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# Background Optical Suppression Scheme (BOSS)

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17 June 1977

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A brief description of the AFGL Background Optical Suppression Scheme (BOSS) is presented. Potential advantages are pointed out and various implementations illustrated. Preliminary results obtained with the technique are also presented, and a future program outlined.

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## Foreword

The experimental demonstration reported herein was performed using AFGL Laboratory Director's Funds under Project ILIR-6K. The research involved is based on the following pending patents:

(1) Double-Beaming in Fourier Spectroscopy
G. Vanasse, AFGL.

(2) Background Suppression-Surveillance Technique
R. Murphy, G. Vanasse, and A.T. Stair, AFGL.

(3) Method of and Apparatus for Background Suppression in Interferometric Analysis, VI-112J
T. Zehnpfenning, Visidyne, Inc.

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# Background Optical Suppression Scheme (BOSS)

## 1. INTRODUCTION

In this report we will give a description of the basic idea of the AFGL background suppression scheme starting from basic principles.[1] The potential advantages of the technique will be pointed out and various schemes for implementing the technique will be illustrated. Some results obtained to date to demonstrate the technique (work which was funded by the AFGL Laboratory Director's Fund) will be presented. Finally, a future program will be outlined and will describe the type of sensor design we propose for future testing of the background suppression scheme from onboard an aircraft. The results of the aircraft test measurements will be used to determine sensor design parameters for optimal performance from aircraft or satellite stations.

## 2. PRINCIPLE OF BOSS TECHNIQUE

The essence of the technique is to use some type of interferometer (Michelson or one of its variations) into which two beams are directed, and also make use of

(Received for publication 16 June 1977)

1. Vanasse, G., Murphy, R., and Cook, F. (1976) Appl. Optics 15:290.

the two beams which exit from the instrument.[2,3] This section will describe implementations of such a system and present reasons for wanting to use such a system, as well as the obvious advantages (over a single input, single output beam system) that such a system yields.

First of all we have indicated we automatically have the well-known throughput[1] advantage inherent to interferometers. Also, if the system is to be used in an "optical path difference scanning" mode, or in a fixed retardation mode, with jittering, we have the other well-known advantage of Fourier spectroscopy called the multiplex advantage.[1] Another advantage of the interferometer is its large free spectral range which is of importance for determining the spectral features of targets and backgrounds over broad spectral regions.

All of the above advantages of interferometers are well known, have been described many times in the literature, and will not be dealt with here. The only reason for their being mentioned is that the heart of the system for BOSS is an instrument which already enjoys the above-mentioned advantages of the interferometer even before we adapt it for the AFGL background suppression scheme.

Let us consider the two Michelson interferometers illustrated in Figure 1 and their corresponding outputs illustrated to their right. In the upper left corner of the figure, radiation enters the interferometer at IN and strikes the upper face of the dielectric beamsplitter B.S. The radiation is divided at the beamsplitter and ideally half the light travels through the beamsplitter to be reflected back to the beamsplitter by mirror M1. The other half of the light is reflected by the beam splitter and again reflected back to the beamsplitter by mirror M2. The two beams are thus recombined at the beamsplitter where part of the radiation is transmitted to the detector, D, and part is reflected in the direction of the incoming beam. If the mirror M1 is moved at a constant speed v, when monochromatic radiation of wavelength $\lambda = 1/\sigma$ ($cm^{-1}$) enters the interferometer, the detector output will be a sinusoidal function of electrical frequency f given by $f_\sigma = 2 v\sigma$. The factor of 2 occurs because the optical path difference in the interferometer is twice the displacement of mirror M1. For radiation of broad spectral distribution $B(\sigma)$, the detector output as a function of path difference x in the interferometer will look like the curve at the upper right of Figure 1. The functional character of the upper curve $D_\mu$ (or the detector output $D_\mu(x)$) as a function of path difference x is given by

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2. Fellgett, P. (1957) Colloques Internationaux du Centre National de la Recherche Scientifique; Les Progres Recents en Spectroscopie Interferentielle, Bellevue, p. 53.

3. Mertz, L. (1965) Transformations in Optics, Wiley, New York.

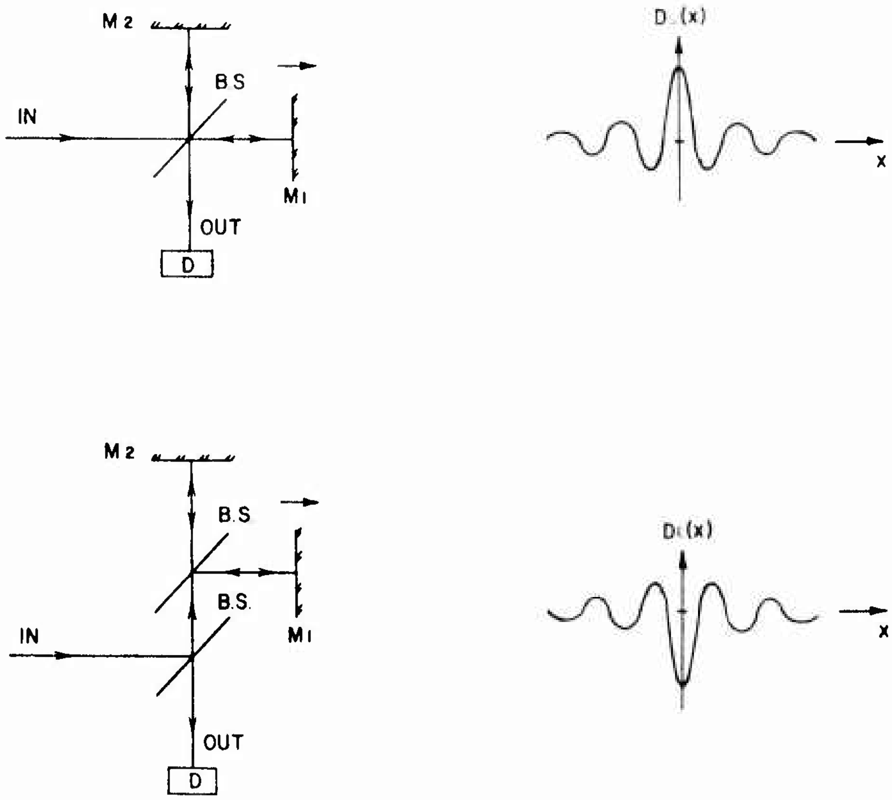



Figure 1. Michelson Interferometer Showing Complementary Characteristics of Interferograms

$$D_\mu(x) = \int_{\sigma_1}^{\sigma_2} B(\sigma) \left[\frac{1}{2} + \frac{1}{2} \cos 2\pi\sigma x\right] d\sigma \qquad (1)$$

where the limits to the integral indicate the bandwidth $\Delta\sigma = (\sigma_2 - \sigma_1)$ of the radiation being studied; these limits will be dropped in the following equations.

We can rewrite Eq. (1) as

$$D_\mu(x) - \frac{1}{2} \int B(\sigma)\, d\sigma = F_\mu(x) \qquad (2)$$

where the function $F_\mu(x)$ is usually called the interferogram in Fourier spectroscopy and is given by

$$F_{\mu}(x) = \frac{1}{2}\int B(\sigma)\cos 2\sigma\pi x d\sigma \quad . \tag{3}$$

In essence then the curve at the upper right of Figure 1, the transmitted radiation, is the interferogram generated by the interferometer at the left when radiation of spectral distribution $B(\sigma)$ enters it. We notice that at $x = 0$ (no retardation) the interferogram has its peak value; that is, all the energy (assuming no losses) entering the interferometer falls on the detector. For another retardation not all of the radiation reaches the detector, some goes back toward the source. In fact, the transmitted radiation which goes to the detector is complementary to the reflected radiation which goes back to the source. Since they are complementary, their sum should add up to a constant which equals the total energy entering the interferometer; which is what it should be from a consideration of the conservation of energy principle.

