



# More than pretty pictures

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Thermography camera makers and suppliers are discovering solar installers as a customer group. Most of the cameras we tested passed with a »B« grade; but there are considerable differences among them when it comes to features and user-friendliness

## o Highlights

- PHOTON Lab has put a number of thermography cameras to the test
- Of the 14 cameras tested, eight achieved a grade of »B«, two a »C« and two received a grade of »E«
- Three cameras were tested non-competitively without assigning a grade, because they did not fit all of our criteria
- Anybody who is considering purchasing a thermography camera should first clarify exactly how it will be used. Not every »B« grade camera we tested is equally good for every application

Thermography cameras are enjoying increasing popularity among solar installers – and rightly so, as our overview and testing demonstrate. Less than 5 years ago, a usable thermography camera still cost over €50,000 (\$68,350) – and installers deployed them as technical aids with an infrequency commensurate with their price. Since then, however, a whole slew of decent cameras have become available for under €10,000 (\$13,670). Furthermore, camera manufacturers have discovered solar installers as an attractive customer base and have adapted their product lines to this new niche market. This is necessary because requirements in the solar industry are different from those in the building sector. Testo AG, for example, offers a special solar mode for its thermal imagers (see also the test report in online edition on p. 138\*).

Which camera is the best choice in each case, however, depends primarily on how it will be used. A small, inexpensive camera is adequate for detecting faults in entire strings (caused by shading or bad connections), whereas a model in the middle of the range would additionally be able to identify hot bypass diodes. If you also want to be able to detect cracks in cells and hot spots as small as a square centimeter, you will need a camera with resolution of at least 640 × 480 pixels, which, however, will cost well over €10,000 (\$13,671). For example, the VarioCAM hr inspect 600/700 Series from Jenoptik AG, which boasts that kind of resolution, goes for €18,950 (net) (\$25,906). And from there upward, there is hardly any limit on how much you can pay. For a solar installer who just wants to check his modules quickly, or somebody working for insurance compa-

◀ We tested 14 thermography cameras for this overview. The champion is the Testo 885 with optional »SuperResolution«, which PHOTON Lab's Juliane Hinz is holding in her hands.

▶ The CS 110 from Dias Infrared GmbH served as the calibration source for the test.



Frank Schuberth / photon-pictures.com (2)

nies and who often inspects large installations (and whose reports should be able to stand up in court if necessary), a lower resolution is sufficient. The installer would probably even be well served with the inexpensive i7 from Flir Systems GmbH (even though the manufacturer expressly states that this camera is not intended for use with PV), whereas the engineer working for an insurance would do better with a Testo 890.

Resolution isn't everything, however. Different cameras may have the same resolution, but where one can distinguish certain structures, the other cannot.

Also important to consider when selecting a camera are its features: Does the camera allow for manual focusing? How about auto focus? Does it have an adaptor for attaching it to a tripod? There are big differences among brands when it comes to accessories, as well. It can

make sense to start with the base model of an inexpensive camera and then buy additional, interchangeable lenses later when the need arises (and money is available). Since lenses with continuously variable focal length (zoom lenses) do not work with thermography cameras, interchangeable lenses are the best way to adapt your thermal imaging camera to frequently changing situations or to expand your range of application over time. The ideal is,

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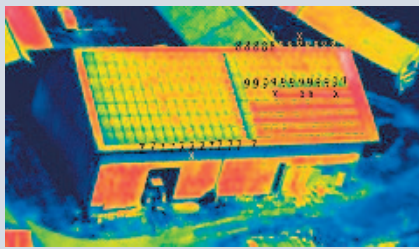
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## Caution when interpreting thermal images

This thermal image was used in a magazine article entitled »Massive Bungling of Solar Installations«. But what does the image really show? We see a picture of a barn roof with an incomplete PV installation. We can clearly make out the roof shingles around the edges, as well as the missing modules on the lower right side of the roof. A spot in front and to the left looks like the coolest area, which could be due to the fact that it's facing downwind. The numbers and crosses are unusual in a thermal image and may have been caused by an imaging or exporting error. Furthermore, the distance to the object is too great. The red dots are very noticeable, but to hazard a guess as



to their cause from afar and without additional information would be inappropriate.

The dots could be a symptom of poor installation, but they could also be shadows cast by dirt that have led to localized hot spots. In any event,

we cannot make a diagnosis of »bungling« on the basis of this image alone since many of the contextual parameters are missing -the general weather data and environmental conditions, the temperature scale (do the false colors represent temperature differences of 2 or 20 K?), the camera inputs (e.g. emissivity), the true-color visual image for purposes of comparison (e.g. to recognize dirt) as well as information about the condition of the installation: Is it still under construction and therefore not connected? All of these unanswered questions mean that, for the reader of the article, the colorful photo really serves no purpose other than decorative. ●jhz

of course, to combine interchangeable lenses with higher detector resolution.

The range of available accessories can thus definitely become a criterion when deciding which camera to buy. Fluke Corp., for example, offers quite a small selection of accessories, which (at least on their website) we also found a bit confusing. Competitor Flir, on the other hand, has a rich assortment of accessories that are clearly presented on its website, so you can find what you want easily.

### More choices

Our current market overview lists 34 thermography cameras (including those we tested), of which five are priced over €10,000 (\$13,670). This means that there are more cameras than ever to choose from (see table, p. 70 - 83).

Despite the wide-ranging prices of cameras in the market overview, all of the devices listed there are actually in the lower price segment: Thermography cameras designed for scientific or military use have infrared light sensors and employ expensive, sensor-cooling technology. Such devices cost tens of thousands of euros,

so unless you have money to burn, you do not need to consider them. Moreover, for the needs of a solar installer, they are really overkill. The inexpensive mobile devices listed in the overview, on the other hand, employ microbolometers, i.e. thermal resistors, as detectors. These measure infrared radiation indirectly.

Another important thing to consider in a camera is its resolution: At prices of €10,000 (\$13,670) and below, resolution reaches up to 320 × 240 pixels. We set a minimum detector resolution of 120 × 120 pixels as a requirement for inclusion in the overview. Good software is at least as important as a good camera, and in this area there were big distinctions among the various cameras. The most convenient software we tried is one currently being offered as an option by Flir called Reporter 9.0 (which, however, PHOTON Lab did not try out during testing, since for that purpose we always use the standard software version rather than any optional software). For €250 (\$342) extra, you get reporting software that uses templates, which means if s need to take new measurements on an installation, you do not have to compile a whole new report. You can save

previously compiled reports and use them as templates for other reports. The software automatically inserts the new thermal images in the existing report, and the analysis tools process the new data. The software supposedly utilizes the full functionality of Microsoft Word and also employs additional tools for creating panorama images as well as videos from image sequences.

### The trick to getting good images

»The biggest mistake a user can make is to take a blurry image,« says Michael Büttner from Testo AG. »If the measurement range has been correctly set and the image is sharp, all is well.« That may sound like a simple formula, but it does the trick. »Other factors, such as emissivity, can be set later in the software,« he says. As you can see, it can't hurt to become a little familiar with the technical aspects of thermal imaging. You should know, for example, the emissivity of the surface you are imaging, i.e. its ability to emit radiation (which also always depends on the viewing angle). The challenge lies in the fact that emissivities

## Selection criteria

The number and variety of thermography cameras available on the market today has made the selection process even more confusing than it was the last time PHOTON Lab compiled this market overview (the previous survey was only published in our national editions). These helpful instruments are employed in any number of fields, be it medicine, research or the construction industry. We must therefore

ask ourselves what the requirements are for thermography cameras used in the field of PV. In the end, we decided to stick with the criteria PHOTON Lab established in 2010 (see table). A major difference compared with the last market overview is that now there are considerably more models priced under €10,000 (\$13,700), which is the upper price limit for inclusion in the survey. ● jhz, ak

### Requirements for thermography cameras used by solar installers

Characteristic	Requirement
Temperature range	minus10 to plus100 °C
Thermal sensitivity (NETD)	0.1 °C or smaller
Temperature accuracy (absolute)	Deviation of no more than 5 percent
Operating temperature range	minus 10 to plus 40 °C
Protection type	IP 54
Frame rate	Higher than 5 Hz
Rechargeable battery run time	At least 2 hours
Sun shield for the LCD	Desirable
Autofocus	Desirable
Visual orientation (using reference point or photo)	Aided by a laser or (better) by a digital visual image
Weight	Up to 1.5 kg
Detector resolution	At least 120 × 120 pixels
Field of view (angle of view) of the lens	Less than 35 degrees
Services offered by the manufacturer	Desirable
Training courses provided by the manufacturer	Desirable
Price (net)	Under €10,000 (\$13,700)

can be different for different surfaces, but most cameras only allow a single emissivity setting for an entire image. In the »solar power« area of application, the frames of solar modules as well as mounting hardware can cause problems because of their very low emissivities. Smooth surfaces like these can moreover reflect infrared radiation.

Another prerequisite for producing a good image is sunny weather. A solar irradiation level of approximately 500 W per m<sup>2</sup> can serve as a

benchmark value for ensuring adequate current and thus also meaningful and visible temperature differences. For our tests, we maintained irradiation levels between 500 and 700 W.

During the actual imaging measurement, the orientation of the camera itself plays an important role. The camera lens should ideally be positioned so that its line of sight is perpendicular to the solar module. However, this would lead to the camera picking up its own reflections. So, instead, the camera should be positioned just

shy of perpendicular. The angle of the camera to the normal axis, i.e. the perpendicular axis over the module, should be no greater than 30 degrees in order to keep angle-related measurement errors to a minimum. The sun, too, should be kept out of the picture in the literal sense. The sun not only can cause measurement errors but can also damage the camera sensor irreversibly, which would amount to a total loss. The sensor is vulnerable even when the camera is off, so the lens should always be covered when not in use.

