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Terminology of electro-optical technology

In spite of relatively long traditions of electro-optical technology there are still no internationally accepted terminology standards in most areas of this technology. At present, only terminology related to quantities of optical radiation and detectors of this radiation is relatively well standardized in the International Lighting Vocabulary published by the International Lighting Commission CIE and the International Electrotechnical Commission CIE in 1987. However, there are vast areas of this technology where terminology is not standardized. It results in situation when different authors use different terminology describing non-contact thermometers in scientific papers, manuals and catalogues making them difficult to understand. There are many terms that are not precisely defined or there are often a few names of the same system. Such a situation is particularly difficult for newcomers to this technology and non-native English speakers. Here we will present some examples of this confusion in electro-optical technology.

First, two different definitions of the term "electro-optical technology" are shown in Tab.1. Please note that in this site we use the first definition and assume that "electro-optical imaging system" means both visible imaging system and infrared imaging systems in contrast to some literature sources that exclude infrared systems from electro-optical technology. Example: popular The Infrared and Electro-Optical Systems Handbook, SPIE 1993.

Tab. 1. Different definitions of the term "electro-optical technology

1	A technology that use conversion of optical radiation into electrical signal (wider interpretation). Equivalent terms: photonics (popular in USA), optoelectronics (popular in Europe), optronics (popular in France, Belgium, Netherlands)
2	A technology that use conversion of visible radiation into electrical signal (narrower interpretation due to historical reasons as the first E-O systems were systems of spectral bands located in the visible range). Equivalent terms: image intensifier technology

Second, thermal imaging is one of the most important parts of electro-optical technology. Thermal imaging system can be defined as a system that created an image of the objects using thermal radiation emitted by these object. Because typical objects emits mostly within the spectral range 3-15 μm, thermal imaging systems can be also called infrared imaging systems as used in this web. However, it is possible to find in literature a dozen or so of different equivalent names of the earlier defined thermal imaging system. There are sometimes subtle differences in meaning of the terms presented in Tab. 2 but basically their meaning is the same.

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Tab. 2. Equivalent names of thermal imaging system

1	thermal imaging system	8	thermal imaging camera
2	infrared imaging system	9	thermal viewer
3	thermal camera	10	infrared viewer
4	FLIR (forward looking infrared)	11	thermal data viewer
5	infrared imaging radiometer	12	thermal video system
6	thermograph	13	
7	thermovision	14	

Third, we can meet in literature different definitions of the infrared range, the visible range or different divisions of the infrared range.

According to the International Lighting Vocabulary published by International Lighting Commission CIE and the International Electrotechnical Commission CIE considered nowadays as an international primary authority on terminology in radiometry, electromagnetic radiation between radio radiation and X radiation is termed the optical radiation. Thus, the optical radiation can be defined as radiation of wavelengths higher than about 1 nm and lower than about 1 mm.

The range of optical radiation is divided into 3 sub-ranges: infrared radiation, visible radiation and ultraviolet radiation. Thermal radiation can be emitted in all three sub-ranges of optical radiation. In fact it is also emitted and can be detected in one of sub-ranges of radio radiation: the microwave radiation. However, for typical temperatures met on the Earth almost all thermal radiation is emitted within the infrared range. Therefore, thermal radiation is often called infrared radiation and vice versa. Such a situation commonly met in literature but can be sometimes very misleading.

There have not been presented so far precise limits of optical radiation or limits of its sub-ranges in international standards. There was presented in the International Lighting Vocabulary of CIE a proposal of division of optical radiation but not as compulsory division but only as a recommended division [Tab. 3]. Additionally, in case of visible radiation, due to human diversity, only approximate limits were given. Next, what is even more important, the CIE recommendations are not accepted in many communities working in the field of optical radiation due to many, mostly historical reasons.

Tab. 3. Division of optical radiation recommended by the CIE

Name	Wavelength range
UV-C	0.1 μm - 0.28 μm
UV-B	0.28 μm – 0.315 μm
UV-A	0.315 μm - 0.4 μm
VIS	approximately 0.36-0.4 μm to 0.76 -0.8μm
IR-A	0.78 μm - 1.4 μm
IR-B	1.4 μm – 3 μm
IR-C	3 μm - 1000 μm

Confusion in area of limits and further division of sub-ranges of optical radiation is particularly clear in case of infrared radiation range. There are many proposals of division of infrared range published in literature, only a few chosen ones are shown in Tab. 4.