If now we consider what happens with the interferometer configuration at the lower left of Figure 1, we notice that the incoming beam strikes the lower face of the main interferometer beamsplitter, and everything goes on as with the previous configuration. The difference, of course, is that the transmitted beam (the one reaching the detector) produces the lower curve at the right of it which has the functional relation given by

$$D_{\ell}(x) = \int \left[\frac{1}{2} B(\sigma) - \frac{1}{2} B(\sigma)\cos 2\pi\sigma x\right] d\sigma \quad , \tag{4}$$

and is complementary to the curve $D_{\mu}(x)$ above it in the figure.

Now that we have finished with the fundamentals, we shall describe how we can take advantage of the complementary characteristics of the interferometer outputs to devise a concept for detecting a target which may be much fainter than its surrounding medium, or its background and/or foreground.

In simple terms, the concept is to somehow obtain complementary background interferograms so as to obtain a constant (or zero for dual output mode) electrical output; that is, an interferogram which has no modulation due to the disturbing background.

It should be indicated that in Figure 1 an extra beamsplitter was necessary in order to get the input beam to strike the lower face of the main beamsplitter. This particular configuration introduces losses and even more so if we are to go to a dual-output system as well. Consequently, to further describe our concept we shall use an interferometer configuration which produces physically separated input beams without extra beamsplitters and also physically separated output beams. We are now ready to describe the AFGL concept for enhanced target detection or discrimination by means of a background suppression technique.

Figure 2 illustrates an interferometer configuration where two input beams are physically separated by using just one extra mirror and no extra beamsplitter. The mirrors M1 and M2 have been replaced either by roof mirrors or cube-corner retroreflectors; cat's eye retroreflectors would probably be better. As shown in the upper drawing, the background radiation is made to enter as one beam $B_\mu$ striking the upper face of the beamsplitter, and as another beam $B_\ell$ striking the lower face of the beamsplitter. We can consider these beams as coming from adjacent fields-of-view of a somewhat uniform background. From what we have shown above (as the mirror assembly M1 is moved), and beam $B_\mu$ by itself would produce a detector output given by

$$D_\mu(x) = \int \frac{1}{2} B(\sigma)[1 + \cos 2\pi\sigma x]\, d\sigma \quad . \tag{5}$$

On the other hand, the lower beam $B_\ell$ itself would produce a detector output which would be

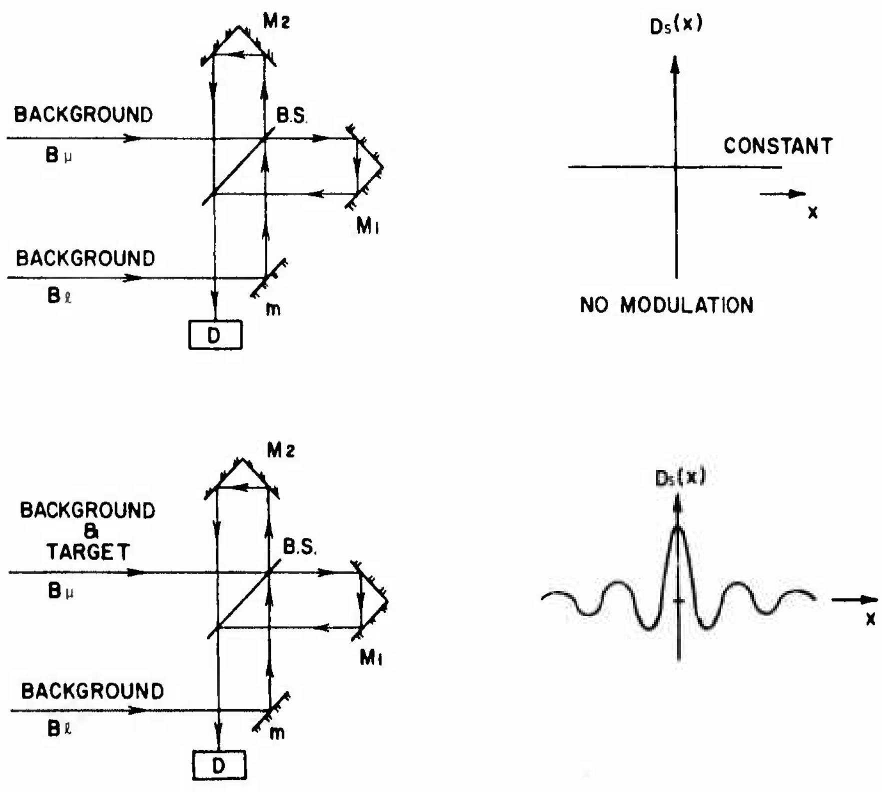



Figure 2. Roof Mirror Michelson Interferometer Showing That Background Interferogram is a Constant While Target Interferogram is Detected

$$D_\ell(x) = \int \frac{1}{2} B(\sigma)[1 - \cos 2\pi\sigma x] \, d\sigma \quad . \qquad (6)$$

However, if we allow both background beams to enter the interferogram simultaneously, the detector output would be the sum $D_s$ of $D_\mu(x) + D_\ell(x)$, namely

$$D_s(x) = \int B(\sigma) \, d\sigma \quad , \qquad (7)$$

which is a constant independent of path difference x as is shown in the upper right-hand trace of Figure 2. Suppose now that a target appears in the upper beam as shown in the lower left drawing in Figure 2. The two background beams will still yield a constant, but now there will appear modulation which will be due to the target radiation only.

With the configuration of Figure 2, we see that the background contribution is a constant output, namely

$$D_s = \int B(\sigma) \, d\sigma \quad . \qquad (8)$$

However, it is possible that the background intensity changes with time, or that the intervening medium produces intensity fluctuations, like scintillation. Although these occur in both beams, their fluctuations occur in phase and will cause $D_s$ to be modulated according to these fluctuations, and would appear as a contribution to the modulation due to the target. To overcome this limitation, the BOSS technique makes use of two output beams as discussed below.

Figure 3 shows the retroreflector interferometer equipped to use the two output beams. In the upper left drawing the upper beam $B_\mu$ strikes the upper face of the beamsplitter, travels on through the interferometer as before, but now use is made of the beam that would go back toward the source, and it is made to fall on the detector D'. Detector D looks at the usual transmitted beam. Again, we see from the corresponding traces on the right that D(x) and D'(x) are complementary. The bottom half of Figure 3 illustrates a similar thing for the beam striking the lower face of the beamsplitter. But again, as before, a change of background intensity (or scintillation) affects both beams the same way as in Figure 4. That is, if scintillation causes D(x) to increase by $\epsilon$, it will also cause D'(x) to increase by $\epsilon$. Consequently, each detector will produce a signal given by