**SOLA** 众森

**EL**

**> 12M Pixel**

NEN

## PHOTON Lab's test procedures

The current round of thermography camera testing is the third time PHOTON Lab has conducted such tests and the first time we have assigned grades to the cameras (the previous tests were only published in our national PHOTON editions). We evaluated each device according to 13 different performance categories of varying weight. These categories are briefly described below. Some of the test results are detailed in the table on p. 66 - 69. These descriptions are intended to assist those of you interested in purchasing a thermography camera in deciding for yourselves which features are more important and which less so.

### Transport of the camera

In order to be able to use the camera as a mobile device, it should come with a robust carrying case with adequate padding and a snug fit that ensures its secure transport together with its accessories. Since the camera may be deployed on rooftops, it should also include some kind of belt, strap, shoulder bag or fanny pack so an installer can carry it onto roofs while keeping his hands free for climbing. If all of these requirements are met, the camera earns full points in this category, which is weighted at 5 percent of the total grade.

### The camera's look and feel

This has to do with our overall impression of the camera's workmanship: Are all of the parts firmly attached? Is anything creaky or loose? Plug connections are judged on how well they fit (snug or wiggly?), their depth and how easy or hard it is to plug and unplug them. With respect to the battery, we also look at how well it fits in its compartment, whether the compartment cover can be securely closed and whether it becomes bothersome when handling the camera due to protruding edges, for example. Points are also deducted if there is no battery compartment or if the battery is built into the camera and cannot be removed. The results of our evaluation in this category account for 2 percent of the total grade.

### Camera usability and handling

Is the camera intuitive to operate and are the input buttons and display symbols clear and easy to understand? If so, the camera earns points in this category. An easy-to-understand user manual that is helpful when problems arise is also good. We assess the reliability of the autofocus (if there is no autofocus, points are deducted) and the manual focus (simple is good). Since optics are sensitive and expensive, the camera should have a protective cover or cap that does not fall off the lens or stay behind in the carrying case when the



camera is taken out. We evaluate the camera's ergonomics, materials and weight as aspects of its overall comfort and ease of use. The results make up 12 percent of the total grade.

### Accessories and kit

Accessories include interchangeable lenses, tripod adapters, card readers, apps and much more. We paid special attention to the visual digital cameras since they are very useful when deployed in tandem with thermographic cameras outdoors. The visual image they produce serves as a frame of reference that helps in locating the problems detected in the thermal image. For this reason, failure of the manufacturer to incorporate a digital visual camera in his product not only earns a bad grade of unsatisfactory but even acts as a deal breaker or elimination criterion. This category makes up 5 percent of the total grade.

### Display

The camera is next to useless if its display is unreadable outdoors. Factors that affect read-

ability are the properties of the screen, viewing angle dependency, brightness and contrast. How sharply does the display show the thermal image? Does the display show all of the necessary basic information (battery status, date, time, emissivity and a scale that includes the temperature range), and can this, as well as additional information, be either hidden or unhidden as desired?

A display that is unreadable in the sun also counts as a deal breaker or elimination criterion. The results of our evaluation in this category contribute 22 percent to the total grade and so can influence overall test results appreciably.

### Power supply

Battery power and usability are both evaluated. The battery should be removable and easy to insert and remove. It is a plus if the camera includes either a simple charger or a station for charging multiple batteries with a charge status indicator. Ideally, the battery can also be charged while inside the camera. This category counts for 8 percent of the total grade.



Frank Schuberth / photon-pictures.com

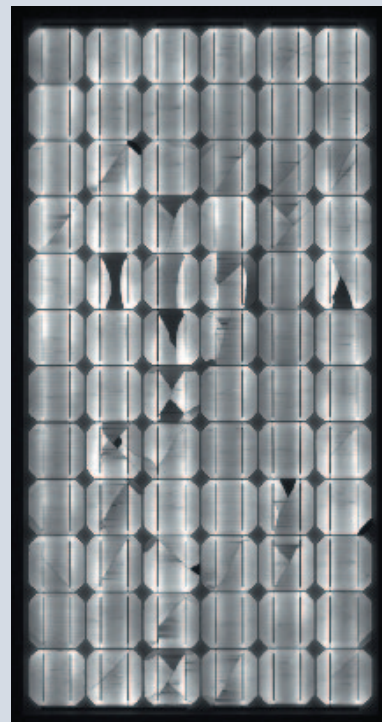
◀ Juliane Hinz and Johannes Neuenstein from PHOTON Lab conduct the »fault detection« test using a ground-mounted solar generator.

the battery run time when the camera is actually scanning and saving thermal images and with the display set to its brightest. If there is no extra battery included, run time must be at least 2 hours, otherwise, the camera flunks the whole test. This category contributes 7 percent of the total grade.

### Fault detection in an elevated PV generator

We use a single module as well as a string of multiple modules under an open sky. Measurements are taken at a minimum irradiation intensity of 500 W per m<sup>2</sup>, though irradiation is usually closer to our maximum of 700 W per m<sup>2</sup>. Cameras are tested on their ability to detect two abnormalities caused artificially before the test in two different module rows that are far apart: 1) shading caused by cardboard strips covering about a fifth of a single cell and 2) modules running in open-circuit condition. Both of these abnormalities produce heat that can be detected by a thermography camera. Once they succeed in detecting the problems, the cameras are also judged on the quality of their thermal images and how clearly the faults are depicted on the camera LCD and on a computer monitor with the help of the software. The results of this test account for 13 percent of the total grade.

### Imaging a single solar module



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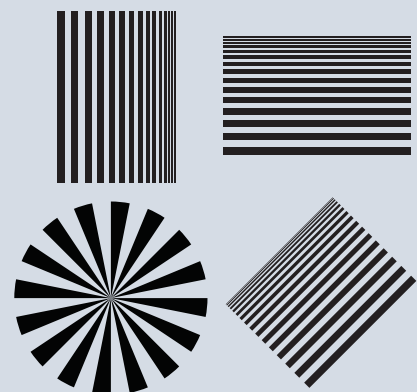
▲ Electroluminescence imaging of the test module.

Each camera must scan a single module, first in MPP operation and then while running in short-circuit. In both cases, a single cell has been partially shaded by artificial means. During MPP operation, the camera scans the partially shaded cell as well as the area of the junction box, while during short-circuit operation, it scans the partially shaded, heated cell of the handicapped module. A camera earns full credit for this test if, in both MPP and short-circuit operation, the shaded cell is clearly visible and the module's individual cells are clearly distinguishable. The results of this test are likewise weighted at 13 percent of the total grade.

### Using a blackbody calibration radiator to test temperature detection accuracy at different temperatures

An infrared calibration source is used to test the accuracy of temperature detection. The test analyzes how different contact temperatures influence the camera's ability to detect an object's radiative temperature accurately, which is important because thermography cameras are often used as mobile devices and are thus exposed to a wide range of contact as well as ambient temperatures. The measurements are taken using calibration source (contact) temperatures of 40 °C and 90 °C. The results of this test, however, are only weighted at 2 percent of the total grade because in the PV field, accurate detection of absolute temperatures is less important than detection of temperature differences.

### Using a line pattern to test camera resolution



graphic: PHOTON

A »target« (see figure) was used to test a camera's maximum resolution, which is reached when the temperature of the line pattern is no longer correctly depicted, i.e. when the temperature deviation is greater than measurement tolerances. The results of this test contribute 2 percent to a camera's overall grade. ● jhk, ak

### Software user-friendliness and analytical capabilities

Just as important as the actual camera is the software it uses to analyze thermal images and generate reports. The more the software has to offer and the easier it is to use, the better the grade in this category. If, for example, report generation is easy but the reports themselves are confusing, points are deducted. We only award the best grade when everything really clicks with the software. This category contributes 7 percent to the total grade.



### Data storage and transfer

Here we investigate the storage capacity of the SD card and which other kinds of storage media can be used. High marks are awarded if data transfer to a PC is fast and smooth. 2 percent of the total grade comes from this category.

