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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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H4.SMR. 405/18

SECOND WORKSHOP ON TELEMATICS

6 - 24 November 1989

Single - Mode Fibre Transmissions: Parameters - Components - Systems

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CSELT, Torino, Italy

These notes are intended for internal distribution only.

SINGLE-MODE FIBRE TRANSMISSIONS:

PARAMETERS - COMPONENTS - SYSTEMS

(R. CAPONI - CSELT - TORINO)

/——/

1) SINGLE-MODE FIBRE PARAMETERS:

- CUT-OFF WAVELENGTH
- MODE FIELD DIAMETER
- REFRACTIVE INDEX PROFILES

$\Longleftrightarrow$ FIBRE DESIGN CONSIDERATIONS

2) FIBRE CABLING AND MEASUREMENTS:

- COUPLING LOSS, FIBRE ENDFACE PREPARATION, MAIN CABLE STRUCTURES, FIBRE CHARACTERIZATION

3) ACTIVE COMPONENTS FOR FIBRE TRANSMISSIONS:

- SOURCES
  - • LEDS
  - • LASERS
- DETECTORS

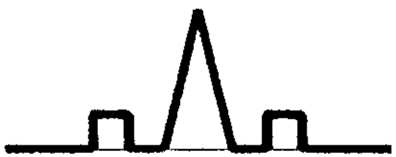
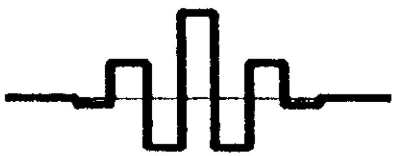
4) SYSTEM SCHEMES AND PROPERTIES:

- DIRECT DETECTION SYSTEMS
- COHERENT SYSTEMS

$\Rightarrow$ S/N RATIO

- SYSTEM PERFORMANCE EVALUATION AND DEVELOPMENT

REFRACTIVE INDEX DESIGNS OF SINGLE-MODE FIBRES

	MATCHED CLADDING	1300 nm OPTIMIZED
	DEPRESSED CLADDING	LOWER BEND LOSSES
	"W" TYPE	DISPERSION MODIFIED
	PURE SILICA CORE	MINIMUM ATTENUATION
	TRIANGULAR CORE	1550 nm OPTIMIZED
	SEGMENTED CORE	1550 nm OPTIMIZED LOWER BEND LOSSES
	QUADRUPLE CLADDING	DISPERSION FLATTENED

[———— SiO_2 LEVEL]

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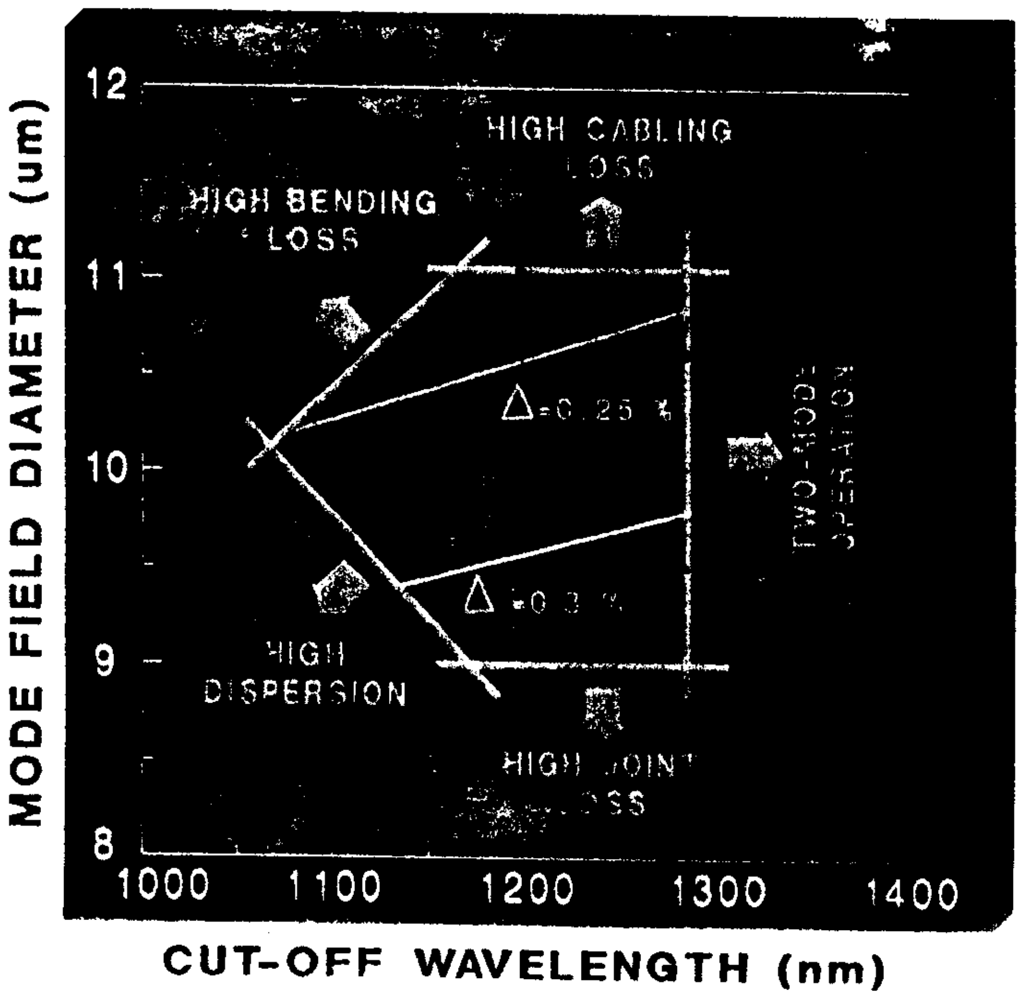
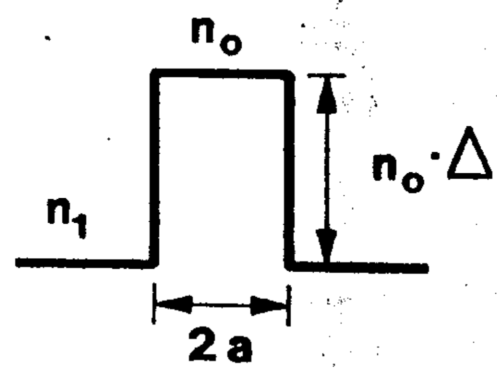
SINGLE-MODE FIBRE DESIGN



