A New Design for Laser Warning System

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Abstract: A new design of laser warning system is proposed. This novel system is composed of an optical antenna based on fiber bundle and a spatially modulated stationary Michelson interferometer as Fourier transform device. The interferometer has no moving parts, which can distinguish laser from background noise and from other non-coherent radiation such as flares, sunlight, and lighting. Based on Fourier transform spectrometer principle, we can timely get laser source spectrum information from interference pattern. We describe the configuration and operating principle of the system in detail. The experiments show that the performances of the system are practical.

Key-Words: Laser warning system, Coherent detection, Fourier Transform, Fiber bundle, DSP, Non-scanning

1 Introduction

Laser has been used in military, such as in lasers designators, range finders and beam riding missiles, and so on. Rapid detection of laser threats plays an important role in optoelectronic countermeasures. Laser warning system can provide real-time detection of arriving angle covering large field of view.

In this study, we give the configuration and operating principle of the novel laser warning system, which is composed of an optical antenna based on fiber bundle and a Michelson interferometer as Fourier transform device [1]. Using optical fiber front end technology can improve the performance of the laser warning system, reduce electromagnetic interference, a non-scanning Michelson interferometer can distinguish laser from background noise and other non- coherent radiation such as flares, sunlight, and lighting. Based on Fourier transform spectrometer principle, we can timely get laser source spectrum information from interference pattern.

2 Basic Configuration and Operating Principle

The **c**onfiguration of designed laser warning system is shown in Fig.1. This system consists of an optical antenna based on fiber bundle, a direction of arrival (DOA) subsystem, the optical spectrum obtaining subsystem and a signal processing subsystem(DSP system). The fiber bundle senses the incoming radiation from certain directions, the output from the fiber bundle illuminates the splitter dividing light between an area imager used for DOA determination and a compact interferometer for coherent light and spectrum capture. Parallel rays emerging from the interferometer is focused by a Fourier Transform lens to produce a fringe pattern, which can be changed into electronic signal by a CCD, then be processed by the DSP system.

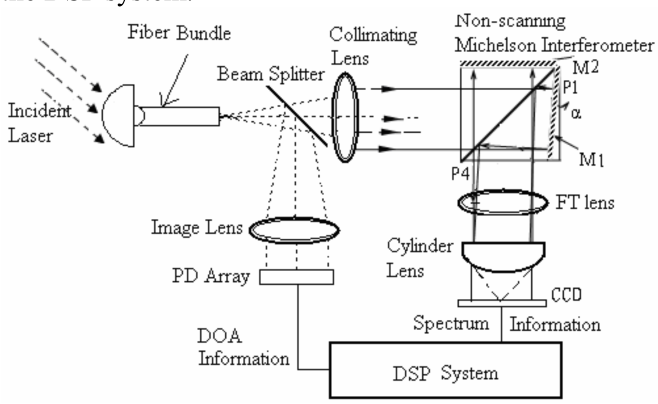

Fig.1 The **c**onfiguration of the Laser Warning System

2.1 The DOA Subsystem

The optical antenna includes two hemispheric light gathering lens and a fiber optic bundle. The first and second lens both are plano-convex lens with a convex and planar surface, the planar surface of the second lens is positioned facing the object side of the lens such that it is optically coupled to the planar surface of the first lens. It can accommodate a plano-concave

fiber optic bundle with a concave and a planar surface.
The radius of curvature of the first lens□the second lens and the fiber optic bundle is expressed by r1, r2 and r3, respectively. So the following equation is satisfied [2]

$$r3 = r2 = r1(n-1) \quad (1)$$

where n represents the refractive index of the material comprising the lens, r represents the radius. The lens is made from BK-7 glass. They have equal refractive index.

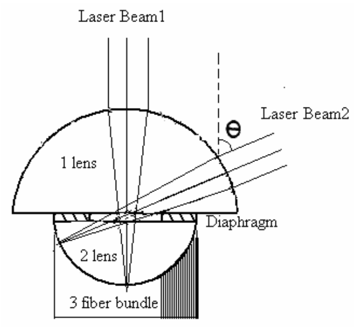

Fig.2 Schematic Diagram of optical antenna

The Fig.2 shows laser beam1 and laser beam2, incident on the convex surface of the first lens. The incident angle of laser beam1 is $\theta = 0^{\circ}$ .arriving angle of beam2 is θ .The maximum angle of incidence $\theta_{\max}$, within which laser can pass through the immersed optical fiber is:

$$\theta_{\max} = \arcsin(NA / n_g) = \arcsin(n_f^{\,2} - n_c^{\,2})^{\frac{1}{2}} / n_g \quad (2)$$

Where NA is the numerical aperture of optical fiber, n_g the refractive index of lens glass; n_f the refractive index of fiber core of optical fiber; n_c the refractive index of the fiber cladding of the optical fiber.
In the experiment, we use a fiber bundle with NA=0.55, and lens with n_g=1.51, so the system can provide an approximate 45 degree field of view. The FOV can be further extended if the refractive index of the fiber core or NA of the fiber is increased.

