Stickley

Center for Research in Electro-Optics and Lasers
University of Central Florida

AFFILIATES' DAY

January 13, 1992

Speakers' Presentations

CREOL
12424 Research Parkway, Suite 400
Orlando, Florida 32826
(407) 658-6800

CONTENTS

CREOL
(Center for Research in Electro-Optics and Lasers)

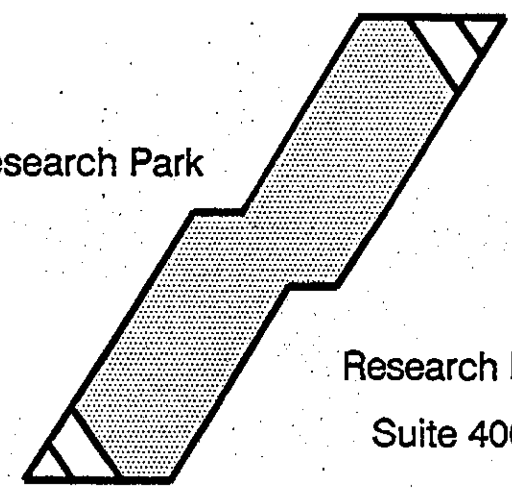
Established 1986
University of Central Florida, Orlando,
Director: M J Soileau
Assistant Director: C M Stickley

Objective:

* Establish a Center of Excellence at UCF in optics and laser research and education
* To assist in the development of Florida's High Tech industries

Description:

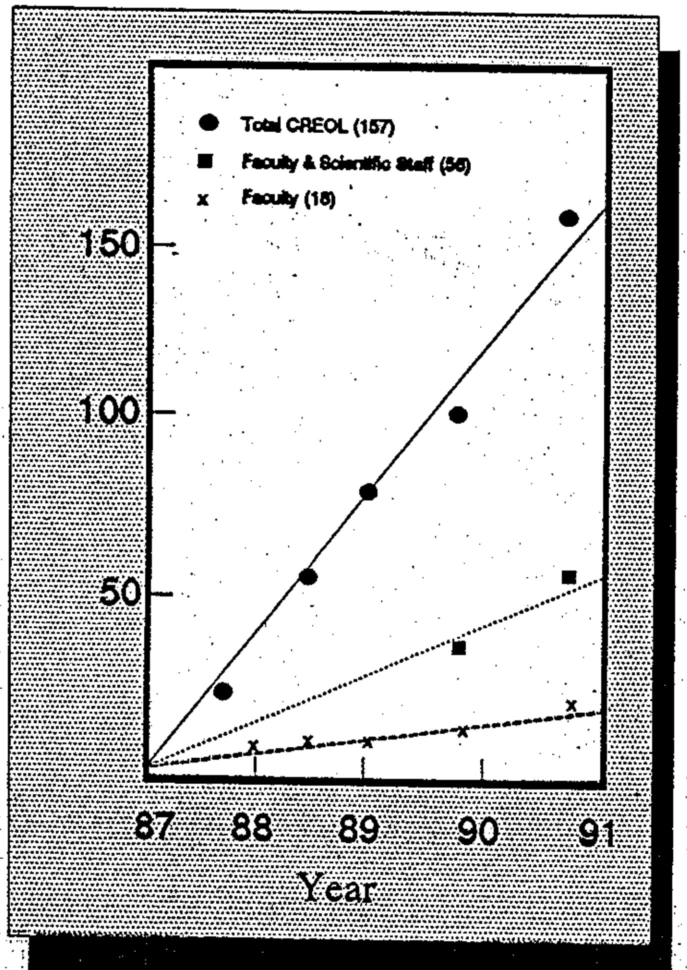
CREOL is an interdisciplinary center involving faculty and students from a variety of academic units including Physics, Electrical Engineering, Mechanical Engineering, Mathematics and Computer Science

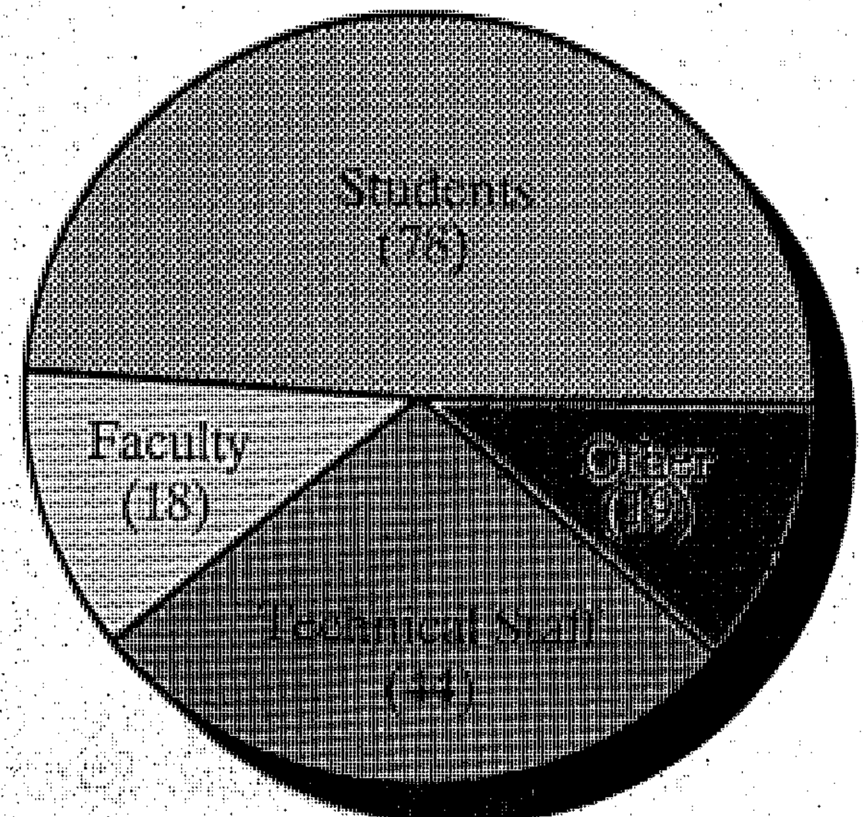


University of Central Florida Research Park

Research Pavillion
Suite 400

CREOL PERSONNEL
Total 157

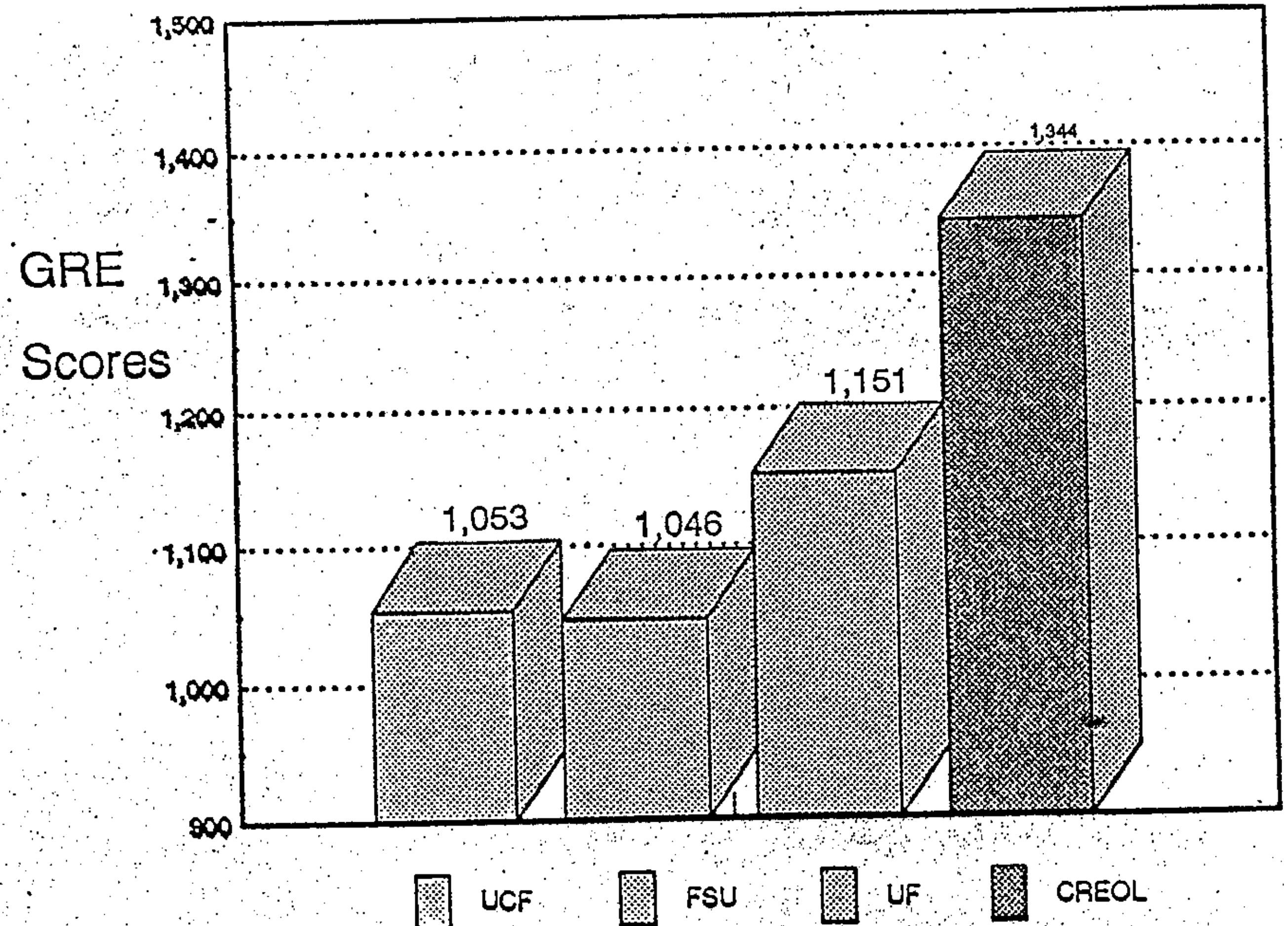




~$7M/yr

GHANGE5

Student Recruiting



CREOL FACULTY PROFILES

- 50% hold rank of fellow in major national and international professional societies.
- CREOL faculty are on boards of governors of 3 out of 4 major professional societies dealing with lasers and optics.
- 50% have chaired, co-chaired or served on organizing committees of major national and international conferences dealing with this research speciality in the past year.
- Over 150 professional publicatons and presentations in AY 90/91.

Conclusion: CREOL faculty are judged by their peers to be among the top people in their research fields

CREOL Faculty & Research Topics

Classical Optics:	G. Boreman J. Harvey	Micro-lasers & Diode Pumping:	J. Dixon
Crystal Growth:	B. Chai	Nonlinear Optics & Limiting:	E.W. Van Stryland D. Hagan
Diffractive Optics:	M.G. Moharam	Laser Induced Damage & Limiting:	M.J. Soileau
Free-Electron Laser:	L. Elias	Integrated Optics:	G. Stegeman
Solid State Spectroscopy:	M. Bass	Quantum Well Optoelectronics:	A. Miller
Laser Propagation:	R. Phillips		
Metal Vapor Lasers & Spectroscopy:	Jin Kim	Plasma Physics & X-ray Lithography:	W. Silfvast M. Richardson
Thin Film Optics:	K. Guenther	Remote Sensing & Photonic Systems:	M. Strickley

OPTICS COURSES

EEL-4440 Optical Engineering
EEL-5441 Introduction to Wave Optics
EEL-5446 Optical Systems Design
EEL-5450C Thin Film Optics
EEL-5451L Electro-Optics Laboratory
EEL-5563 Fiber Optics Communication
EEL-6443 Electro-optics
EEL-6457 Advanced Topics in Electro-Optics
EEL-6560 Laser Engineering
EEL-6561 Fourier Optics
EEL-6562 Diode Pumped Lasers
EEL-6564 Optical Communication Theory
EEL-6565 Infrared Technology

PHY-4424 Optics
PHY-5446 Laser Principles
PHY-5431 Optical Properties of Materials
PHY-5938 Introduction to Crystal Growth
PHY-6434 Nonlinear Optics
PHY-6448 Laser Systems
PHY-6424 Optical Properties of Solids
PHY-6204 Atomic Spectroscopy
PHY-6400 Physics of Free Electrons
PHY-6410 Modern X-Ray Science
PHY-6447 Laser Physics

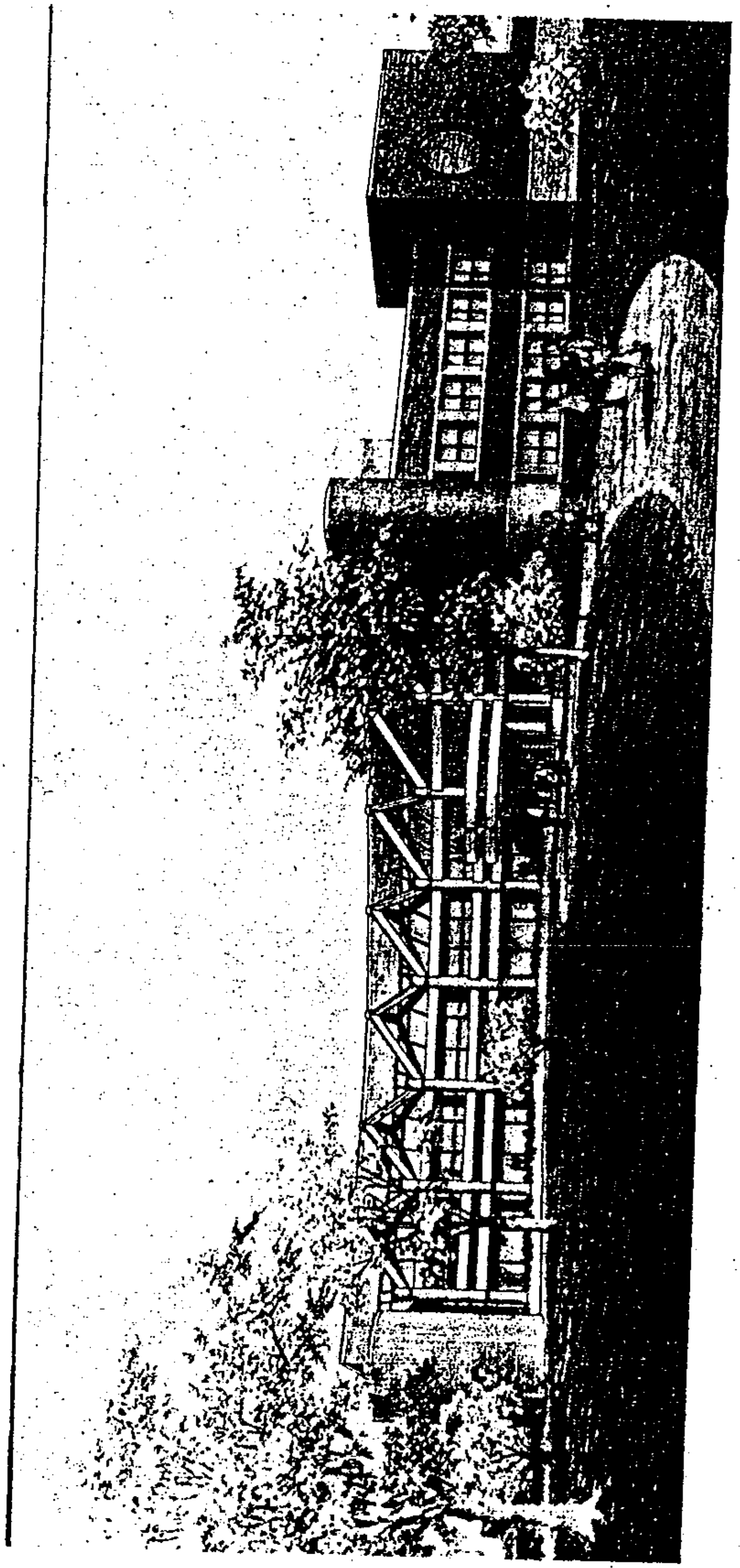
CREOL LABORATORIES

Present

- 51 Laboratories
- $8M+ State-of-the Art Capital Equipment
- 33,000 sq ft Office and Labs (Research Pavillion)
- 14,000 sq ft Offices & Labs (Site #2, Research Park)
- 2,000 sq ft Labs on Campus

Future

- 76,000 sq ft CREOL Building Planned
  - ground breaking Sept 1992



CREOL Industrial Affiliates Program

Membership Requirements

Sustaining Member:
Participate in Eminent Scholar Program

Senior Member:
Annual Donation of $10,000

Member:

1. Gross sales greater than $10,000,000: $5,000 annual donation
2. Gross sales greater than $1,000,000: $2,500 annual donation
3. Gross sales less than $1,000,000: $1,000 annual donation

Membership in this special category is restricted to small business as defined by the U.S. Government

CREOL Industrial Affiliates Program

Membership Benefits*

- Establishes a formal relationship between the company and CREOL
- The *Highlights* newsletter of the Center for Research in Electro-Optics and Lasers
- Copies of any unrestricted publications, upon request arising from research carried out by the Center
- The CREOL Director's reports on the status of ongoing research, prospective programs and other activities
- A directory of the graduate students involved in CREOL-related programs
- Participation in the Annual Corporate Affiliates Meeting
- Influence direction of CREOL research
- Senior members are given a seat of the CREOL Industrial Advisory Board

*The honest truth is that CREOL is the primary beneficiary of this program because it supplies us with our only source of unrestricted funds.

CREOL

(Center for Research in Electro-Optics and Lasers)

Established 1986
University of Central Florida, Orlando,
Director: M J Soileau
Assistant Director: C M Stickley

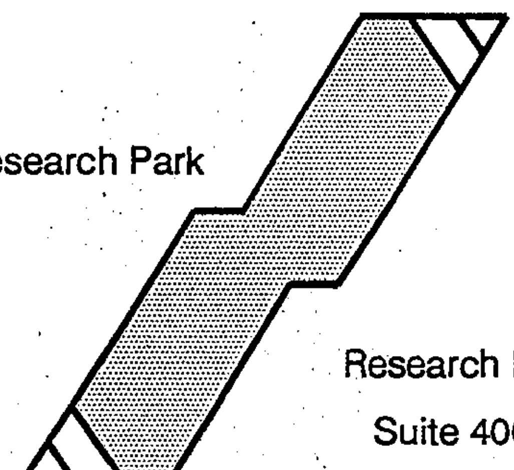
Objective:

* Establish a Center of Excellence at UCF in optics and laser research and education
* To assist in the development of Florida's High Tech industries

Description:

CREOL is an interdisciplinary center involving faculty and students from a variety of academic units including Physics, Electrical Engineering, Mechanical Engineering, Mathematics and Computer Science

University of Central Florida Research Park



Research Pavillion
Suite 400

CREOL1

SENSOR PROTECTION

Faculty:
E.W. Van Stryland
M.J. Soileau
D.J. Hagan
A. Miller

PhD Scientists:
D. Hutchings
M. Sheik-Bahae
A.A. Said

Students:
Tai Wei, Richard DeSalvo, Jiangwei Wang, Zho Wang, T. Xia and Mike Hasselbeck

Two of the PI's (MJS and EVS) hold security clearances. This helps in communicating research results to company scientists working with classified military systems (eg. Martin Marietta).

Funding Received:

US CNVEO/DARPA (1988-92)................ $1,200,000
"Passive Spatial Beam Control" with M.J. Soileau
This was a direct match to the FHTIC funding.

SBIR Funded with Schwartz E-O (we split award)...... $49,992

Battelle Columbus Laboratories (1987-88)............ $25,000
"Measurement of Nonlinear Optical Properties of Materials", with M.J. Soileau and D.J. Hagan

General Dynamics (1987-88) $44,731
"Laser Damage and Limiting", with M.J. Soileau

McDonnell Douglas (1988-89)...................... $19,594
"Pulse Laser Test", with M.J. Soileau

Jet Propulsion Laboratory (1988-89) $50,000
"Cascaded Optical Limiter"
with M.J. Soileau and D.J. Hagan

Army Research Office (1990) $75,000
"Optical Limiting"
with D.J. Hagan and M.J. Soileau

McDonnell Douglas (1990) $22,293
"Limiting Test"
with M.J. Soileau

National Science Foundation (1987-90) $248,000
"Engineering of Two-Photon Nonlinearities in Bulk and Artificially Structured Semiconductors"
with M.J. Soileau, and D.J. Hagan

Battelle Columbus Laboratories (1992)............... $75,000

National Science Foundation (1992-95) $252,000
"Dispersion of Optical Nonlinearities in Solids"
with M.J. Soileau, D.J. Hagan and M. Sheik-Bahae

Florida High Technology and Industrial Council (1991) .. $21,161
"Passive Optical Switching"
with D.J. Hagan and M.J. Soileau

DISSERTATIONS

The research funded by the Florida High Technology and industrial Council the past year has resulted in the completion of the following doctoral dissertations.

1 Edesly Canto-Said, "Picosecond Degenerate Four-Wave-Mixing in Semiconductors", 1989.
2 Yuen Yuan Wu, "Semiconductor Nonlinearities for Passive Spatial Beam Control", 1990.
3 Kamjou Mansour, "Characterization of Optical Nonlinearities in Carbon Black Suspensions in Liquids", 1990.
4 Ali A. Said, "Development and Application of a Nonlinear Optical Characterization Technique", 1991.

Masters Thesis: Jayant Malhotra, "Laser Induced Darkening in Semiconductor Doped Glasses", Univ. of Central Florida, 1988. Funded by the Florida High Technolgy and Industry Council

APPROACH

1. develop techniques and facilities for the nonlinear optical characterization of materials
2. work with the materials people to optimize the nonlinear optical properties based on the results of our studies
3. implement these materials in the design and construction of optical limiting devices for sensor protection.

This last step is to be accomplished in collaboration with industry and government laboratories (eg. Martin Marietta, Shwartz E-O, JPL, CNVEO).

We organized three topical meetings of the SPIE held in Orlando entitled "Materials for Optical Switches, Isolators, and Limiters". This conference brought to Florida the primary researchers from around the U.S. working in this field. We presented several talks each year.

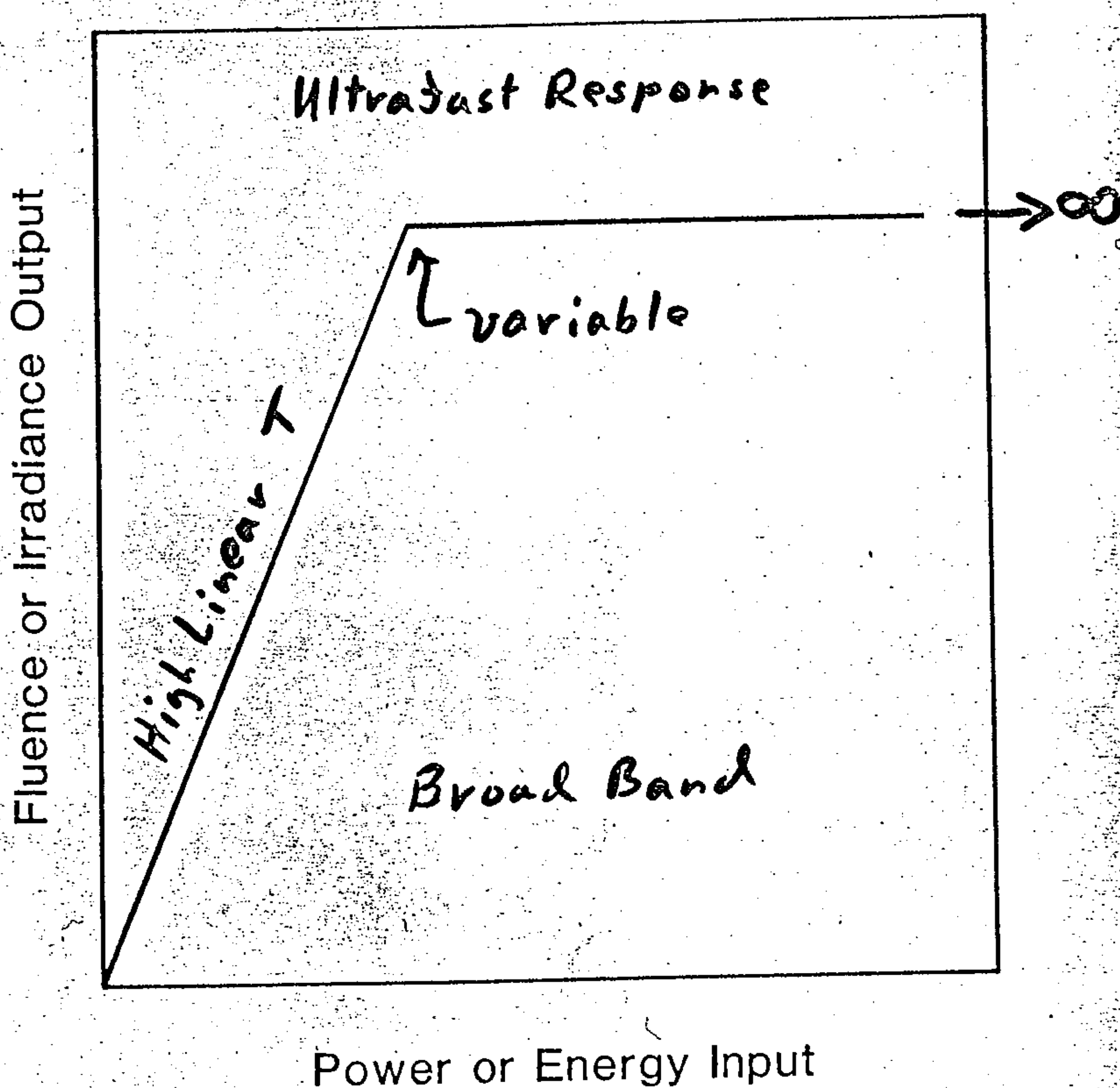
History

- o original OPL patent M.J. Soileau. 1978
- o screening test for OPL. 1980
- o semiconductor limiter (2PA) 1985
- o Patent; "OPL Based on Two-Photon
  Absorption". 1988
- o designed and built MONOPOL 1988
  self-protecting semiconductor limiter
  10 nJ (300 W) limiting for psec 0.53μm pulses
  1 μJ (80 W) limiting with nsec 0.53μm pulses
- o developed Z-scan 1988
- o limiting in carbon suspensions 1989
- o developed psec DFWM (1 and 0.5 μm) 1989
- o developed method to model thick limiters 1989
  can optimize focusing geometry 1990
- o related n_2 to β the 2PA coefficient via
  nonlinear Kramers-Kronig 1990

COLLABORATIONS:

o with RSRE Malvern, England
modified liquids, V_xO_y, liquid crystals
o with Jet Propulsion Lab on organics
o with Westinghouse on TAS at 10 μm (Singh)
also AgGaSe from Stanford (R. Route)
also AgGaS from Martin Marietta
o with DuPont on n_2 of KTP (Vanherzeele)
o with McDonnell Douglas for screening materials
o with Battelle Columbus for screening materials
o with LLNL (R. Adair, L. Chase)
n_2 of a series of materials at several λ
they have interest in n_2 at 355 and 266 nm
o with Bruce Chai (CREOL)
n_2 of LiCaAlF (of interest to LLNL)
o with Wright Patt. (C. Lee, Spire)
n_2 of organic thin films (in plastic host)
o with University of Florida (Joe Simmons)
DFWM, n_2, Darkening of semiconductor doped glass
o with Kent State Liquid Crystal Institute on organics
o with U. of Iowa (A.L. Smirl) semiconductor doping
o with Oklahoma State Univ. (R.C. Powell)
o with CNVEO for;
help in setting up in-house experiments

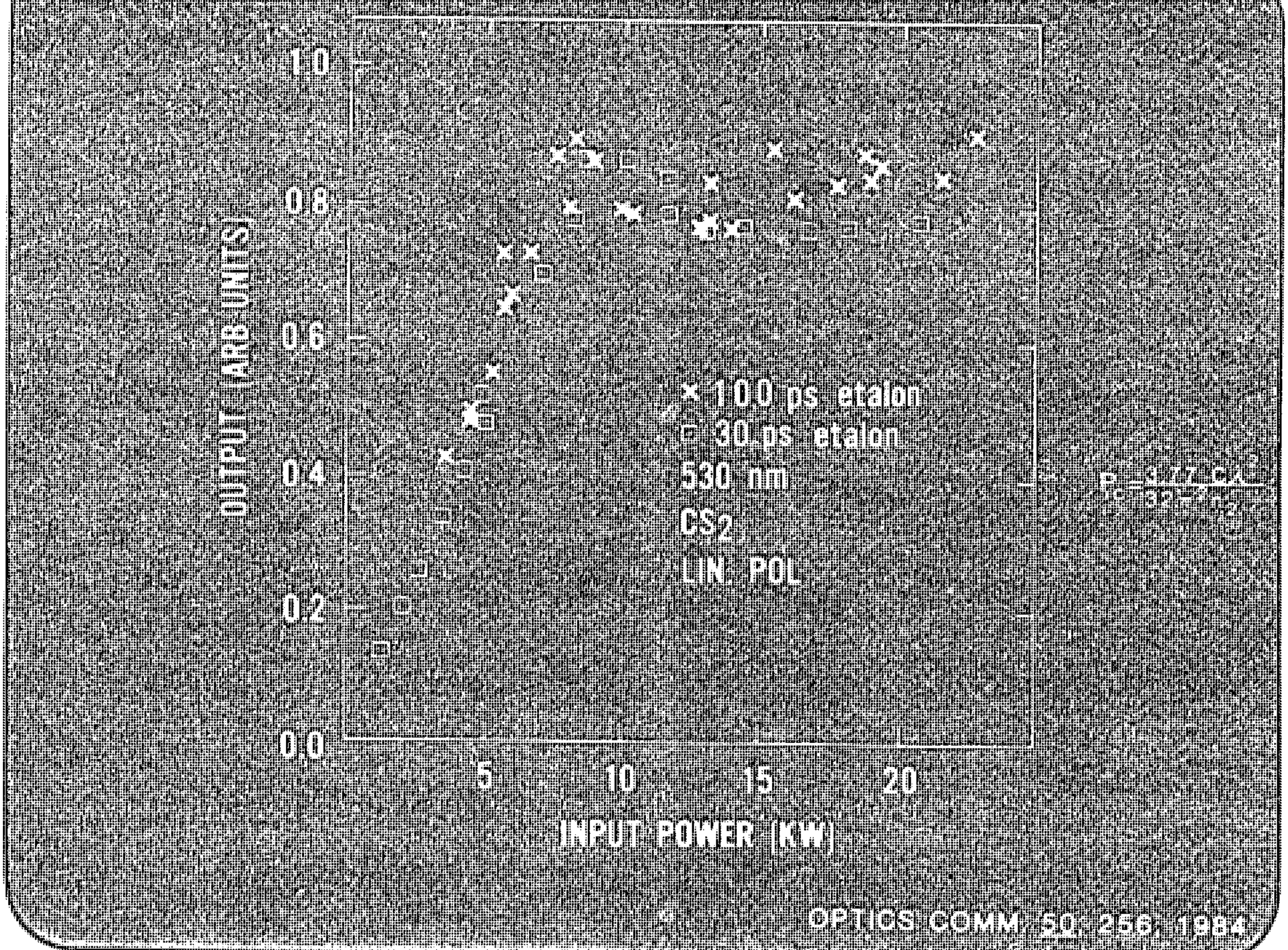
Ideal Optical Limiter Response



45°

variable

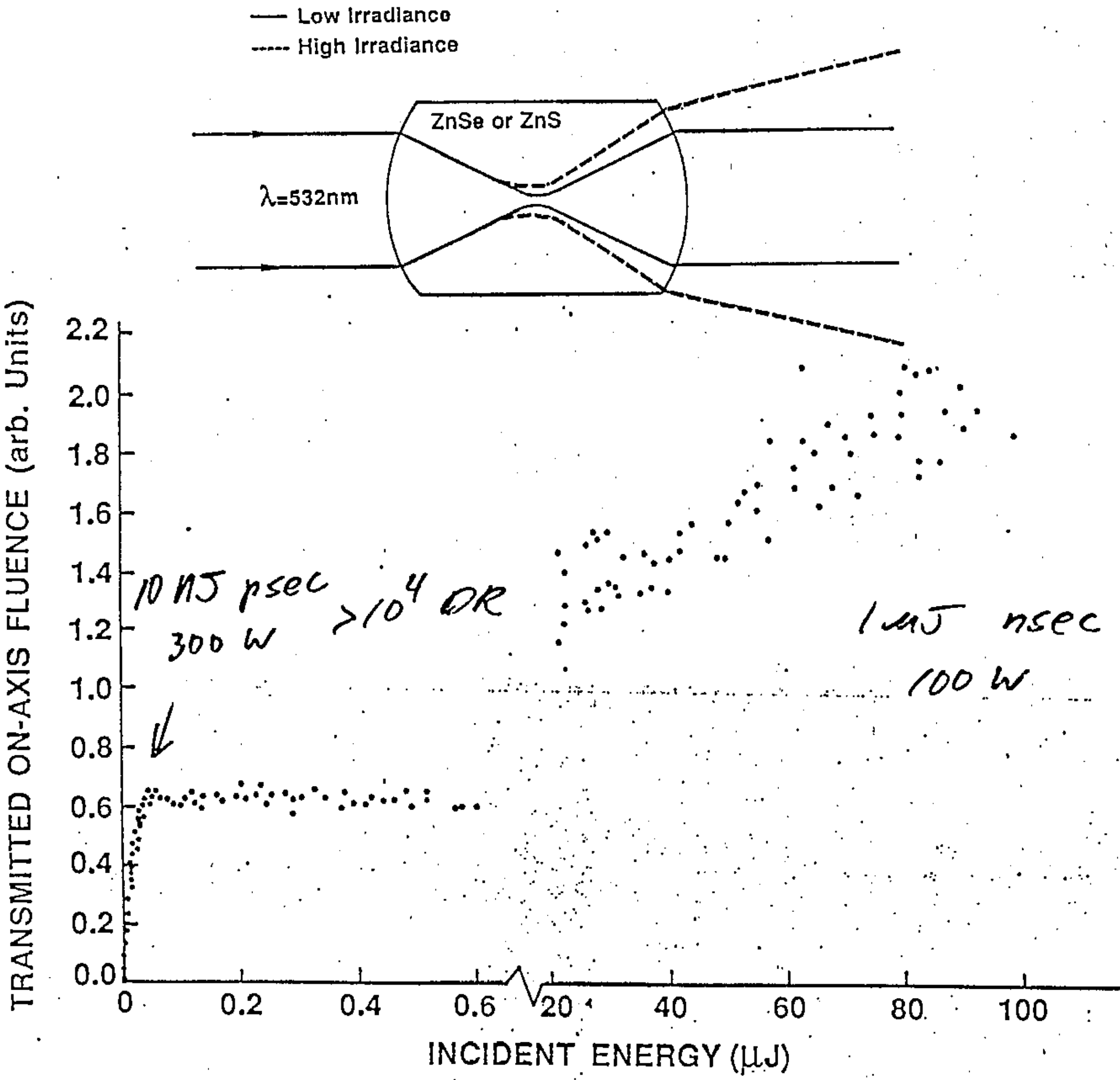
fast [illegible]



In the case of Kerr liquids such as CS_2, you can get exactly the shape desired and have high linear transmission. Also the screening test can be used to calculate the critical power and obtain an

You can get a very large dynamic range with CS_2, since liquids self-heal, and you can vary the cutoff power- but only to higher values. You do this by diluting it. That's the *only* thing wrong

Semiconductor Limiter



thermal problem

Combine with other NL material
(Joint with JPL)

grad. student

Nonlinear Scattering in a Carbon Black Suspension

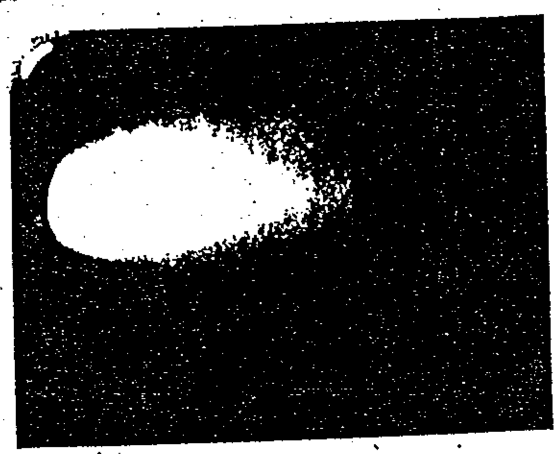
λ =532 nm
t_p=14 nsec

Low Intensity

(a)

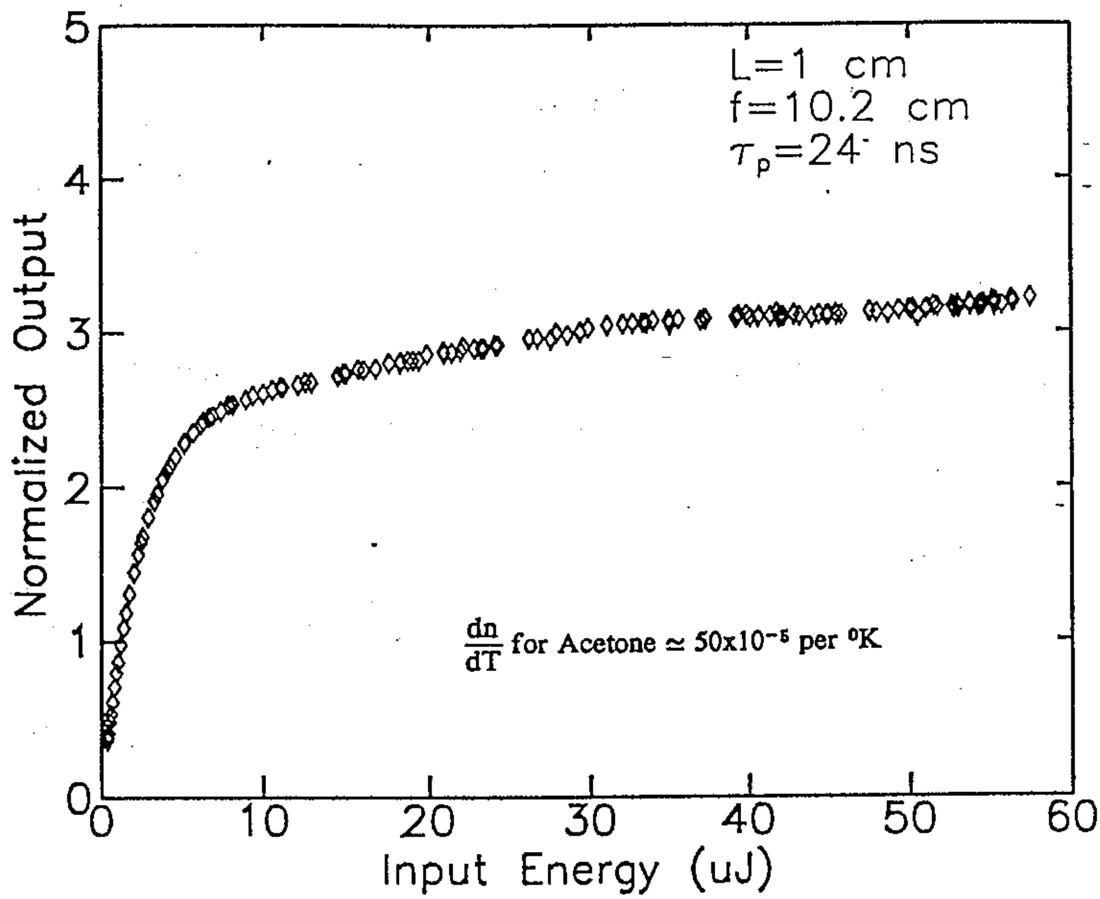
Front of the Cell ← 1 CM → Back of the Cell

High Intensity

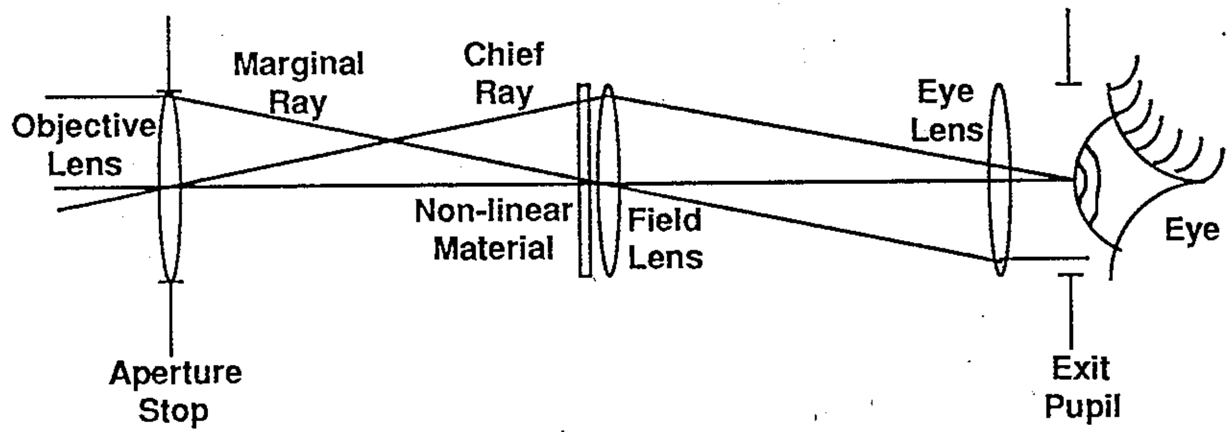


(b)

LIMITING BY THERMAL EXPANSION FOR NSEC PULSES



CONCEPTUAL DESIGN CHARACTERISTICS



o for a 2 inch input lens and a 1/4 inch iris opening, the energy in the limiting medium is $\simeq 70$ times the energy entering the eye in the linear regime.

- An F/4 Objective with Identical Eye Lens constitutes Afocal System
- Non-linear Material is positioned at Prime focus of Objective Lens
- Stop at Objective Lens is reimaged by Field Lens to produce Exit Pupil at Eye
- Spherical Aberration designed in to dominate Coma and Astigmatism (controls image size and makes it uniform over 30° field)
- Erecting Prism (not shown) to be between Field Lens and Eye Lens

Announcement and Call for Papers

Nonlinear and Electro-Optic Materials for Optical Switching

rt of SPIE's International Symposium
d Exhibition on Optical Engineering and Photonics
–24 April 1992
arriott's Orlando World Center Resort and Convention Center
rlando, Florida USA

OE/AEROSPACE SENSING ORLANDO '92

nference Chair: M. J. Soileau, CREOL/Univ. of Central Florida

chairs: L. C. Klein, The Pennsylvania State Univ.; Edward J. harp, U.S. Army Ctr. for Night Vision and Electro-Optics; Eric W. n Stryland, CREOL/Univ. of Central Florida

is conference will emphasize materials concepts and basic science sues relevant to optical switching. Of particular interest are papers aling with materials and physical mechanisms that are relevant to is application; papers on nonlinear optical phenomena that can be ed to fabricate optical switches are also welcome. Topics include:

- broadband fast optical nonlinearities
- liquid crystals
- nonlinear properties of organics
- solid-state materials
- photorefractive materials
- nonlinear absorption, refraction, and scattering
- beam steering

Abstract Due Date: 23 September 1991*
Manuscript Due Date: 23 March 1992
*Note: Late abstract submissions may be considered, subject to program time availability and chair's approval.

SPIE—The International Society for Optical Engineering

IE is a nonprofit society dedicated to advancing engineering and scientific applications of optical, electro-optical, and optoelectronic instrumentation, systems, d technology. Its members are scientists, engineers, and users interested in the reduction to practice of these technologies. SPIE provides the means for mmunicating new developments and applications to the scientific, engineering, and user communities through its publications and symposia.

