

MULTIMODALITY IMAGING FOR MAPPING OF RADIOACTIVE CONTAMINATION

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ABSTRACT

The remote methods of search and mapping of the radioactive contamination are very effective. Now they use radiation of one range - gamma. And optical range is used for a substrate of layout of the obtained position of a gamma sources. The paper consider usage of obtaining of the maps in other wave ranges IR and UV for solution the important tasks of radioactive sources search and mapping of radiocontamination. The available systems are described and their sensitivity estimated. The ways of sensitization and improvement of serviceability are indicated. Some concrete applications are considered. Search of small-size high-activity sources with usage of a video, gamma and IR imaging is discussed; applications of UV imagers for definition of alpha contamination in different cases is presented.

Introduction

The remote methods for search of the radioactive sources and mapping of the radioactive contamination are very effective. They are based on scanning of a signal from radioactive sources over some angle and reconstruction of outcome synthetic picture or on obtaining of the map as gamma-image at once. Now these methods use radiations of one range - gamma. And video range image is a substrate of layout of the obtained allocation of gamma radiation. The consideration of imaging in other wave ranges IR and UV for solution the important tasks of search of radioactive sources and mapping of radioactive contamination is presented. The different available systems of obtaining of UV images are discussed and their sensitivity estimated. The paths of sensitization and improvement of serviceability of industrial systems are indicated. Some concrete applications are considered, namely are discussed search of small-sized but high-activity gamma sources with usage of simultaneous video, gamma and IR mapping. The application of different systems UV imaging for detection and mapping of alpha contamination is considered also.

The case of search for strong gamma-sources

Very useful applications for a method of multi modal mapping is the search and localization a very strong gamma –ray sources. An example of such situation is search for the sources of irradiating installations used in industrial apparatus or for the medical purposes. Operation on search and packing of such sources in city Groznii, Chechen Republic of Russian Federation recently was conducted. The sources were pirately extracted from containers on Chemical Combine and are diffuse in a location of one of premise among garbage. Because of a small size of sources they were very difficult for identifying among garbage, though the direction on them was fast defined by the portative collimated spectrometric detector. The fig 1 shows the

general view of area with one of source and one of sources clamped in a header before loading in the container.

The scheme of search and identification of radioisotope sources in a canyon was complex and include the using: 1- telescopic bars, 2 - videocamera, 3 - independent source of illumination, 4 - the gamma detector. Gamma detector was moved by bar in field of view of a videocamera and where we find max rate of detector there in building dust on a floor the source lied. The described technique of search of strong gamma sources allows remote localization and identification of the sources, enables to use of various protective shelter that considerably reduces the personnel dose.

In result of the works in canyon #1 four open high-activity sources and some sources, which were located in two transport containers in a non-standard position were found and taken out GCC. The found sources were packed into the special containers and sent to Moscow for processing, identification and permanent storage.

The experience obtained at realization of the described works has shown, that for increase of efficiency and safety of the search for gamma sources in complex radiation conditions it is necessary to have a complex of the measuring instruments and devices including, except of used, devices for visualization of sources by their gamma - radiation (portable gamma-imager [1-3]) or by thermal radiation (high sensitive thermo-imager) and to use robotic means for remote operations.

