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# PMMA-based GI-POF (OM-Giga)

Optimedia, Inc.  
Seongnam-Si, Korea

May, 2006



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# TOPICS

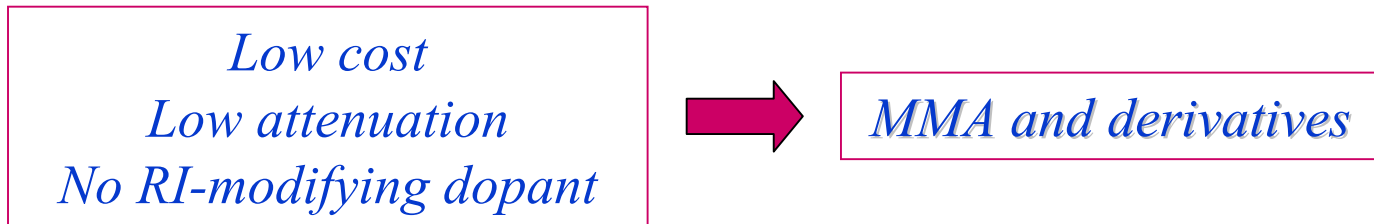
- **OM-Giga Technology**
  - *Product design*
  - *Process*
  - *Product line*
  - *Comparison with other products*
- **Current & Future Products**

# OM-Giga Technology

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## Product Design

- **Material selection:**



- **Bandwidth:**

*Bandwidth & RI profile needed ? (application dependent)*

- **Home network** (100 Mbps  $\Rightarrow$  ~1 Gbps at < 100 m)
- **Video link** (analog  $\rightarrow$  digital (S100  $\Rightarrow$  S200  $\Rightarrow$  S400))
- Optical interconnect (**3.2 Gbps, 10 Gbps**)
- Automotive (400 Mbps)
- Image guide (high NA for brightness)

# OM-Giga Technology

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## Product Design

- **Numerical Aperture:**

*Smaller NA*



*Higher bandwidth  
Smaller acceptance angle  
Higher bending loss*

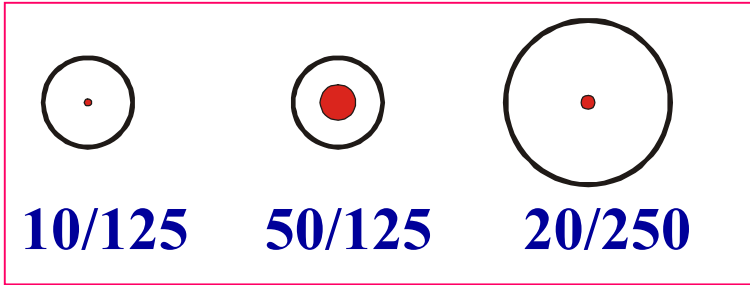
- **Fiber Dimension (core/cladding)**

- *Easy connection (existing connectors)*
- *Easy handling*
- *Cost competitive (production rate)*
- ***Standards***

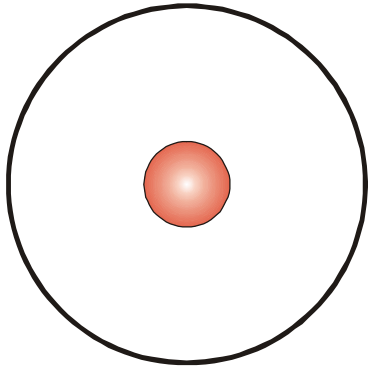


*900/1000  $\mu\text{m}$   
500/750  $\mu\text{m}$*

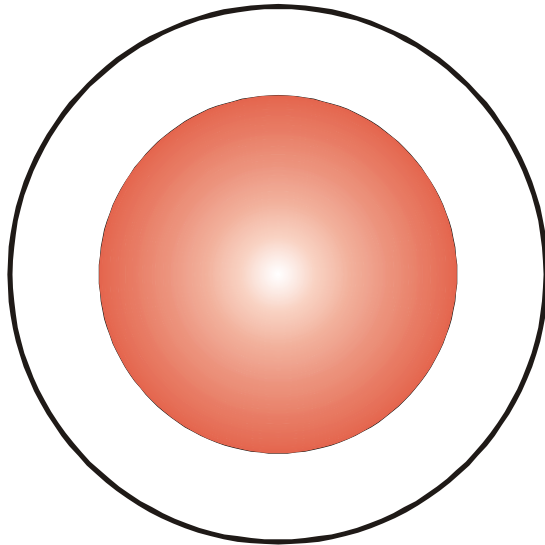
*\* Fiber dimension (core/cladding,  $\mu\text{m}$ )*