North America: SPIE • P.O. Box 10 • Bellingham, Washington 98227-0010 USA
Telephone 206/676-3290 (Pacific Time) • Telex 46-7053
Telefax 206/647-1445 • OPTO-LINK 206/733-2998
ipping address: SPIE • 1000 20th Street • Bellingham, Washington 98225 USA
Europe: SPIE • Karlsruhe Strasse 22, D-1000 Berlin 15, FR Germany
Telephone 49 30 881 9867 • Telefax 49 30 882 2026 • Telex 181 472 [illegible]
the Far East, stralia, and w Zealand: SPIE • c/o O.T.O. Research Corporation • Takeuchi Building • 1-34-12 Takatanobaba, Shinjuku-ku, Tokyo 160 Japan • Telephone 03/3208-7821
Telex 232 4119 (OTORES J) • Telefax 03/3200-2889

CHARACTERIZATION OF NONLINEAR OPTICAL MATERIALS

Personnel

Faculty:

D. J. Hagan
E.W. Van Stryland
M.J. Soileau
M. Sheik-Bahae

Postdoctoral:

D.C. Hutchings (Theory)
A.A. Said

Students:

P. Buck, T. Xia, J. Wang, Z. Wang
R. DeSalvo, M. Hasselbeck, T.H. Wei

Nonlinear Refraction and Absorption:

$$n = n_0 + n_2 |E|^2 + n_4 |E|^4 + \cdots$$

$$\alpha = \alpha_0 + \beta I + \cdots$$

more generally:

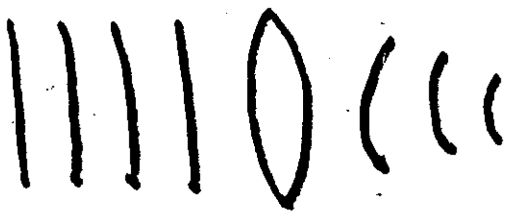
$$n \longrightarrow n(I)$$

$$\alpha \longrightarrow \alpha(I)$$

- Strong light propagating in a medium can alter its optical properties.

Self-Focussing: ($n_2 > 0$)

1/ Regular lens

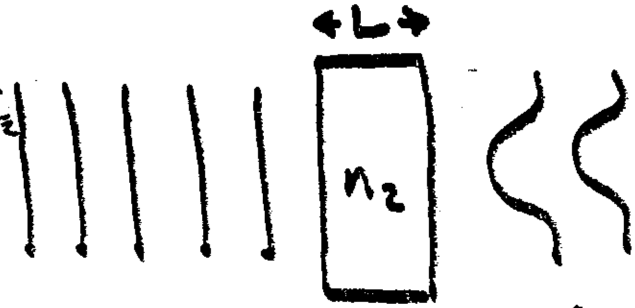


plane wave

spherical wave - $e^{-ikr^2/2f}$

2/ Nonlinear Medium ; $n = n_0 + n_2 |E|^2$

$I(r) \propto |E_0|^2 e^{-2r^2/w^2}$

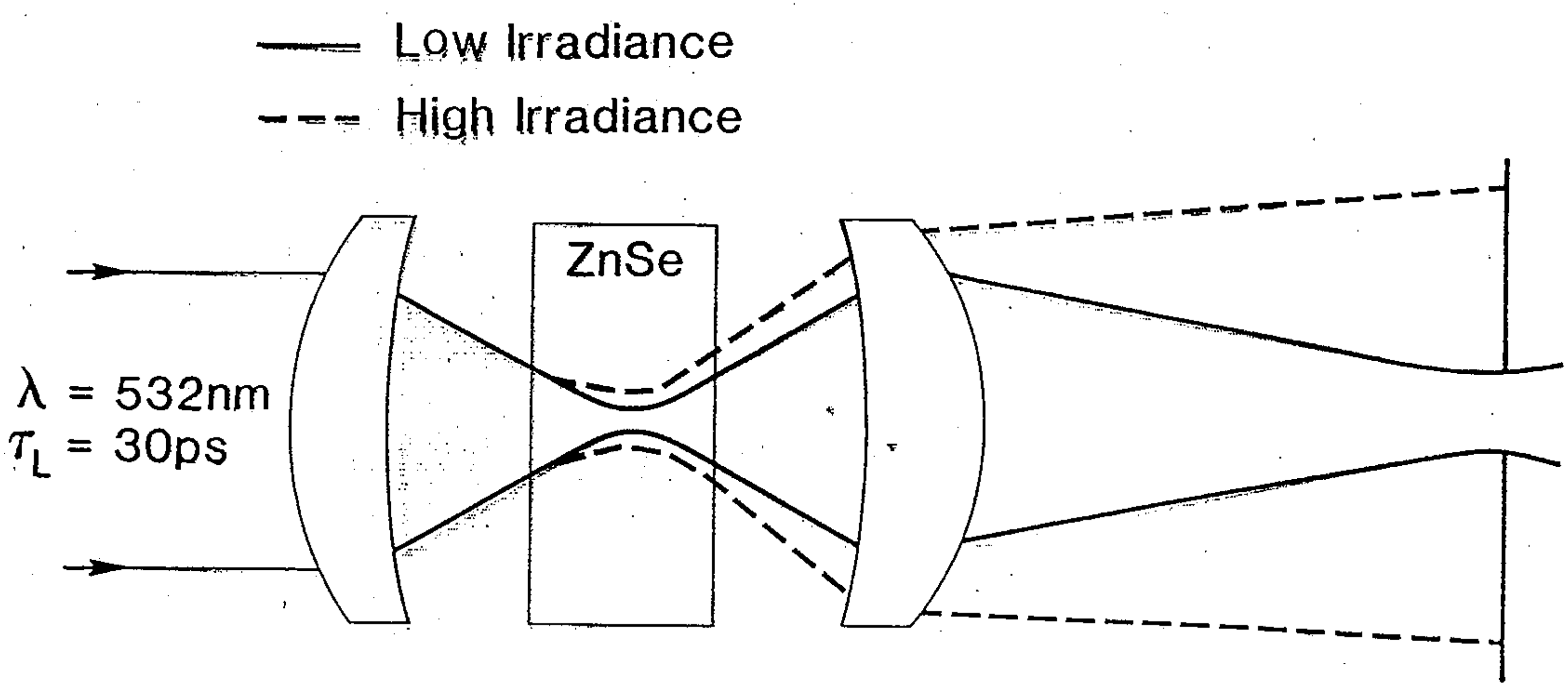


Plane - Gaussian Wave

↑ Gaussian Wave - fronts

- effective focal length

$$f_{eff} \doteq \frac{w^2}{n_2 |E|^2 L}$$



Low Irradiance
High Irradiance
ZnSe
λ = 532nm
τL = 30ps

Measurement Techniques

Nonlinear Transmission

Optical Limiting

Beam Distortion

Excite-Probe

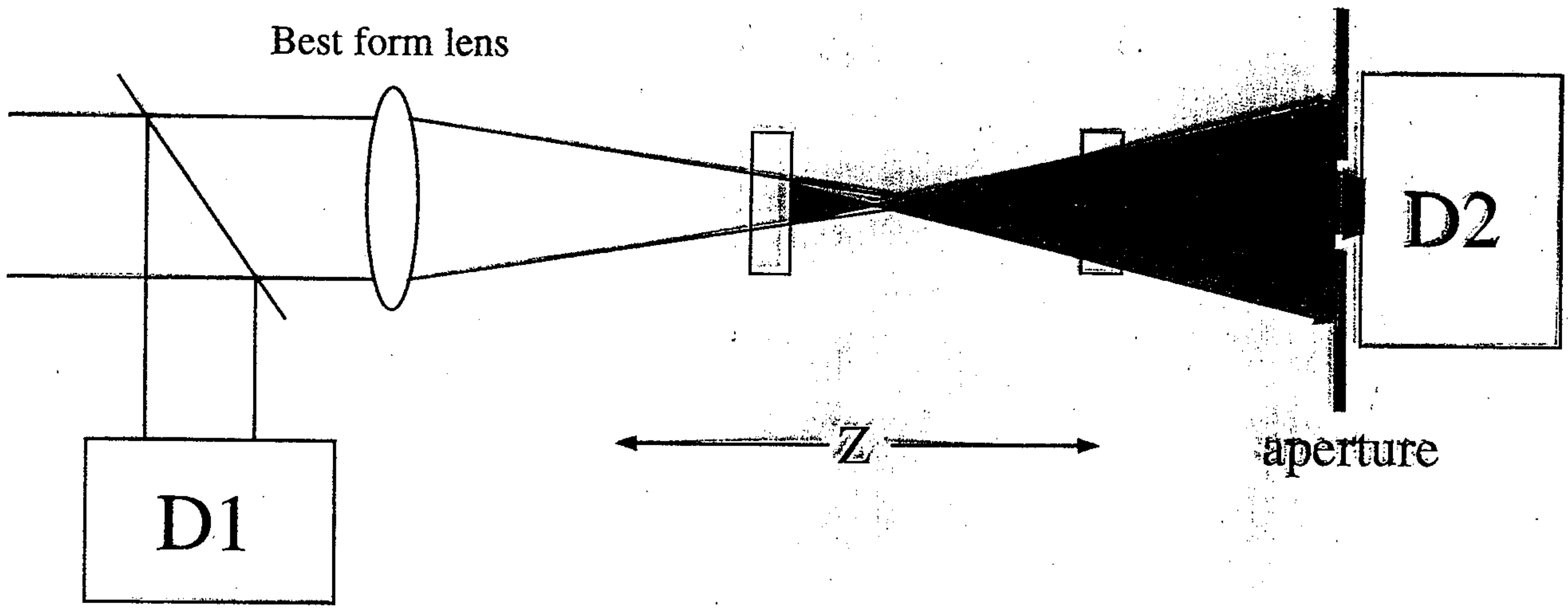
Degenerate Four-Wave Mixing

Z-Scan*

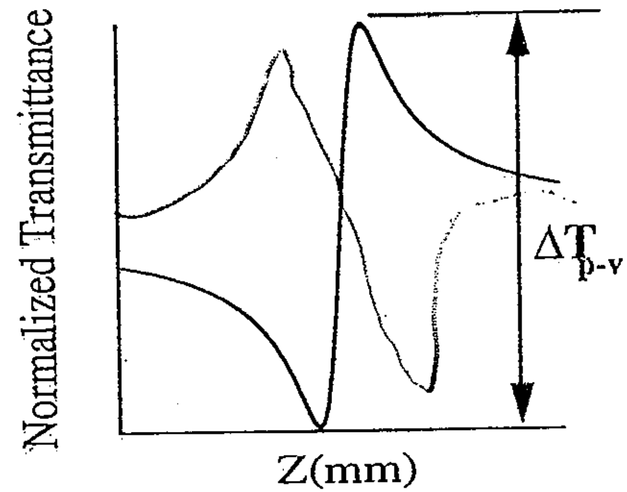
Exite-Probe Z-Scan*

(* Developed at CREOL)

Z-Scan Set-up



Z-Scan



$$\Delta T_{p\text{-}v} = p\,|\Delta\Phi^{NL}|$$

where $p = 0.36$ for a 40% aperture

The NL phase shift is defined as:

$$\Delta\Phi^{NL} = k\, n_2\, I\, L$$

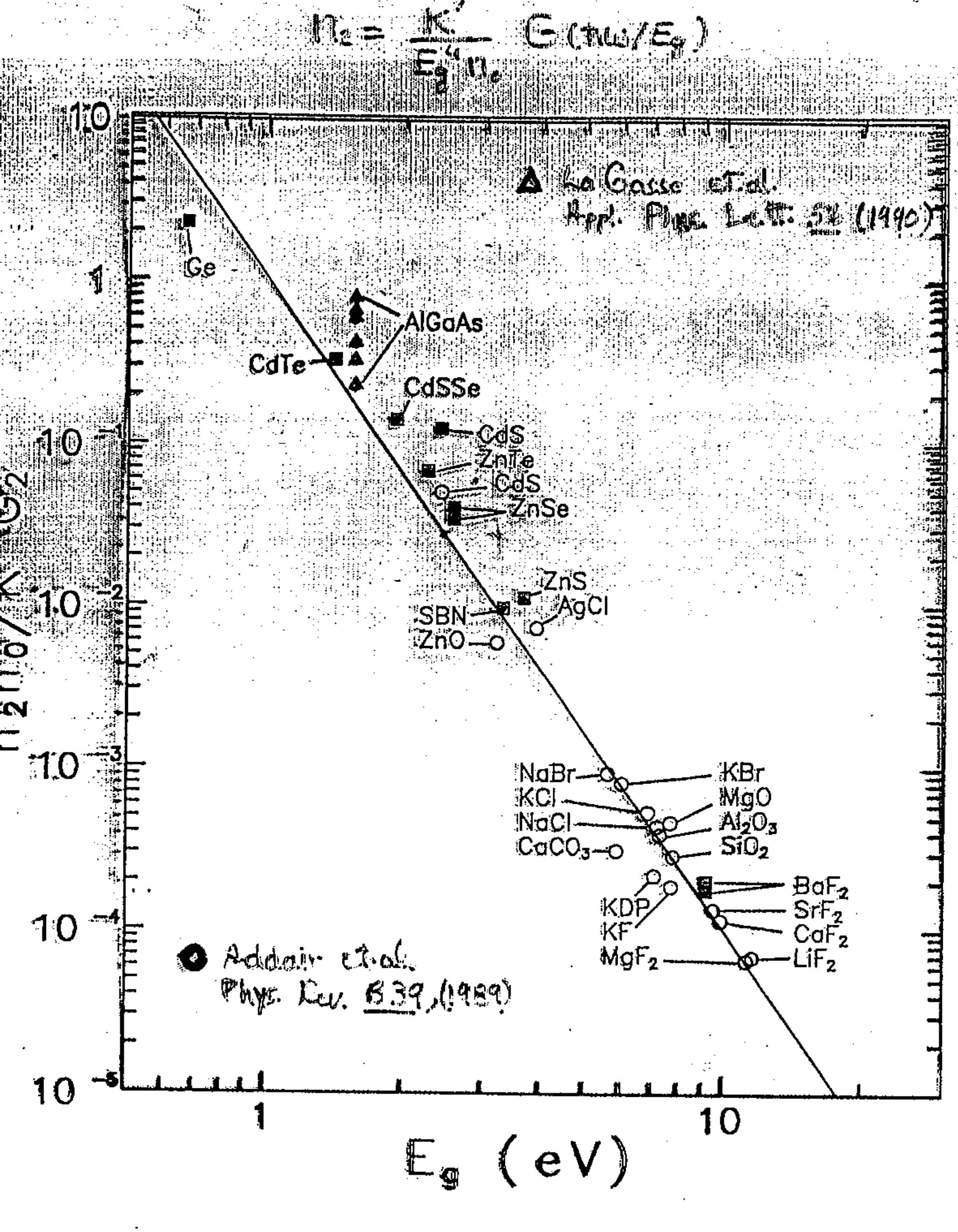
k is the wave vector

I is the peak irradiance

L is the sample length

n_2 is the nonlinear refractive index

BAND-GAP SCALING OF n_2



LABS & FACILITIES

10-Hz Picosecond Nd:YAG lab
- Excite-Probe Z-scan & DFWM

10-Hz Picosecond Nd:YAG / Dye laser lab
- Z-Scans in IR, Visible & UV.

Picosecond / Nanosecond CO_2 lab
- Characterization in the mid-IR (9-11 micron band)

Single mode Nanosecond Nd:Yag lab
- Streak camera / vidicon for study of nsec limiting.
- nsec Z-Scans in IR and Visible

Picosecond Cr:$LiSrAlF_6$ laser lab
- Tuneable 50 psec 850 nm laser with 100 microjoule output.

* Femtosecond Ti:Sapphire / Cr:LiSrAlF regenerative amplifier system
- 200 fsec, millijoule energy pulses
- fsec broadband continuum source

Picosecond Nd:YLF laser
- Electro-Optic Sampling

Development of New Lasers and NLO Materials

Bruce H.T. Chai

CREOL
(Center for Research in Electro-Optics and Lasers)
University of Central Florida
12424 Research Parkway
Orlando, Florida 32826

Tel: (407) 658 - 6847
Fax: (407) 658 - 6880

January 13, 1992

* This work is supported by DARPA, FHTIC

§ Introduction:

⇨ Objectives:

◊ Establish a state-of-art crystal growth center in a university environment for

- » Research
- » Education

◊ Developing high optical quality crystals

- » Solid state laser hosts
- » Nonlinear optical devices
- » Substrates

◊ Supply materials internally and externally for R & D

◊ Technology transfer

- » from abroad to CREOL
- » from CREOL to industry and government laboratories

§ Crystal Growth Facilities at CREOL:

◊ The Crystal Growth Laboratory is established under AMMP (the Advanced Microelectronics and Materials Program) funded by both DARPA and the State of Florida.

◊ Laboratory planning started in March 1989.

◊ Installation of power, water and utilities started in July 1989.

◊ Testing first crystal puller at the end of September, 1989.

◊ Current Facilities:

Five stations fully optional, four to be completed. They include

3 RF heated pullers (two 30KW and one 50KW)
2 resistant heating fluoride pullers
3 TSSG furnaces (flux growth)
1 Cambridge pressurized puller

◊ Low temperature solution growth stations

⇨ nonlinear organic compounds.

◊ A fiber puller is under construction ⇨ with J. Dixon

◊ Optical fabrication laboratory.

◊ Most completed bulk crystal growth facility in U.S. universities.

§ **Crystal Growth Stations at CREOL:**

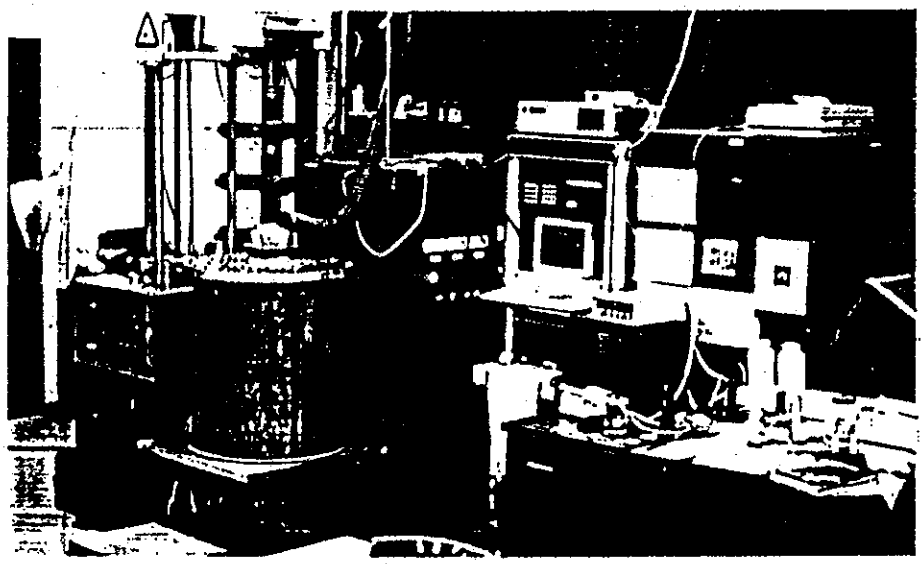


Fig. 2, Induction heated Czochralski station

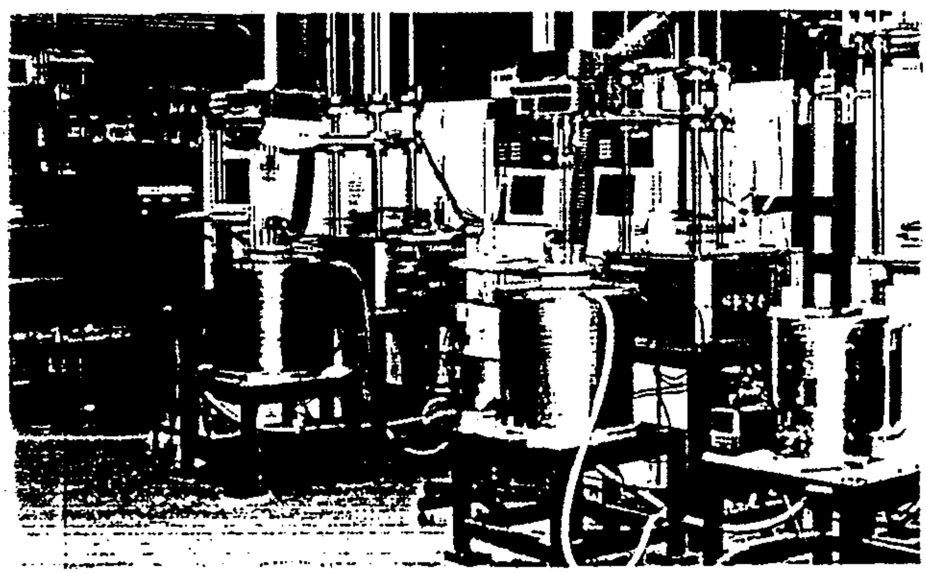


Fig. 3, Resistance heated Czochralski station

§ Czochralski Pulling:

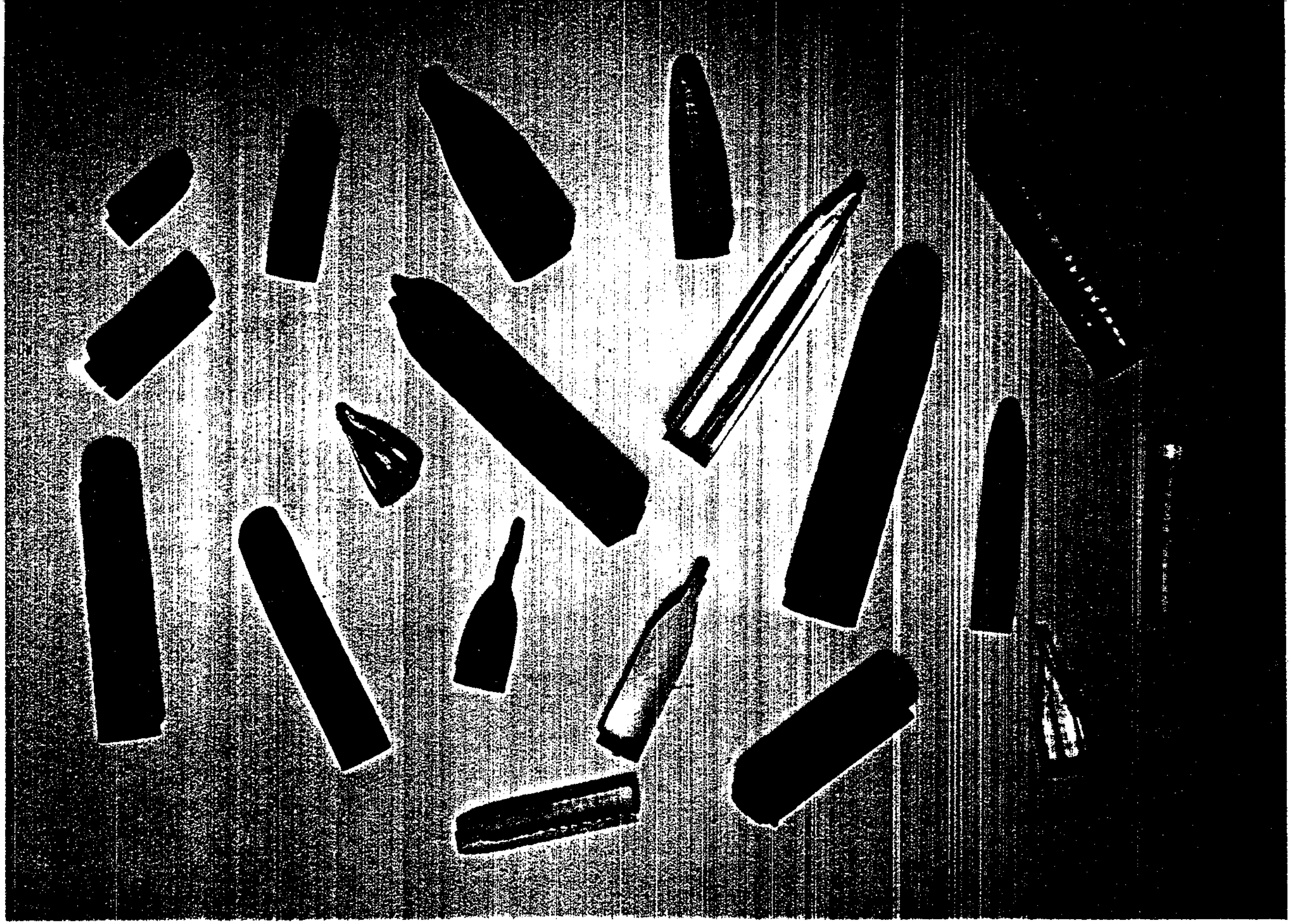
- Pulling crystals directly from melt
- Best developed growth technique because it can produce large, dislocation free crystals in a reasonable time.
- Produces highest optical quality crystal
- Require smooth rotation and pull movement
- Crystal diameter depends on temperature and pull rate.
- Free standing crystal after growth
- Can tolerate to some degree of nonstoichiometry and peritectic melting
- Two types of pullers used

  (1) RF heated → for oxide crystals,

    - high melting point (up to 2200°C)
    - Iridium metal containers

  (2) Resistant heated → for fluorides

    - low melting point (up to 1100°C)
    - Platinum metal containers



CRYSTALS PRODUCED AT CREOL

§ Current Research Programs:

(A) New Laser Materials Research

- Oxides
- Fluorides

(B) Nonlinear Optical Crystals

- Borates
- Niobates

§ Selection of Laser Materials :

- Selection of host crystals
  - transparent
  - rubust
  - high thermal conductivity
  - low refractive indices

  Cline's rule – High Al and Be for good laser materials

- Selection of dopants
  - rare earth elements – intrinsic transition
  - transitional metals – extrinsic transition
  - codoping – energy transfer

- Matching crystal to dopants
  - ionic size
  - coordination number
  - chemical stability

- Site distortions
  - fluorescence lifetime
  - nonradiative absorption
  - excited state absorption

- Crystal growth

* Crystal defects
  - scattering, smoke
  - stress
  - inclusions, voids, solid particles, Ir, etc.
  - inhomogeneity

§ Current Laser Materials Research

◊ Oxides :

- Cr^{4+} doped laser materials
  - Mg_2SiO_4, YAG, CAS, CGS, CAO, YSO, FAP
  - Cr^{4+} doped YSO has been successfully lased
- Rare earth doped laser materials
  - YAG, YAP, YSO, FAP, $CaYAlO_4$

◊ Fluorides :

- Cr3+ doped laser materials
  - LiSAF, LiCAF, LiSCAF, LiSCrF
- Rare earth doped laser materials
  - YLF, KYF, BYF
  - First demonstration of TSSG of KYF

§ Current Nonlinear Optical Materials Research

◊ Borates:

- BTO, SNB, KNB
- KNB – a new potential useful crystal

◊ Niobates:

- $LiNbO_3$, KLN, SBN
- Rare earth doped NLO materials
  - -- $LiNbO_3$, SBN,
  - – Self frequency doubling
- Periodical structures for quasi-phase matching
  - -- $LiNbO_3$, $LiTaO_3$, BNN,

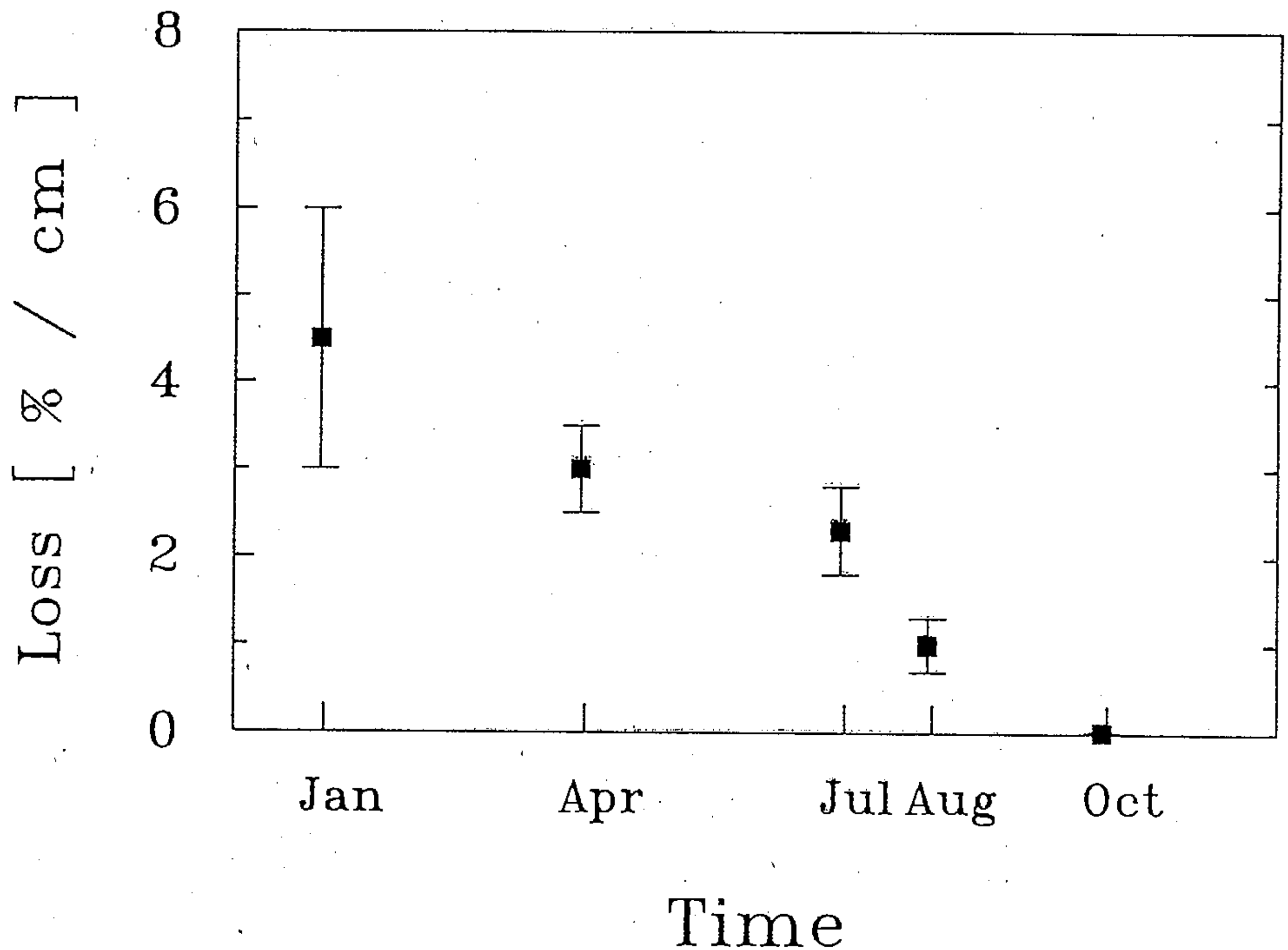
NEW SOLID STATE LASERS

Presented by Dr. Michael Bass

Industrial Affiliates' Day

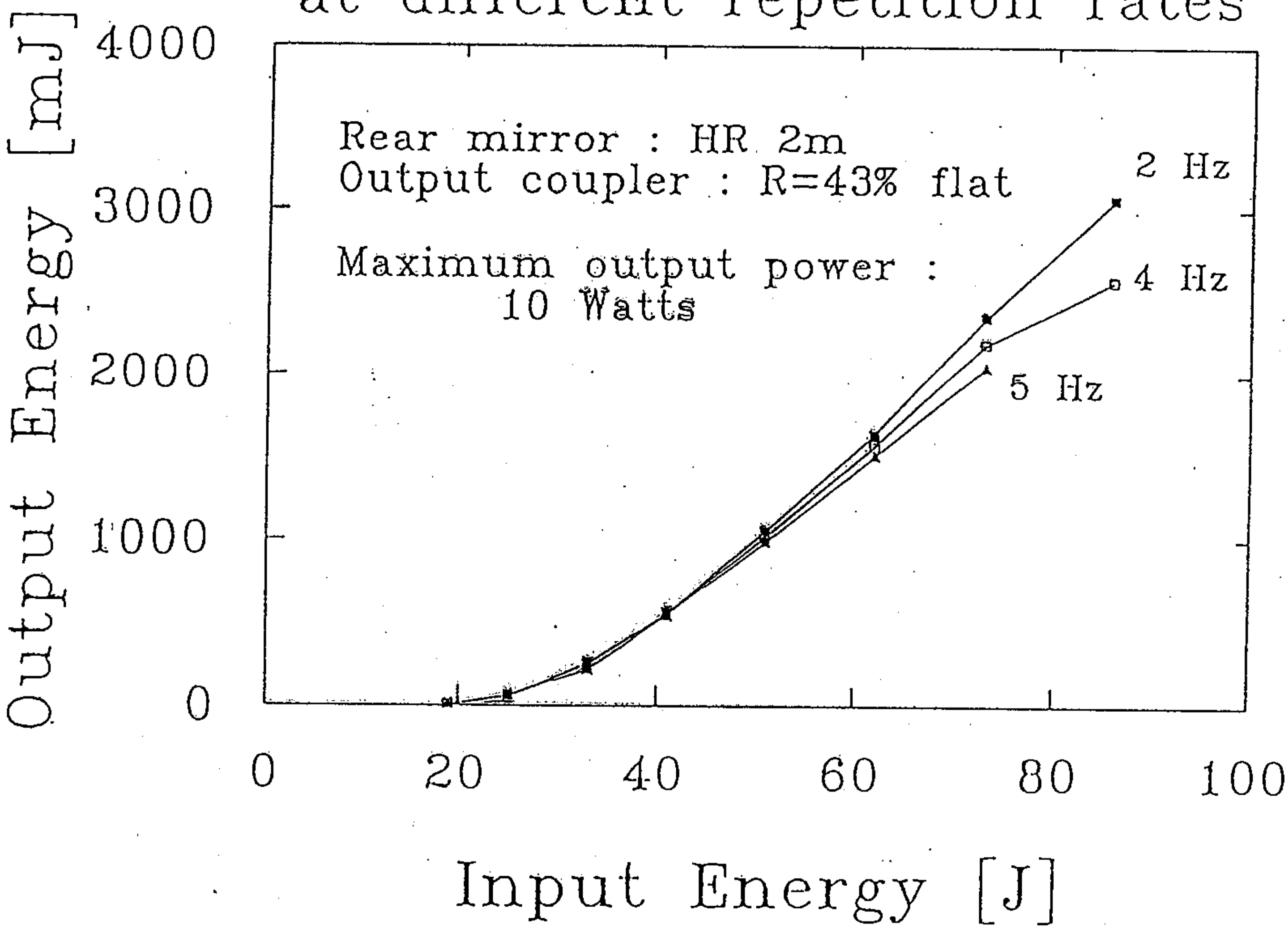
Monday, January 13, 1992

Losses in Cr:LiSAF

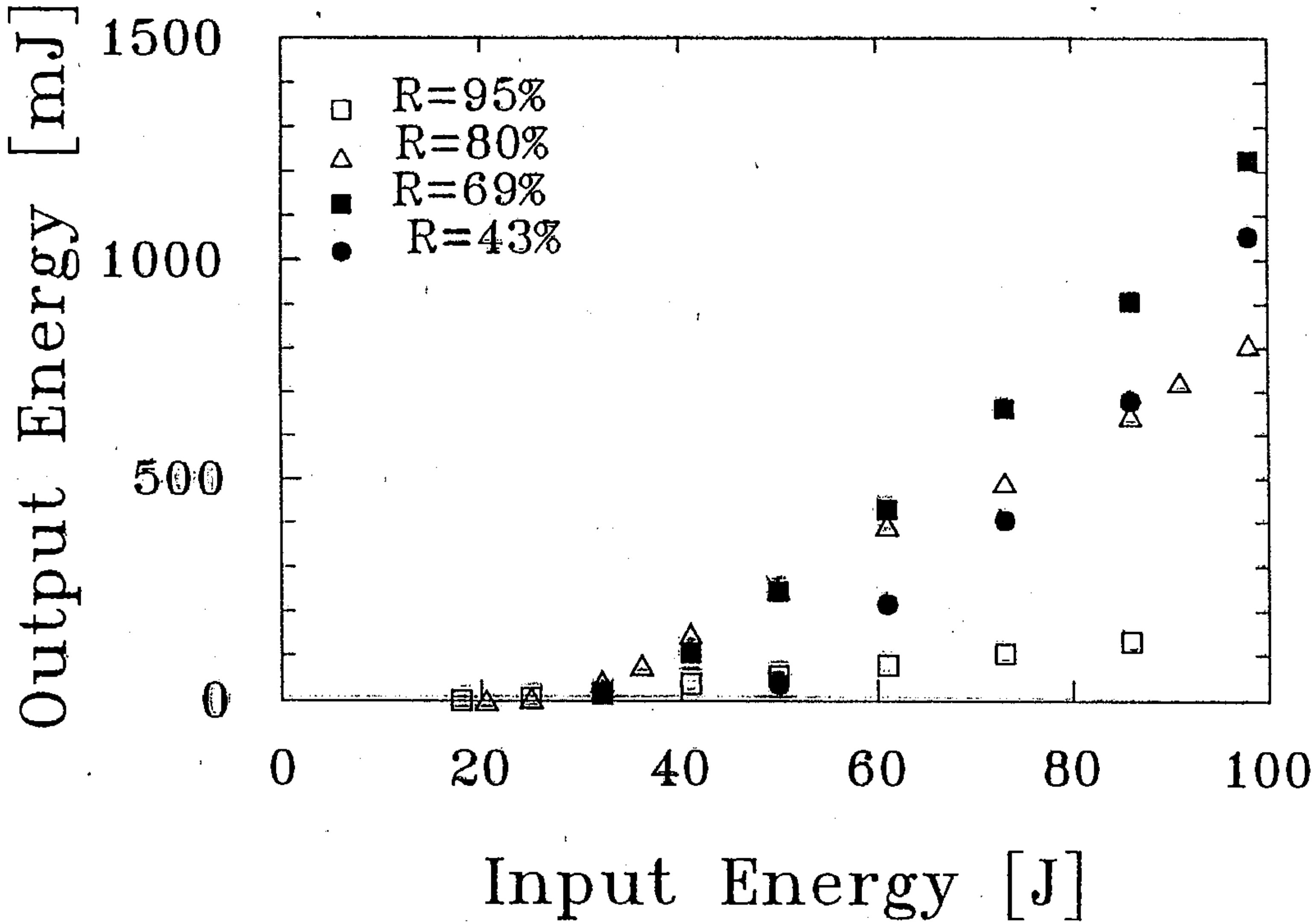


CREOL

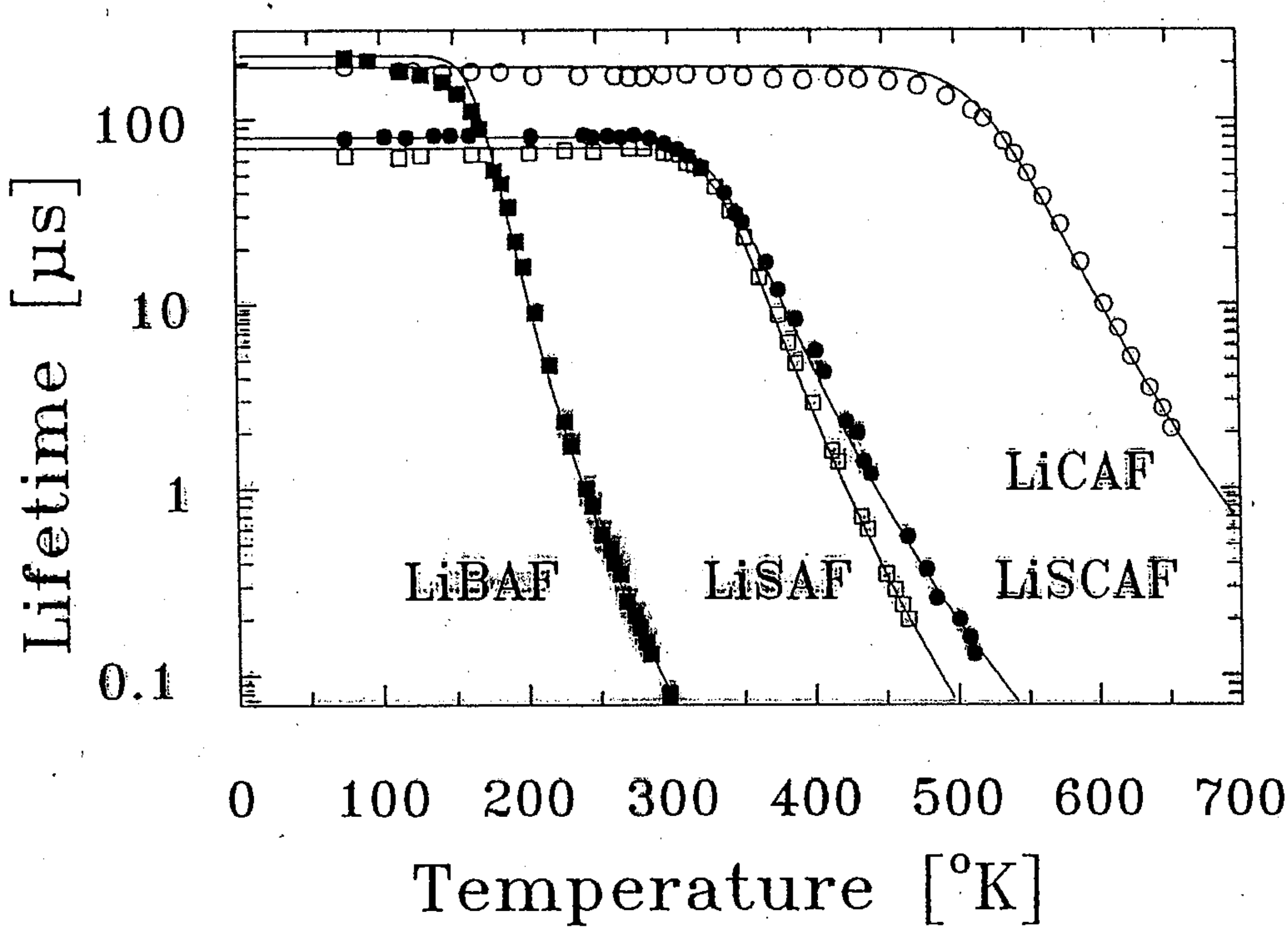
Laser performance of Cr:LiSAF at different repetition rates



