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TWO COMPACT TANDEM ARCHITECTURES FOR THE IMPLEMENTATION OF TIME-INTEGRATING CORRELATORS

by

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ABSTRACT

This technical note presents two new ways to build time-integrating correlators. The new methods are characterized by a tandem configuration of the Bragg cells that produces an almost common path for the interfering beams. It is also characterized by simplified, smaller illumination systems. In the first method, the illumination system consists of a beam-splitting cube used in an unconventional way. A hologram is used to illuminate the second system. In both cases, important reduction in the size and complexity of the systems is achieved. Results from the operation of both systems are presented.

RESUME

Cette note technique présente deux nouvelles façons de construire un corrélateur à intégration temporelle. Les nouvelles méthodes sont caractérisées par un arrangement en tandem des cellules de Bragg qui produit des chemins optiques presque communs et par des systèmes d'illumination simplifiés et plus petits. La première méthode d'illumination utilise de façon non conventionnelle un cube séparateur. Le second système d'illumination est constitué d'un hologramme. Les deux approches produisent des réductions importantes de la grandeur et de la complexité des systèmes. Des résultats produits par les deux nouveaux systèmes sont présentés.

EXECUTIVE SUMMARY

Time integrating correlators are analog optical computers designed to correlate long duration data streams. Generally speaking they are interferometric structures whose operations depend on the interaction of two beams of light that have been modulated with data. There are many ways to build time-integrating correlators. However, it is always desirable to reduce to a minimum the number, complexity, size and weight of the components involved in their construction. The resulting systems are thus smaller, easier to package and have a better chance of providing reliable operation over long periods of time.

This technical note presents two new ways to build compact time-integrating correlators. The new methods are characterized by a tandem configuration of the Bragg cells that produces an almost common path for the interfering beams. It is also characterized by simplified, smaller illumination systems. In the first method, the illumination system consists of a beam-splitting cube used in an unconventional way. A hologram is used to illuminate the second system. In both cases, important reduction in the size and complexity of the systems is achieved. Results from the operation of both systems are presented.

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LIST OF ABBREVIATIONS

CBS:	Cube Beam-Splitter
C-T:	Cube-tandem
H-T:	Hologram-tandem
TIC:	Time-Integrating Correlator

1.0 INTRODUCTION

Time-Integrating Correlators (TIC)s are used to correlate long duration data streams. The signals to be processed are introduced into the system by Bragg cells that transform the RF input signals into modulation of a laser beam via an acousto-optic interaction. The laser light is amplitude modulated by the acoustic waves [1] generated in the Bragg cells. Since no bias is used, a larger linear modulation region is available, resulting in larger dynamic range. The correlation is produced by the coherent addition, on a time-integrating linear detector array, of the images of the two light distributions to be correlated. The read-out operation of the detector array is computer controlled. The production and mixing of the two light distributions carrying the information is usually made in an interferometric structure of the Mach-Zehnder type.

Generally speaking, TICs are interferometers whose operation depends on the interaction of two separate beams of light that have been modulated with data. That feature makes them sensitive to temperature fluctuations and mechanical vibrations, since any perturbation in one of the light paths leads to instabilities in the output. It is also desirable to reduce to a minimum the number of components involved in the construction of an interferometer. Any reduction in size is also welcome as it makes the system easier to package. Reduction of component complexity is also likely to reduce the cost and weight of the system.

There are many ways to build Mach-Zehnder TICs using bulk interaction Bragg cells and amplitude modulation of the laser light. A modified Mach-Zehnder architecture as described in [2,3] and illustrated in Figure 1 can be used. A more compact version using a special prism [4] to generate the two illuminating beams for the Bragg cells has also been proposed. The system illustrated in Figure 1 has a few disadvantages. It uses many parts, the two light paths are completely separated and thus make the whole system more sensitive to air turbulence and vibrations and, finally, it is a large, complex and heavy system. A photograph of an implementation of the design of Figure 1 produced at DREO is presented in Figure 2.

The design illustrated in Figure 3 uses Bragg cells in a tandem configuration and greatly alleviates the problems associated with the system illustrated in Figure 1. However, the special prism used to generate [2] the two illumination beams is a complex, expensive and custom made component. Enough space has to be left between the Bragg cells and the prism to separate the two beams for the desired aperture.

The purpose of this technical note is to describe two new ways to build TICs that lead to simpler and smaller systems. Both approaches use Bragg cells set-up in a tandem configuration similar to Figure 3 but differ in the way the illumination system is implemented. The illumination system of the first system uses

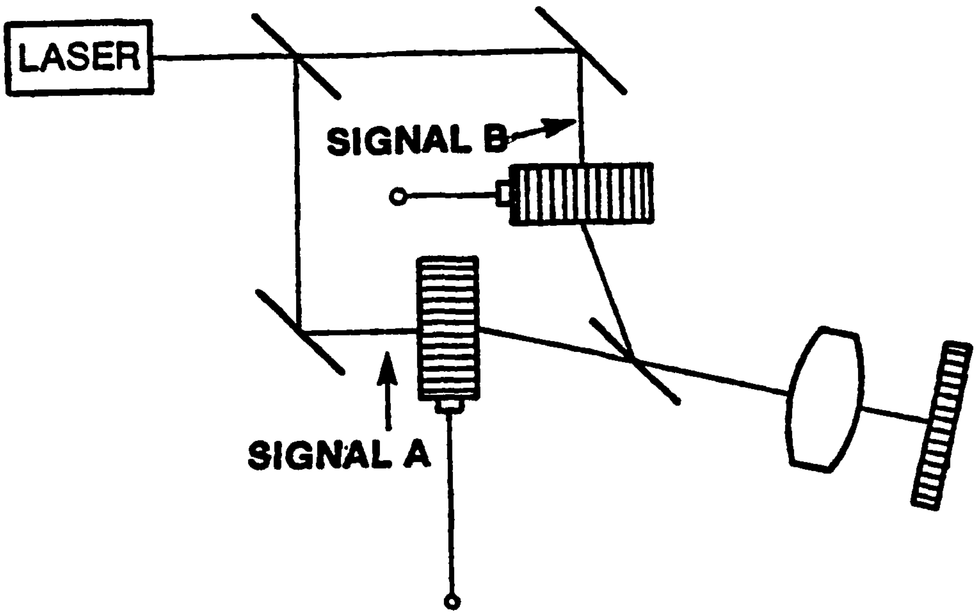

FIGURE 1: SCHEMATIC OF A TIME-INTEGRATING CORRELATOR (MACH-ZEHNDER CONFIGURATION)

