

AD-A174 524

OPTICAL SIGNAL PROCESSING USING NON-LINEAR OPTICS(U)
UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES
W H STEIER APR 86 AFOSR-TR-86-2011 AFOSR-84-0207

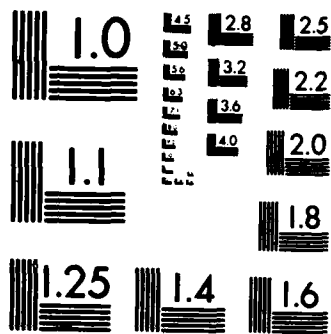
1/1

UNCLASSIFIED

F/G 20/6

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR		8b. OFFICE SYMBOL (If applicable) NE		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-84-0207	
8c. ADDRESS (City, State and ZIP Code) same as 7b			10. SOURCE OF FUNDING NOS.		
			PROGRAM ELEMENT NO. 61102F	PROJECT NO. 2305	TASK NO. B4
11. TITLE (Include Security Classification) Optical Signal Processing Using Non-Linear Optics			2505-84		
12. PERSONAL AUTHOR(S) Steier					
13a. TYPE OF REPORT Annual		13b. TIME COVERED FROM 8/1/84 TO 11/30/85		14. DATE OF REPORT (Yr., Mo., Day) April 1986	15. PAGE COUNT 9
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB. GR.			
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>The 2-D correlation/convolution which can be achieved in real time via four wave mixing in nonlinear materials has been investigated in detail to determine the accuracy and signal power investigated in detail to determine the accuracy and signal power possible. This analysis was initiated under other support; the experimental confirmation was completed under this contract. The analysis which is based on Fourier transforms of the equations of non-linear interaction has resulted in a closed form solution for the output and clearly shows how it differs from the desired 2-D correlation. In the example of a scene that is searched for given objects, the accuracy decreases as the ratio of scene to object size increases. The accuracy also resulting in a trade-off between accuracy, size of scanned scene, and power or signal to noise ratio in the output. The analysis was confirmed experimentally in a colinear four wave interaction in the photorefractive material bismuth silicon oxide at 5145 A. The accuracy of the correlation between relatively simple patterns was measured and agreed reasonably well with the prediction of the analysis.</p>					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION		
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. C Lee Giles			22b. TELEPHONE NUMBER (Include Area Code) 767-4933		22c. OFFICE SYMBOL NE

AFOSR-TR- 86 - 2011

**OPTICAL SIGNAL PROCESSING USING NON-LINEAR OPTICS
RESEARCH PROGRESS AND FORECAST REPORT**

**For the Period
August 1, 1984 through November 30, 1985**

ANNUAL

Approved for public release;
distribution unlimited.

Grant AFOSR-84-0207

Submitted by:

**William H. Steier
Professor of EE/Electrophysics
University of Southern California
University Park
Los Angeles, CA 90089-0483
(213) 743-0149**

Submitted to:

**Air Force Office of Scientific Research
Building 410
Bolling Air Force Base, DC 20332**

86 11 25 366

results in a lateral translation between the patterns as they propagate through the non-linear material. The result is a correlation between smoothed versions of the inputs and a considerable error.

A colinear interaction is possible so long as the two inputs are distinguishable via either polarization or wavelength. A typical polarization scheme is shown in Figure 1. Input 2 interacts with the plane wave pump 3 to write a grating in the non-linear material. Input 1 reads the grating and results in the scattered output 4. Note that a true X_3 material such as CS_2 will not work in all cases since the output will contain the correlation and its complex conjugate. If the inputs are real, this is not objectionable.

The result for the colinear cases is:

$$B_4(x,y) = K_c \int_{-\infty}^{+\infty} dx' dy' B_1(x',y') B_2(x'+x, y'+y) \frac{1 - \exp(i\gamma_c z_o)}{-i\gamma_c z_o}$$

where

$$\gamma_c = i\alpha \frac{k_0}{nF^2} (xx' + yy')$$

K_c = constant containing the nonlinear coefficient X_3

z_o = thickness of non-linear material

α = linear loss coefficient

F = Focal length of the F.T. lens.

The above expression differs from the desired 2-D correlation by the last bracketed term containing the exponent. The origin of this term is the k vector mismatch. Near the origin the correlation is relatively accurate, but the accuracy decreases as the size of the two input patterns increase. This is important in a typical case where a scene is scanned for a particular object. For large fields of scan, the accuracy decreases, and the possibility of false alarms increases.

