FINNISH-JAPANESE WORKSHOP
ON FUNCTIONAL MATERIALS
Espoo and Helsinki, Finland

May 25, 2009

Status of Photonics Polymers for "Fiber to the Display"

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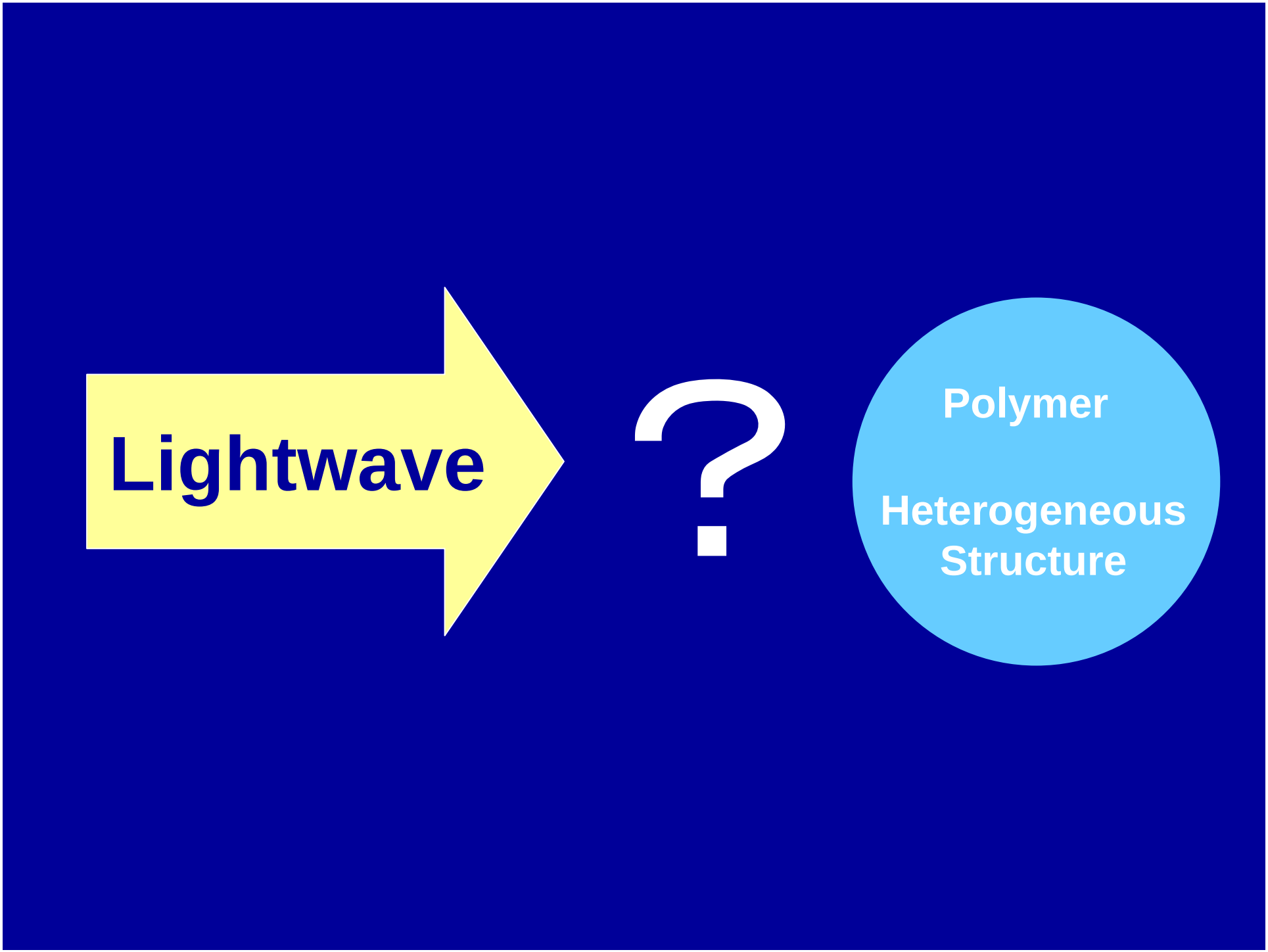
Yasuhiro Koike


Lightwave
?
Polymer
Heterogeneous
Structure

Correlation Length

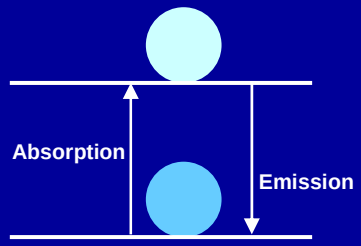
Å (10^{-10}) nm (10^{-9}) μm (10^{-6}) mm (10^{-3})

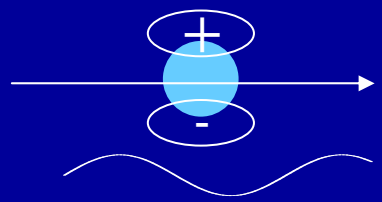
Absorption Emission

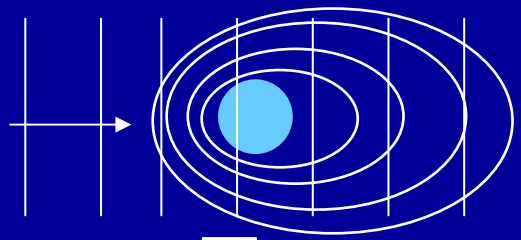
Polarization

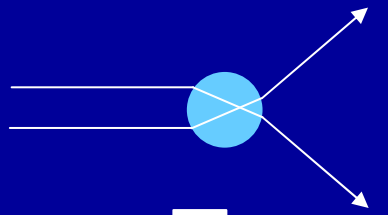
Scattering

Refraction Reflection





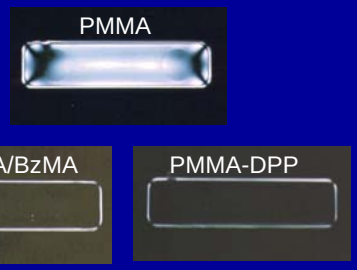




High-Power Optical Fiber Amplifier and Laser

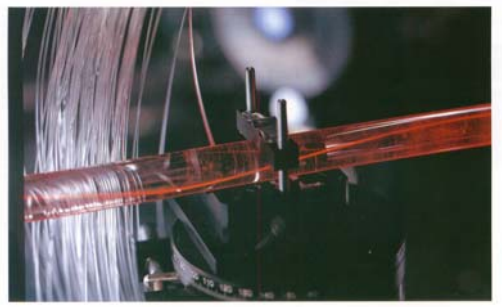
Zero absorption Loss Polymer

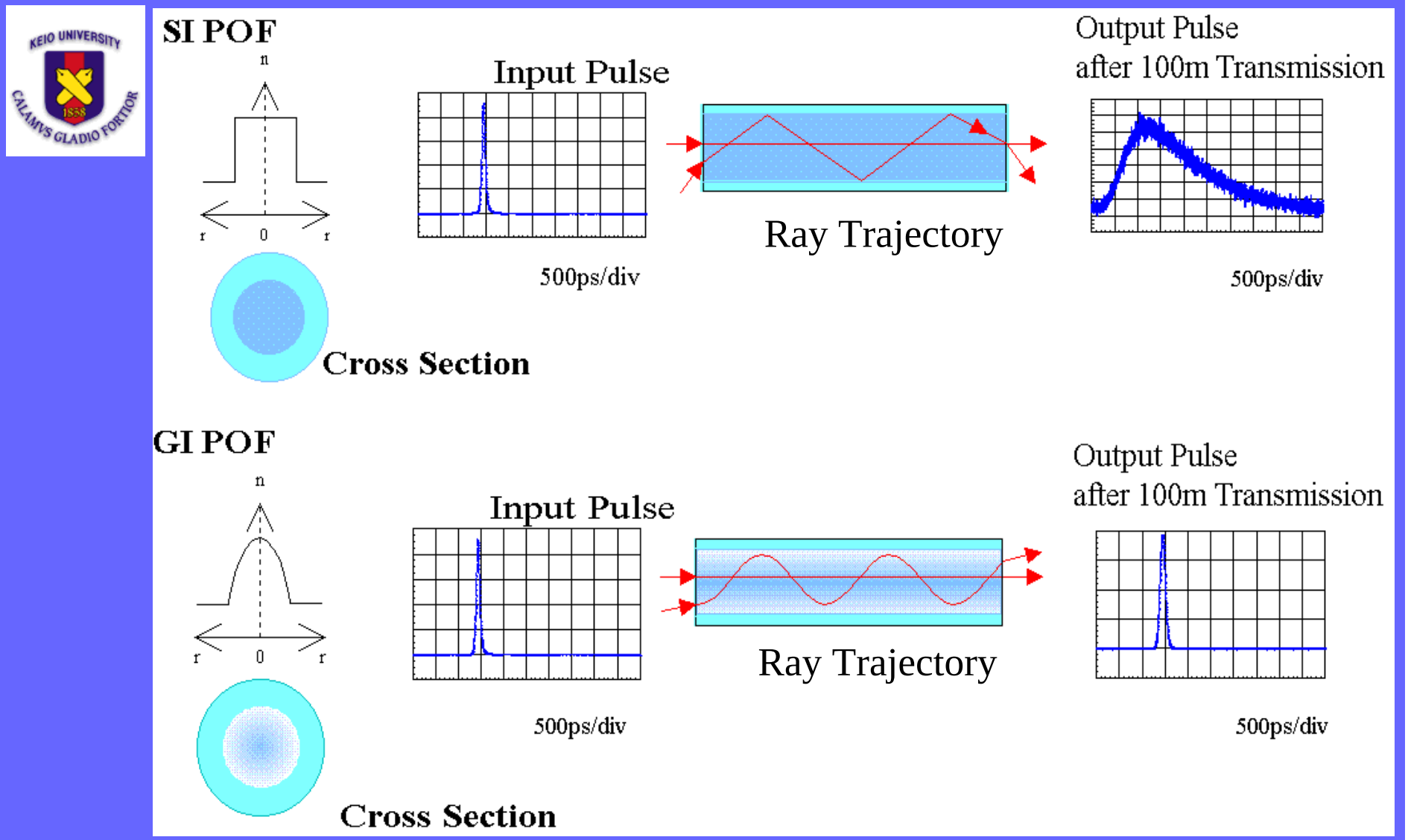
Zero-Birefringence Polymer



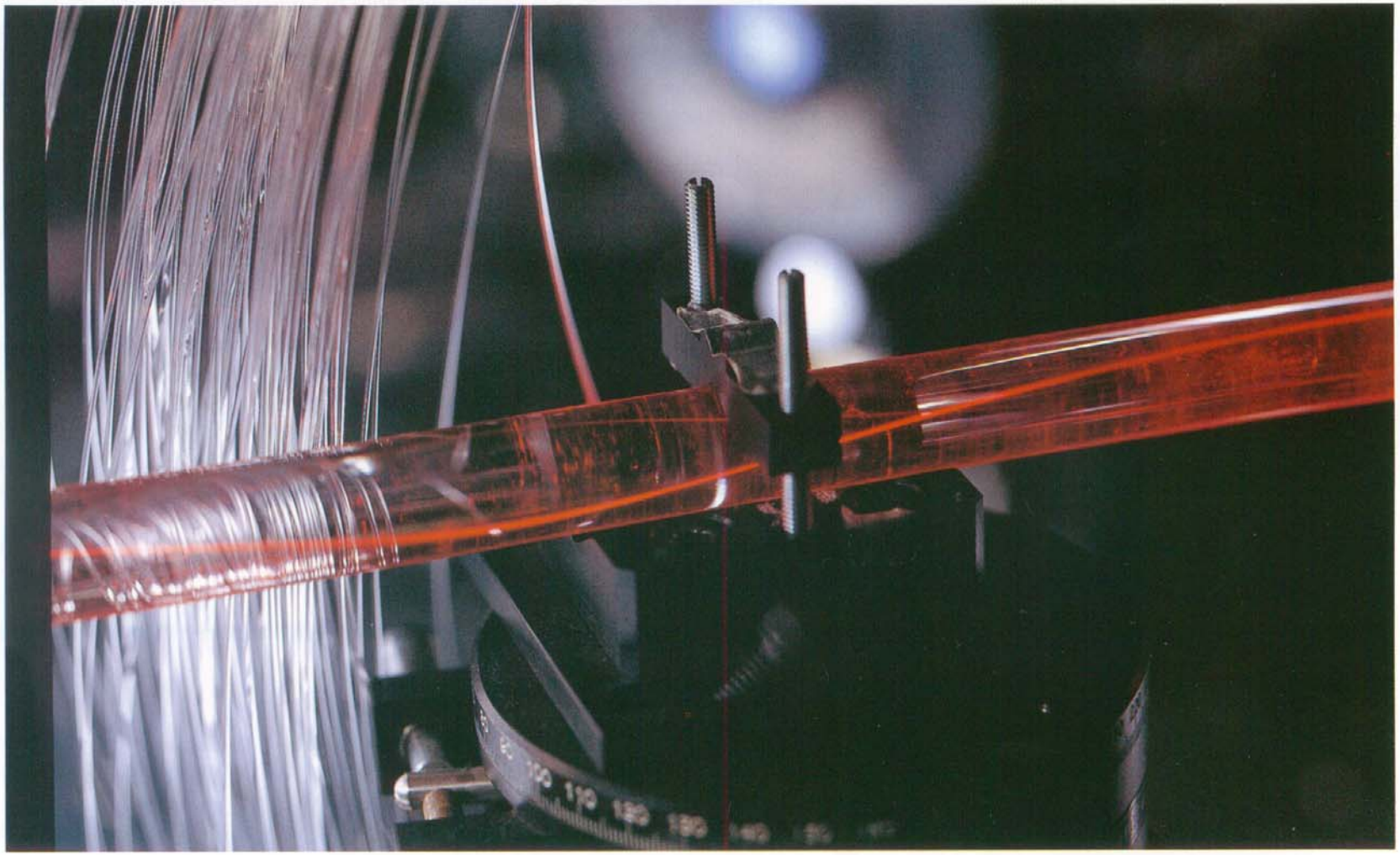
Highly Scattering Optical Transmission (HSOT) Polymer