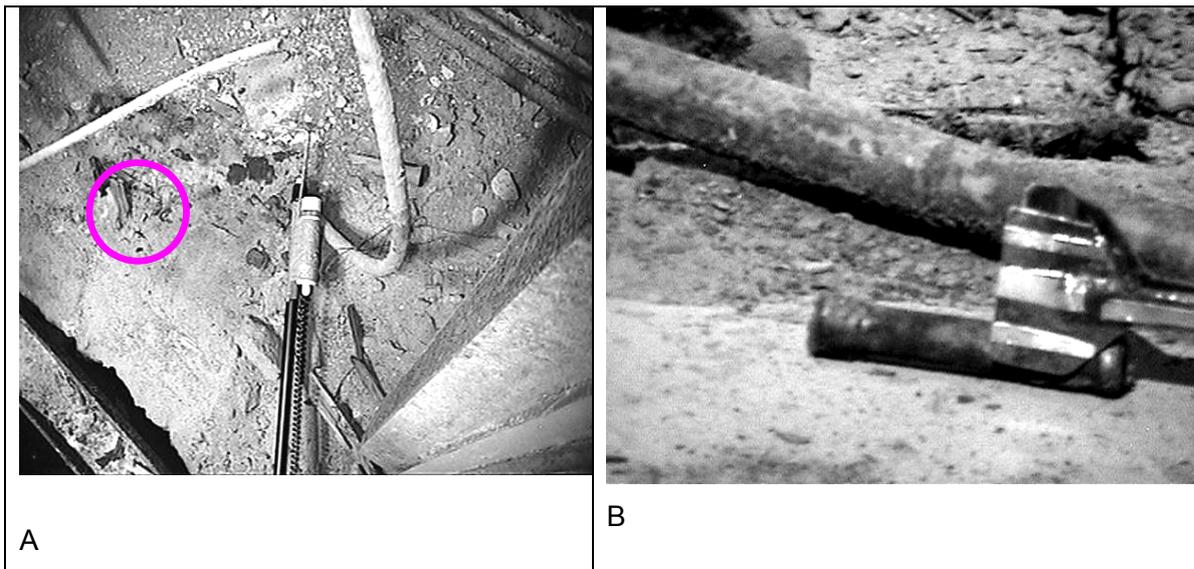


Fig. 1 A.. Identification of the source with remote video-camera and moving dose meter on telescopic bar. B. A photo of an identified source in a jaw.

The gamma images have angular resolution 1.5 – 2 degrees for cobalt-60 or 10 cm at distance 5 m (circle in Fig.1A). This resolution is not satisfied for positioning of actual small-size source.

Combine Gamma-imaging and Thermography-imaging for search of sources.

Joint using of gamma and thermo imaging will give additional modality in search of sources: gamma-channel will quickly give direction to the source with angle accuracy about 1- 2° and IR channel will show exact position in this area.

The IR imaging experiments were carried out with test sample source (presented in Fig.3). The source with shape typical for medical gamma source simulated heat production of strong gamma source. Imaging were carried with Flir IR camera [4]