$$D'(x) + \epsilon(t) \text{ and } D(x) + \epsilon(t) \quad . \qquad (9)$$

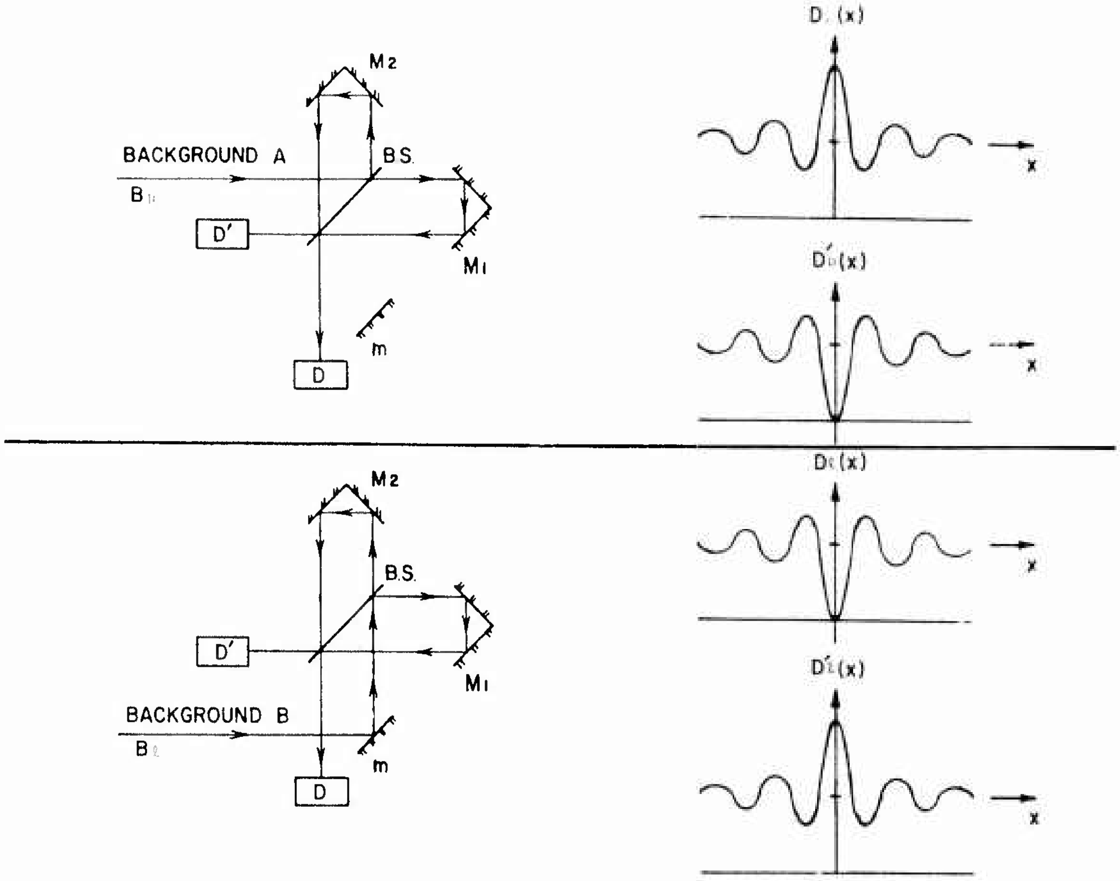



Figure 3. Interferometers Showing That Two Outputs are also Complementary

The solution for overcoming background temporal changes (or scintillation) is to difference the electrical outputs of the detectors and in that way obtain a zero signal (and not only a constant) for the background even when it is changing with time.

Figure 5 shows conceptually the dual-input, dual-output interferometer configuration. In essence, what this system accomplishes is to suppress the background radiation and temporal fluctuations to yield a zero electrical output for the background.

The detector modulation due to the target appears in both detectors in a complementary fashion. If $T(\sigma)$ is the target spectral distribution, then the detector electrical outputs are

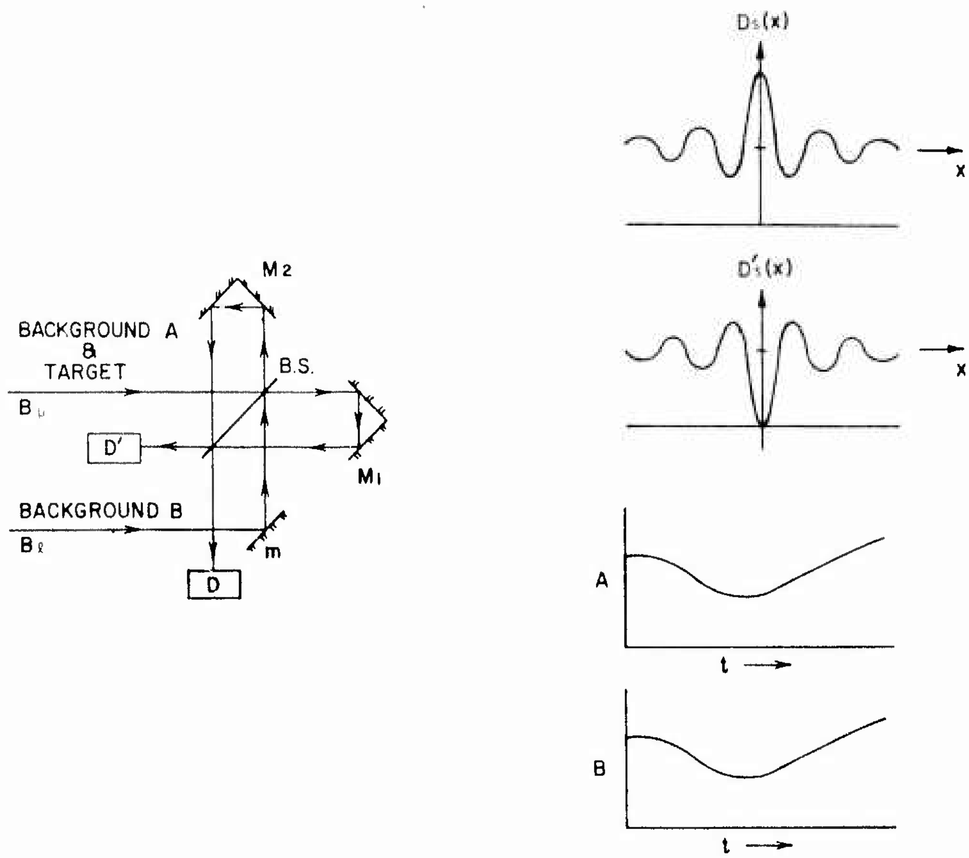



Figure 4. How Temporal Fluctuations in a Source Appear in Phase With Two Output Beams

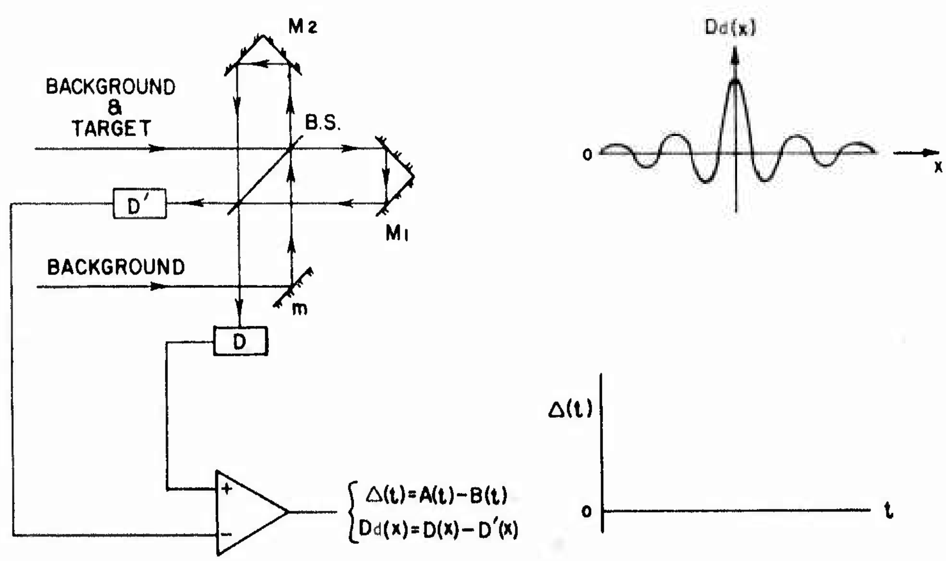



Figure 5. How Temporal Fluctuations can be Removed by Differencing Detector Outputs

$$D(x) = \int \frac{1}{2} T(\sigma) [1 + \cos 2\pi\sigma x] \, d\sigma$$

and (10)

$$D'(x) = \int \frac{1}{2} T(\sigma)[1 - \cos 2\pi\sigma x] \, d\sigma \quad ,$$

which yields a $D_d$ for the difference of

$$D_d = \int T(\sigma) \cos 2\pi\sigma x \, d\sigma \quad . \tag{11}$$

This $D_d$ is a target signal which is twice what one would obtain with one detector. However, using two detectors increases the noise by the $\sqrt{2}$, so that the gain in S/N is the $\sqrt{2}$. Thus, the Figure 5 configuration is capable of background suppression, including intensity fluctuations and yields a gain in S/N of the $\sqrt{2}$.

## 3. CONCEPTUAL IMPLEMENTATIONS

### 3.1 Adjacent Fields-of-View

This is the simplest implementation (see Figure 2) which consists of two adjacent apertures to the interferometer, corresponding to adjacent footprints in the target vicinity. For the interferometer set at zero retardation, a positive or negative signal would be generated as the target came within one field-of-view.