FIGURE 2: PHOTOGRAPH OF A TIME-INTEGRATING CORRELATOR (MACH-ZEHNDER CONFIGURATION)

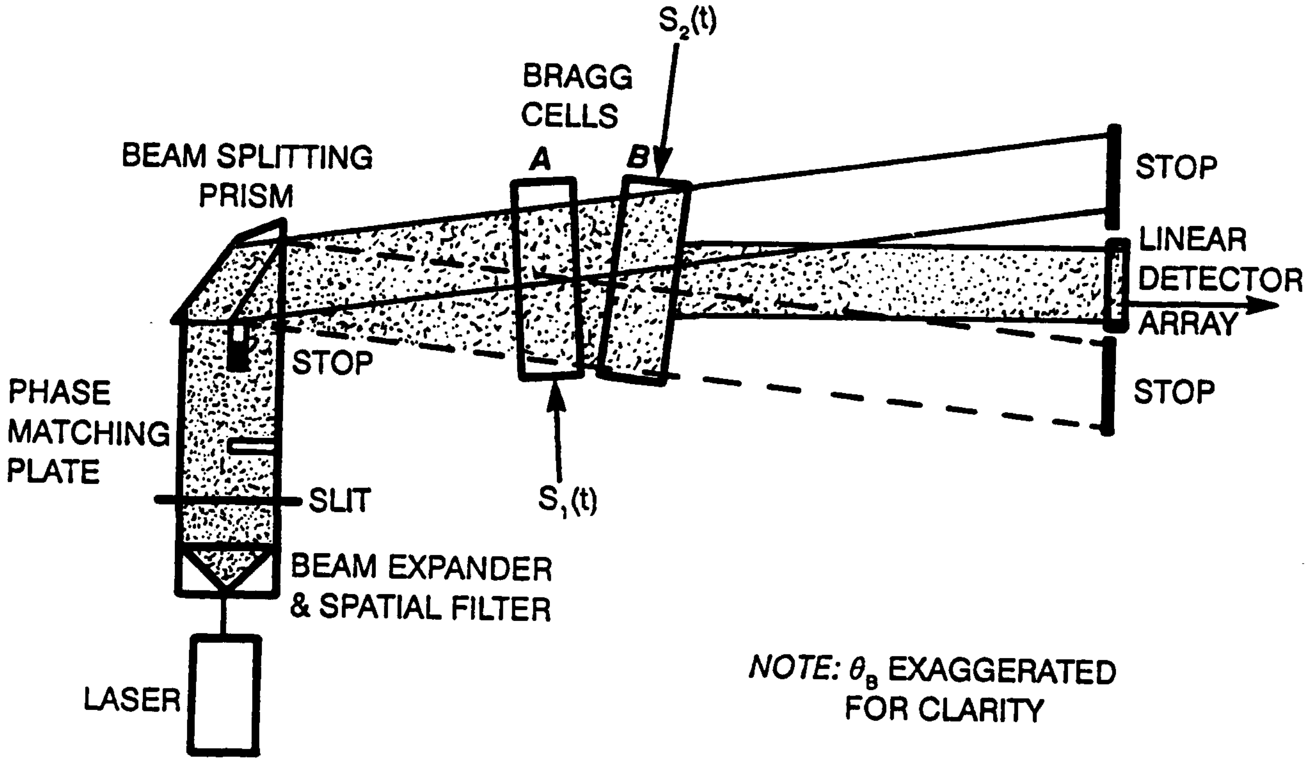

FIGURE 3: TIME-INTEGRATING CORRELATOR WITH A BEAM-SPLITTING PRISM AS AN ILLUMINATION SYSTEM (FROM [3], FIGURE 2)

a conventional cube beam-splitter and the second system uses a hologram. Both systems will be described in the next two sections and results produced by both of them are included.

2.0 CUBE-TANDEM ARCHITECTURE

The reduction in size and complexity of TICs is desirable because it leads to lighter, less expensive, and more stable systems easier to package for reliable performance. The first step to reduce the size and complexity of TICs is to use the tandem configuration proposed in [4] for the Bragg cells. This architecture also has the advantage of almost common paths for the two beams, which contributes to the system's stability. The second step to reduce the size is to use a simplified illumination system made of a Cube Beam-Splitter (CBS).

CBSs have been used to illuminate other types of interferometric systems [5] similar to TICs. CBSs can also be used in a non-conventional way to provide illumination for a compact TIC. Figure 4 illustrates the ability of a CBS to produce two beams that can be diverging, parallel or converging. One of the output beams is always parallel to the input beam. The direction of the second beam depends on the angle of incidence of the input beam. The angle between the two output beams can be adjusted easily by rotating the cube. The CBS also produces large aperture illumination.

There are, however, drawbacks in using a CBS as a TIC illumination system. They produce undesirable beams originating from multiple reflections unless proper anti-reflection coatings are used on the surfaces. Also, as in the tandem architecture of Figure 3, the distance between the CBS and the Bragg cells has to be large enough to allow both illumination beams to converge towards a common aperture on the Bragg cells.

