Methane detection in far infrared using multispectral IR camera

by M. Kastek, T. Piątkowski, H. Polakowski, T. Sosnowski

Institute of Optoelectronics, Military University of Technology, S.Kaliskiego 2, Warsaw, Poland

Abstract

The article presents the problem of methane detection using multispectral IR camera. The project of such camera and some theoretical calculations regarding the possibility of methane detection are presented. The calculation of optical path: "camera-cloud of methane–background" were also shown. Verification of theoretical result will be made by laboratory measurement. Some result of methane detection will be reported in article.

1. Introduction

Standoff detection, identification and quantification of chemicals in the gaseous state are fundamental needs in several fields of applications. The required sensor characteristics include high sensitivity, low false alarms and high-speed (ideally realtime) operation, all in a compact and robust package. The thermal infrared portion of the electromagnetic spectrum has been utilized to implement such chemical sensors, either with spectrometers (with none or moderate imaging capability) or with imagers (with moderate spectral capability). Only with the recent emergence of high-speed, large format infrared imaging arrays, it has been possible to design chemical sensors offering uncompromising performance in the spectral, spatial as well as the temporal domain.

One method of a thermal camera application for searching gas leakages is a thermal camera system equipped additionally with a Fabry-Perot interferometer. An interferometer in IR system plays a role of a tunable optical filter. It selects the wavelength of IR radiation illuminating, at the given moment, the pixels of FPA of a thermal camera. Another method used some spectral filters with characteristics and resolution matched to the absorption bands of a compound to be detected – methane. And many of the devices used active method of gas detection, based on the absorption of laser beam by gases.

Fig. 1. *The Field-portable Imaging Radiometric Spectrometer Technology FIRST [2].*

The Telops has developed an innovative instrument that can not only provide an early warning for chemical agents and toxic chemicals, but also one that provides a "Chemical Map" of the field of view. To provide to best field imaging spectroscopy instrument, Telops has developed the FIRST - Field-portable Imaging Radiometric Spectrometer Technology (fig. 1). This instrument is based on a modular design that includes: a high performance infrared FPA and data acquisition electronics, on board data processing electronics, a high performance Fourier transform modulator, dual integrated radiometric calibration targets and a visible boresighted camera. These modules, assembled together in an environmentally robust structure, used in combination with Telops' proven radiometric and spectral calibration algorithms make this instrument a world-class passive standoff detection system for chemical imaging [1].

There are several systems and devices for gas detection in the infrared range that use thermal camera or IR-sensitive FPA, for example GasFindIR by FLIR.

2. Detection of methane

The computer simulation of a methane gas detection process was performed in order to estimate the detection capabilities of a thermal camera. The variation of a signal reaching the camera caused by the presence of a gas was calculated and compared with the reference signal obtained without the presence of a gas in the camera's field of view. When there is methane in a field of view of the thermal camera (fig. 2), total infrared radiance incident on the sensor at given wavelength NMSC is the sum of the contributions from each layer and given by:

$$N_{MSC}(\lambda) = \tau_{MSC} \cdot \left[\tau_a \cdot \tau_m \cdot N_b(\lambda, T_b) + \tau_a \cdot (1-\tau_m) \cdot N_m(\lambda, T_m) + (1-\tau_a) \cdot N_a(\lambda, T_a)\right]. \qquad (1)$$

where Nb is the Planck radiance of the background, Nm is radiance of the methane cloud and Na is the atmospheric radiance. The quantities τ_m and τ_a are the spectral transmission of the methane cloud and the transmission atmosphere between the methane cloud and IR camera [2]. The τ_{MSC} represents the spectral transmission of objective and spectral filters of the multispectral IR camera, this transmission will be shown in full text of article.

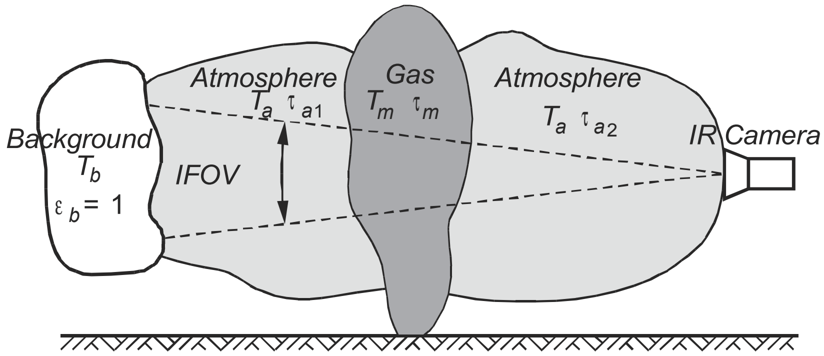

Fig. 2. Scheme of a measuring process and notations accepted for gas analysis in atmosphere.

The radiance from the background as attenuated by the chemical cloud and intervening atmosphere and it represents first term in Eq. (1). The second term is the radiance of the chemical cloud – methane – as attenuated by the atmosphere between the cloud and the camera. The third term in Eq. (1) is the radiance of the atmosphere between the cloud and the camera.

The scheme of multispectral IR camera was shown in fig. 3. The basic blocks of multispectral camera are: lens, spectral filters, microbolometer focal plane array, electronic read out system and signal analysis system.

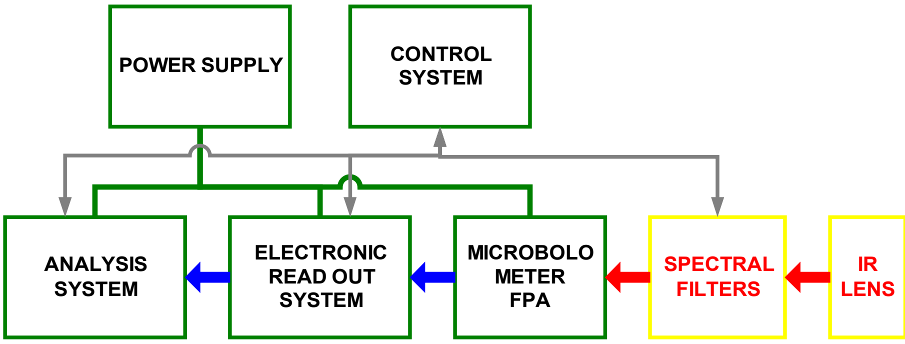

Fig. 3. Scheme of multispectral IR camera.

The Umicore Gasir Standard Lens 60 mm F/1.1 was used as the objective of the multispectral IR camera. It has the field of view of 18.5° and the transmission better than 92% in LWIR range. The microbolometer FPA was commercially available UL 03 08 1 array detector (ULIS, France) working in the long wavelength infrared (LWIR) range of 8-14 μm and consisting of 384×288 microbolometers (pixels) with the 35 μm pitch. For the tests, a laboratory circuit for signal readout from the FPA has been designed as well as a complete path of digital signal processing, data collecting, and image displaying on VGA monitor. A clock signals generator to control a readout integrated circuit (ROIC) in the FPA and all modules for digital signal processing have been made by means of Altera DSP Development Kit Stratix II Edition with the field programmable gate array (FPGA) EP2S60-1020C4 device. The raw image data were received from a FPA board with the 14-bit resolution [3]. This system realized signal analysis – image processing for methane detection. The control system for changing the spectral filters between the lens and microbolometer FPA was implemented in the same FPGA system. The spectral characteristic of filters are matched to the absorption bands of methane.

The project and numerical analysis of multispectral thermovision camera will be shown in this paper. Some of the numerical calculation for detection of methane will be reported. The laboratory model of multispectral thermovision camera for detection of methane and some experimental result during tests will be reported too.

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