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Tab. 4. Different divisions of infrared range proposed in literature

Nr	Source	Proposal
1	International Lighting Vocabulary of CIE	IR-A 0.78 μm - 1.4 μm IR-B 1.4 μm - 3 μm, IR-C 3 μm - 1000 μm
3	Guide for Spectroscopy - Catalog, Jobin Yvon, 1993.	Near IR - 0.65μm - 1.5μm Middle IR 1.5- 5μm, Far IR >5μm
4	The Photonics Spectrum Reference Wall Chart, Photonics Spectra, 1995	Near IR - 0.68μm -3μm Middle IR 3- 30μm, Far IR 30-1000 μm
5	Hudson R.D., Infrared System Engineering, John Wiley&Sons, 1969.	Near IR - 0. 76 μm –3 μm Middle IR 3- 6 μm, Far IR 6-15 μm Extremely Far IR >15 μm
6	Mc Graw-Hill Encyclopedia of Physics, ed. Sybil P. Parker, 1993. P. 570	IR radiation: 1μm-1000μm
7	ed. Robert M. Besancon, The encyclopedia of physics, Van Nostrand Reinhold Company,1974	IR radiation: 0.7μm -1000μm 0.7-1.5μm - near IR 1.5-20μm - intermediate IR 20-1000μm - far IR
8	www.FSI.com\meas.html	0.7 –100 μm The infrared band is often further subdivided into four smaller bands, the boundaries of which are also arbitrarily chosen. They include: the "near infrared" (0.75 - 3 μm), the "middle infrared" (3-6 μm), the "far infrared" (6-15 μm) and the "extreme infrared" (15-100 μm).
9	www.FSI.com\glossary.html	-SWIR band from about 0.7 μm to 1.1 μm (sentence from definition of infrared film) -MWIR -the middle infrared spectrum, usually from 2.4 to 7.0 microns. -Near Infrared(SWIR) - The shortest wavelength infrared radiation band - 0.7 to 1.4 μm. -Thermal Radiation - Electromagnetic energy whose natural wavelength fall between 0.7 and 100 microns.

Existing terminology of modern thermal cameras increases confusion in area of division of infrared range. So far, almost all thermal cameras have their spectral bands optimized for 3-5 μm or 8-12μm atmospheric windows. The cameras of 8-12 μm spectral band are usually called long-wavelength LW cameras. The 3-5 μm cameras should be more properly called mid-wave MW cameras. However, they are often termed “short-wave SW thermal cameras” as the real short-wave cameras almost do not exist.

Precise division of infrared radiation is important for a website dedicated to electro-optical technology as infrared technology is the core of the E-O technology. Therefore a precise division of infrared radiation shown in Tab. 5 will be mostly used in this website.

The division shown in Tab. 5 is based on limits of spectral bands of commonly used infrared detectors. Wavelength 1 μm is a sensitivity limit of popular Si detectors. Similarly wavelength of 3 μm is a long-wave sensitivity limit of PbS and InGaAs detectors; wavelength 6 μm is a sensitivity

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limit of InSb, PbSe, PtSi detectors and HgCdTe detectors optimised for 3-5μm atmospheric window; and finally wavelength 15 μm is a long-wave sensitivity limit of HgCdTe detectors optimised for 8-12 μm atmospheric window.

Tab. 5. Division of infrared radiation used in website

Name	**Wavelength range**
near infrared NIR	0.78 μm - 1 μm
short wave infrared SWIR	1 μm - 3 μm
mid-wave infrared MWIR	3 μm - 6 μm
long-wave infrared LWIR	6 -15 μm
very long-wave infrared VLWIR	15 μm - 1000 μm

Fourth, if we assume that infrared imaging systems are all imaging systems of spectral bands located at least partially in the infrared range then both thermal imaging systems, image intensifier systems, intensified CCD cameras, monochrome CCD/CMOS cameras are infrared imaging systems. However, spectral bands of image intensifier systems, intensified CCD cameras, and monochrome CCD/CMOS cameras are only partially located in the infrared range and therefore the term infrared imaging systems is typically limited to thermal imaging systems. We have done the same in this website.

Fifth, it is not clear what really is “night vision device”. Thermal imaging systems enable observation at night conditions and should be considered as NVD. However, the first NVDs were image intensifier systems and now meaning of the term “night vision device” is usually limited to image intensifier system, and sometimes also to ICCD cameras.

We will finish now this list of examples of confusion in terminology of electro-optical technology, although it is possible to expand this list quite significantly.