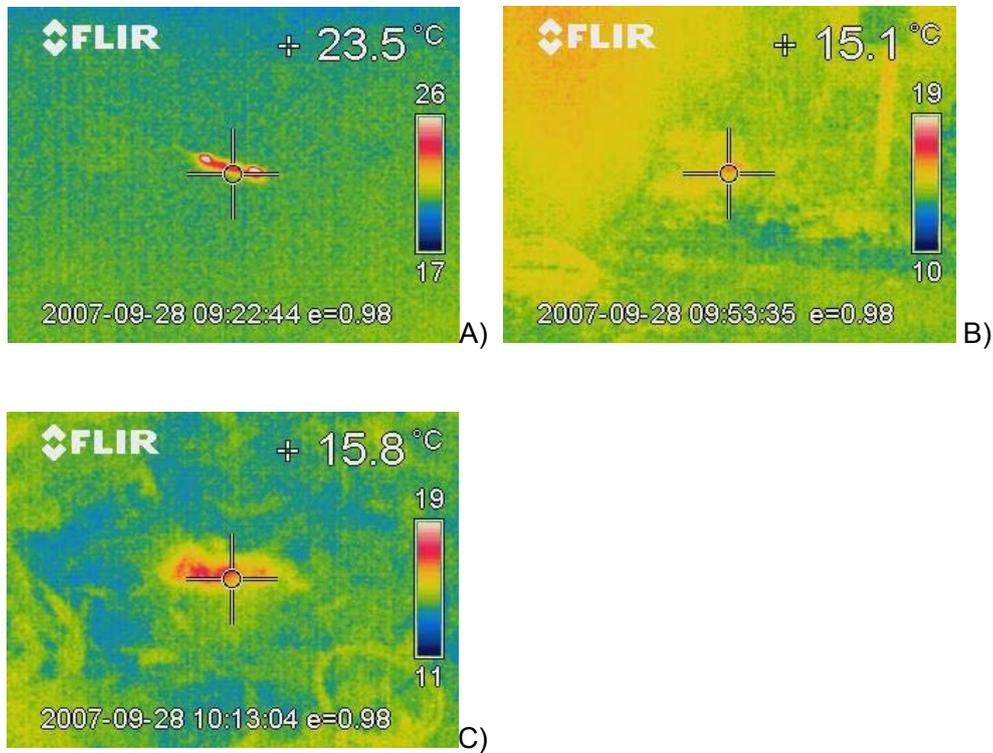


Fig. 2. IR images of test sample source simulating heat production of strong gamma source (Heat power 0.7 W)

A) - source on the wood flour; B) - source on the surface of wet soil ; C) - source in soil, depth 5 cm, after 10 min of presence in soil.

Visualization of radioactive sources without gamma-radiation/ uv imaging systems

In designing an imaging system capable of remotely displaying of alpha contamination it is difficult to rely directly on alpha particles themselves because of their short range in air. One possible solution involves detecting secondary "conversion particles", resulting from alpha emission. The effective converter is the nitrogen molecule (N_2) that is abundant in the atmosphere of facilities during decommissioning. Under the effect of charged particles this molecule emits electromagnetic radiation with a discrete spectrum, particularly in the near ultraviolet (wavelength - 280–390 nm) (see Fig 3.) These emissions are characterized by their fluorescence efficiency, defined as the ratio of the radiated energy to the energy lost by the incident particle.

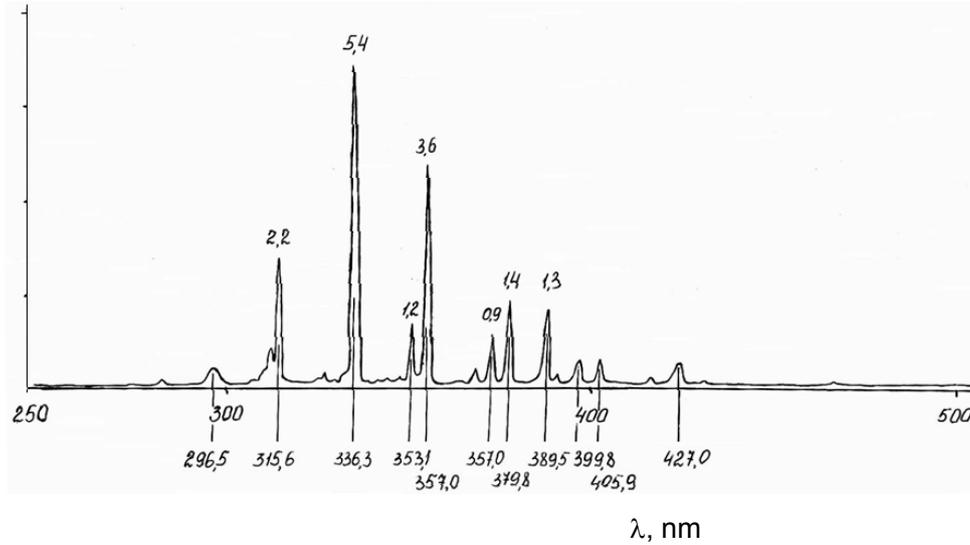


Fig. 3 Luminescence spectra of air for excitation by Cm-244 source with activity 100 mCi. Number at lines are their corresponding luminescence $\times 10^5$.

The fluorescence efficiency was quantified with several types of exciting radiation (Table I) on pure nitrogen and air. It was lower in air because of the quenching effect of oxygen. According to this physical process, α - particles react with nitrogen in the air to produce an emission of ultraviolet photons. The number of UV photons emitted varies according to the energy of the α - particles and the temperature and pressure conditions (30 UV photons per α for ^{239}Pu). The emission is relatively concentrated around the radioactive source because of the short range length of α - radiation. However, the long mean free range length in air of UV radiation at these energies (several tens of meters) allows remote detection. This emission can thus be used to form remote images of the alpha radioactivity [5].