High Speed Graded-Index Polymer Optical Fiber

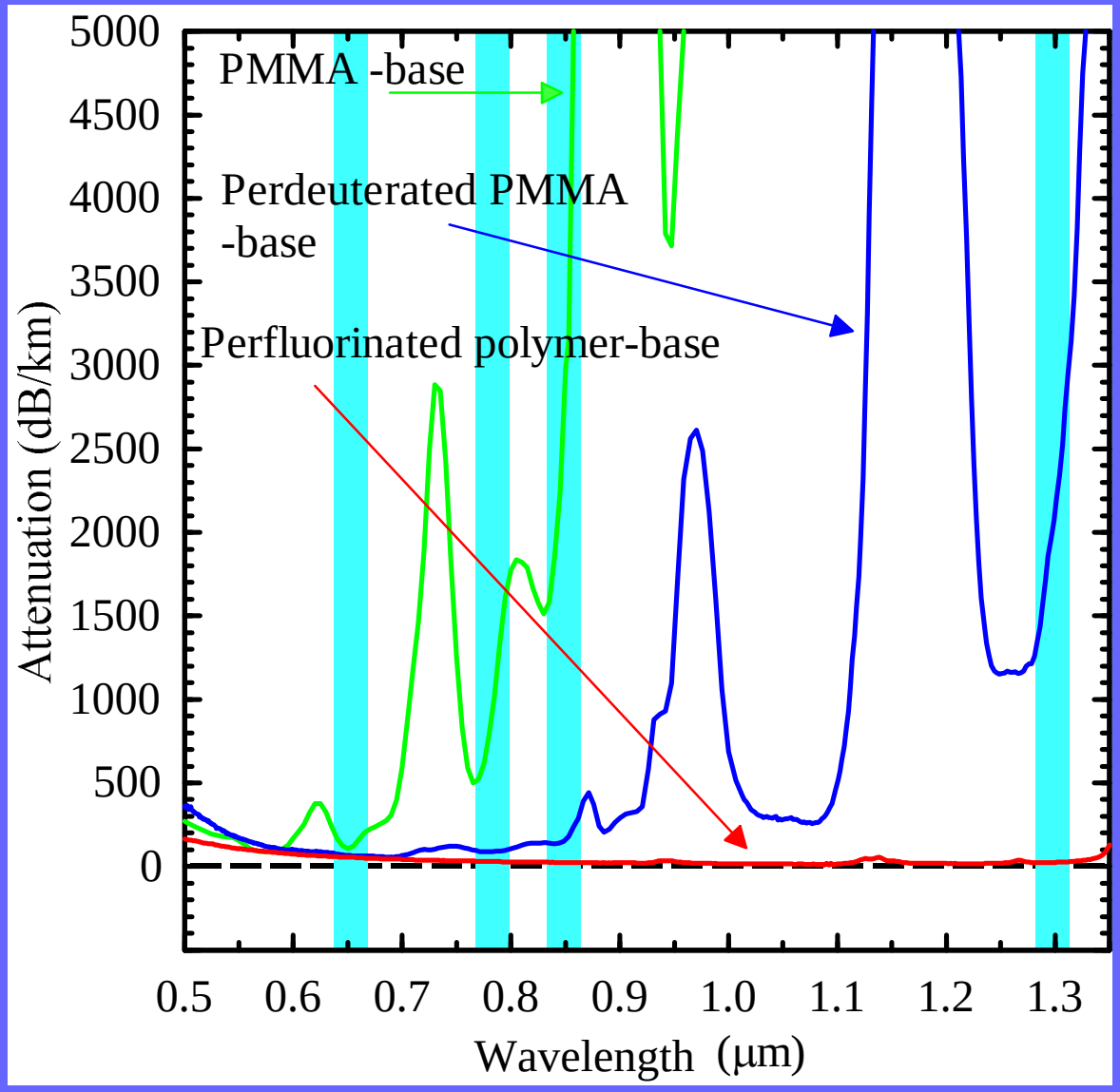




Comparison of Step-Index Plastic Optical Fiber (SI POF) and Graded-Index Plastic Optical Fiber (GI-POF).



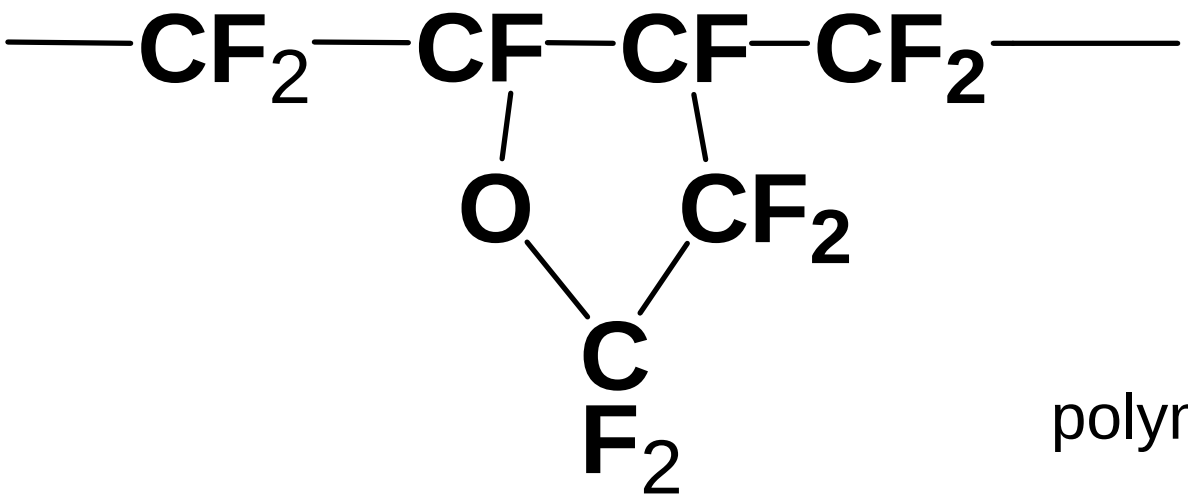
High-Speed GI Plastic Optical Fiber



Total Attenuation Spectra of GI POFs.

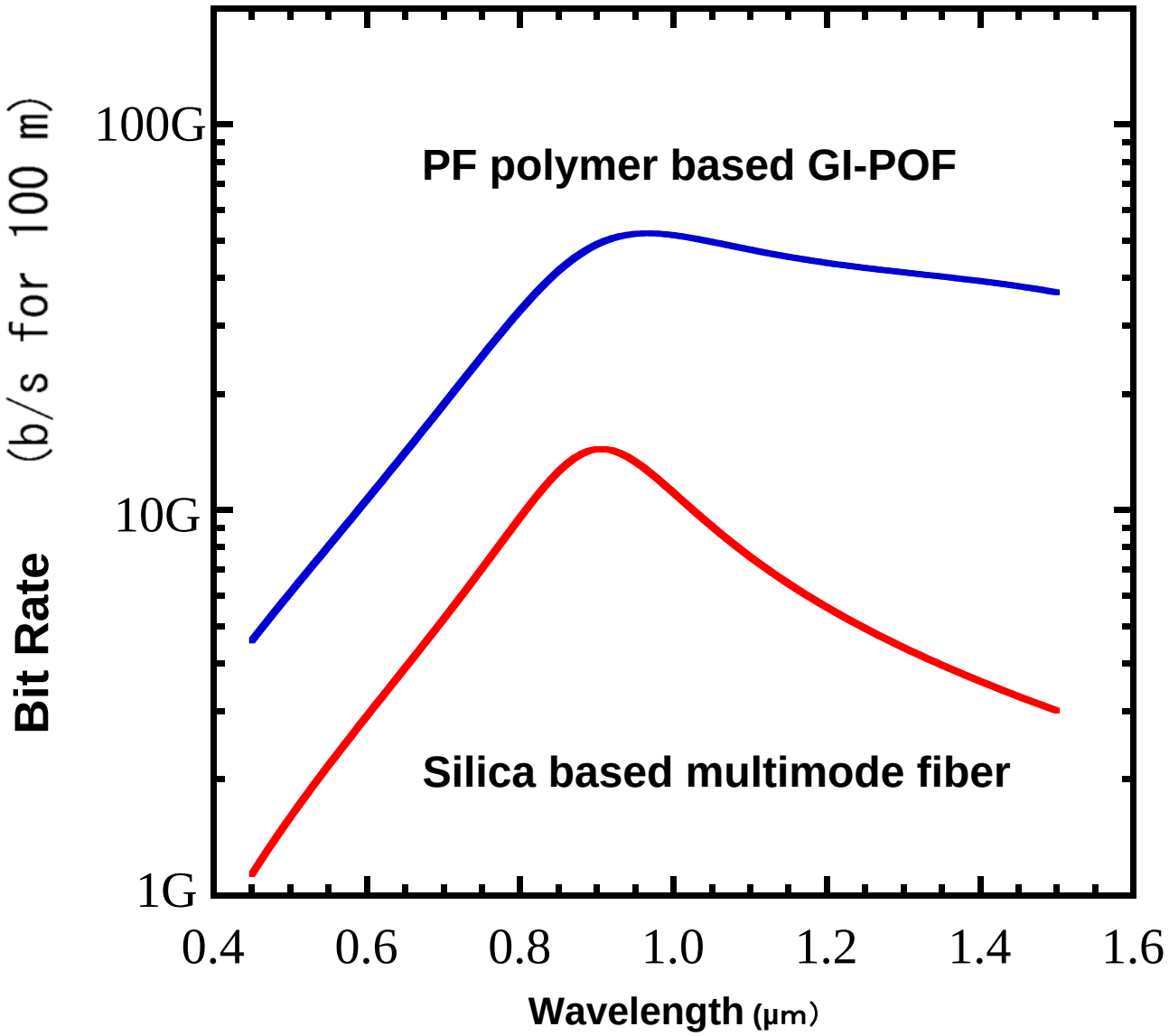
CYTOP(Perfluoro butenyl vinyl ether)
-Asahi Glass Co.-