This analysis has been confirmed by an experiment which was performed under the support of this grant. In the experiment, input 1 is a square aperture of side "a" located

on the axis. Input 2 is similar square aperture but located X_0 off axis. We are, therefore, searching over range $2X_0$ by $2X_0$ for the square aperture of side "a". In the experiment, the relative correlation power (RCP) was measured and compared to the calculated value. The RCP is the ratio of the total integrated power in the correlation peak, relative to the power in the perfect correlation and is, therefore, the relative detected power for a threshold detection scheme.

The experimental layout is shown in Figure 2. C is the photorefractive material bismuth silicon oxide which is oriented so that the beams propagated along the 001 direction. The half wave plate H_1 rotates the polarization of the write beam $B_2(x,y)$ to be perpendicular to that of the read beam $B_1(x,y)$. The mask I contains an on-axis rectangular aperture which is illuminated by B_1 and three off-axis rectangular apertures illuminated by B_2 . Three correlations are thus recorded simultaneously for accuracy. The slit on the chopper (Ch) wheel selected one of the correlations at a time for measurement by the PMT.

Typical comparison of the experimental data (crosses and dashed line) and the calculated data is shown in figure 3. The parameters c, d, and b are defined on the figures and earlier in this report. The results closely follow the predicted curve and confirm the analysis.

Two Dimensional Modulator/Switch Using the Photorefractive Etalon

A study has been initiated of an optical etalon filled with a photorefractive material. The transmission of the etalon at the read wavelength (λ_R) can be controlled by the intensity of the control beam at wavelength λ_C . Two dimensional arrays of these devices have numerous applications in optical signal processing, optical computing, and optical interconnect networks. The preliminary analysis predicts switching times of ~ 100 ns and switching energies of ~ 100 pJ. While these numbers are about one order of magnitude

larger than those for the GaAs-GaAlAs excitation nonlinearity, the photorefractive devices have some definite advantages and appear to have several potential applications. In particular, the photorefractive effects is wideband while the excitation effect is very narrow band.

The analysis for BSO is complicated by the optical activity of the medium which causes the normal modes to be elliptically polarized. The change in the etalon resonant frequency, Δf , due to the change in index Δn , caused by the photorefractive effect is given by:

$$\frac{\Delta f}{f_o} = \left(\frac{\Delta n}{n_o} \right)^2 + \left(\frac{\rho \lambda_o}{2\pi} \right)^2 \quad 1/2$$

Where

- f_o = resonant frequency of the etalon
- n_o = index of refraction
- ρ = optical rotary power of BSO = $10^\circ/\text{mm}$ at $\lambda_R = 8500\text{\AA}$
- λ_o = resonant wavelength.

In a particular example in which the "on" transmission of the etalon was set at 75% and "off" transmission was set at 7.5%, the following table summarizes the design.

- l = etalon thickness = 3mm
- R = mirror reflectivity at $\omega_R = 90\%$
- E_o = d.c. electric field = 10kV/cm
- F = etalon finesse = 26
- Δn = required index change due to photorefraction = 25×10^{-6} .

The predicted switching time is 400 nsec, and the predicted switching energy is 2.4 nJ. The cross-sectional area of the switch is $6.3 \times 10^{-6} \text{cm}^2$. The optical rotary effect in BSO seriously effects the performance of the switch. Without this effect the switching time and the switching energy would both be reduced by a factor of four.

The semi-insulating semiconductors (InP:Fe, GaAs:Cr) are very promising photorefractive materials. They are also expected to be as sensitive as BSO, to have high speed because of their high mobility, and to be usable in the near IR where semi-

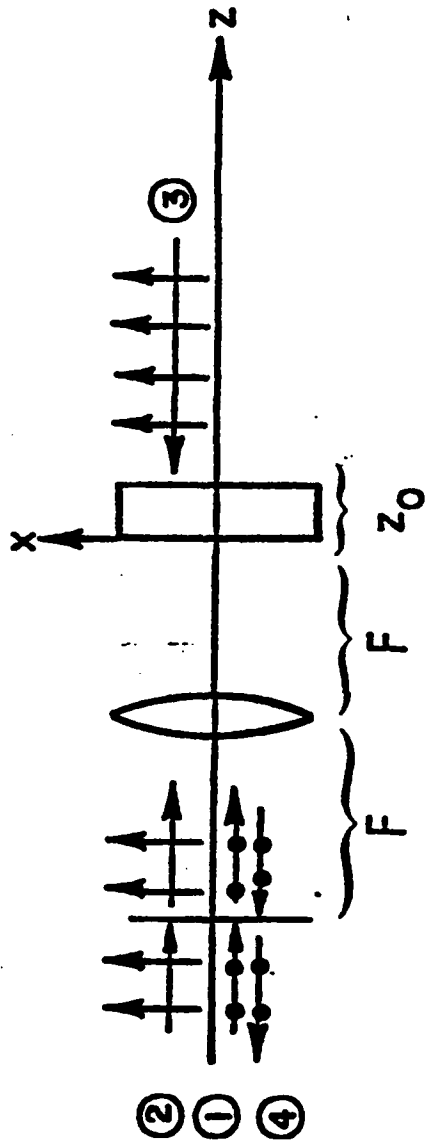
conductor lasers are available. At present, the data available on these materials is not complete. Measurements of the material properties are underway in our laboratory under separate support.