Input output energies for 2%Cr:LiSCAF



Lifetimes of Cr^{3+} in LiBAF, LiSAF LiSCAF and LiCAF



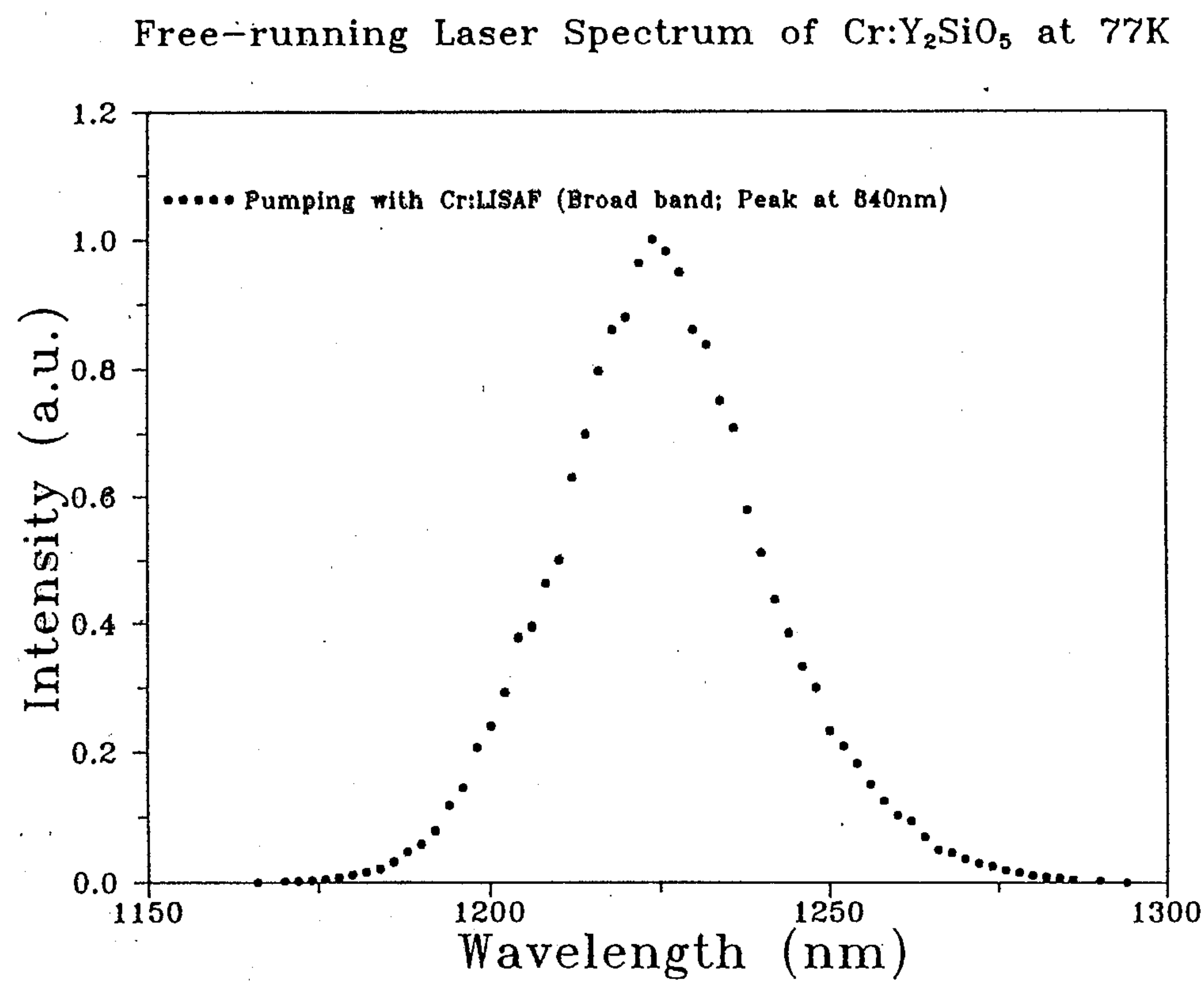

Free-running Laser Spectrum of Cr:Y2SiO5 at 77K
Pumping with Cr:LISAF (Broad band; Peak at 840nm)
Intensity (a.u.)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1150
1200
1250
1300
Wavelength (nm)

FIG 10

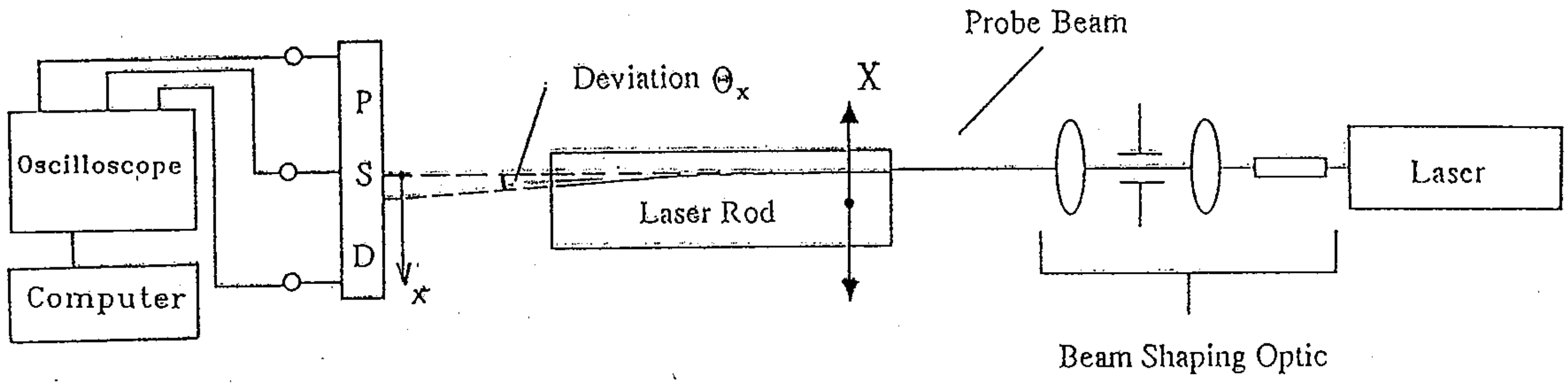
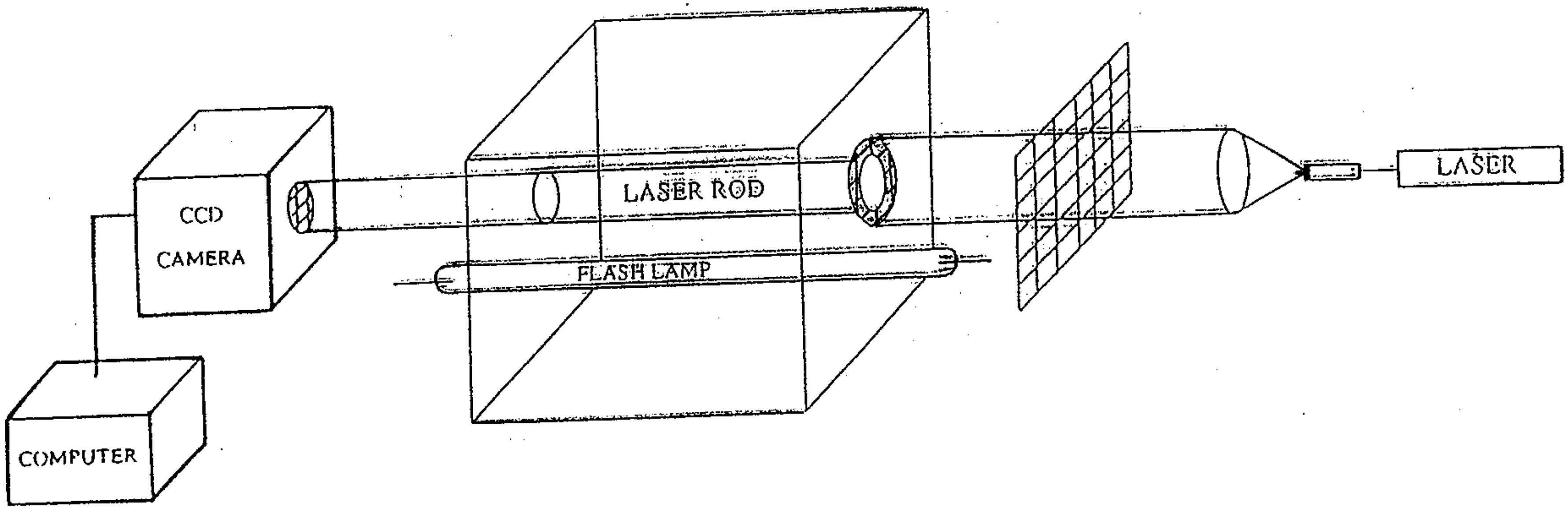
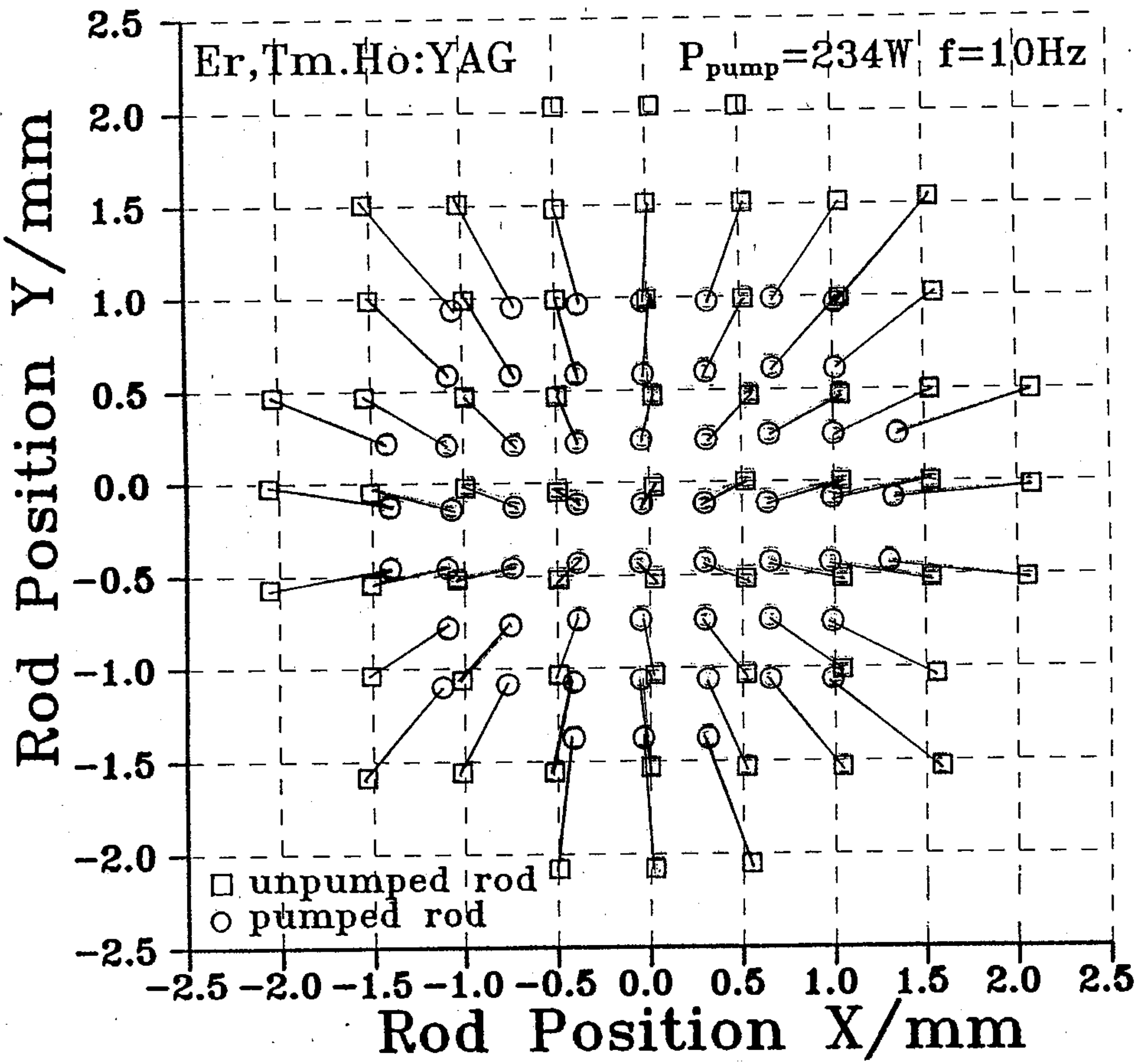

Probe Beam
Deviation Θx
X
Oscilloscope
P
S
D
x
Laser Rod
Laser
Computer
Beam Shaping Optic

Fig. 1


COMPUTER
CCD
CAMERA
LASER ROD
FLASH LAMP
LASER



Er,Tm.Ho:YAG
P_{pump}=234W f=10Hz
□ unpumped rod
○ pumped rod
Rod Position Y/mm
Rod Position X/mm
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5

SOLID STATE LASERS AND LASER SPECTROSCOPY

Faculty:

Jin J. Kim, Professor of Physics and Electrical Engineering

Bruce H.T. Chai, Professor of Physics and Mechanical Engineering

Postdoctoral:

Chil-Min Kim

Students:

Jim Scheid

Kijun Park

Ron Raike

Solid State Lasers and Laser Spectroscopy

Jin J. Kim and Bruce H. T. Chai

Center for Research in Electro-Optics and Lasers

University of Central Florida

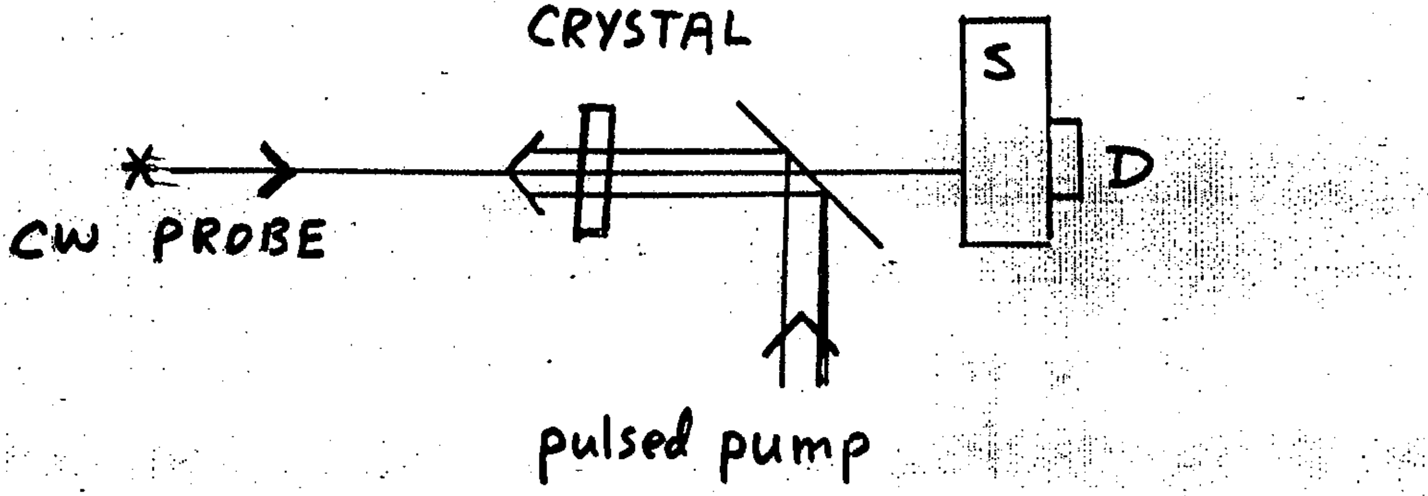
Orlando, FL 32826

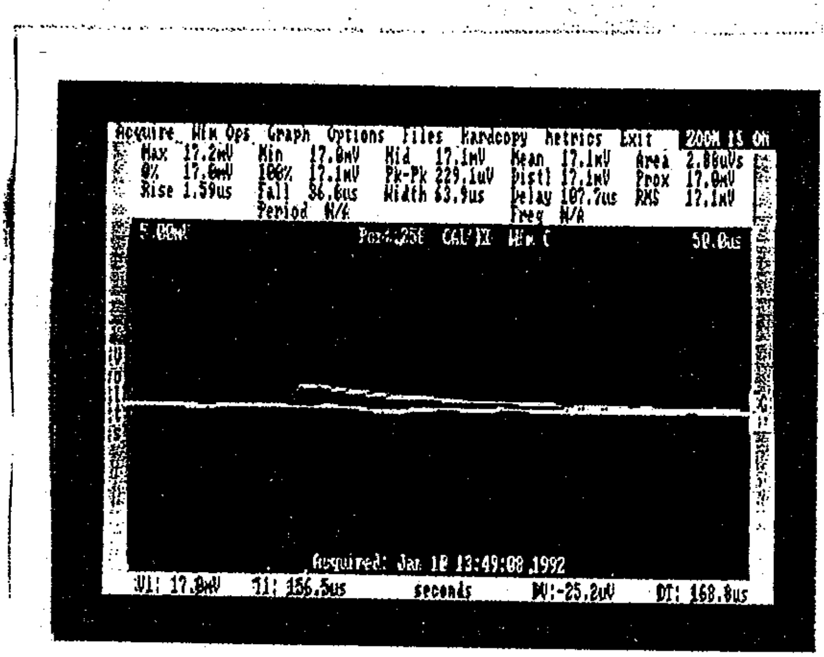
Study the Physical Properties of Tunable Laser Host Materials such as Cr^{3+}:LiSAF, LiCAF, LiSCAF, and Pr^{3+}:YLF for Diode Laser Pumping

---measurements of thermal expansion coefficients and the indices of refraction
---excited state absorption cross sections
---transition properties
---laser gain

- **Conduct Pulsed Dye Laser Pumping Experiments in Simulation of High Average Power Diode Laser Pumping of Tunable Solid State Lasers**

- **Set up CW Diode Laser Pumping of Pr^{+3}:YLF Laser**





Pump at 640 nm

Signal at 520 nm

Excited State Absorption Measurements

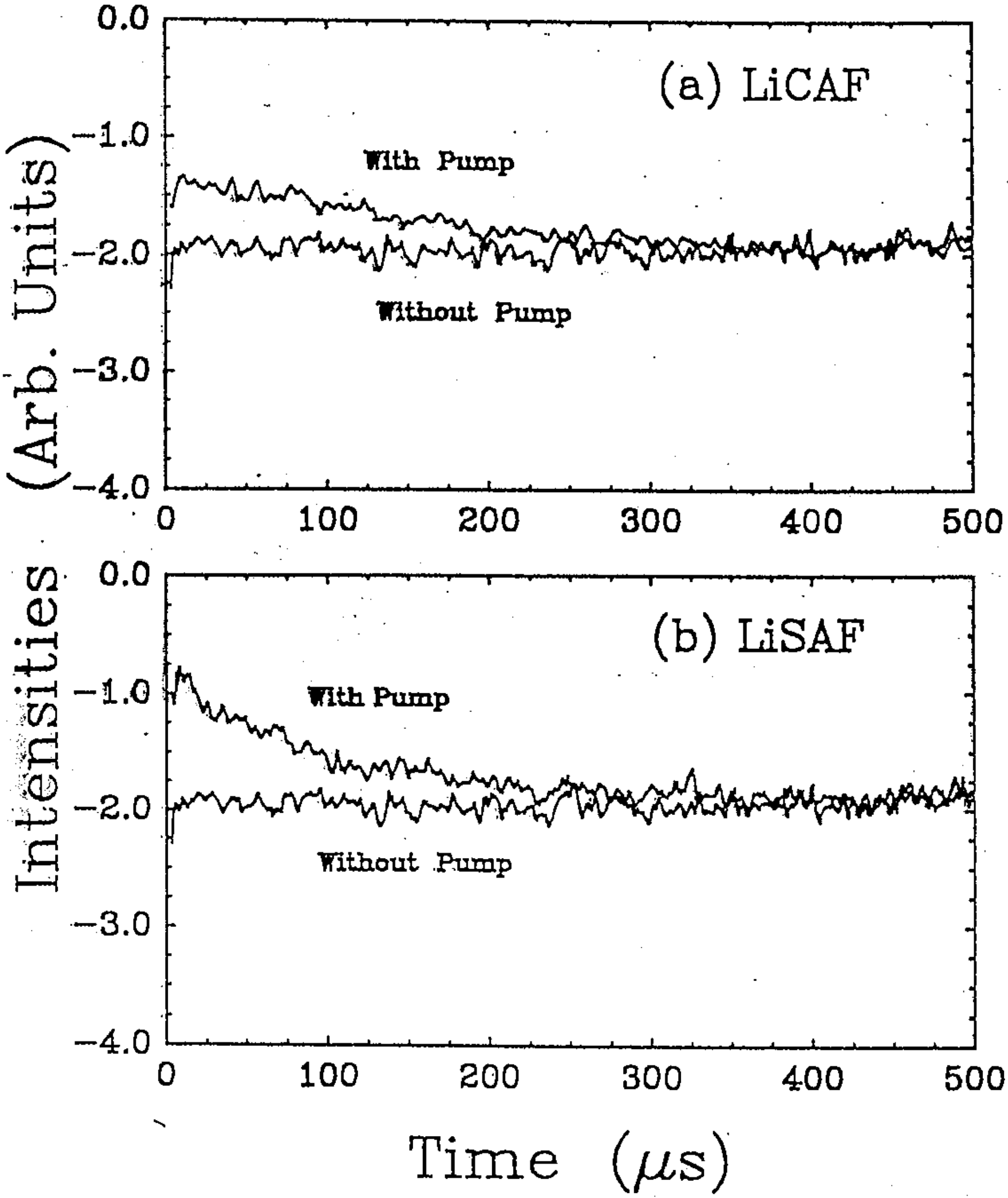


Fig. 3

J. J. Kim, et al.

Cr-doped LiSAF Laser Pumped by a Pulsed Dye Laser

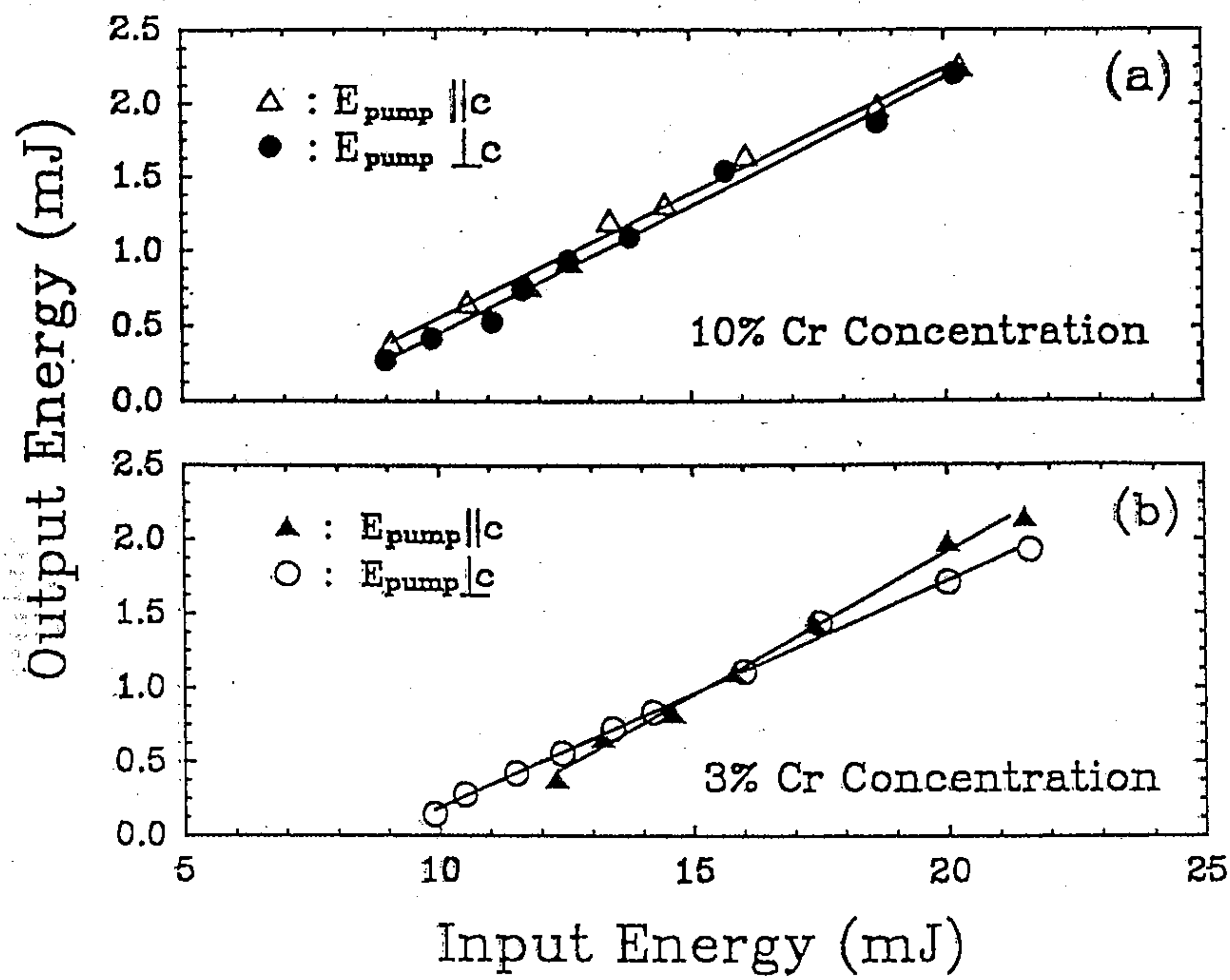


Fig. 1

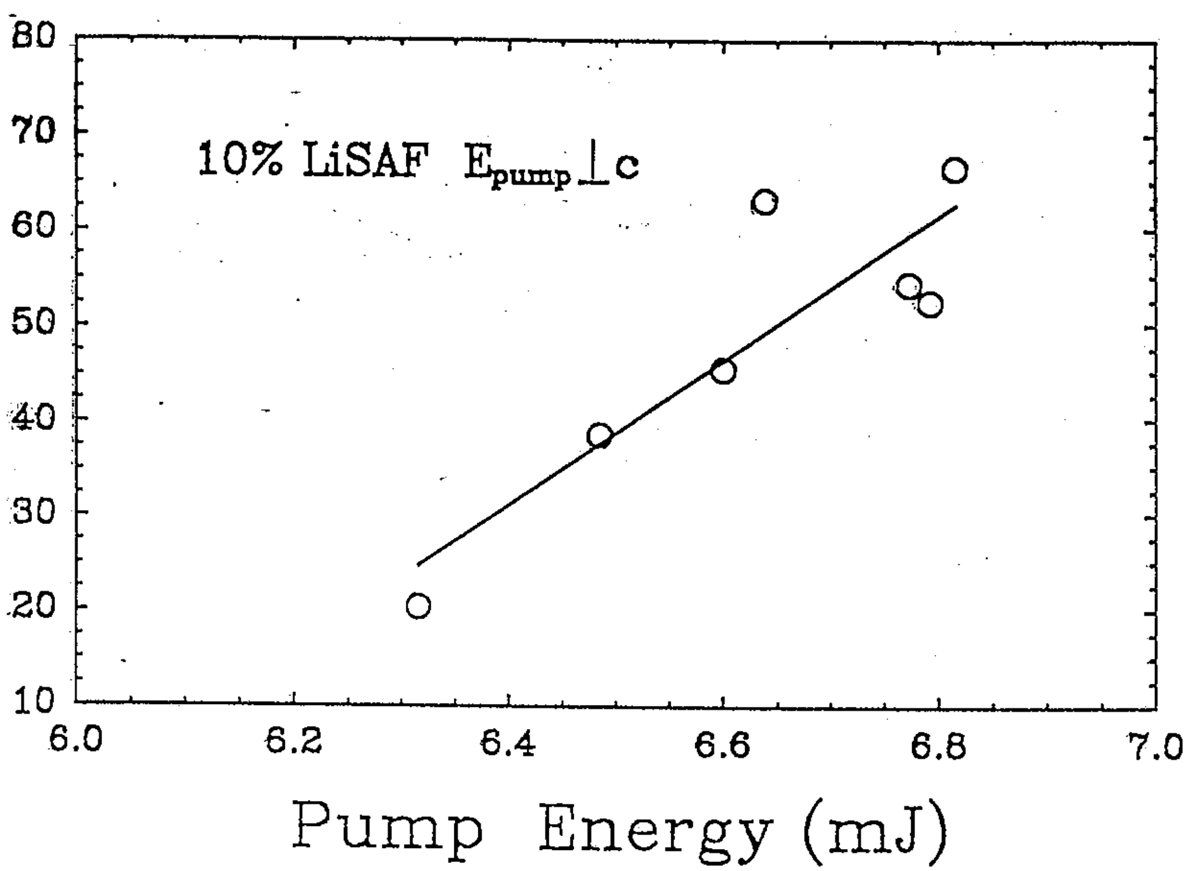


Fig. 2
J. J. Kim, et al
Cr^{3+}: LiSAF

ummary

We have expertise in spectroscopic studies of materials and laser research and development

We also have expertise in applications of pulsed power technology to laser research and development

DIODE-LASER-PUMPED SOLID-STATE LASERS

JEFF DIXON
DEPARTMENT OF ELECTRICAL ENGINEERING

CREOL INDUSTRIAL AFFILIATES MEETING
JANUARY 13, 1992

GROUP PERSONNEL

DR. DIVINDER SAINI - POSTDOCTORAL FELLOW

DR. PETER N. KEAN - POSTDOCTORAL FELLOW

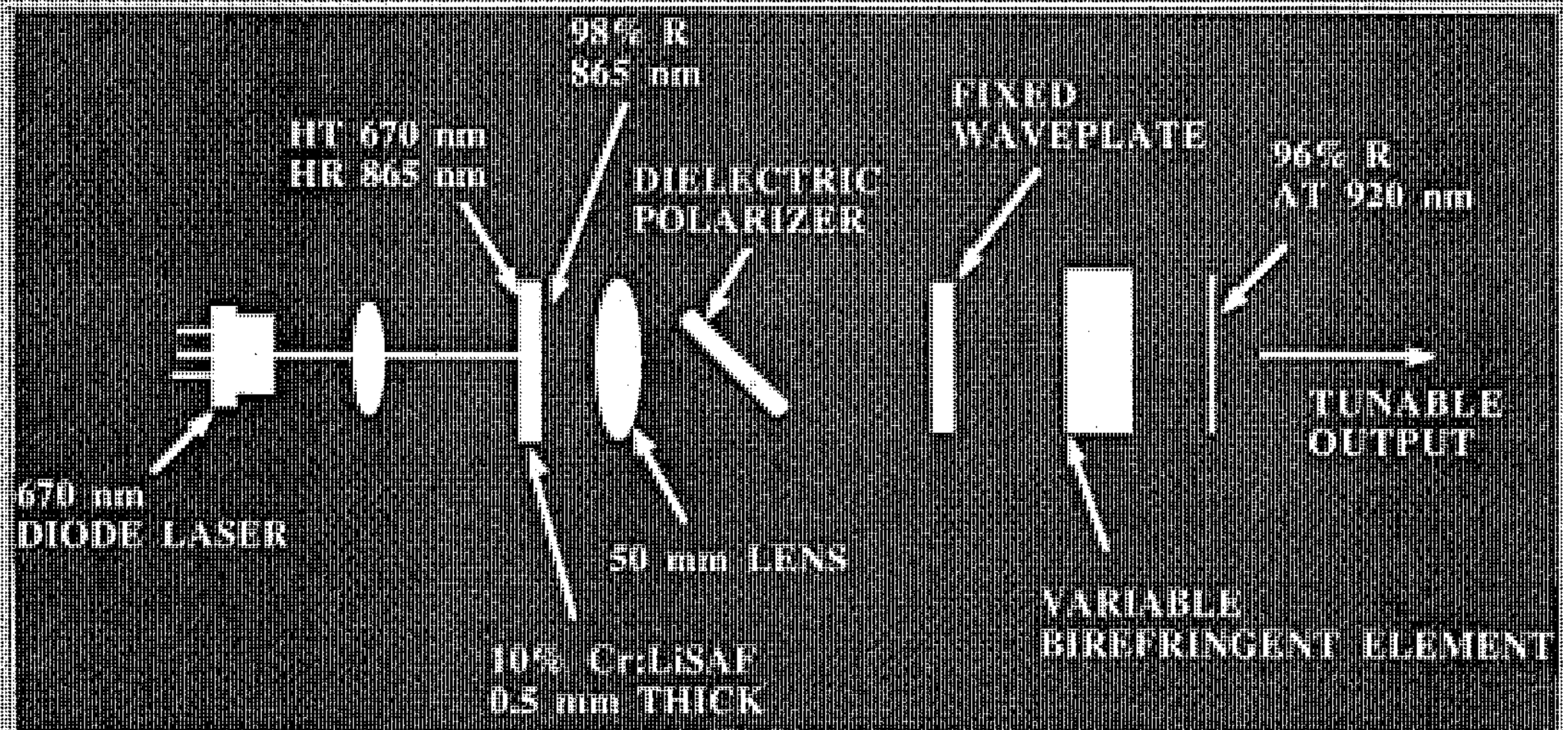
JEFF CUTHBERTSON - STUDENT

ERIC GRANN - STUDENT

HEIKE VOSS - STUDENT

QI ZHANG - STUDENT

ELECTRONICALLY-TUNABLE DIODE-PUMPED Cr:LiSAF LASER



PROS AND CONS OF DIODE PUMPING

ADVANTAGES	DISADVANTAGES
COMPARED TO DIODES	
- AMPLITUDE STABILITY - SPECTRAL COHERENCE - SPATIAL COHERENCE -ENERGY STORAGE - NEW WAVELENGTHS	- EFFICIENCY SIZE/COMPLEXITY (?)
COMPARED TO FLASHPUMPING	
- EFFICIENCY - SIZE - STABILITY -COHERENCE -LIFETIME	-HIGH COST - LOW OUTPUT POWER

PRIMARY GROUP OBJECTIVES

- INVESTIGATE NEW LASER MATERIALS

- DEVELOP PUMPING TECHNIQUES
    - NEW DIODES
    - NOVEL WAYS TO USE 'OLD' DIODES

- DEVELOP TECHNIQUES FOR NONLINEAR FREQUENCY CONVERSION
    - INTRACAVITY PROCESSES
    - EXTERNAL RESONANT PROCESSES
    - NONLINEAR OPTICAL MATERIALS

GROUP PERSONNEL

DR. DIVINDER SAINI - POSTDOCTORAL FELLOW

DR. PETER N. KEAN - POSTDOCTORAL FELLOW

JEFF CUTHBERTSON - STUDENT

ERIC GRANN - STUDENT

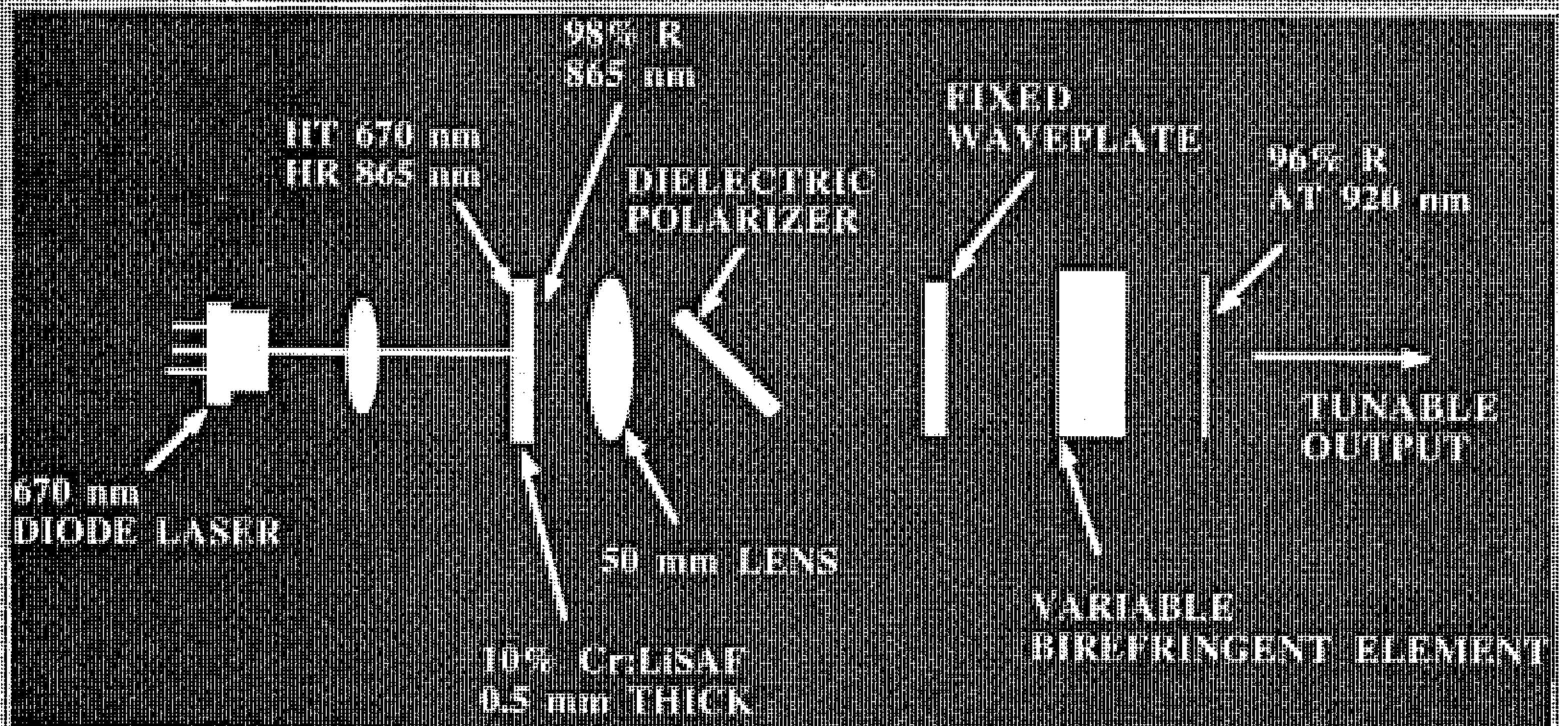
HEIKE VOSS - STUDENT

QI ZHANG - STUDENT

NEW MATERIALS

1. Cr:LiSAF
2. STOICHIOMETRIC Nd COMPOUNDS
3. SPECTROSCOPY LAB
4. SINGLE-CRYSTAL FIBER PULLER

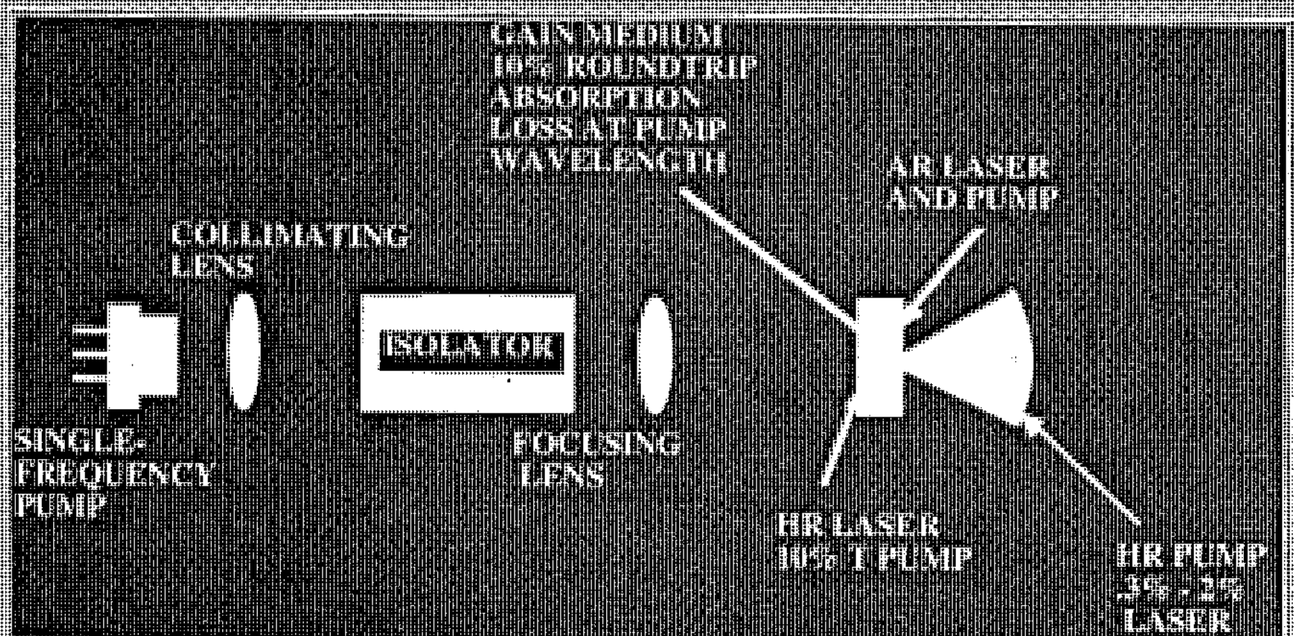
ELECTRONICALLY-TUNABLE DIODE-PUMPED Cr:LiSAF LASER



PUMPING TECHNIQUES

1. INTRACAVITY PUMPING
2. RESONANT PUMPING
3. CLOSE-COUPLED PUMPING
4. 670-nm PUMPING

RESONANTLY-PUMPED SOLID-STATE LASER

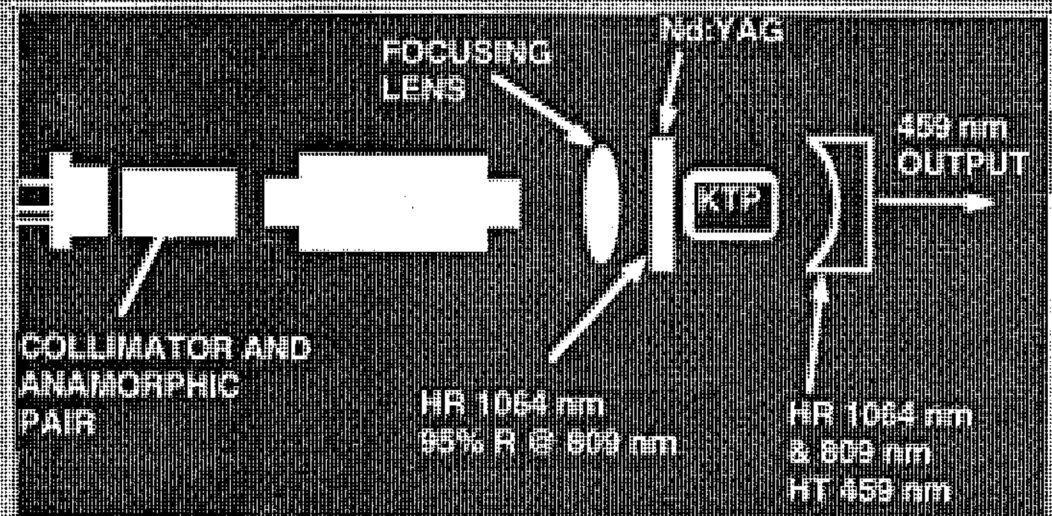


NONLINEAR FREQUENCY CONVERSION

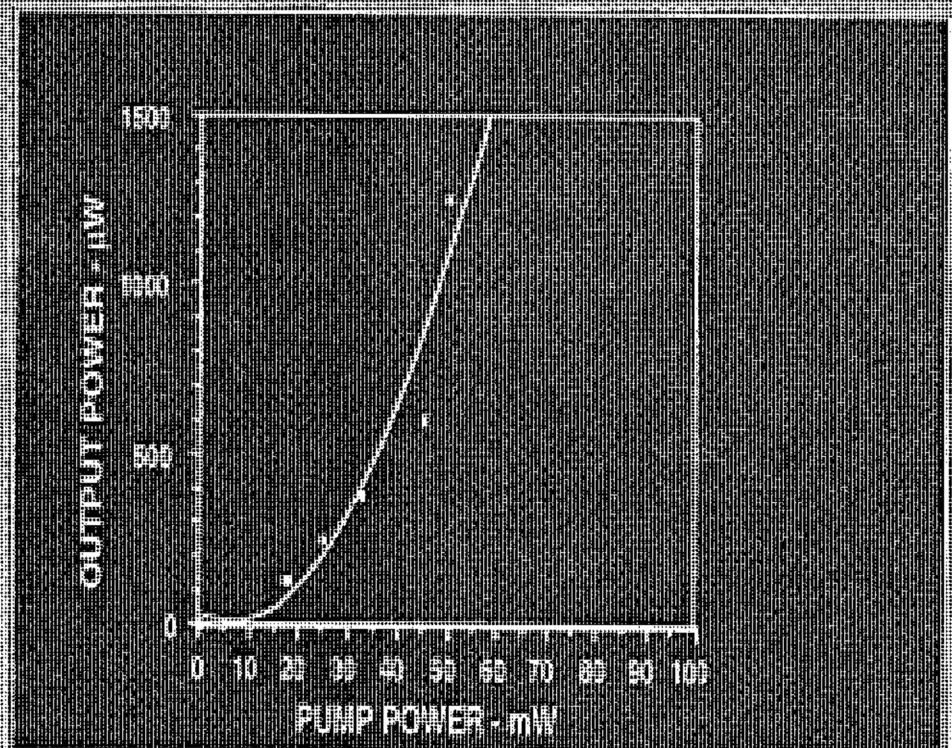
1. RESONANTLY-PUMPED SUM FREQUENCY GENERATION

