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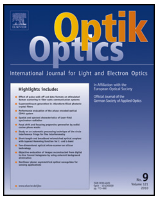

A dual-band flame detector based on video

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ABSTRACT

High quality medium band-pass infrared filters are often adopted in optical systems to improve signal-to-noise ratio. In order to extract the flame feature more easy, a band-pass film is designed and fabricated with using germanium (Ge) and silicon oxide (SiO) as the higher and the lower refractive index materials, respectively. The selection of materials and the design principles of the mid-infrared band-pass filter were introduced in detail, the film structure is also given. Then a dual-band flame detector was developed based on video. The TI DaVinci technology was used to process fire video and then regional connectivity sign algorithm was employed to detect the edge contour for obtaining the parameters of the flame circle. Realization of four modules for the proposed flame detector is introduced. All the hardware was designed, and the circuit board of the flame detector was divided into two part boards. Furthermore, it realized the software for the flame detector. Finally, an experiment was done to test the detector. The results show that the developed detector can find the fire quickly.

1. Introduction

The use of automatic detection methods drew increasing attention in the literature during the 1980s, 1990s and early 21st century. Applications are wide and include identifying and tracking human motion [1,2], identifying ships, surveillance and security, robotics, and human–computer interaction. To detect and identify the targets are based on color video for most of the applications. Although the color video is more feature information of targets can be obtained, but sometimes can not achieve significant feature information, and the processing of multi feature information leads to slow operation speed, often affect the actual project applications.

On the other hand, the characteristics of the target itself and its full visibility are with respect to the background. Recognizing and tracking moving objects in color video sequences is generally a very challenging task with the complex environment. It also has the same problem for video-based fire detection.

In recent years, thanks to the improvement of infrared (IR) technology and the drop of its cost, also thermal infrared imagery has been widely used in tracking applications [3,4]. It is easy and quick to detect the targets by using passive infrared sensor technology, with or without the cooperation of the subject. IR therefore provides a capability for identification under all lighting conditions including total darkness. The second motivation for exploring infrared detection and tracking is that research in other, related, areas has shown an improvement over algorithms using visible images. To extract feature information of the target based on infrared image is accurate and can improve the operation speed.

In today's society, fire security is a priority for any factory, home or business in every country around the world. Therefore, there are many concerns in automatic fire detection, of which the most important ones are about different sensor combinations and appropriate techniques for quick and noise-tolerant fire detection. Fire detectors are designed to respond at an early stage to one more of the four major characteristics of combustion, heat, smoke, flame or gas.

A smoke detector is a device that detects smoke, typically as an indicator of fire. However, the problem with such detection is with high false alarm rates in fire detection [5]. Furthermore, when a fire occurs, smoke detector cannot point to the specific location of the fire. Moreover, some other methods have been compiled for fire detection. In this paper, video was employed for fire detectors. Besides, the fusion of visible and infrared imagery is explored as a way to improve the fire detector performance.

In this paper, the problem of fire detection and tracking is faced by processing multi-source information acquired using a vision system capable of color and IR vision. Combining the two acquisition modalities assures different advantages consisting, to obtain

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an improvement of fire detection capability and robustness, guaranteed by the strength of both media as complementary vision modalities. Infrared vision is a fundamental aid when low-lighting conditions occur or the fire has similar color to the background. On the other hand, the color imagery has a higher resolution and can supply more detailed information about fire feature and localization with respect to the background. Moreover, as a detection of the thermal radiation of the fire, the IR information can be manageably acquired through an optical structure with a pass-band filter.

With development of thin-film technology and optical devices, optical filter has been widely used in various science and technology fields because of its characteristic able to transmit infrared radiation at a certain wavelength region. For a certain application particularly in military technologies, an optical filter that operates at a mid-IR wavelength region at around 3–5 μm is considered to be very important as jet and rocket plumes produce radiation in that spectrum region [6]. Obviously, there is no material which can be used in so that region. By virtue of the high refractive index in the infrared region, the use of semiconductor materials such as Si, Ge in combinations with low index materials such as ZnS,ZnSe,SiO,YbF3,YF3 are of interest because it allows a reduction of the number of layers on the substrate of Si, Ge,sapphire,CaF2,glass and so on[7].

According to the fire characteristics, usually, the characteristic bands are in the mid infrared. Therefore, the paper needs to design a 3.8–4.4 band pass filter, to directly obtain the flame characteristics. Then they will be further integration with color video features to detect and identify the fire.