The Cube-Tandem TIC built at DREO includes two TeO Bragg cells operating at a center frequency of 45 MHz with a bandwidth of 30 MHz. The angle between the beams is 6.2° and the distance between the Bragg cells and the CBS is about 35 cm. Despite the long distance, using a CBS as an illumination system is still worthwhile because CBS's are easier to build than the special prism used in the system illustrated in Figure 3. The aperture of the output beam as a function of the input beam angle of incidence is illustrated in Figure 5. Diverging beams produce a larger aperture than converging beams and, the bigger the angle between the converging beams, the smaller is the width of the output beams.

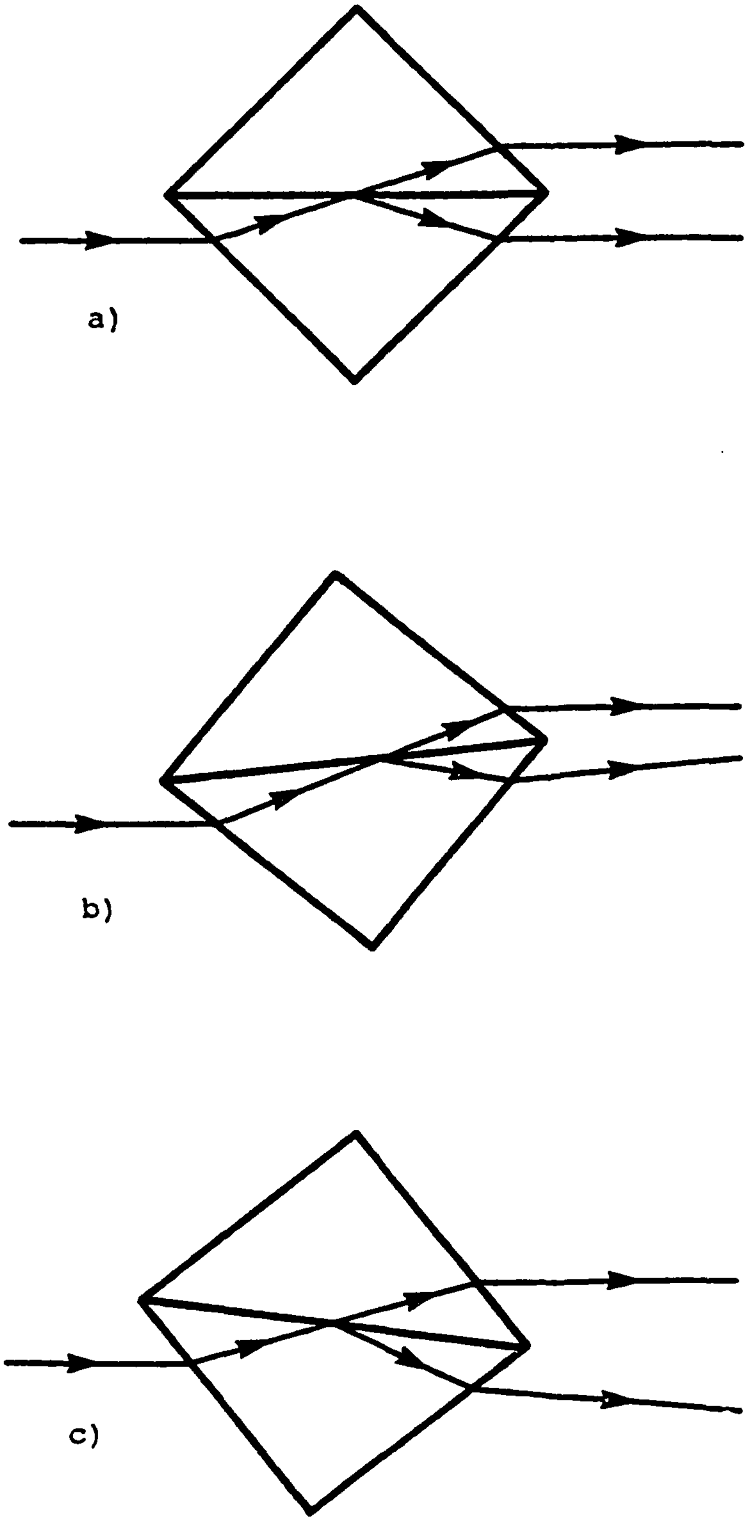

FIGURE 4: BEAM FORMATION BY A CUBE BEAM-SPLITTER
a) PARALLEL OUTPUT BEAMS
b) CONVERGING OUTPUT BEAMS
c) DIVERGING OUTPUT BEAMS

