertise

Polaroid and Kent State, the primary subcontractors, offered technical expertise, technological validation, and valuable industry insight. Polaroid was responsible for thinning and decreasing the weight of the color switch by using plastic cells. Early samples were achieved by the end of the second year of the ATP project, but Polaroid dropped out due to internal financial issues that were unrelated to this project. Although the project failed to reduce filter thickness and weight, reductions in thickness proved to be unnecessary because ColorLink focused on more viable opportunities in the projection display market instead of miniature displays.

Kent State worked primarily in liquid crystal development, in particular trying to increase the switching speed of the liquid crystal devices. One solution they developed involved adding a small amount of polymer to stabilize a particular liquid crystal state, which resulted in a faster relaxation rate. Kent State performed a number of experiments in this area, but results were not promising enough to proceed further. Kent State also assisted ColorLink in other relevant areas, including field-of-view compensation, the design of compound-element liquid crystal switches for improved speed, and the development of diagnostic hardware.

ColorLink also awarded a small subcontract to MicroContinuum, Inc., to assist in the solvent-welding process. MicroContinuum was instrumental in proving the viability of the process, identifying a class of solvents, and developing hardware for generating stacks using solvent welding.

Technical Success in Image Capture and Display

By the end of its three-year ATP project, ColorLink had developed several components that support image capture and display applications. These components have enabled the company to achieve good color quality with filter transmission exceeding 90 percent, something that was previously not possible. In addition, ColorLink produced a five-cell color switch that provides average turn-on and turn-off times of under 0.2 milliseconds, times that are significantly faster than previous color-switching technologies.

ColorLink's Target Shifts to HDTVs and Monitors

Over the course of the project, ColorLink realized that the most promising application was in projection displays, rather than digital imaging. Consumer demand for thin, large-area monitors was high, but so was the cost. For example, a 21-inch flat-panel liquid crystal display (LCD) monitor was over $3,000 and a high-definition television (HDTV) plasma display cost $10,000. However, ColorLink's revolutionary color management components enable a new lower cost class of computer monitors and digital televisions. These new monitors and digital TVs offer larger screens in a slimmer profile with resolution, color, contrast, and brightness that are superior to existing products.

LCOS microdisplay-based TVs with ColorLink technology are emerging as the best solution in this potentially exploding market. LCOS microdisplay-based systems with ColorLink technology can provide a high-quality, greater-than-24-inch screen with enhanced resolution in a 6-inch-deep monitor for about $1,000. The future in projection systems includes computer monitors and digital TVs, a multibillion-dollar market with annual growth rates in excess of 15 percent. The demand for computer monitors and projection devices that utilize LCOS is estimated at 10 million units per year by 2004.

Commercialization

ColorLink has formed partnerships to commercialize this technology. To decrease manufacturing costs and expand into new projection display markets, ColorLink sought a partnership to expand its international operations. In 2000, before the ATP project ended, the company completed a joint venture agreement with material supplier Arisawa of Japan to form ColorLink Japan, Ltd. This partnership would greatly increase ColorLink's investment in research and development as well as decreasing its manufacturing costs and improving its product line for U.S customers. ColorLink and Thomson RCA have recently entered into a partnership and plan to explore various applications for the ATP-funded technology.

ColorLink's revolutionary color management components enable a new lower cost class of computer monitors and digital televisions.

Conclusion

With ATP's funding support, ColorLink obtained the resources necessary to explore the potential of color sequential imaging. Based on its ATP project, the company was able to commercialize its LCOS technology. In the earliest stages of the technology development effort, when prototypes were unproven and the technology was untested, ColorLink parlayed the ATP-supported research into the nascent LCOS microdisplay and HDTV markets. This successful transition to a new color imaging and display technology has made ColorLink's vision a reality and has led to successful commercialization of its products.

PROJECT HIGHLIGHTS
ColorLink, Inc.

Project Title: LCOS Technology Expands Potential of Color Imaging and Display (Color Sequential Imaging)

Project: To introduce a new paradigm in high-resolution display and imaging by developing the underlying technologies for a high-efficiency, solid-state, electro-optic tunable filter for color sequential imaging.

Duration: 5/1/1997-4/30/2000
ATP Number: 96-01-0263

Funding (in thousands):

ATP Final Cost	$ 1,790	84%
Participant Final Cost	340	16%
Total	$2,130	

Accomplishments: With ATP's support, ColorLink developed an innovative technology that decreased the cost and size of projection displays, while simultaneously allowing improvements in display resolution and brightness. Utilizing its ATP-funded project as a springboard, ColorLink successfully developed and refined several technologies that are presently being commercialized in the television and monitor display industries. Highlights of the technology include:

- Development of a custom lamination technology that provides a low-cost product with little optical loss and high optical power handling
- Refinement of retarder-stack technology

ColorLink has received a number of patents associated with the technology developed during the ATP project, including the following:

- "Retarder stacks for polarizing a first color spectrum along a first axis and a second color spectrum along a second axis"
  (No. 5,953,083: filed May 8, 1997; granted September 14, 1999)
- "Retarder stack for preconditioning light for a modulator having modulation and isotropic states of polarization"
  (No. 5,929,946: filed May 9, 1997; granted July 27, 1999)
- "Color selective light modulators employing birefringent stacks"
  (No. 5,990,996: filed May 9, 1997; granted November 23, 1999)
- "Optical retarder stack pair for transforming input light into polarization states having saturated color spectra"
  (No. 5,999,240: filed May 9, 1997; granted December 7, 1999)
- "Polarization manipulating device modulator with retarder stack which preconditions light for modulation and isotropic states"
  (No. 6,049,367: filed May 9, 1997; granted April 11, 2000)
- "Optical system for producing a modulated color image"
  (No. 6,417,892: filed July 30, 1998; granted July 9, 2002)
- "Color imaging systems and methods"
  (No. 6,183,091: filed May 14, 1999; granted February 6, 2001)
- "Display architecture using electronically controlled filters"
  (No. 6,273,571: filed October 1, 1999; granted August 14, 2001)

Commercialization Status: ColorLink is continuing development of the liquid crystal tunable filter for one-, two-, and three-panel systems. Since the completion of the ATP-funded project, ColorLink has entered into a partnership with Thomson RCA.

Outlook: ColorLink has formed partnerships with Arisawa Manufacturing and Thomson RCA, has established relationships with original equipment manufacturers, and has the funding and market demand to remain a market innovation leader. ColorLink's technology developed through the ATP project has received considerable attention and has facilitated additional fundraising opportunities. Finally, ColorLink holds the rights to more than 30 patents (8 that resulted from the ATP-funded research). The funding, partnerships, intellectual property, and market opportunities bode well for the future of the technology that ColorLink developed during this ATP-funded project.

Composite Performance Score: * * * *

Number of Employees: Five employees at project start, 65 as of December 2001

Company:

ColorLink, Inc.
2425 55th Street
Suite 250
Boulder, CO 80301

Contact: Gary Leslie, CEO
Phone: (303) 545-5843

Subcontractors:

Kent State University, Liquid Crystal Institute
Polaroid Corporation
MicroContinuum, Inc.

Research and data for Status Report 96-01-0263 were collected during October - December 2001.