2. DOUBLY-RESONANT HARMONIC GENERATION

PUMP-RESONANT SUM FREQUENCY LASER



OUTPUT CURVE FOR PUMP-RESONANT SUM FREQUENCY LASER



CREOL — Laser Plasma Laboratory for Science and Technology

Faculty

Dr Martin C. Richardson
Professor, Physics & Electrical Engineering

Dr William T. Silfvast
Professor, Physics & Electrical Engineering

Graduate Research Students

Howard Bender	Physics
Charles Bogusch	Electrical Engineering
Yinfei Chen	Electrical Engineering
Art Hanzo	Electrical Engineering
Feng Jin	Physics
Edward Miesak	Electrical Engineering
Gary A. Sweezey	Electrical Engineering

Visiting Scientists & Research Associates

Dr Paul Beaud
Institute of Applied Physics, University of Bern, Switzerland

Dr Ann Marie Eligon
CREOL

Dr Victor Yanovsky
General Physics Institute, Academy of Sciences, Moscow, USSR

Research Assistants

Karin Karpinchik	Physicist
Douglas Lattman	Computer Scientist
Jerry Thorpe	Physicist

Undergraduate Research Students

Tony DeLia	Physics
Nanette J. Gruber	Electrical Engineering

CREOL Laser Plasma Laboratory for Science and Technology

Faculty

Dr Martin C. Richardson
Professor, Physics & Electrical Engineering

Dr William T. Silfvast
Professor, Physics & Electrical Engineering

Graduate Research Students

Howard Bender	Physics
Charles Bogusch	Electrical Engineering
Yinfei Chen	Electrical Engineering
Art Hanzo	Electrical Engineering
Feng Jin	Physics
Edward Miesak	Electrical Engineering
Gary A. Sweezey	Electrical Engineering

Visiting Scientists & Research Associates

Dr Paul Beaud
Institute of Applied Physics, University of Bern, Switzerland

Dr Ann Marie Eligon
CREOL

Dr Victor Yanovsky
General Physics Institute,Academy of Sciences, Moscow, USSR

Research Assistants

Karin Karpinchik	Physicist
Douglas Lattman	Computer Scientist
Jerry Thorpe	Physicist

Undergraduate Research Students

Tony DeLia	Physics
Nanette J. Gruber	Electrical Engineering

Laser Plasma Laboratory Funding

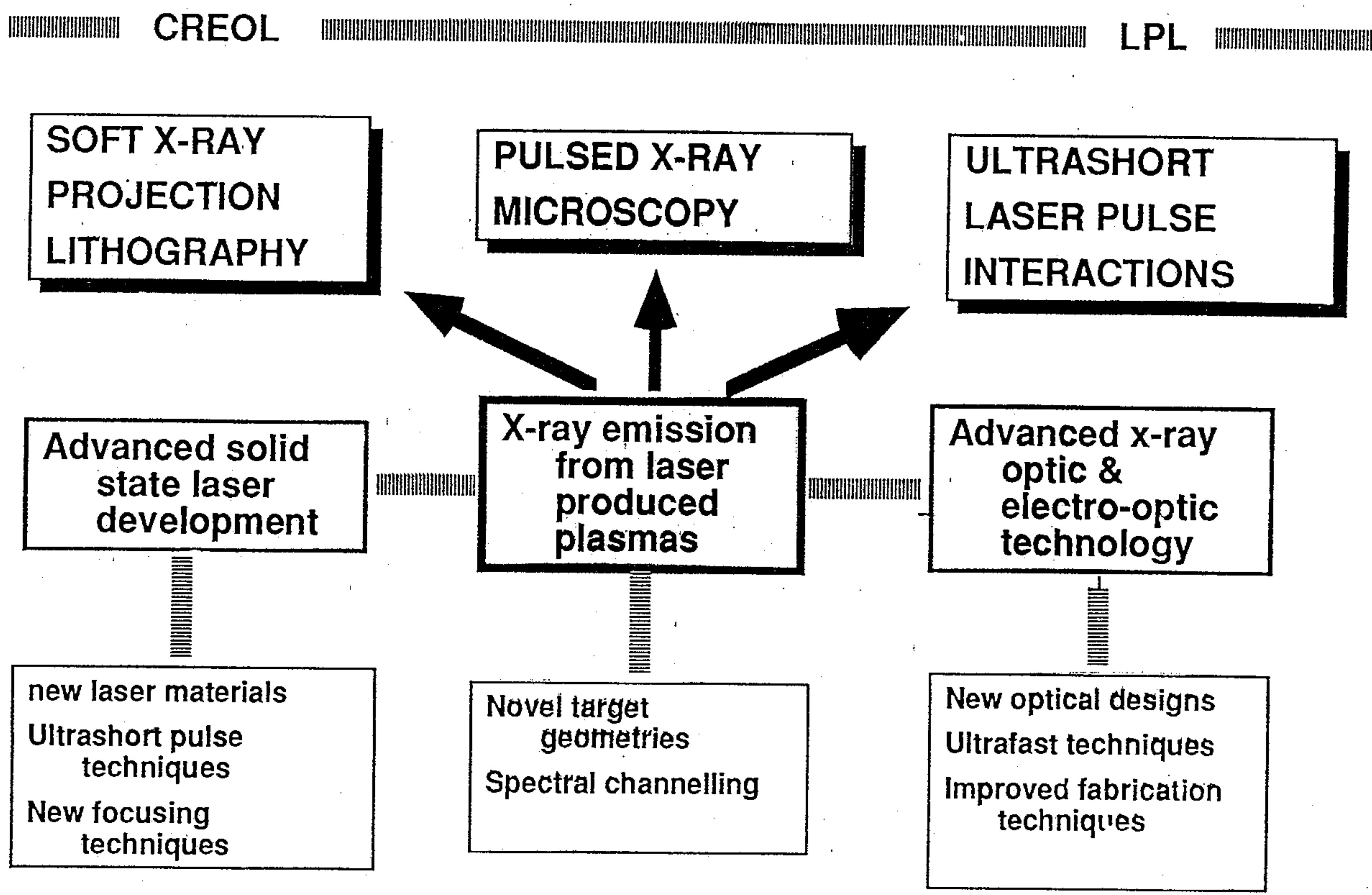
Funding Support

State of Florida
National Science Foundation
Defence Advanced Research Projects Agency
Lawrence Livermore National Laboratory
Florida High Technology & Industry Council

Industrial Support

Laser Ionics Inc, Orlando, FL
Lightning Optical Corp, Tarpon Springs, FL
Newport Corp, Fountain Valley, CA
Quantum Technology Inc, FL
Schwartz Electro-Optics Inc, Orlando, FL
Tektronix Inc, Beaverton WA

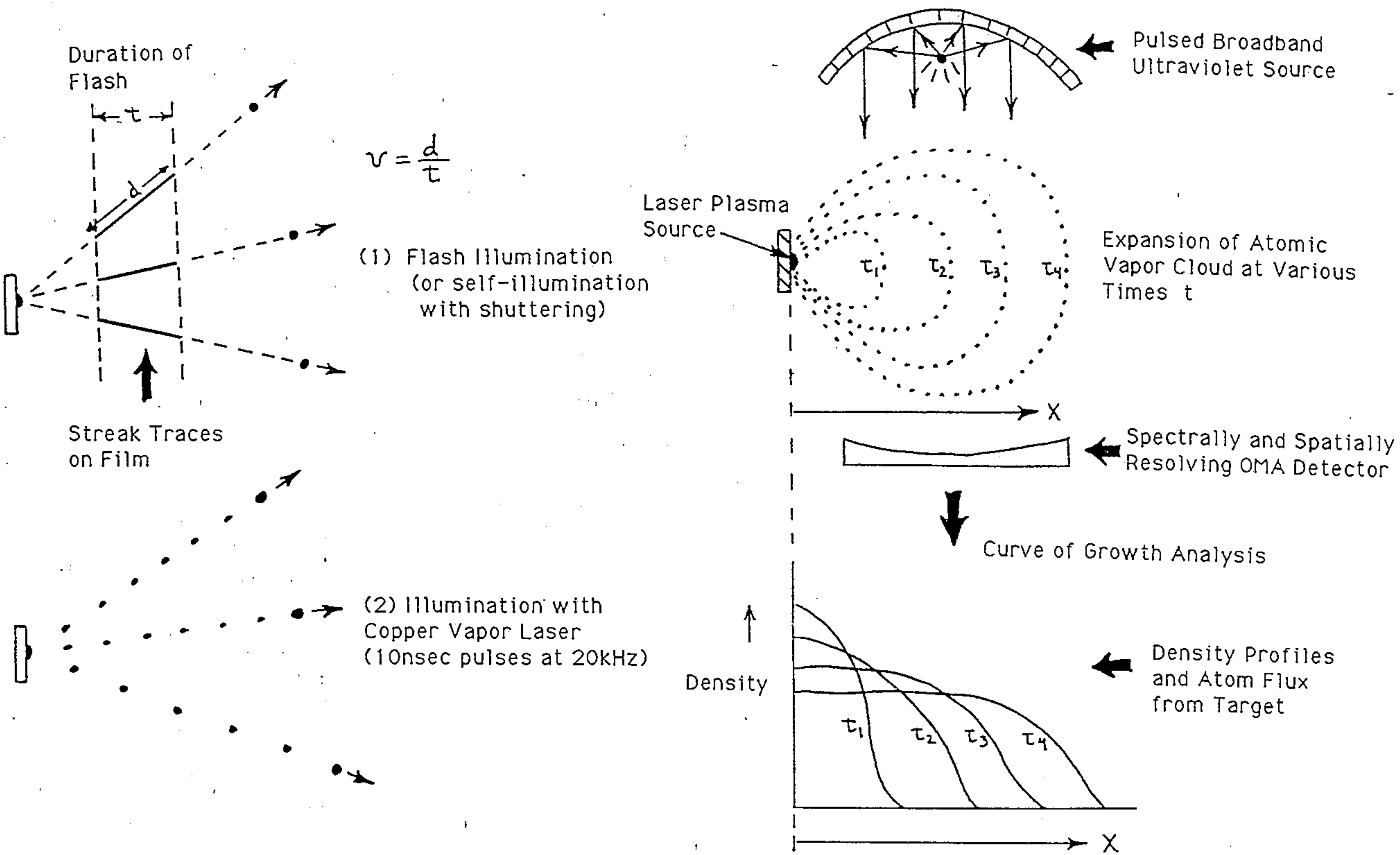
PRIMARY COMPONENTS OF LPL



Unique properties of Laser Plasma X-Ray Sources

POINT SOURCE	Micron-size point source. Stable to microns in position
BRIGHTNESS	High conversion efficiency to continuum and line emission. Isotropic or directional.
VARIABLE SPECTRUM	Multi-component spectrum. Strong line emission. Target dependent.
PULSED EMISSION	Pulsed duration from millisecond to picosecond. flash and time-resolved studies.
COMPACT	Laboratory-size footprint. Low cost. Clean vacuum environment. High repetition rate.

Atomic & heavy particle kinetics



Impact Areas of X-ray Microscopy

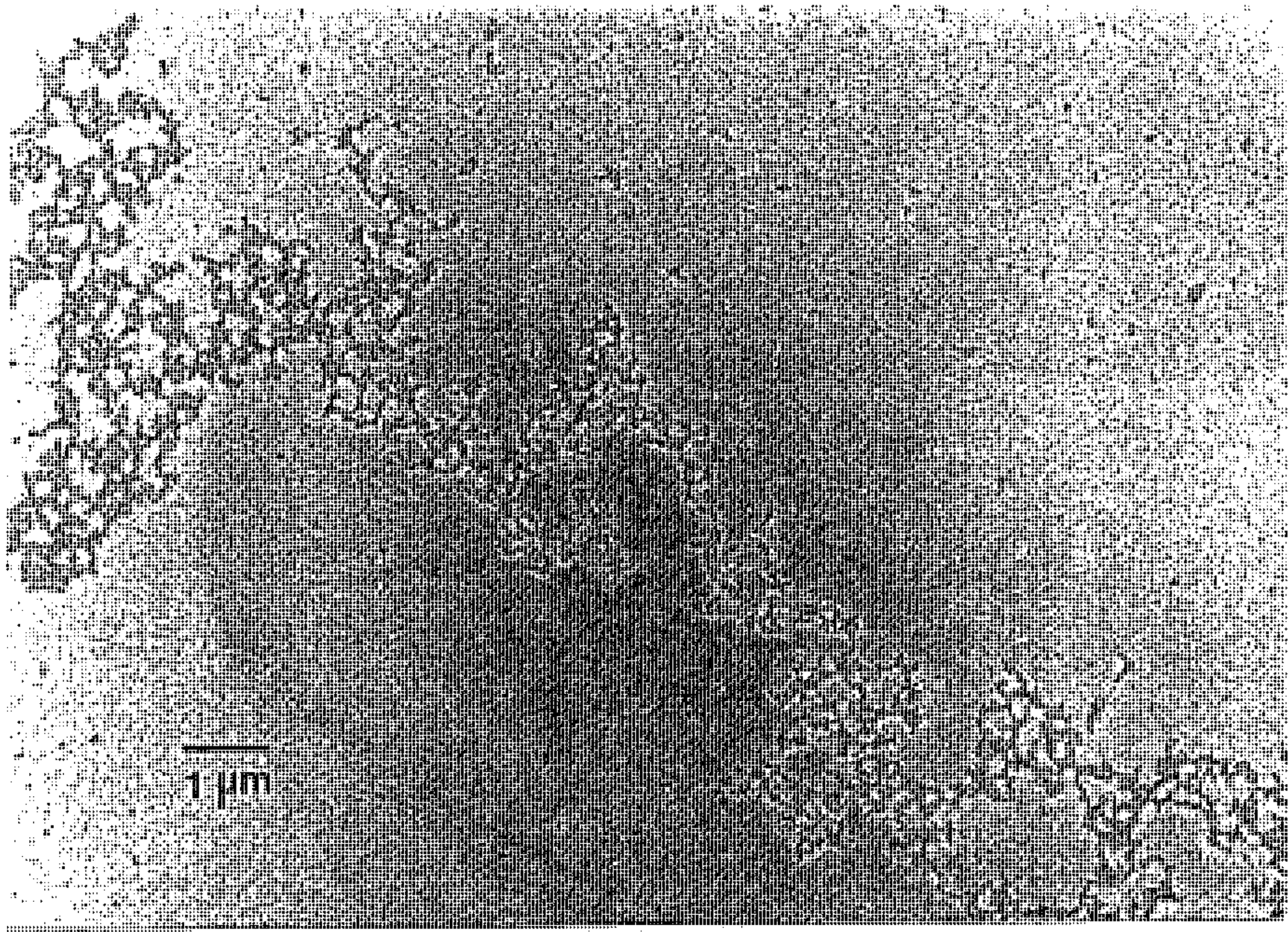
In vitro studies of live specimens. Soft X-rays are the only radiation which can penetrate several microns thick of biological stuff and provide high contrast images.

Dynamic studies of subcellular structure. Pulsed x-rays, say from a laser-plasma source provide picosecond (even less) time resolution.

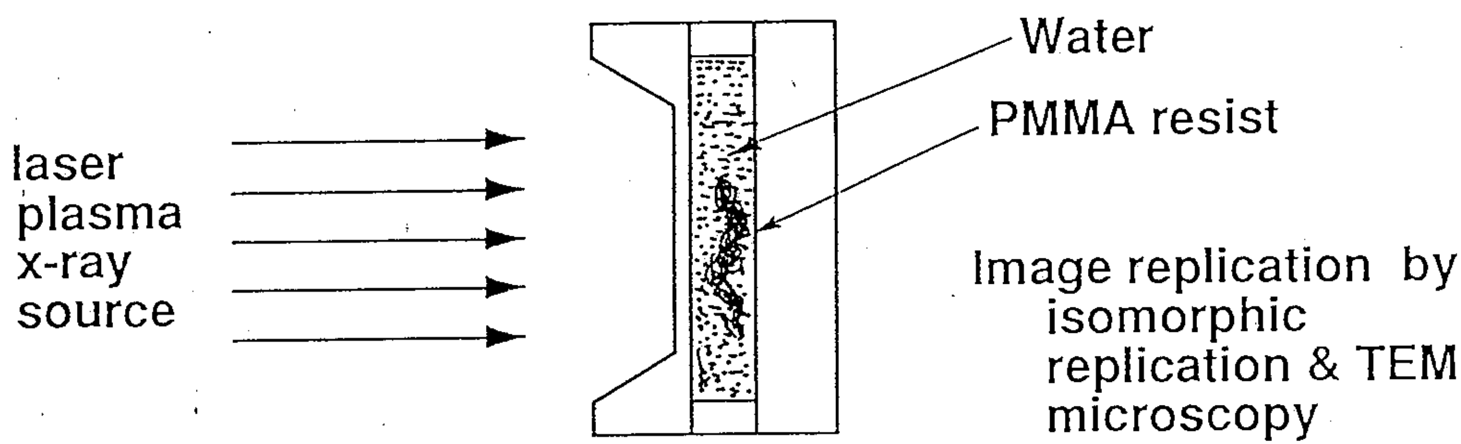
Location of specific elements. Elements possess specific absorption bands in the soft x-ray range. It is therefore possible to isolate the location of specific elements in color-sensitive images.

Thick specimens. The large depth of field permits thick cell structures to be imaged. Structures as thick as 50 microns may be possible.

High Resolution Image of *in-vitro* Human Chromosome



We have demonstrated a robust, reliable technique which permits the rapid application of x-ray microscopy to many biological and life science issues

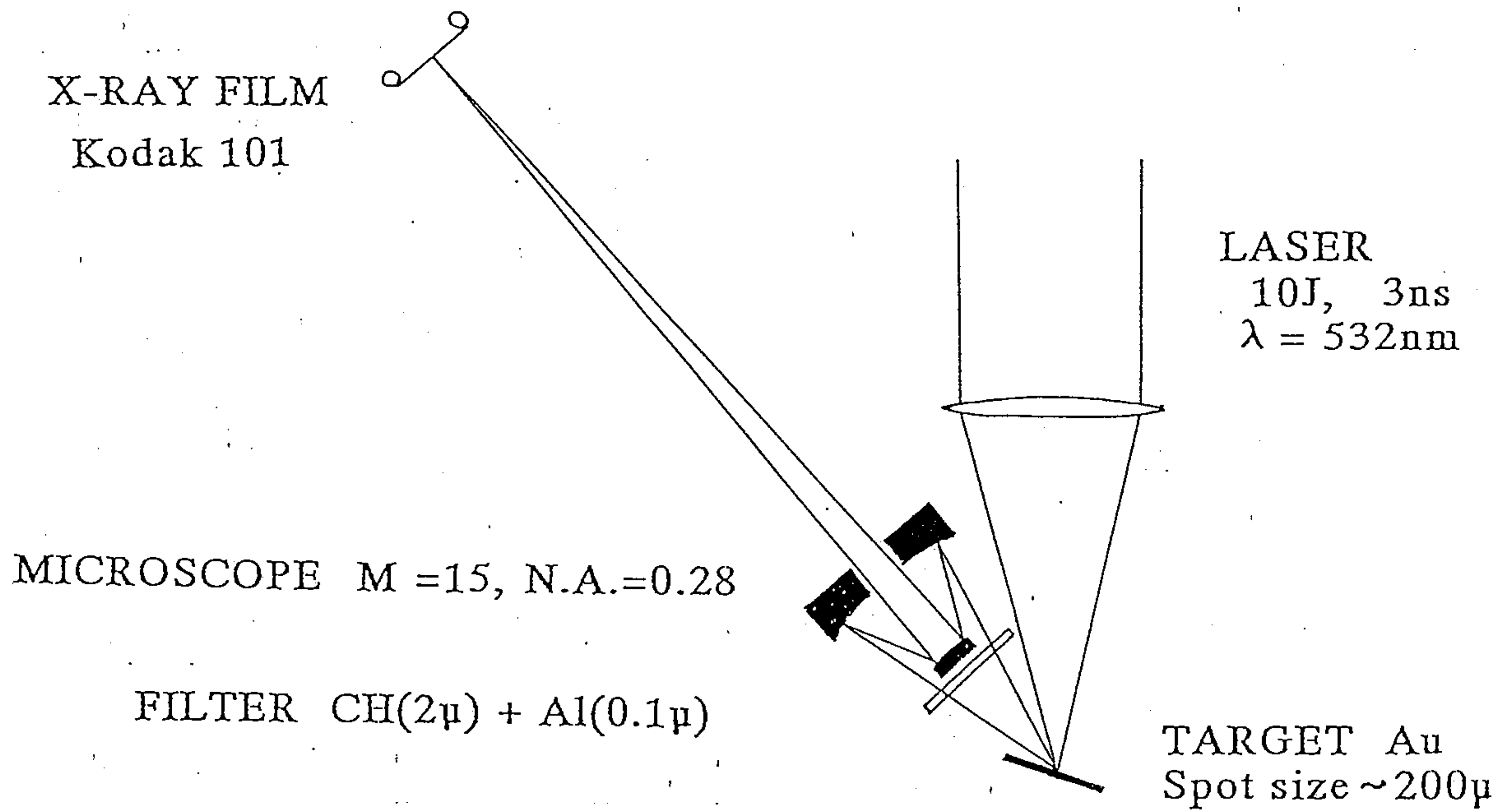


Advantages

Technique is non - specific to specimens studied

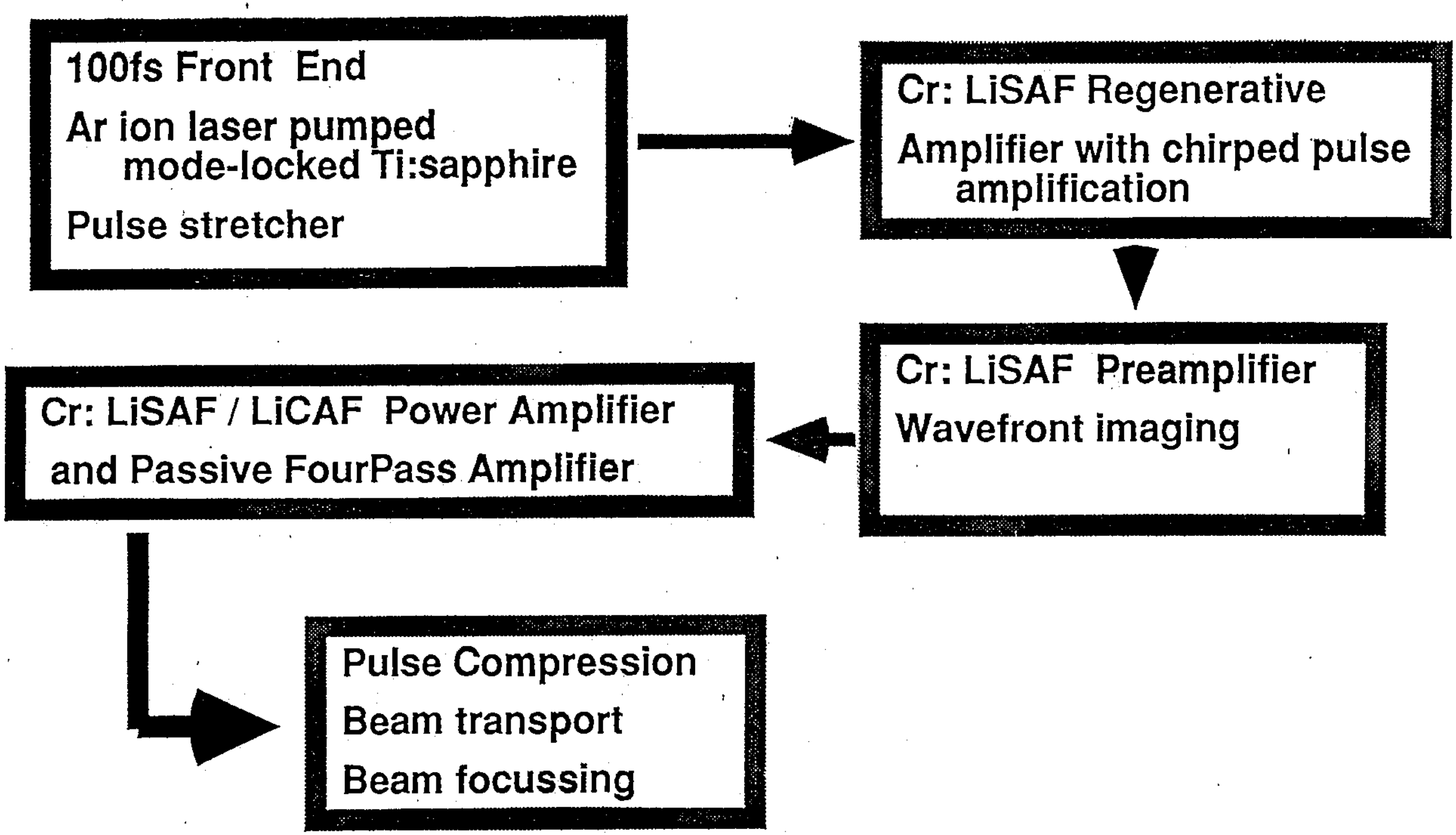
Relatively simple laser - plasma experimental set-up

Schwarzschild Microscope at 44A



A multi-media laser system

UCF — CREOL



Primary Scientific Objectives

Laboratory x-ray lasers

- Recombination lasers
- Fast photoionization
- Resonant photo-pumping

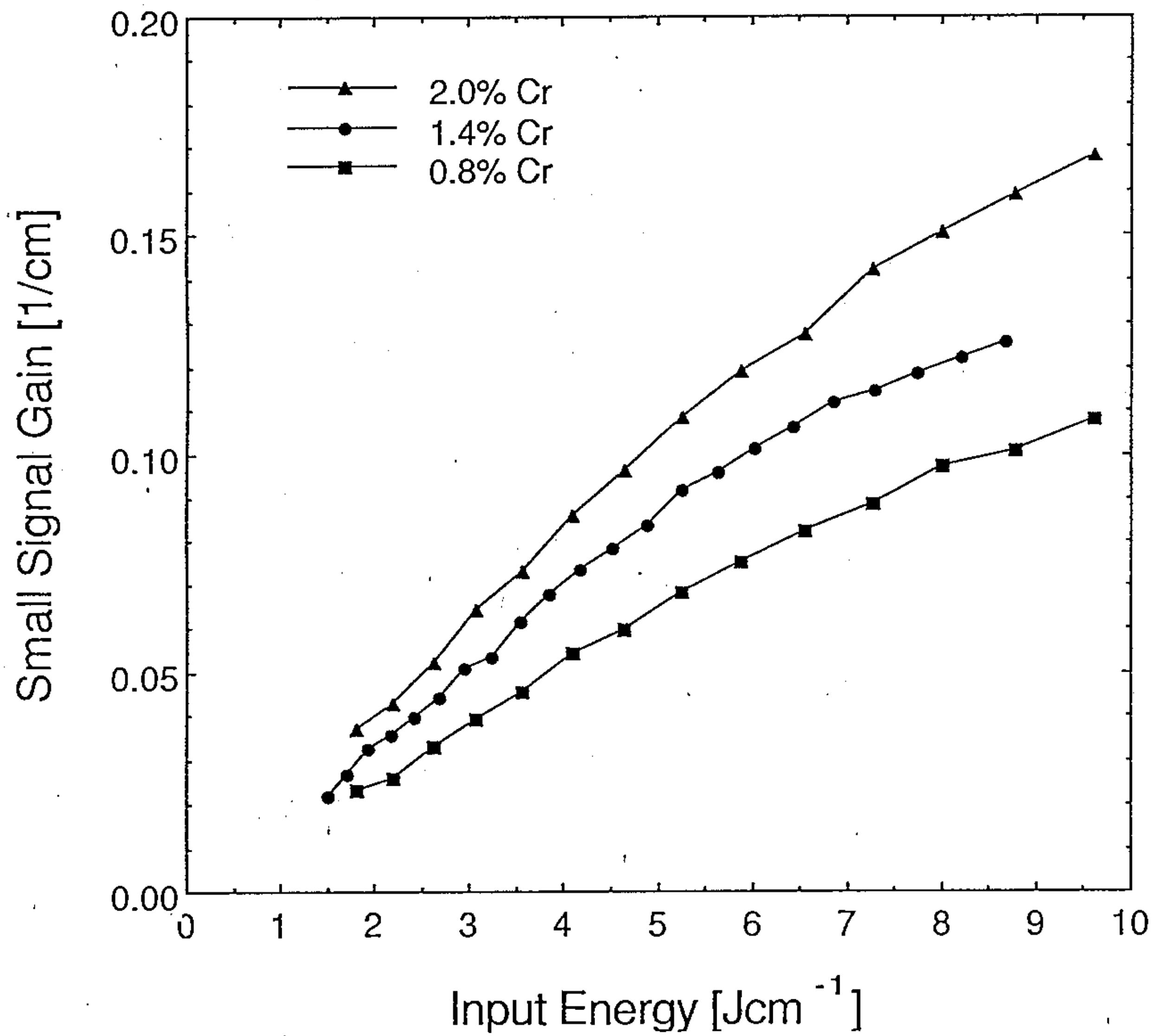
Dense plasma production

- High density plasma physics
- Quasi - molecular ions
- Super ionization of heavy Z elements
- High field effects on ionized media
- QED effects
- Nuclear studies

Ultrashort X-ray pulse generation

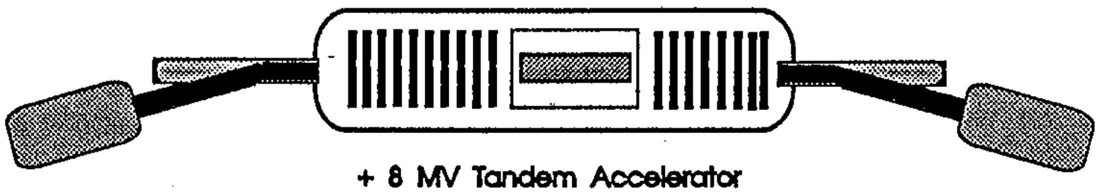
- Dynamic materials studies (crystal & interfaces)
- X-ray fluorescence
- Dynamic absorption measurements
- Picosecond x-ray microscopy

Small signal gain measurements of LiSAF



XUVFEL and FIRFEL(X-Ray/Vacuum-UV and Far-Infrared FEL)

Accelerator and Electron Beam Layout



Average Power: 1-3 kW !!

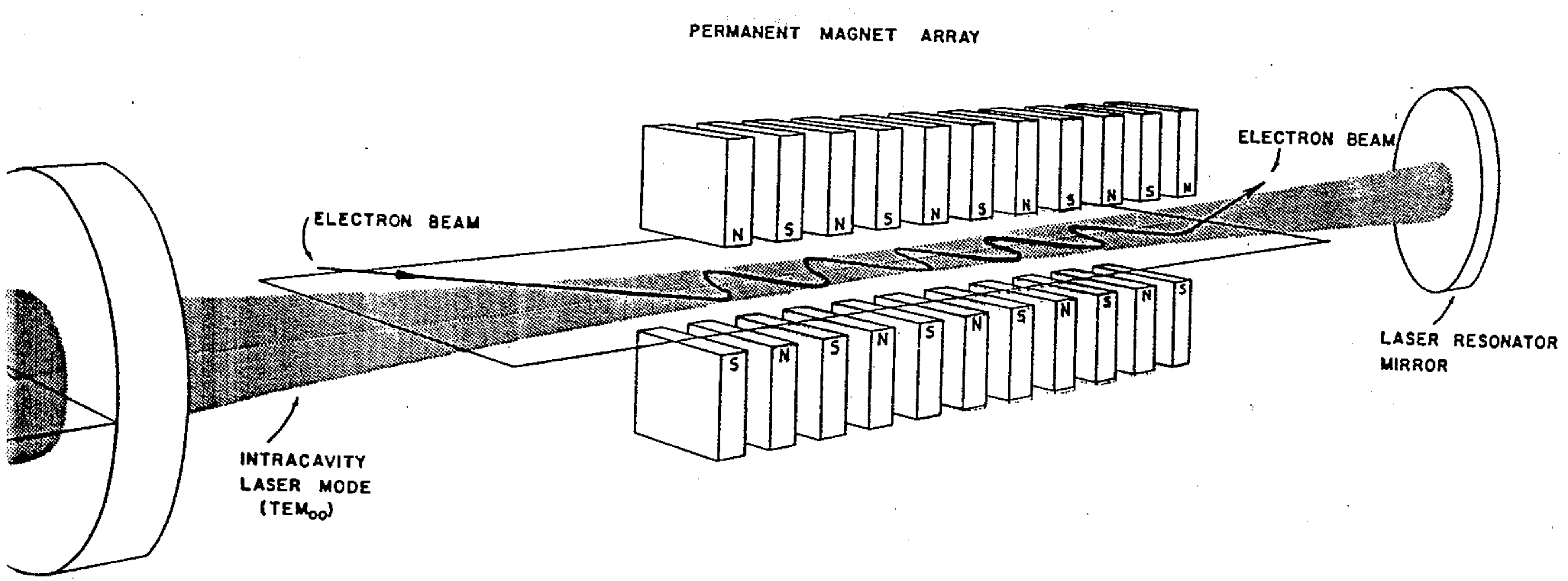
Wavelength Range

- **Phase I: Mid- Infrared Region**

  λ = 10 - 80 microns

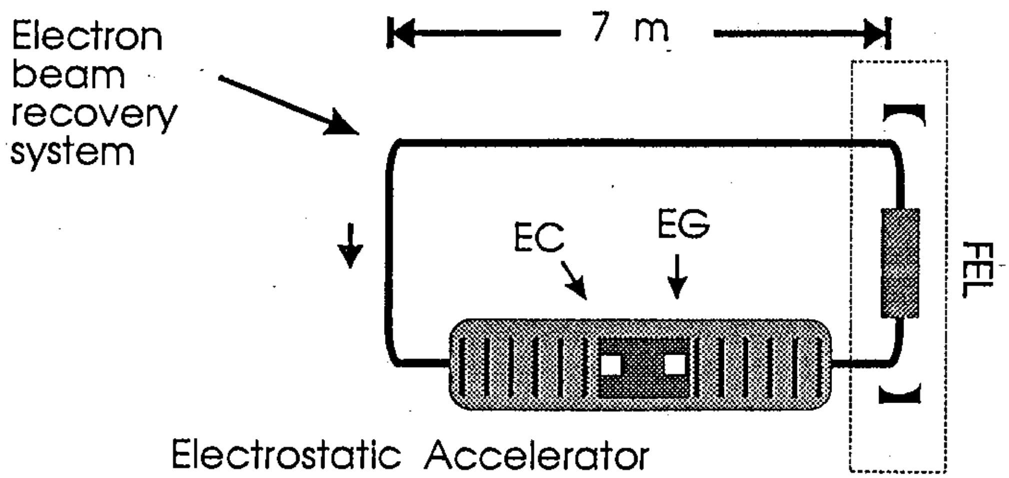
- **Phase II: Vacuum-Ultraviolet/ Soft X-Ray**

  λ = 0.04-0.4 microns



BASIC COMPONENTS OF
A FREE ELECTRON LASER
UCSB - QUANTUM INSTITUTE

<u>CFELI</u> (Compact Free-Electron Laser)

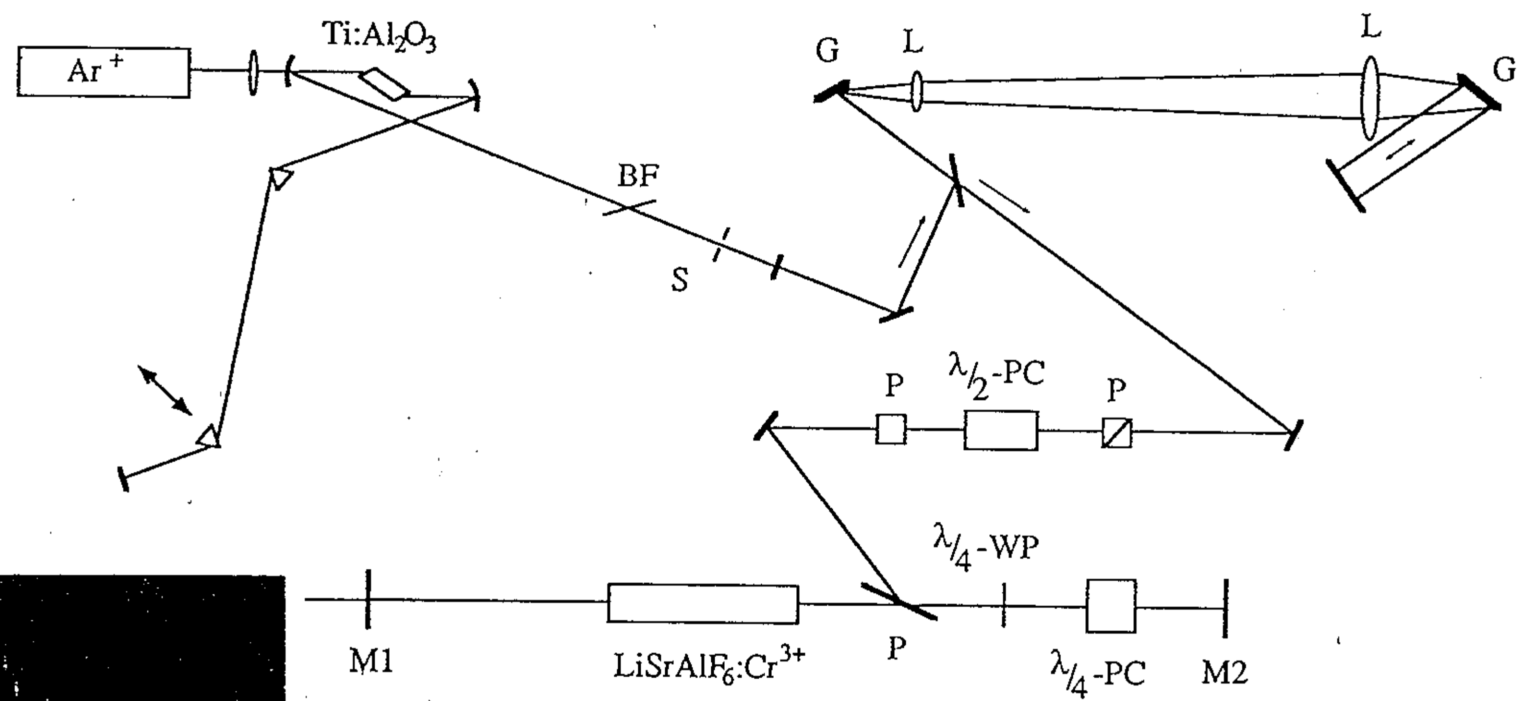


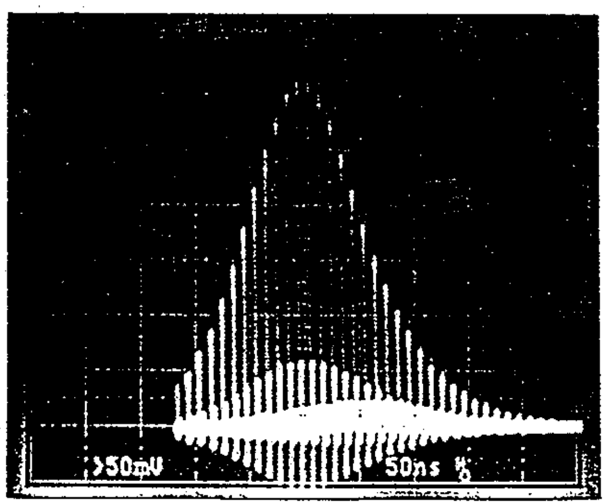
CFELI is presently under construction.

Average Power: 1 kW

Waevlength Range: 120 - 800 micrometers

LiSAF regenerative amplifier for chirped 100fs pulses





Future Work

Improved laser plasma x-ray sources

- Reduced effects of plasma and particulate debris
- Higher x-ray conversion efficiency
- High repetition rate

High resolution x-ray optics

- Further experiments with contact and reflection microscopes
- Active image magnification and registration
- Applications to biology and life sciences

High intensity lasers

- Amplifier studies
- Experiments at ultra-high focused intensities

CREOL FEL PROJECT

Major Objectives:

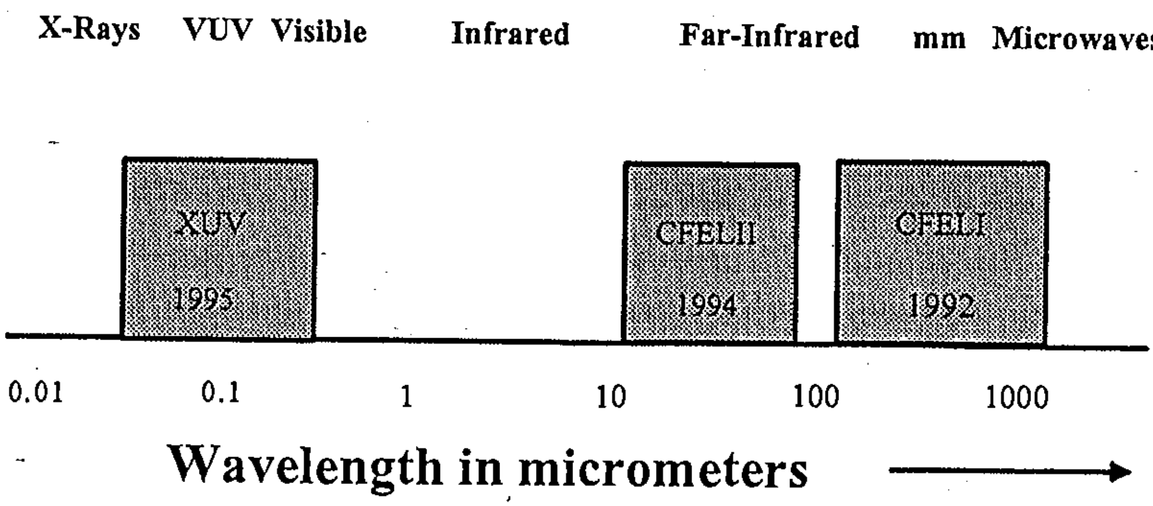
- Develop continuously tunable sources in regions of the electromagnetic spectrum where conventional sources do not exist.
- Make the laser sources available to science and industry through a state funded user's facility.