### 3.2 Multiple Aperture Single Field-of-View

This concept is illustrated in Figure 6. The system is a cat's eye retroreflector interferometer, where now one field-of-view impinges on a mask consisting of alternate reflecting and transmitting facets. This mask breaks up the background between beams striking the upper face of the beamsplitter and beams striking the lower face, to produce background suppression. The target is mostly either transmitted or reflected by the mask and would generate a positive or negative signal as it goes across the mask.

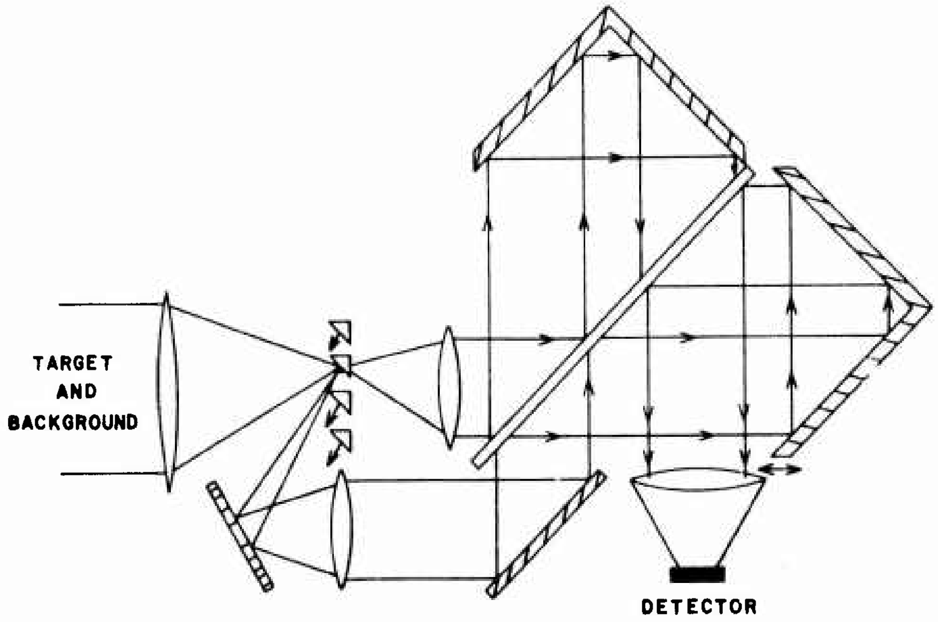



Figure 6. How Field-of-View can be Broken Down into Smaller Patches

### 3.3 Beam Defocusing Technique (Proprietary to Visidyne)*

#### 3.3.1 TWO FIELDS-OF-VIEW

This implementation is illustrated in Figure 7. The principle is to defocus the radiation from one beam so as to smear out target and background. For a uniform background the result should be as shown in the upper right, while for the target it should be as shown in the lower right.

#### 3.3.2 SINGLE FIELD-OF-VIEW

This implementation is shown in Figure 8, where an extra beamsplitter is inserted to produce two beams out of one field-of-view. Again, one beam is slightly defocused with respect to the other beam.



*Patent pending.

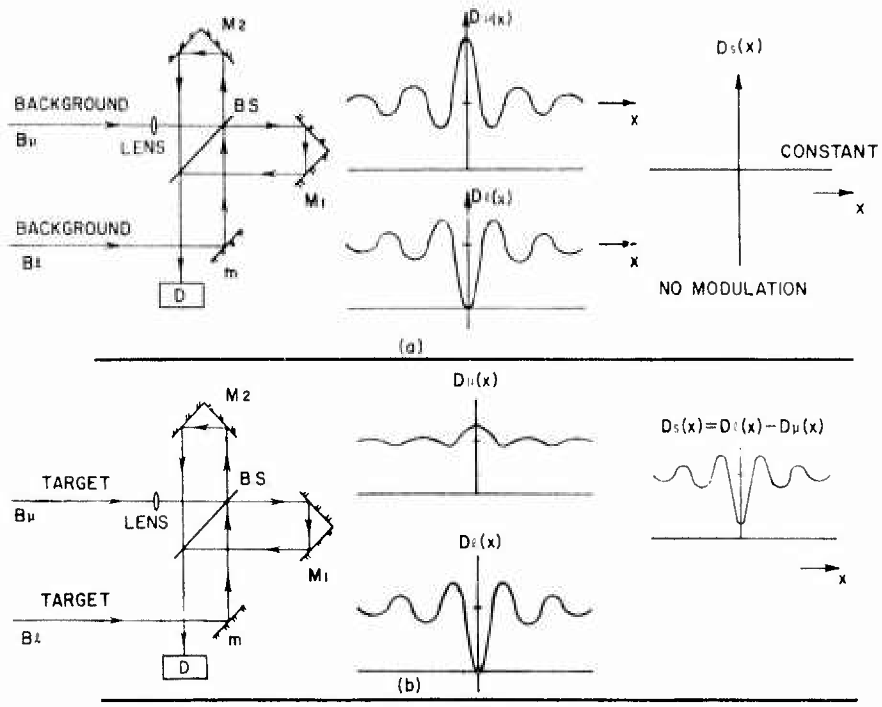



Figure 7. How Defocusing Technique can be Applied With Adjacent Fields-of-View

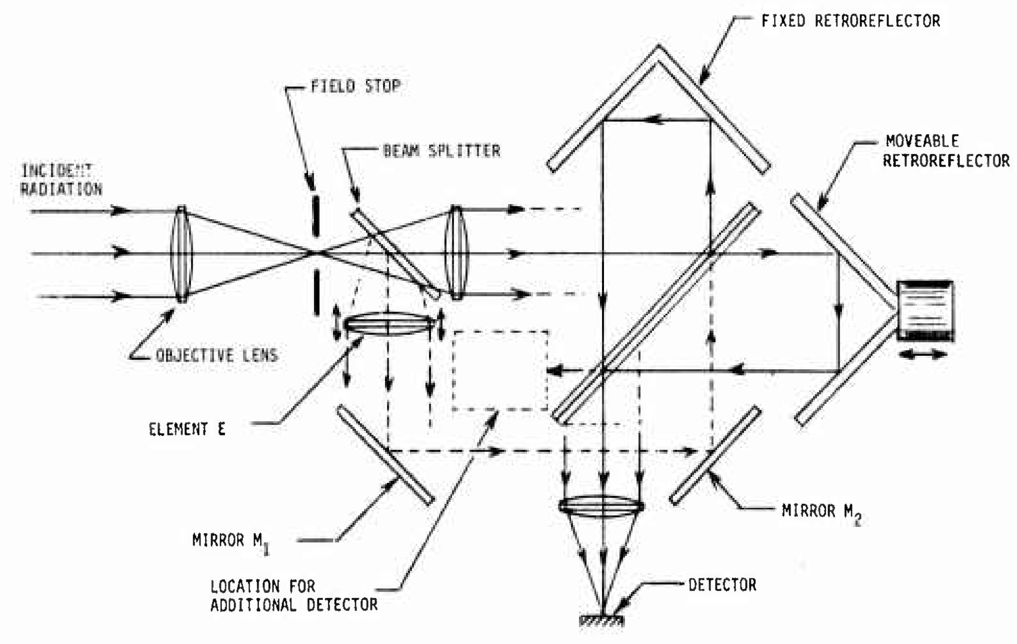



Figure 8. Defocusing Technique When Using a Single Field-of-View

## 4. PROBLEM OF NONUNIFORM BACKGROUND

The Lockheed data appear to indicate that the Wiener spectrum of the background goes down as the square of the spatial frequency. If this is so it implies that the fine structure in the background that would tend to degrade the background suppression scheme is of low amplitude. On the other hand, the large amplitude background fluctuations occur for large-scale structure and may not affect the background suppression technique.

The multiaperture system described above should allow accepting higher spatial frequency background structure than the first implementation described. The single beam, defocusing technique is also very promising from this point of view. Figure 9 illustrates the anticipated effect of the defocusing technique. It is clear from the figure that for slight defocusing it is only the high spatial frequency response of a system which deteriorates. The optical transfer function (OTF) for the two beams are essentially the same for the low spatial frequencies. Because of this, these should be suppressed in the dual beam mode. The high spatial frequencies will not be so suppressed, but because of the natures of the power spectrum of the background and a point target, the system should show an enhancement for target detection.