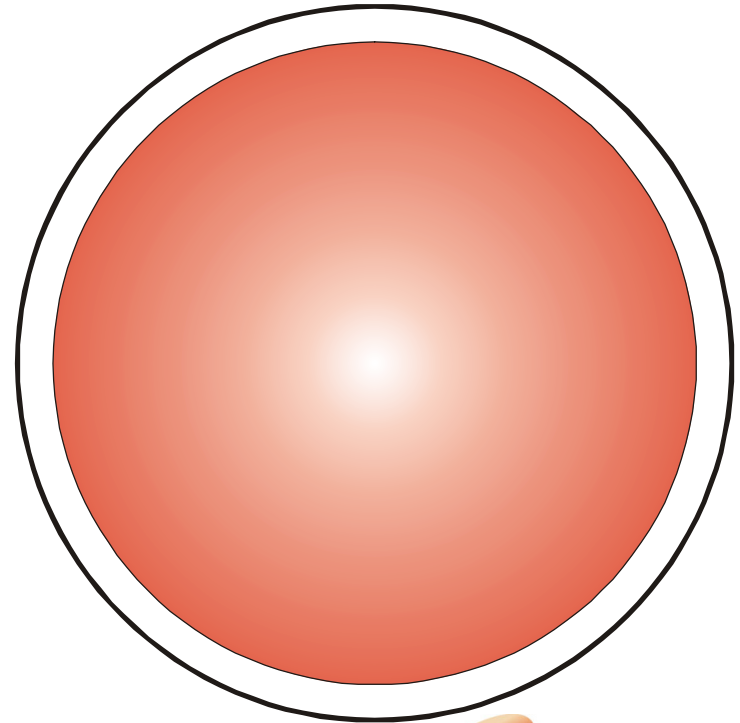
**900/1000 (OM-Giga)**



**120/500**  
**Lucina**

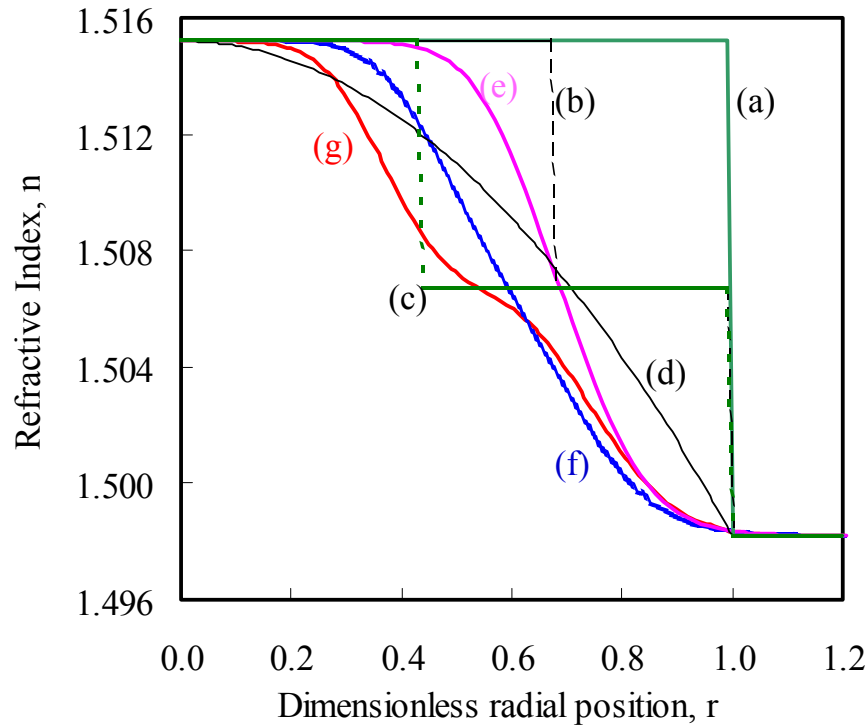


**500/750**



## \* Bandwidth & RI profile

### Various RI Profiles:

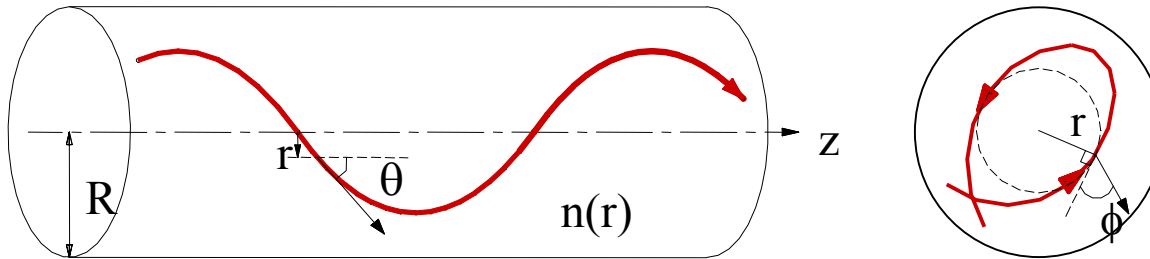


- (a) SI
- (b) 3-layer MSI
- (c) 3-layer MSI
- (d) ideal GI
- (e) 2-layer (diffused)
- (f) 3-layer (diffused)
- (g) 3-layer (diffused)

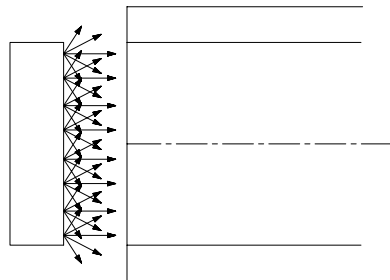
Sohn & Park, *Ind. Eng. Chem. Res.*, **40**, 3740 (2001)

# Estimation of Bandwidth

RI Profile	Solution
Power-law	Analytic (WKB)
Arbitrary	Numerical (EM or Ray Optics)