Scientific and Technical Staff:

Luis Elias, Professor of Physics, Director of CREOL FEL
Isidoro Kimel, Theoretical Senior Physicist
Huabei Jiang, Postdoctoral Researcher
Muffit Tecimer, Postdoctoral Trainee
Kent Hopkins, Junior Physicist, FEL Laboratory Manager
Eduardo Ugaz, Visiting Physicist
Paul Tesch, Graduate Student
3 Undergraduate Students

Administrative Staff:

Gerald Grover, Administrative Assistant



Applications

Chemistry
Microchip etching

Solid State Physics
Biophysics
Medical

Fusion Energy

GROUND-BASED LASER TRACKING AND IMAGING OF SPACE AND AIRBORNE OBJECTS

WAVE PROPAGATION GROUP

Ronald L. Phillips

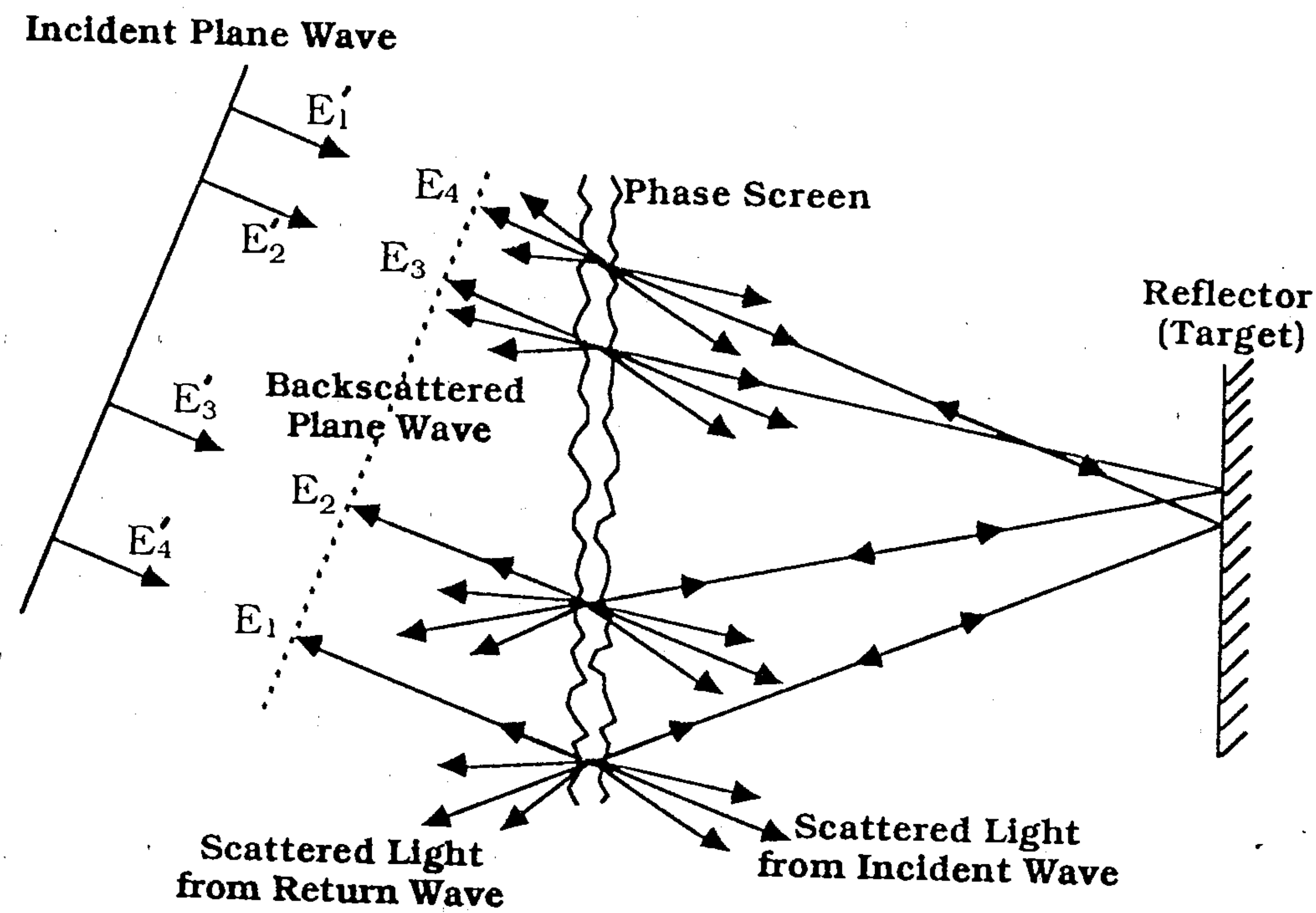
Professor of Electrical Engineering
and
Professor of Mathematics

Students

Robert Heileman, M.S. Electrical Engineering

Robert Murphy, Ph.D. Electrical Engineering

Dara Molen, M.S. Mathematics


Incident Plane Wave
E'1
E'2
E'3
E'4
E4
E3
E2
E1
Backscattered Plane Wave
Phase Screen
Reflector (Target)
Scattered Light from Return Wave
Scattered Light from Incident Wave

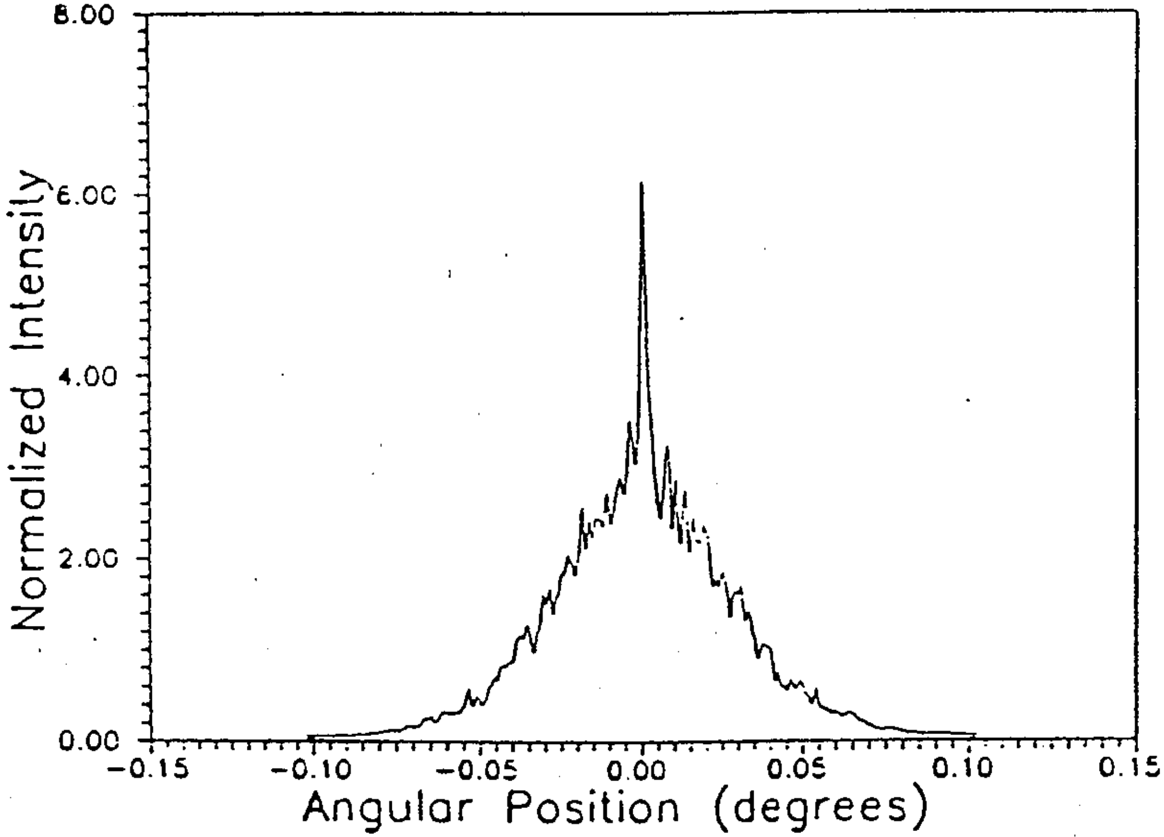


Figure 2. Angular distribution of the far field intensity of the backscatter for a normally incident wave. The computer simulation was performed for a strong turbulent random phase screen with averaging of returns from 100 pulses.

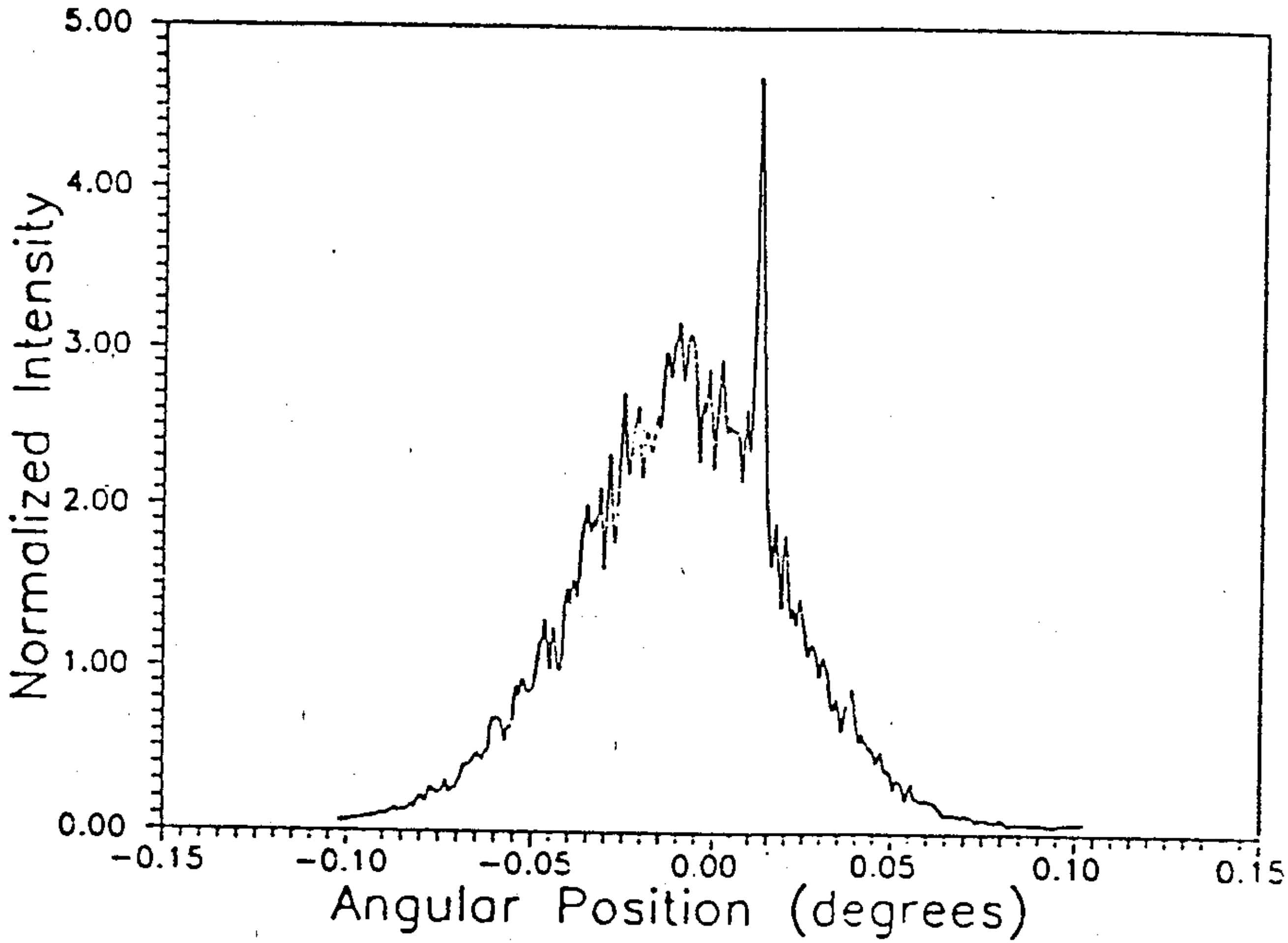


Figure 3. Angular distribution of the far field intensity for a wave incident at an angle of 0.012 degree with the same parameters as in Figure 2 except for averaging of 80 pulses.

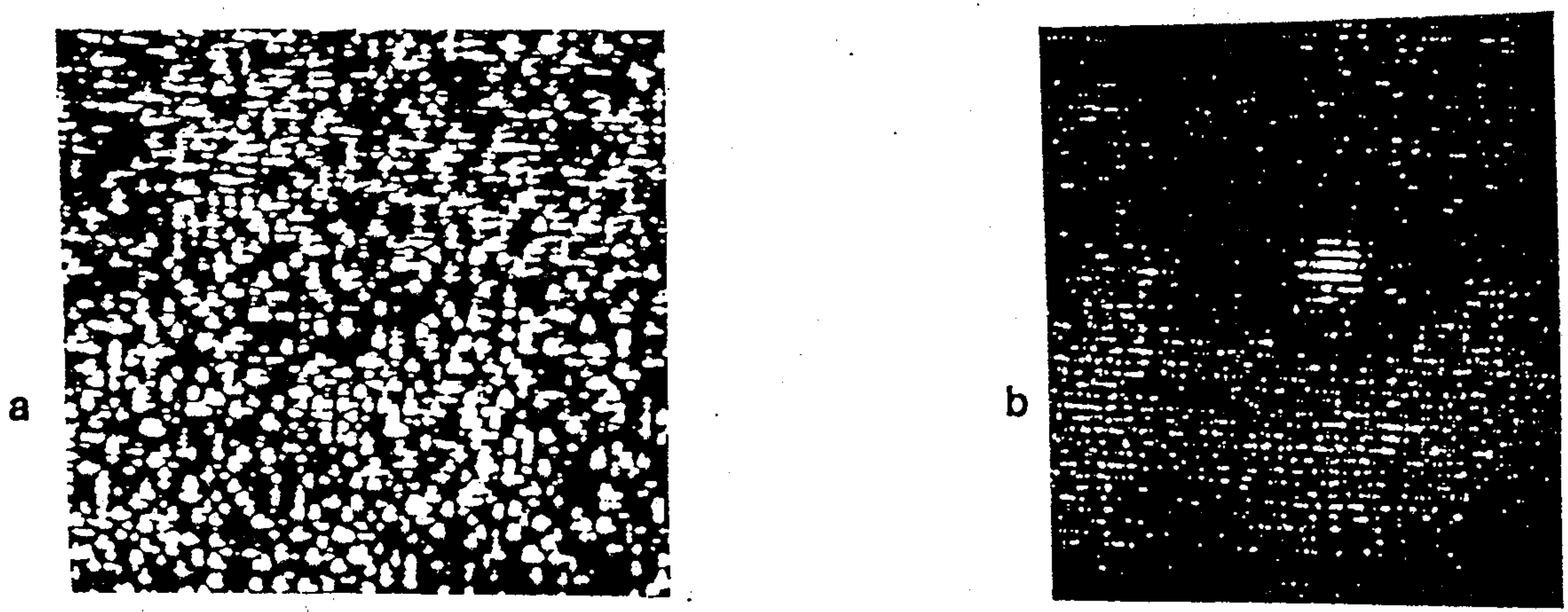


Figure 5. (a) TV image of a laser beam after passing twice through the same screen; (b) an averaging of the TV images. The bright spot is the conjugate return.

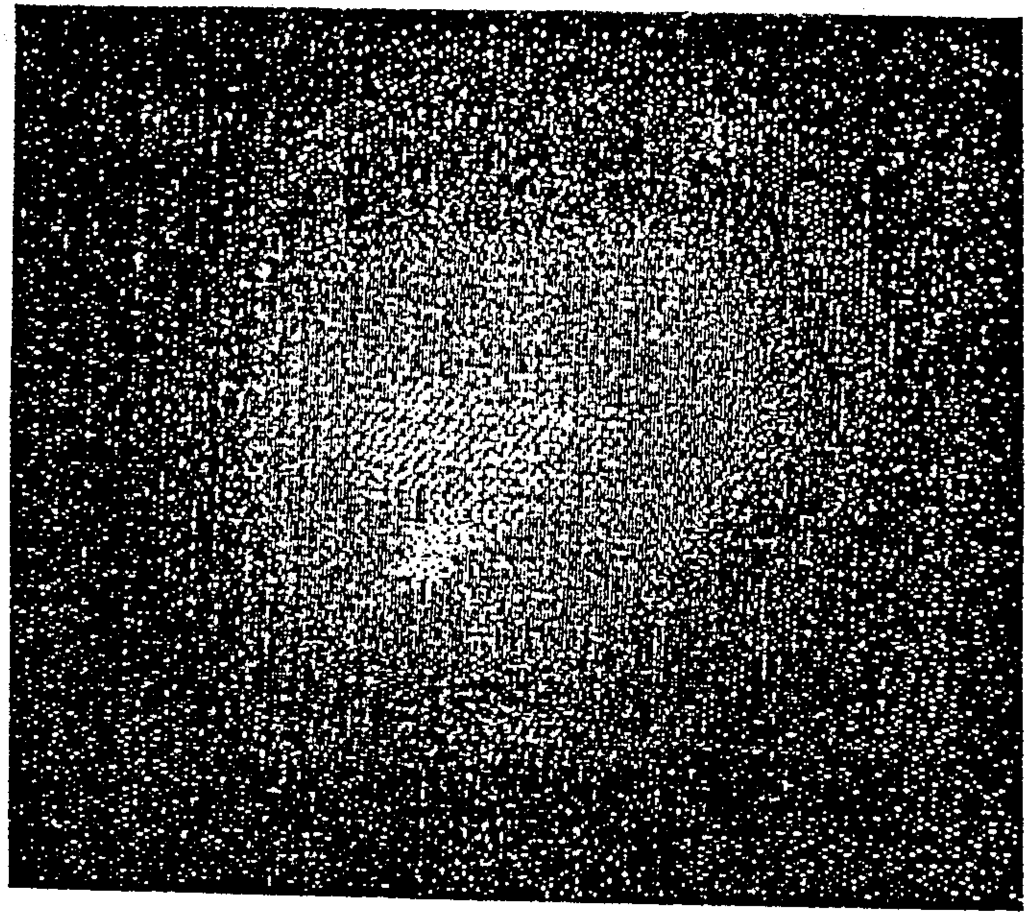


Figure 6. Image of the detected return beam from a retro-reflector located at 1,000 m from the transmitter. The image has been processed by averaging the data from a CCD array.

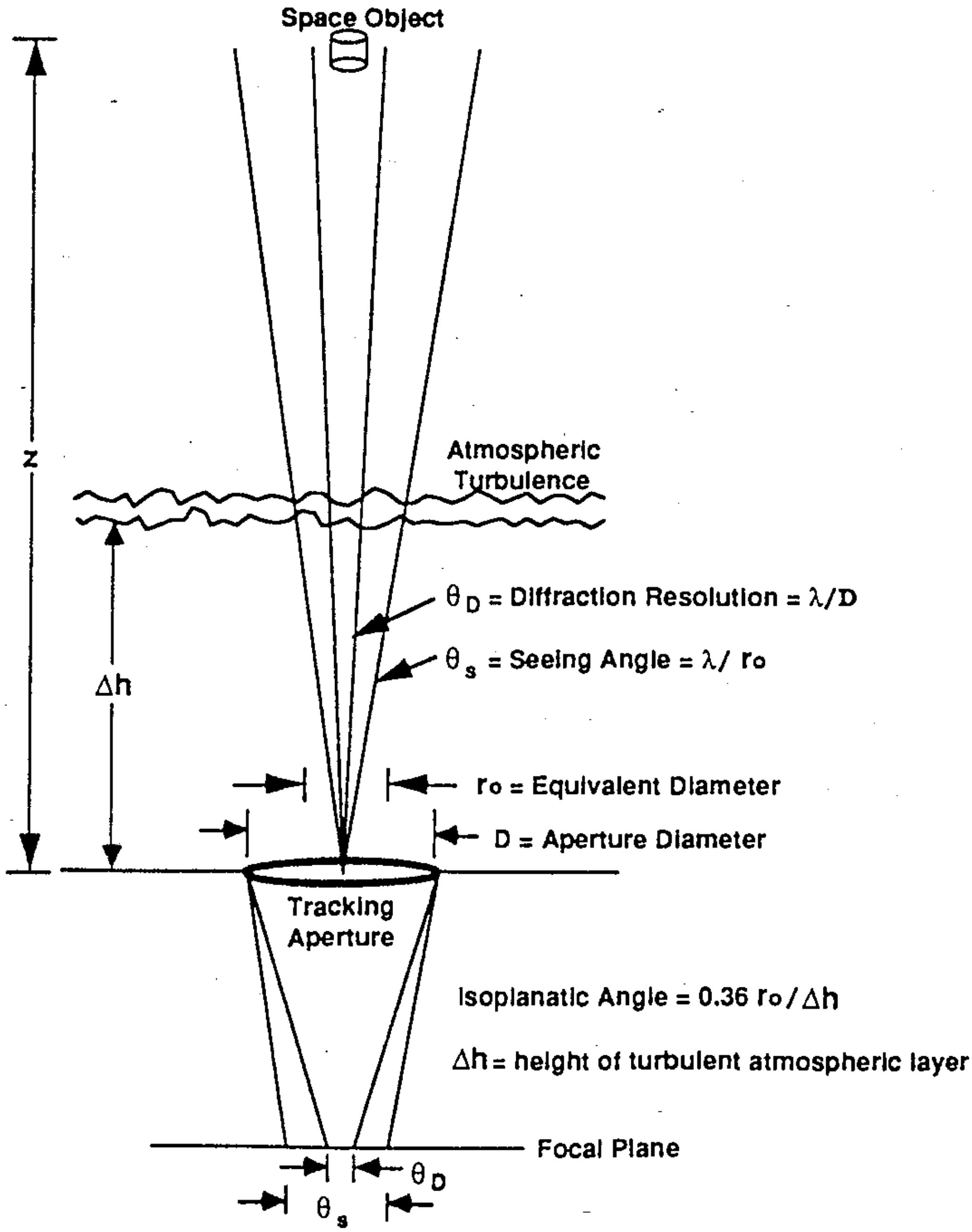
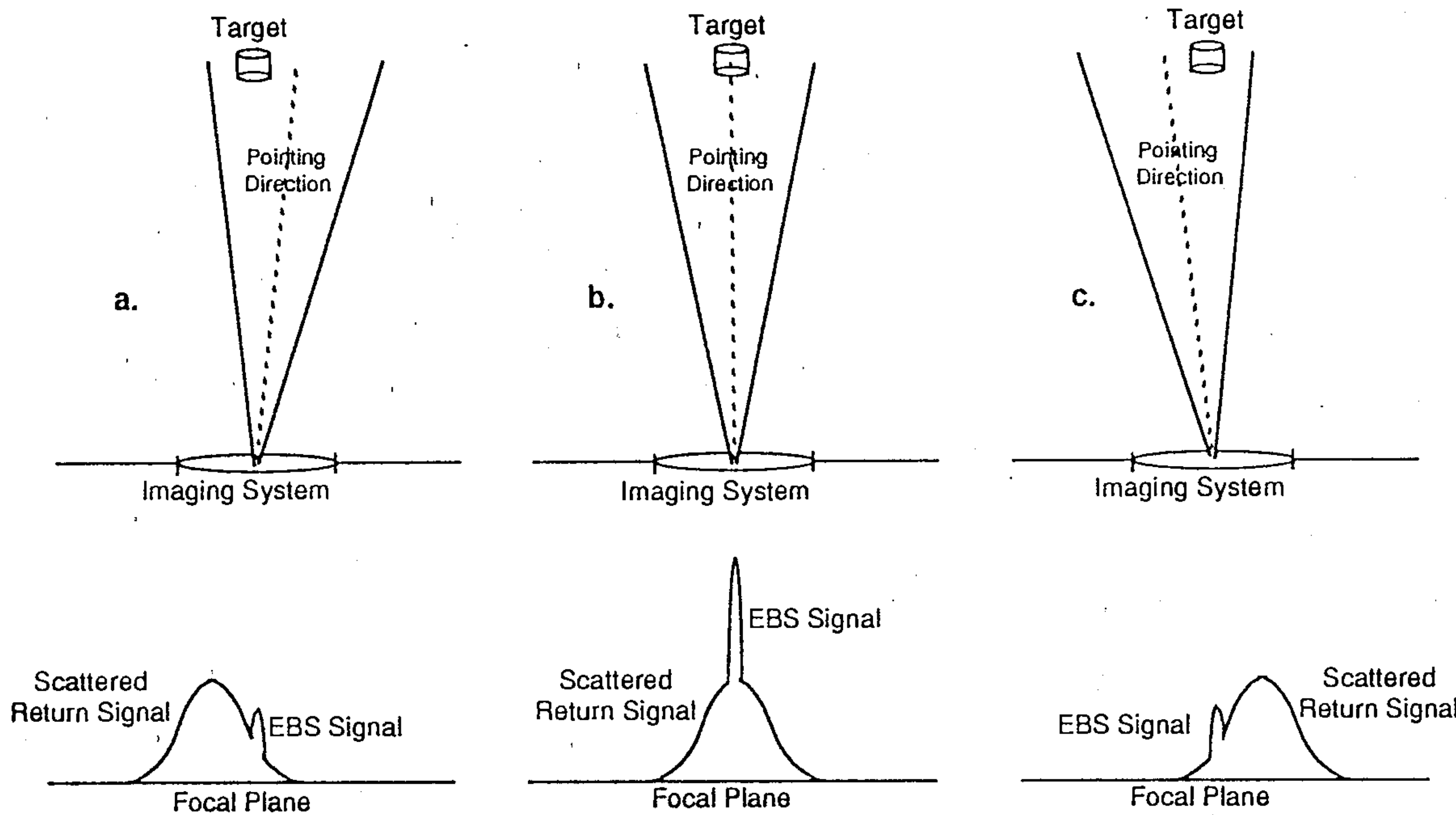


Figure 7. Schematic diagram of optical system and definition of resolution angles.


a.
Target
Pointing
Direction
Imaging System
Scattered
Return Signal
EBS Signal
Focal Plane
b.
Target
Pointing
Direction
Imaging System
EBS Signal
Scattered
Return Signal
Focal Plane
c.
Target
Pointing
Direction
Imaging System
EBS Signal
Scattered
Return Signal
Focal Plane

LASER RADAR RESEARCH

Objective:

- The evaluation, analysis and development of advanced coherent array laser radar receivers with emphasis on atmospheric effects and target signatures.

CREOL Activities:

- Coherent array receiver development
- Laser radar simulation
- Array image processing
- Prototype Nd:YAG ladar testbed

UCF PARTICIPANTS

- Dr. C. Martin Stickley - Professor, EE/CREOL
- Dr. Philip Gatt - Research Scientist, CREOL
- Dr. Arthur R. Weeks - Assistant Professor, CpE
- Dr. Harley R. Myler - Associate Professor, CpE
- Mr. Robert Murphey - Graduate Student, EE/CREOL
- Mr. Robert Beeson - Graduate Student, EE/CREOL
- Mr Wilson Perez - Graduate Student, CpE/CREOL
- Mrs. Michelle V. Lewis - Graduate Student, CpE/CREOL
- Mr. Tony Centore - Undergraduate Student, EE/CREOL
- Mrs. Kathy VanScoter - Administrative Assistant, CREOL

COHERENT ARRAY RECEIVER DEVELOPMENT

To evaluate, develop and characterize coherent array laser radar technologies with emphasis in the following areas:

- Heterodyne efficiency optimization
- Fiber optic receivers
- Detector Arrays
- Distributed aperture arrays

LASER RADAR SIMULATION

To develop a laser radar simulation capability to evaluate the performance of laser radar systems.

- In house end-to-end laser radar performance simulation
- Computer simulation of array laser radar systems for diffuse targets
- Atmospheric scintillation effects on laser radar systems
- Computer modeling of track mount jitter
- LOWTRAN7 (Low frequency resolution transmittance and background radiance)
- FASCOD3p (High frequency resolution transmittance)
- DELTAS (Laser Radar Simulator)

ARRAY IMAGE PROCESSING

To develop new techniques of using optical computing devices to implement image processing algorithms normally calculated using digital computers.

- Spatial light modulators for optical image processing
  - Hybrid homomorphic (non-linear) filters to remove image shading
  - Coherent processing for phase reconstruction using deformable mirror devices
- Adaptive filters:
  - Image processing filter using feature extraction techniques to preserve edge detail
- UCFImage©:
  - An MS-DOS based image processing software package that includes 2-D FFT, histogram equalization, edge detectors, morphological and adaptive filters, and color capability

PROTOTYPE Nd:YAG LADAR TESTBED

Development, packaging and delivery of a solid state 1.06 μm incoherent laser radar testbed to a facility at Kennedy Space Center

- Source:
  - Continuum NY82-20, Nd:YAG, injection seeded, 1.5 J, 8 ns
- Transceiver optics:
  - Bistatic 10 cm transmitter, 50 cm receiver
- Experiments:
  - Hard target and plume backscatter at 532 nm and 1064 nm
  - Autodyne laser tracker
  - Target discrimination

FACILITIES

Laser Ladar Lab:

- Lightwave 122-50, 50 mW ring laser with fast PZT frequency tuning
- Lightwave 120-01, 5 mW ring laser with fast PZT frequency tuning
- Newport super cavity optical spectrum analyzer
- Newport acousto-optic modulator
- Hewlett Packard RF spectrum analyzer (2.9Ghz)
- Optical tables (Qty 2)
- MS-DOS 386 PC's (Qty 3)
- Beam diagnostic system (CREOL developed)

Image Processing Lab:

- Ncube supercomputer
- Sun 4 fileserver
- SunSparc 1 color workstations (Qty. 5)
- Sun 3 color workstation
- NCR Towerviews display terminals (Qty. 4)
- DATA TRANSLATION video frame grabber for the Sun 4 fileserver
- Video frame grabber boards for MS-Dos Compatible Computers

APPLICATIONS OF THERMAL IMAGING

CREOL AFFILIATES DAY

JANUARY 13, 1992

DR. GLENN BOREMAN

ASSOCIATE PROFESSOR, EE

INFRARED SYSTEMS LABORATORY

UCF/CREOL

(407) 658-6815

THE INFRARED GROUP

DR. BOREMAN - 8 YRS IN UCF'S ELECTRICAL ENGINEERING DEPT.

CURRENTLY 3 MS AND 3 PHD CANDIDATES

RESEARCH SPECIALTIES

INFRARED/OPTICAL SYSTEMS: ANALYSIS & DESIGN

PROTOTYPE INSTRUMENTATION DEVELOPMENT

DETECTOR AND FOCAL PLANE CHARACTERIZATION

MODULATION TRANSFER FUNCTION

INFRARED SCENE PROJECTION

CUSTOM MEASUREMENTS

SPECIALIZED TRAINING

APPLIED RESEARCH IN COLLABORATION WITH INDUSTRY

CURRENT RESEARCH

IR SCENE PROJECTION - REFLECTIVE LIGHT MODULATOR

Supported by:

Photonic Systems, MELBOURNE, FL (SBIR COLLABORATION)

AND **Florida High-Tech Council**

ANALYSIS OF FUNDAMENTAL PERFORMANCE ENVELOPE, AND DEVELOPMENT OF PROOF-OF-PRINCIPLE INSTRUMENT

CHARACTERIZATION OF DETECTOR-ARRAY IMAGE QUALITY

Supported by:

Air Force Armament Lab, EGLIN AFB, FL

DEVELOPMENT OF INSTRUMENTATION FOR RESOLUTION TESTING USING STATISTICAL PROPERTIES OF LASER SPECKLE

ANGULAR DEPENDENCE OF IR EMISSIVITY & REFLECTANCE

Supported by:

ALCOA Corporation, PITTSBURGH, PA

MEASUREMENT OF IR SIGNATURES FROM HIGH-TEMPERATURE ALUMINUM SURFACES

THERMAL IMAGING OF CORNEA TISSUE

In collaboration with:

University of Miami Medical School

MEASUREMENT OF TIME DEPENDENCE & TEMPERATURE PROFILES DURING LASER SURGERY

MODELS FOR MINIMUM RESOLVABLE TEMPERATURE

Supported by:

CI Systems, HAWTHORNE, NY

DEVELOPMENT OF NEW FIGURES OF MERIT FOR IR IMAGING SYSTEMS

REPRESENTATIVE PAST PROJECTS

SPRITE DETECTOR ANALYSIS

Supported by:

McDonnell Douglas Missile Systems, TITUSVILLE, FL

THEORETICAL ANALYSIS AND MEASUREMENT OF DETECTORS USED IN THE SENSOR OF THE DRAGON MISSILE; DEVELOPMENT OF NEW FIGURES OF MERIT RESULTING IN DESIGN MODIFICATIONS

SINCE 1986, THIS PROJECT HAS GENERATED 6 JOURNAL ARTICLES, 2 MS GRADUATES, AND ACCEPTANCE OF OUR ANALYTICAL MODELS FOR SPRITE PERFORMANCE IN THE US ARMY STANDARD COMPUTER CODE (MICOM IMAGING IR SYSTEM PERFORMANCE MODEL)

LASER BEAM STABILITY MEASUREMENT

Supported by:

Laser Ionics, ORLANDO, FL

INSTRUMENTATION DESIGN AND MEASUREMENT OF ARGON LASER ANGULAR BEAM STABILITY

IR SYSTEMS LAB FACILITIES

Using seed support from CREOL, Florida High-Tech Council, and loans & donations from industry, we have built a complete infrared research facility.

IMAGERS

- IR 512 × 512 PtSi CCD CAMERA: 3-5 MICRON
- IR SPRITE SCANNER CAMERA: 8-12 MICRON
- IR PYROELECTRIC VIDICON CAMERA: 1-12 MICRON
- VISIBLE CCD ARRAYS
- VARIOUS IR DETECTORS AND VACUUM DEWARS

SOURCES

- BLACKBODY SOURCE TO 1300 C
- 3.39 MICRON HE-NE LASER (50 mW)
- 10.6 MICRON CO_2 LASER

INSTRUMENTATION

SCANNING SPECTRORADIOMETER: 2-14 MICRON

INTERFEROMETER - SURFACE FIGURE TESTING

IR SCENE PROJECTOR

VIDEO-BAND SPECTRUM ANALYZER

VIDEO-TRIGGERED OSCILLOSCOPE

COMPUTER SYSTEM

SUN WORKSTATIONS: SPARC 330 AND SLC1

VIDEO DIGITIZER

IDL NUMERICAL ANALYSIS SOFTWARE

SEMPER IMAGE PROCESSING SOFTWARE

CODE-V OPTICAL DESIGN SOFTWARE

FLIR-90 INFRARED SYSTEMS DESIGN SOFTWARE

OPTICS

IR ZOOM TELESCOPE (8-12 MICRON)

12" DIAMETER OFF-AXIS PARABOLIC COLLIMATOR

IR LASER COLLIMATOR

POLYGON SCANNERS

VISIBLE AND INFRARED INTEGRATING SPHERES

IR ACOUSTO-OPTIC MODULATOR

HUGHES LCLV

21-ELEMENT DEFORMABLE MIRROR

FUTURE FACILITY

RF ISOLATION CHAMBER (NEW BLDG)

FOR LOW-NOISE

DETECTOR & SYSTEM SENSITIVITY MEASUREMENTS

Graduates of the IR Systems Lab are working at:

MARTIN MARIETTA - ORLANDO, FL (3)

LITTON LASER SYSTEMS - ORLANDO, FL

MCDONNELL DOUGLAS - TITUSVILLE, FL

AIR FORCE ARMAMENT LAB - EGLIN AFB, FL

NASA - HUNTSVILLE, AL

INTERGRAPH - HUNTSVILLE, AL

ARNOLD AFB ENGINEERING CENTER -
TULLAHOMA, TN

MEMPHIS STATE UNIVERSITY - MEMPHIS, TN

IT&T ELECTRO-OPTICS CENTER - ROANOKE, VA

NAVAL COMBAT SYSTEMS CENTER - NORFOLK, VA

Principal Investigator:

Dr. James E. Harvey, Associate Professor
CREOL/UCF
12424 Research Parkway
Orlando, FL 32826
(407) 658-6818

Graduate Research Assistants:

Kenneth J. Jerkatis, Ph.D. (EE)
Kristin L. Lewotsky, M.S. (EE)
J. Brooks Sweet, M.S. (EE)
Anita Kotha, M.S. (Physics)
William Gresslor, M.S. (EE)

CURRENT RESEARCH AREAS OF INTEREST

A. **The optical design and image analysis of advanced optical systems** for state-of-the-art applications in the laboratory, in the industrial marketplace, and in space.

B. **The simulation and modeling of systems performance for unconventional optical systems** such as diffractive optical elements (binary optics), synthetic aperture optical systems (phased telescope arrays), and X-ray/EUV imaging systems for both astronomical and lithographic applications.

C. **The experimental characterization of various optical materials and optical fabrication processes for precision optical surfaces and components.** Of particular interest is the diffraction efficiency and scattering behavior of current state-of-the-art binary optical elements, the anomalous scattering behavior of beryllium optics for space applications, and the image degradation due to small angle scattering in X-ray multilayer coatings for enhanced reflectance at normal incidence.

X-RAY/EUV IMAGING SYSTEMS*

- **EUV Performance of Wolter II Telescopes for Space Astronomy Applications**

- **Performance Limitations of Imaging Microscopes for Soft X-ray Applications**

- **Nested Conical Foil Imaging Mirrors for High-energy X-ray Telescopes**
  - NASA/GSFC: BBXRT with 101 Concentric Mirror Pairs
  - Soviet Spectrum-X-Gamma Mission: XPECT with 154 Concentric Shells
  - Japanese SXO with 89 Concentric Foil Shells
  - Italian X-ray Astronomy Satellite (SAX) with 30 Nested Coaxial Shells

- **Interface Correlation Effects in Enhanced Reflectance X-ray Multilayers**

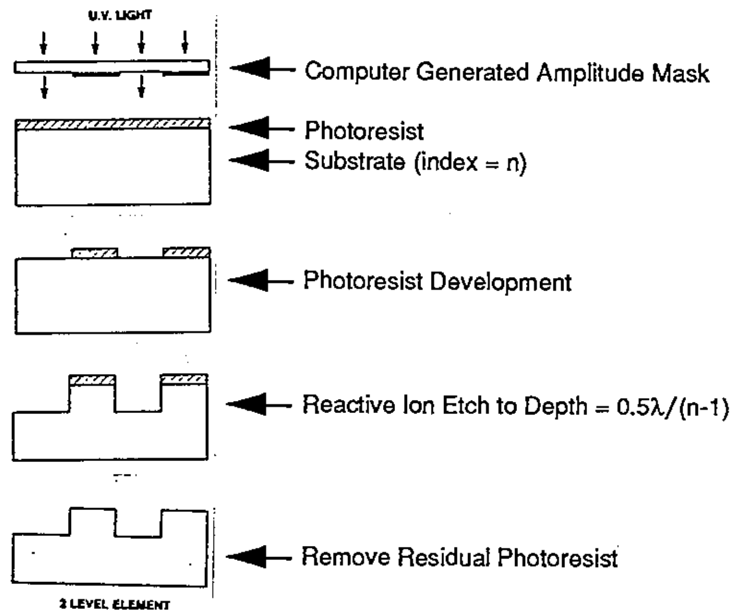
* Residual design errors are seldom the limiting factor in the performance of very short wavelength high-resolution imaging systems. Even our best optical surfaces are not smooth relative to these wavelengths; hence, optical fabrication errors (over the entire range of relevant spatial frequencies) must be included in the modeling and simulation of such systems. Commercially available optical design codes do not adequately model these effects.

BINARY OPTICS CHARACTERIZATION

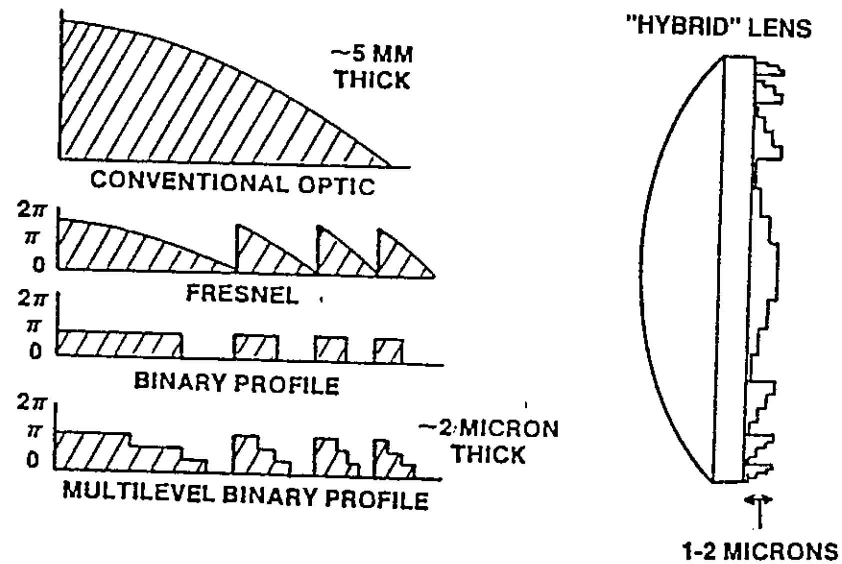
CREOL / UCF

The concept of binary optics is to fabricate diffractive multi-level Fresnel zone phase profiles with the lithographic technology used in the production of integrated circuits. These "binary' optical elements can be used by themselves or in conjunction with conventional refractive or reflective optical elements.

FABRICATION PROCESS



CONCEPT OF BINARY OPTICS



POTENTIAL ADVANTAGES OF BINARY OPTICS

- Improved Performance
- Reduced Weight
- Reduced Cost
- Meets Emerging Needs for Micro-optics
- Enabling Technology for the Integration of Micro-optics and Micro-electronics

PROPOSED EXPERIMENTAL PROGRAM

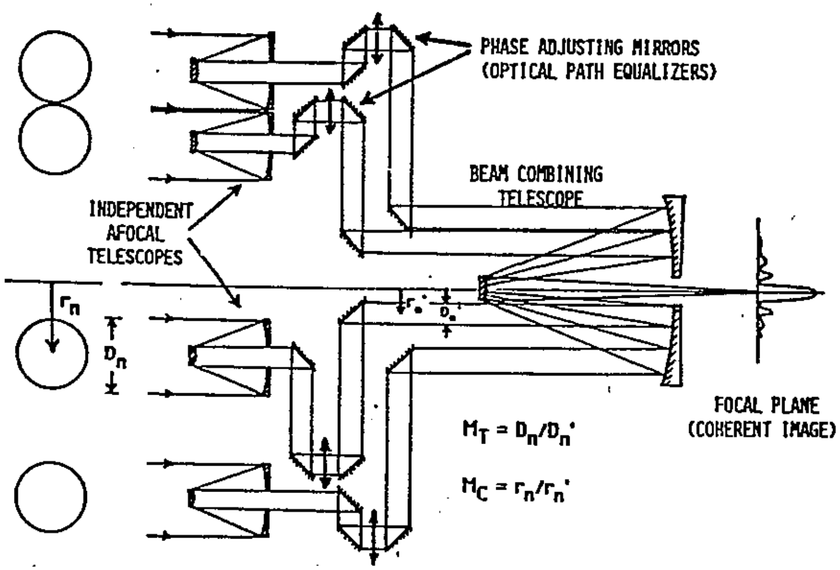
- Theoretical Predictions of Diffraction Effecienc
- Measurements of Diffraction Effeciency
- Measurements of Scattering Behavior
- Comparison of Theory with Experiment
- Parametric Results and Sensitivity Analyses

PHASED TELESCOPE ARRAYS

MOTIVATION

- Fabrication and Testing
- Reduction of Weight and Moment of Inertia
- Potential Cost Savings
- Emerging Technology to be Evaluated

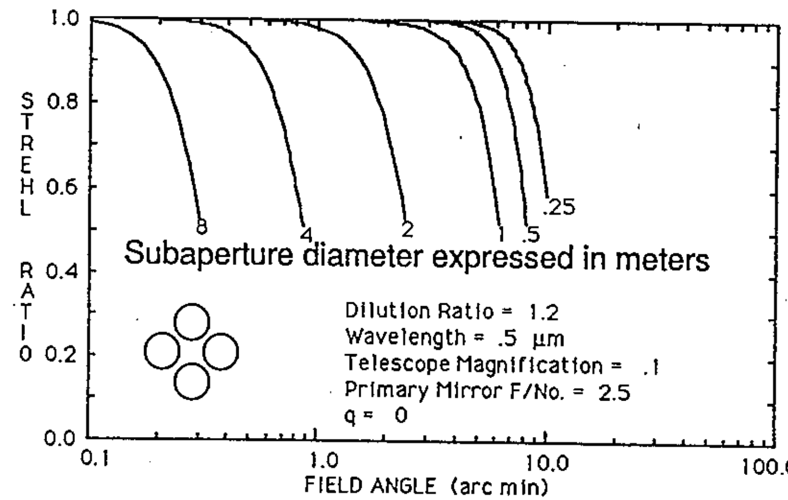
PHASED TELESCOPE ARRAY CONCEPT



POTENTIAL ERROR SOURCES

- Phasing Errors
- Relative Pointing Errors
- Relative Focus Errors
- Optical Fabrication Errors
- Assembly and Alighnent Errors
- Lateral Pupil Mapping Errors
- Longitudinal Pupil Mapping Errors
- Relative Magnification Errors
- → Off-axis Aberrations

FIELD-OF-VIEW LIMITATIONS



Large apertures (small field angles) Dominated by Field Curvature
Small Apertures (large field angles) Dominated by Distortion.