### Battery run time

A long-lasting rechargeable battery is particularly important if you want to be able to take hassle-free thermal measurements in the field. We assess

## Test results thermography cameras

Manufacturer				Flir				Fluke	
Test category	Important for PV	Percentage of grade (%)	Grading scale	i7 <sup>3)</sup>	E30	E60	T440	TiR125	TiR32
<b>Transport of camera</b>									
Carrying case included	Yes	50	1/5	1	1	1	1	1	1
Camera and accessories can be transported securely		25	1 - 5	1	1	1	1	1	2
Shoulder bag, pack, strap or belt for hands-free transport included or available for purchase		25	1/5	1	1	1	1	1	1
<b>Category grade (or percentage of total grade)</b>		<b>5</b>		<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.3</b>
<b>Look and feel of camera (workmanship)</b>									
Housing	No	50	1 - 5	2	1	1	1	1	2
Plug connections		25	1 - 5	2	2	2	2	2	2
Battery / battery compartment		25	1 - 5	5	1	1	1	2	2
<b>Category grade (or percentage of total grade)</b>		<b>2</b>		<b>2.8</b>	<b>1.3</b>	<b>1.3</b>	<b>1.3</b>	<b>1.5</b>	<b>2.0</b>
<b>Usability and handling of camera</b>									
Intuitive operation	No	25	1 - 5	1	1	1	1	1	1
Understandable input buttons and display symbols		10	1 - 5	1	1	1	1	1	1
User manual easy to understand, helps solve problems		10	1 - 5	2	2	2	2	2	2
One-handed operation possible (exception: focusing)		5	1/5	1	1	1	1	1	1
Camera orientation adjustable: rotatable display, rotatable lens or pistol grip shape		5	1/3	3	3	3	1	1	3
Reliable autofocus		10	1 - 5	5	5	5	2	2	5
Simple manual focus		20	1 - 5	5	1	1	2	2	3
Lens protective cap stays on		10	1 - 5	1	1	1	2	2	1
Ergonomics of camera, comfort when carrying and holding		5	1 - 5	1	1	1	1	1	1
<b>Category grade (or percentage of total grade)</b>		<b>12</b>		<b>2.4</b>	<b>1.6</b>	<b>1.6</b>	<b>1.5</b>	<b>1.5</b>	<b>2.0</b>
<b>Accessories and kit</b>									
Integrated digital camera	Yes	40	1/5	 5	1	1	1	1	1
Integrated interfaces, both necessary and »nice to have«	No	25	1 - 5	2	1	1	1	1	2
Tripod adapter	No	10	1/3	3	1	1	1	1	1
Many accessories, both necessary and »nice to have« (interchangeable lenses, apps, etc.)	No	25	1 - 5	3	2	1	1	1	3
<b>Category grade (or percentage of total grade)</b>		<b>5</b>		<b>3.6</b>	<b>1.3</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.8</b>
<b>Display</b>									
Matte or glossy screen	Yes	11	1 - 5	2	2	2	2	2	4
Extra measurement spot markers, moveable hot/cold spot markers	No	5	1 - 5	5	5	3	2	2	2
Sharpness	Yes	10	1 - 5	3	3	2	2	2	3
Brightness	Yes	10	1 - 5	2	2	2	2	2	1
Contrast	Yes	10	1 - 5	2	2	2	2	2	2
Display's readability in the sun	Yes	17	1 - 5	3	3	3	3	3	3
Readability improved with a sun shield or viewfinder if available (display's view angle, suitability for those who wear glasses)	Yes	18	1 - 5	3	3	2	2	2	3
Objects in the environment are recognizable	Yes	5	1 - 5	1	1	1	1	1	2
Informational content	No	6	1 - 5	1	1	1	1	1	1
Viewing angle dependency	Yes	4	1 - 5	2	2	2	2	2	2
Number of thermal images and/or visual digital images that can be saved	No	4	1 - 5	1	1	1	1	1	1
<b>Category grade (or percentage of total grade)</b>		<b>22</b>		<b>2.5</b>	<b>2.5</b>	<b>2.1</b>	<b>2.0</b>	<b>2.0</b>	<b>2.5</b>
<b>Power supply</b>									
Battery charging time	No	30	1 - 5	2	2	2	2	2	1
Removable interchangeable batteries or only a built-in rechargeable battery	Yes	40	1/5	 5	1	1	1	1	1
Battery usability: ease of insertion/removal, charging station for multiple batteries	Yes	30	1 - 5	 5	1	1	2	2	1
<b>Category grade (or percentage of total grade)</b>		<b>8</b>		<b>4.1</b>	<b>1.3</b>	<b>1.3</b>	<b>1.6</b>	<b>1.6</b>	<b>1.0</b>

	HT		Infratec/ Jenoptik	Testboy	Testo			Trotec	
	THT44	THT49	580S	TV 309	876	885	885 SR	EC060 V	IC080 LV
1	1	1	1	1	1	1	1	5	1
2	1	1	1	1	1	1	1	4	1
1	1	1	1	1	1	1	1	5	1
<b>1.3</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>4.8</b>	<b>1.0</b>
2	3	3	1	4	2	3	3	4	4
3	2	2	2	3	2	2	2	2	2
2	3	3	3	3	1	1	1	4	3
<b>2.3</b>	<b>2.8</b>	<b>2.8</b>	<b>1.8</b>	<b>3.5</b>	<b>1.8</b>	<b>2.3</b>	<b>2.3</b>	<b>3.5</b>	<b>3.3</b>
2	4	4	3	3	2	2	2	3	3
2	3	3	3	3	2	3	3	3	3
2	3	3	1	3	1	1	1	4	4
1	1	1	1	1	1	1	1	1	1
3	3	3	1	1	1	1	1	1	1
5	4	5	2	5	5	4	4	5	5
1	4	1	2	1	1	1	1	4	3
1	4	2	1	2	1	3	3	1	1
1	2	2	4	3	3	4	4	4	3
<b>2.0</b>	<b>3.5</b>	<b>2.8</b>	<b>2.2</b>	<b>2.5</b>	<b>1.9</b>	<b>2.1</b>	<b>2.1</b>	<b>3.2</b>	<b>2.9</b>
1	1	1	1	1	1	1	1	1	1
5	2	2	3	2	2	2	2	2	2
3	3	3	1	3	1	1	1	1	3
4	3	3	2	3	1	2	2	3	3
<b>3.0</b>	<b>2.0</b>	<b>2.0</b>	<b>1.8</b>	<b>2.0</b>	<b>1.3</b>	<b>1.5</b>	<b>1.5</b>	<b>1.8</b>	<b>2.0</b>
4	4	4	1	4	2	4	4	4	4
3	4	4	2	2	2	2	2	2	2
1	4	3	1	3	3	1	1	2	2
2	4	4	2	3	2	1	1	2	3
2	4	4	1	3	2	1	1	3	3
3	⚠ 6	⚠ 6	2	3	3	2	2	3	4
3	⚠ 5	⚠ 5	1	3	3	2	2	2	3
2	4	3	1	3	2	1	1	4	4
2	4	4	2	3	1	1	1	2	2
3	4	4	3	4	3	2	2	4	3
1	1	1	1	1	1	1	1	1	1
<b>2.5</b>	<b>4.4</b>	<b>4.3</b>	<b>1.5</b>	<b>3.0</b>	<b>2.4</b>	<b>1.8</b>	<b>1.8</b>	<b>2.6</b>	<b>3.0</b>
1	2	2	1	2	1	1	1	2	2
1	1	1	1	1	1	1	1	5	5
1	3	3	2	3	1	1	1	4	4
<b>1.0</b>	<b>1.9</b>	<b>1.9</b>	<b>1.3</b>	<b>1.9</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>3.8</b>	<b>3.8</b>



▲ So many choices: Some users prefer cameras with pistol grips (here, the Fluke TiR32), while others swear by cameras with a rotatable display.

During thermal imaging, not only should direct and reflected sunlight be avoided, but there must also be no shadow falling on the module. The best weather and time for taking thermal images is a cloudless sky at midday when the sun is close to the module's normal axis. Then, the areas of camera reflection and the direct path of the sun's rays to be avoided largely overlap, leaving more space in which to position the camera. Alternately, at least with elevated modules, you can consider taking an image of the back of the module, which in principle should detect the same damage as would a frontal image. Images taken from the back are similar to those taken from the front because glass and foil both conduct heat. And an advantage of taking thermal images from the rear of the module is that you get a somewhat better view of the heat build-up in the junction box.


We strongly recommend receiving some introductory training in how to handle your thermography camera. Many manufacturers offer courses for this purpose, which people definitely should take advantage of. In the experience of Michael Mende, a salesman at Flir Systems, »Most energy consultants cannot operate the cameras.« Mende adds that the training is »very relevant and extensive« because, while it is easy to take a colorful picture, it is much more challenging to take a truly meaningful thermal image and then to interpret it correctly (see box, p. 62).

### Encouraging test results

The manufacturers of 14 of the cameras listed in the market survey made their cameras available to PHOTON Lab for testing. We required that every camera tested be the manufacturer's