Wavelength (nm)	Electrons, 1.4 MeV	Electrons, 50 keV	Deuterons, 4 MeV
337.1	$2.10 \cdot 10^{-5}$	$2.10 \cdot 10^{-5}$	$1.50 \cdot 10^{-5}$
357.7	$2.20 \cdot 10^{-5}$	$1.50 \cdot 10^{-5}$	$1.20 \cdot 10^{-5}$
391.4	$0.84 \cdot 10^{-5}$	$0.70 \cdot 10^{-5}$	$0.43 \cdot 10^{-5}$

Table I: Fluorescence efficiency for main emission wavelengths of nitrogen molecule in air and for different charged particles.

Using sensitive CCD cameras research team of CEA-Marcoule have developed "alpha – imaging" system for mapping contamination [6,7]. This UV camera has sensitivity for detection of $400\text{Bq}/\text{cm}^2$ surface alpha source in 10 minutes at total darkness

There are industrial UV imaging camera based on new solar blind UV photocathodes which can produce imaging of UV luminescence of air in day light [8,9]

Cameras are applied as pinpoint sources of surface partial discharge, corona and arcing in full daylight and at almost any weather condition.

We have tested these cameras for imaging of radioactive alpha and beta sources/ Some results are present in Fig. 4.

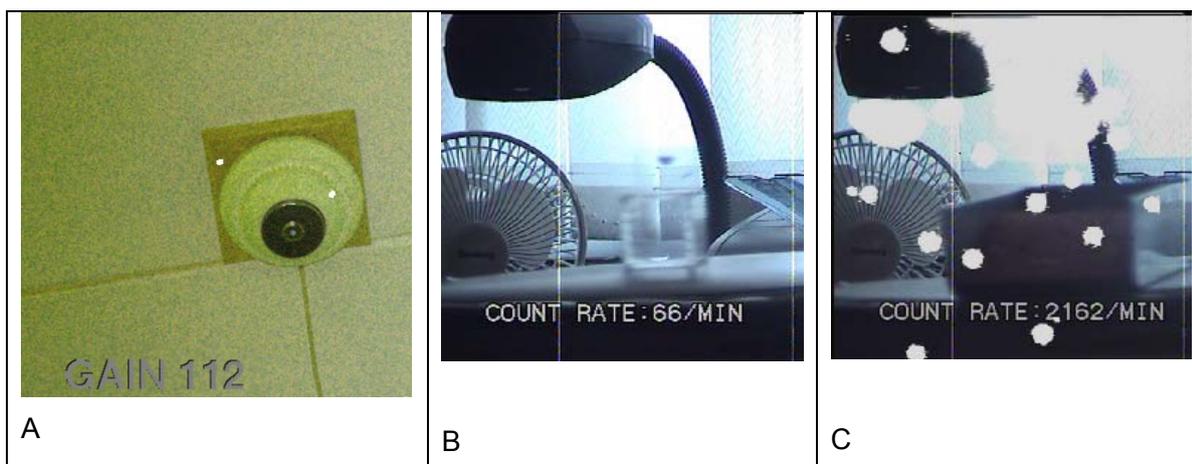


Fig. 4 A: UV image of alpha source in fire alarm probe made with CoroCam camera; B: Background signal in laboratory and C: Signal at presence of 16 kBq beta source ^{40}K (in K nutrition) in device's FOV (DayCor camera).

UV imaging devices parameters:

FOV for detecting in UV spectral region is $8^\circ \times 6^\circ$. The optical FOV is about $48^\circ \times 36^\circ$

DayCor SUPERB[8] UV sensitivity $3 \times 10^{-18} \text{ W/cm}^2$ enables detection and displaying corona emission as weak as 1.5pC at distance 8m, and capture moving targets without smearing the output image. Built in UV counter and display for estimation of the corona strength.