**Lambertian Source:**

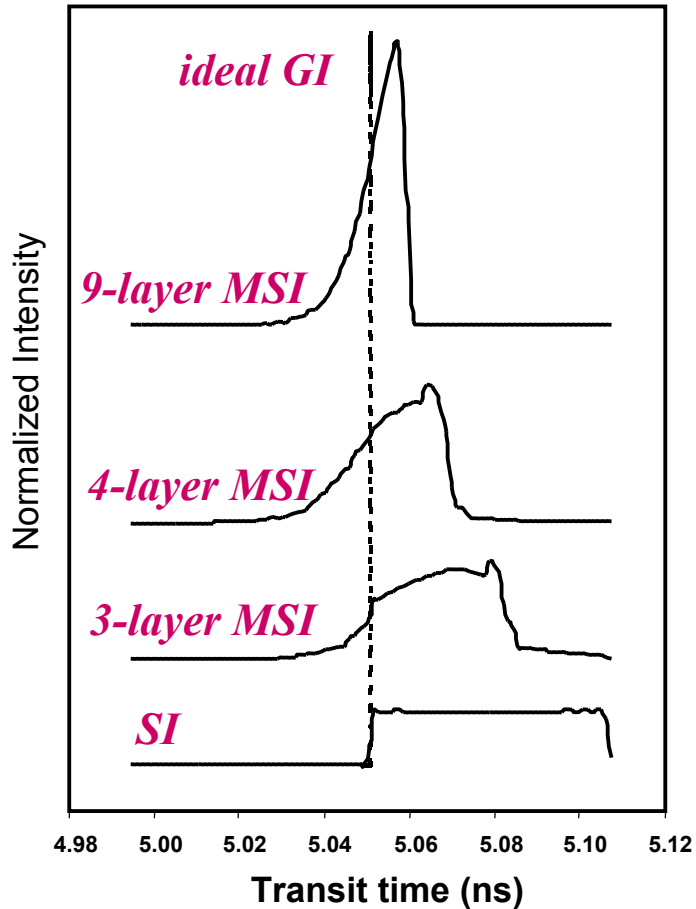


**Eikonal Equation:**

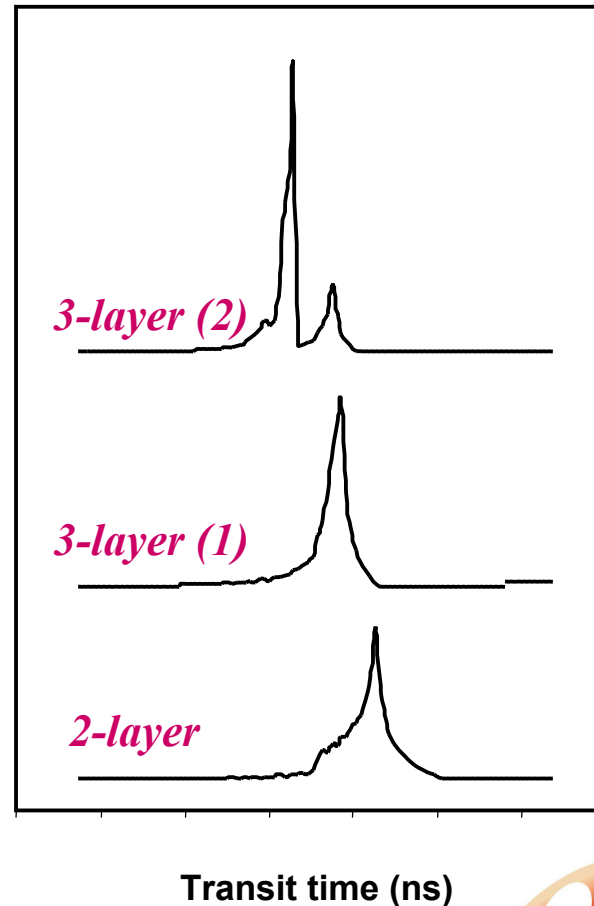
$$\frac{d}{ds} \left( n \frac{d\mathbf{r}}{ds} \right) = \nabla n$$

# Impulse Responses

*step profiles*



*diffused profiles*



## Bandwidth Estimate (Mbps-100m)

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### *Multi-Step-Index fibers*

2-layer	154	
3-layer ( $R_f=0.4, 0.6$ )	200	
4-layer	242	( <i>Eska-Miu</i> )
6-layer	327	
9-layer	415	

### *Gradient-Index fibers*

2-layer	319
3-layer	413
5-layer	660
7-layer	813

# OM-Giga Technology

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## Process

- **Fabrication method:**
  - *Best to achieve the desired RI profile*