The material for commercial GI-POF (Lucina)
Tg: ～108℃



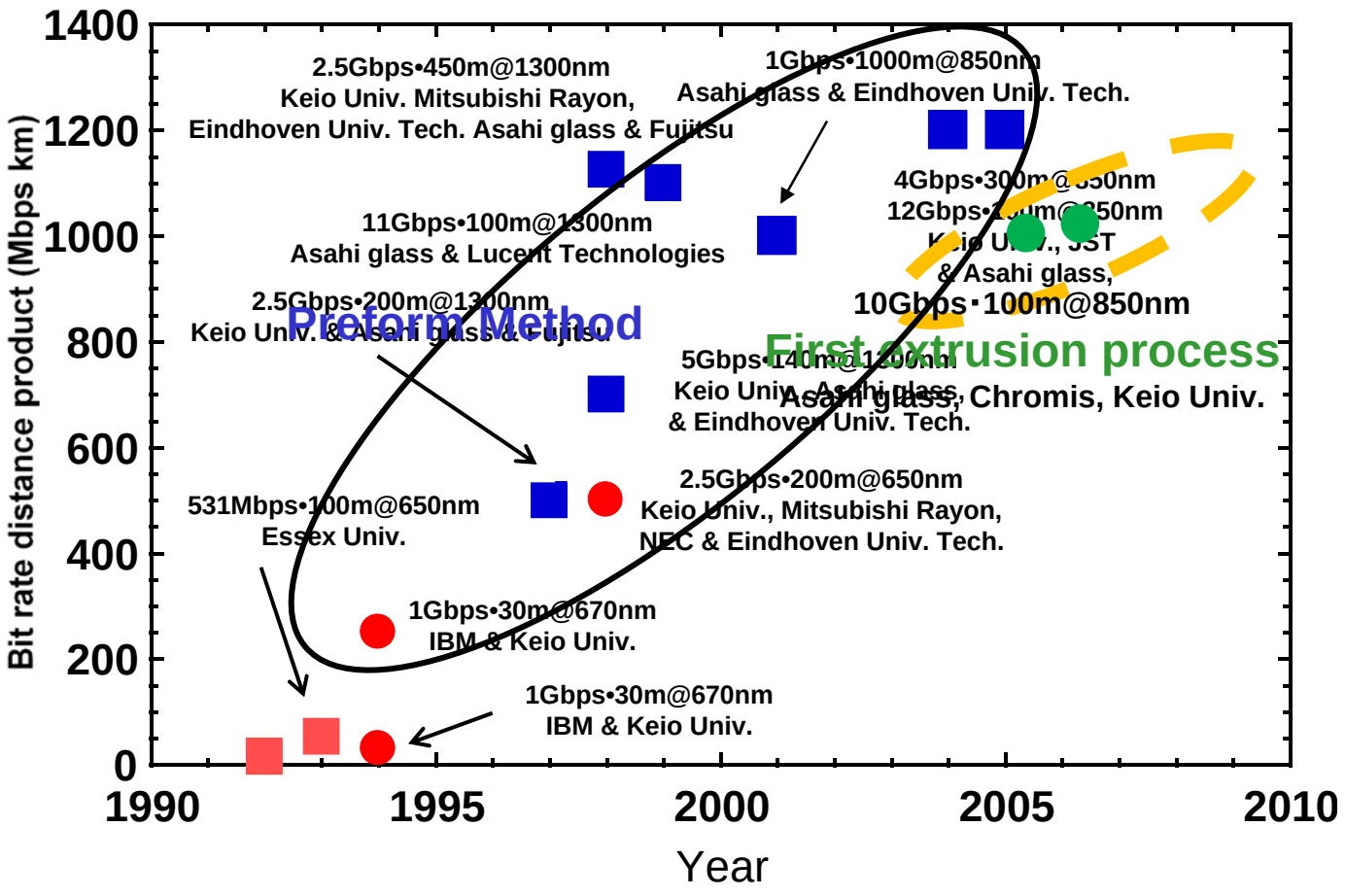
polymer

$F_2C{=}CF{-}O{-}CF_2{-}CF_2{-}CF{=}CF_2$ monomer



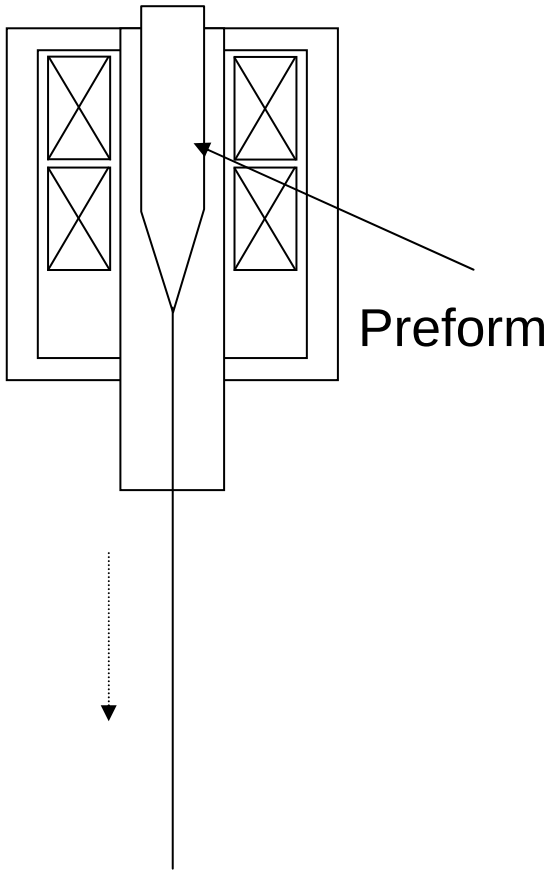
Calculated bandwidth potential of PF polymer based GI-POF compared with that of silica based MMF.

Development of data rate achieved by POF links

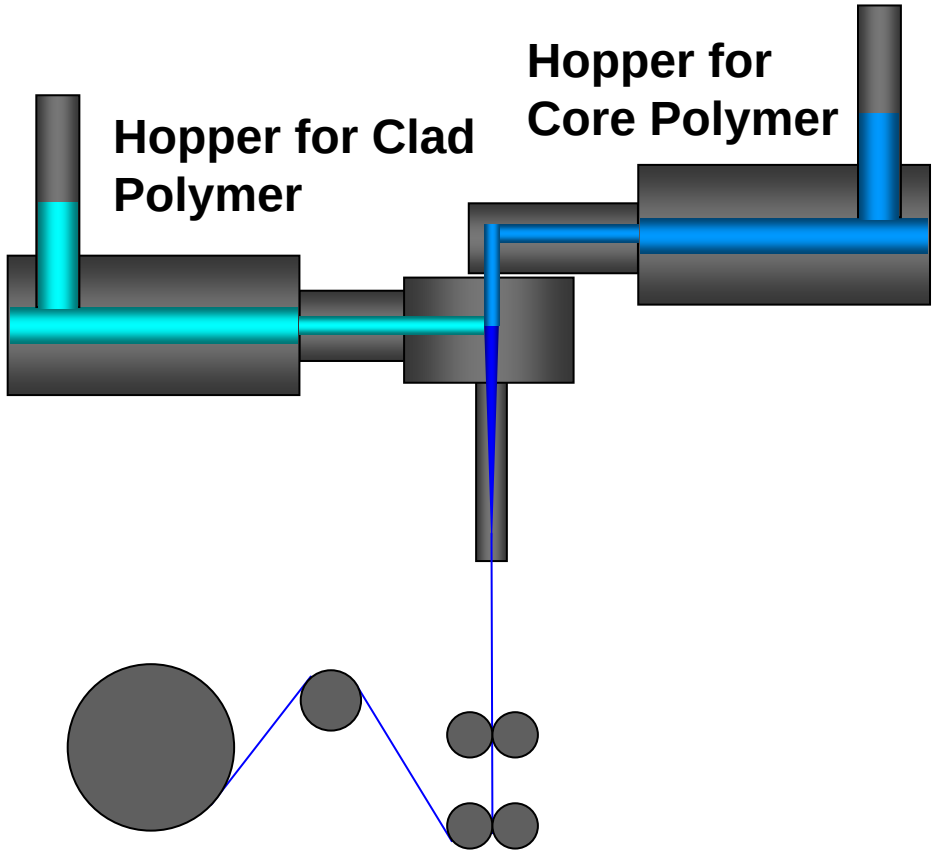


R&D Project of Polymer Devices for Constructing Next-Generation FTTH (METI, 2004-2006)

Preform Method



Extrusion Process



A New Co-Extrusion Tower

Hopper for Core and Clad Polymer

Diffusion Zone

Control Panel

Correlation Length

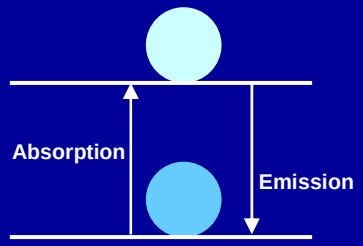
Å (10^{-10}) nm (10^{-9}) μm (10^{-6}) mm (10^{-3})

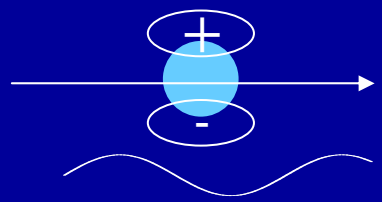
Absorption Emission

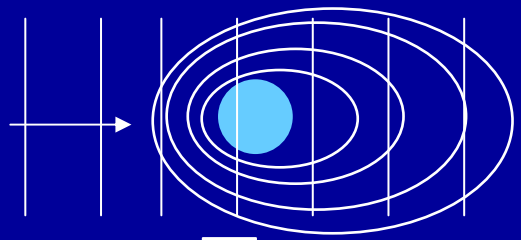
Polarization

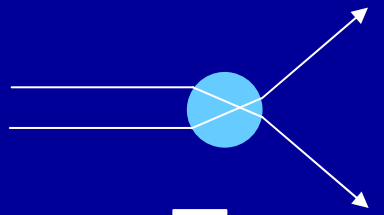
Scattering

Refraction Reflection









High-Power Optical Fiber Amplifier and Laser

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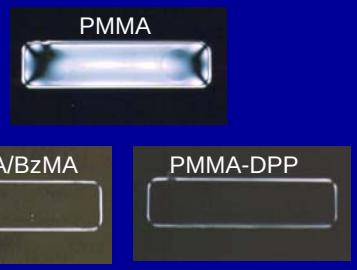
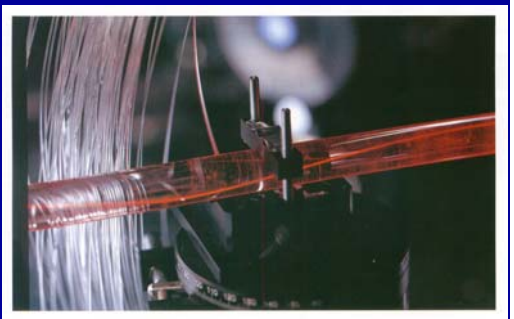


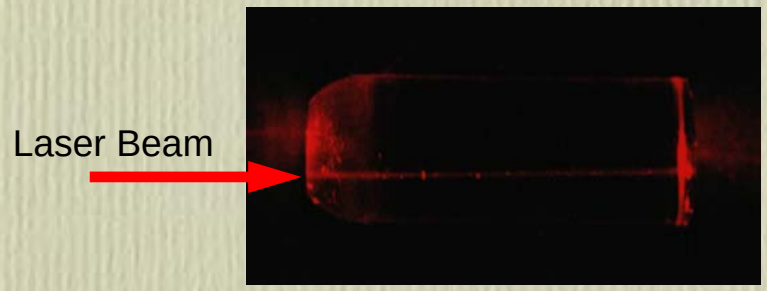
Highly Scattering Optical Transmission (HSOT) Polymer

High Speed Graded-Index Polymer Optical Fiber

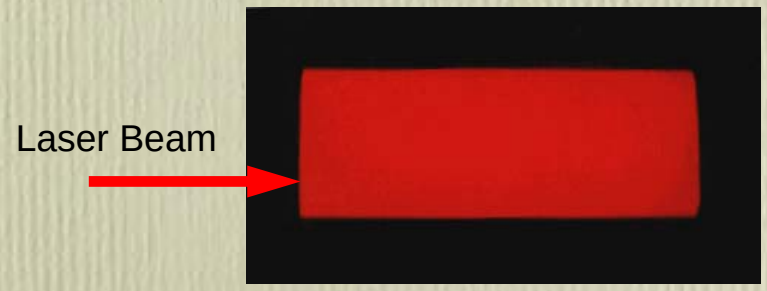


Proposal of Highly Scattered Optical Transmission (HSOT) Polymer

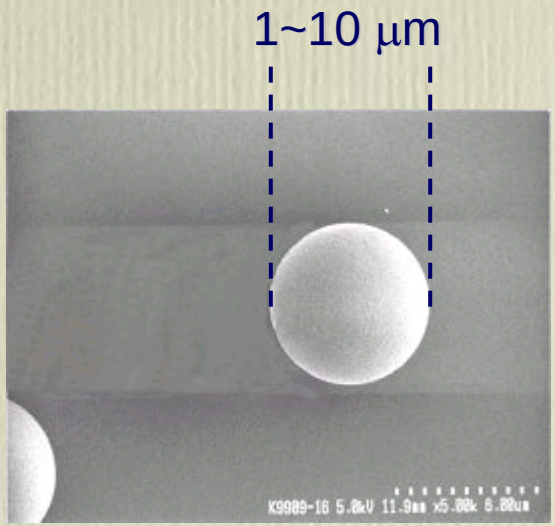
Highly Scattering Optical Transmission (HSOT) Polymer