## Test results thermography cameras

Manufacturer				Flir				Fluke		
	Test category	Important for PV	Percentage of grade (%)	Grading scale	i7 <sup>3)</sup>	E30	E60	T440	TiR125	TiR32
<b>Software user-friendliness and analytical capabilities</b>										
Easy installation	No	9	1 - 5	1	1	1	1	1	1	1
Intuitive operation		15	1 - 5	1	1	1	1	1	1	1
Menu navigation clearly structured		9	1 - 5	1	1	1	1	1	1	1
User manual understandable, helps solve problems		15	1 - 5	2	2	2	2	2	3	
Software (automatic) updates included in purchase price		9	1 - 5	1	1	1	1	1	1	1
Raw data remain accessible		4	1/5	5	5	5	5	5	1	1
Extra measurement spot markers, moveable hot/cold spot markers		15	1 - 5	2	2	2	2	2	1	1
Informational analysis and content		9	1 - 5	2	2	2	2	2	1	1
Presentation of information / Report generation / Printing		15	1 - 5	2	2	2	2	2	2	2
<b>Category grade (or percentage of total grade)</b>		<b>7</b>			<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.5</b>
<b>Data storage and transfer</b>										
Time required to save one thermal image, easy to do or prone to error	No	50	1 - 5	1	2	1	1	1	3	
Time required to transfer data to a PC by cable with a card reader and SD card (fast = 1 sec. / slow = 10 sec.)		50	1/5	1	1	1	1	1	1	1
<b>Category grade (or percentage of total grade)</b>		<b>2</b>			<b>1.0</b>	<b>1.5</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>2.0</b>
<b>Battery run time</b>										
Under 1 hr: failing grade of 5; up to 2 hrs: grade is 4; up to 3 hrs: grade is 3; up to 4 hrs: grade is 2; over 4 hrs: grade is 1	Yes	100	1 - 5	1	2	2	2	2	1	
<b>Category grade (or percentage of total grade)</b>		<b>7</b>			<b>1.0</b>	<b>2.0</b>	<b>2.0</b>	<b>2.0</b>	<b>2.0</b>	<b>1.0</b>
<b>Fault detection in an elevated PV generator</b>										
Detecting a hot cell in the first and third module rows	Yes	50	1 - 5	2	2	2	-	-	2	
Detecting the open circuit module in the first and third rows		50	1 - 5	3	2	2	-	-	3	
<b>Category grade (or percentage of total grade)</b>		<b>13</b>			<b>2.5</b>	<b>2.0</b>	<b>2.0</b>	<b>-</b>	<b>2.5</b>	
<b>Imaging an individual module</b>										
Module in the MPP: Detecting and imaging a shaded cell	Yes	25	1 - 5	4	3	3	3	3	4	
Module in the MPP: Imaging structures, recognizing the individual cells of a module		25	1 - 5	3	3	3	3	3	3	
Module in short circuit: Detecting and imaging a shaded cell		25	1 - 5	1	1	1	1	1	1	
Module in short circuit: Imaging structures, recognizing the individual cells of a module		25	1 - 5	2	2	2	2	2	2	
<b>Category grade (or percentage of total grade)</b>		<b>13</b>			<b>2.5</b>	<b>2.3</b>	<b>2.3</b>	<b>2.3</b>	<b>2.5</b>	
<b>Test of temperature detection accuracy using a blackbody calibration radiator at different temperatures</b>										
Calibration at blackbody temperature of 23 °C: Grade is 1 if deviation is within tolerances; grade is 5 if deviation is outside of tolerances	No	40	1/5	1	1	1	1	1	1	1
Deviation at blackbody temperatures of 5 °C and 40 °C: < 0.5: grade is 1; 0.5 to < 1.0: grade is 2; 1.0 to < 1.5: grade is 3; 1.5 to < 2.5: grade is 4; ≥ 2.5: grade is 5		15	1 - 5	4	2	2	2	2	3	
Deviation at blackbody temperatures of 5 °C and 90 °C: < 0.5: grade is 1; 0.5 to < 1.0: grade is 2; 1.0 to < 1.5: grade is 3; 1.5 to < 2.5: grade is 4; ≥ 2.5: grade is 5		15	1 - 5	2	2	3	1	1	5	
Deviation at blackbody temperatures of 40 °C and 40 °C: < 0.5: grade is 1; 0.5 to < 1.0: grade is 2; 1.0 to < 1.5: grade is 3; 1.5 to < 2.5: grade is 4; ≥ 2.5: grade is 5		15	1 - 5	2	2	2	2	2	2	
Deviation at blackbody temperatures of 40 °C and 90 °C: < 0.5: grade is 1; 0.5 to < 1.0: grade is 2; 1.0 to < 1.5: grade is 3; 1.5 to < 2.5: grade is 4; ≥ 2.5: grade is 5		15	1 - 5	4	2	3	2	2	3	
<b>Category grade (or percentage of total grade)</b>		<b>2</b>			<b>2.2</b>	<b>1.6</b>	<b>1.9</b>	<b>1.5</b>	<b>2.4</b>	
<b>Test of camera resolution using a line pattern: When the temperature deviation is greater than measurement tolerances, resolution is no longer adequate</b>										
Vertical: Quality of image, grade for number of lines depicted: Grade 1: 13 or more; grade 2: 11 to 12; grade 3: 9 to 10; grade 4: 7 to 8, grade 5: < 7	No	100	1 - 5	3	4	2	-	-	3	
<b>Category grade (or percentage of total grade)</b>		<b>2</b>			<b>3.0</b>	<b>4.0</b>	<b>2.0</b>	<b>-</b>	<b>3.0</b>	
<b>Final grade not including deal-breaker criterion</b>		<b>100</b>	<b>-</b>		<b>-</b>	<b>1.9</b>	<b>1.8</b>	<b>-</b>	<b>2.0</b>	
<b>Final grade including deal-breaker criterion</b>					<b>-</b>	<b>1.9</b>	<b>1.8</b>	<b>-</b>	<b>2.0</b>	
<sup>1)</sup> Deviation from reference temperature greater than 4 K <sup>2)</sup> »SuperResolution« (SR) is ineffective with a tripod, category grade (grade 1.9) from model 885 used <sup>3)</sup> According the manufacturer, the camera is not recommended for PV application, therefore no final grade  = »deal breaker«, i.e. an elimination criterion (see article)										

HT		Infratec/ Jenoptik		Testboy	Testo			Trotec		
THT44	THT49	580S	TV 309	876	885	885 SR	EC060 V	IC080 LV		
1	1	1	1	2	1	1	1	5	5	
1	4	4	1	4	1	1	1	4	4	
1	4	4	1	4	1	1	1	4	4	
3	3	3	1	3	2	2	2	5	5	
1	2	2	2	1	1	1	1	4	4	
1	5	5	1	5	1	1	1	1	1	
1	3	3	1	2	2	2	2	3	3	
1	3	3	2	4	2	2	2	4	4	
2	4	4	3	4	2	2	2	4	4	
<b>1.5</b>	<b>3.2</b>	<b>3.2</b>	<b>1.5</b>	<b>3.1</b>	<b>1.5</b>	<b>1.5</b>	<b>1.5</b>	<b>4.0</b>	<b>4.0</b>	
3	3	3	3	2	3	3	3	2	2	
1	1	1	1	1	1	1	1	1	1	
<b>2.0</b>	<b>2.0</b>	<b>2.0</b>	<b>2.0</b>	<b>1.5</b>	<b>2.0</b>	<b>2.0</b>	<b>2.0</b>	<b>1.5</b>	<b>1.5</b>	
2	2	3	3	2	1	1	1	3	3	
<b>2.0</b>	<b>2.0</b>	<b>3.0</b>	<b>3.0</b>	<b>2.0</b>	<b>1.0</b>	<b>1.0</b>	<b>1.0</b>	<b>3.0</b>	<b>3.0</b>	
1	1	1	1	1	1	1	1	2	2	
3	3	2	2	2	3	2	1	3	2	
<b>2.0</b>	<b>2.0</b>	<b>1.5</b>	<b>1.5</b>	<b>1.5</b>	<b>2.0</b>	<b>1.5</b>	<b>1.0</b>	<b>2.5</b>	<b>2.0</b>	
3	4	3	3	3	3	3	3	3	3	
3	3	4	3	3	3	3	3	3	3	
1	1	1	1	1	1	1	1	1	1	
2	2	2	2	2	2	2	2	3	3	
<b>2.3</b>	<b>2.5</b>	<b>2.5</b>	<b>2.3</b>	<b>2.3</b>	<b>2.3</b>	<b>2.3</b>	<b>2.3</b>	<b>2.5</b>	<b>2.5</b>	
1	1	5	5	1	1	1	— <sup>2)</sup>	5	5	
2	5	5	3	4	1	2	—	4	5	
2	4	5	2	5	1	3	—	5	4	
4	5	4	2	2	1	1	—	4	3	
2	5	5	3	4	2	4	—	5	4	
<b>1.9</b>	<b>3.3</b>	<b>4.9</b>	<b>3.5</b>	<b>2.7</b>	<b>1.2</b>	<b>1.9</b>	<b>1.9</b>	<b>4.7</b>	<b>4.4</b>	
3	4	5 <sup>1)</sup>	2	5	4	3	2	5 <sup>1)</sup>	2	
<b>3.0</b>	<b>4.0</b>	<b>5.0</b>	<b>2.0</b>	<b>5.0</b>	<b>4.0</b>	<b>3.0</b>	<b>2.0</b>	<b>5.0</b>	<b>2.0</b>	
<b>2.1</b>	<b>2.9</b>	<b>2.8</b>	—	<b>2.4</b>	<b>1.8</b>	<b>1.7</b>	<b>1.6</b>	<b>3.0</b>	<b>2.8</b>	
<b>2.1</b>	<b>6.0</b>	<b>6.0</b>	—	<b>2.4</b>	<b>1.8</b>	<b>1.7</b>	<b>1.6</b>	<b>3.0</b>	<b>2.8</b>	

standard, mass-produced version rather than a custom version. This is even more important with thermography cameras than with most other devices we test because even without any hardware modifications, test results could be positively influenced through very careful and targeted calibration. All models have small tolerances, i.e. small possible deviations in calibration. In the case of the Testo 885, this kind of small deviation led to the randomly selected camera doing somewhat more poorly in the test of measurement precision than the manufacturer had expected. »Although the test values show we are within tolerances, I had hoped for a better result,« confided Cornel Rombach from the product management department of Testo AG. Rombach explained that the company's measurement engineering department had provided him with feedback and, as he told us, »the camera that went to you for the test was on the lower end with respect to measurement precision. But of course that is always possible when the camera used is not specially selected but is really any camera taken off the production line.«Each test report includes the thermal images taken and processed with the tested camera and software (for individual test reports see online version, p. 118 - 145\*). The images thus provide information about the overall system, consisting of the camera and its software, but do not allow you to draw any direct conclusions about the quality of the camera's optical system (lens and sensor). Furthermore, the files of the various analytical programs lack a unified standard for conversion to printable images, so you cannot compare them to each other in a very meaningful way.

We evaluated the cameras' handling and extra options as well, which vary a great deal from brand to brand and are also reflected in the price. In the end, good service is also vital, although we did not test it. Flir, for example, offers custom calibration of its cameras for the end user's intended area of application. There are also service agreements available that, among other things, ensure the delivery of a replacement camera within a certain timeframe if yours is being serviced. You will find our specific evaluation criteria in the box on p. 63.