  - *Flexibility*
  - *Minimum attenuation possible*
  - *Low cost production*

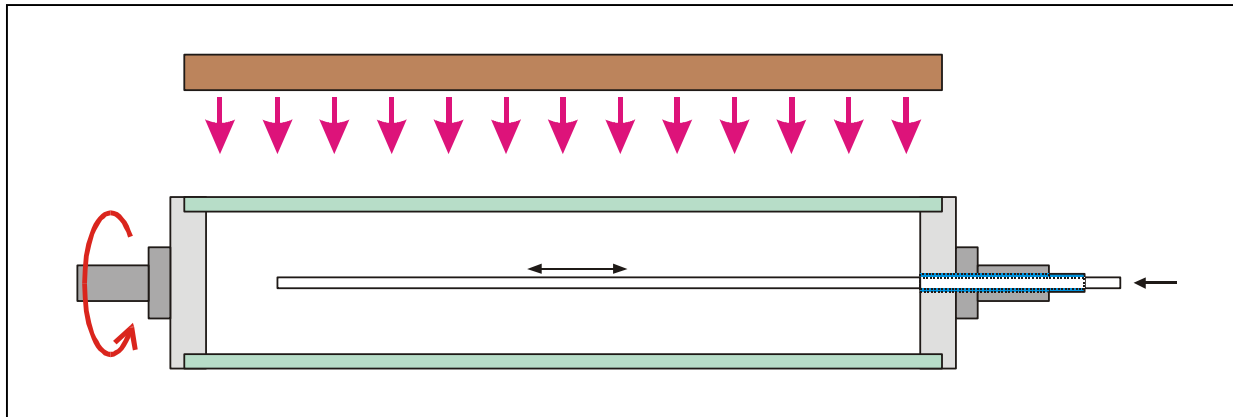
### **4-step batch process:**

- (1) *Materials purification*
- (2) *Preform making*
- (3) *Thermal drawing*
- (4) *Jacketing*

# Preform Making

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## Continuous/Stepwise Feeding & Reaction



### *Multi-Stage Reaction*

- Rotating cylindrical reactor
- Continuous or stepwise feeding of reactants
- Heat or UV-radiation for polymerization

# Multi-Stage Reaction

## Input variables:

- feed composition
- additive (initiator, CTA, AO)
- reaction temperature
- radiation intensity
- rotational speed
- feed rate
- time interval between feeding