(A) PMMA



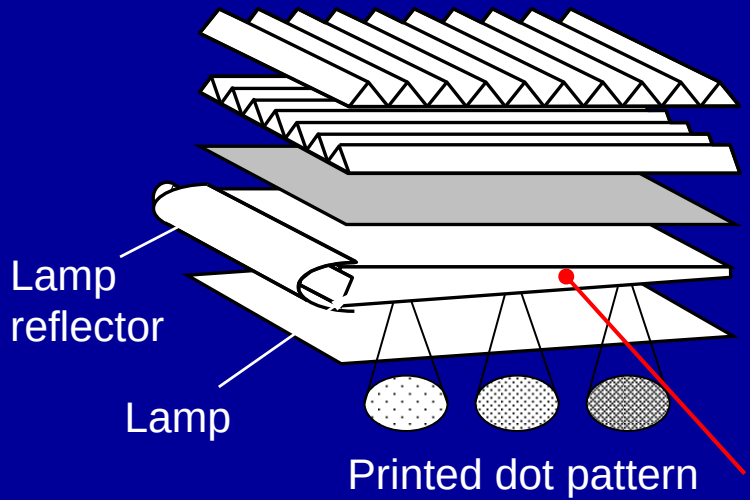
(B) HSOT polymer

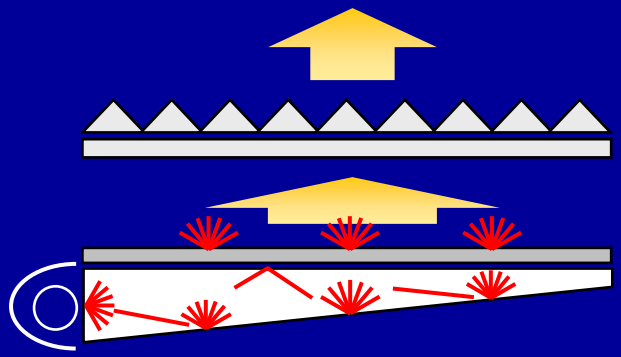


Scatterers

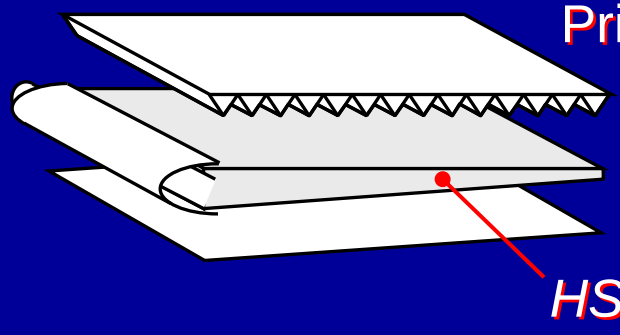
(FIG.1.1, p.11)

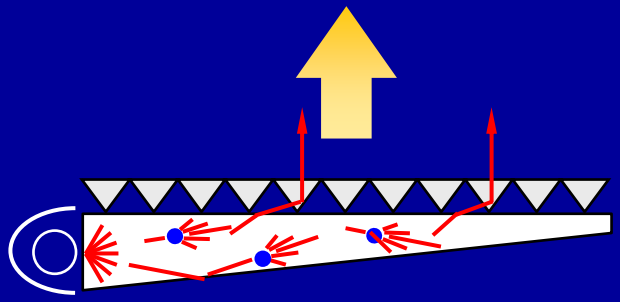
(A) Conventional backlighting system



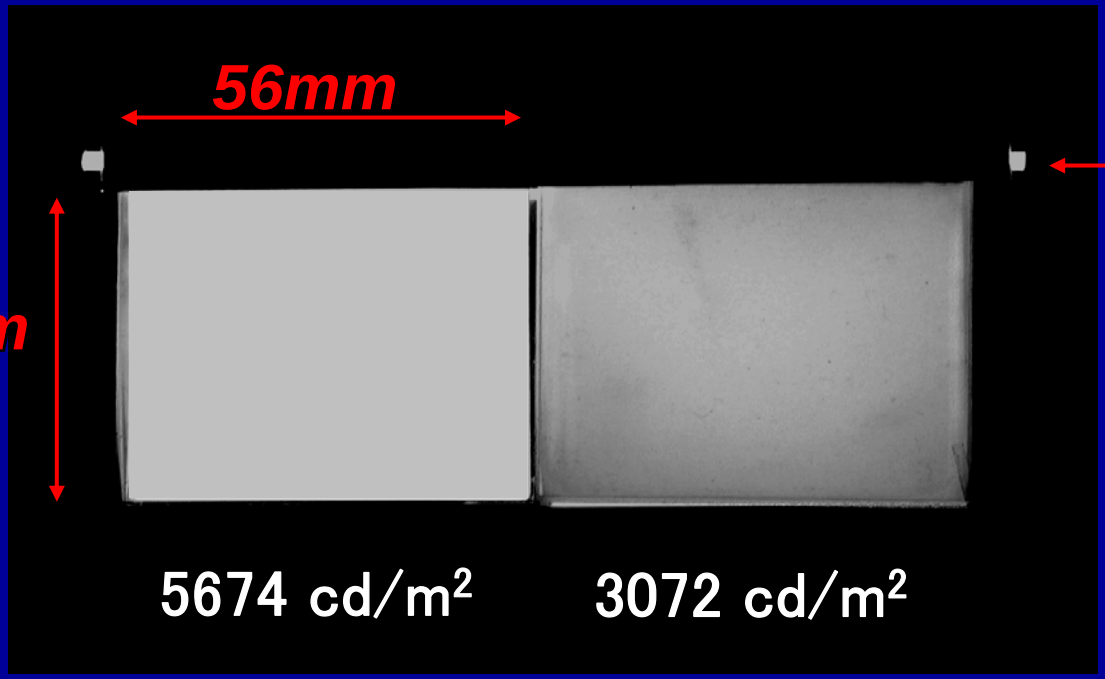


(B) HSOT backlighting system





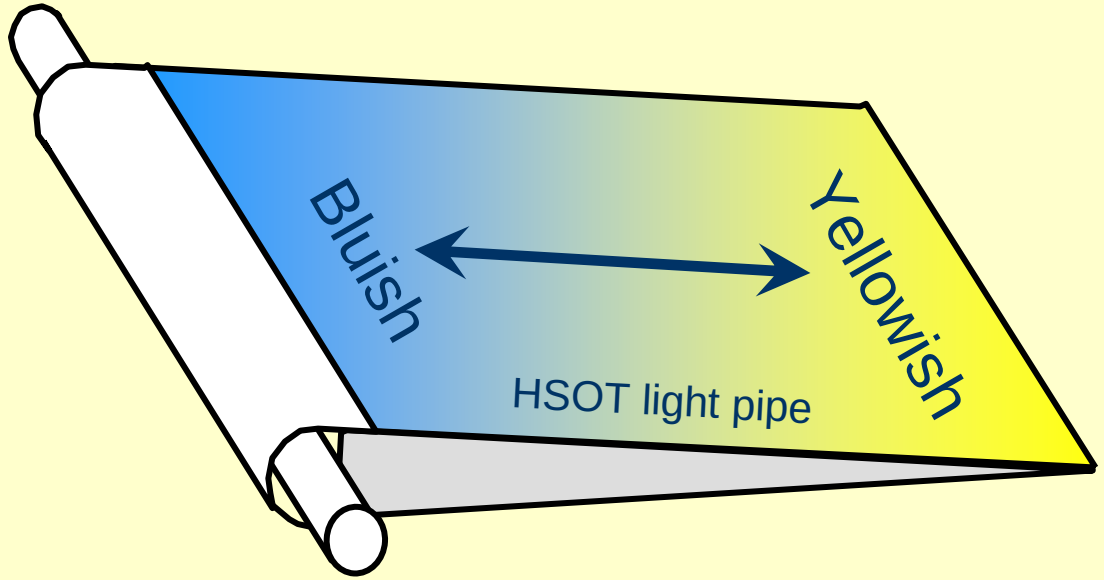
HSOT and conventional backlights



HSOT backlight

Conventional backlight

Is General Concept of Light Scattering Always True?



Color dispersion due to general light scattering phenomenon

Photograph of Sunset

Mie scattering theory

$$I(\alpha,\theta) = \lambda^2 \left(i_1 + i_2\right) / 8\pi^2$$

$$K(\alpha) = \frac{2}{\alpha^2} \sum_{n=1}^{\infty} (2n+1)\left(|a_n|^2 + |b_n|^2\right)$$

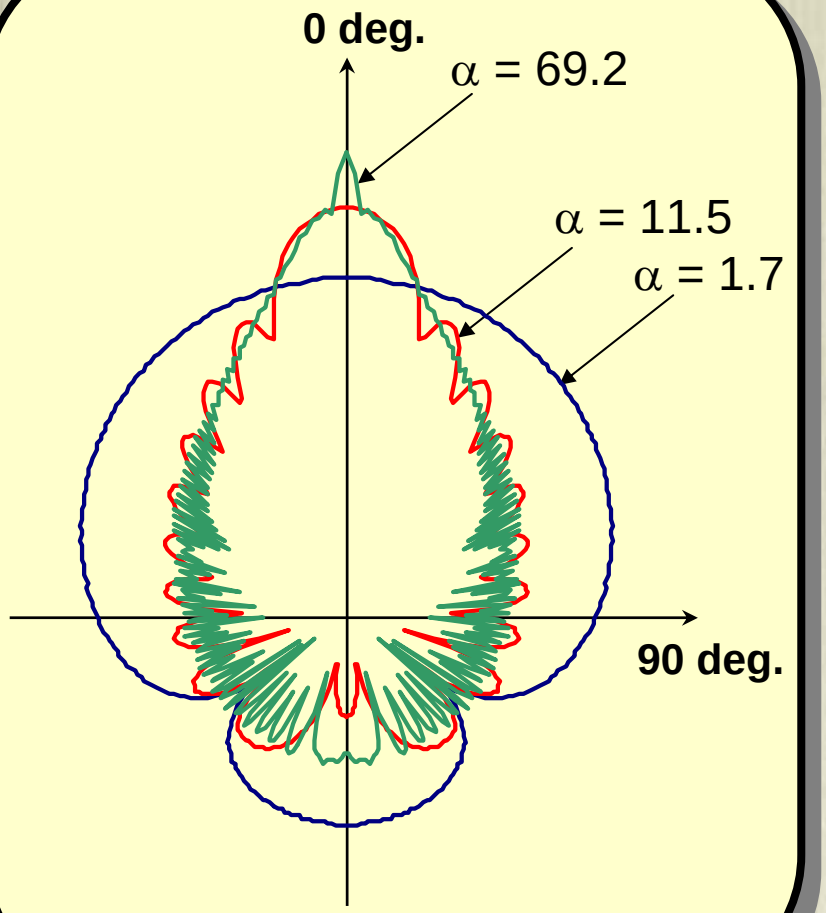
$$a_n = \frac{\psi_n(\alpha)\psi_n'(m\alpha) - m\psi_n(m\alpha)\psi_n'(\alpha)}{\zeta_n(\alpha)\psi_n'(m\alpha) - m\psi_n(m\alpha)\zeta_n'(\alpha)}$$

$$b_n = \frac{m\psi_n(\alpha)\psi_n'(m\alpha) - \psi_n(m\alpha)\psi_n'(\alpha)}{m\zeta_n(\alpha)\psi_n'(m\alpha) - \psi_n(m\alpha)\zeta_n'(\alpha)}$$

$$i_1 = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} \left\{ a_n \frac{P_n^{(1)}(\cos\theta)}{\sin\theta} + b_n \frac{dP_n^{(1)}(\cos\theta)}{d\theta} \right\} \right|^2$$

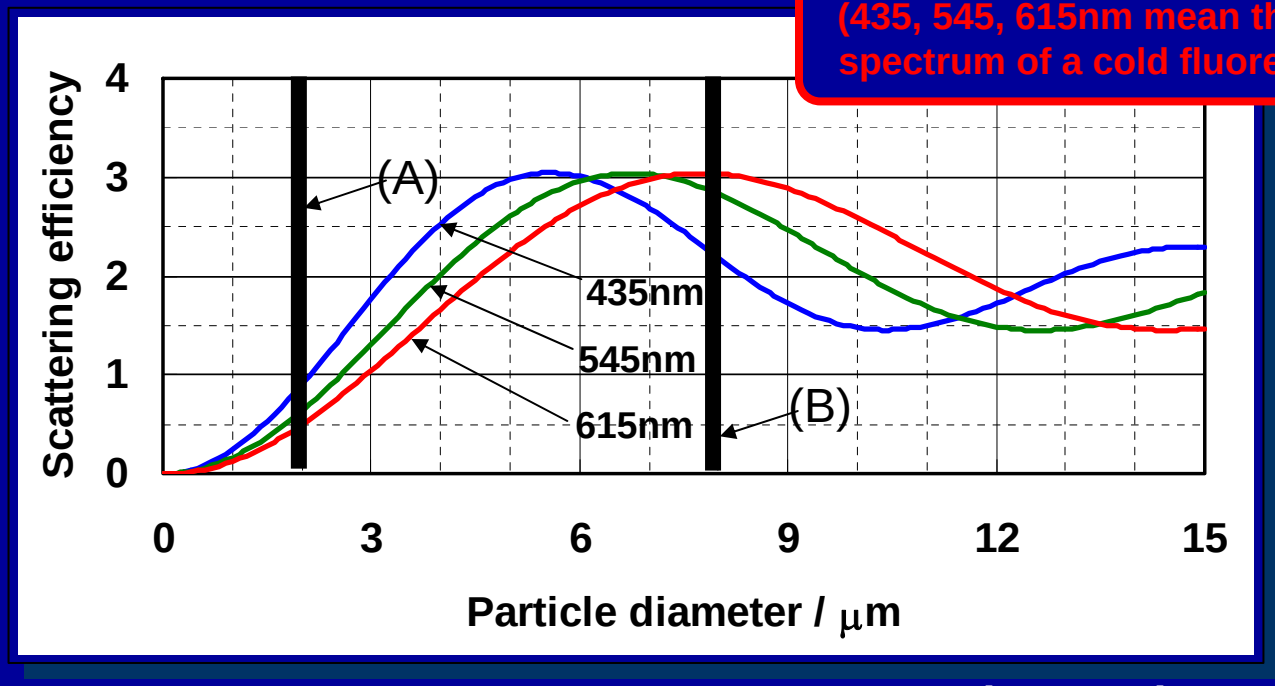
$$i_2 = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} \left\{ b_n \frac{P_n^{(1)}(\cos\theta)}{\sin\theta} + a_n \frac{dP_n^{(1)}(\cos\theta)}{d\theta} \right\} \right|^2$$