MATCHED CLADDING FIBRE:



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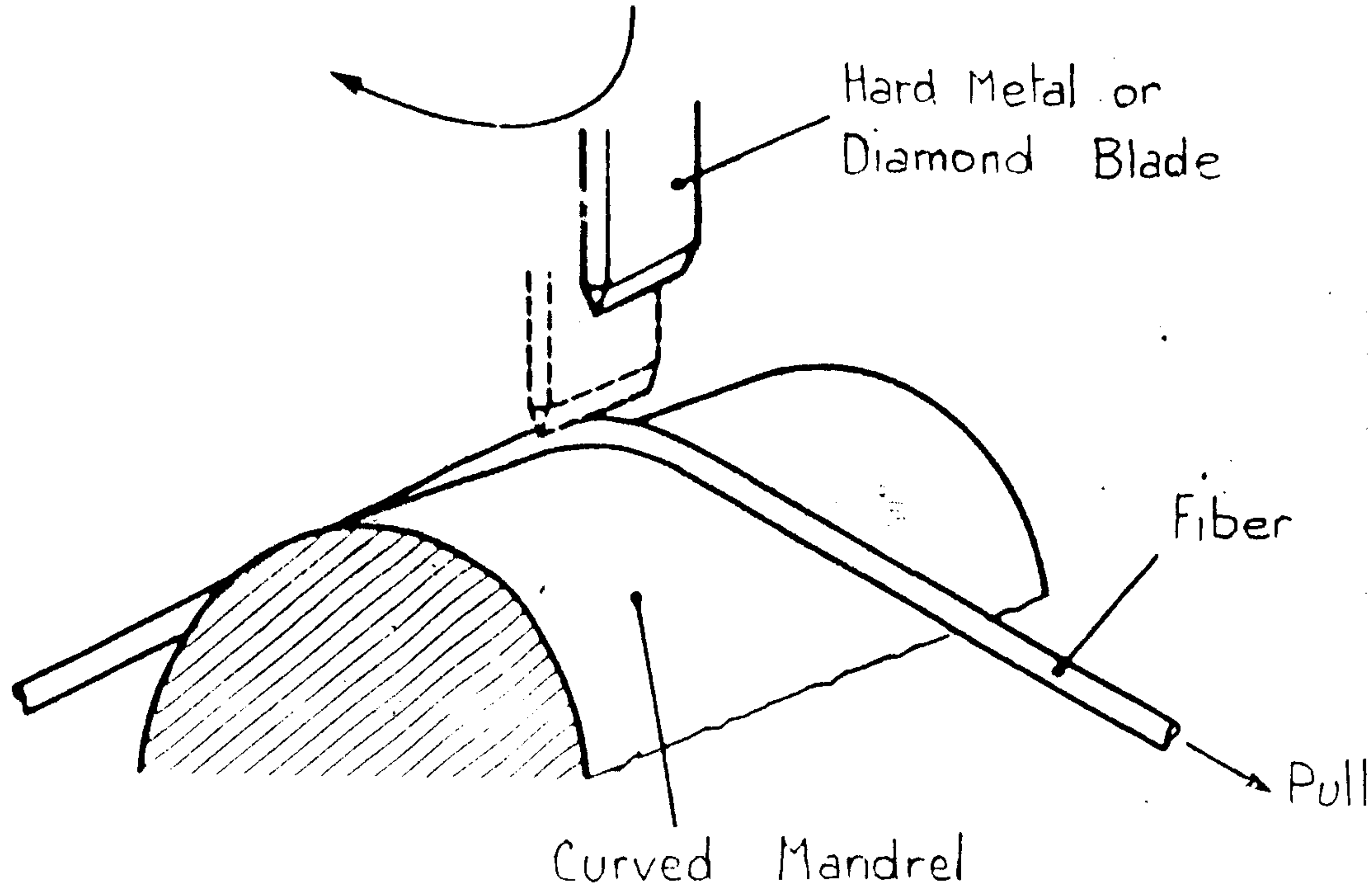