**MW distribution**  
**Spatial variation of MW**



**RI profile**

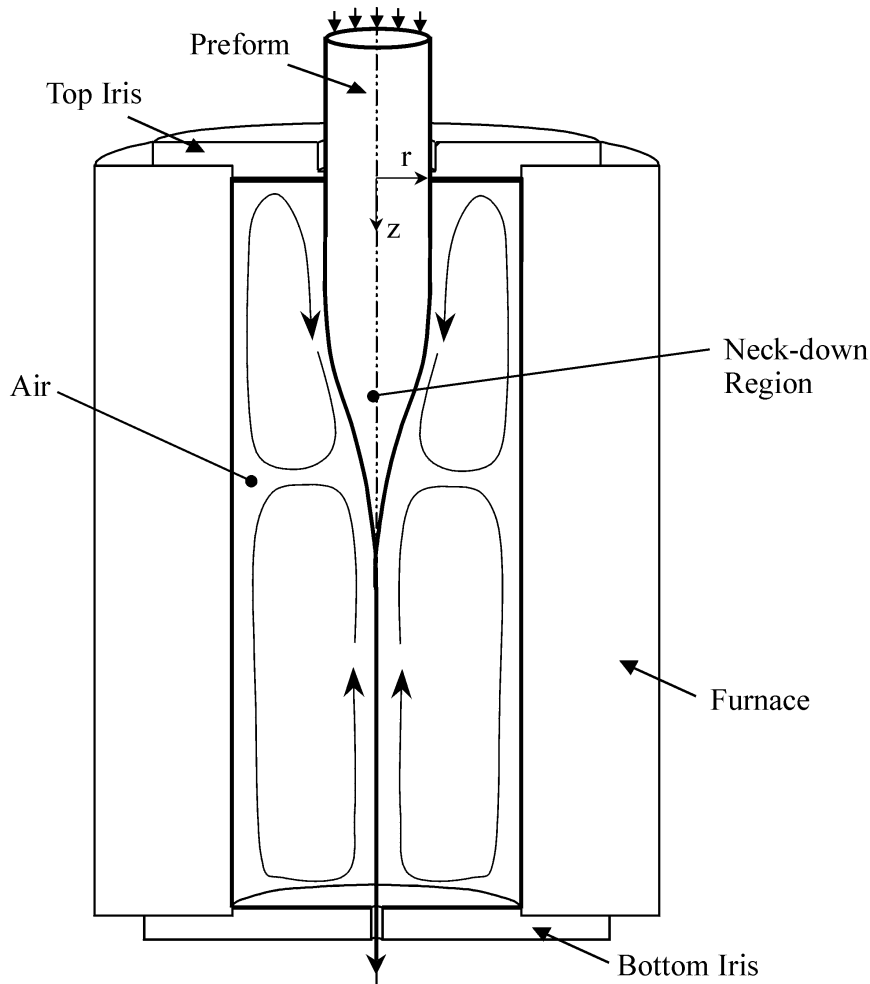


Drawing Characteristics:  
*Temperature*  
*Stability*  
Mechanical Properties:  
*Tensile Strength*  
*Bending Strength*

***Bandwidth & Attenuation***



# Thermal Drawing



- Preform: MW, diameter
- Oven: diameter, length
- Draw span
- Temperature
- Feed rate & drawing speed
- Cooling



Drawing Characteristics:  
*Cylindricity,*  
*Diameter variation*

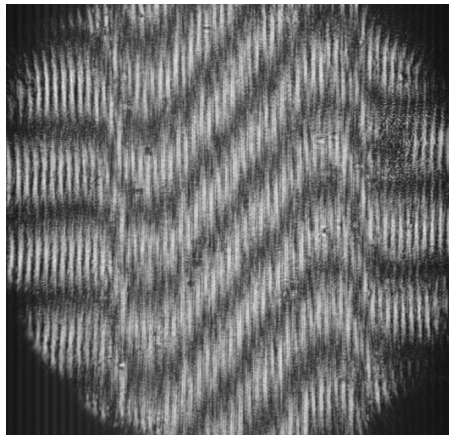
Mechanical & optical properties

# OM-Giga

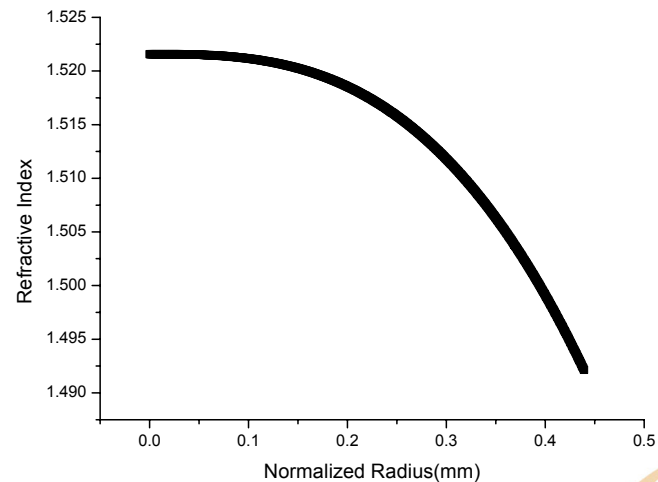
- Commercial since 2004
- PMMA-based material, process patent
- Bandwidth: 3 Gbps-50m (at 650 nm), Attenuation < 200 dB/km