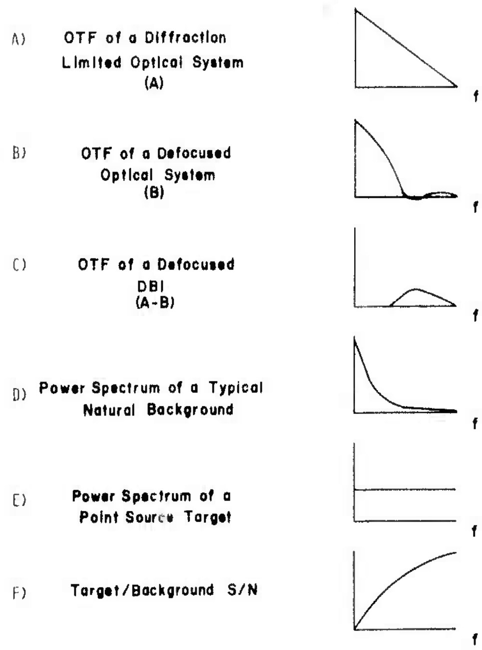



Figure 9. Effect on System Optical Transfer Function When Defocusing Technique is Used

## 5. ADVANTAGES OF THE TECHNIQUE

### 5.1 Dynamic Range Reduction

By using two input beams for optical background suppression the detectors never see the large central peak in the interferogram due to background radiation. If there occurs a dynamic range problem, it's because the target is too bright.

### 5.2 Work With Unknown Spectral Distributions

It is not necessary that the target spectral signatures be uncorrelated with the background spectral distribution. In fact, the background could radiate a sharp line at the same wavelength as the target, and it would still be suppressed.

### 5.3 Automatic Background Suppression

If the system views a changing background, whether spatially, temporally, or spectrally (as might happen for a scanning system, or for a staring system which drifts) the background suppression scheme will still be effective.

### 5.4 Capability of Making Use of Known Signatures

For example, if it is known that a target emits lines which are equally, or about equally spaced, then the system can preferentially modulate the target energy versus the background. This is in addition to the background suppression which is always being done. If the lines happen to have spacing $\Delta\sigma$ equal to 1 $cm^{-1}$, then the interferometer is placed at a retardation X of $1/2\ \Delta\sigma = 1$ cm. At the retardation, the transmission function for the interferometer peaks at exactly where the target line emissions occur. If the retardation is made to oscillate about this 1 cm position, then the target radiation is chopped, but not the background radiation.

### 5.5 Insensitive to Multiplicative Noise

As described above, using the two outputs in an electronic differencing mode compensates for apparent or actual temporal fluctuations of the background.

## 6. OTHER CAPABILITIES

Other capabilities consist of

(1) obtaining target velocity,

(2) obtaining target extent,

(3) working as well in occulation mode,

(4) working as detection and discrimination scheme,

(5) obtaining target signatures covering large spectral band,

(6) obtaining background target signatures in single-input mode, and

(7) interferometer being field-widened.

Electronic filtering can be accomplished by tuning to the retardation jitter frequency bandpass. Jitter period could be done about 1/5 to 1/10 the time it takes the target to move across the field-of-view; larger size objects would produce much lower frequencies.

In dual-input only, approach of adjacent fields-of-view, the focal plane fill factor could be reduced by two.

## 7. WHAT HAS BEEN DEMONSTRATED?

A Michelson interferometer, using roof mirrors instead of plane mirrors, was designed and assembled, and is shown in Figure 10. The system was tested in the dual-input mode for its background suppression capability, and Figure 11 illustrates the results. The upper left trace of Figure 11 shows a background interferogram due to one beam only, while the upper right trace is the interferogram obtained from the other beam only. The lower left trace shows the resultant interferogram when both background beams enter the interferometer simultaneously; the modulation is practically all gone. The lower right trace is again the dual-input beam interferogram with a gain change of 20. The large periodic oscillations that can be seen are due to source fluctuations since at the time of measurement, no other detector was available for differencing the two output beams. The suppression ratio is estimated to be about two orders of magnitude.

Figure 12 shows the laboratory results when the technique is used in the occulting mode. The lower right trace is the resultant detection.

This present work is being funded at a very low level by the AFGL Laboratory Director's Fund. It is for a laboratory study to determine the level of background suppression one can obtain for uniform backgrounds and backgrounds with structure.

## 8. DEVELOPMENT OF INSTRUMENTATION FOR BACKGROUND OPTICAL SUPPRESSION

Many problems of interest today to DoD concern the detection and identification of a weak target signal in the presence of strong background signals. The intrinsic limits on the target detectability are set by

(1) the quantum noise inherent in the detector (for the temperature and instrument configuration in which it is used) and,

(2) the statistical fluctuations in that part of the background signal which can be suppressed.

Detector quantum noise will not be discussed other than to indicate that the detector noise will generally provide a lower limit to the achievable background suppression. A simple case can be used to illustrate the principle of background suppression. Consider a staring radiometric measurement of 4 $\mu$m in which the background power on the detector is $2 \times 10^{-8}$ W. In a 1 sec measurement time,

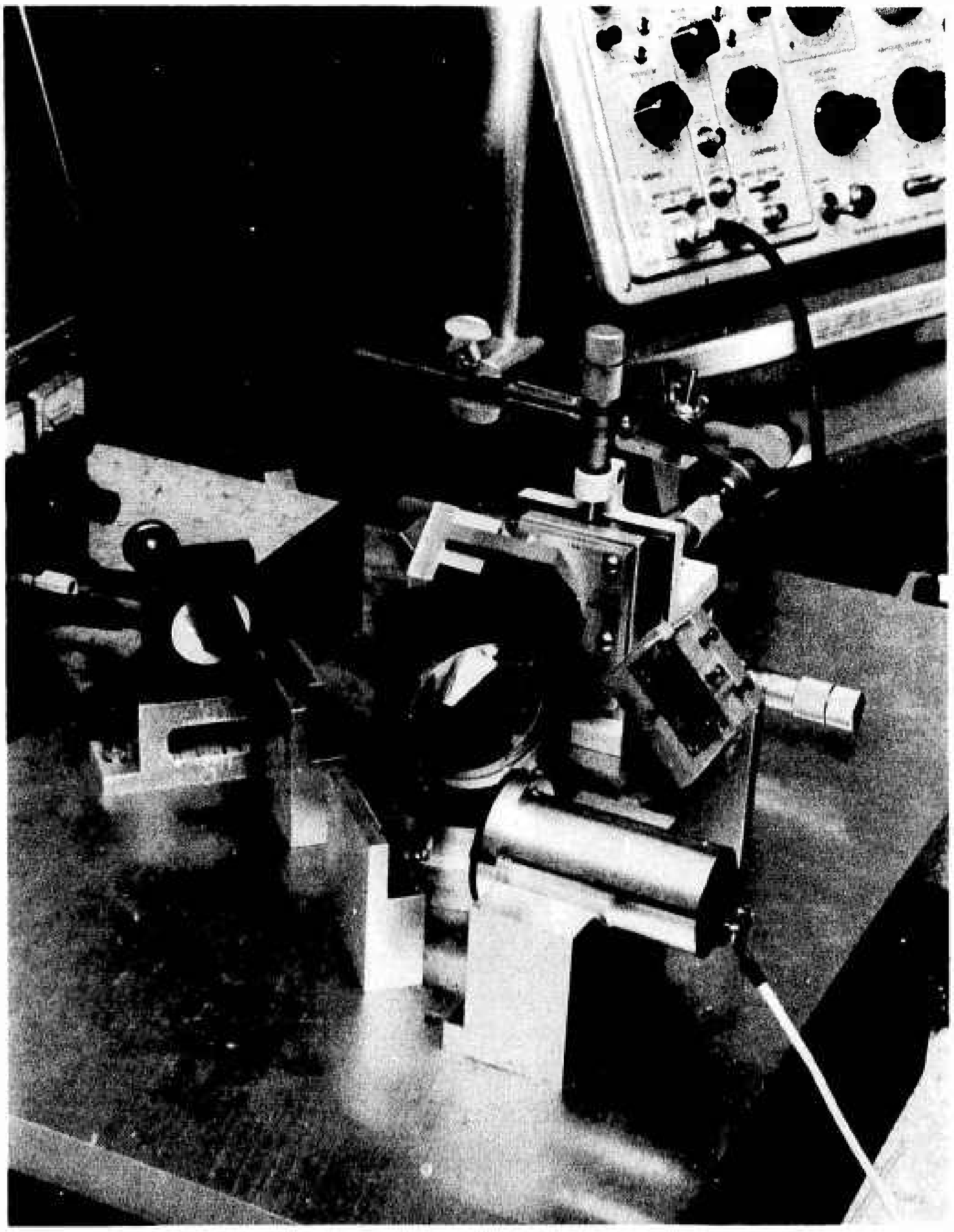
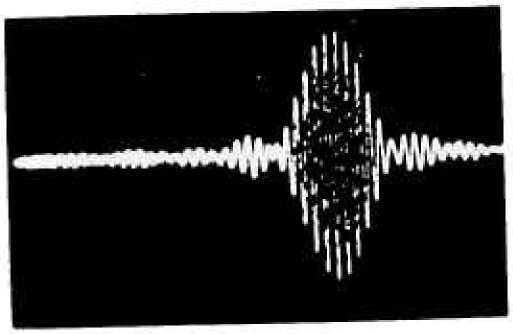
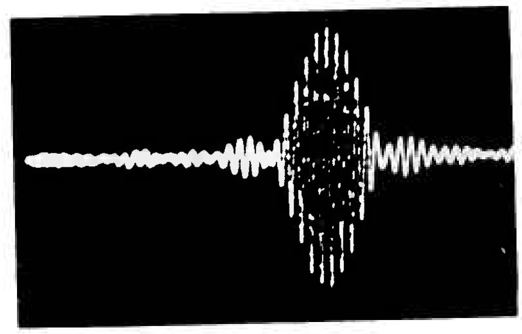