Hard Metal or
Diamond Blade
Fiber
Pull
Curved Mandrel

SOURCES

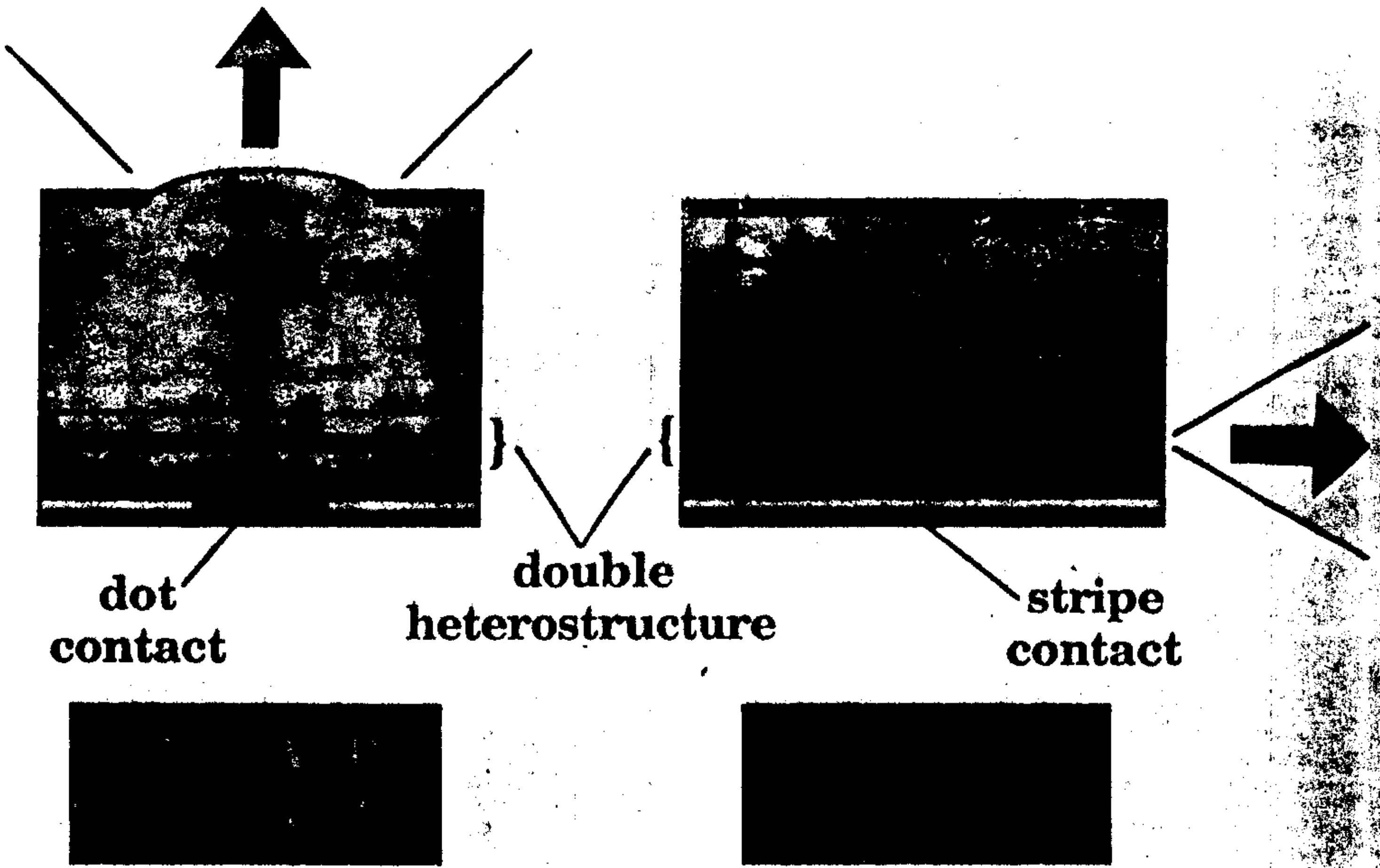
LED

SPONTANEOUS EMISSION
UNIFORM RADIATION
WIDE SPECTRUM
LOW POWER INTO FIBRE
BAND LIMITATIONS
HIGH STABILITY
LONG LIFETIME
LOWER COST

LASER

STIMULATED EMISSION
THRESHOLD CURRENT
DIRECTIONAL EMISSION
NARROW SPECTRUM
HIGH POWER INTO FIBRE
WIDEBAND
TEMPERATURE VARIATIONS
SHORTER LIFETIME
HIGHER COST

LIGHT EMITTING DIODE (LED)



to increase coupling efficiency:

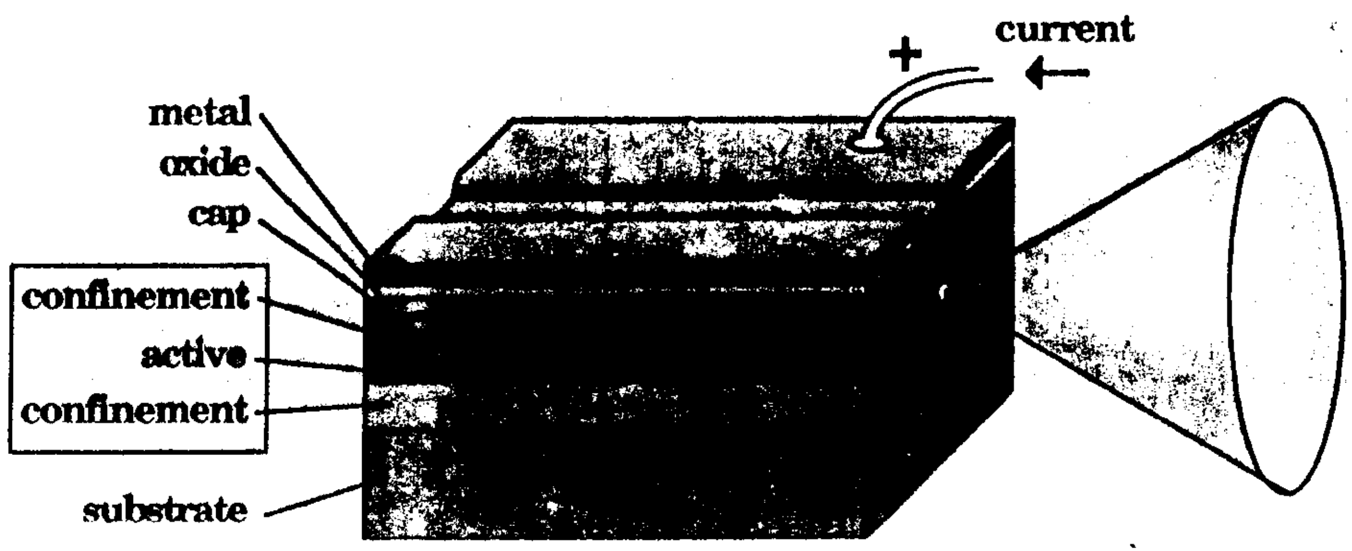
- monolithic lens

to prevent from lasing:

- AR coated facets
- truncated stripe
- thin active layer

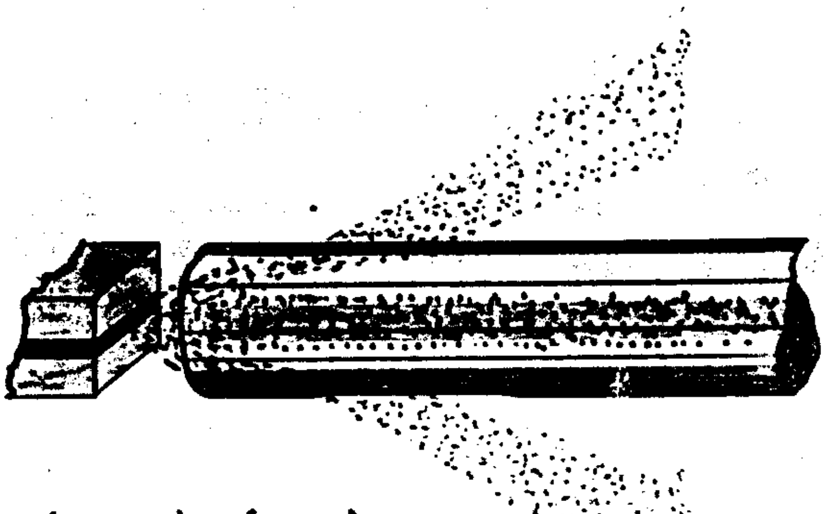
Both AlGaAs/GaAs and InGaAsP/InP are used

LASER DIODE



- Double heterostructure, stripe geometry
- Cleaved mirrors (Fabry-Perot resonator)
- AlGaAs/GaAs for 0.85 μm operation
  InGaAsP/InP for 1.3 - 1.55 μm operation
- Epitaxial growth: LPE, MO-CVD, MBE, ...

LAUNCHING AND COUPLING PROBLEMS



$$W_e = W_o + W_i$$

EMITTED POWER ➡ GUIDED POWER + RADIATED (LOST) POWER

* LAUNCHING EFFICIENCY: $\Lambda = W_o / W_e$ (% typ.)
* COUPLING LOSS: $L = W_i / W_e$ (dB typ.)