**Advantages:** high speed, low cost, large diameter (0.75~1mm)

**Disdvantages:** short distance communication (< 60m)

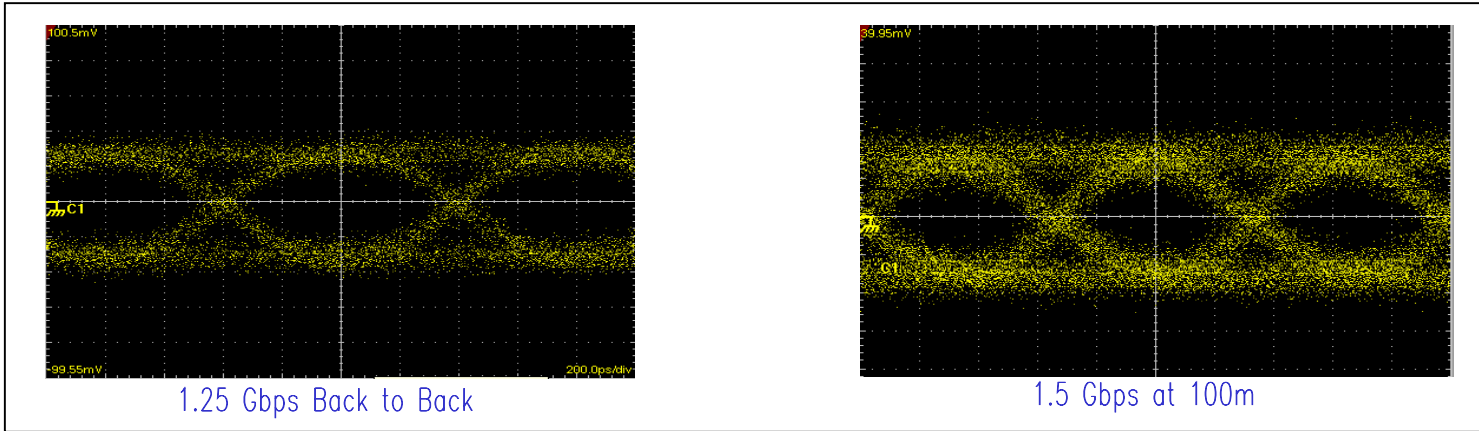


Moire Fringes

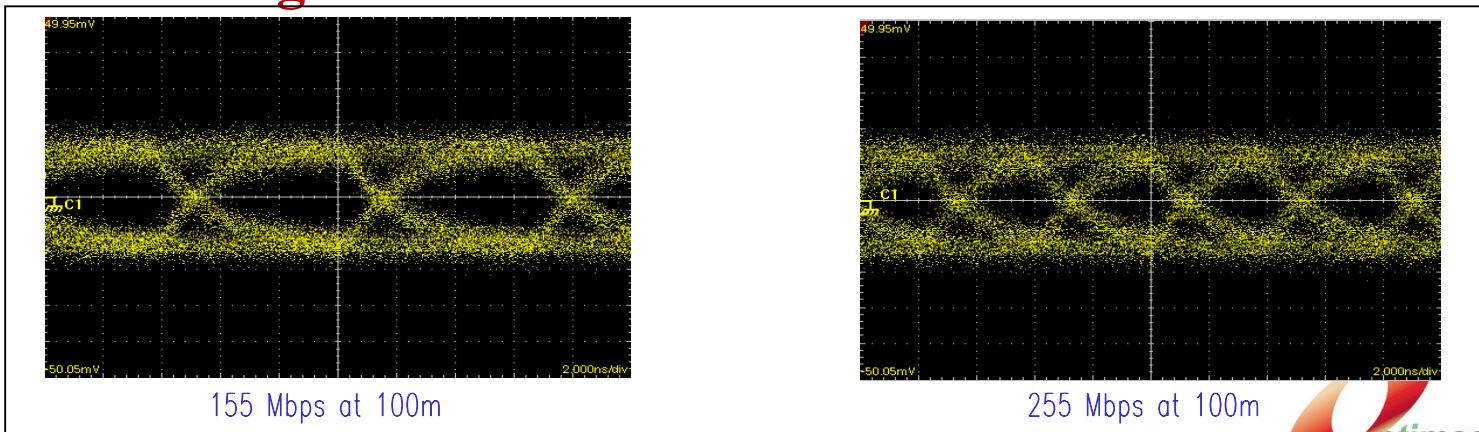


# Eye Diagram

## OM-Giga



## ESKA Mega



# Specification

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Diameter (core)	mm	1.0 (0.9)	
Variation of Diameter	%	$\pm 5$	
Tensile at break	N	$> 65$	$>70$ if jacketed
Bending Radius	mm	25	
Operating Temperature	$^{\circ}\text{C}$	$-30 \sim 60$	$-30 \sim 70$ if jacketed
Attenuation	dB/km	$< 200$	at 650 nm
Bandwidth	Gbps	$> 3$	at 50 m

# Jacketing

*Minimization of thermal damage*