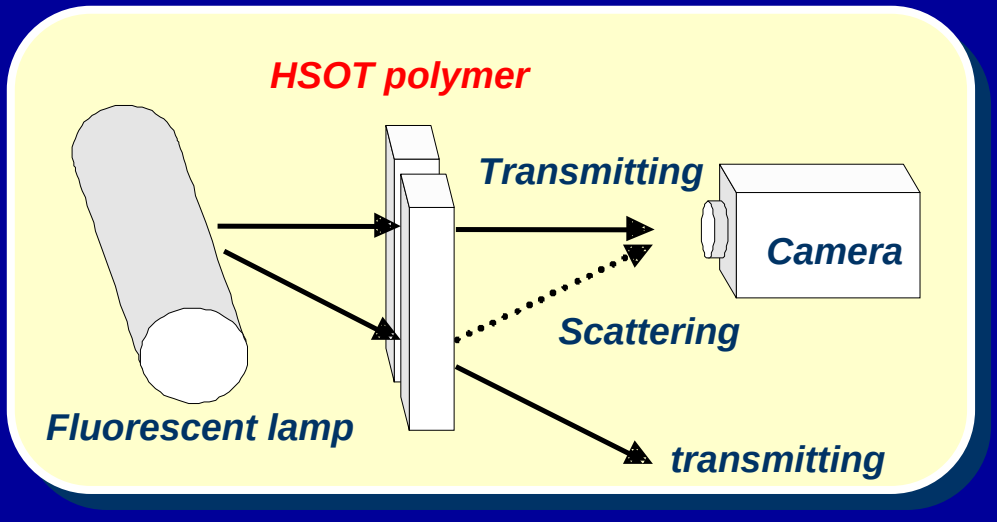
$$\alpha = 2\pi r / \lambda$$



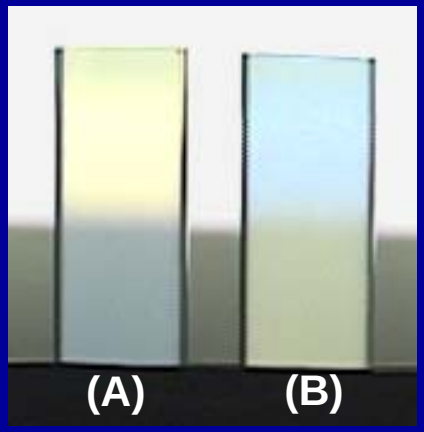
Scattering Efficiency

(435, 545, 615nm mean three peaks in spectrum of a cold fluorescent lamp.)

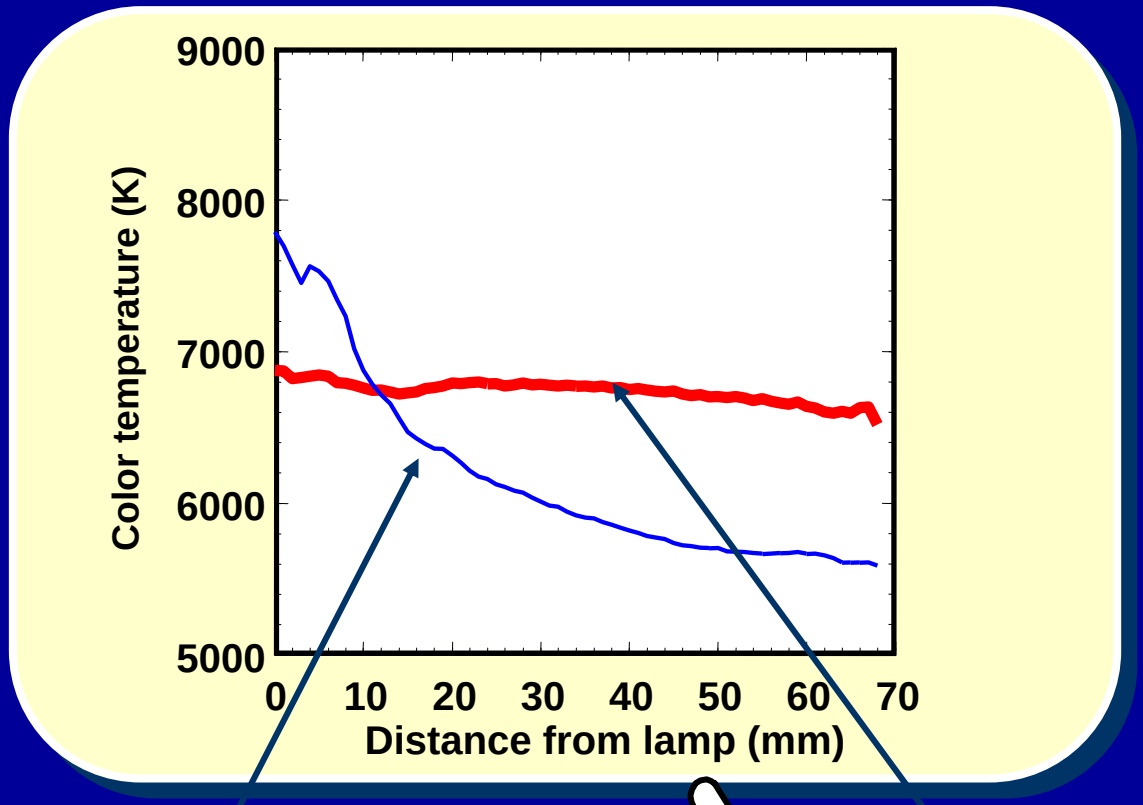


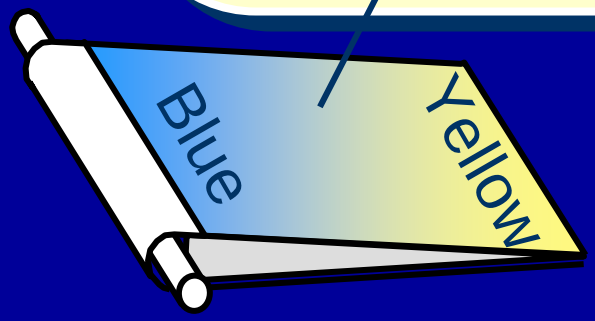


Observation result

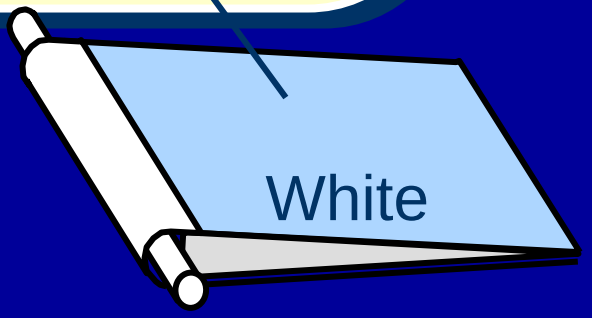


Color Dispersion on HSOT Backlights





Not optimized HSOT



Optimized HSOT

HSOT Polymer Products

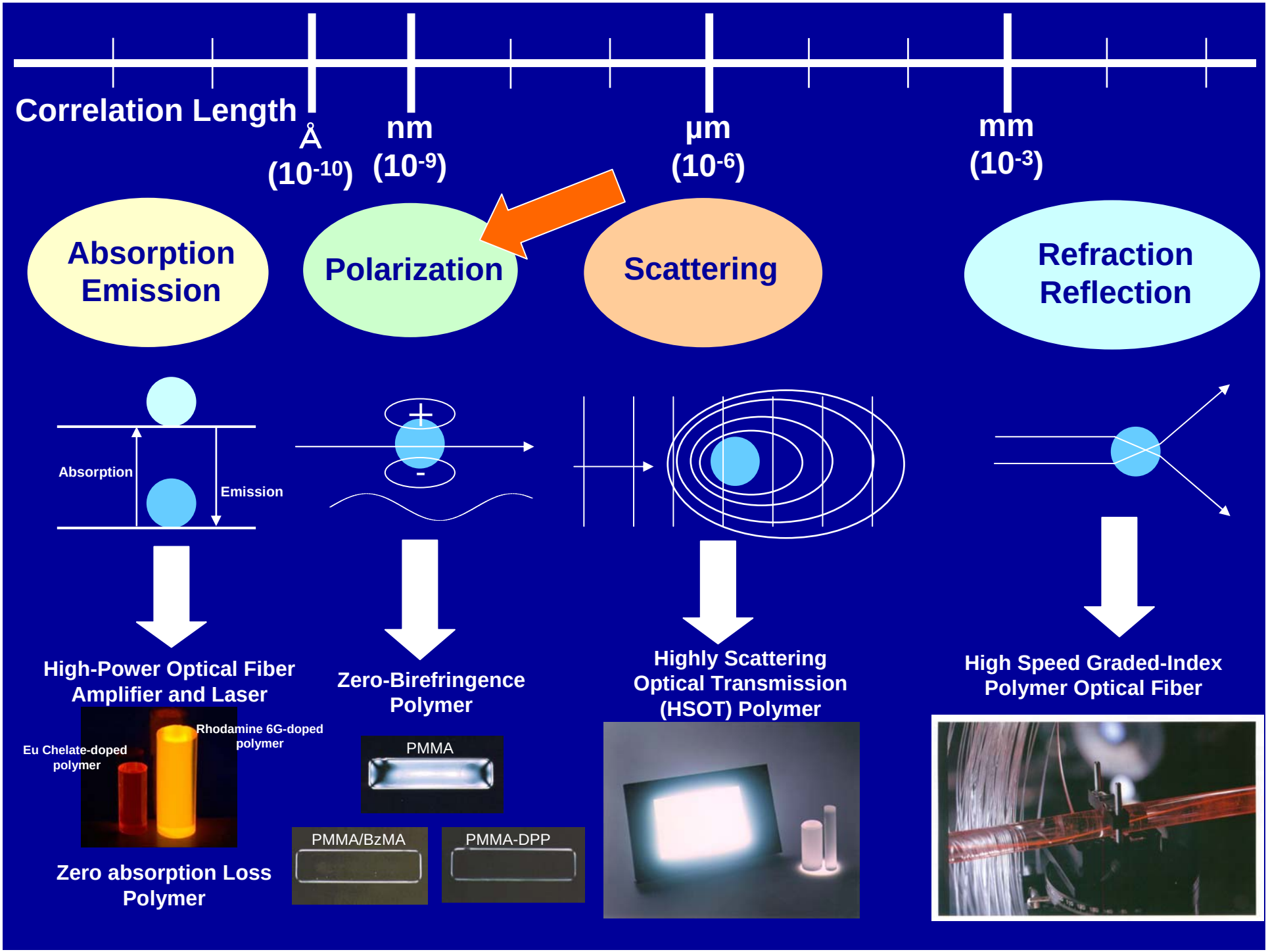
Notebook PCs

SONY Vaio Note series
Panasonic Let's Note series
TOSHIBA Dynabook series
Samsung, Dell etc.

Various Mobile Devices

Mobile phones
PDA
Pocket TV


Light Guide for LCD-TV
FUJIFILM
Light Guide for LCD TV
FUJIFILM
Novel Transparent Conductive Film
New technology combined with the Shield Rex film for PDP
Features
1.Ultra High Conductivity: Surface resistance 0.3Ω/□.
2.High Flexibility: Stable conductivity even after repeated bendin
(4mmφ, bend test 100 times.)
3.High Transparency: Transparency over 80%.
4.Seamless Pattern: Seamless/Continuous fine conductive line pat
Current Shield Rex Film
New Film
Do NOT Touch!
FUJIFILM

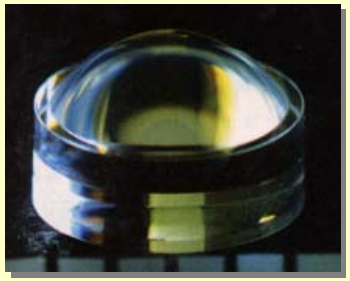

Correlation Length
Å
(10-10)
nm
(10-9)
μm
(10-6)
mm
(10-3)
Absorption
Emission
Polarization
Scattering
Refraction
Reflection
Absorption
Emission
+
-
High-Power Optical Fiber
Amplifier and Laser
Rhodamine 6G-doped
polymer
Eu Chelate-doped
polymer
Zero absorption Loss
Polymer
Zero-Birefringence
Polymer
PMMA
PMMA/BzMA
PMMA-DPP
Highly Scattering
Optical Transmission
(HSOT) Polymer
High Speed Graded-Index
Polymer Optical Fiber

Advantage of zero-birefringence optical polymers

Flexibility
Light weight
Low cost

⟺

Birefringence

- ***Solvent Casting*** ･･･Low birefringence, **High cost.**

Zero-birefringence polymers

- ***Extrusion processing*** ･･･High speed, Low cost and zero-birefringence.