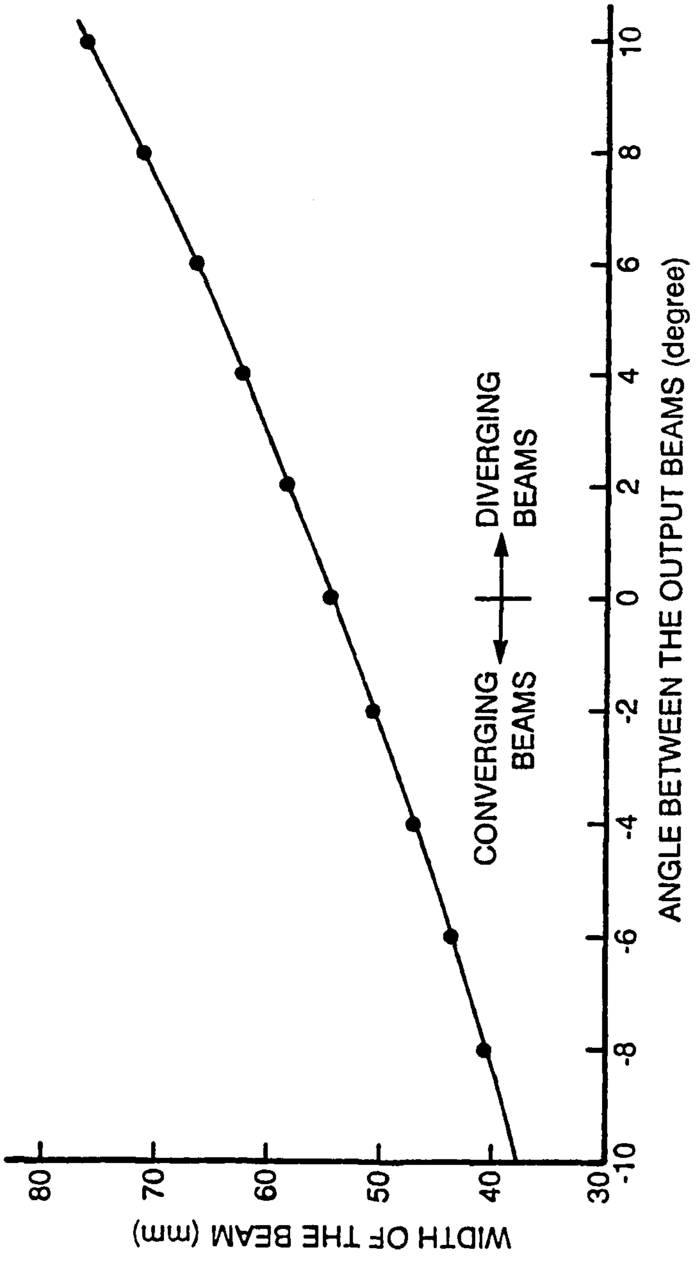

FIGURE 5: APERTURE OF THE OUTPUT BEAM AS A FUNCTION OF THE ANGLE OF INCIDENCE OF THE INPUT BEAM

A TIC was constructed upon delivery of a CBS of size 102 mm x 102 mm. This system will be referred to as C-T TIC, standing for Cube-Tandem TIC. Figure 6 shows a schematic of the C-T TIC and Figure 7 shows a photograph of the system. Figure 8 shows a correlation peak produced by the C-T TIC when two identical 255-bit long pseudo-random spread spectrum sequences are used as RF input to the Bragg cells.

Like the prism illuminated system of Figure 3, the C-T TIC has an almost identical path for the two beams. It is much smaller and uses fewer parts than the classical Mach-Zehnder configuration of Figure 1. Also, compared to the prism system of Figure 3, it has a simpler illumination system.

3.0 HOLOGRAM-TANDEM ARCHITECTURE

Although the C-T TIC has a simpler illumination system than the prism TIC of Figure 3, it is still necessary, in both cases, to have enough distance between the Bragg cells and the beam forming device to allow separation of the two beams as they converge on the Bragg cells at the formation plane. In the system that we built and demonstrated, that distance is about 35 cm. It is possible to reduce that distance considerably by using a hologram to illuminate the TIC.

The tandem TIC using a holographic illumination system will be referred to as the H-T TIC. The hologram is designed to be recorded and used at about 3 cm from the first Bragg cell. Figure 9 illustrates how the hologram is recorded. The holograms were recorded on silver halide emulsion (Kodak 649F), subsequently bleached and packaged for protection against environmental changes. The particular hologram used to demonstrate the system has a diffraction efficiency of 22%, distributed in the two illumination beams. The profile of the two output beams, when reconstruction is done with a uniform reference beam, is illustrated in Figure 10. The profile of one of the illumination beams is quite uniform while the other one has a strong linear slope. Those two light distributions, after diffraction by the Bragg cells, are likely to be quite different. As optimal performance of the H-T TIC is obtained when the two optical signals reaching the detector array are spatially uniform, deteriorated performance is expected. Just how much deterioration takes place will be the subject of further studies.

Figure 11 illustrates the lay-out of the H-T TIC. Figure 12 is a photograph of the implementation of the system. The reduction in size is dramatic. A typical correlation produced by the system is shown in Figure 13. It was obtained in the same conditions and with the same signals as the correlation of Figure 8 from the C-T TIC. The graininess of the hologram is expected to increase the scattering of light and to lead to a reduction in the dynamic range of the system. A comparison of