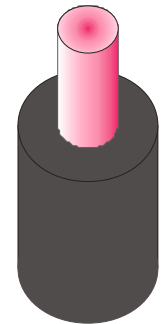


- PE, PVC, PA
- Die design
- Jacketing condition
- Fiber dimension

## Product line

900/1000			
500/750			
hybrid			

Tight buffer



## \* *Evaluation by POF-AC*

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- **Bandwidth & bending loss:**

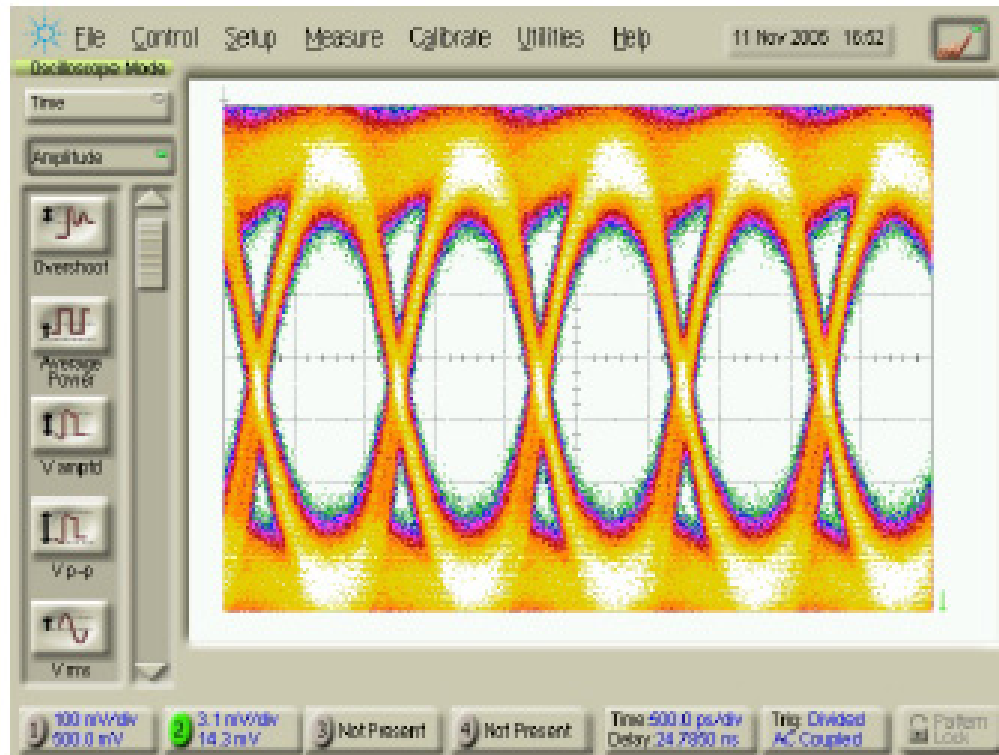
- *Bandwidth: 1.5 Gbps (650 nm), BER < 10<sup>-11</sup>*
- *Bending loss: (at 1.5 Gbps)*

Bending radius	Signal Level	Bending Loss	BER
35mm	640 mV	0.0 dB	< 10 <sup>-11</sup>
30mm	608 mV	0.2 dB	< 10 <sup>-11</sup>
25mm	556 mV	0.6 dB	< 10 <sup>-11</sup>
20mm	450 mV	1.5 dB	< 10 <sup>-11</sup>

