Thinking Outside the Glass
New Market Opportunities for GigaPOF® GI-POF
Market dynamics driving greater interest in GI-POF

- Increasing data transmission rates in non-data-center applications
- Technology developments and strategic investments are enabling new capabilities
- Durability of optical fiber links is becoming a key competitive differentiator
- GI-POF becoming a viable technical and commercial alternative to GOF
- Capacity and cost remain biggest hurdles to broader adoption
Display technology trends favor use of optical solutions

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</thead>
<tbody>
<tr>
<td><strong>Resolution</strong></td>
<td>535line</td>
<td>720x480</td>
<td>1920x1080</td>
<td>4K / 8K</td>
<td></td>
<td></td>
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<tr>
<td><strong>Frame rate</strong></td>
<td>30fps</td>
<td>30fps</td>
<td>60fps</td>
<td>120fps</td>
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<tr>
<td><strong>Color Gamut</strong></td>
<td>BT.1700</td>
<td>BT.601</td>
<td>BT.709</td>
<td>xvYCC, BT.2020</td>
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<tr>
<td><strong>Color Depth</strong></td>
<td>-</td>
<td>8 bits</td>
<td>10 bits ~ 16 bits</td>
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<tr>
<td><strong>Dimension</strong></td>
<td>2D</td>
<td>2D</td>
<td>3D (glasses)</td>
<td>3D (native)</td>
<td></td>
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</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>10MHz</td>
<td>0.25Gbps</td>
<td>1Gbps</td>
<td>10Gbps</td>
<td>&gt; 100Gbps</td>
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**Copper Based Systems** ↔ **Fiber Based Systems**

Source: Professor Yasuhiro Koike, Keio University
High-speed data traveling over copper-wire cables
High-speed data delivered by optical fiber cables
Optical fiber outperforms copper over longer distances.

- = Cu wire
- = GigaPOF® Graded Index Polymer Optical Fiber (GI-POF)
- = Glass Optical Fiber (GOF)
Practical limitations of copper cables

**Bandwidth**
- HDMI 2.0 (18 Gb/s) length limitation ~5 meters
- Active electronics can extend reach to +/- 10 meters
- HDMI 2.1 (48 Gb/s) maximum length expected to be ~2 meters

**Other problems**
- Long passive copper cables are large, heavy and stiff
- Difficult to pull through conduit, ceiling, walls and other tight spaces
- Stress on connectors can unplug cable from source and sink devices
Active Optical Cables (AOCs) solve practical limitations of copper cables at higher data rates

- support much longer distances than copper
- cable form factor reminds thin and flexible
- no need to keep exposed optical connectors clean as with passive fiber patch cords
- uses standard electrical port (e.g., HDMI) - no dedicated optical port needed
Construction of GigaPOF® GI-POF HDMI AOCs

Simple design is economical to produce at scale
- fully ribbonized fiber/copper hybrid bulk cable elements
- mechanical durability of GI-POF simplifies assembly
- non-hermetic OSA with chip-on-board mounting of VCSELs and PDs
First commercially successful GI-POF HDMI AOC (~2012)

HDMI 1.3
Active Optical Cable
powered by USB
Award-winning next-generation GI-POF HDMI 1.4 AOC

InfoComm “Best New AV Accessory”

Commercial Integrator “25 Best of 2013”

EC&M “2014 Product of the Year”

First large-scale use of GI-POF worldwide

- no external (USB) power needed
- UL plenum (CMP-OF) rated for commercial installations
- ~ 100,000 units now installed in North America
- volumes now migrating to new HDMI 2.0 product
GigaPOF® AOCs simplify long-reach custom install links

• One GigaPOF® AOC cable is the same as:
  - bulk twisted pair cable with an extender set
  - bulk fiber cable with an extender set

• Simple installation
  - Install just like a standard copper wire HDMI cable
  - No external power required — powered by ports from source and sink
  - No extenders or boosters required — everything is built into the cable and connectors

• Excellent customer experience
  - Quick installation
  - Lower cost than most bulk cable and electronics
  - Fewer failure points
  - No ongoing maintenance costs

Just one of these...