Changing in polarization state through a birefringent medium

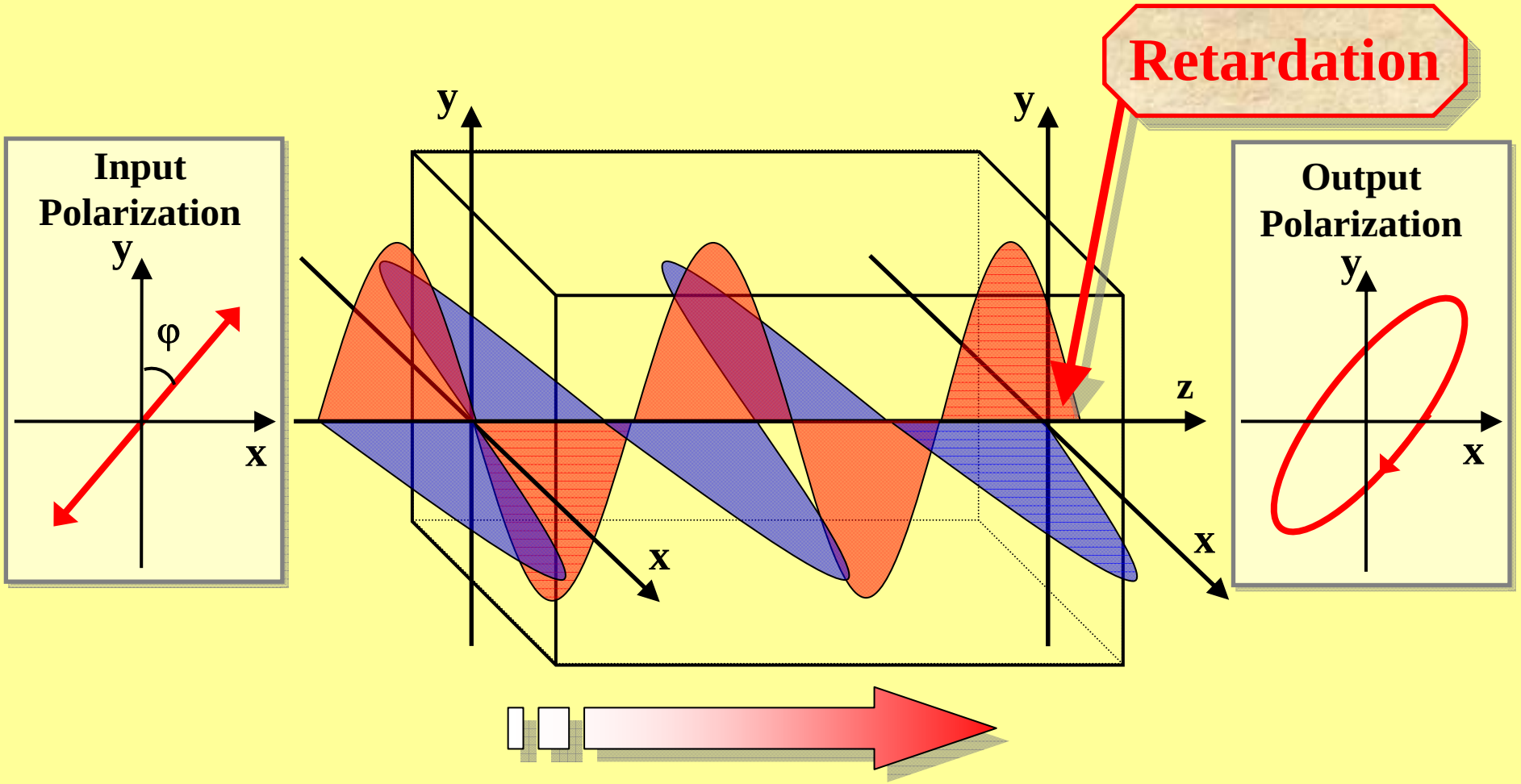


Figure Polarization property in a birefringent medium.

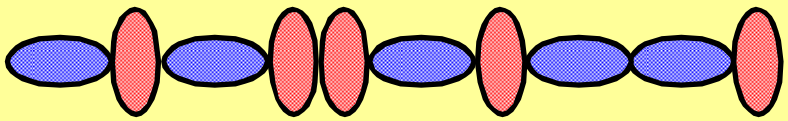
Our proposal of compensating orientational birefringence of polymers

Random copolymerization method

Positive (+) birefringence monomer

Negative(-) birefringence monomer

Random copolymerization



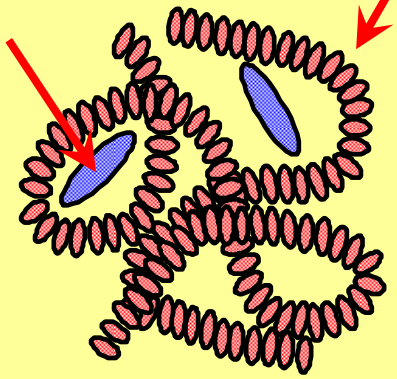
Zero-birefringence copolymer

MMA / BzMA = 82 / 18 (wt./wt.)

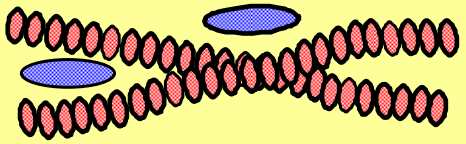
Anisotropic molecule dopant method

Polarizability ellipsoid of anisotropic molecule

Polarizability ellipsoid of monomer unit

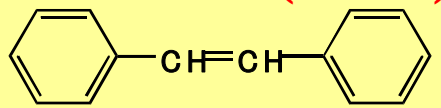


Drawing

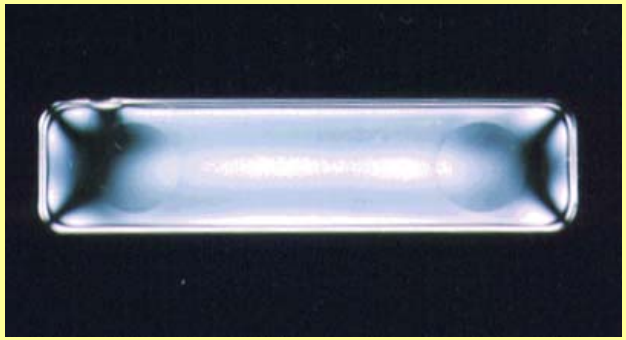


MMA / *trans*-stilbene = 100 / 3 (wt./wt.)

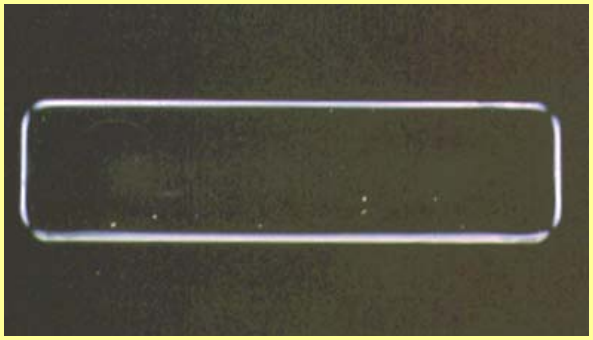
Typical dopant



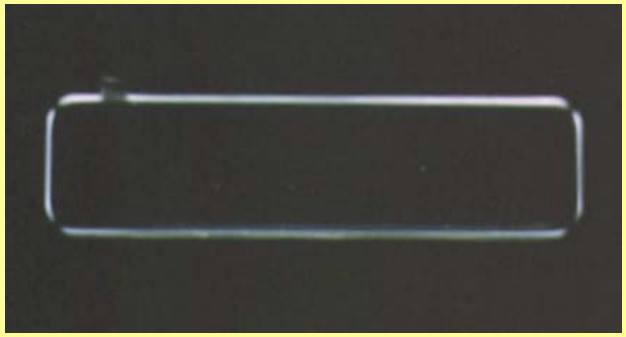
Injection molded samples



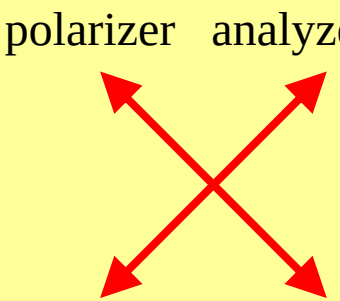
(a) PMMA



(b) MMA/BzMA=82/18 (wt./wt.)



(c) PMMA-*trans*-stilbene (3 wt.%)



Photoelastic Birefringence

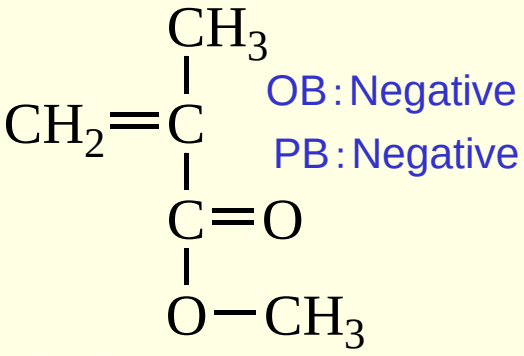
$$\Delta n = n_{//} - n_{\perp} = c \cdot \Delta \sigma$$

c : Photoelastic Coefficient

$\Delta \sigma$: Stress

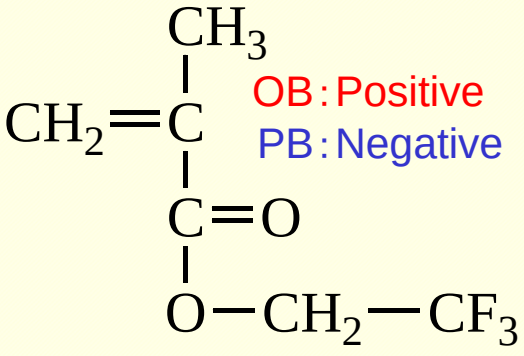
Components of Zero-Zero Polymers

Monomers



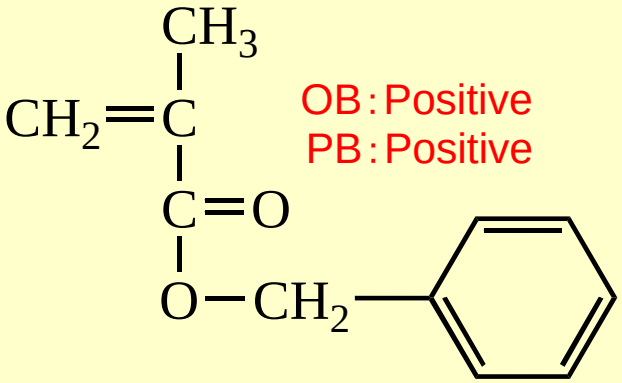
OB : Negative
PB : Negative

Methyl methacrylate (MMA)



OB : Positive
PB : Negative

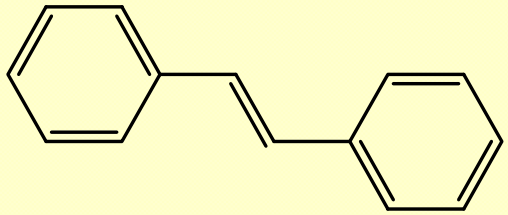
2,2,2-Trifluoroethyl methacrylate (3FMA)



OB : Positive
PB : Positive

Benzyl methacrylate (BzMA)