- **Temperature stability:**

*No performance degradation at 70°C for 700 hour  
(1.5 Gbps, BER < 10<sup>-11</sup>)*

## \* *Evaluation by Firecomms*



**40m OM-Giga, 1 Gbps, PRBS-7 test pattern (655 nm VCSEL)**

## *\* Evaluation by Firecomms*

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- The **fiber size** of OM-GIGA works very well with existing connectors (SMI/i-link in particular). This is important for easy and fast time to market.
- **Bandwidth** - it looks ideal for Home-networking Gigabit Ethernet and high speed IEEE1394(S800).
- **Distance performance:**  
OM-GIGA works well for lower data rates over distances greater than 50m whereas ESKA-MEGA begins to fail for phase drift. OM-GIGA outperforms by providing a cleaner optical eye. So for operation at data rates of 10T/100T (125Mbps) or IEEE1394 S200(250Mbps)over 100m OM-GIGA outperforms ESKA MEGA.

# Other Commercial Products

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## SI-POF:

- **ESKA** by Mitsubishi Rayon (since 1976)
  - PMMA-core/fluoropolymer-cladding, diameter: 0.5~1.0 mm
  - *ESKA Premier*: 100 Mbps/50m (at 650 nm), NA=0.5, 160~180 dB/km
  - *ESKA Mega*: 200 Mbps/50m (at 650 nm), NA=0.3, 160~180 dB/km
- *Raytela* (Toray), *Luminous* (Asahi Chemical)

## GI-POF:

- **Lucina** by Asahi Glass (commercial since 2000)
    - Perfluoro-polymer (patented material “Cyttop”)
    - 1 Gbps/200m (at 850 nm), 120/500  $\mu\text{m}$ , < 40 dB/km
- Advantages:** longer distance communication
- Disadvantages:** expensive patented material,  
small core  $\Rightarrow$  loose buffer jacketing



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## GI-POF:

- **Japan:**

- *Lumistar* by Fuji Film (commercial ??)
- *ESKA-Miu* by Mitsubishi Rayon (**MSI-POF**, commercial ??)

- **USA:**

- Chromis Fiberoptics (formerly OFS)  
*Similar to Lucina but made by a coextrusion process.*
- DOC (joint venture between Samyang-Sa and Nanoptics)  
*DOC now closed. Product not available.*

- **Europe:** Nexans

- **Korea:** Nuvitech (commercial ??)

# Product Comparison

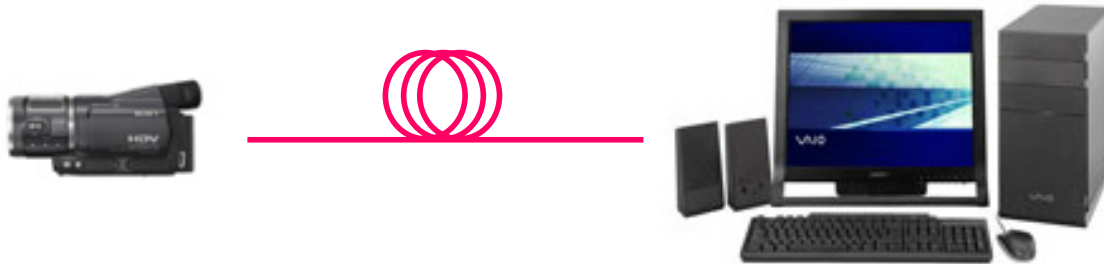
	ESKA Mega	OM-Giga	Lucina
Maker	Mitsubishi	Optimedia	Asahi Glass
Material	PMMA	PMMA	Fluoro-polymer
Type	Step index	Graded index	Graded index
Loss(dB/km)	180	200	22~40
Wavelength (nm)	650	650	850, 1300
Bandwidth	300Mbps/50m	>3 Gbps at 50m	1 Gbps at 200m
Core/Fiber (um)	980/1000	900/1000	120/500
NA	0.3	0.3	0.170 ~ 0.195





# Video Link

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- **Surveillance cameras for security**
- **Industrial cameras for defect inspection**
  - Digital for higher resolution
  - Link distance limited

*e.g., (metal) cable length for 1394 digital cameras < 5 m*  
*GI-POF can extend the length to ~50 m*

# OM-Giga Pricing Projection

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1000 units:	160 USD/ea	(or 1.60 USD/m)
10,000 units:	80 USD/ea	(or 0.80 USD/m)
100,000 units:	40 USD/ea	(or 0.40 USD/m)

*\* 1 Unit: 100 meters of duplex cable*