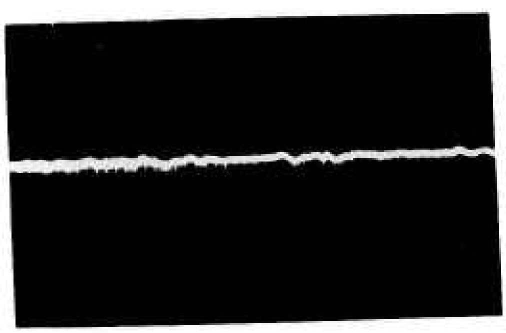
Figure 10. Photograph of Actual Interferometer Setup



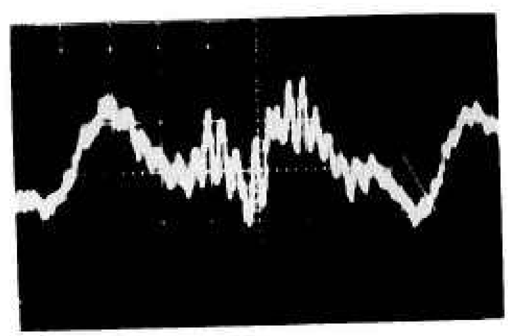
SINGLE-BEAM BACKGROUND INTERFEROGRAM



SINGLE-BEAM COMPLEMENTARY BACKGROUND INTERFEROGRAM



DOUBLE-BEAM BACKGROUND INTERFEROGRAM



DOUBLE-BEAM BACKGROUND INTERFEROGRAM (20X GAIN)

Figure 11. Some Results Obtained

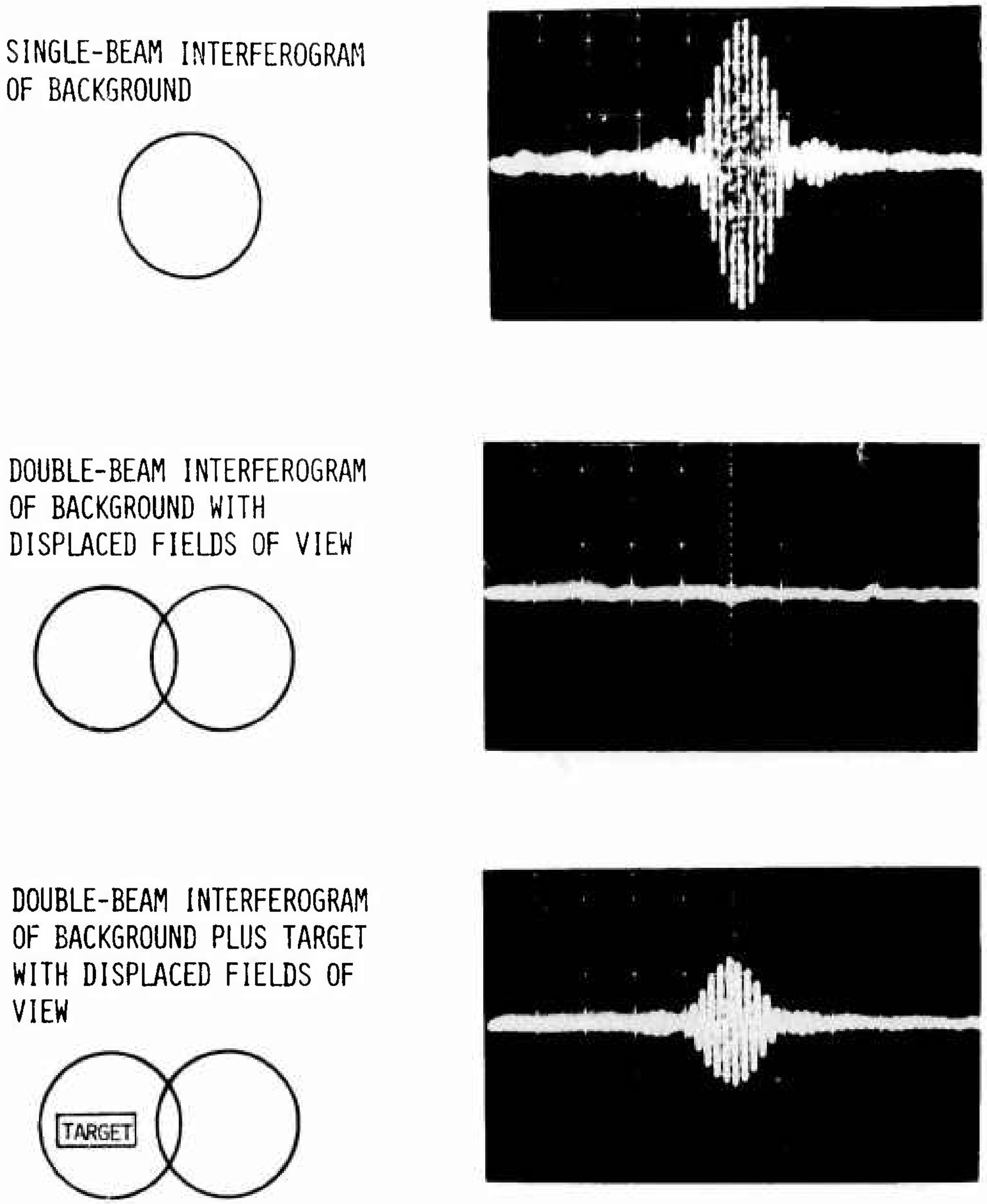



Figure 12. Results Obtained in the Occulting Mode

the statistical noise in the background power is $4 \times 10^{-14}$ W at one standard deviation. Obviously, there is an enormous advantage in working against the noise in the background power rather than the total power.

In this particular example, the radiometric background power could be suppressed by comparing sequential measurements from a single detector and using as a target signal threshold fluctuations which are ten standard deviations or greater above the mean noise in the background measurement. In the staring mode, the increase above threshold would be due to targets moving through the footprint.