Quantum Well Optoelectronics & Femtosecond Spectroscopy

Alan Miller

Physics of advanced semiconductors — New ultrashort pulse laser sources

↓

Semiconductor optical switching devices

↓

Integrated optical circuits

Post-Doctoral Research Scientists:

- Patrick Li Kam Wa — MQWs, all-optical switching, mode-locked lasers
- Michael Snelling — Solid state spectroscopy, spin relaxation in MQWs
- David Hutchings — Theory of optical nonlinearities, MQWs and switching devices

Collaborations:

- ETDL, Fort Monmouth
- AT&T, Holmdel
- Amoco, Naperville
- CSELT, Turin, Italy
- University of Florida, Gainesville
- University College London, UK
- University of Sheffield, UK

Funding: DARPA, ARO, FHTIC, NATO

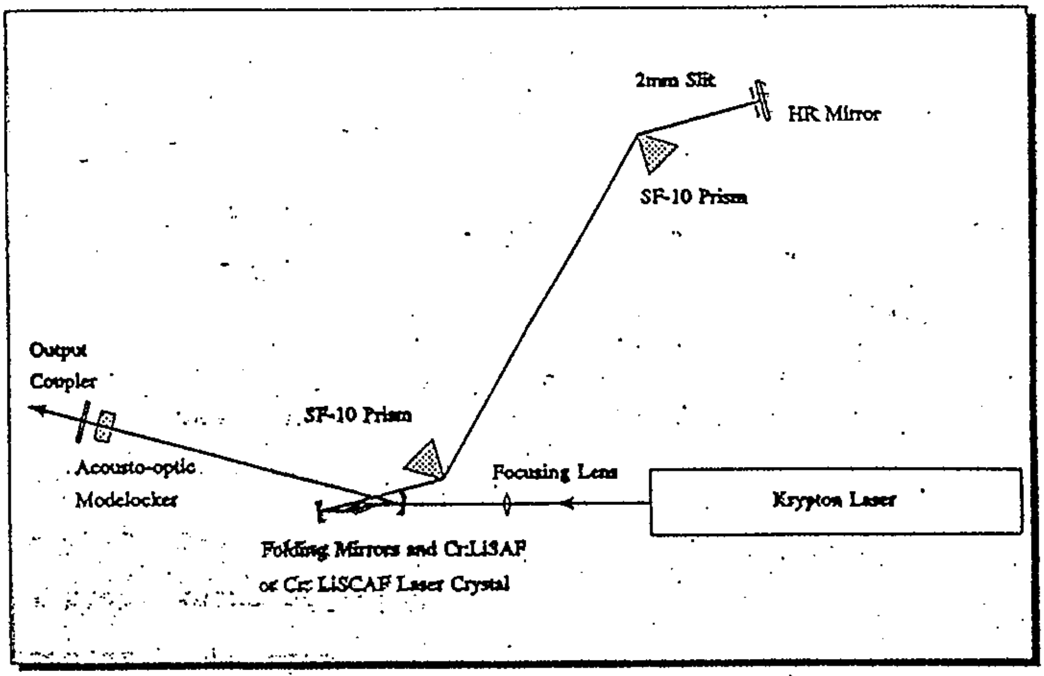
New Tunable Femtosecond Solid State Laser Sources

Patrick Li Kam Wa, Bruce Chai, Alan Miller

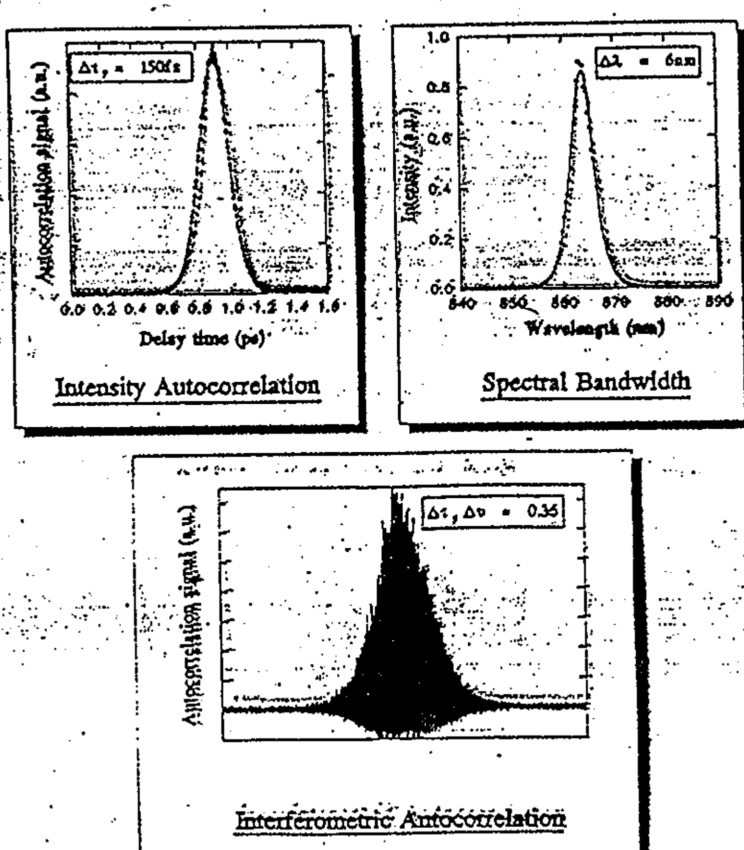
• cw argon pumped Ti:sapphire	80 fsec
• Nd:YAG synchronously-pumped Ti:sapphire	170fsec
• cw krypton pumped Cr:LiSAF	150fsec
• cw krypton pumped Cr:LiSCAF	150fsec
• cw krypton pumped Cr:LiCAF	in progress

Collaborations:

Laser Ionics
NEOS
Schwartz EO
Lightning Optical Corp.

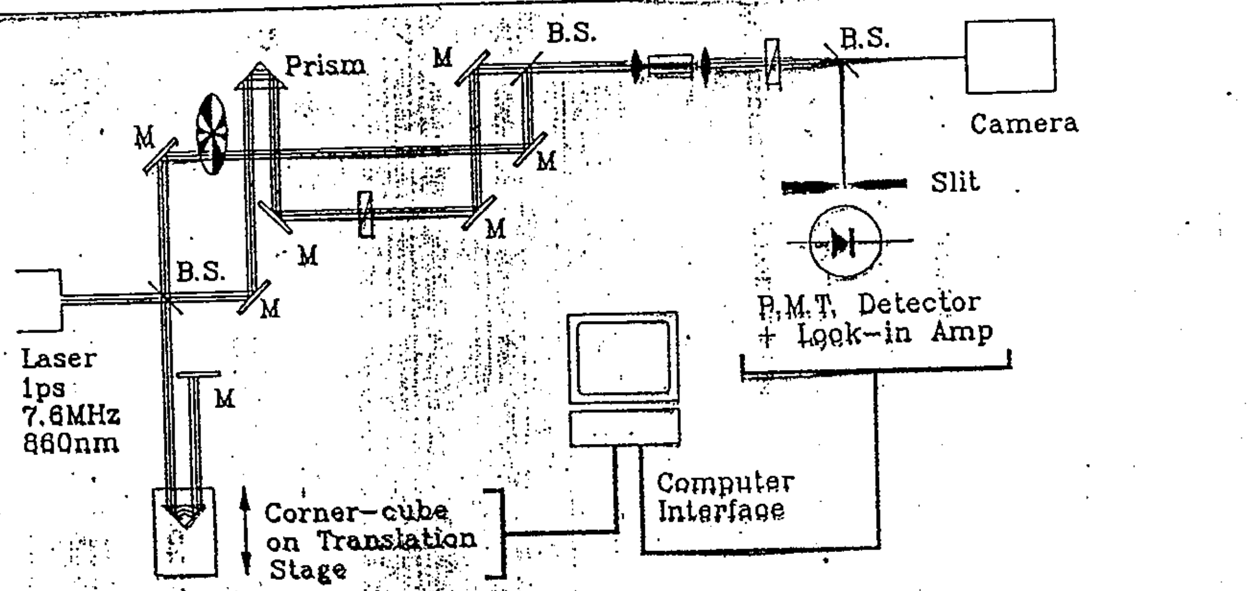


Schematic layout of X-fold, dispersion compensated LiSAF or LiSCAF laser

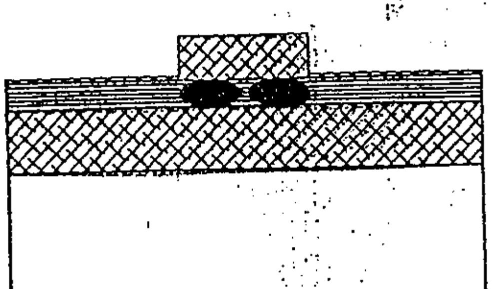


Characteristics of the dispersion compensated LiSCAF laser

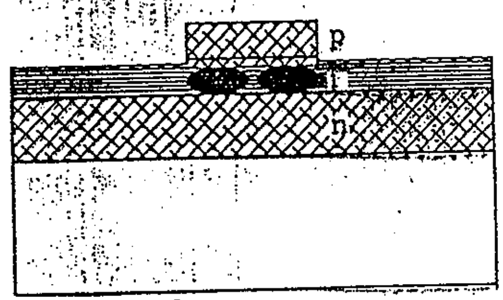

50nm



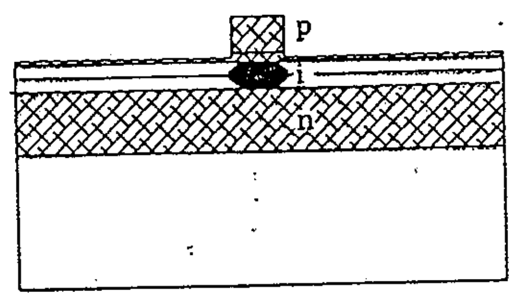
Time resolved optical pump-probe set-up



(1) Undoped MQW zero-gap directional coupler



(2) P-i-n doped MQW zero-gap directional coupler



(3) P-i-n doped SQW single mode waveguide

Response Speed of QW Waveguide Switches

DARPA — CREOL

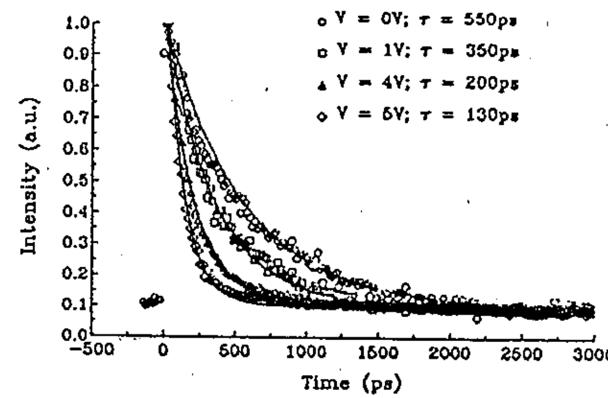
MQW Directional Coupler

- Zero-gap directional coupler to minimize length
- Band-filling and exciton saturation nonlinearities
- Undoped structure gave 1.5ns recovery
- P-i-n doped structure gave ~100psec recovery by employing carrier sweep-out in an applied field
- Potential for < 10psec recovery

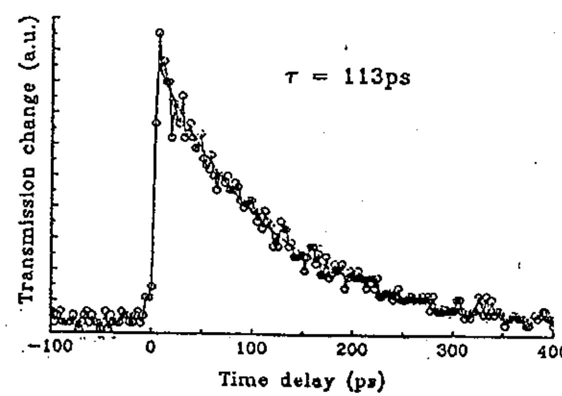
SQW Waveguides

- Both QCSE effects and exciton saturation monitored
- 113psec saturation recovery due to carrier sweep-out with no applied field (in collaboration with A Moretti, Amoco)
- Asymmetric barriers studied to distinguish between the role of electrons and holes (in collaboration with D A B Miller, AT&T)

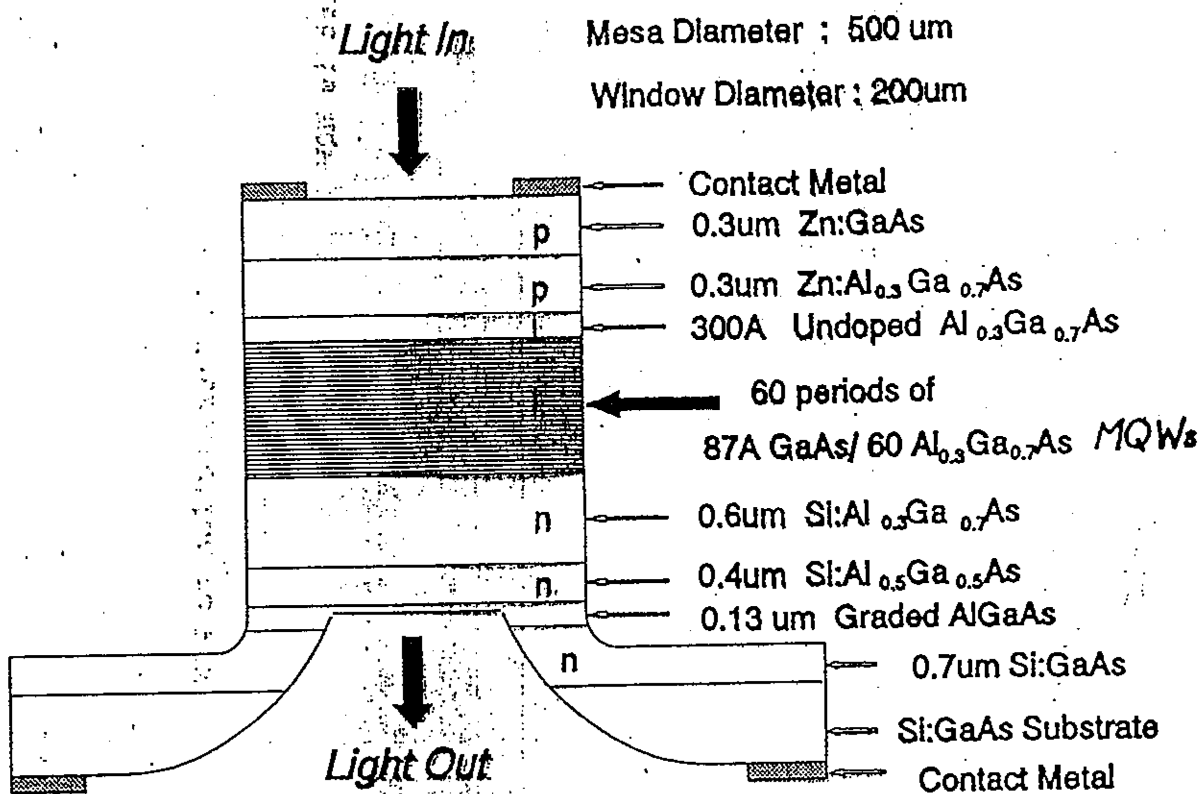
Picosecond pump-probe measurements



MQW waveguide directional coupler response as a function of reverse bias.



SQW waveguide response showing fast recovery in the absence of an applied field



GaAs/AlGaAs SEED Structure

Fundamental Limits of Optical Switching

Approach

- Time resolved measurements of the dynamical quantum confined Stark effect (QCSE) in p-i-n doped structures.
- Modeling of the cross-well carrier dynamics to determine carrier emission rates, tunneling rates and retrapping times.

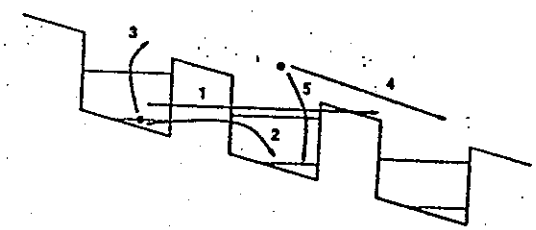
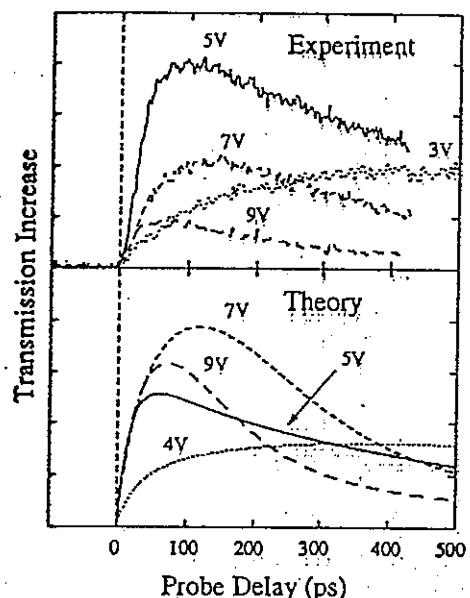
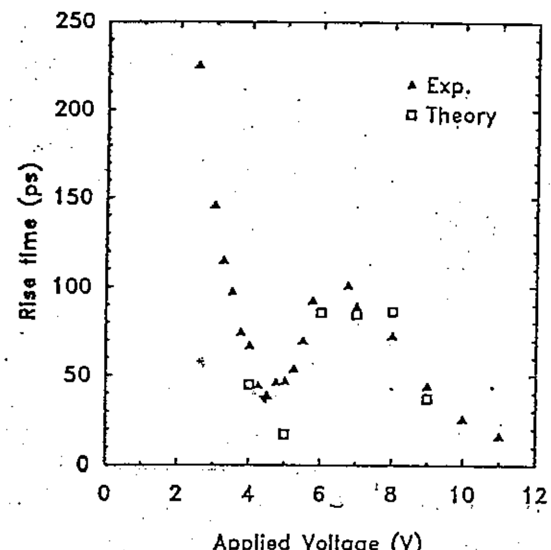


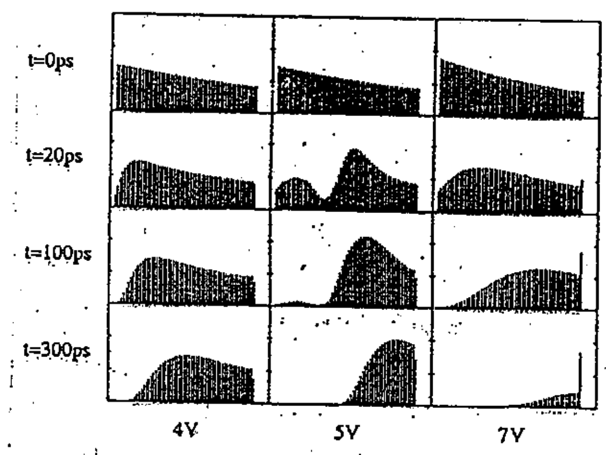
Diagram representing the various time constants involved in cross-well transport of carriers



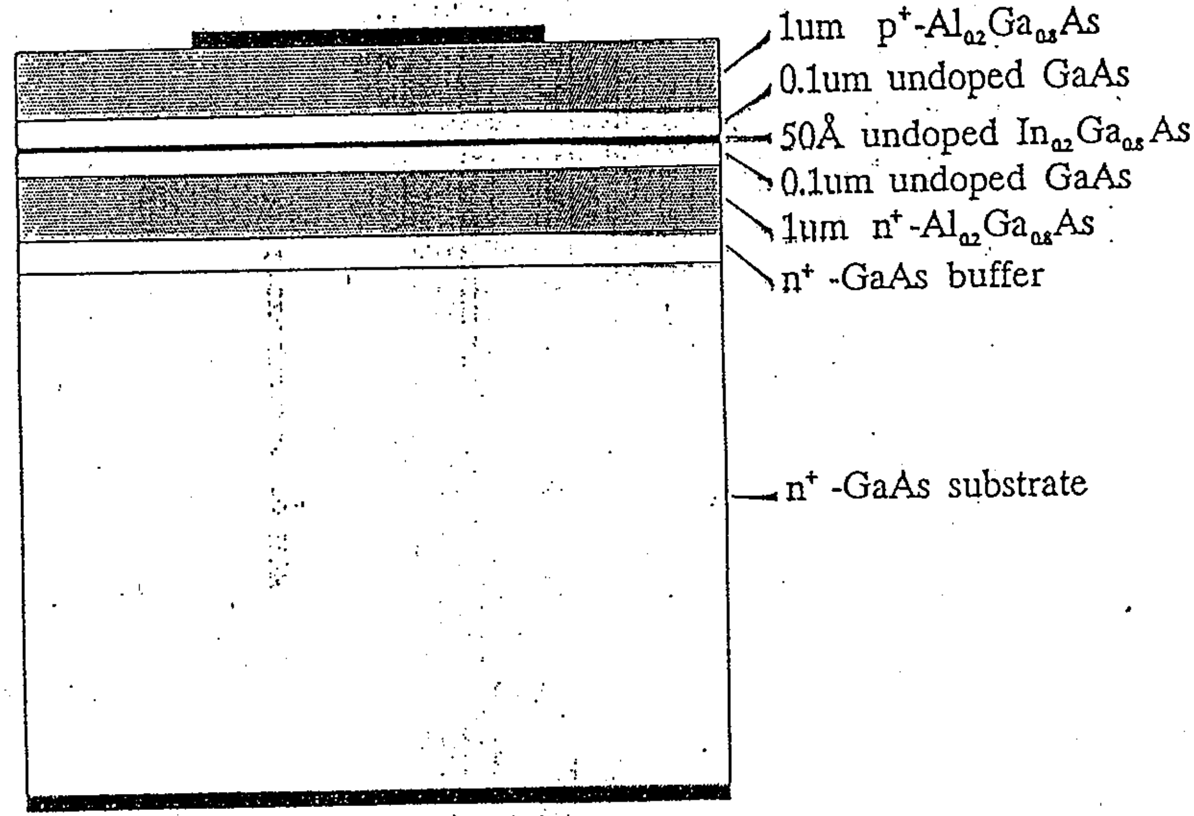
Comparison of experimental transient transmission changes with the theoretical model for different bias voltages.



Comparison of experimental and theoretical rise times showing resonant tunneling at 5V bias.



Representation of the electron densities in the quantum wells at various delay times and bias voltages.


1um p+-Al0.2Ga0.8As
0.1um undoped GaAs
50Å undoped In0.2Ga0.8As
0.1um undoped GaAs
1um n+-Al0.2Ga0.8As
n+ -GaAs buffer
n+ -GaAs substrate

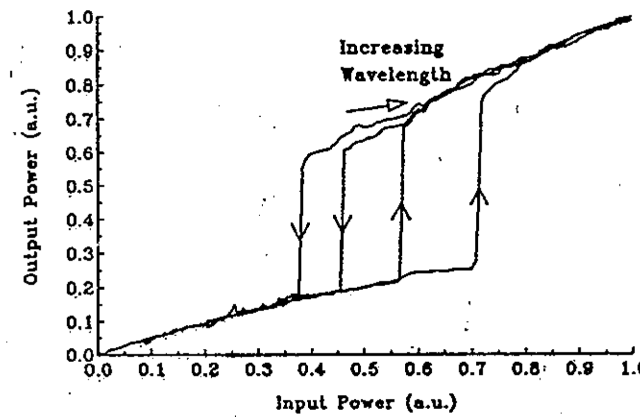
CREOL

Optical Switching with Gain

Results

- First demonstration of dispersive optical bistability with gain in a quantum well laser.
- InGaAs/GaAs single quantum well strained layer laser biased below threshold.
- Measurements of gain saturation

  (in collaboration with Robert Park, U. Florida)

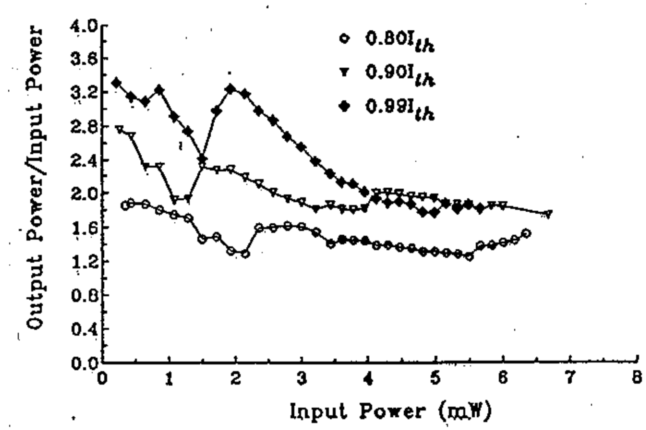


Optical bistability at 960nm at an electrical bias of 0.8th.

Goals

- Time resolved measurements of gain recovery
- Optical bistability in a single mode laser
- Demonstrate a directional coupler switch with gain

  (in collaboration with Paul Cook, ETDL)



Gain saturation at 965nm for three different bias conditions

MQW Intermixing for Low Loss ...

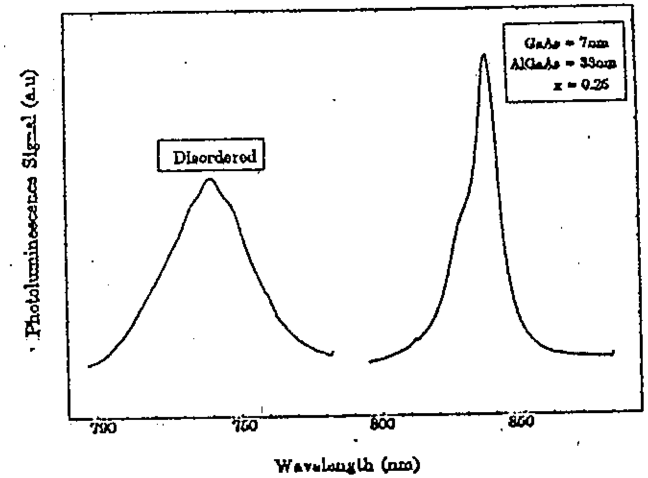
CREOL

Approach

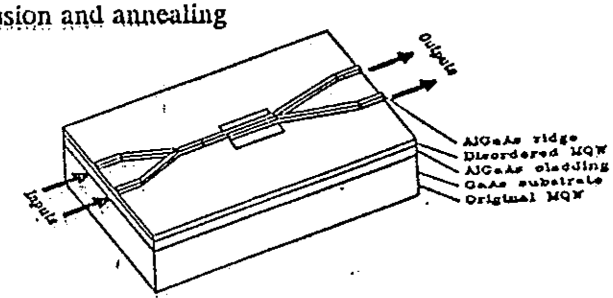
- A large blue shift of the absorption edge is induced by disordering the MQWs by zinc diffusion and annealing
  (in collaboration with Mitra Dutta, ETDL)
- Non-dopant, gallium vacancy induced disordering is being investigated
  (in collaboration with Gareth Parry, UCL)

Goals

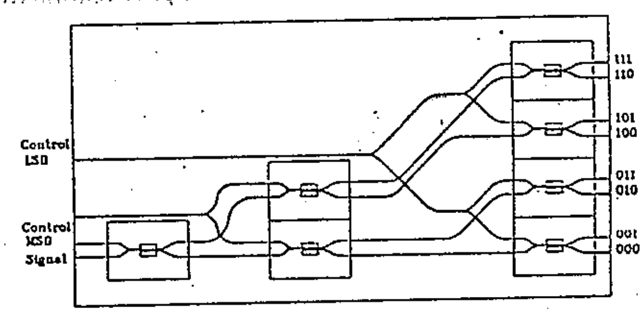
- Characterization and optimization of selective area partial intermixing of MQW waveguides
- Cascading of MQW directional coupler switches
- Demonstration of an all-optical waveguide switching circuit



Photoluminescence of GaAs/AlGaAs MQW before and after zinc diffusion and annealing



Directional coupler switch with selectively disordered interconnects



Concept for an all-optical switching circuit

NONLINEAR WAVEGUIDES

Presetented by Dr. George Stegeman,

Professor of Pysics and Electrical Engineering

and

Cobb-Hooker Eminent Chair

NONLINEAR WAVEGUIDES

George Stegeman

Long Range Goals:
To investigate the physics and applications of nonlinear optics in waveguides.

Personnel:
5 post-doctoral fellows, 1-3 visitors, 9 graduate students, 1 technician

Program:

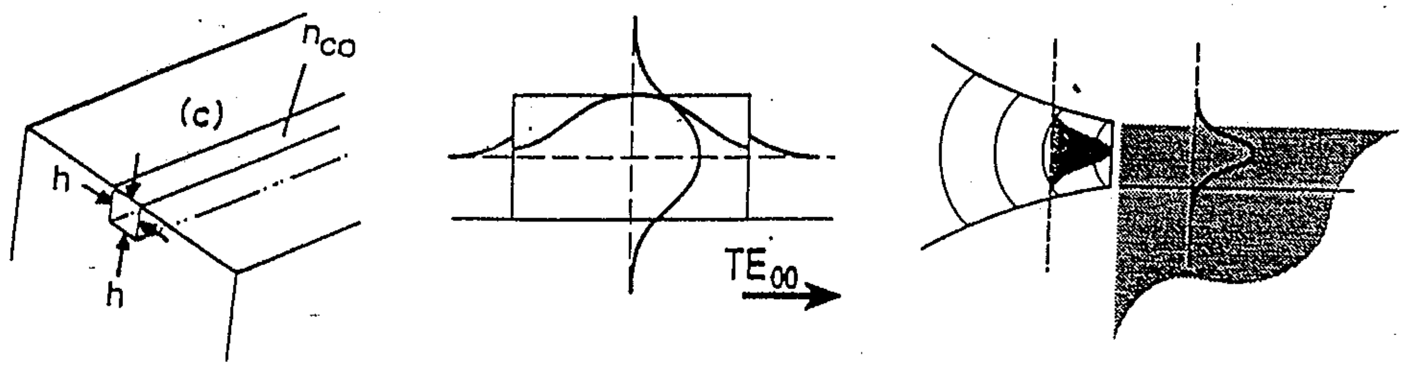
1. Nonlinear Materials
   - characterization from 450 → 2000 nm
   - physics of the nonlinearities
   - device figures of merit

2. Waveguide Fabrication
   - fabrication of thin film and channel waveguides
   - grating couplers
   - waveguiding characteristics, loss etc.
   - nonlinear characterization

3. Nonlinear Waveguide Phenomena
   - physics of nonlinear waveguides
   - soliton phenomena
   - out-of-plane second harmonic generation
   - all-optical switching in fibers and channels

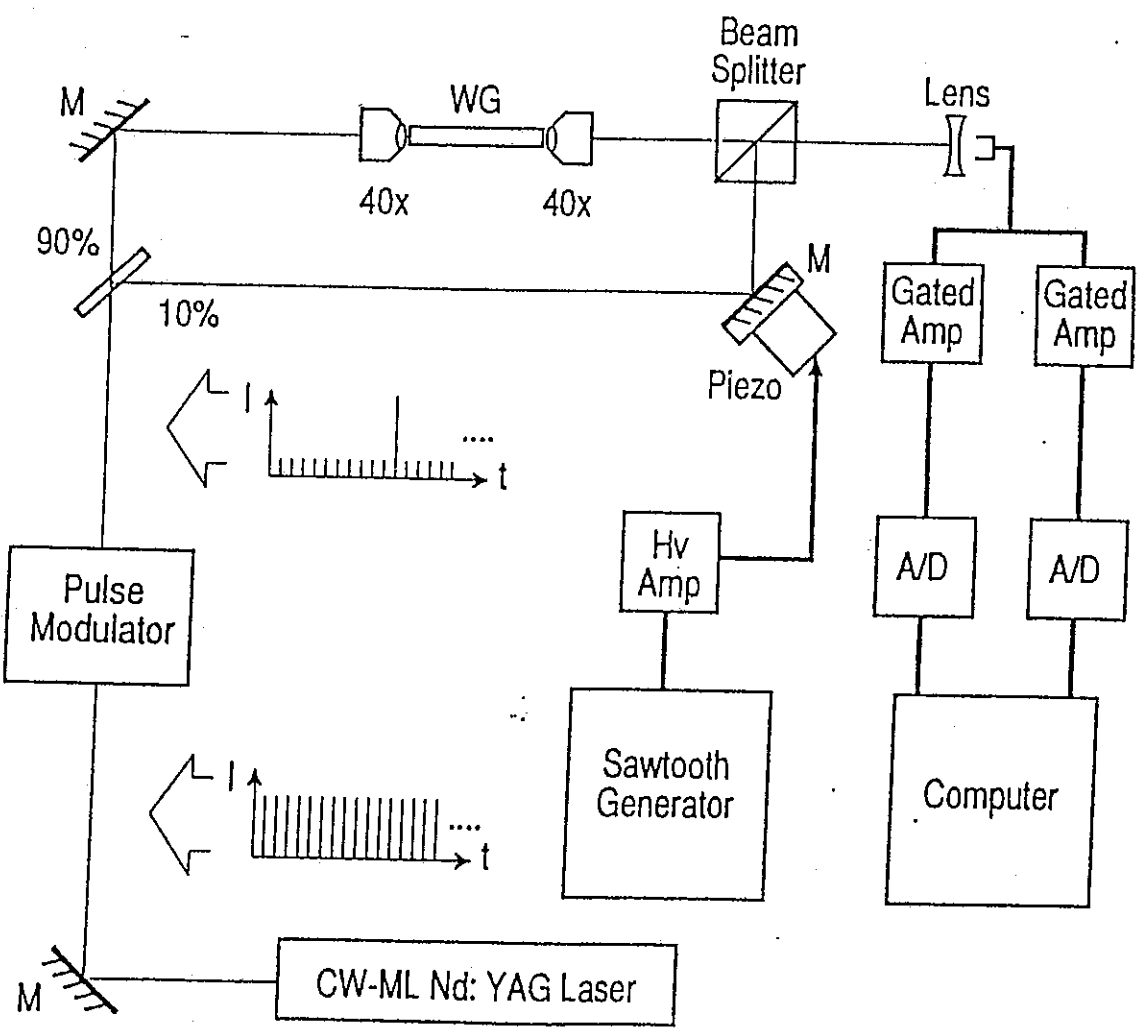
WAVEGUIDE MACH-ZEHNDER INTERFEROMETER

Channel Waveguides

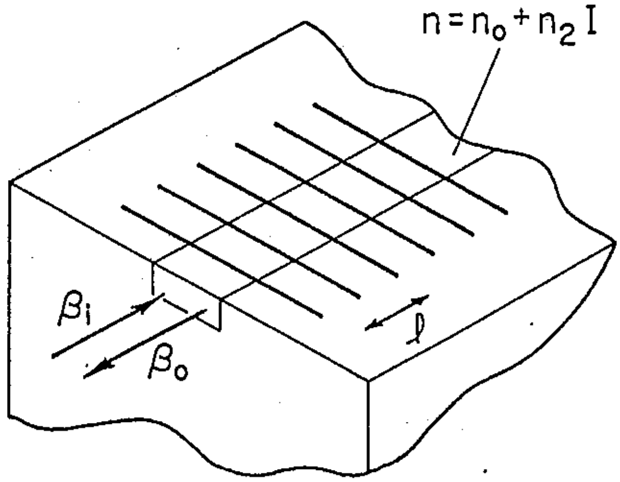


Nonlinear Interferometer

$$\Delta\phi^{NL} = n_2 I \; k_0 \; L_{eff}$$

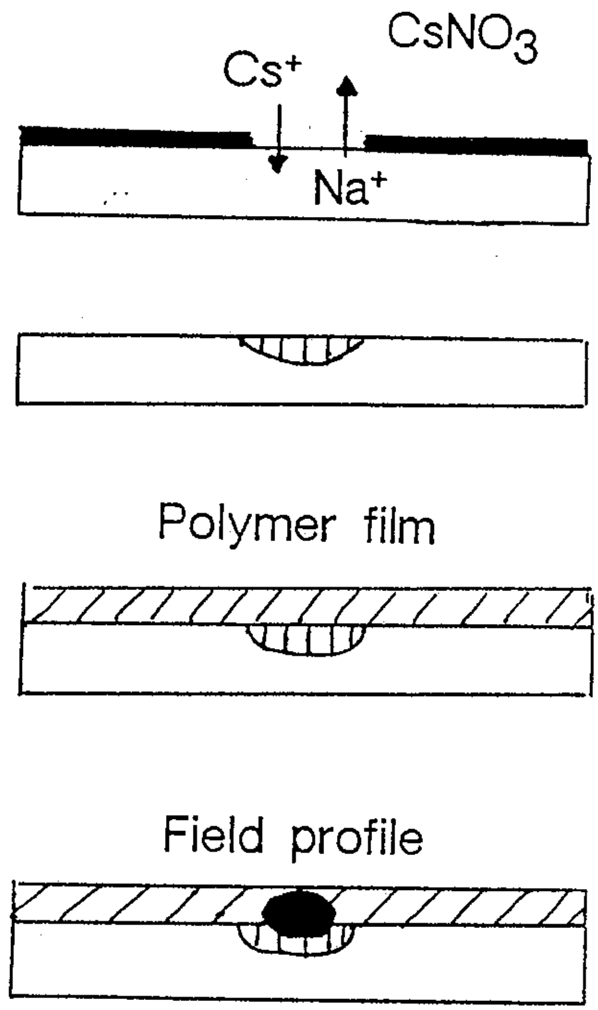


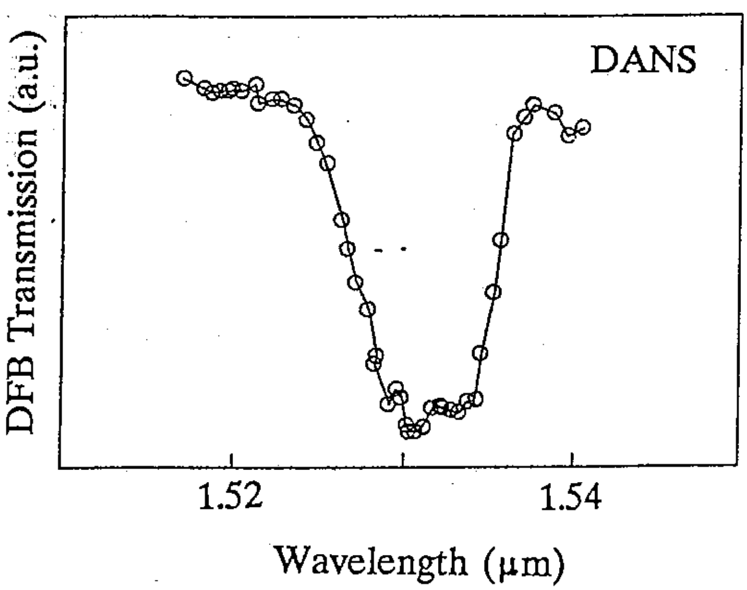
NONLINEAR DISTRIBUTED FEEDBACK GRATINGS



$\beta_i + \beta_o = 2\pi/\ell$

Schott BGG21 glass has ~ 10% Na

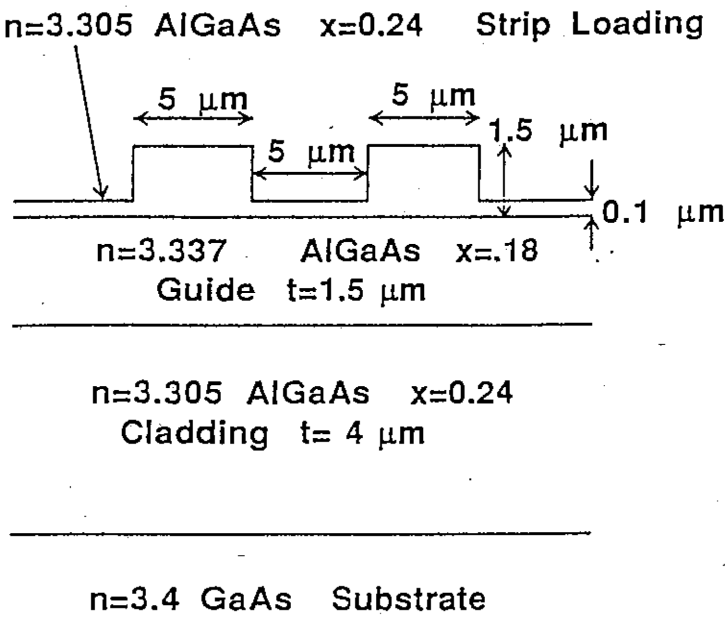


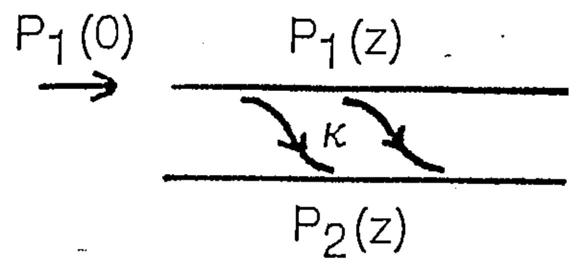


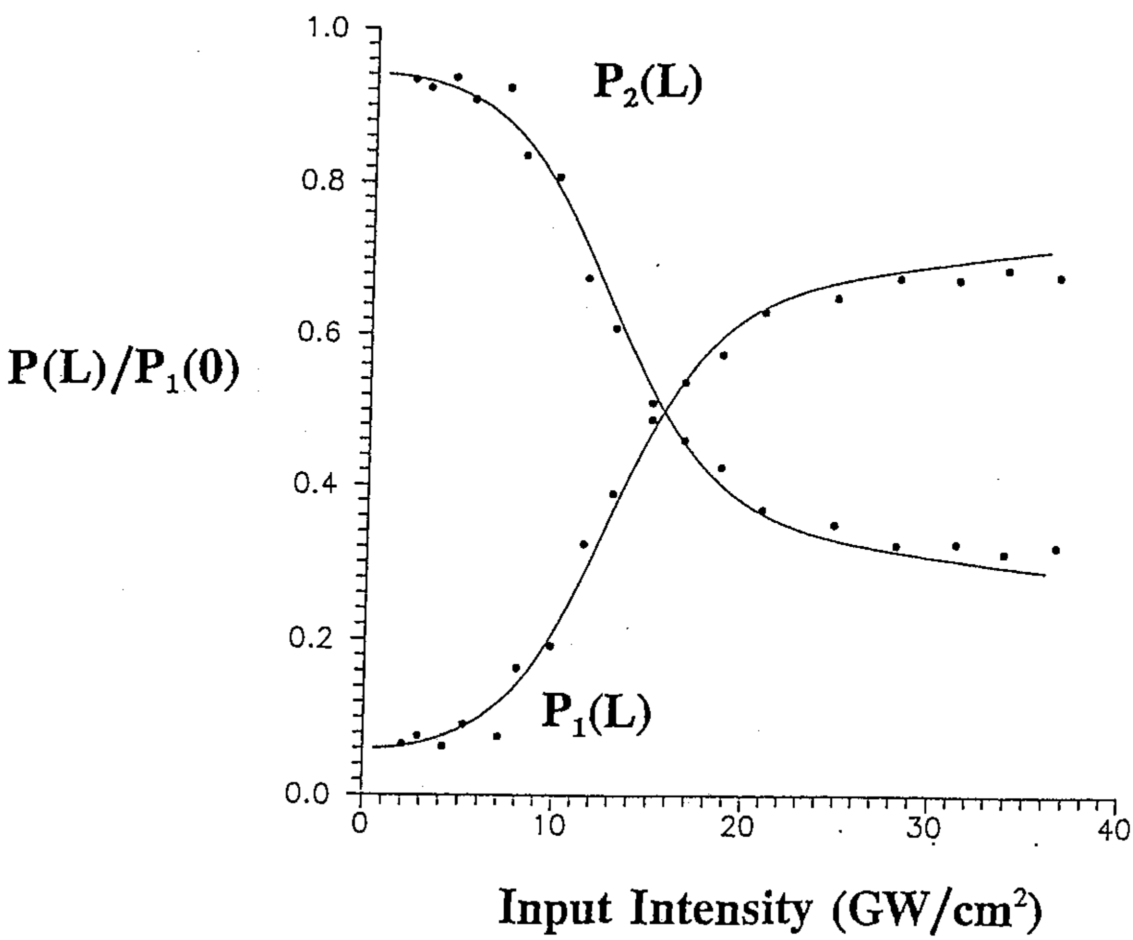
- **$3\mu m$ wide, 1 cm long channels, > 20% throughput**
- **planar waveguide losses ≃ 0.6 db/cm (channel ≃ same)**