Instruments sensitivity for alpha contamination registration in terms of minimum measurable activities (MMA) have been estimated and presented in table II. (MMA) are estimated according to [10]

Measurement time, sec	$A_p, 10^4 \text{ Bq}$	$A_s, \text{ Bq/cm}^2$
10	8	800
60	3	300
600	1	100
3600	0.5	40

Table 2: Estimated sensitivity of UV imager for search of alpha contamination ($E_\alpha \sim 5 \text{ MeV}$)

The manufactures of UV cameras consider combined IR and UV - complementary inspection technologies. Their arguments are the following [8]:

- Infra Red (IR) thermography detects **hot spots** and indicates temperature difference
- The IR technology **does not locate corona**

- Some severe corona and arcing activity cases in transmission may generate enough heat so it can be located with IR equipment but these may be revealed in **advanced stages of degradation** where corrective action may be too late
- In distribution usually **heavy line loading** is requested which makes it inconvenient and sometimes even impractical procedure for inspection of distribution lines
- Corona and arcing occur by stress of the electric field and is **not current dependent** and therefore can be revealed by UV inspection and not by thermographic equipment
- In cases where severe corona or arcing evolves temperature gradient lighting and **weather conditions** may set limitation to the inspection
- Bright light and humid or foggy conditions may **obscure the visibility** of the thermal gradient
- Partial discharges in **motor and dry transformer coils** and windings will be located by UV inspection and not by the IR camera.
- **Internal defects** in the transmission and distribution cables, components and insulators will be mainly exhibited as hot spots and thermal gradients and will not be revealed by UV inspection.
- **Strong arcing** emits both UV and IR.
- Corona is a **blinking flickering event** and to capture it a video camera is a must. IR can do with stills camera.

The IR thermographic technology and the UV inspection technology are **complementary** and both are therefore required in a well established predictive maintenance procedure in transmission distribution and substations and in commissioning stages of new installations.

The same is true and for search and mapping of radioactive contamination. Alpha decay in volume of sample will produce heating, additional IR radiation and image in thermographic picture, but surface contamination will produce UV radiation of air. So using of two range for imaging will produce more reliable mapping.

Ways of application of uv imaging systems

We can propose some actual areas for using UV imaging systems for search and mapping of alpha and beta ray sources where they may be very effective.

That such RITEGs

One of applications of peace atom - production of the electric power on the basis of disintegration of radioactive strontium in radioisotopic thermoelectric generators (RITEG) for power supply of beacons, radio-beacon stations and meteo-stations, placed in the distant deserted places and not requiring presence of staff.

Unique in Russia the organization, which develops, produces, realizes overhaul, modernization and extension of life expectancies RITEGs, - All-Russia research and development institute of

technical physics and automation. The institute delivers RITEGs to different departments, organizations and firms. The main customers RITEGs in Russia are DoD, Ministry of Transportation, Government Committee of HydroMeteorology and Ministry of Geology.

So, in hydrographic firm of department of a sea transport Ministry of Transportation now is present 386 RITEGs, used for support by the electric power of coastal navigation resources in the remote and hard-to-reach places of coast of Arctic Region. In the ministry of a defense there are 535 RITEGs.

Radioisotopic sources of heat (RSH) in all RITEGs are made on the basis of strontium - 90 (period of radioactive half-decay –29.1 years). Depending on a RITEG's type in each of them is contained from 5 000 up to 350 000 Ci, the common activity issued RITEGs with allowance for of derived radionuclide of yttrium - 90 makes about 100 millions Curies. For matching: the total activity of all radionuclides which have dropped out on ground as a result of a crash on Chernobyl NPP, has made about 50 millions Curies.

In former USSR for RITEGs was carried out a constant control. Up to a pore before time...

Along coasts of Sakhalin and Kuril islands is located about 70 beacons having RITEGs. Some of them are in an abnormal status. Government Committee of Ecology offered to conduct inspection all RITEGs. Unfortunately, neither from the governor, nor from regional authorities no answers how to do till now...