Anisotropic Dopant



OB : Positive
PB : Positive

trans-stilbene

Ternary Copolymers

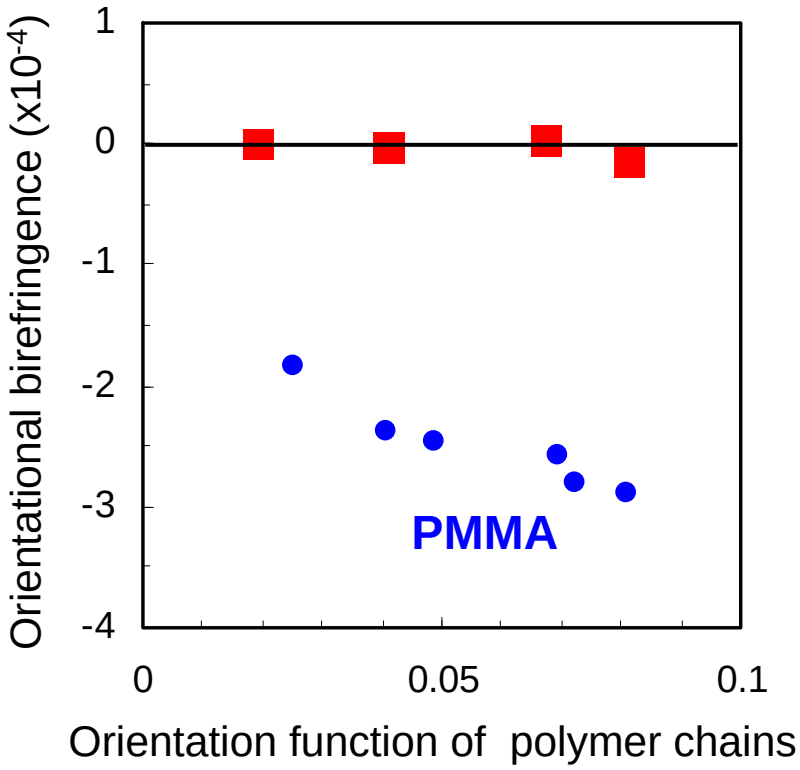
OB: Orientational Birefringence

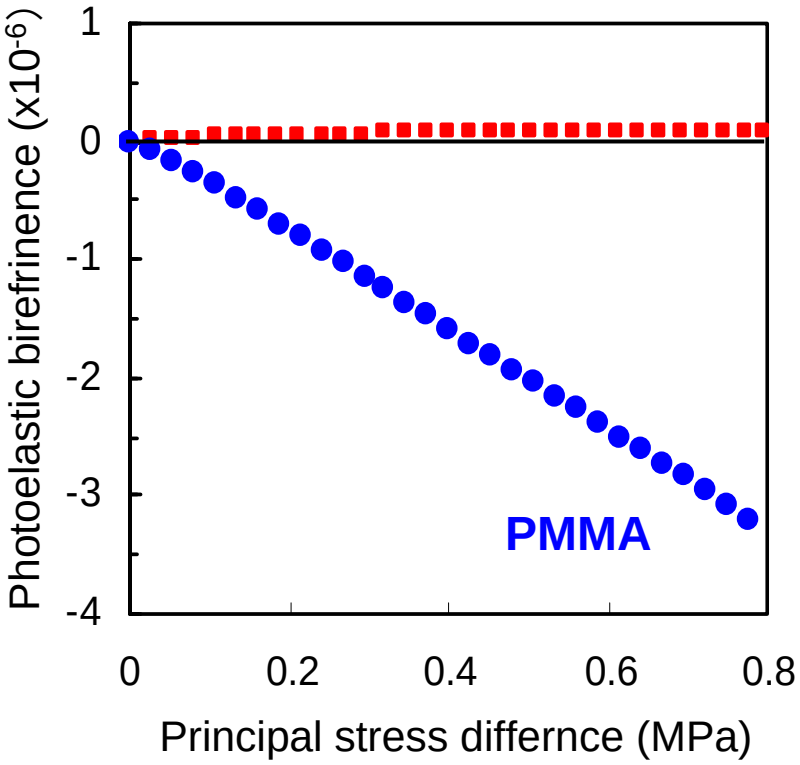
PB: Photoelastic Birefringence

Binary Copolymers Containing an Anisotropic Dopant

Birefringence of Binary Copolymers Containing an Anisotropic Dopant

Simultaneous elimination of the orientational birefringence and photoelastic birefringence was achieved. Zero-zero polymers that exhibit no birefringence with any orientation of the polymer main chains and in elastic deformation was realized.

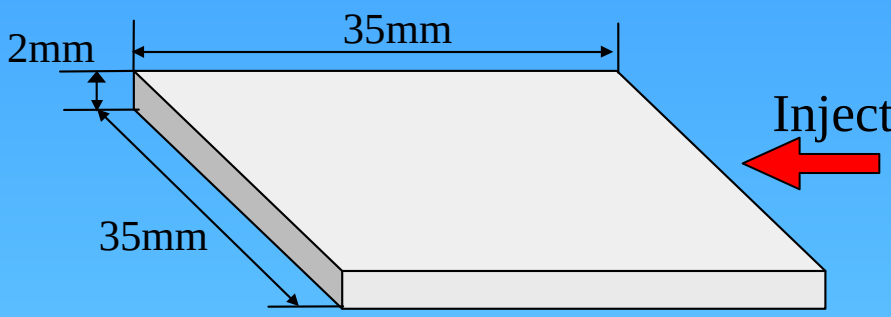




Composition of the zero-zero polymer

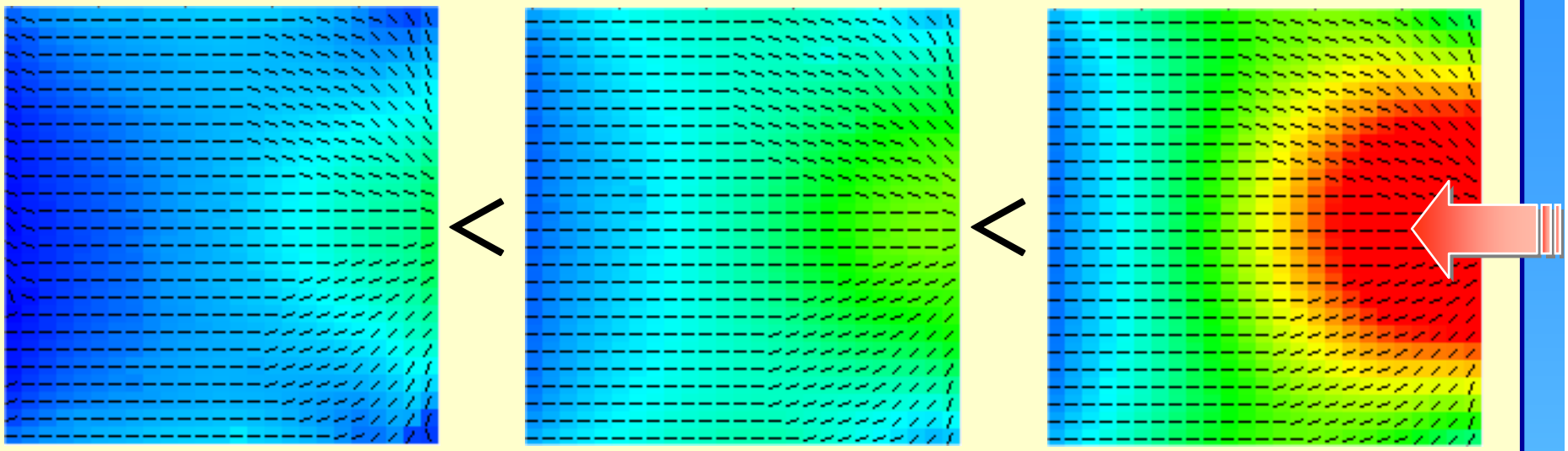
P(MMA/3FMA=85/15) + *trans*-stilbene 2.8 wt%

Injection Molding



Injection

Injection Molded Samples of Binary Copolymer



(a) 230 ˚C

Re_{ave} = 2.4 (nm)

(b) 220 ˚C

Re_{ave} = 4.7 (nm)

(c) 210 ˚C

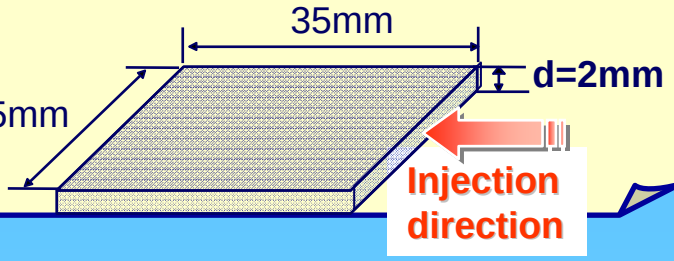
Re_{ave} = 9.1 (nm)

Re (nm)

0 7.5 15

Re = Δn x d (= 2mm)

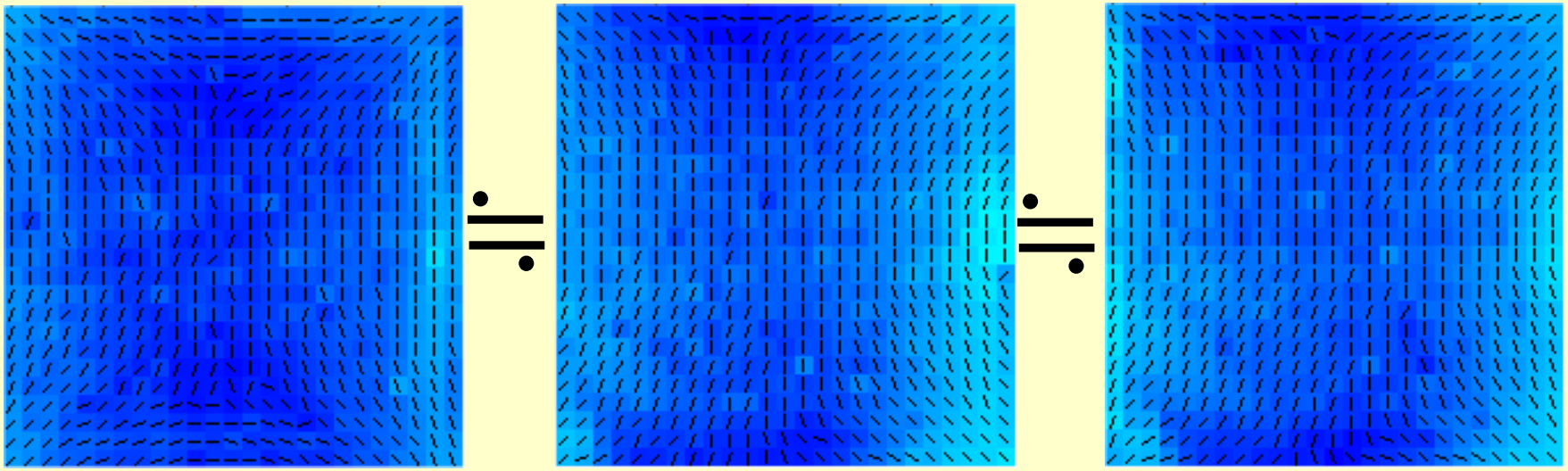
／, ＼, —, | : Fast axes



P(MMA/BzMA = 92/8)

Orientational birefringence increased with a decrease in molding temperature. The directions of fast axes were parallel to injection direction.

Injection Molded Samples of the Ternary Copolymer



(a) 230 ˚C

Re_{ave} = 0.4 (nm)

(b) 210 ˚C

Re_{ave} = 0.5 (nm)

(c) 190 ˚C

Re_{ave} = 0.5 (nm)

／, ＼, —, ｜ : **Fast axes**

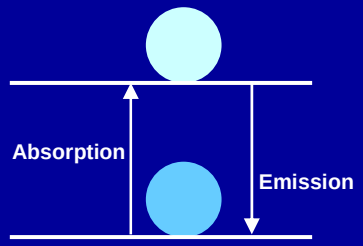
P(MMA/3FMA/BzMA = 52/42/6)

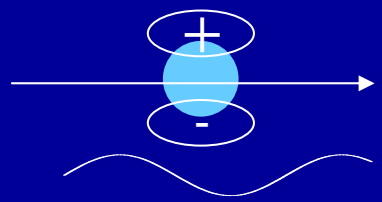
Ternary copolymer exhibited close to zero birefringence at any points regardless of molding temperature.

