Opportunity to gain proprietary interest in

Waveguide Displays

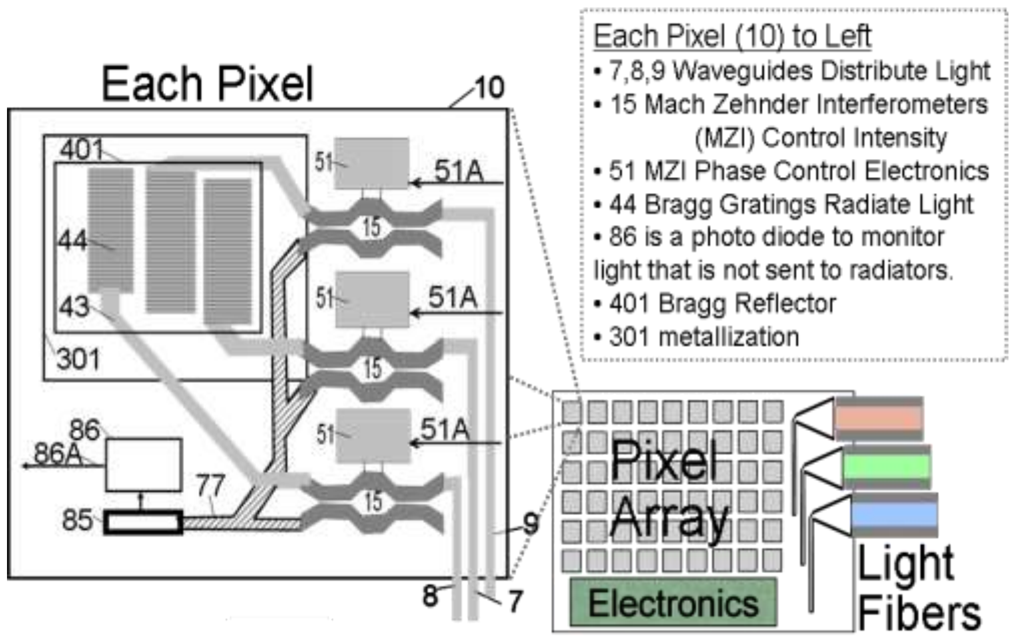
RHV Electro-Optics, LLC
Dr. Richard H. Vollmerhausen
rvollmerhausen@att.net
Phone: 407 807 9731

This paper describes an innovative display that is fabricated using Complementary Metal Oxide Semiconductor (CMOS) processes commonly used in silicon foundries. RHV Electro-Optics, LLC is seeking a mutually beneficial contractual relationship with a company or investor willing to fund Waveguide Display development.

Waveguide Displays:

- Are covered by US Patent 10,885,828 granted 5 January 2021.
- Are fabricated using widely available CMOS processes.
- Provide a quantum jump in image quality over existing displays
    - Several million color pixels per square inch of silicon.
    - Dynamic range (contrast rendition) that is an order of magnitude beyond current technology.
    - Frame rates limited only by the CMOS electronics.
    - Operation at any wavelength from 0.4 to 5 micrometers.
    - Generate imagery at multiple wavelengths simultaneously.
        - Images can be infrared as well as visible color.
- Waveguide Displays provide 3D imaging of the scene
    - Brightness uniformity is controlled real-time by photo detectors in each pixel.
    - The in-pixel photo detectors are available to image the scene for most of a frame time.
    - The photo detectors provide a fast user interface for gaming.
    - The photo detectors can also provide range to each scene location via time-of-flight or structured light imaging.

Waveguide Displays Are Implemented Using CMOS Technology: All of the functions needed to fabricate a high resolution CMOS display have been demonstrated in recent years. Waveguide Display implementation is illustrated in the first figure. As shown at bottom right in the figure, a pixel array, light couplers, and electronics are all fabricated on the same photonics circuit. Light is coupled into the image array from pigtailed light emitting diodes (LED) or laser diodes. Each pixel is illustrated in the blowup. For a color display, red, green, and blue light enters the pixel via waveguides, and the pixel intensity of each color is controlled by a combination of Mach Zehnder Interferometers (MZI) and LED timing. Light is radiated from Bragg Gratings with light control provided by Bragg Reflectors and metallization. Light that is not radiated is coupled to a silicon diode in order to monitor uniformity and to determine the correct MZI phase settings for each pixel and color of light.

