WAVEGUIDE OPTICS—SYNOPSIS FROM DIGILENS INC. WHITE PAPER, JANUARY 2015

Switchable Bragg Gratings (SBG) based waveguides used by DigiLens Inc. vs. Surface Relief Gratings (SRG) licensed by Nokia used by other companies in augmented and virtual reality displays.

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DigiLens Inc., a leader in optical waveguide technology, is developing solutions for the augmented and virtual reality markets. This class of integrated waveguide optics is the most critical aspect of delivering a wearable display that comfortably blends computer generated and real world imagery seamlessly to the user. As integration and component technology improves, today's headsets will be tomorrow's glasses. This note sets out to highlight the differences between two rival diffractive waveguide technology platforms developed over the last decade by DigiLens, Inc. and Nokia Corporation.

Waveguides are inherently flat and thin, where light bounces through the guide efficiently using total internal reflection. Waveguide optics goes a step further by patterning different and often complex diffractive patterns that guide the light to perform key optical functions.

The most basic example of diffractive waveguide optics is what enabled LCD TVs to become ultra-thin. Here, thin LEDs were mounted on the edge of a thin glass sheet backlight and etched diffractive dots were patterned across the surface. The light is out-coupled or "extracted" uniformly, enabling a single 1 mm thin curved sheet backlight to illuminate a 70-inch curved TV. Guiding and extracting illumination is one waveguide function, but guiding and manipulating images injected into the waveguide is the breakthrough that has taken waveguide optics technology to the next level.

DigiLens' waveguide technology is based on "Switchable Bragg Gratings" (SBGs) and has several advantages over its nearest rival's "Surface Relief Gratings" (SRGs). SRG's were pioneered by Nokia labs in 2001 for eyeglass mobile displays. The labs were disbanded due to severe corporate cutbacks, and the principle inventor joined Microsoft.

The technology is currently licensed to Microsoft who rebranded it "HoloLens" for use in its revolutionary augmented reality display. It is also licensed to Vuzix Inc. (VUZI) for a similar application. Microsoft's called the Nokia waveguide "a breakthrough" for its integrated wearable AR solution. Journalists loved it, as they felt less disorientated due to its lack of side-to-side obscuration. Users could naturally interact with the digital world in several useful scenarios. Clearly early, but very exciting days!

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ELECTRICALLY SWITCHABLE WAVEGUIDE OPTICS

In appreciating the performance contrast between the two waveguide technologies, the most obvious difference is DigiLens can electrically switch their Bragg gratings. This is a major advantage for a variety of waveguide applications including eye tracking or variable image depth plane generation which is used to solve the vergence-accommodation conflict (a major contributor to sickness) in VR or AR imaging applications.

WIDER FIELD-OF-VIEW WAVEGUIDE OPTICS

The most critical requirement of any waveguide technology used in AR displays is to carry a high quality, wide field-of-view (FOV) image. To do this, the color image must be coupled in and out of the waveguide and manipulated within the waveguide, all by using diffractive gratings. Here the performance contrast is profound, as DigiLens' SBGs can accommodate and deliver a 40° diagonal FOV, whereas the Nokia SRG waveguides are limited to around 20°.

EFFICIENT WAVEGUIDE OPTICS

DigiLens' SBG-based waveguides are also fundamentally more efficient, providing higher brightness, better uniformity, and lower power consumption. The gratings are regularly printed with 97% efficiency.

Unique to DigiLens' technology, two or more gratings can be combined into the same waveguide. This is called optical multiplexing, where the SBG can guide and extract much more of the available image intensity.

AFFORDABLE WAVEGUIDE OPTICS

DigiLens manufactures its SBG waveguides using a printing process that offers a significant cost advantage over the high-precision SRG process. By printing, we can accommodate any waveguide grating architecture simply by building the complexity into the "master holographic optic" from which the "optical copy" is duplicated. A DigiLens copy is a perfect duplication and has only 0.1% performance loss today.

In contrast, the SRG process gets exponentially more challenging to duplicate, as optical complexity increases. As the surface relief nano-features decrease in size and increase in complexity, the cost and yield of duplicating parts greatly reduces quality in terms of haze, which severely impacts display contrast. The only alternative for SRG developers is to uniquely etch the parts individually using silicon wafer tools. SRG manufacturing to the quality needed for display waveguide optics remains unproven.

HIGHLY INTEGRATED WAVEGUIDE OPTICS

DigiLens' approach to designing and fabricating SBG waveguides is based on proprietary functional elements called *IP Cores.* By using these IP cores to perform the various optical system functions, the complex functionality needed for devices, such as color displays and eye trackers, can be encoded within the waveguide. SRG structures however are limited to a very small set of functionalities, as they are unable to make use of complex 3D recording geometries that the SBG-based platform can.

By revolutionizing the design and fabrication of flat, thin, waveguide based optical systems, DigiLens' technology stack of SBG IP cores, like the microelectronics "system on a chip" analogy, drives radical form factor reduction in next generation wearable and mobile display product design.

REFERENCES

Comment: The following references discuss SRG architectures suitable for wearable displays. The papers highlight the difficulties of achieving high field of view (the limit is around 20 degrees for a single monochrome waveguide), and high efficiency (typically around 30%). High index substrates are also required, with refractive index of at least 1.7 and preferably much higher.

References

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