2.2 The Optical Spectrum Obtaining Subsystem

The non-scanning Michelson interferometer is the core of this subsystem, which consists of two orthogonal prisms by clinging together, and the clinging surface BS acts as beam splitter [3]. The incident laser reaches the clinging surface. The transmitted part of the beam propagates towards mirror M1 and the reflected part, towards mirror M2. Light reflected from M2 propagates towards the beam splitter; where part of it reflected back towards the source and the other part is transmitted towards plate surface P2. Similarly, light reflected back from M1 propagates towards the clinging surface; where part of it is transmitted through and propagates back to the source and the other is reflected towards P2. A continuous optical path difference will be formed because of the small tilt angle α=0.15^{o} (2.6mrad) between plane mirror M1 and P1. After the Michcolson interferometer, the Fourier-transform lens focuses the interferogram onto the cylindrical lens. The cylindrical lens images in only the vertical dimension. Thus each row on the CCD records an interferogram corresponding to a particular element in the one-dimension. A one-dimensional Fourier transform is performed on the data to transform the interferograms into spectra.
The recorded optical power as a function of the path difference δ is proportional to the interferogram F(δ),and the interferogram is the Fourier transform of the spectrum of the incident light. Therefore, since the Fourier transform is a reciprocal operation, one has only to take the Fourier transform of the interferogram to recover the spectrum.
Suppose a two-beam interferometer which is perfectly symmetric, i.e. the optical and geometrical path differences are equal, and assume that the interferometer receives a monochromatic radiation of wavenumber σ_0 with a spectral component of power B0, the power $P(\delta)$ at the output of the interferometer will vary as

$$P(\delta) = B_0\cos^2[\pi\sigma_0\delta] \quad (3)$$

Where $\sigma = 1/\lambda$;
Using a trigonometric relation, Eq. (3) can be rewritten as

$$P(\delta) = \frac{1}{2}B_0 + \frac{1}{2}B_0\cos[2\pi\sigma_0\delta] \quad (4)$$

The resulting interferogram is

$$F(\delta) = B_0\cos[2\pi\sigma_0\delta] \quad (5)$$

2.3 The Signal Processing Subsystem.

The block diagram of Processing Subsystem is shown as Fig.3:

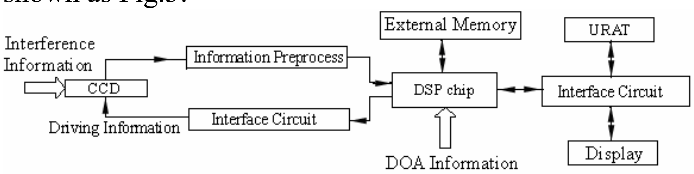

Fig.3 Block Diagram of Processing Subsystem

3 The Test Result and Conclusions

Fig.4-Fig.7 show two interference pattern formed by different lasers with wavelength 650nm and 850nm, and the corresponding spectrum gained through FFT.

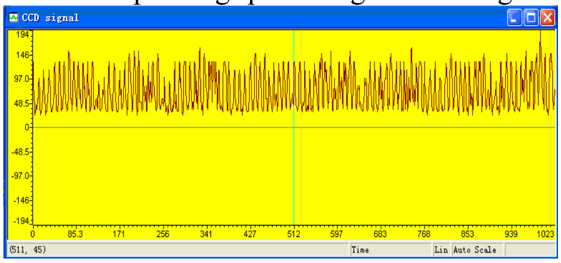

Fig.4 650nm laser interferograms formed by CCD

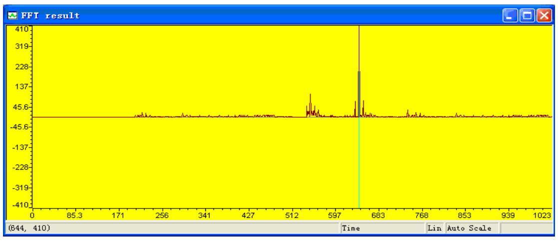

Fig.5 Corresponding spectrum of 650nm

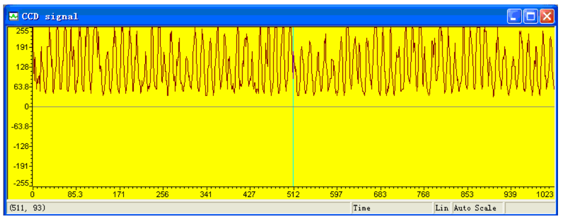

Fig.6 850nm laser interferograms formed by CCD

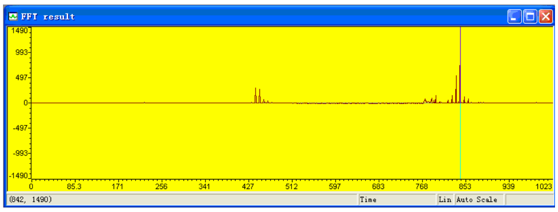

Fig.7 Corresponding spectrum of 850nm

From the experiment, we can see the proposed system can be used in spectrum capture, provides a new way to design a novel laser warning system. The system based on Fourier transform spectrometer principle is important for discriminating narrow laser pulse, using this research result, we can distinguish laser from background noise and from other non coherent radiation.

4 Acknowledgements

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