In any event, the overall results of our tests are encouraging. Of the 14 cameras tested, we were happy to confer a grade of »B« on eight of them. And one of those eight, the test champion Testo 885 with optional »SuperResolution«, came within a hair's breadth of earning the highest possible grade of »A«. ●

#### Further information




Contacts page 94

For the market survey table, see p. 70 - 83.

\*The detailed product and test descriptions including thermography test images are exclusively available to subscribers in an extended PDF version (see appendix, p.118 - 145), which can be downloaded at [www.photon.info](http://www.photon.info).

## Thermography cameras survey

Manufacturer		Flir Systems	Flir Systems
Model		Flir i7	Flir E30
		Test report on page 122	Test report on page 118
			
<b>Possible PV applications</b>		Close-up imaging	All
<b>Problems the camera can detect</b>		All	All
<b>Camera usability and handling</b>			
Weight		365 g	825 g
Dimensions		223 × 79 × 83 mm	246 × 97 × 184 mm
Protection rating		IP 43	IP 54
Batteries interchangeable? / battery run time		Yes / 5 hours	Yes / 4 hours
<b>Data output and processing</b>			
Storage	Storage media	SD card	SD card
	Storage capacity	2 GB, > 10,000 images (JPEG radiometric)	2 GB, > 2,000 images (JPEG radiometric)
Interfaces (connectivity)		USB	USB, analog video, radiometric data streaming via USB, video via USB
<b>Additional measurement features</b>			
Laser positioning		No	With laser marker shown in the thermal image and corrected for parallax
(Digital) camera for visible light		No	Yes (2 megapixels)
Number of measuring points in display		19,600	19,200
Can emissivity be input?		Yes, manually and using a table	Yes, manually and using a table
<b>Specifications</b>			
Measurement temperature range		-20 to 250 °C	-20 to 120 °C
Operating temperature range		0 to 50 °C	-15 to 50 °C
Sensitivity (NETD)		100 mK at 30 °C	100 mK at 30 °C
Accuracy		±2 °C or 2 % of measured value	±2 °C or 2 % of measured value
Detector resolution		140 × 140 pixels	160 × 120 pixels
Field of view (FOV) with standard lens (H° × V°)		29° × 29°	25° × 19°
Frame rate		9 Hz	60 Hz
<b>Prices / Service / Availability</b>			
Price (before taxes) of standard configuration for installers		€ 2,095 (\$2,841)	€2,995 (\$4,061)
Lease option		Yes	Yes
Technical support		Hotline, direct service, 48-hour service, Web service, email	Hotline, direct service, 48-hour service, Web service, email
Warranty		24 months (camera w/o battery) / 120 months (detector)	24 months (camera w/o battery) / 120 months (detector)
Training		1-day training, 2-day training, certification course, onsite training	1-day training, 2-day training, certification course, onsite training
Calibration at factory with certificate included in delivery		Yes	Yes
Additional services		Service contracts available	Service contracts available
<b>Internet address</b>		www.flir.de	www.flir.de

Flir Systems Flir E40bx	Flir Systems Flir E50bx	Flir Systems Flir E60
		Test report on page 120 
All	All	All
All	All	All
825 g 246 × 97 × 184 mm IP 55 Yes / 4 hours	825 g 246 × 97 × 184 mm IP 55 Yes / 4 hours	825 g 246 × 97 × 184 mm IP 55 Yes / 4 hours
SD card 2 GB, > 1,500 images (JPEG radiometric)  USB, WLAN/WiFi, Bluetooth, analog video, radiometric data streaming via USB, video via USB, thermal images and video via WiFi, connection via Bluetooth for headset, current clamp meter and moisture measuring devices	SD card 2 GB, > 1,500 images (JPEG radiometric)  USB, WLAN/WiFi, Bluetooth, analog video, radiometric data streaming via USB, video via USB, thermal images and video via WiFi, connection via Bluetooth for headset, current clamp meter and moisture measuring devices	SD card 2 GB, > 1,500 images (JPEG radiometric)  USB, WLAN/WiFi, Bluetooth, analog video, radiometric data streaming via USB, video via USB, thermal images and video via WiFi, connection via Bluetooth for headset, current clamp meter and moisture measuring devices
With laser marker shown in the thermal image and corrected for parallax Yes (3.1 megapixels) 19,200 Yes, manually and using a table	With laser marker shown in the thermal image and corrected for parallax Yes (3.1 megapixels) 43,200 Yes, manually and using a table	With laser marker shown in the thermal image and corrected for parallax Yes (3.1 megapixels) 76,800 Yes, manually and using a table
-20 to 120 °C  -15 to 50 °C 45 mK at 30 °C  ±2 °C or 2 % of measured value  160 × 120 pixels 25° × 19° 60 Hz	-20 to 120 °C  -15 to 50 °C 45 mK at 30 °C  ±2 °C or 2 % of measured value  240 × 180 pixels 25° × 19° 60 Hz	-20 to 120 °C; 0 to 650 °C  -15 to 50 °C 45 mK at 30 °C  ±2 °C or 2 % of measured value  320 × 240 pixels 25° × 19° 60 Hz
€3,995 (\$5,418) Yes Hotline, direct service, 48-hour service, Web service, email 24 months (camera w/o battery) / 120 months (detector) 1-day training, 2-day training, certification course, onsite training  Yes Service contracts available	€5,495 (\$7,452) Yes Hotline, direct service, 48-hour service, Web service, email 24 months (camera w/o battery) / 120 months (detector) 1-day training, 2-day training, certification course, onsite training  Yes Service contracts available	€7,495 (\$10,165) Yes Hotline, direct service, 48-hour service, Web service, email 24 months (camera w/o battery) / 120 months (detector) 1-day training, 2-day training, certification course, onsite training  Yes Service contracts available
www.flir.de	www.flir.de	www.flir.de

Romana Brentjens / photon-pictures.com (5)

## Thermography cameras survey



Manufacturer		Flir Systems	Flir Systems
Model		Flir T420	Flir T440
		Test report on page 124	
			
<b>Possible PV applications</b>		All	All
<b>Problems the camera can detect</b>		All	All
<b>Camera usability and handling</b>			
Weight		880 g	880 g
Dimensions		106 × 201 × 125 mm	106 × 201 × 125 mm
Protection rating		IP 55	IP 55
Batteries interchangeable? / battery run time		Yes / 4 hours	Yes / 4 hours
<b>Data output and processing</b>			
Storage	Storage media	SD card	SD card
	Storage capacity	2 GB, > 1,500 images (JPEG radiometric)	2 GB, > 1,500 images (JPEG radiometric)
Interfaces (connectivity)		USB, WLAN/WiFi, Bluetooth, analog video, radiometric data streaming via USB, video via USB, thermal images and video via WiFi, connection via Bluetooth for headset, current clamp meter and moisture measuring devices	USB, WLAN/WiFi, Bluetooth, analog video, radiometric data streaming via USB, video via USB, thermal images and video via WiFi, connection via Bluetooth for headset, current clamp meter and moisture measuring devices
<b>Additional measurement features</b>			
Laser positioning		With laser marker shown in the thermal image and corrected for parallax	With laser marker shown in the thermal image and corrected for parallax
(Digital) camera for visible light		Yes (3.1 megapixels)	Yes (3.1 megapixels)
Number of measuring points in display		76,800	76,800
Can emissivity be input?		Yes, manually and using a table	Yes, manually and using a table
<b>Specifications</b>			
Measurement temperature range		-20 to 120 °C; 0 to 350 °C; 200 to 1,200 °C	-20 to 120 °C; 0 to 350 °C; 200 to 1,200 °C
Operating temperature range		-15 to 50 °C	-15 to 50 °C
Sensitivity (NETD)		45 mK at 30 °C	45 mK at 30 °C
Accuracy		±2 °C or 2 % of measured value	±2 °C or 2 % of measured value
Detector resolution		320 × 240 pixels	320 × 240 pixels
Field of view (FOV) with standard lens (H° × V°)		25° × 19°	25° × 19°
Frame rate		60 Hz	60 Hz
<b>Prices / Service / Availability</b>			
Price (before taxes) of standard configuration for installers		€8,950 (\$12,138)	€10,950 (\$14,850)
Lease option		Yes	Yes
Technical support		Hotline, direct service, 48-hour service, Web service, email	Hotline, direct service, 48-hour service, Web service, email
Warranty		24 months (camera w/o battery) / 120 months (detector)	24 months (camera w/o battery) / 120 months (detector)
Training		1-day training, 2-day training, certification course, onsite training	1-day training, 2-day training, certification course, onsite training
Calibration at factory with certificate included in delivery		Yes	Yes
Additional services		Service contracts available	Service contracts available
<b>Internet address</b>		www.flir.de	www.flir.de

Fluke TiR32	Fluke TiR125	HT Instruments THT41
Test report on page 128	Test report on page 126	
		