The same approach in theory can be used for interferometric measurements. In practice it presents certain difficulties particularly for mosaic detectors: the interferogram from each detector must be stored and compared with subsequent interferograms. The dynamic range is the ratio of background power to minimum detectable signal multiplied by the dynamic range required for the specified target spectral resolution.

For example, consider the case when the background is three orders of magnitude greater than the target (10 bits) and a target spectral radiance amplitude resolution of 1 percent (7 bits) is required in each of 128 spectral bins. For this minimum resolution, more than 2000 bits per pixel must be stored and compared to the subsequent interferogram. Furthermore, this approach to background suppression is degraded by background and detector drift between measurements.

As an alternate, we are developing an optical background suppression technique. The suppression is done optically, in real-time eliminating data processing for each detector and the effects of temporal changes. The technique can be used for surveillance systems scanning or staring at the earth and for targets which are fixed or moving with respect to the background.

For each scenario the details of implementation may vary, but the basic concept is the same. The target has certain spatial (or temporal) frequencies associated with it. Signal from this frequency interval is selected and from all other frequency intervals is suppressed. The resulting interferogram will contain spectral information only from the range of spatial (or temporal) frequencies associated with the target.

One implementation of this concept is based on a proprietary design of Visidyne, Inc. for which a patent has been applied. Consider a target fixed on the ground and a staring sensor array. Let the target be small compared to the pixel size and further let the pixel be sized to the diffraction limit of the system. The optical suppression technique is shown conceptually in Figure 13. The incident radiation from the footprint is divided at the beamsplitter, strikes the retroreflectors, and recombines at the beamsplitter. If the two optical paths from the beamsplitter to each of the retroreflectors are balanced, then the total power coming

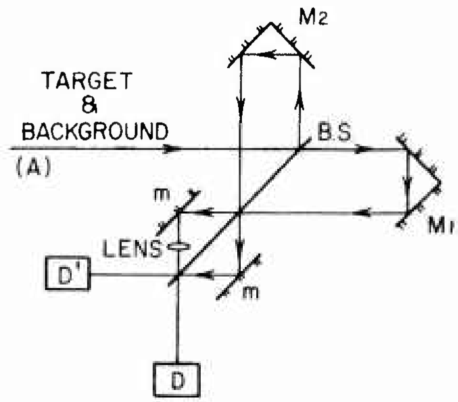



Figure 13. Single Field-of-View Operation With Defocusing



out of the interferometer will be constant independent of the position of the mirror. Therefore, if we combine the two outputs of the interferometer equally, the signal from Detector 1 or Detector 2 will be a constant independent of mirror position. Now, if the radiation in Arm 2 is slightly defocused prior to reimaging (for example, the blur circle is twice the pixel size), the incident power from an object whose image size was the diffraction limited pixel element size spread over a number of pixel elements. There is an imbalance in the total power delivered to the pixel element from the two outputs and a resulting modulation in the interferogram.

This defocusing has no significant effect on the signal generated by objects which are large compared to a pixel element. The essence of the dual beam optical suppression technique is to balance the power delivered to the detector by the two arms of the interferometer, so that the power delivered to the detector is a constant except for spatial frequencies associated with the target.

Table 1 illustrates the degree of background suppression achievable in a state-of-the-art system. The background is a $300^{\circ}$ K blackbody and the wavelength interval selected is a 0.32 $\mu$m band centered at 4 $\mu$m. The background power is $2 \times 10^{-8}$ W. However, the fluctuations in the background signal (background noise) are an order of magnitude less than the detector NEP.

Table 1. Comparison of Single Beam With Dual Beam Operation

SINGLE BEAM

- Background Power Must be Suppressed Electronically.
  Each Detector Requires Data Processing Electronics.
  Dynamic Range Determined by Background Power and Target Spectral Resolution.
- Temporal Fluctuations Cannot be Suppressed.

DUAL BEAM

- Background Power Suppressed Optically.
  Only Detectors Above Threshold Require Data Processing.
  Dynamic Range Determined by Target Spectral Resolution.
- Temporal Fluctuations Can be Suppressed in Dual Output Mode.

$\lambda = 4\mu$, $\Delta\lambda = 0.32$, 11 $cm^2$ aperture, 35,000 ft altitude, 350 ft footprint, interferometer scan time 1 sec, 400 spectral elements

| | |
|---|---|
| -7 | |
| | Background Power |
| -8 | |
| -9 | |
| -10 | |
| -11 | |
| | NEP Detector |
| -12 | |
| | NEP Background |
| -13 | |
| -14 | |
| -15 | |

Table 2. Listing of Advantages of Double-Beam Operation

- DBI is an Imaging System, Therefore the Technique is Applicable to Multielement Focal Plane Detection Systems.
- Technique is Applicable to Diffraction Limited Optical Systems.
- Background Suppression is Done Optically and in Real-Time, thus Minimizing the System Post Detection Data Processing Requirements.
- Background Optical Suppression Reduces the Dynamic Range Requirements of the Detection Electronics.
- DBI Output Signals Contain Target Spectral, Temporal and Positional Information.

Table 2 summarizes the advantages of a dual beam interferometer used for background suppression.

AFGL and Visidyne are presently engaged in the development of instrumentation for BOSS. Table 3 shows the proposed milestones for the development program. The first phase is a laboratory breadboard and demonstration which is funded by the AFGL Laboratory Director's Fund, Project ILIR-6K (Table 4). Initial results from this effort are shown in Figures 11 and 12.

The next phase of the program is the development of a brassboard instrument for measurements from an aircraft platform. The objective of the brassboard development (Table 5) is to

(1) demonstrate optical background suppression with real targets and real backgrounds, and

(2) demonstrate system performance in a aircraft environment.

Table 3. Listing of Milestones for BOSS Technique

- Design and Test a Laboratory Breadboard. Funded by AFGL Laboratory Director's Fund, Completion June 1977.
- Design and Develop, Fabricate and Assemble Brassboard.
- Laboratory Test and Calibration of Brassboard.
- Brassboard Field Measurements.
- Evaluation of Measurements.

Table 4. Status of Effort as of February 1977

| | |
|---|---|
| • Laboratory Breadboard. Funded by AFGL Laboratory Directors' Fund, ILIR-6K. | |
| • Present Status | Laboratory Breadboard is Complete. Preliminary Measurements have Demonstrated a Background Suppression Ratio of 100. |
| • Status of Completion May 1977 | Evaluation of BOSS Capability Based on Laboratory Breadboard Measurements for Various Target to Background Signal Ratios. |

Table 5. Suggested Goals

- Brassboard DBI Development Objectives.
- Demonstration of the Capability of BOSS/DBI Techniques in the Detection and Measurement of Selected Sources Against Various High-Level Natural Backgrounds.

    Optical Background Suppression.

    Operation in Airborne Environment.

## 9. BRASSBOARD HARDWARE

A double-beam brassboard interferometer for use on a flying laboratory type aircraft is discussed. This would be a brassboard type of instrument which would be capable of operating in both the single-beam and double-beam mode. It would be easily modified so as to incorporate design changes made evident from field measurements.

Figure 14 is an outline drawing of the instrument mounted in a flying laboratory aircraft in a side looking configuration.

The Foreoptics Specifications are listed in Table 6, and a conceptual drawing is shown in Figure 15. A simple 1X relay configuration is shown but this can be changed to meet specific experiment requirements. A rocking secondary mirror is used to stabilize image in the focal plane and to remove aircraft motion from the viewed scene, for short periods of time (30 sec, maximum). The focal plane could be used for reticle spatial scanning if required.

The Interferometer Specifications are listed in Table 7. Figures 16 and 17 show schematic diagrams of the double beam interferometer. The interferometer may be of a two-level design with the inputs entering the interferometer on the upper level, being incident on the beamsplitter, and then the retroreflectors translating the beams to the lower level. Roof retroreflectors are shown but cat's eyes or corner cubes may be used.

A white light reference source and detector is used to monitor the zero path length position of the moving retroreflector. A HeNe laser and detector will be used to control the moving retroreflector speed and to control interferogram sampling. PZT dynamic alignment of the interferometer will be considered.