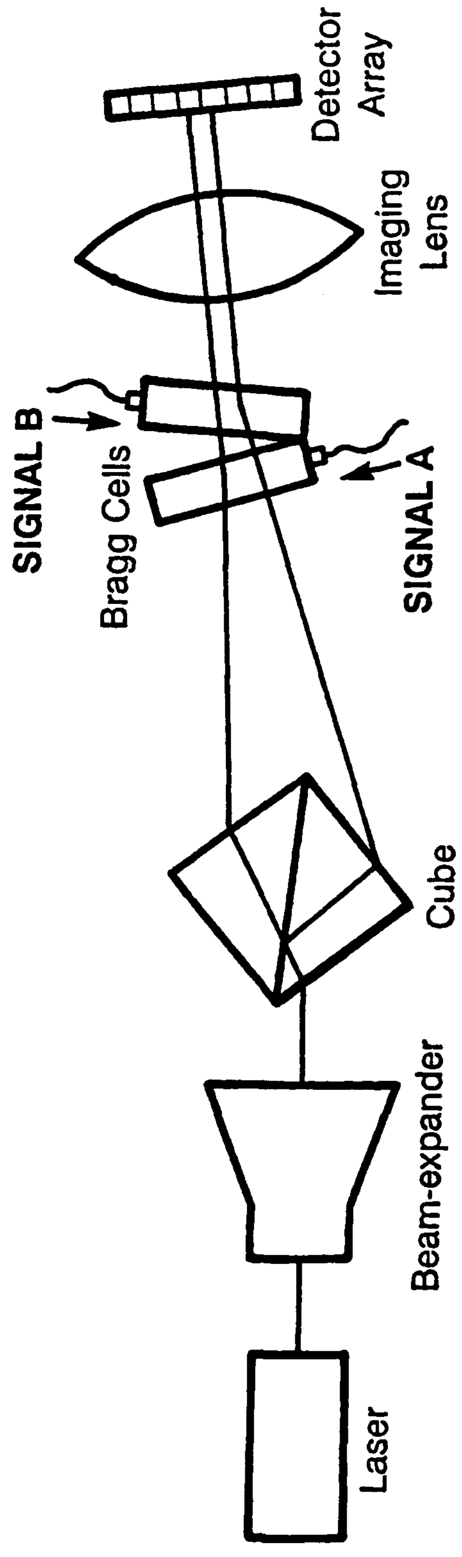

FIGURE 6: SCHEMATIC OF A TIME-INTEGRATING CORRELATOR WITH A CUBE BEAM-SPLITTER ILLUMINATION SYSTEM

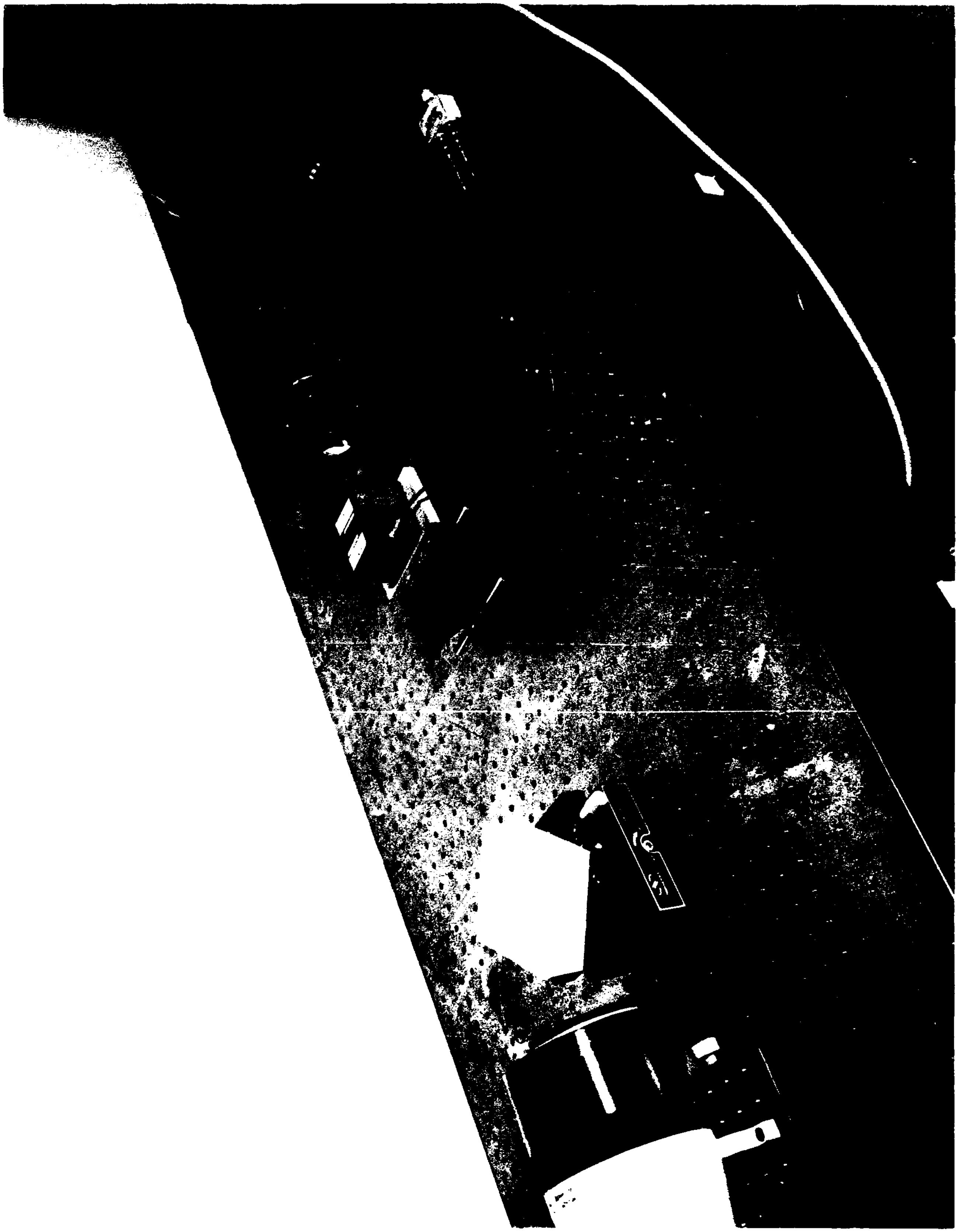

FIGURE 7: PHOTOGRAPH OF A TIME-INTEGRATING CORRELATOR WITH A CUBE BEAM-SPLITTER ILLUMINATION SYSTEM

12:32:19 **Correlation Report** November 2, 1990

Correlation Parameters		Code	
Integration Time:	499.8 us	Code Number:	3
Pixel Clock:	3.3333 MHz	Code Type:	
Pixel Count:	1666	Initial State:	776
Code Rate:		Polynomial:	515
Chips Integrated:			
Illumination:	4.0 dB		
		Results	
Phase Shift:	-122.7 °		
Amplitude Offset:	0 %	Peak Height:	57.3 %
Pairs Averaged:	1	Peak Width:	31.2 px
Threshold:	100.0 %	Peak Centre:	1082.4 px
Detection Rqmt:	1 (M)	Fringe Period:	0.0 px
Number of Blocks:	1 (N)	Detection Count:	1
Number of Phases:	1	Phase Number:	1