SINGLE-MODE FIBRES:

$I_e(r)$ – Emitted power radial distribution

$\boxed{\Lambda \text{ DEPENDS ON THE "LIKENESS" OF } I_e(r) \text{ AND } I(r)}$

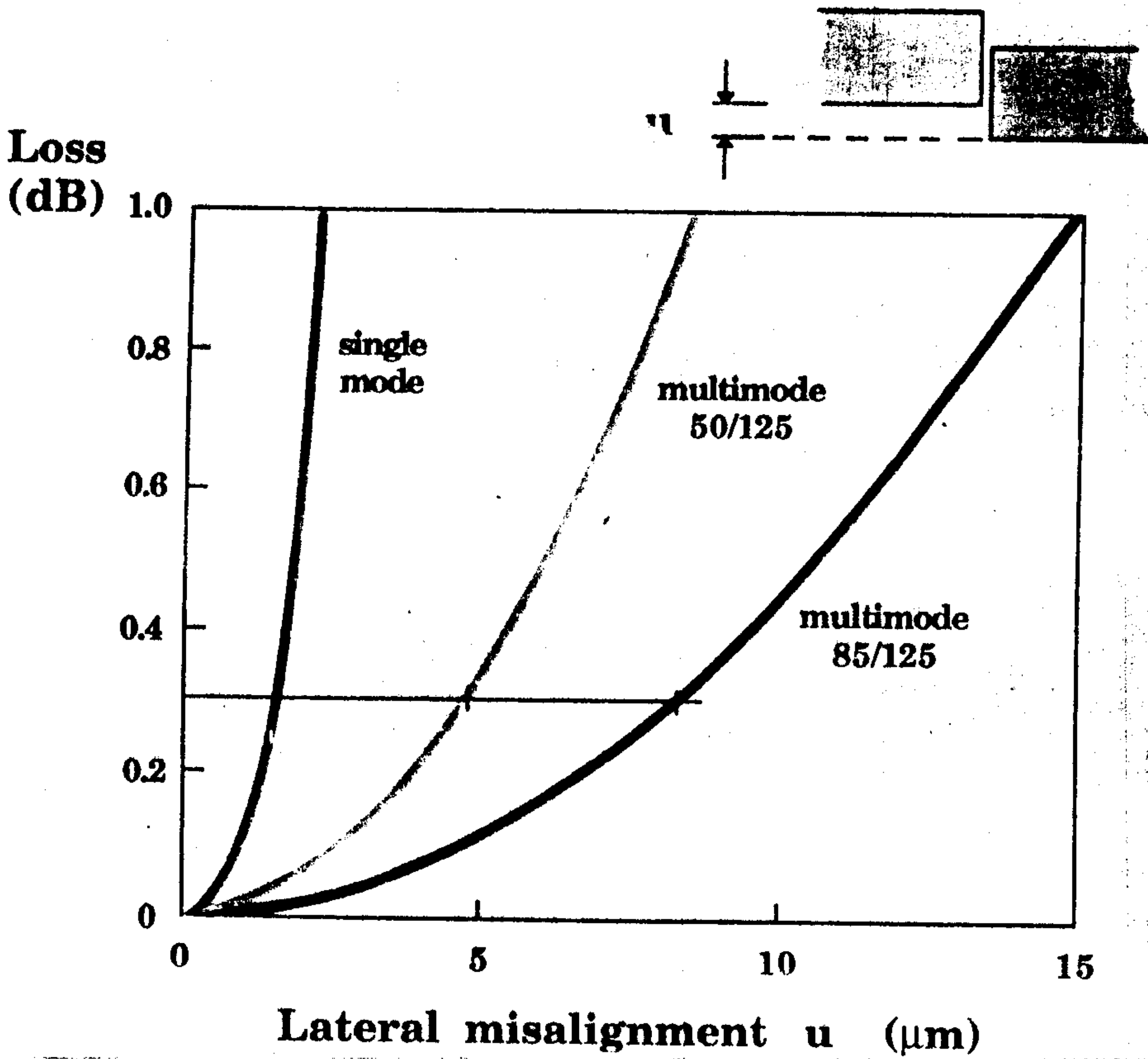
$\Lambda = [\text{Overlap integral between } I_e \text{ and } I]^2$

* TYPICAL Λ-VALUES FOR INJ. LASER–FIBRE COUPLING:

~20% from multimode laser

~80% from single-mode laser

COUPLING LOSS DUE TO LATERAL MISALIGNMENT



DETECTORS

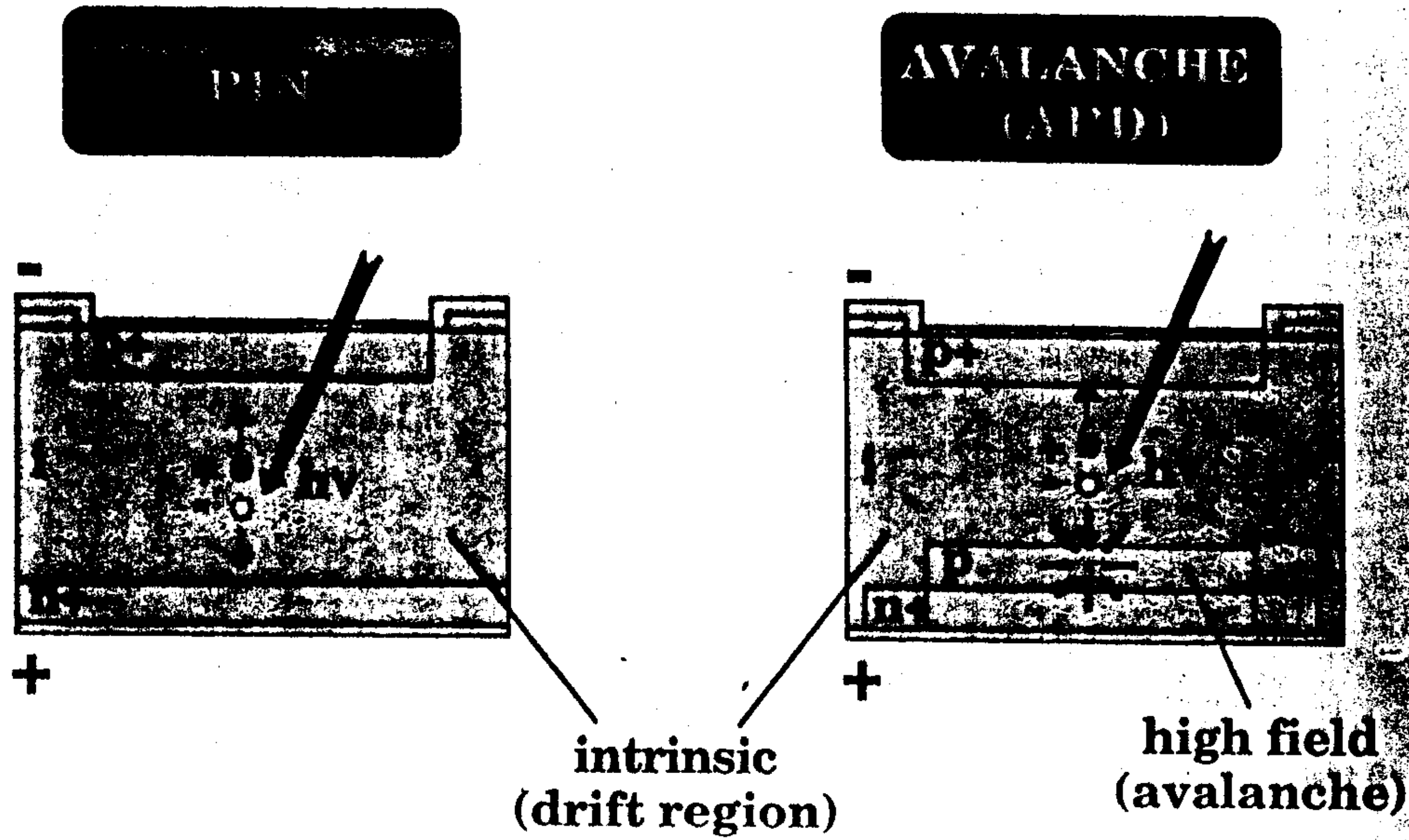
PIN PHOTODIODES

- HIGH STABILITY
- LOW BIAS VOLTAGE
- LOW COST

AVALANCHE PHOTODIODES (APDs)

- AVALANCHE GAIN
- LOWER STABILITY
- HIGH BIAS VOLTAGE
- HIGHER COST

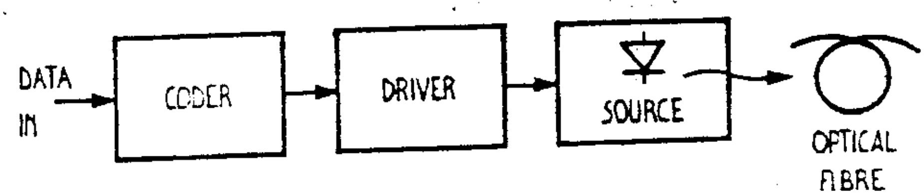
PHOTODETECTORS



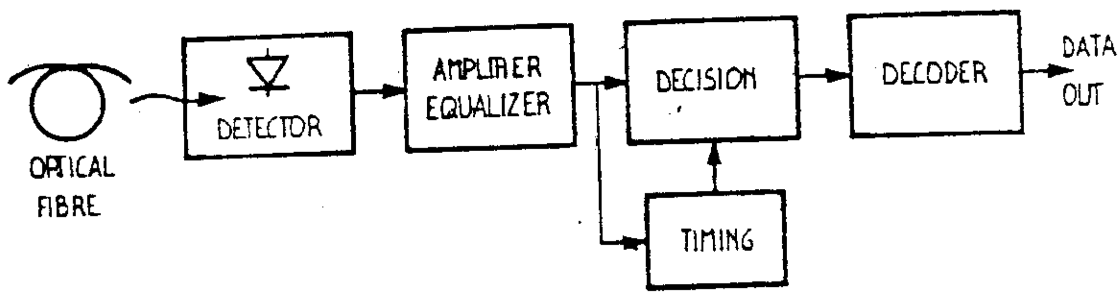
Material:

• Silicon	up to:	~1 μm
• Germanium	"	~1.5 μm
• InGaAs	"	~1.6 μm

OPTICAL SYSTEM BLOCK DIAGRAM



TRANSMITTER



RECEIVER

REPEATER SPACING DETERMINATION

OPTICAL POWER INTO FIBRE

$P_0 = 20 \div 100\ \mu W$ for LEDs

$P_0 = 0.3 \div 2\ mW$ for LASERs

RECEIVER SENSITIVITY

Signal peak current : $I_p = 2\rho G P_r$

Noise currents :

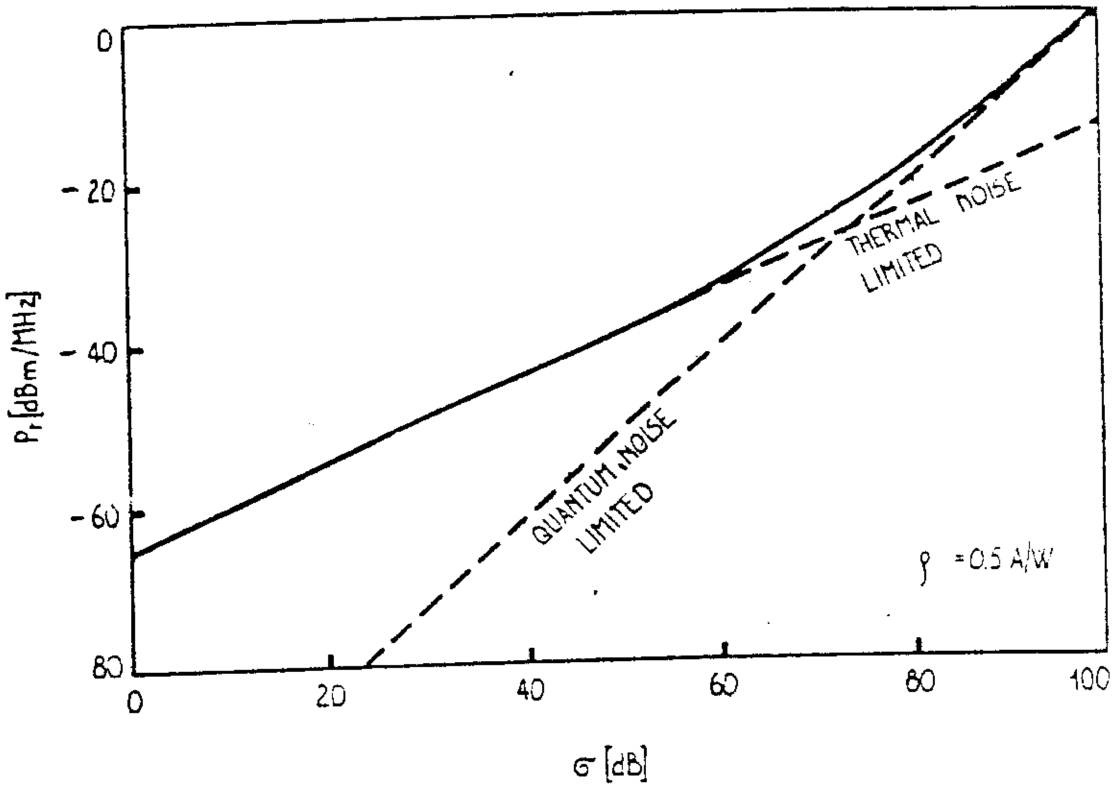
thermal : $I_{tn}^2 = \frac{4KTBF}{R}$

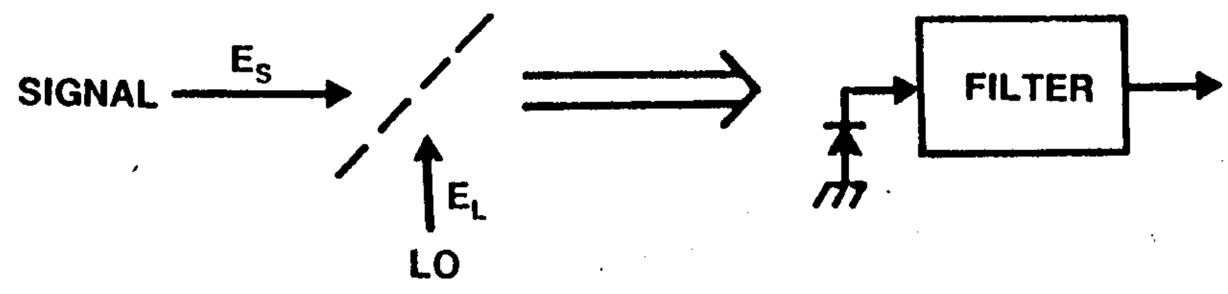
quantum : $I_{qn}^2 = 2q\rho G^2 F_G B P_r$