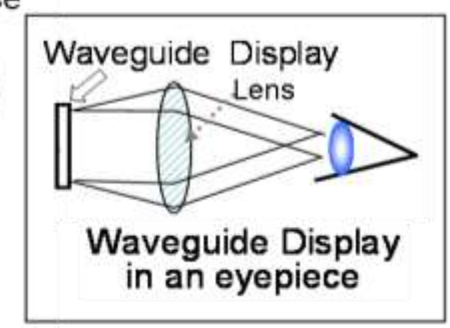


This figure illustrates Waveguide Display implementation.
For clarity, functional components are shown side-by-side.

Display Applications: Waveguide Displays provide a cost-effective and highest quality image source for many applications. The Waveguide Display itself is just a CMOS chip, but as described below, implementing a display product is straightforward. Images in multiple wavebands can be generated simultaneously at any wavelengths between 0.4 and 5 micrometers. Pixel speed is fast and limited only by the behavior of silicon logic. Waveguide Displays are cost competitive with existing display technologies while providing a quantum jump in image quality. Further, the wavelength flexibility, high speed, and small size of Waveguide Displays will enable new and popular products.

In addition, the silicon or germanium diodes included on Waveguide Displays to ensure picture uniformity can be shared; the array of light detection diodes can act as a user interface for rapid gaming or other applications. That is, a Waveguide Display is also a camera focal plane that simultaneously images the scene in front of the display.

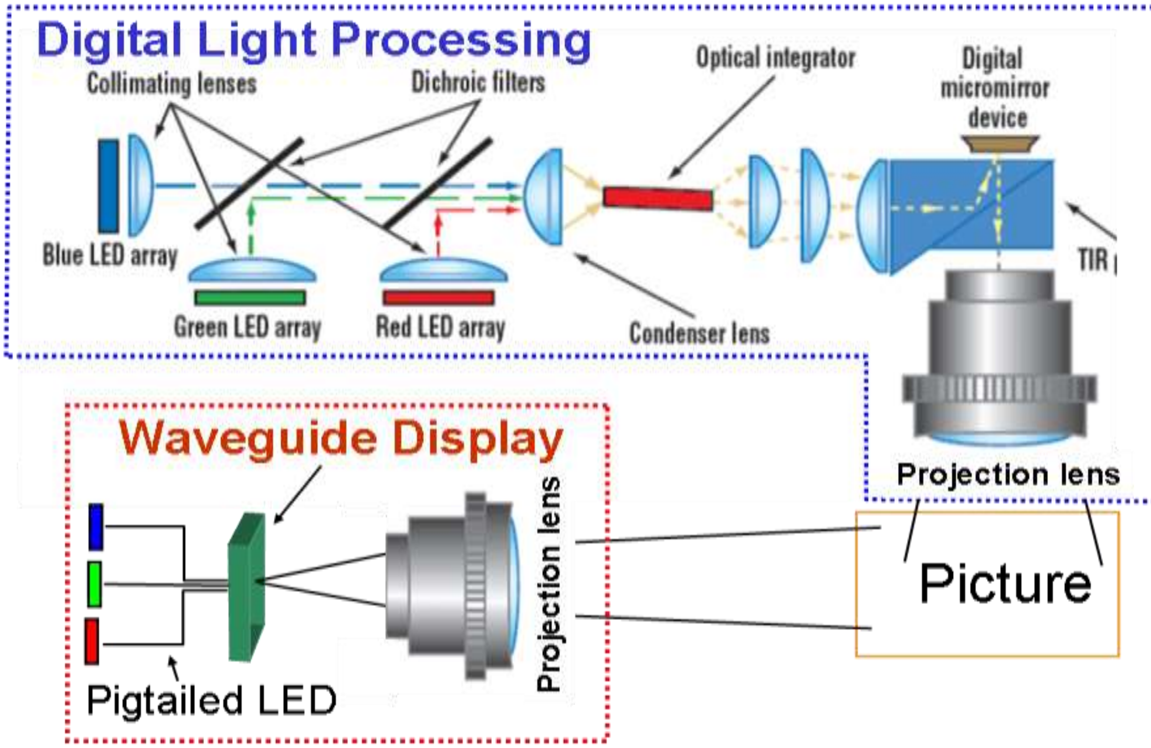
The first picture below illustrates Waveguide Displays used as camera viewfinders. Waveguide Displays have the pixel count and speed needed to match even the newest generation of video and digital cameras. Specifically, a 1280 by 960 pixel, High Definition Television (HDTV) image source would require a silicon chip approximately one-third by one-quarter inch. In order to match the 4K video format of 4096 by 3072 pixels, about a square inch of silicon would be required for a full-color Waveguide Display operating at 120 (or 144) frames per second.