NONLINEAR DIRECTIONAL COUPLER

λ = 1555 nm (communications band)   500 fs pulses







Novel Applications of Diffractive Optics

Graduate Students

Tim Ayers - MS student

Dan Gray - Ph.D Student

Drew Pommet - Ph.D. Student

Government and Industrial Sponsors and Collaborators:

Florida High Technology Industrial Council

Harris Corporation Electronics System Division - Melbourne, Fl

CECOM Center for Night Vision & Electro-Optics - Fort Belvoir, VA

LTV Missiles and Electronics Group - Dallas, TX

Northrup Electronics Systems Division - Hawthorne, CA

Teledyne Brown Engineering - Huntsville, AL

Geltech - Alachua, FL

Binary Diffractive Elements Applications

Multi-Level Binary Broadband Anti-reflection Surfaces

Surface-Relief Gratings for Spot Array Generation

Multiplexed Gratings for Optical Interconnects

Two-Dimensional Binary Grating Filters

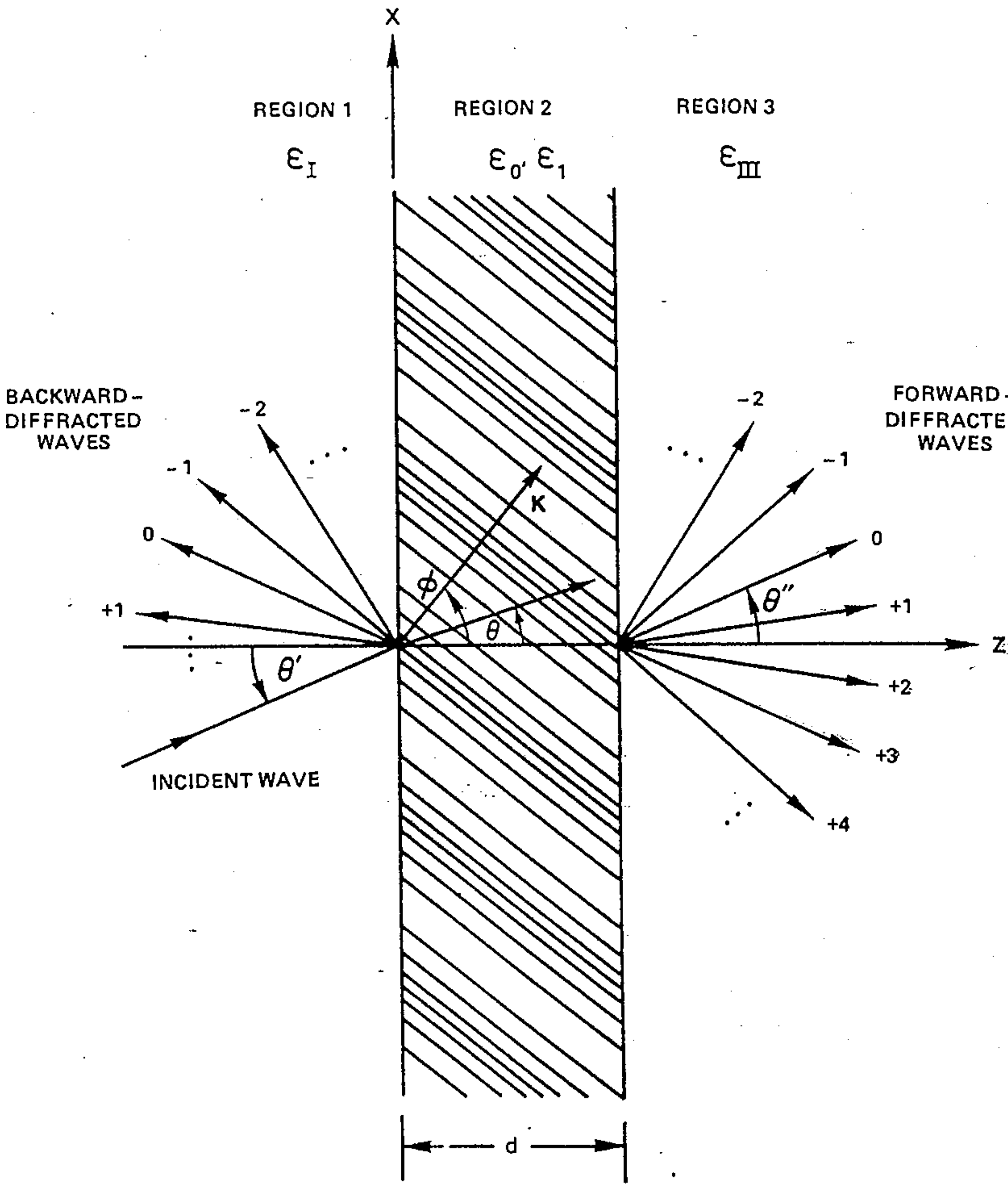
Binary Grating Polarizers

Real Time Holography Applications

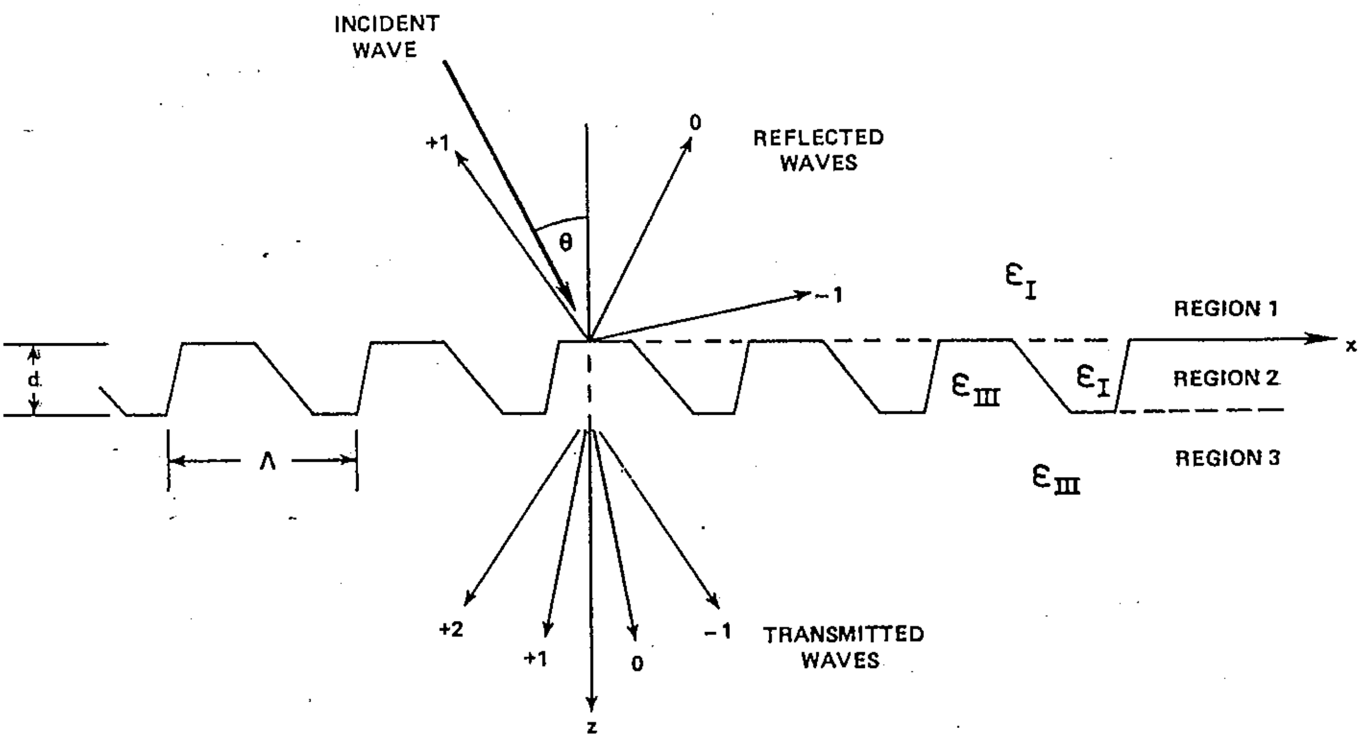
Acousto-Optics-Photorefractive Signal Processing

Correlation and Adaptive Nulling

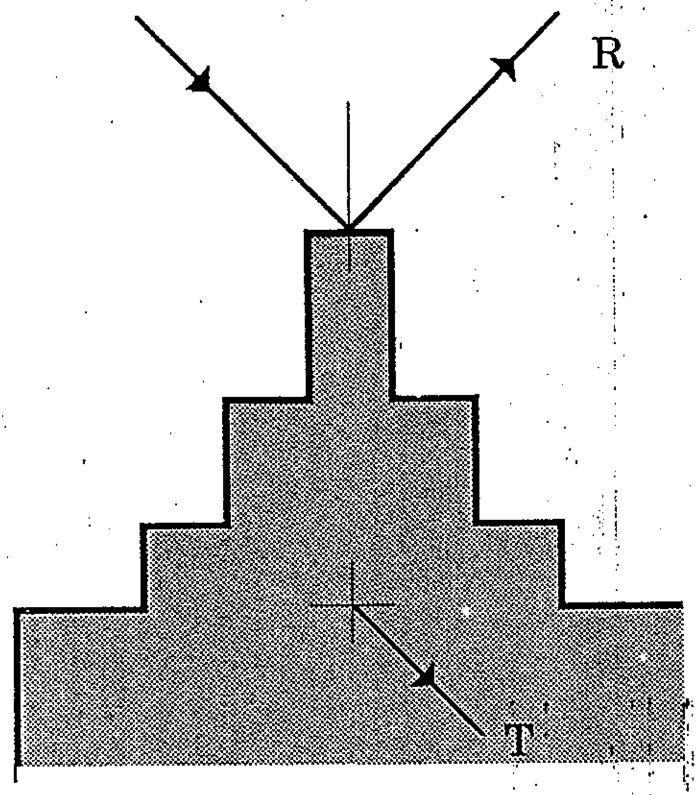
Novel Technique for the Characterization of Photorefractive Materials



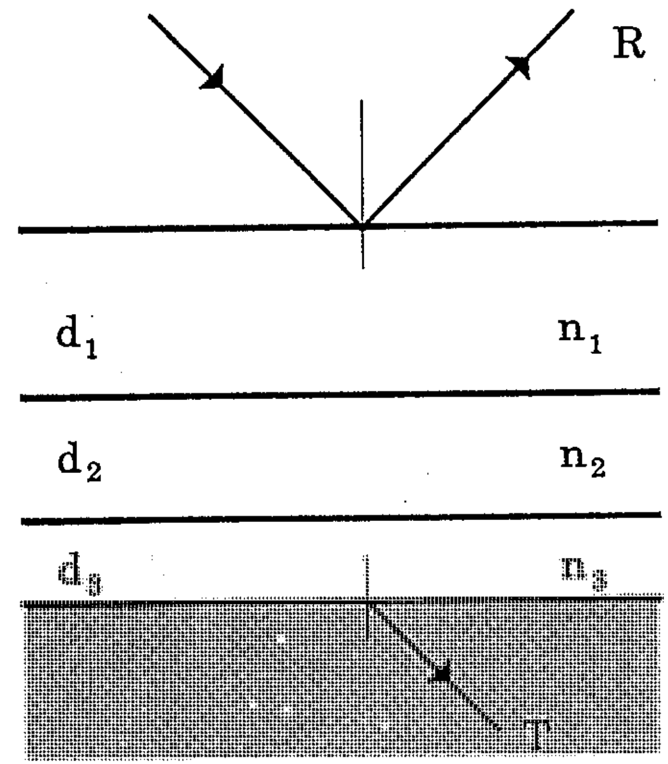
X
REGION 1
REGION 2
REGION 3
ε_{I}
$\varepsilon_0, \varepsilon_1$
ε_{III}
BACKWARD-DIFFRACTED WAVES
FORWARD-DIFFRACTED WAVES
-2
-1
0
+1
K
ϕ
θ
θ'
θ''
-2
-1
0
+1
Z
+2
+3
+4
INCIDENT WAVE
d



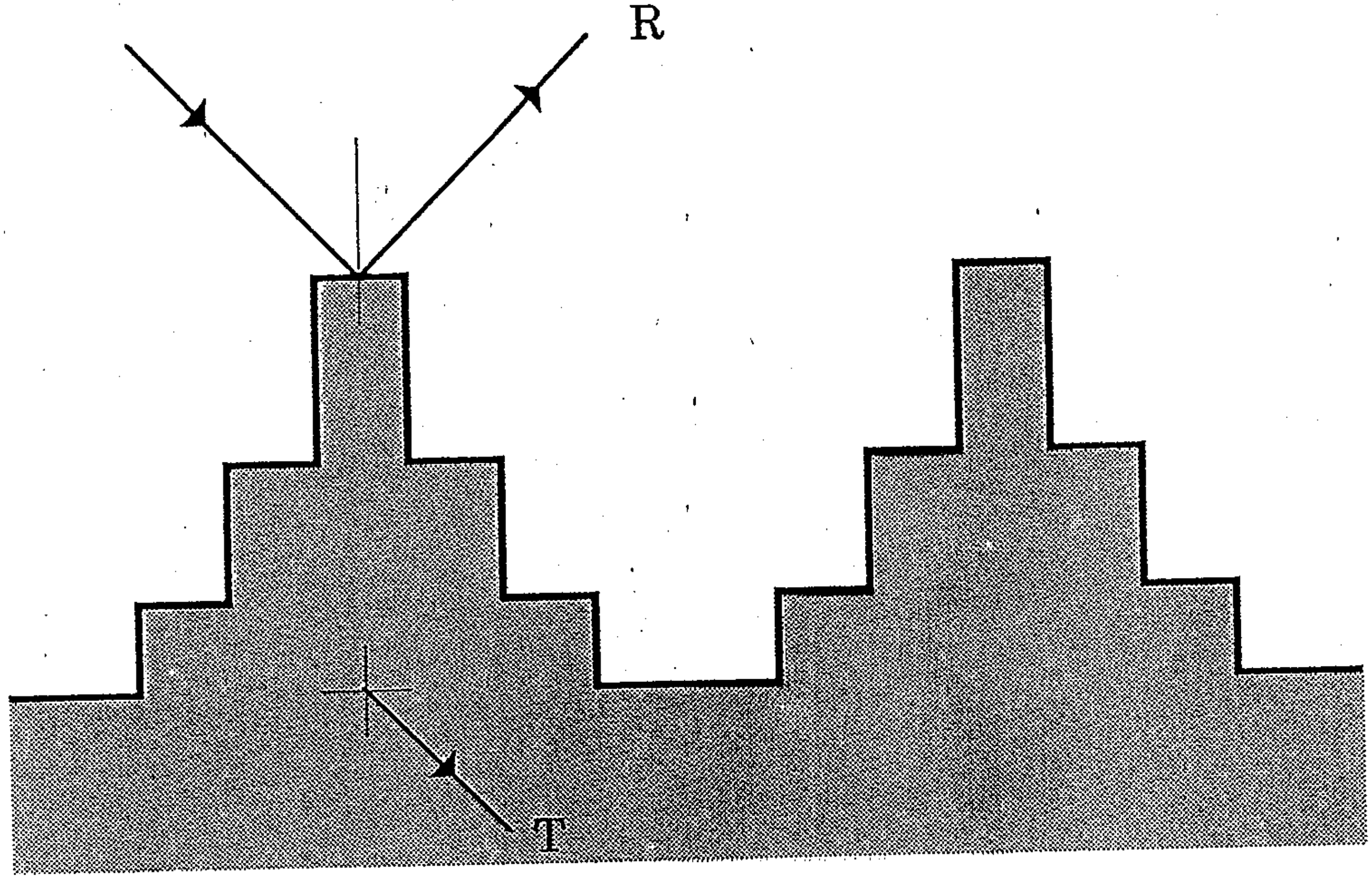
INCIDENT
WAVE
+1
0
REFLECTED
WAVES
θ
−1
ε_I
REGION 1
x
d
ε_{III}
ε_I
REGION 2
Λ
REGION 3
ε_{III}
+2
+1
0
−1
TRANSMITTED
WAVES
z

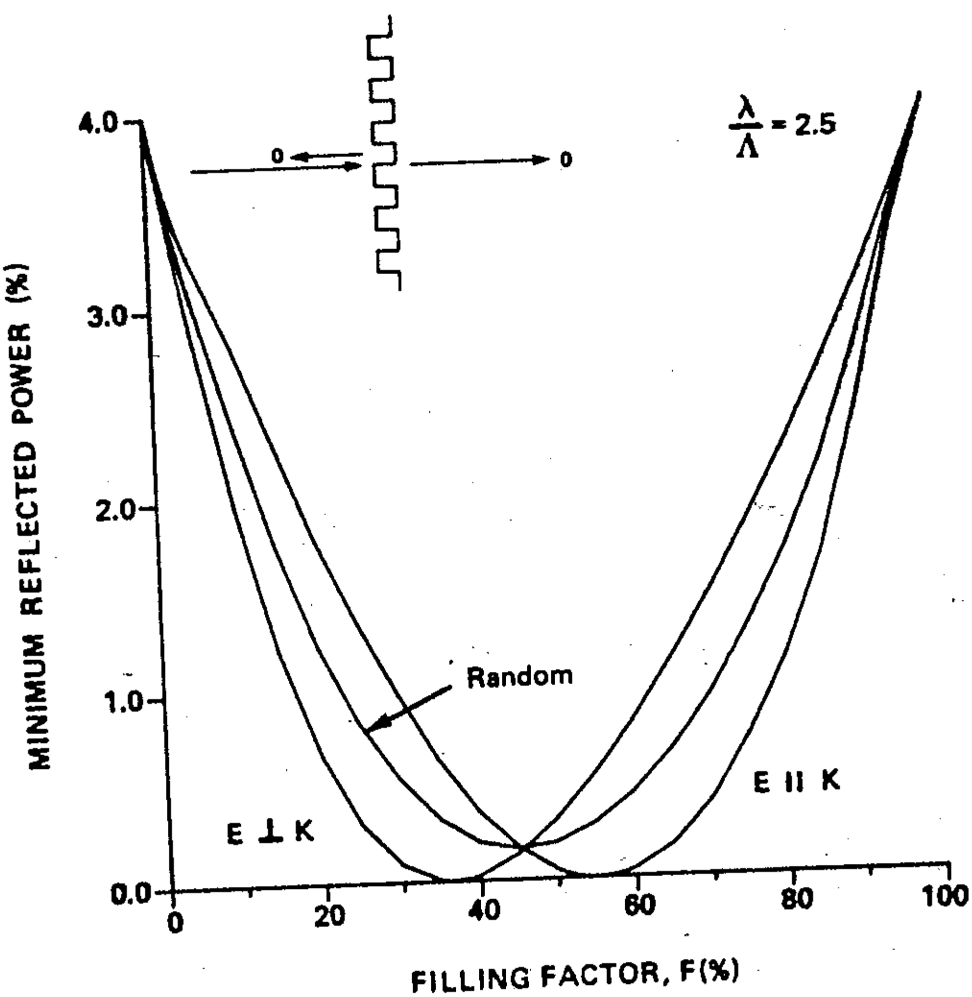


Binary Grating

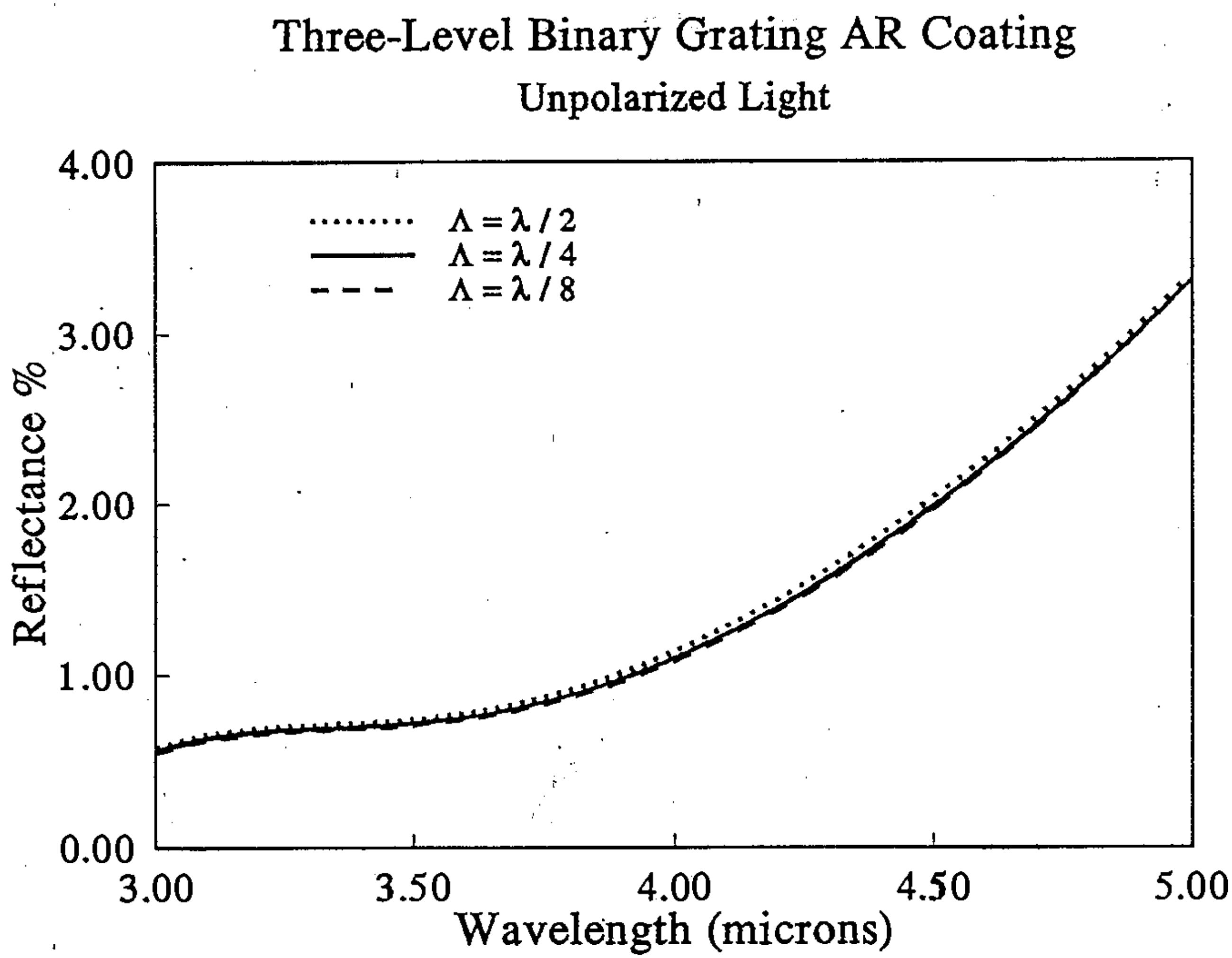


Thin Film

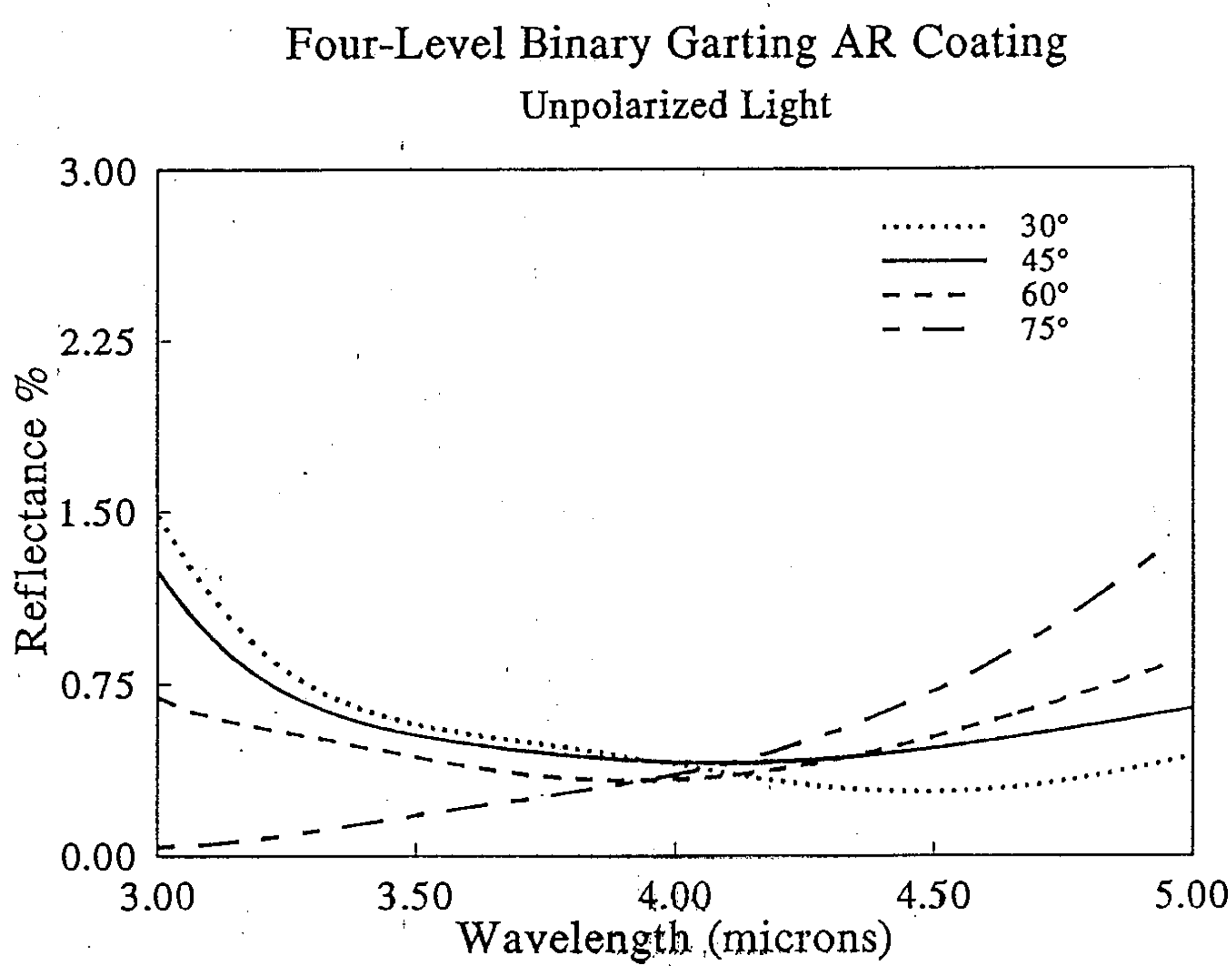

R
T



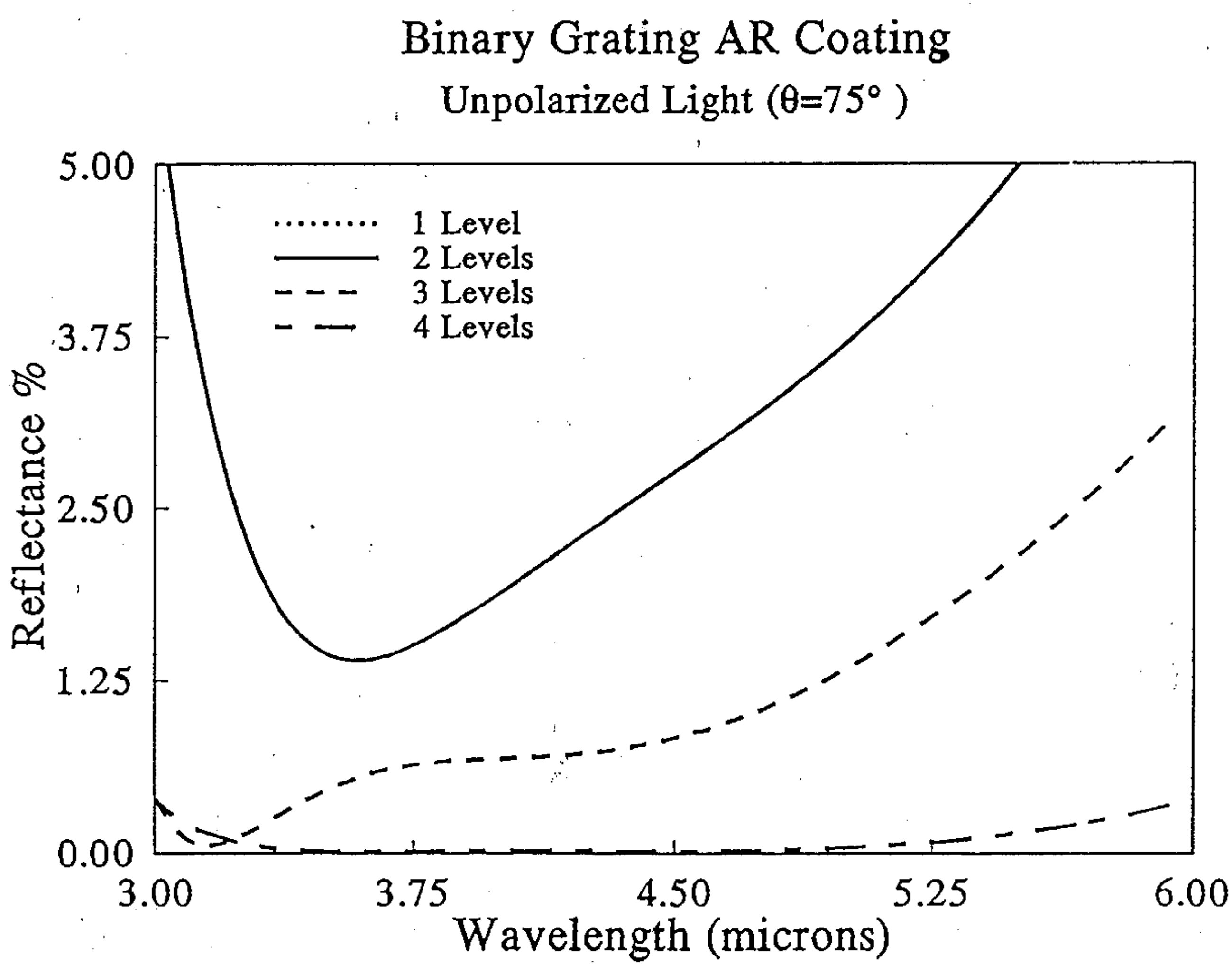
4.0
3.0
2.0
1.0
0.0
MINIMUM REFLECTED POWER (%)
0
0
$\frac{\lambda}{\Lambda}$ = 2.5
Random
E ⊥ K
E ∥ K
0
20
40
60
80
100
FILLING FACTOR, F(%)

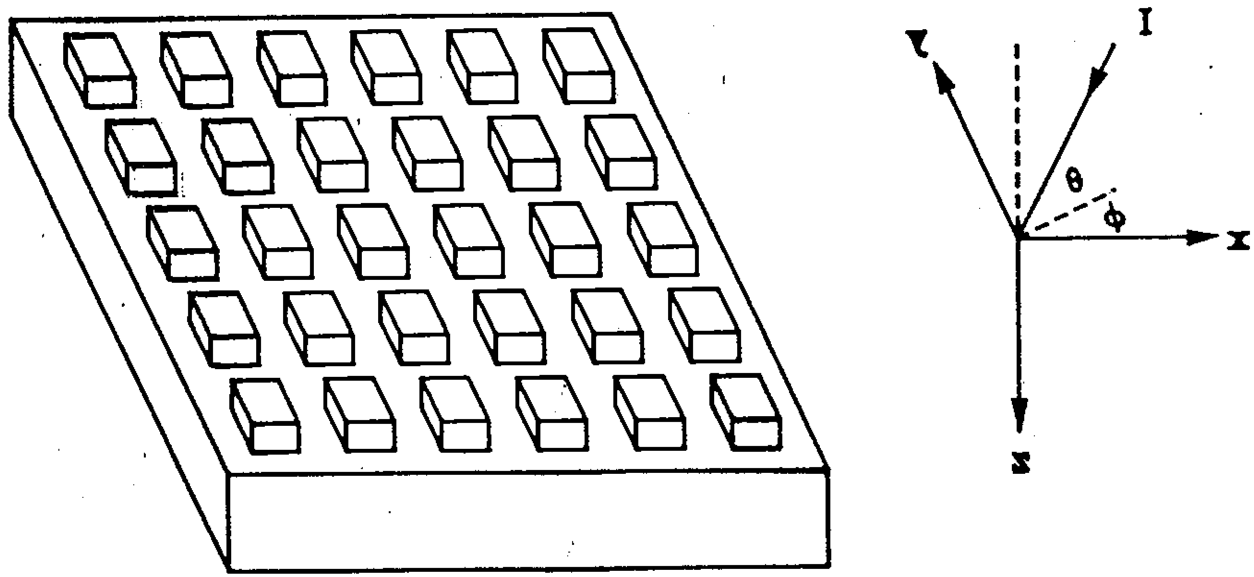


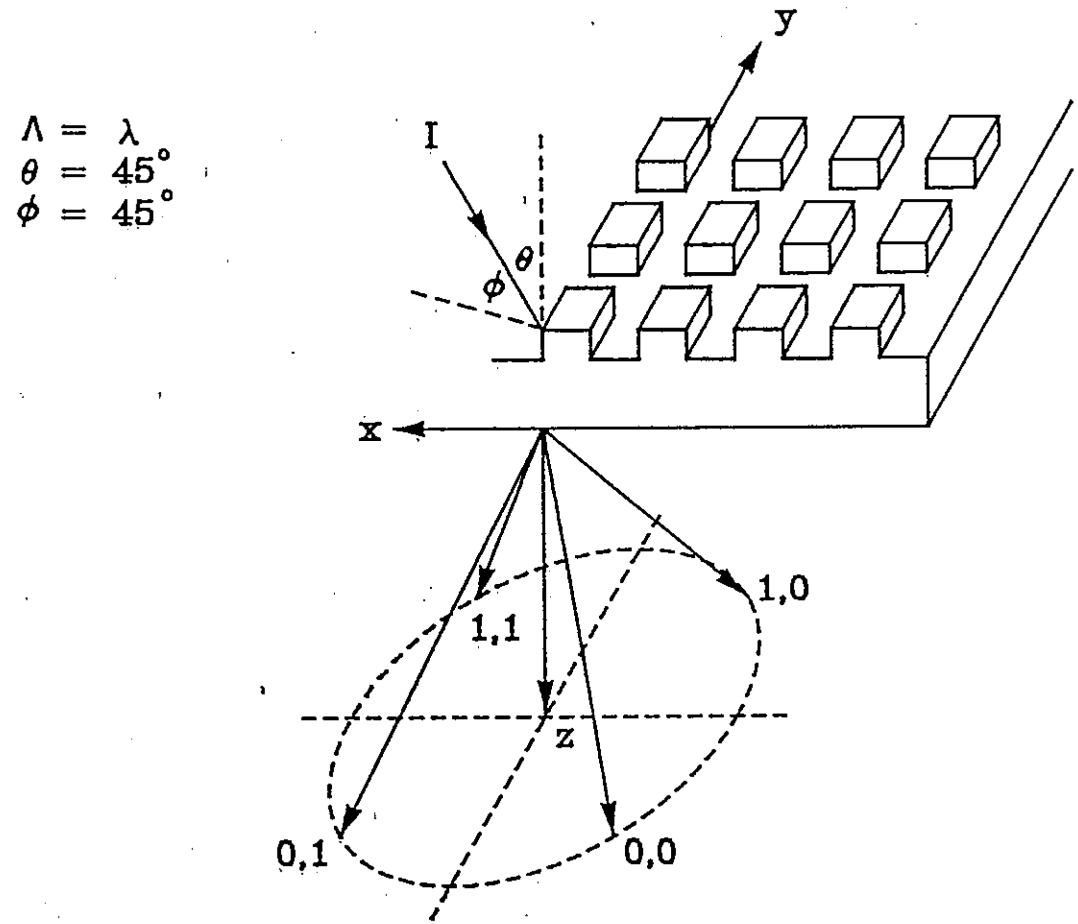
Three-Level Binary Grating AR Coating
Unpolarized Light
Λ = λ / 2
Λ = λ / 4
Λ = λ / 8
Reflectance %
4.00
3.00
2.00
1.00
0.00
3.00
3.50
4.00
4.50
5.00
Wavelength (microns)



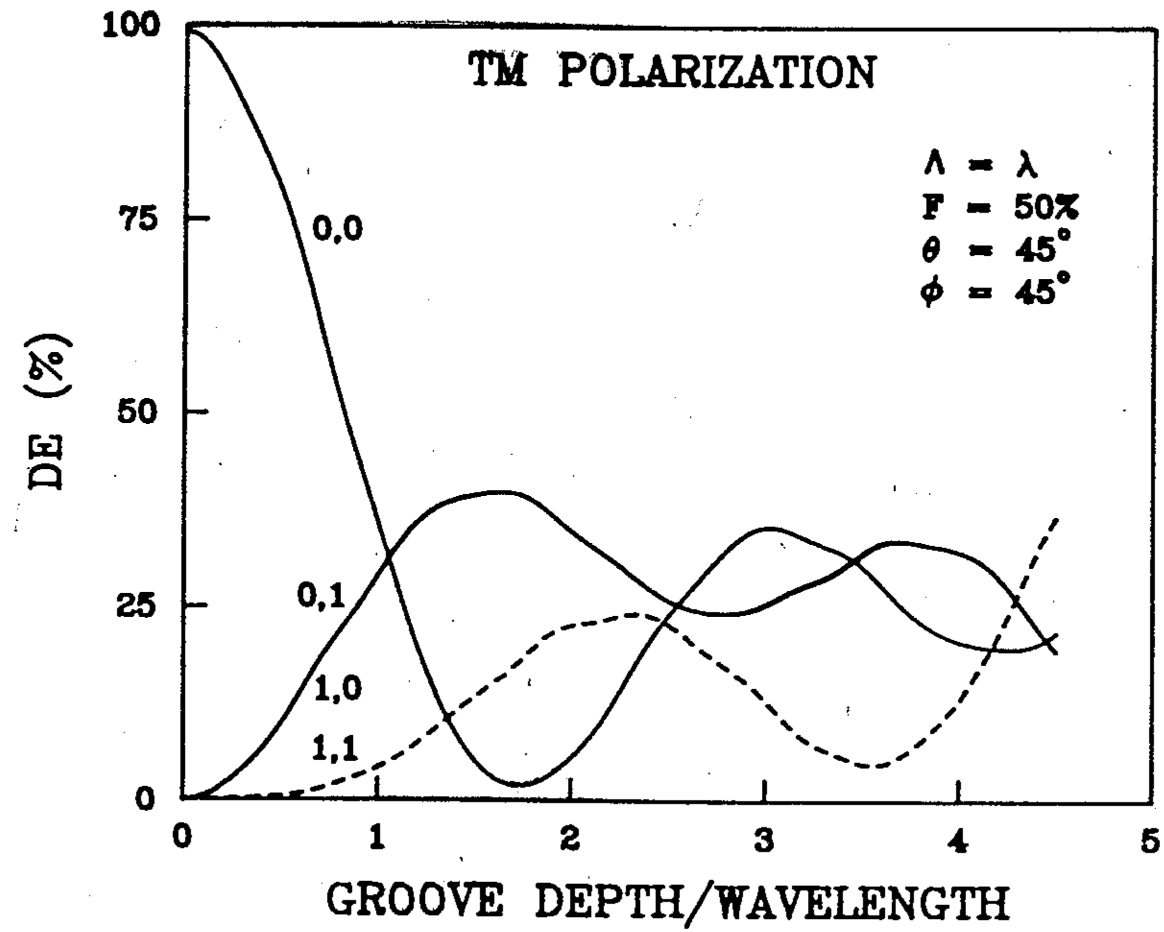
Four-Level Binary Garting AR Coating
Unpolarized Light
3.00
2.25
1.50
0.75
0.00
Reflectance %
3.00
3.50
4.00
4.50
5.00
Wavelength (microns)
30°
45°
60°
75°

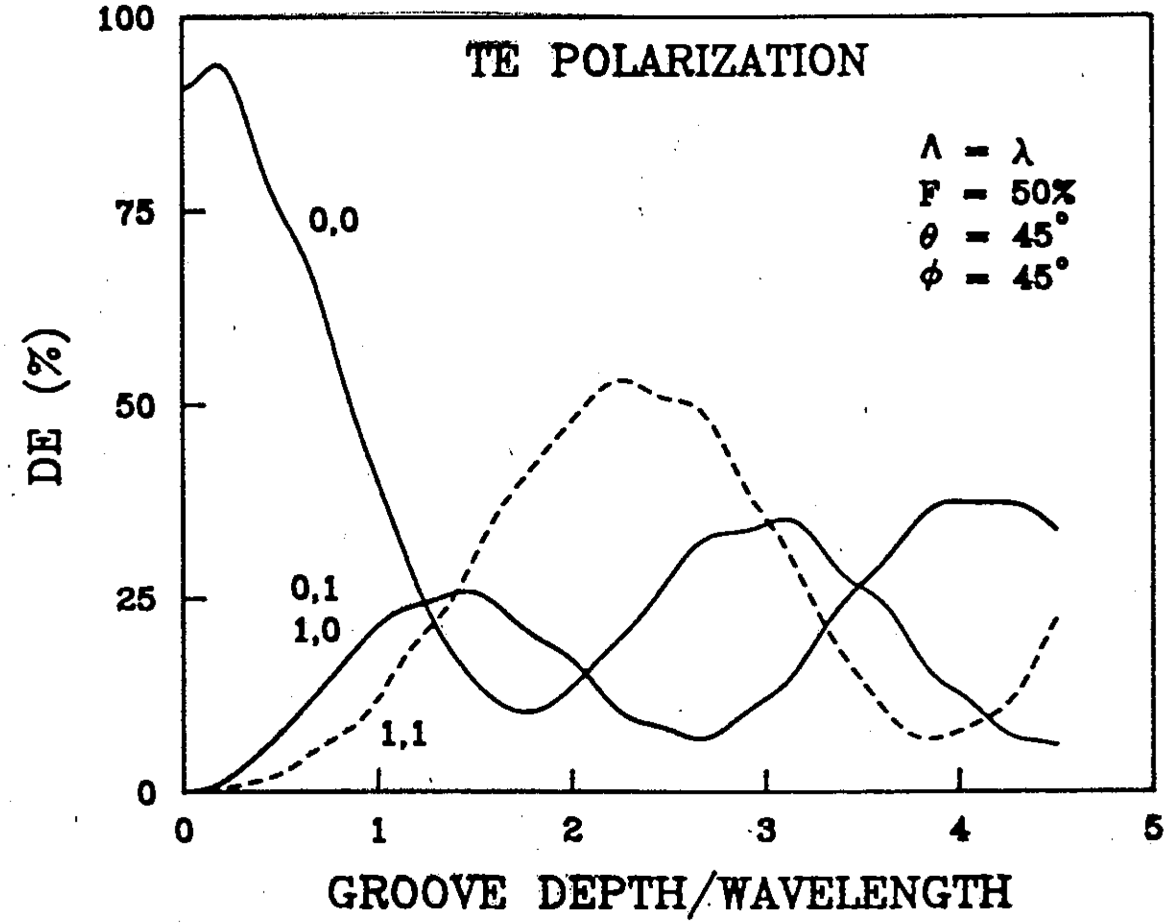

Binary Grating AR Coating
Unpolarized Light (θ=75°)
1 Level
2 Levels
3 Levels
4 Levels
5.00
3.75
2.50
1.25
0.00
Reflectance %
3.00
3.75
4.50
5.25
6.00
Wavelength (microns)