Close-up imaging, large installations, thermal images, visual images, fusion of thermal and visual images, picture in picture	Close-up imaging, large installations, thermal images, visual images, fusion of thermal and visual images	Individual modules, large installations
Shading, wiring problems, defective modules, hot spots, microfissures, faults in servo motors	Shading, wiring problems, defective modules, hot spots, microfissures, faults in servo motors	Shading, wiring problems, hot spots
1,050 g	730 g	730 g
277 × 122 × 170 mm	284 × 86 × 135 mm	240 × 111 × 124 mm
IP 54	IP 54	Unknown
Yes / > 4 hours	Yes / > 4 hours	Yes / > 2 hours
SD card	SD card	SD card
2 GB, > 3,000 images (non-radiometric, BMP or JPEG; or fully radiometric, IS2)	3 GB, > 3,000 images (non-radiometric, BMP or JPEG; or fully radiometric, IS2)	2 GB, max. 1,000 images (JPEG)
USB	USB	USB
No	Yes	No
Yes (2 megapixels)	Yes (2 megapixels)	No
Fully radiometric, every measuring point can be shown	Fully radiometric, every measuring point can be shown	2
Yes	Yes	Yes
-20 to 150 °C	-20 to 150 °C	-20 to 250 °C
-10 to 50 °C	-10 to 50 °C	-10 to 50 °C
≤ 40 mK	≤ 80 mK	Unknown
± 2 °C	± 2 °C	±2 °C or 2 % of measured value
320 × 240 pixels	160 × 120 pixels	Unknown
Unknown	22.5° × 31°	21° × 16°
9 Hz	9 Hz	50 Hz
€7,495 (\$10,165)	€4,995 (\$6,774)	€1,995 (\$2,706)
No	No	No
Hotline, email	Hotline, email	Hotline, email
24 months	24 months	24 months
Yes	Yes	Yes
No	No	Yes
Training videos, repair, calibration	Training videos, repair, calibration	Calibration protocol
www.fluke.de	www.fluke.de	www.ht-instruments.de

Romana Brengers / photon-pictures.com [3]

HT Instruments GmbH

## Thermography cameras survey

<b>Manufacturer</b>		<b>HT Instruments</b>	<b>HT Instruments</b>
<b>Model</b>		<b>THT44</b>	<b>THT49</b>
		Test report on page 130	Test report on page 132
			
<b>Possible PV applications</b>		Individual modules, large installations	Individual modules, large installations, close-up imaging, distance imaging
<b>Problems the camera can detect</b>		Shading, wiring problems, defective modules, hot spots	Shading, wiring problems, defective modules, hot spots
<b>Camera usability and handling</b>			
Weight		730 g	790 g
Dimensions		240 × 111 × 124 mm	252 × 182 × 112 mm
Protection rating		Unknown	Unknown
Batteries interchangeable? / battery run time		Yes / > 2 hours	Yes / > 2 hours
<b>Data output and processing</b>			
Storage	Storage media	SD card	Mini SD card
	Storage capacity	2 GB, max. 1,000 images or 55 minutes of video	4 GB, max. 1,000 images or 55 minutes of video
Interfaces (connectivity)		USB, HDMI video	USB, HDMI video
<b>Additional measurement features</b>			
Laser positioning		Yes	Yes
(Digital) camera for visible light		Yes (1,600 × 1,200 pixels)	Yes (1,600 × 1,200 pixels)
Number of measuring points in display		2	2
Can emissivity be input?		Yes	Yes
<b>Specifications</b>			
Measurement temperature range		-20 to 250 °C	-20 to 250 °C
Operating temperature range		-10 to 50 °C	-10 to 50 °C
Sensitivity (NETD)		Unknown	Unknown
Accuracy		±2 °C or 2 % of measured value	±2 °C or 2 % of measured value
Detector resolution		Unknown	Unknown
Field of view (FOV) with standard lens (H° × V°)		21° × 16°	22° × 16°
Frame rate		50 Hz PAL / 60 Hz NTSC	50 Hz PAL / 60 Hz NTSC
<b>Prices / Service / Availability</b>			
Price (before taxes) of standard configuration for installers		€3,695 (\$5,011)	€6,480 (\$8,788)
Lease option		No	Yes
Technical support		Hotline, email	Hotline, email
Warranty		24 months	24 months
Training		Yes	Yes
Calibration at factory with certificate included in delivery		Yes	Yes
Additional services		Calibration protocol	Calibration protocol
<b>Internet address</b>		<a href="http://www.ht-instruments.de">www.ht-instruments.de</a>	<a href="http://www.ht-instruments.de">www.ht-instruments.de</a>



ICO-Data S 80 HR	ICO-Data TI 160	ICO-Data TI 395
		
Close-up imaging, large installations	Close-up imaging, large installations	Close-up imaging, large installations
Shading, wiring problems, defective modules, hot spots, microfissures	Shading, wiring problems, defective modules, hot spots, microfissures	Shading, wiring problems, defective modules, hot spots, microfissures
700 g	650 g	393 g
82 × 125 × 95 mm	Unknown	128 × 62 × 154 mm
IP 54	IP 54	IP 54
Yes / 3 hours	Yes / 3 hours	Yes / 3 hours
Mini SD card	Built-in memory card	Mini SD card
Unknown	1,500 images	2 GB, 10,000 images
No	No	USB
Yes	Yes	Yes
Yes (640 × 480 pixels)	No	Yes (2 megapixels)
4	4	4
Yes	Yes	Yes
-20 to 250 °C, optional to 1,500 °C	-20 to 350 °C, optional to 1,200 °C	-20 to 350 °C, optional to 1,200 °C
Unknown	Unknown	Unknown
500 mK at 30 °C	650 mK at 30 °C	650 mK at 30 °C
±2 °C or 2 %, whichever is higher	±2 °C or 2 %, whichever is higher	±2 °C or 2 %, whichever is higher
384 × 288 pixels	160 × 120 pixels	384 × 288 pixels
24° × 18°	21° × 16°	21° × 16°
50 / 60 Hz	50 / 60 Hz	50 / 60 Hz
€4,995 (\$6,774)	€2,295 (\$3,113)	€5,995 (\$8,131)
Yes	Yes	Yes
Phone support from 8 am to 6 pm, email	Phone support from 8 am to 6 pm, email	Phone support from 8 am to 6 pm, email
12 months	12 months	12 months
Courses for operators, photovoltaic thermography and other courses	Courses for operators, photovoltaic thermography and other courses	Courses for operators, photovoltaic thermography and other courses
Yes	Yes	Yes
Calibration check, calibration	Calibration check, calibration	Calibration check, calibration
www.icodata.de	www.icodata.de	www.icodata.de

Romana Bräutigam / photon-pictures.com (2)

ICO-Data GmbH (8)

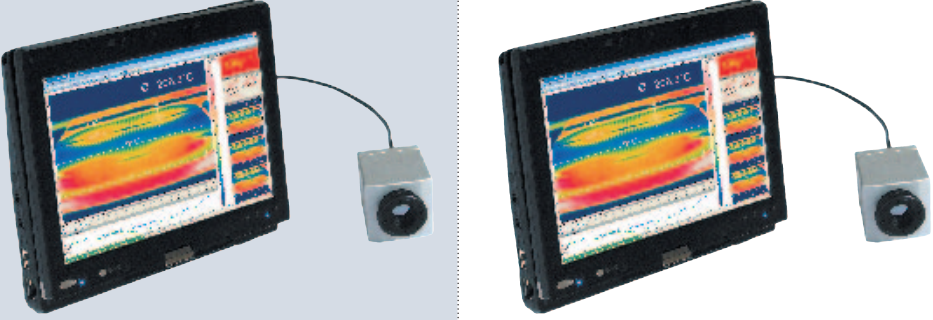


## Thermography cameras survey

Manufacturer		Infratec	Jenoptik
Model		MobileIR E9	VarioCAM hr inspect 400/500 series (2013 model)
			
			Test report on page 134
Possible PV applications		From close-up imaging to small installations	From close-up imaging to small installations
Problems the camera can detect		Shading, wiring problems, defective modules, hot spots, microfissures	Shading, wiring problems, defective modules, hot spots, microfissures
Camera usability and handling			
Weight		980 g (complete kit)	1,500 g (complete kit)
Dimensions		112 × 182 × 252 mm	133 × 106 × 110 mm
Protection rating		IP 54	IP 54
Batteries interchangeable? / battery run time		Yes / > 2 hours	Yes / > 3 - 5 hours
Data output and processing			
Storage	Storage media	SD card	SD card
	Storage capacity	4 GB, > 2,000 IR images	2 GB, > 2,000 IR images
Interfaces (connectivity)		USB	WLAN/WiFi, Bluetooth, FireWire, GPS receiver available as an option
Additional measurement features			
Laser positioning		Yes	Yes
(Digital) camera for visible light		Yes (1.92 megapixels)	Yes (1.3 megapixels)
Number of measuring points in display		2	10
Can emissivity be input?		Yes	Yes
Specifications			
Measurement temperature range		-20 to 250 °C	-40 to 600 °C
Operating temperature range		-10 to 50 °C	-15 to 50 °C
Sensitivity (NETD)		< 60 mK at 30 °C	< 30 mK at 30 °C
Accuracy		± 2 °C or ± 2 %	±1.5 °C or ±1.5 %, precision calibration of ±1 °C or ±1 % is available as an option
Detector resolution		384 × 288 pixels	384 × 288 pixels
Field of view (FOV) with standard lens (H° × V°)		22° × 16°	30° × 23°
Frame rate		50 Hz fully radiometric	60 Hz fully radiometric
Prices / Service / Availability			
Price (before taxes) of standard configuration for installers		From €6,800 (\$9,222)	From €11,950 (\$16,207)
Lease option		Yes	Yes
Technical support		24-hour hotline, direct service, email	24-hour hotline, direct service, email
Warranty		24 months	36 months
Training		Basic course, special courses in photovoltaic inspection, building thermography courses, software training, »Level 1« course	Basic course, special courses in photovoltaic inspection, software training, »Level 1« course
Calibration at factory with certificate included in delivery		Yes, a calibration certificate for the entire temperature measurement range is included in the standard scope of delivery	Yes, a calibration certificate for the entire temperature measurement range is included in the standard scope of delivery
Additional services		Calibration service, repair service, consultation and technical support	Calibration service, repair service, consultation and technical support
Internet address		www.infratec.de	www.infratec.de