S/N ratio :

$$\boxed{\sigma = \frac{2\rho G P_r}{\sqrt{2q\rho G^2 F_G B P_r + 4KTBF/R}}}$$

$P_r(\sigma)$ FOR A PIN DETECTOR

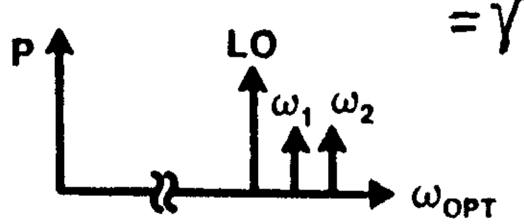


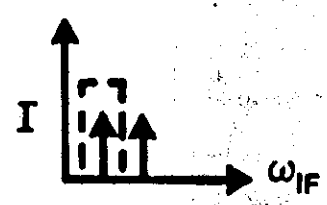


$$I_{det} \sim (E_S \cos \omega_S t + E_L \cos \omega_L t)^2$$

$$\sim E_S \cdot [E_L \cos (\omega_S - \omega_L) t] + \ldots$$

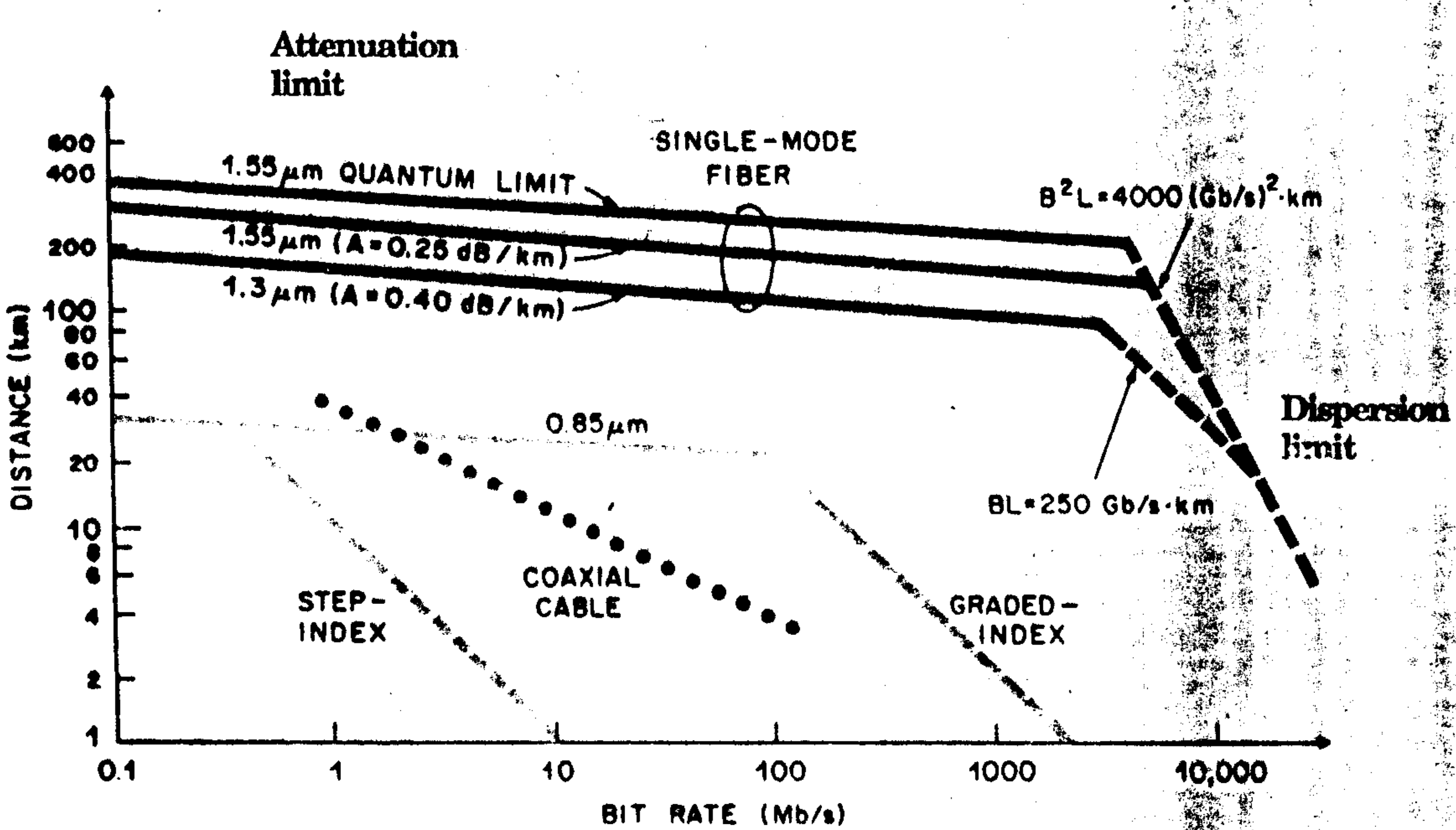
$$= \sqrt{P_r P_L} \cos(\Delta\omega t)$$





- SEPARATING ω_1 and ω_2 AT OPTICAL FREQUENCIES REQUIRES ~0.1 Å RESOLUTION;
- SAME TASK AT I-F REQUIRES ~1 GHz FILTER

REPEATER SPACING VS. BIT RATE



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After: P.S. Henry, IEEE J. QE, dec. 1985

LIGHTWAVE PROGRESS