Small video projectors for use in sales, kitchen, or office are another application. The picture at left shows cookbook instructions being projected onto a kitchen counter. The subsequent figure compares the construction of a Waveguide Display (WD) projector with construction of a Texas Instruments Digital Light Processing (DLP) projector. The WD requires only fiber coupled light and a lens, whereas the DLP requires a more complicated design. Further, the WD is much faster.

Waveguide Display Projecting Cooking Instructions on a Kitchen Counter

The low cost and simplicity of Waveguide Display (WD) projectors make them competitive with Liquid Crystal Displays (LCD) for applications where a thin enclosure is not critical. For example, a WD projector mounted in the back or a car or airplane seat would be lighter and less expensive than an LCD while providing a better and brighter picture.



This figure compares the layout of a Waveguide Display projector to a projector using DLP technology

The near-future market demand for head-mounted displays is not obvious. (By head-mounted we mean mounted on glasses, a helmet, a head-band, or a cap.) At present, the ergonomics environment when wearing head-mounted displays limits their popularity. Even the resolution of an HDTV display appears blurred when expanded to a large field of view in front of the eye. In addition, current head-mounted technology either blocks vision of the surroundings or the picture on the display disappears in sunlight. Add the discomfort of heavy weight and associated mounting harness on the head, and the problems with current technology outweigh the benefits.

However, a glasses-mounted display that is both comfortable and provides beyond-HDTV image quality with see-through vision against even bright backgrounds has not been available to excite the interest of gamers, businessmen, and lap top users. We expect that the combination of the affordability and small size of the Waveguide Display, coupled with a quantum jump in image quality beyond the current state-of-the-art, will popularize many head-mounted display applications. The small size and weight of Waveguide Displays can greatly improve head-mounted display ergonomics.

Cell phones today integrate high-performance computers with GPS and rapid communications. A display that could be mounted on the head as easily as ear buds would provide popular capabilities like watching video with quality better than home wide-screen television and playing “Where’s Waldo” with Waldo sitting in the neighbor’s yard. These ideas have been talked about for years, but the enabling display technology is not yet on the market. Waveguide Displays can fill that void.

Ranging Applications: Structured light ranging using Waveguide Displays provides an ideal solution for applications like automobile obstacle avoidance and driving automation.

- Each ranging sensor is small, inexpensive, and completely solid state.
- Both the light emitters and electronic circuitry are capable of being rapidly gated.
- The single Waveguide Display chip is both staring-array transmitter and staring-array receiver operating through one lens.
- A small array of optical switches like those used in each pixel can be added to the fiber optic input waveguide. (These switches are not shown in the first figure above.) The added switches rapidly direct all of the input light to selected portions of the pixel array. All of the light from the emitting diode can be focused on a small portion of the viewed scene. Since optical switching is quite rapid, the light is quickly scanned across the entire scene, thereby illuminating each part of the scene briefly but brightly. That feature greatly enhances the range achieved from low power light emitting diodes.

Applications Requiring Wavelength Tailoring: A great deal of research has been published on CMOS waveguide ring resonators. Only a small area of silicon is needed to divide light emitting diode light into multiple wavebands suitable for holographic imaging or optical computing. Waveguide Displays provide a flexible image source to help implement these evolving technologies.

Summary: Based on the open literature, all of the functions needed for Waveguide Displays can be fabricated in CMOS. A pixel array with several million color pixels (dots) per square inch can be fabricated at any silicon foundry. The previous research greatly reduces program risk. However, although the CMOS features needed to fabricate a functional, high performance display have been demonstrated, development of the processing steps needed to fabricate a producible Waveguide Display requires significant investment of engineering hours and capital.

We expect that Waveguide Displays will find a home in many products. That expectation is based upon the combination of low production cost, small size, simple system integration, and imaging characteristics of the Waveguide Display.

RHV Electro-Optics expects that any eventual contractual arrangement with a company or an investor (the interested party) would include three considerations. First, that the interested party would assist in the preparation of business and management plans. Second, that the interested party agrees to a timely commitment of funds and other resources to Waveguide Display development. And third, that RHV Electro-Optics, LLC would be funded to provide technical advice, program advice, and program monitoring during product development. If your organization is interested in further discussion or additional information about the Waveguide Display, please contact Rich Vollmerhausen at RHV Electro-Optics, LLC by clicking the contact button.