The UV imaging systems are very good instrument to carry out this project.

Seach for contamination of surfaces and soil

An old plant for uranium and plutonium processing may have areas with strong contamination of different radionuclides and often they have low level of gamma contamination. But levels of beta and alpha contamination is high enough for application of UV imaging systems. So these objects may be efficient area for application of proposed systems.

Discussion and conclusions

In work the ways of visualization of alpha radiating radioactive sources on ultra-violet radiation arising as a result of interaction of alpha radiation with molecules of nitrogen of atmospheric air are considered. The estimations of sensitivity of a method are carried out. The devices developed around the world, for visualization of alpha sources and UV imaging are described, the examples of the images, received with them are given. The devices used for imaging of alpha sources have a number of the essential lacks determining their limited application. To them concern, first of all, low sensitivity, impossibility of work in day time, insufficiently evident information.

The registration of the image in ultra-violet beams is urgent not only at visualization of alpha radiating objects. In last some years have appeared new industrial ultra-violet cameras not sensitive to day time light. Such ultra-violet cameras are effectively used at detecting of corona discharges on high-voltage transmission lines.

In the given work the features of the device and basic technical parameters of modern industrial ultra-violet cameras, and also examples of the images received with the help of these cameras are considered. The most known industrial portable ultra-violet cameras are South-Africa devices CoroCam IV+, CoroCam 504, and Israeli UV cameras of various configurations from family DayCor. The cameras are convenient in operation, as their weight is insignificant and makes approximately 3.5 kg.

Besides the basic nitric spectral lines in a range 300-400 nm the small part UV of radiation gets in a range 230-290 nm. In this spectral range the radiation of the Sun is completely suppressed by an ozone layer of an atmosphere. It allows complete filtering of solar light. For increase of sensitivity the ultra-violet radiation amplifies with the help of electron-optical converters (image intensifiers-ImIn). In particular on devices CoroCam is used image intensifiers with Cs-Te type photocathode. The efficiency of photon transformation in photoelectrons in working area of a spectrum is in this case 18 %. The two-step microchannel plate (MCP) increases a weak signal in 2 million times. Photoelectrons induced light is read out by the standard CCD camera.

Because of using of MCP based ImIns the industrial UVcamera have enough high sensitivity. So the sensitivity of DayCor series cameras is $3 \cdot 10^{-18}$ W/cm².

The analysis carried out shows, that such sensitivity is enough for visualization of strong enough, alpha sources without additional updating of industrial ultra-violet cameras. Thus for a point source of alpha radiation (typical energy of rays $E_{\alpha} = 5\text{MeV}$) located on distance 3 m activity for which it can be found out is equal 10^5Bq . Homogeneous surface contamination, which can be revealed is 300 Bq/cm².

It is necessary to note, that the sensitivity of industrial UV cameras can essentially be increased if to increase time of an exposition of the light readout devices (CCD cameras) of the UV channel up to tens minutes. It is possible for carrying out by various ways, and the work on updating cameras in such a way is very perspective and important.

At measurements with accumulation of a signal, at time of an exposition 600 sec it is possible to expect, that for a dot source of alpha radiation ($E_{\alpha} = 5\text{MeV}$) located on distance 3 m the activity, at which it can be found out, is equal 10^4Bq . Homogeneous superficial pollution, which can be revealed in this case makes 100 Bq/cm².

The received results, undoubtedly, present significant interest for search and visualization of alpha sources pollution. Therefore works on development of a method of application of available UV cameras for search and mapping of alpha pollution should be continued. The researches of their opportunities for mapping of pollution by sources of alpha radiation in real conditions should be carried out at complex nuclide structure of contamination source, containing alongside with alpha, beta and gamma irradiators. It is required to investigate also possible achievable sensitivity of cameras at use of tool and program ways of increase of effective time of an exposition and development of the methodical instructions on application of such modified systems for realization of inspections at a conclusion from operation of objects of nuclear industry.

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