Jenoptik VarioCAM hr inspect 600/700 series (2013 model)	Jenoptik VarioCAM HD inspect 800er/900 series	Optris Optris PI160
		
From close-up imaging to large installations (with high efficiency)	From close-up imaging to large installations (with highest efficiency)	Close-up imaging, cell flasher, large installations
Shading, wiring problems, defective modules, hot spots, microfissures	Shading, wiring problems, defective modules, hot spots, microfissures	Shading, defective modules, hot spots, microfissures
1,500 g (complete kit) 133 × 106 × 110 mm IP 54 Yes / > 3 - 5 hours	1,700 g (complete kit) 210 × 125 × 155 mm IP 54 Yes / > 3 hours	195 g 45 × 45 × 62 mm IP 65 Unknown
SD card 2 GB, > 2,000 IR images WLAN/WiFi, Bluetooth, FireWire, GPS receiver available as an option	SDHC card 4 GB, > 2,000 IR images USB, WLAN/WiFi, Bluetooth, GigE Vision interface standard, integrated GPS receiver	Unknown Unknown USB, Ethernet, extension optional
Yes Yes (1.3 megapixels) 10 Yes	Yes, a laser rangefinder is available as an option Yes (8 megapixels) 10 Yes	No No Unknown Yes
-40 to 1,200 °C -15 to 50 °C < 30 mK at 30 °C ±1.5 °C or ±1.5 %, precision calibration of ±1 °C or ±1 % is available as an option 640 × 480 pixels 30° × 23° 60 Hz fully radiometric	-40 to 1,200 °C -25 to 50 °C < 50 mK at 30 °C ±1.5 °C or ±1.5 %, precision calibration of ±1 °C or ±1 % is available as an option 1,024 × 768 pixels 32° × 24° 30 Hz with (1,024 × 768) IR pixels / 60 Hz with (640 × 480) IR pixels / 120 Hz with (384 × 288) IR pixels / 240 Hz with (1,024 × 96) IR pixels	-20 to 100 °C, 0 to 250 °C, 150 to 900 °C, additional range: 200 to 1,500 °C 0 to 50 °C 80 mK with 23° × 17° FOV / F = 0.8; 300 mK with 6° × 5° FOV / F = 1.6, 100 mK with 41° × 31° FOV and 72° × 52° FOV / F = 1 ±2 °C or ±2 % 160 × 120 pixels 23° × 17° 120 Hz
From €18,950 (\$25,700) Yes 24-hour hotline, direct service, email 36 months Basic course, special courses in photovoltaic inspection, building thermography courses, software training, »Level 1« course Yes, a calibration certificate for the entire temperature measurement range is included in the standard scope of delivery Calibration service, repair service, consultation and technical support	From €34,490 (\$46,776) Yes 24-hour hotline, direct service, email 36 months Camera and software training, basic course, special courses in photovoltaic inspection, building thermography courses, »Level 1« course Yes, a calibration certificate for the entire temperature measurement range is included in the standard scope of delivery Calibration service, repair service, application advice, service packages, consultation and technical support	€2,950 (\$4,000) No Hotline, direct service, email 24 months Upon request Yes Unknown
www.infratec.de	www.infratec.de	www.optris.de

## Thermography cameras survey

Manufacturer		Optris	Optris
Model		Optris PI200	Optris PI230
			
Possible PV applications		Close-up imaging, cell flasher, large installations	Close-up imaging, cell flasher, large installations
Problems the camera can detect		Shading, defective modules, hot spots, microfissures	Shading, defective modules, hot spots, microfissures
Camera usability and handling			
Weight		215 g	215 g
Dimensions		45 × 45 × 62 mm	45 × 45 × 62 mm
Protection rating		IP 65	IP 65
Batteries interchangeable? / battery run time		Unknown	Unknown
Data output and processing			
Storage	Storage media	Unknown	Unknown
	Storage capacity	Unknown	Unknown
Interfaces (connectivity)		USB, Ethernet, extension optional	USB, Ethernet, extension optional
Additional measurement features			
Laser positioning		No	No
(Digital) camera for visible light		Yes (640 × 480 pixels)	Yes (640 × 480 pixels)
Number of measuring points in display		Unknown	Unknown
Can emissivity be input?		Yes	Yes
Specifications			
Measurement temperature range		-20 to 100 °C, 0 to 250 °C, 150 to 900 °C, additional range: 200 to 1,500 °C	-20 to 100 °C, 0 to 250 °C, 150 to 900 °C, additional range: 200 to 1,500 °C
Operating temperature range		0 to 50 °C	0 to 50 °C
Sensitivity (NETD)		80 mK with 23° × 17° FOV / F = 0.8; 300 mK with 6° × 5° FOV / F = 1.6, 100 mK with 41° × 31° FOV and 72° × 52° FOV / F = 1	80 mK with 23° × 17° FOV / F = 0.8; 300 mK with 6° × 5° FOV / F = 1.6, 100 mK with 41° × 31° FOV and 72° × 52° FOV / F = 1
Accuracy		±2 °C or ±2 %	±2 °C or ±2 %
Detector resolution		160 × 120 pixels	160 × 120 pixels
Field of view (FOV) with standard lens (H° × V°)		23° × 17°	23° × 17°
Frame rate		128 Hz	128 Hz
Prices / Service / Availability			
Price (before taxes) of standard configuration for installers		€3,900 (\$5,298)	€3,900 (\$5,289)
Lease option		No	No
Technical support		Hotline, direct service, email	Hotline, direct service, email
Warranty		24 months	24 months
Training		Upon request	Upon request
Calibration at factory with certificate included in delivery		Yes	Yes
Additional services		Unknown	Unknown
Internet address		www.optris.de	www.optris.de

<b>Optris</b> <b>Optris PI400</b>	<b>Optris</b> <b>Optris PI450</b>	<b>PCE Instruments</b> <b>PCE-TC 9</b>
		
Close-up imaging, cell flasher, large installations, drones	Close-up imaging, cell flasher, large installations, drones	Close-up imaging, overview imaging
Shading, defective modules, hot spots, microfissures, IR flight applications	Shading, defective modules, hot spots, microfissures, IR flight applications	Shading, wiring problems, defective modules, hot spots, microfissures
320 g 46 × 56 × 90 mm IP 65 Unknown	320 g 46 × 56 × 90 mm IP 65 Unknown	363 g (with battery) 126 × 62 × 154 mm IP 50 Yes / > 3 hours
Unknown Unknown USB, Ethernet, extension optional	Unknown Unknown USB, Ethernet, extension optional	SD card, internal and external 500 images (JPEG) on internal media and 4,000 images on external media USB, online video via USB possible
No No Unknown Yes	No No Unknown Yes	Yes Yes (3 megapixels) 4 Yes
-20 to 100 °C, 0 to 250 °C, 150 to 900 °C, additional range: 200 to 1,500 °C 0 to 50 °C 80 mK with 32° × 24° FOV / F = 0.7; 80 mK with 62° × 49° FOV / F = 0.8; 100 mK with 13° × 10° FOV / F = 1.0 ±2 °C or ±2 % 382 × 288 pixels 32° × 24° 80 Hz	-20 to 100 °C, 0 to 250 °C, 150 to 900 °C, additional range: 200 to 1,500 °C 0 to 70 °C 80 mK with 32° × 24° FOV / F = 0.7; 80 mK with 62° × 49° FOV / F = 0.8; 100 mK with 13° × 10° FOV / F = 1.0 ±2 °C or ±2 % 382 × 288 pixels 32° × 24° 80 Hz	-20 to 250 °C -20 to 50 °C < 0.65 mK at 30 °C ±2 °C 384 × 288 pixels 21° × 16° 50 Hz
€4,950 (\$6,713) No Hotline, direct service, email 24 months Upon request Yes Unknown	€5,900 (\$8,002) No Hotline, direct service, email 24 months Upon request Yes Unknown	€4,495 (\$6,096) No Hotline, email 24 months Upon request No Upon request
<a href="http://www.optris.de">www.optris.de</a>	<a href="http://www.optris.de">www.optris.de</a>	<a href="http://www.warensortiment.de">www.warensortiment.de</a>