Correlation Function

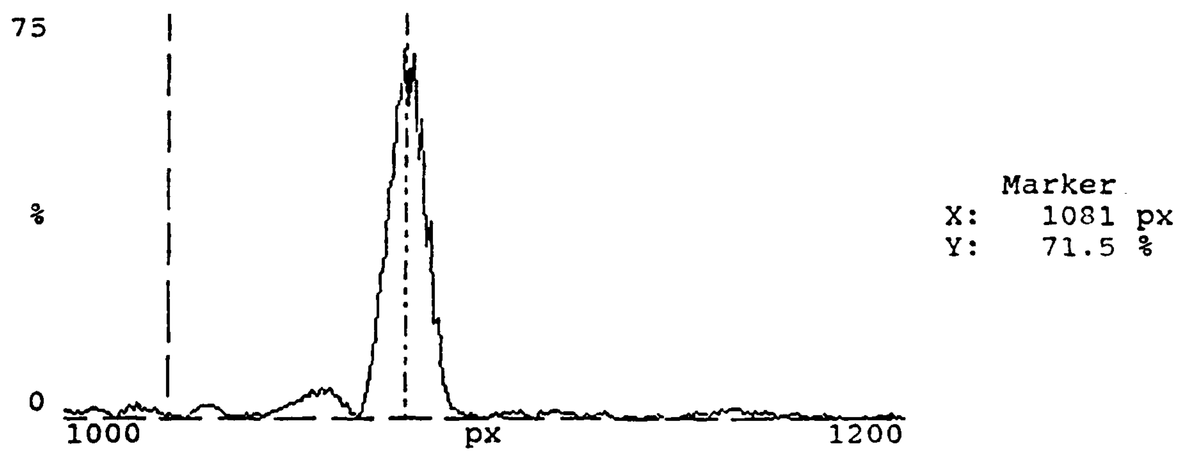

FIGURE 8: A CORRELATION PRODUCED BY A TIME-INTEGRATING CORRELATOR WITH A CUBE BEAM SPLITTER ILLUMINATION SYSTEM

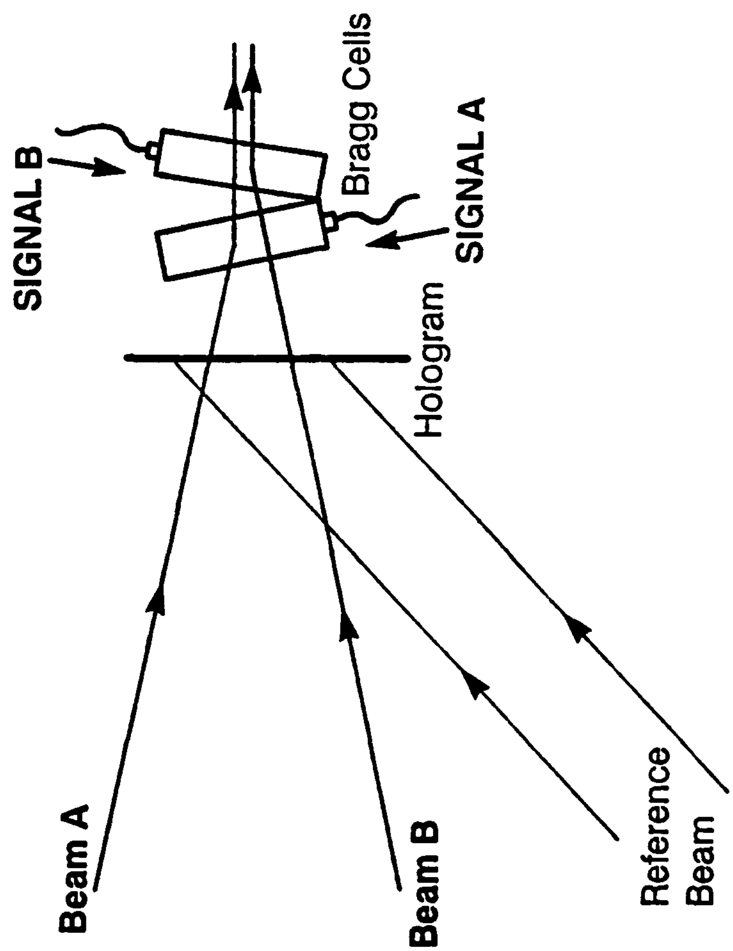

FIGURE 9: RECORDING OF A HOLOGRAM TO ILLUMINATE A TIME-INTEGRATING CORRELATOR

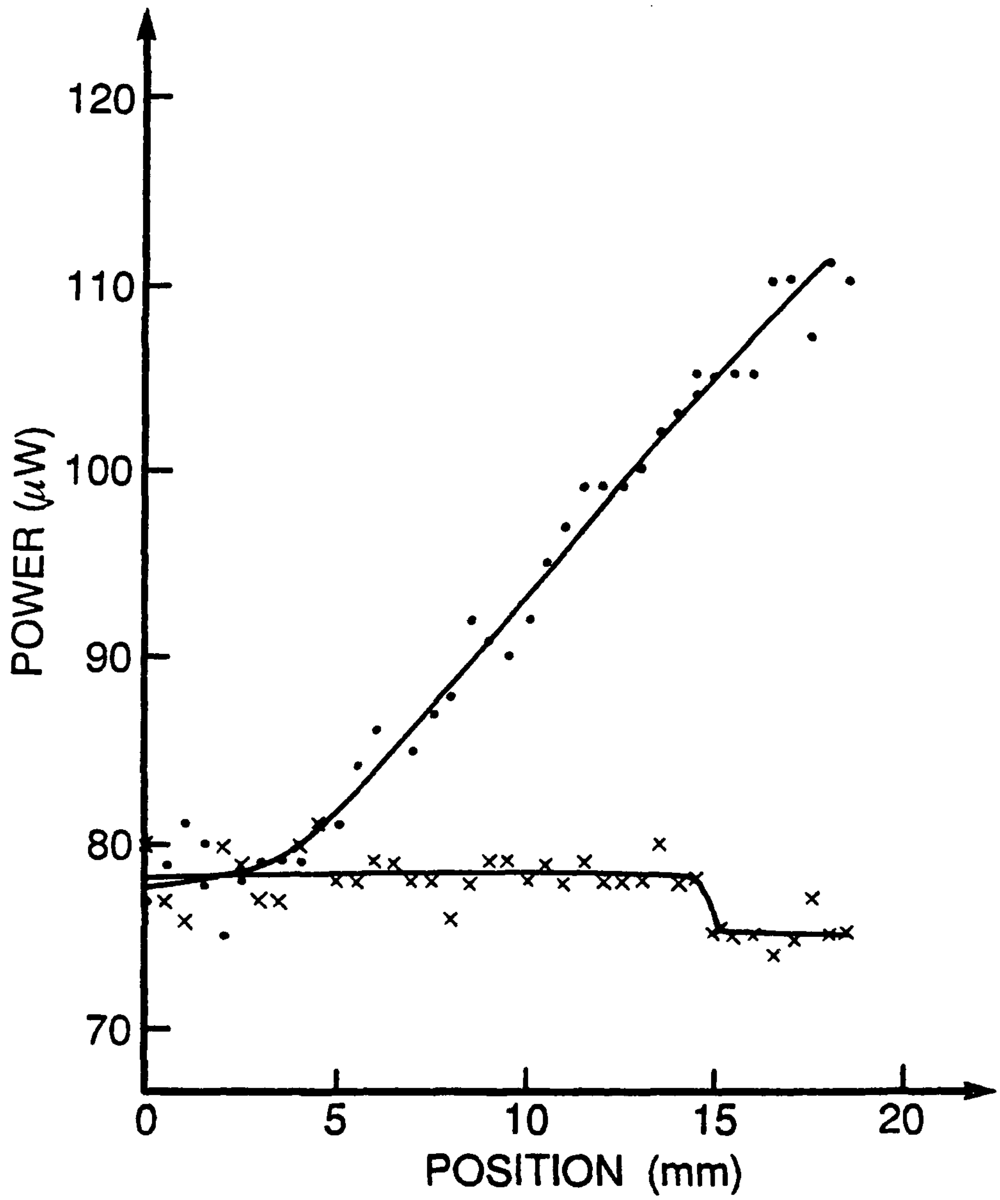

FIGURE 10: PROFILE OF THE TWO BEAMS PRODUCED BY THE HOLOGRAM WHEN RECONSTRUCTED WITH A UNIFORM INTENSITY BEAM

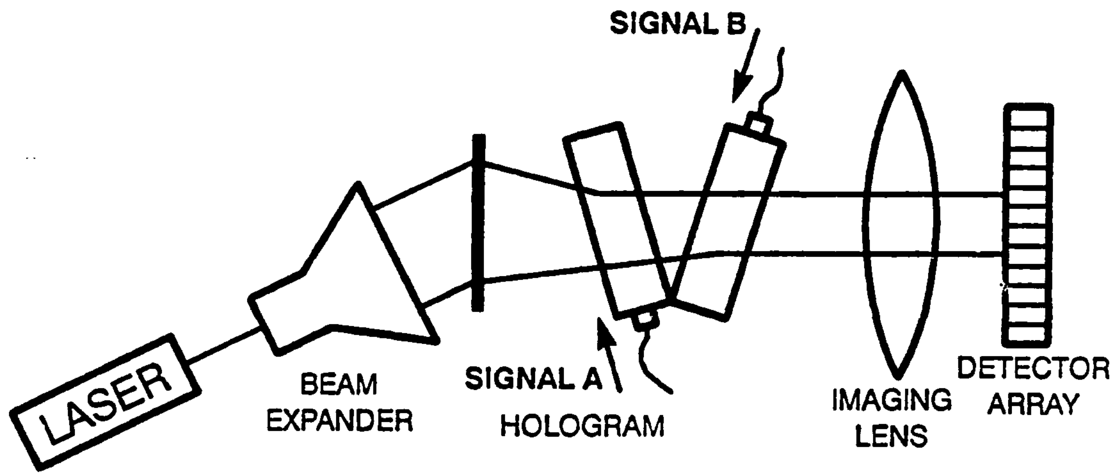

FIGURE 11: SCHEMATIC OF A TIME-INTEGRATING CORRELATOR ILLUMINATED WITH A HOLOGRAM

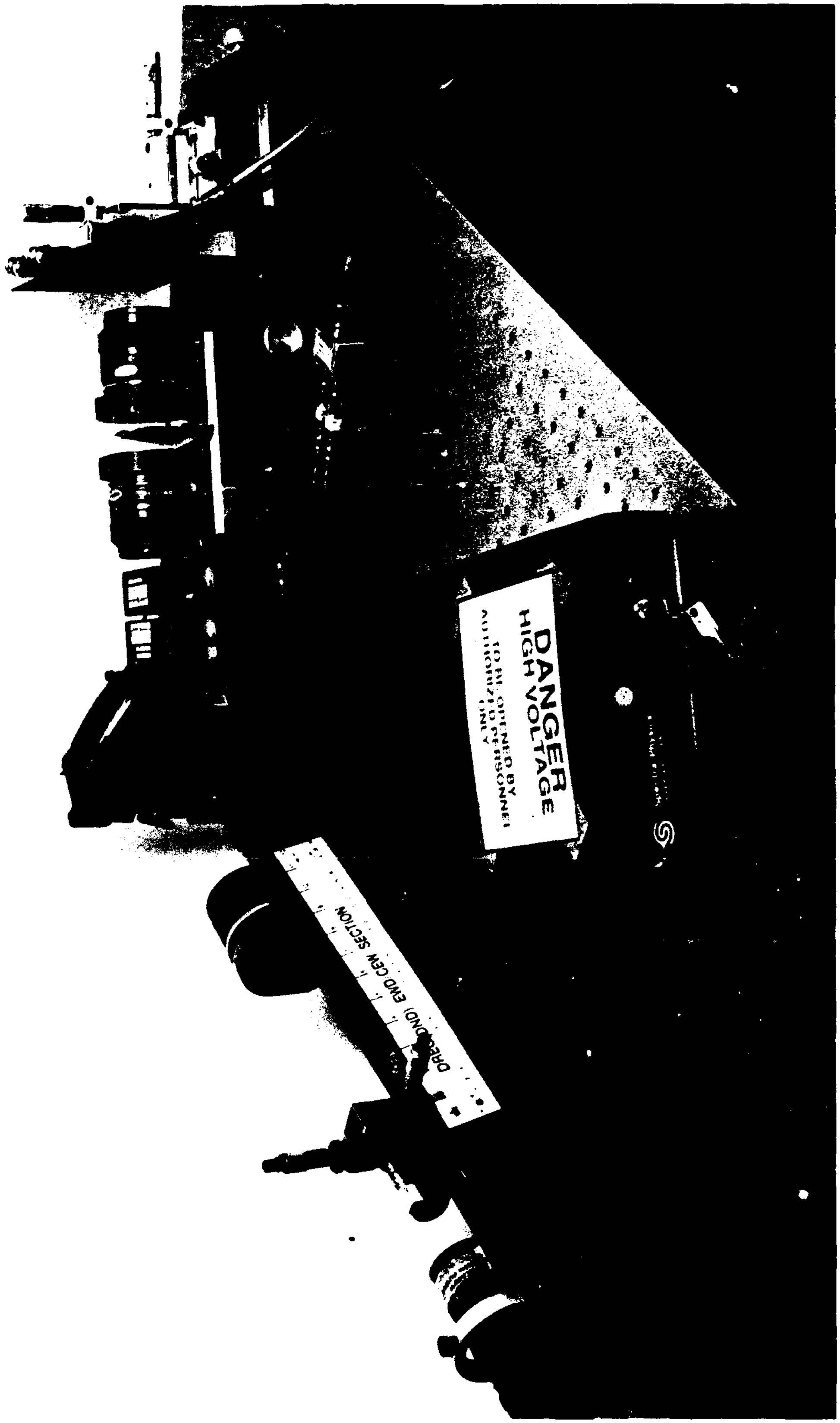

FIGURE 12: PHOTOGRAPH OF A TIME-INTEGRATING CORRELATOR ILLUMINATED WITH A HOLOGRAM

10:41:05 Correlation Report April 30, 1991

Correlation Parameters

Integration Time:	3279.3 us
Pixel Clock:	588.2 kHz
Pixel Count:	1929
Code Rate:	
Chips Integrated:	
Illumination:	12.0 dB
Phase Shift:	-25.6 °
Amplitude Offset:	0 %
