



INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION



INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

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WINTER COLLEGE ON
LASER PHYSICS: SEMICONDUCTOR LASERS
AND INTEGRATED OPTICS

(22 February - 11 March 1988)

INTRODUCTION TO INTEGRATED OPTICS

B. Costa
CSELT
Torino, Italy

INTEGRATED OPTICS

OPTICAL ELEMENTS:

- CAPABLE OF PERFORMING VARIOUS FUNCTIONS ON OPTICAL BEAMS
(GENERATION, AMPLIFICATION, DETECTION, WAVEGUIDING, MODULATION, SPLITTING, DEFLECTION, ...)
- MADE OF OPTICAL WAVEGUIDES IN PLANAR FORM
- OBTAINED BY THIN FILM TECHNOLOGIES
- ON PLANAR SUBSTRATES
- SEVERAL ON SINGLE CHIP (!)

MOTIVATIONS FOR I.O.

- 1960: REALIZATION OF LASER
- 1964+1966 FREE SPACE OPTICAL COMMUNICATIONS
- 1966 PROPOSAL FOR OPTICAL FIBRE COMMUNICATIONS
- 1970
 - FIRST TELECOMMUNICATION GRADE OPTICAL FIBRE
 - FIRST CW SEMICONDUCTOR LASER
- 1962-1968 EARLY EXPERIMENTS WITH PLANAR WAVEGUIDES
- 1969 TERM "INTEGRATED OPTICS"
(COINED BY MILLER)
- 1970-1975 DEVELOPMENTS

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MATERIALS -

ADVANTAGES OF I.O.

AMORPHOUS, ORGANIC

- SMALL SIZES
- PERMANENT ALIGNMENT
- INSENSITIVITY TO VIBRATIONS, MOISTURE, DUST, THERMAL CHANGES
- ROBUSTNESS
- EFFICIENT DEVICES (FAVORABLE L/W RATIO)
 - LOW DRIVE POWER
 - ULTRA HIGH SPEED
 - BROAD BAND
- SINGLE MODE PROPAGATION
- POSSIBILITY OF OPTICAL AND ELECTRONIC INTEGRATION
- MASS PRODUCTION

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PHYSICAL PHENOMENA INVOLVED

• WAVE GUIDING

MATERIALS TRANSPARENT IN N.E.O.P. - 1.6 μm AND BEYOND)

- STIMULATED EMISSION, LIGHT AMPLIFICATION, LASING
- PHOTODETECTION
- ELECTRO-OPTIC EFFECT (POCKELS, KERR)
- ACOUSTO-OPTIC EFFECT
- MAGNETO-OPTIC EFFECT
- ELASTO-OPTIC EFFECT
- THERMO-OPTIC EFFECT
- INTERFEROMETRIC EFFECT
- DIFFRACTION (PERIODIC STRUCTURES, CORRUGATED WAVEGUIDES)
- COUPLED RESONATORS, EVANESCENT WAVE COUPLING
- NON LINEAR INTERACTIONS
- OPTICAL BISTABILITY

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FUNCTIONS PERFORMED BY I.O. DEVICES

- INTERCONNECTION, WAVEGUIDING
- LIGHT GENERATION
- LIGHT AMPLIFICATION
- LIGHT DETECTION
- LIGHT MODULATION
 - PHASE
 - INTENSITY
 - POLARIZATION
- POWER SPLITTING
- POWER COMBINING
- LIGHT SWITCHING (TIME - SPACE)
- WAVELENGTH MULTI-DEMULTIPLEXING
- FREQUENCY TRANSLATION
- LIGHT FOCUSING, DEFLECTION
- POLARIZATION MODIFICATION

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BASIC I.O. DEVICES

- CHANNEL WAVEGUIDES
- RIDGE WAVEGUIDES
- PHASE MODULATOR
- DFB, DBR LASER
- P-I-N PHOTODETECTORS
- SYMMETRIC, ASYMMETRIC Y JUNCTION
- DIRECTIONAL COUPLER (SWITCHED)
- MACH-ZEHNDER INTERFEROMETER
- TE-TM MODE CONVERTER
- LENSES...

FABRICATION PROCESSES

THIN FILM DEPOSITION

- EVAPORATION
- R.F. SPUTTERING
- SPIN ON DYE COATING
- CHEMICAL VAPOR DEPOSITION (CVD)

EPITAXIAL GROWTH

- R.F. SPUTTERING
- MELTING
- LIQUID PHASE EPITAXY (LPE)
- VAPOR PHASE EPITAXY (VPE)
- METAL-ORGANIC CVD (MOCVD)
- MOLECULAR BEAM EPITAXY (MBE)

MATERIAL MODIFICATION

- OUT-DIFFUSION
- IN-DIFFUSION
- ION EXCHANGE
- PHOTOLITHOGRAPHY
- ETCHING

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MATERIALS FOR I.O.

AMORPHOUS

INORGANIC

- SiO_2
- Si_3N_4
- Al_2O_3

ORGANIC

- POLYURETHANE
- POLYSTYRENE
- EPOXY
- PHOTORESIST
- ORGANOMETALLIC SOLUTIONS

CRYSTALS

$LiNbO_3$

$LiTaO_3$

$LiNbO_3/LiTaO_3$

$Bi_2O_3/TeO_2/Bi_2O_3$

$LiNbO_3/LiTaO_3/LiNbO_3/LiTaO_3$

SEMICONDUCTORS

Si

Ge

Al

As

Bi

Fe

Co

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MATERIAL COMPARISON

PROPERTY	LiNbO ₃	GaAs/AlGaAs	THIN FILM ON SILICA
FORM	SINGLE CRYSTAL	EPITAXIALLY GROWN	EVAPORATED OR SPUTTERED
REFRACTIVE INDEX	2.2	3.5	DEPENDS ON MATERIAL
ATTENUATION	0.5 dB/cm	~1-2 dB/cm	0.1 dB/cm
BIREFRINGENCE	VERY HIGH	LOW	HIGH
E. F. COEFFICIENT	HIGH 30×10^{-12} m/V	MEDIUM 1.8×10^{-12}	MEDIUM
PIEZOELECTRIC	GOOD	NO	MAY DEP
ELECTRONIC COMPATIBILITY	NO	YES	YES
LASER COMPATIBILITY	NO	YES	NO

APPLICATIONS OF I.O.

TELECOMMUNICATIONS

- TRANSMITTER
- RECEIVER
- REGENERATOR
- FIBER OPT. SWITCHING

SIGNAL PROCESSING, COMPUTING

- SPECTRUM ANALYZER
- CORRELATOR
- AD, D/A CONVERTERS
- LOGIC GATES

SENSORS

- PRESSURE
- HUMIDITY
- THERMAL
- DISPLACEMENT
- FLOWMETER

OTHER

- OPTICAL DISK READER (PICK-UP)
- LASER PRINTER