## Thermography cameras survey

Manufacturer		Testboy	Testboy
Model		Testboy TV 303	Testboy TV 309
			
			Test report on page 136
<b>Possible PV applications</b>		Locating defective modules in operation	Locating defective modules in operation
<b>Problems the camera can detect</b>		See applications	See applications
<b>Camera usability and handling</b>			
Weight		600 g (without battery)	700 g (without battery)
Dimensions		270 × 100 × 72 mm	197 × 178 × 73 mm
Protection rating		Unknown	Unknown
Batteries interchangeable? / battery run time		Yes / up to 3 hours nonstop operation	Yes / up to 3 hours nonstop operation
<b>Data output and processing</b>			
Storage	Storage media	Internal flash drive	Internal flash driver, SD card
	Storage capacity	2,000 images (JPEG)	1 GB (SD card), 4,000 images (JPEG)
Interfaces (connectivity)		USB, video/audio output: PAL, NTSC, JA	USB, video HDMI, video/audio output: PAL, NTSC, JA
<b>Additional measurement features</b>			
Laser positioning		Yes	Yes
(Digital) camera for visible light		No	Yes
Number of measuring points in display		1	4
Can emissivity be input?		Yes	Yes
<b>Specifications</b>			
Measurement temperature range		-20 to 350 °C, optional to 600 °C	-20 to 350 °C, optional to 600 °C
Operating temperature range		-15 to 50 °C	-15 to 50 °C
Sensitivity (NETD)		100 mK	100 mK
Accuracy		2 °C or 2 % (whichever is higher)	2 °C or 2 % (whichever is higher)
Detector resolution		160 × 120 pixels	160 × 120 pixels
Field of view (FOV) with standard lens (H° × V°)		18° × 13°	12° × 9°
Frame rate		50 Hz	50 Hz / 60 Hz
<b>Prices / Service / Availability</b>			
Price (before taxes) of standard configuration for installers		€4,540 (\$6,157)	€4,540 (\$6,157)
Lease option		No	No
Technical support		Hotline, email	Hotline, email
Warranty		24 months (manufacturer's warranty)	24 months (manufacturer's warranty)
Training		Software training	Software training
Calibration at factory with certificate included in delivery		Yes, upon request	Yes, upon request
Additional services		Calibration service center	Calibration service center
<b>Internet address</b>		www.testboy.de	www.testboy.de

<b>Testo</b> <b>Testo 875 / 875i (pistol)</b>	<b>Testo</b> <b>Testo 876 (camcorder)</b>	<b>Testo</b> <b>Testo 882 (pistol)</b>
	Test report on page 138  	
Overview imaging of small installations, close-up imaging, medium-range imaging (with telephoto lens)	Overview imaging of small installations, close-up imaging, medium-range imaging (with telephoto lens)	Overview imaging of small installations, close-up imaging
All	All	All
Approx. 900 g 152 × 108 × 262 mm (L × W × H) IP 54 Yes / 4 hours	Approx. 900 g 210 × 85 × 97 mm (L × W × H) IP 54 Yes / 4 hours	Approx. 900 g 105 × 108 × 262 mm (L × W × H) IP 54 Yes / 4 hours
SD card 2 GB, approx. 2,000 images (BMT; exportable as BMP, JPEG, PNG, CSV, XLS) USB, video streaming via USB	SD card 3 GB, approx. 2,000 images (BMT; exportable as BMP, JPEG, PNG, CSV, XLS) USB, video streaming via USB	SD card 2 GB, approx. 1,000 images (BMT; exportable as BMP, JPEG, PNG, CSV, XLS) USB, video streaming via USB
Yes Yes, with high power LEDs (640 × 480 pixels) 2 Yes (0.01 - 1)	No Yes (640 × 480 pixels) 1 Yes (0.01 - 1)	Yes Yes, with high power LEDs (640 × 480 pixels) 2 Yes (0.01 - 1)
-20 to 100 °C, switchable to range of 0 to 350 °C, optional high-temperature measurement from 350 to 550 °C -15 to 40 °C < 50 mK at 30 °C  ±2 °C, ±2 % of measured value, ±3 % of measured value (350 to 550 °C) 160 × 120 pixels 32° × 23° 33 Hz	-20 to 100 °C, switchable to range of 0 to 280 °C -15 to 40 °C < 80 mK at 30 °C  ±2 °C, ±2 % of measured value 160 × 120 pixels 32° × 23° 9 Hz	-20 to 100 °C, switchable to range of 0 to 350 °C, optional high-temperature measurement from 350 to 550 °C -15 to 40 °C < 50 mK at 30 °C  ±2 °C, ±2 % of measured value, ±3 % of measured value (350 to 550 °C) 320 × 240 pixels 32° × 23° 33 Hz
From €1,995 (\$1,621), depending on configuration No Hotline, direct service, email 24 months Testo Academy thermography courses	From €3,495 (\$4,740), depending on configuration No Hotline, direct service, email 24 months Testo Academy thermography courses	From €5,995 (\$8,131), depending on configuration No Hotline, direct service, email 24 months Testo Academy thermography courses
Yes  ISO calibration certificate – calibration at 0 °C, +25 °C, 50 °C / calibration at 0 °C, +100 °C, 200 °C / custom calibration upon request	Yes  ISO calibration certificate – calibration at 0 °C, +25 °C, 50 °C / calibration at 0 °C, +100 °C, 200 °C / custom calibration upon request	Yes  ISO calibration certificate – calibration at 0 °C, +25 °C, 50 °C / calibration at 0 °C, +100 °C, 200 °C / custom calibration upon request
www.testo.de	www.testo.de	www.testo.de

## Thermography cameras survey

Manufacturer		Testo	Testo
Model		Testo 885 (camcorder)	Testo 890 (camcorder)
		Test report on page 140	
			
Possible PV applications		Overview imaging of medium-sized installations, close-up imaging, imaging from a greater distance (with telephoto lens)	Overview imaging of large installations, close-up imaging, long-distance imaging (with telephoto lens)
Problems the camera can detect		All	All
Camera usability and handling			
Weight		1,570 g	1,630 g
Dimensions		253 × 132 × 111 mm (L × W × H)	253 × 132 × 111 mm (L × W × H)
Protection rating		IP 54	IP 54
Batteries interchangeable? / battery run time		Yes / 4.5 hours	Yes / 4.5 hours
Data output and processing			
Storage	Storage media	SD card	SD card
	Storage capacity	2 GB, 2,000 - 3,000 images (BMT; exportable as BMP, JPEG, PNG, CSV, XLS)	2 GB, 800 - 1,000 images (BMT; exportable as BMP, JPEG, PNG, CSV, XLS)
Interfaces (connectivity)		USB, Bluetooth, video streaming via USB	USB, Bluetooth, video streaming via USB
Additional measurement features			
Laser positioning		Yes	Yes
(Digital) camera for visible light		Yes, with high power LEDs (3.1 megapixels)	Yes, with high power LEDs (3.1 megapixels)
Number of measuring points in display		3	3
Can emissivity be input?		Yes (0.01 - 1)	Yes (0.01 - 1)
Specifications			
Measurement temperature range		-20 to 100 °C, switchable to range of 0 to 350 °C, optional high-temperature measurement from 350 to 1,200 °C	-20 to 100 °C, switchable to range of 0 to 350 °C, optional high temperature measurement from 350 to 1,200 °C
Operating temperature range		-15 to 50 °C	-15 to 50 °C
Sensitivity (NETD)		< 30 mK at 30 °C	< 40 mK at 30 °C
Accuracy		±2 °C, ±2 % of measured value	±2 °C, ±2 % of measured value
Detector resolution		320 × 240 pixels	640 × 480 pixels
Field of view (FOV) with standard lens (H° × V°)		30° × 23°	42° × 32°
Frame rate		33 Hz	33 Hz
Prices / Service / Availability			
Price (before taxes) of standard configuration for installers		From €6,500 (\$8,815), depending on configuration	From €11,950 (\$16,207), depending on configuration
Lease option		No	No
Technical support		Hotline, direct service, email	Hotline, direct service, email
Warranty		24 months	24 months
Training		Testo Academy thermography courses	Testo Academy thermography courses
Calibration at factory with certificate included in delivery		Yes	Yes
Additional services		ISO calibration certificate – calibration at 0 °C, +25 °C, 50 °C / calibration at 0 °C, +100 °C, 200 °C / custom calibration upon request	ISO calibration certificate – calibration at 0 °C, +25 °C, 50 °C / calibration at 0 °C, +100 °C, 200 °C / custom calibration upon request
Internet address		www.testo.de	www.testo.de

<b>Trotec</b> <b>EC060 V</b>	<b>Trotec</b> <b>IC080 LV</b>
Test report on page 142	Test report on page 144
	
Close-up imaging	Close-up imaging, standard imaging, distance imaging (with change of lens as needed)
Shading, defective modules, hot spots	Shading, defective modules, hot spots, microfissures
500 g	650 g
175 × 55 × 160 mm	230 × 80 × 195 mm
IP 54	IP 54
Yes / up to 2.5 hours	Yes / up to 2.5 hours
SD card	SD card
2 GB, several thousand images (IR format/CCD)	2 GB, several thousand images (IR format/CCD)
USB (usable in conjunction with USB real time), optional Bluetooth in the EC060 V+, optional FireWire in the EC060 V+ in conjunction with USB real time software, composite video via docking station	USB (usable in conjunction with USB real time), optional Bluetooth in the EC060 V+, optional FireWire in the EC060 V+ in conjunction with USB real time software, composite video via docking station
Yes	Yes
Yes (640 × 480 pixels)	Yes (640 × 480 pixels)
5 (4x manual, 1x auto hot/cold spots)	5 (4x manual, 1x auto hot/cold spots)
Yes	Yes
-20 to 250 °C	-20 to 600 °C
-15 to 50 °C	-15 to 50 °C
80 mK at 30 °C	50 mK at 30 °C
±2 °C, ±2 % of measured value	±2 °C, ±2 % of measured value
160 × 120 pixels	384 × 288 pixels
20° × 15°	24° × 21°
50 Hz	50 Hz
€1,995 (\$2,706)	€4,995 (\$6,774)
Yes	Yes
Hotline, direct service, 24-hour service when possible, email	Hotline, direct service, 24-hour service when possible, email
12 months for resellers, 24 months for end-customers	12 months for resellers, 24 months for end-customers
Thermography basics course (photovoltaics training upon request)	Thermography basics course (photovoltaics training upon request)
Yes	Yes
Calibration	Calibration
www.trotec.de	www.trotec.de

Trotec AG

Romana Breinigens / photon-pictures.com (3)