Pairs Averaged:	1
Threshold:	100.0 %
Detection Rqmt:	1 (M)
Number of Blocks:	1 (N)
Number of Phases:	1

Code

Code Number:	1
Code Type:	
Initial State:	777 774
Polynomial:	210 013

Results

Peak Height:	6.5 %
Peak Width:	14.9 px
Peak Centre:	1384.4 px
Fringe Period:	13.0 px
Detection Count:	1
Phase Number:	1

Correlation Function

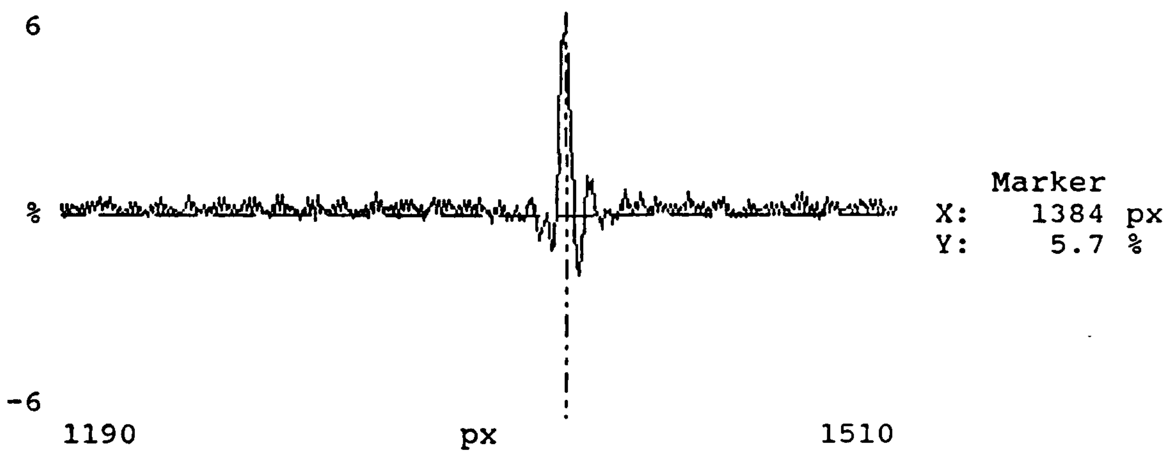

FIGURE 13: A CORRELATION PRODUCED BY A TIME-INTEGRATING CORRELATOR WITH A HOLOGRAPHIC ILLUMINATION SYSTEM

the peaks in Figures 8 and 13 suggests that the peak produced by the C-T TIC has better signal to noise ratio than the peak produced by the H-T TIC. Detailed testing and comparison of the performance of the Mach-Zehnder architecture of Figure 3, of the C-T TIC of Figure 7, and of the H-T TIC of Figure 12 will be the subject of further studies.

4.0 CONCLUSION

Two new ways to build TICs have been presented. They are both characterized by a tandem configuration of the Bragg cells that produces an almost common path for the interfering beams. The two methods use smaller and simplified illumination systems. In the first method, a CBS is used in an unconventional way thus producing a simplified illumination system. The second method uses a hologram to achieve a dramatic reduction in the size and weight of the system. The operation of both systems has been demonstrated. The two methods lead to a substantial reduction of the size, weight and complexity of the systems, thus making the packaging of the systems for field operations easier and more likely to produce a reliable system.

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[5] M.D. Koontz, "Miniature Interferometric Spectrum Analyser", SPIE, vol.639, Optical Information Processing II, 1086, p.126-130.

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OPTICAL DATA PROCESSING
HOLOGRAPHIC ILLUMINATION SYSTEMS