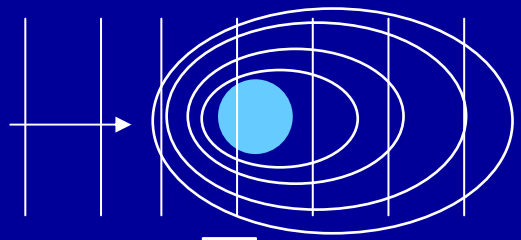
Correlation Length

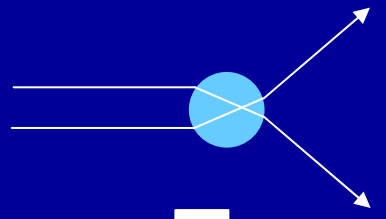
Å (10^{-10}) nm (10^{-9}) μm (10^{-6}) mm (10^{-3})

Absorption Emission | **Polarization** | **Scattering** | **Refraction Reflection**





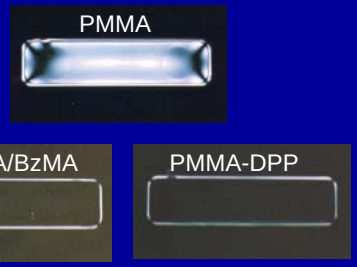




High-Power Optical Fiber Amplifier and Laser

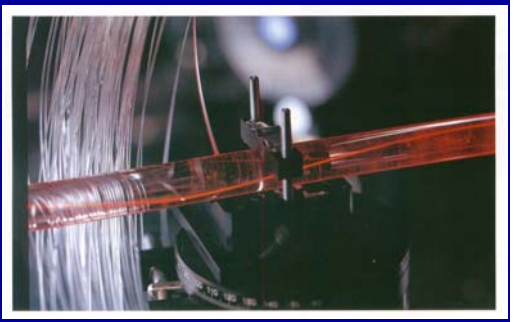
Zero absorption Loss Polymer

Zero-Birefringence Polymer

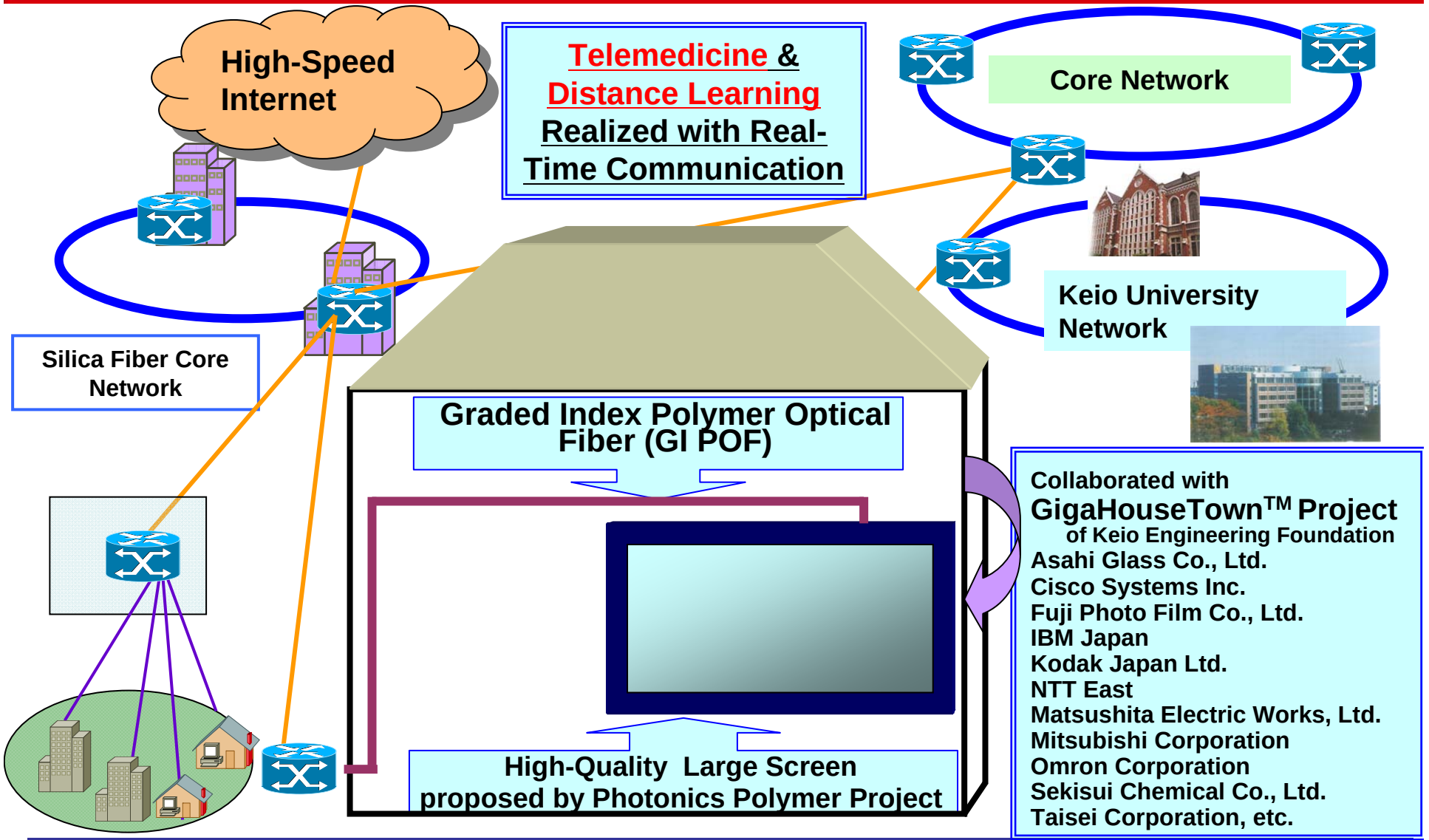


Highly Scattering Optical Transmission (HSOT) Polymer

High Speed Graded-Index Polymer Optical Fiber

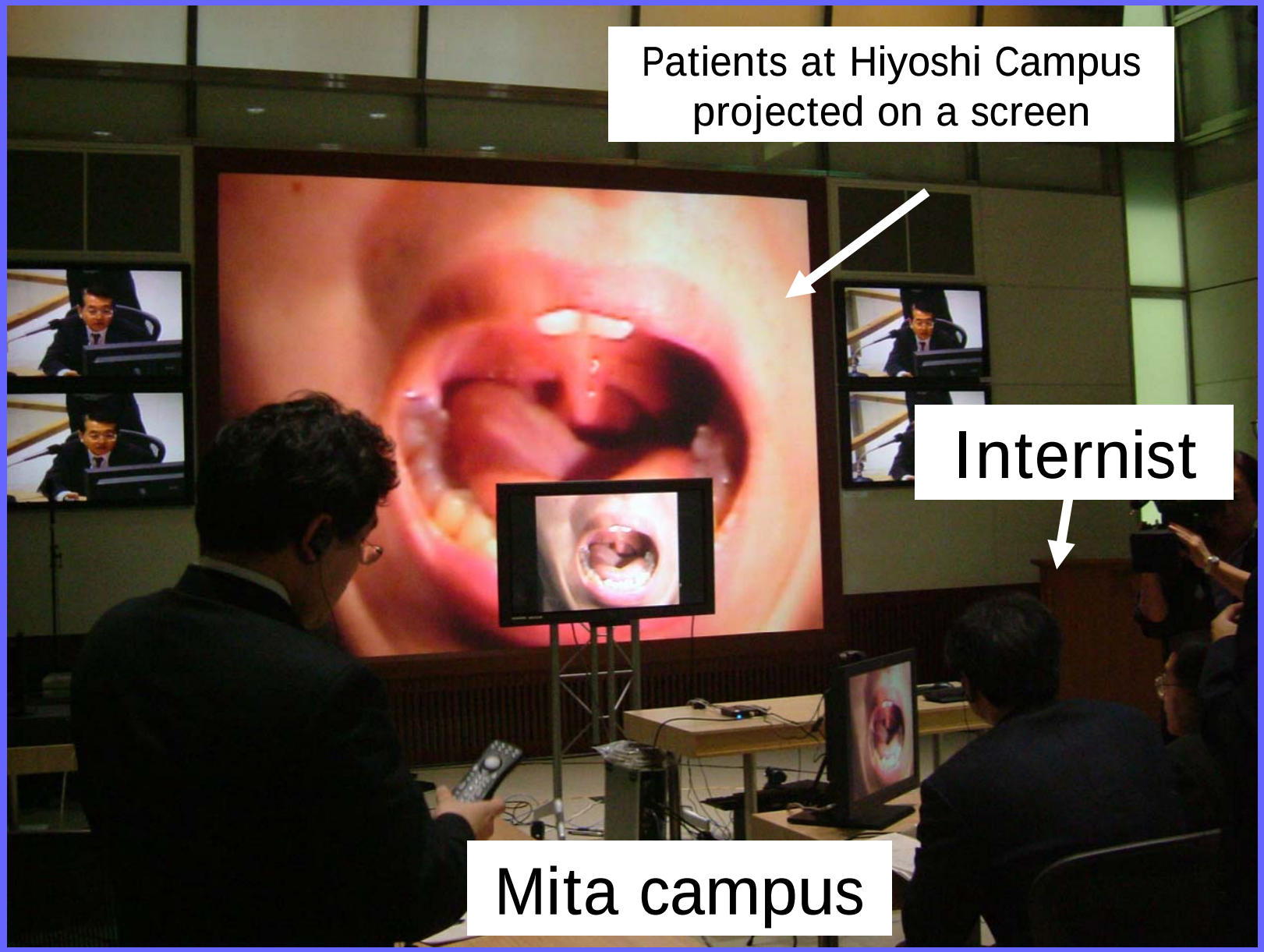


Photonics Polymer Project

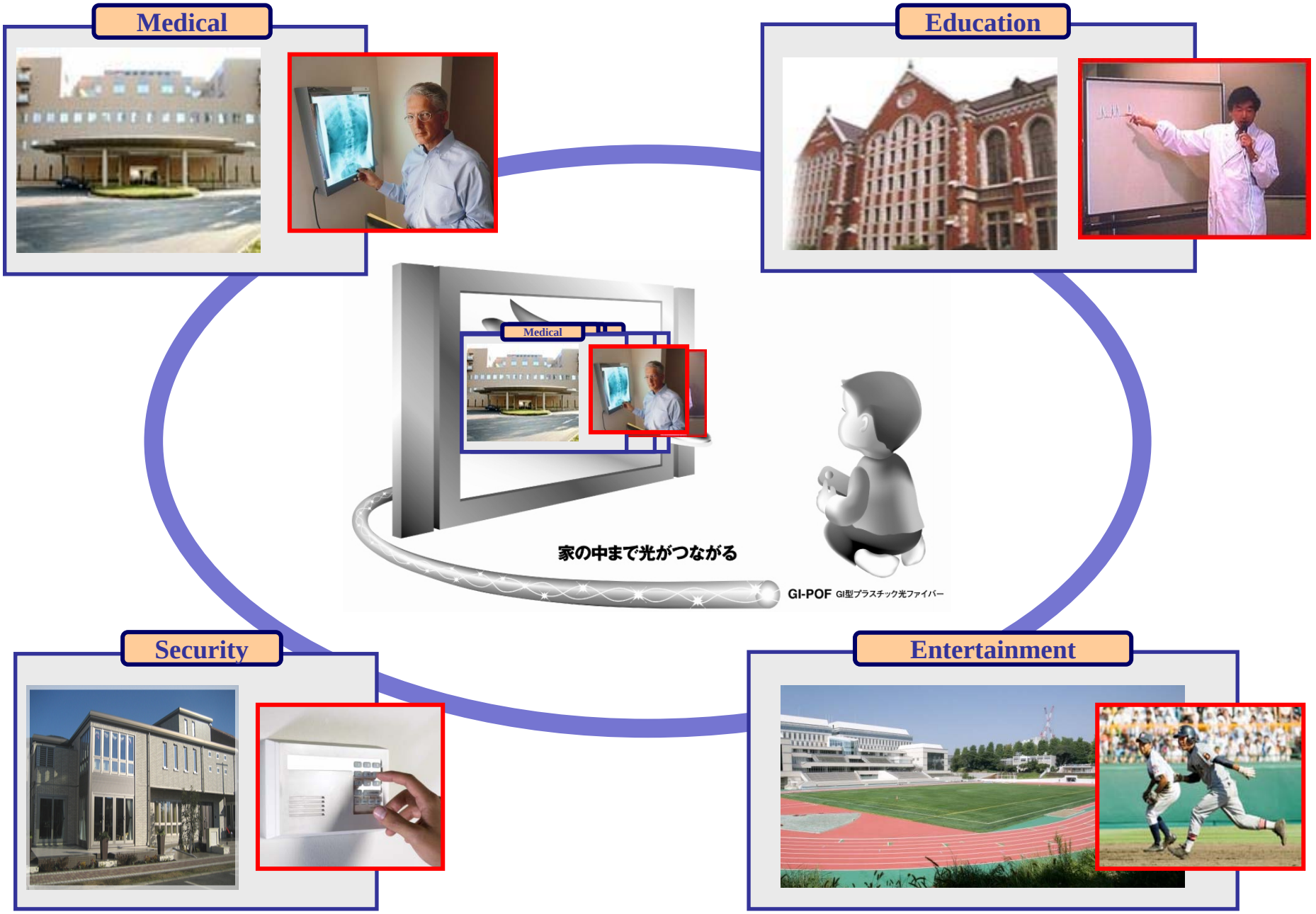


Concept of "Fiber-to-the-Display" by Photonics Polymer Project at Keio University

Telemedicine by internist



Vision of the Fiber-to-the-Display Project



Summary

- The Status of “Photonics Polymer” was reviewed , and the concept of “Fiber to the Display” was proposed.

- We believe that the innovation of giga-bit technologies based on these photonics polymers will bring us back to

“Face-to-Face Communication”.