Based on some recent results, the etalon switch using InP:Fe would have less than one microsecond switching speed and ~ 200 pJ switching energy. The control wavelength is 1.06μ , the read wavelength is 1.32μ .

A more detailed analysis of the etalon switch is being developed which includes the transverse spatial properties. The analysis predicts the transverse pattern of the output beam for a given control beam pattern and hence gives a more accurate picture of the beam switching.

An experiment is currently being designed to observe the switching phenomena. The experiment includes an oven to stabilize the etalon temperature, a tunable laser for the read beam, and an ion or a Nd-YAG laser for the control and erase beam.

- Collinear, degenerate FWM using orthogonal polarizations:



- ② and ③ write a grating, ① reads it
- Can't use a true $\chi^{(3)}$ material (e.g., CS_2)
- Strong noise at the input/output plane

FIGURE 1

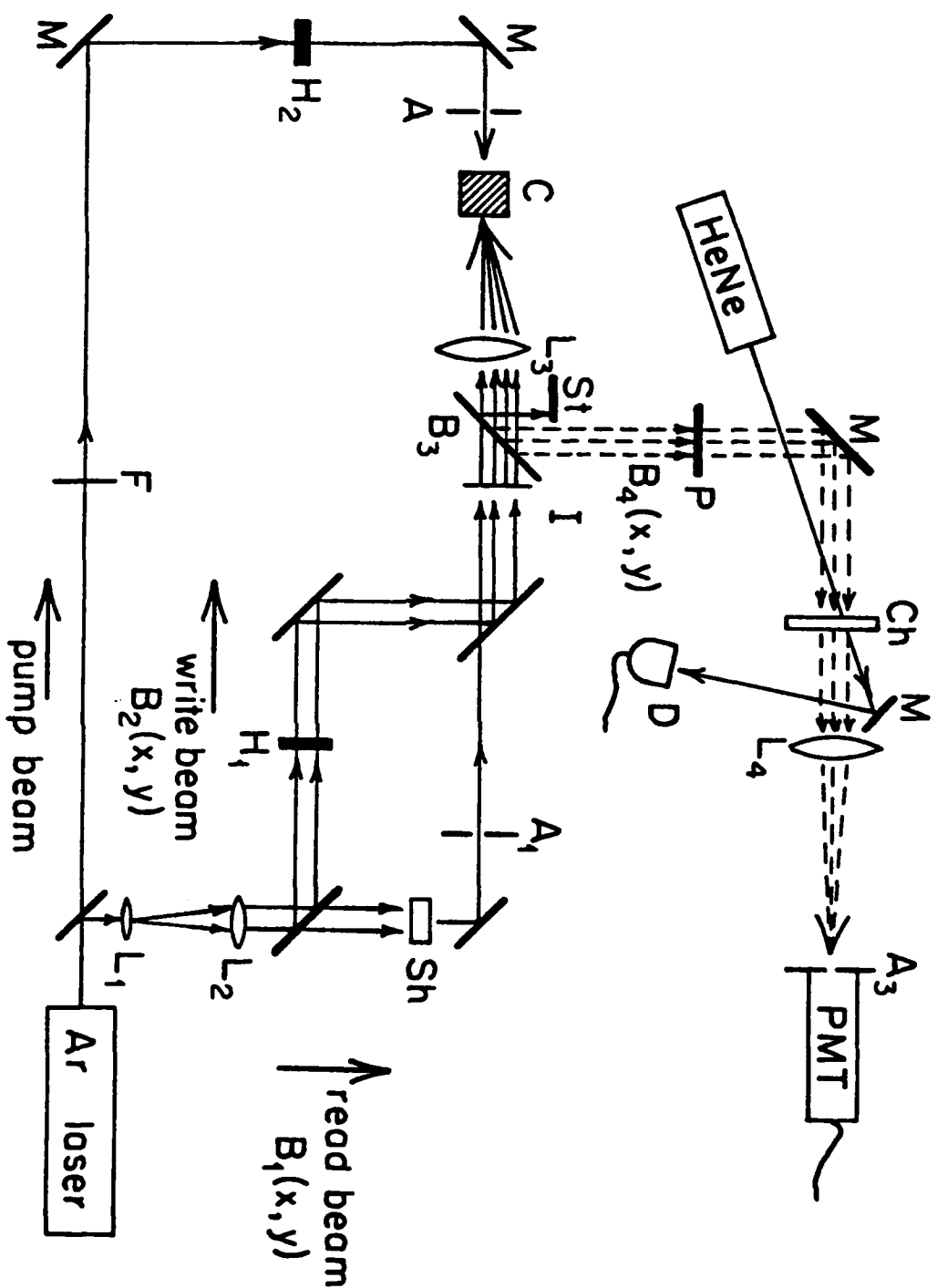
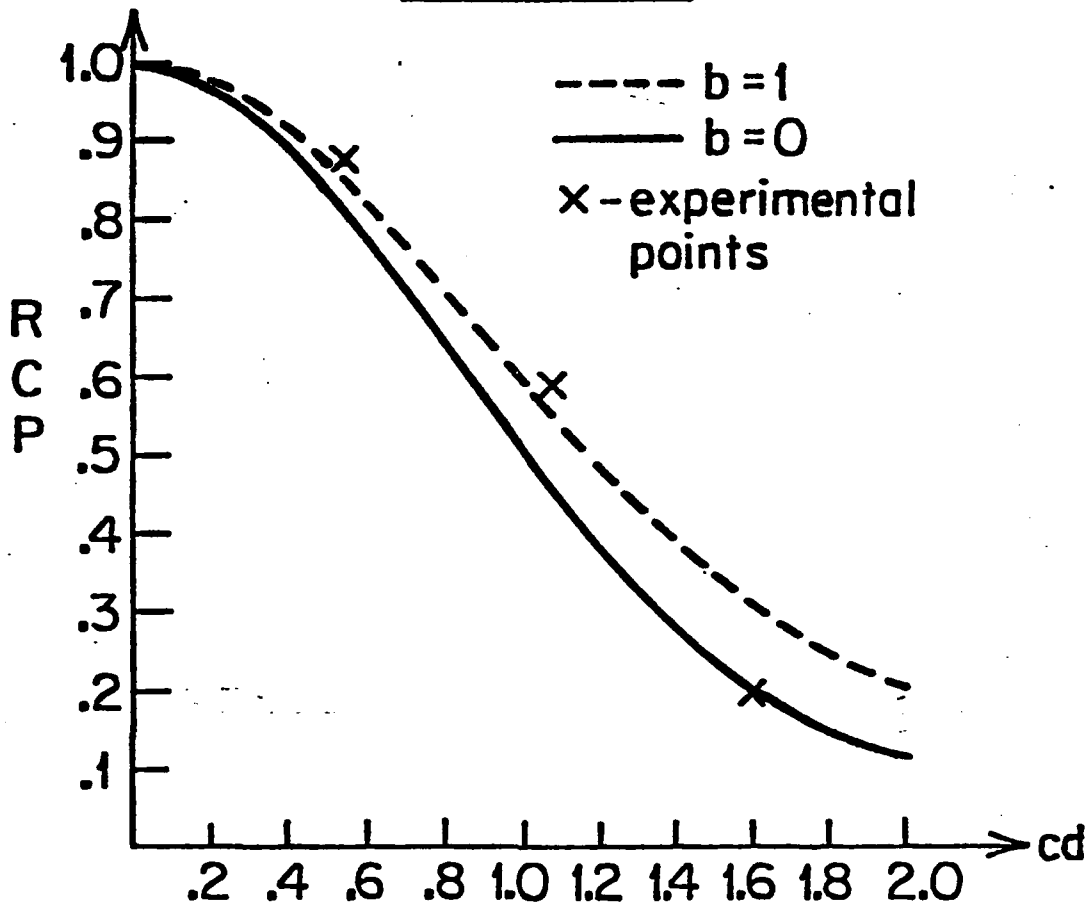


FIGURE 2

RCP vs cd



$$\left(c = \frac{z_0 a^2}{h \lambda F^2}; \quad d = \frac{x_0}{a}; \quad b = \alpha z_0 \right)$$

$$cd = \frac{z_0 a x_0}{h \lambda F^2}$$

FIGURE 3

END

12-86

DTIC