The preliminary detector array specifications are listed in Table 8. The BOSS will be tested and initial measurements made with single InSb detectors for each output.

The technology requirements for the BOSS development are listed in Table 9.

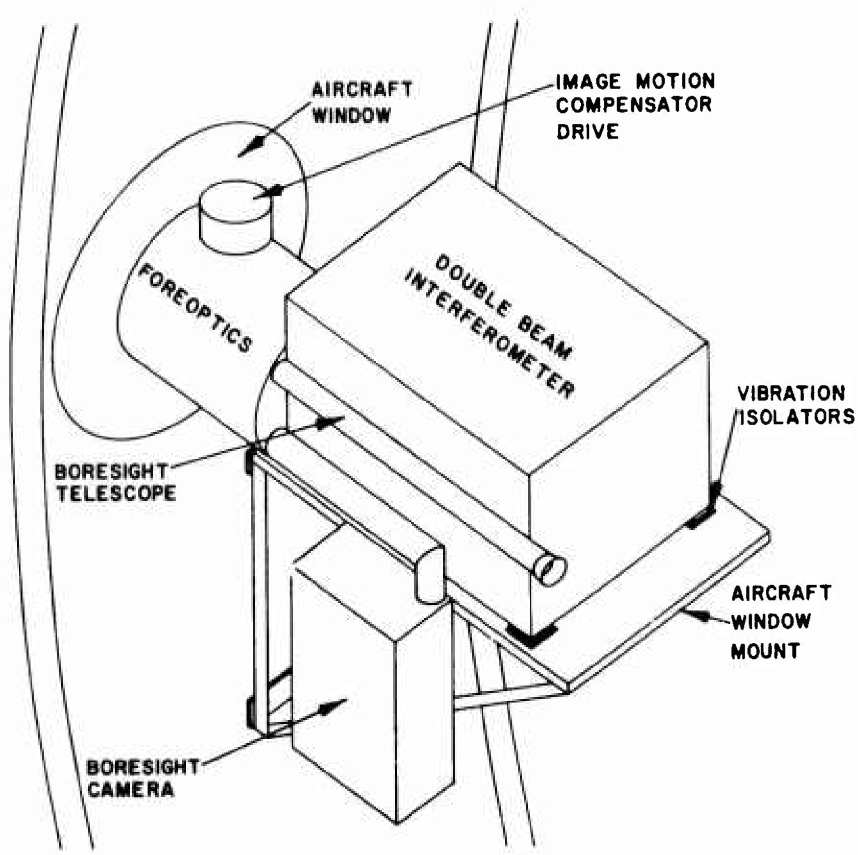



Figure 14. Possible Configuration for Airborne Application

Table 6. Foreoptics Specification

| | |
|---|---|
| Aircraft Window Material | $CaF_2$ (Transmission 0.2 - 7 $\mu$m) |
| Aperture | 12 cm dia. |
| f/No | f/2 - f/4 |
| Type | All reflective axial four mirror telescope |
| Image Motion Compensator | Rocking secondary servo driven by $\frac{V}{h}$ |

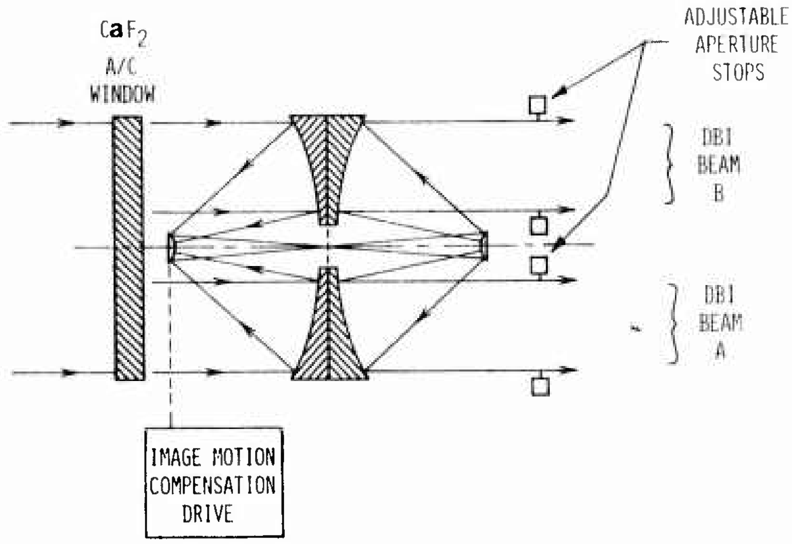



Figure 15. Foreoptics to Interferometer

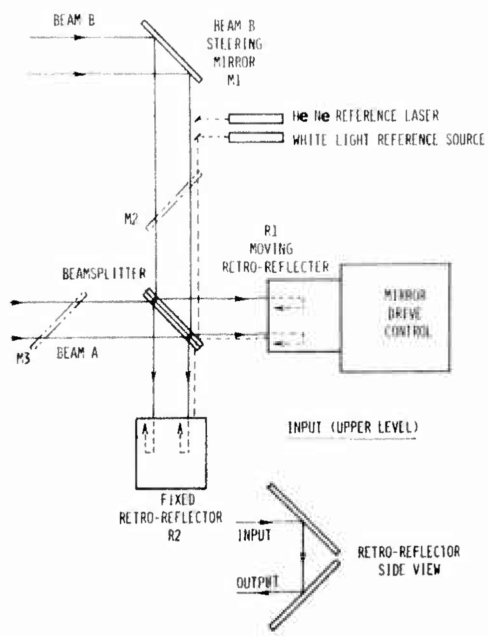



Figure 16. Detailed Sketch of Interferometer Setup

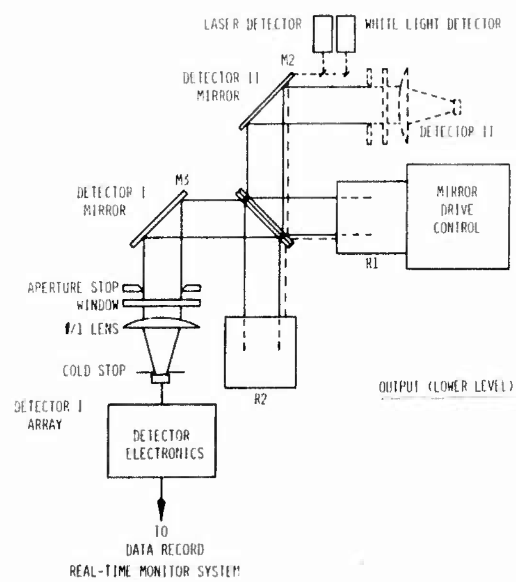



Figure 17. Other View of Interferometer

Table 7. Interferometer Specifications

| | |
|---|---|
| Type | Double-beam input – Double-beam output |
| Wavelength Range | 2 $\mu$m to 5 $\mu$m<br>5000 $cm^{-1}$ to 2000 $cm^{-1}$ |
| Spectral Resolution | 1 $cm^{-1}$ |
| Aperture | 3.75 cm dia |
| Field-of-View | 2.3 deg |
| Pixel Field-of-View | 0.58 deg |
| Ground Footprint<br>h = 10 km | 108 m × 108 m |
| Mirror Scan Rate | 1 scan/sec to 10 scans/sec |

Table 8. Detector Specifications

| | |
|---|---|
| Type | InSb (PV) 77°K |
| Array Format | 4 × 4 Square detectors |
| Detector Size | 0.38 mm × 0.38 mm |
| $D^*pk$<br>[295°K Background<br>180° FOV] | $2 \times 10^{11}$ cm $(Hz)^{1/2}$ $(watt)^{-1}$ |

Focal Plane Detector Array Will Be of the Type Developed for the BAMM Program

Table 9. Technology for Brassboard

- OPTICS

  Design and Adjustment for Optically Balanced Dual-Beam Interferometer.

  Beamsplitter Design and Fabrication.

- DETECTORS – State-of-the-art.
- IMAGE MOTION COMPENSATOR – State-of-the-art Requirements.