Y
I
θ
φ
X
Z

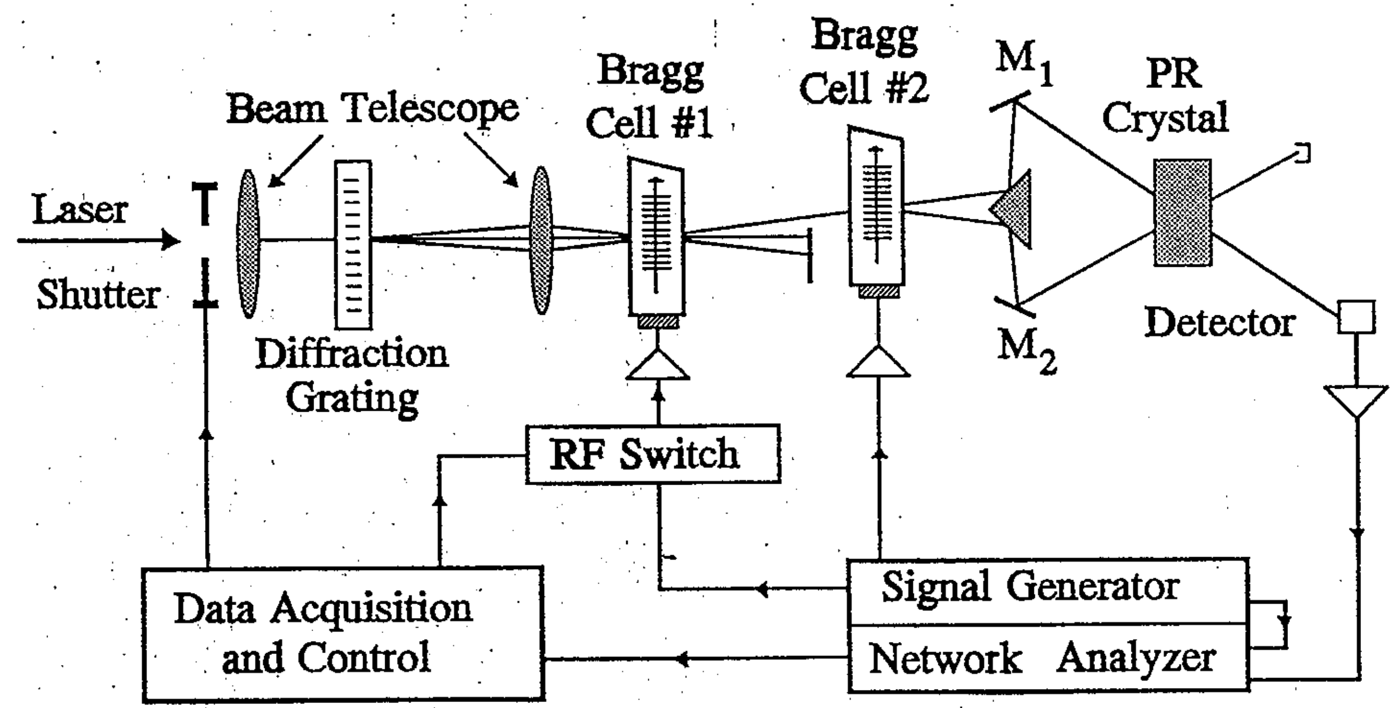


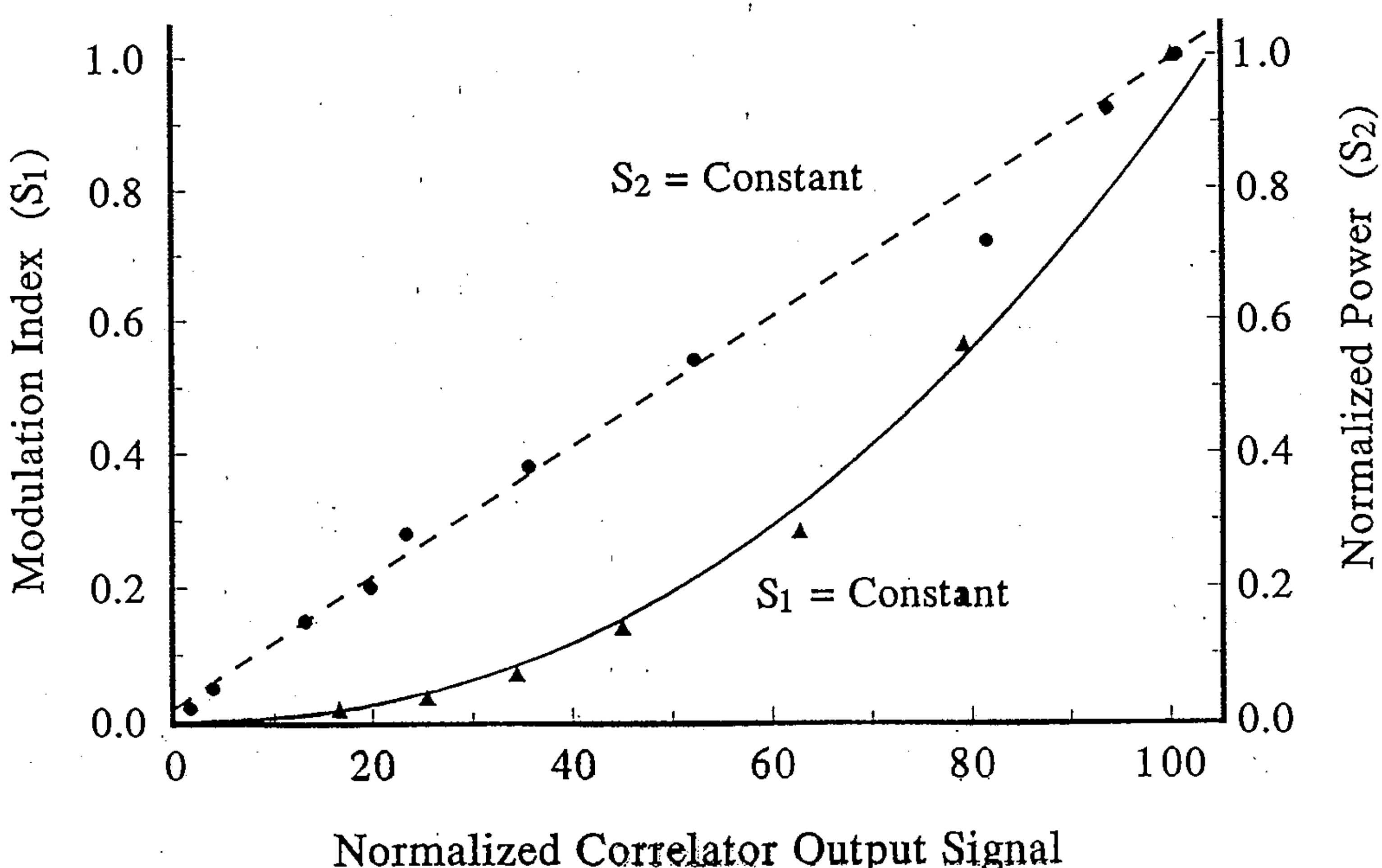
Λ = λ
θ = 45°
φ = 45°
I
θ
φ
y
x
z
1,0
1,1
0,1
0,0


TM POLARIZATION
Λ = λ
F = 50%
θ = 45°
φ = 45°
0,0
0,1
1,0
1,1
DE (%)
100
75
50
25
0
0
1
2
3
4
5
GROOVE DEPTH/WAVELENGTH


TE POLARIZATION
Λ = λ
F = 50%
θ = 45°
φ = 45°
0,0
0,1
1,0
1,1
DE (%)
100
75
50
25
0
0
1
2
3
4
5
GROOVE DEPTH/WAVELENGTH

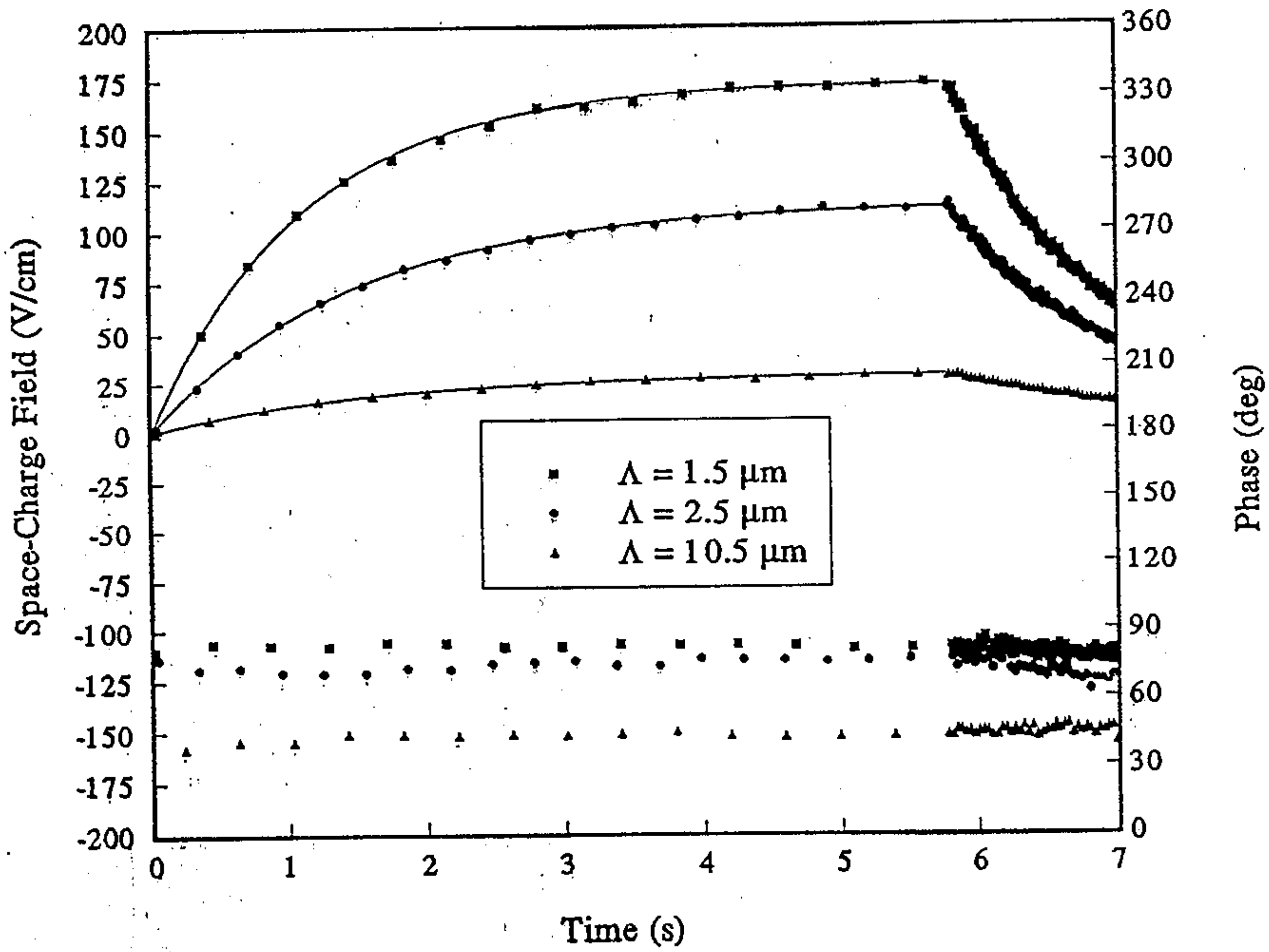
Experimental Configuration

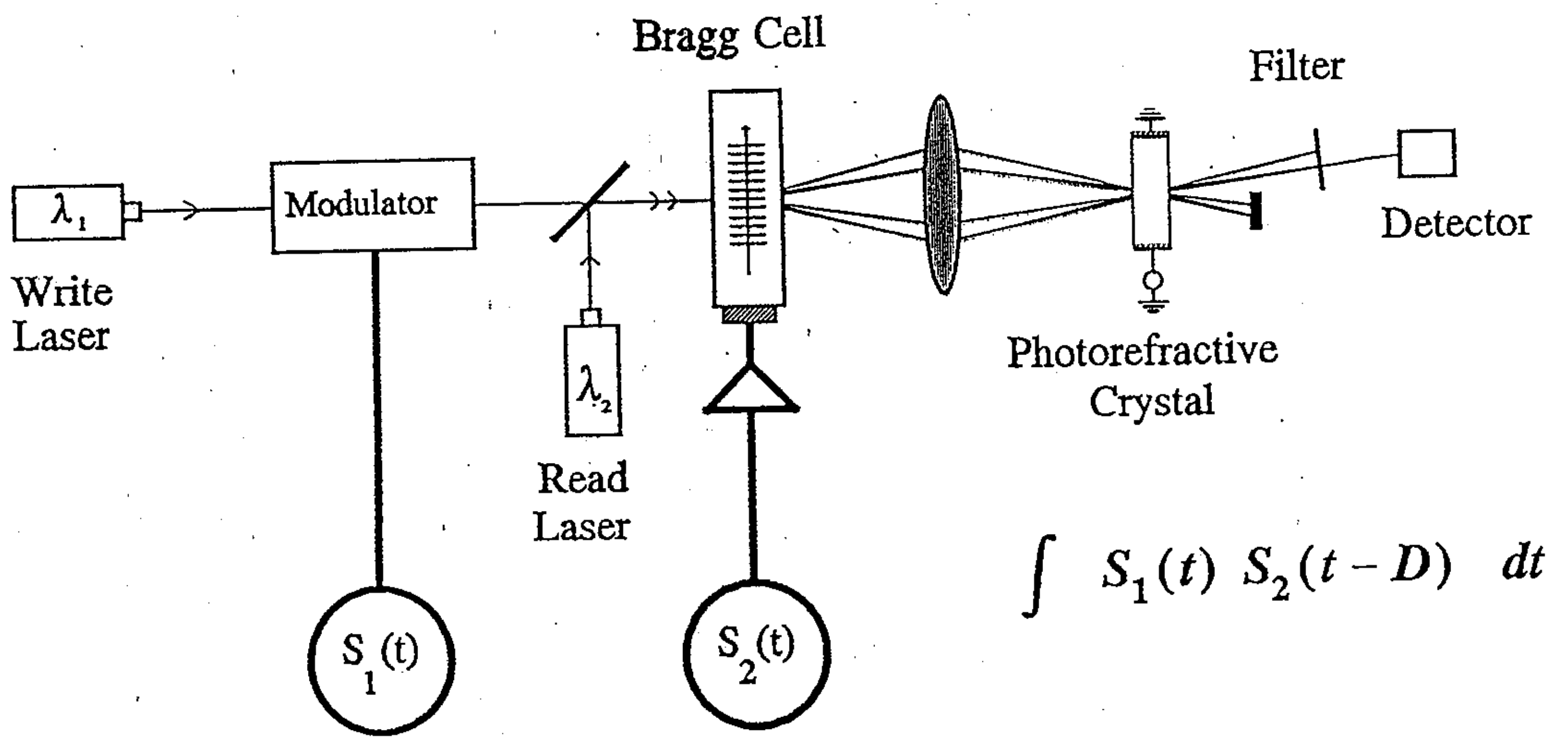




S2 = Constant
S1 = Constant
Modulation Index (S1)
Normalized Power (S2)
Normalized Correlator Output Signal
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100

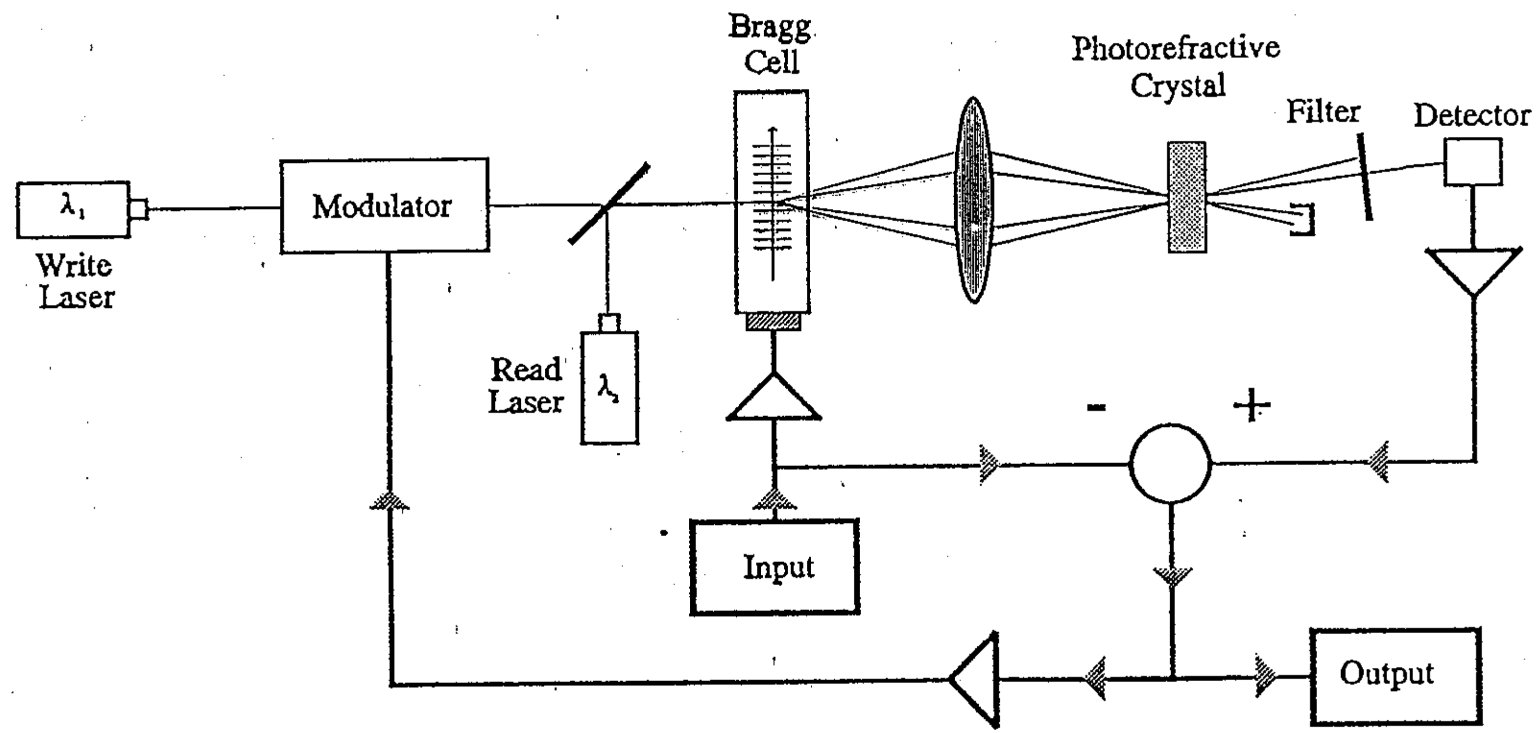
Response of $BaTiO_3$ as a Function of Spatial Frequency





$$\int S_1(t)\ S_2(t-D)\ dt$$

Photorefractive Correlator Concept



Photorefractive Adaptive Filter Concept

A NEW CLASS OF OPTICAL THIN FILMS

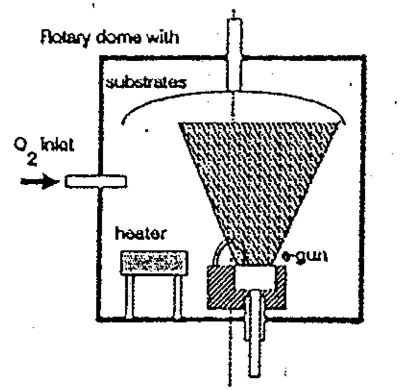
Principal Investigator:
Prof. Karl H. Guenther
Electrical Engineering and Physics
Collaborators:
Dr. K. Balasubramanian
Drs. M. Himel (now at AT&T) and S. Zarrabian
Prof. K. Beck (Chemistry) and Prof. A. Grogan (ME)

MAJOR TOPICS	ACCOMPLISHMENTS
React. Low Voltage Ion Plating	Glassy, Dense, Smooth Films
Plasma Process Diagnostics	Better Oxidation Mechanism
Thin Film Characterization and Analysis	Optical Micrometrology and Surface Microanalysis Labs
Feasibility Studies for Florida and National Industry, Federal Agencies and Labs	Laser Coatings, Eye Protection, Polarizers, AR-Coatings Waveguide Beam Deflector

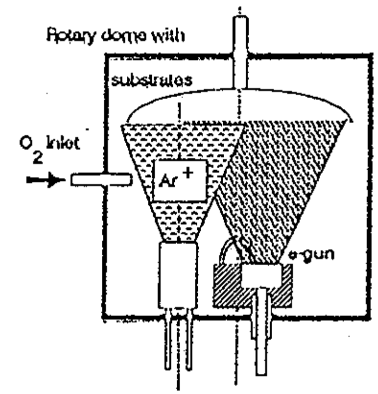
CERAMIC OPTICAL COATINGS?

K. H. Guenther

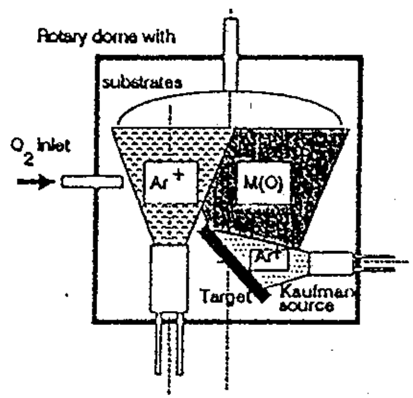
Comparison of Thin Film Deposition Processes



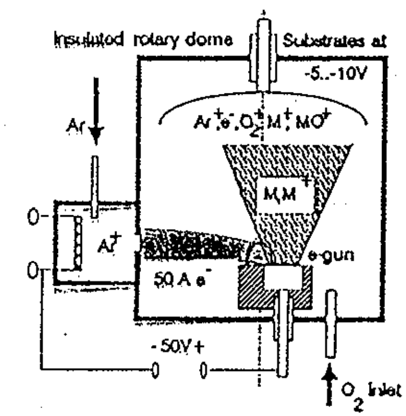
Reactive Evaporation



Ion Assisted Deposition



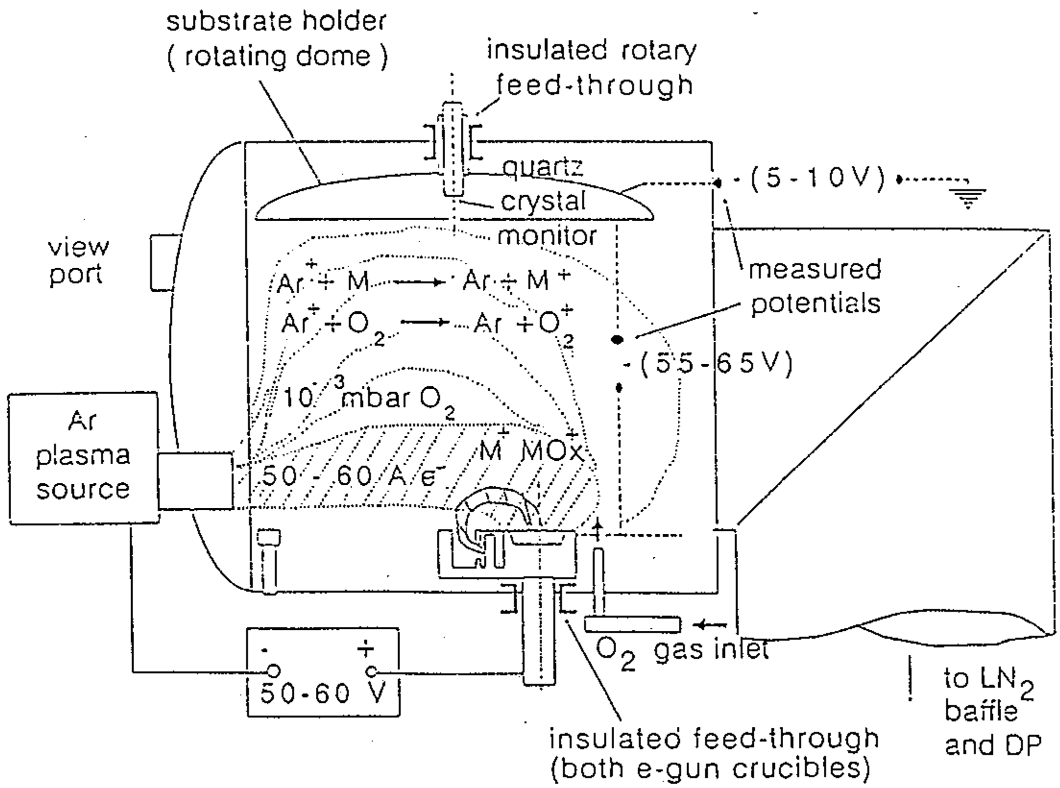
Ion Beam Sputtering

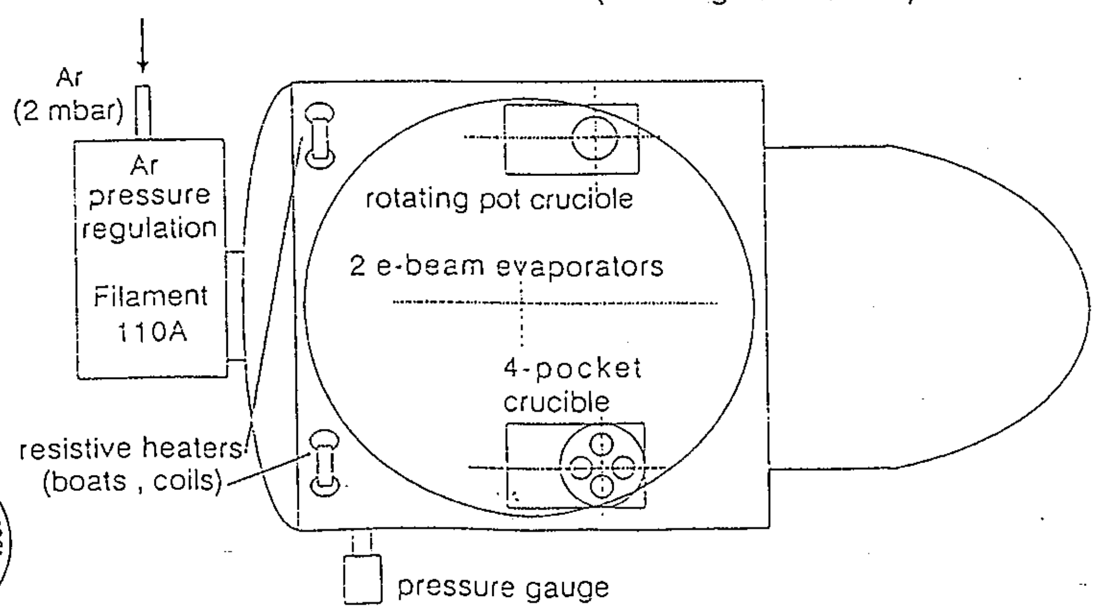


Low Voltage Ion Plating

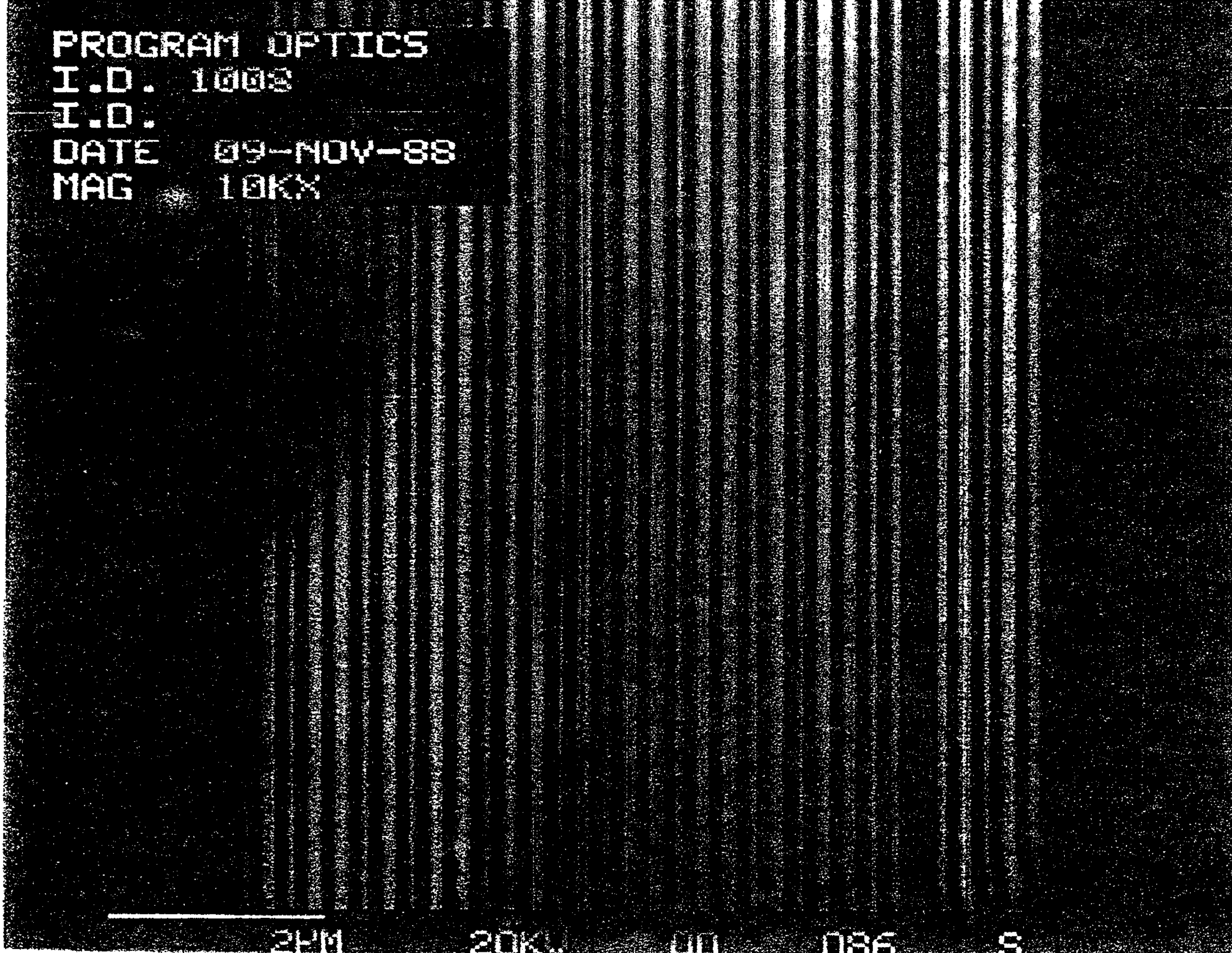
CREOL

High Vacuum Deposition System (Balzers BAP 800) for Reactive Electron Beam (EB) and Thermal Evaporation and Reactive Low Voltage Ion Plating (RLVIP)





Center for Research in Electro-Optics and Lasers


PROGRAM OPTICS
I.D. 1003
I.D.
DATE 09-NOV-88
MAG 10KX
2μM 20KV 086 S

ZrO_2/SiO_2, ion plated multilayer coating: electron micrograph of a direct cross-section obtained by microtome slicing normal to its interfaces (orig. magn. 100 000x, D. Windham)

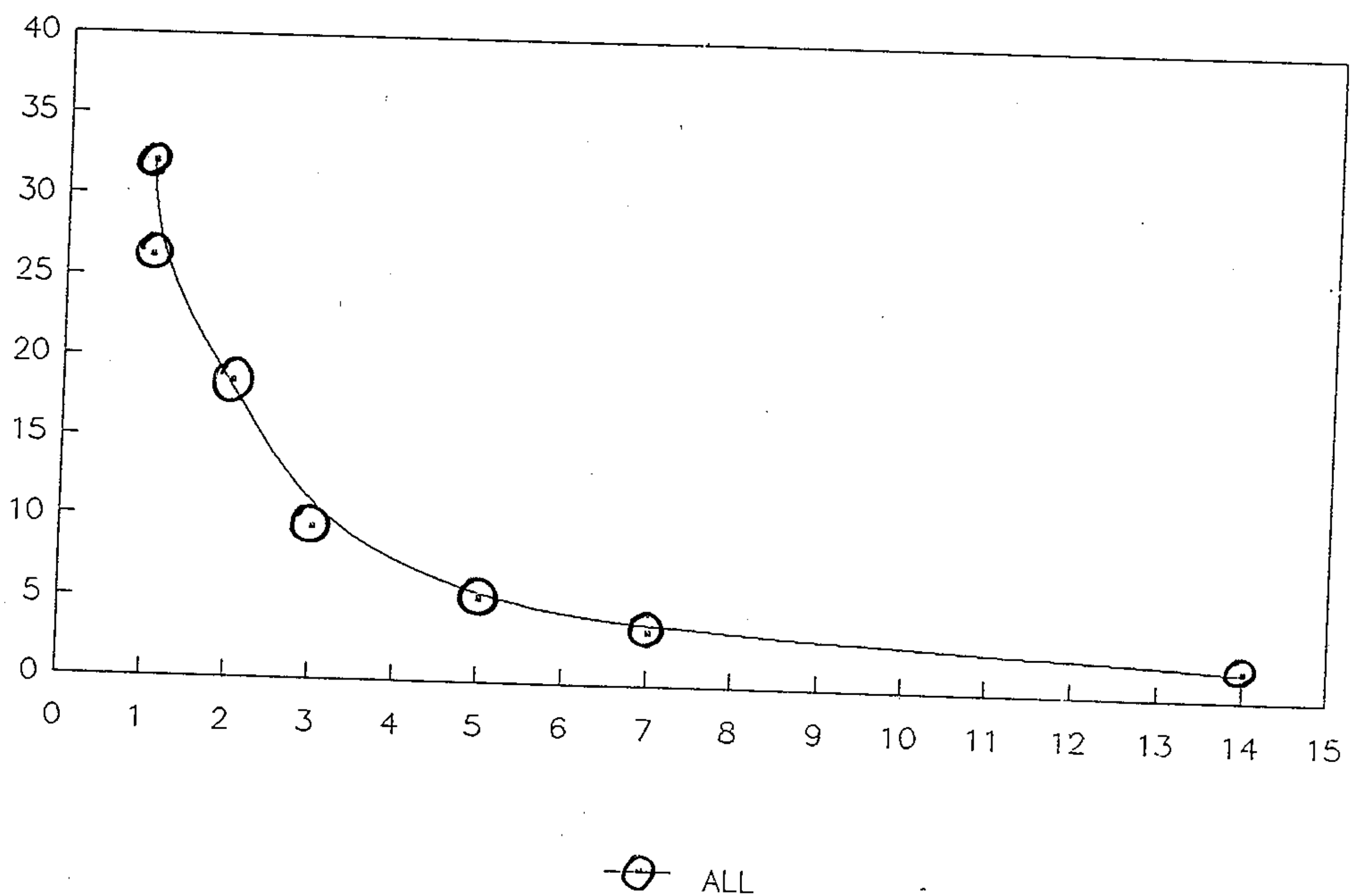
Laser-Quality Coatings Deposited by

Reactive Low Voltage Ion Plating (RLVIP)

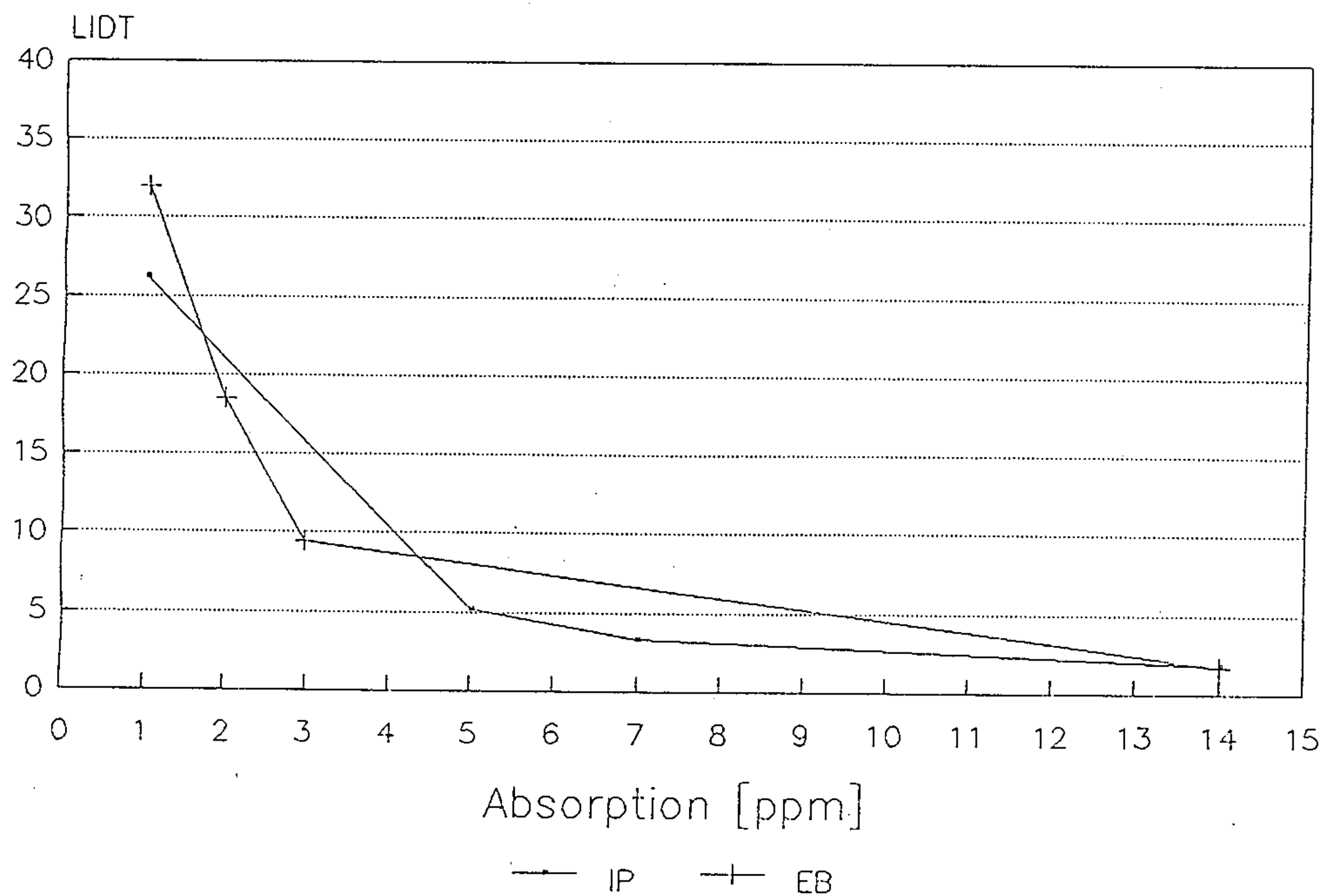
K. H. Guenther, K. Balasubramanian, and X.-Q. Hu
Center for Research in Electro-Optics and Lasers
(CREOL)
University of Central Florida
Orlando, FL 32826

R. Chow and C. J. Stolz
Optical Initiative Project and KMI
Lawrence Livermore National Laboratory
University of California
Livermore, CA 94551

CLEO/QELS
May 12-17, 1991
Baltimore, Maryland

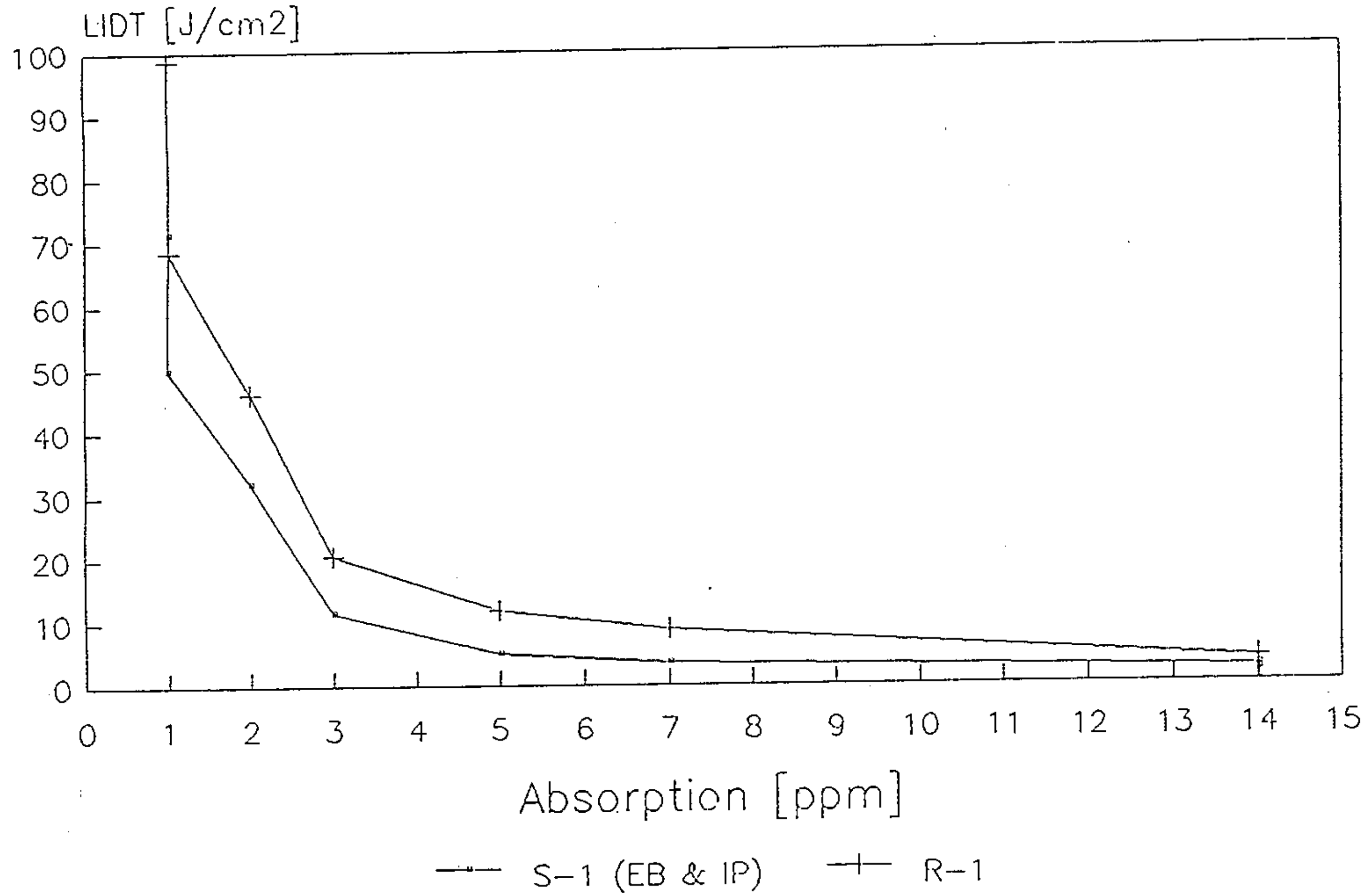

40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ALL

LIDT @ 532 nm of 1 QWOT Single Layers, EB–Deposited and Ion–Plated (IP) on FS



CREOL

LIDT @ 1064nm of Single Layers, QWOT@532 EB–Deposited and Ion–Plated (IP) on FS



LLNL–ICF Damage Testing

Center for Research in Electro-Optics and Lasers

Discussion

- RLVIP coatings have desirable properties:
  - o Refractive index invariant to environment (stable spectral characteristic)
  - o Expected high durability / longevity (hardness, imperviousness, abrasion resistance)
- Microstructure and surface roughness investigation indicate dense, glassy (vitreous) or nano-crystalline phases with little (or no) increase of surface roughness
- RLVIP is suitable for mass production and scale-up to large substrate sizes alike (potentially 2 m diameter)
- Absorption of our RLVIP single layer samples is higher than that of comparative e-beam evaporated thin films
- Absorption seems to be a dominant factor for laser damage, <u>independent of the deposition process</u>

Conclusions

- RLVIP thin films still have good promise for becoming <u>ideal optical and laser coatings</u>

- Further investigations into the influence of absorption on laser induced damage and, conversely, of process parameters on absorption are necessary

- Collaboration between industry, national labs, and universities <u>works</u> and assures broad base for leading edge technology.