In this study, the design and the fabrication of pass-band filter was reported to be used in video-based fire detector. The TI DaVinci technology to process fire video, and uses regional connectivity sign algorithm to detect the edge contour for obtaining the parameters of the flame circle. Then the video output would be transferred to fire control center, they will be transmitted to PC client through the Video acquisition and output module. All the hardware were designed and made into a small fire detector.

2. Infrared pass-band filter design

Infrared pass band filter have been widely investigated during the past twenty years. It is well-known that filter structure is prepared by introducing stacked layer materials of high and low refractive indices as a period layer. Most of these filters usually use Zinc oxide (ZnO), Germanium (Ge) and rarely silicon materials, because of the large transmittance of ZnO and Ge compared to Si material [8]. However, for the infrared, germanium for the region beyond 1.8 μm with an index around 4.0, or lead telluride for the region beyond 3.5 μm, with an index around 5.7, is a good high-index material for filter applications. In the near infrared, silicon monoxide (SiO) is frequently used as the low-index material accompanying germanium [9].

The main aim of the present work is to design and develop narrow band antireflection coatings on Ge substrates in its whole transmitting region from 3.8 to 4.4 μm. Ge and SiO were used, respectively, as high and low refractive index substances that are transparent in the visible range. Refractive index of SiO is about 1.85 and refractive index of Ge is about 4.0. We have followed these materials to develop an efficient, durable, narrow band antireflection coating on Ge substrate.

The Fabery Perot multicavity narrow band-pass interference filter is still the most widely used device for multiplexing and demultiplexing of the different wavelengths transmitted over the optical fiber. The basic design of narrow band-pass filter is constructed on the Fabry–Perot multi-cavity interferometer. Their basic structure is a multilayer stack of alternately high index and low index thin film, most of which are one-quarter wave thick at the design wavelength, deposited on an opthalmic glass or silica substrate[10]. The Fabry–Perot structure is used to design bandpass filter in this work. Let the refractive index of the substrate be n_g, that of the Ge be n_H, and that of the SiO be n_L. H is representative of Ge, and L is representative of SiO. Then high refractive index layer is used as the middle layer. For designing of the proposed bandpass optical filter, the filter structure of (HLHL2HLHLH) is used as the main form of stack.

2.1. Peak wavelength

The transmission peaks would be obtained at wavelengths given by

$$\delta = m\pi \tag{1}$$

where order number $m = 0, \pm 1, \pm 2, \ldots$

On the other hand, the phase thickness d is given by $\delta = 2\pi nd/\lambda$, with d and n being the physical thickness and refractive index of the spacer layer. So we can introduce a quantity λ_0, and write

$$\lambda_0 = \frac{2 \cdot n_H \cdot d}{m} \tag{2}$$

2.2. Peak transmittance

Because Ge is used as the substrate, and its refractive index is large. When the structure of Ge/HLHL2HLHLH/Air is used, the transmittance would be no high, due to be not a particularly good match to Ge and air. The more usual approach is to add matching layers at either side of the multilayer to match it to the substrate and to the medium. For the proposed filter structure, then, matching will best be achieved by adding a number of quarter-wave layers to the period. The symmetrical section must then be matched to the substrate and the surrounding air, and matching layers are added for that purpose on either side. On the side of the Ge substrate, the matching layer is Ge/L. On the other side of the air, the matching layer is LHL/Air.

The Ge/L combination alters this equivalent admittance to

$$Y_1 = \frac{n_L^2}{n_g} \tag{3}$$

Then LHL/Air combination alters this equivalent admittance to

$$Y_2 = \frac{n_L^4}{n_H^2} \tag{4}$$

Or, since n_L^2 is approximately equal to the index of germanium $\left(n_H \approx n_L^2\right)$, then

$$Y_2 = \frac{n_L^4}{n_H^2} \approx \frac{n_L^2}{n_H} = Y_1 \tag{5}$$

The complete design of the filter is then Ge/LHLHL2HLHLHLHL/Air. And the combination admittance of the proposed film structure is

$$Y = \frac{n_L^2}{n_H^2} \cdot n_g \tag{6}$$

The reflectance (R) of the film is given by

$$R = \left[\frac{1 - \left(n_L^2/n_H^2\right) \cdot n_g}{1 + \left(n_L^2/n_H^2\right) \cdot n_g}\right]^2 \tag{7}$$