...instead of all this!
Faster AOCs for future UHD links

Higher bandwidths coming

- From 18 Gb/s for HDMI 2.0 (4K) to 48 Gb/s for HDMI 2.1 (8K)
- Proprietary links between TV processing units and display likely to exceed 100 Gb/s in near future

Source: HDMI.org
More durable AOCs for future UHD links

Durability now becoming a critical performance factor

- Moving from controlled environments of data centers, telecom central offices to
- semi-skilled ProAV custom installations, pulling cables through conduit and inside walls and ceilings, and
- with HDMI 2.1 and TV links, AOCs will enter consumer electronics realm with no control over abuse of cables

- Glass optical fibers are susceptible to static fatigue
- GigaPOF® GI-POF is immune to static fatigue

Source: Corning, Inc.
Cheaper AOCs for future UHD links

Lower costs needed for mass market penetration
GI-POF AOC ecosystem is evolving and maturing

$MMs Strategic Investments & Acquisitions in 2017

Chromis Fiberoptics Proprietary and Confidential
R&D innovations open new markets & applications

**New Materials**

- **PBVE synthesis**
- **PBVE-4M (100°C) synthesis**

**New Optical Fibers**

- **High Numerical Aperture GigaPOF®**
- **85°–85% GigaPOF®**
- **100°C GigaPOF®**

**LEGEND**

- Current GigaPOF® GI-POF
- Future GigaPOF® GI-POF

**ProAV Commercial & Residential Custom Install**

- Consumer Electronics, IoT, AR/VR/CAVE
- Data Center & HPC
- Aerospace, Autonomous Vehicles, Robotics, Factory Automation
- Medical

**Chromis Fiberoptics Proprietary and Confidential**
Optimizing polymer synthesis for ultra-durable fibers

Material choices are critical for ultra-durable GI-POF

- Chromis started by making GI-POF using only the PBVE homopolymer and an index-raising dopant

- dopant solubility and $T_g$ depression limits effective NA to 0.18

- bend tolerance of ~1 mm requires NA ~ 0.23

- higher NA requires use of lower-index polymers as cladding materials

Copolymers for ultra-durable GI-POF

- co-polymerize PBVE with other monomers

- enable fibers with a much higher NA and/or $T_g$
Enabling optical performance with copper economics

Graded-Index Polymer Optical Fiber (Chromis GigaPOF® GI-POF)

+ Patented monolithic GigaPOF® ribbon

+ Lens- and prism-free optical engine

Innovative technology cuts bill of materials and assembly costs to make inexpensive AOCs possible

GigaPOF® Salus Series Plenum HDMI 2.0 AOC
Patented monolithic GigaPOF® ribbon is easy to terminate

GigaPOF® Monolithic Ribbon Patent #9046670

Patented Monolithic GigaPOF® Ribbons

• Terminate multiple fibers as a single unit
• No need to strip overcladding to terminate fiber
• 100% passive alignment of fiber to OSA

Reduces fiber termination costs
Innovative optical engine optimized for GigaPOF®

- Prism- and lens-free optical sub-assembly design
- Attaches to PCB as single unit with solder reflow
- Shaped for Chromis monolithic GigaPOF® ribbon
- Cheaper to make than traditional optical engines

Lower AOC bill of materials and assembly costs
The future of GI-POF is more promising than ever

- Increasing data rates for video transmission are expanding the market opportunity for GI-POF
- GI-POF ecosystem is attracting substantial investment capital
- End users giving serious consideration to GI-POF as an alternative to GOF
- Quality, quantity and [especially] cost remain biggest hurdles to greater market penetration
- Ease-of termination-and durability of GI-POF will win
Commercialization of GI-POF has been a long time coming

“It takes 20 years to make an overnight success.”

- Eddie Cantor (comedian, singer, actor and songwriter)
Thank You

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