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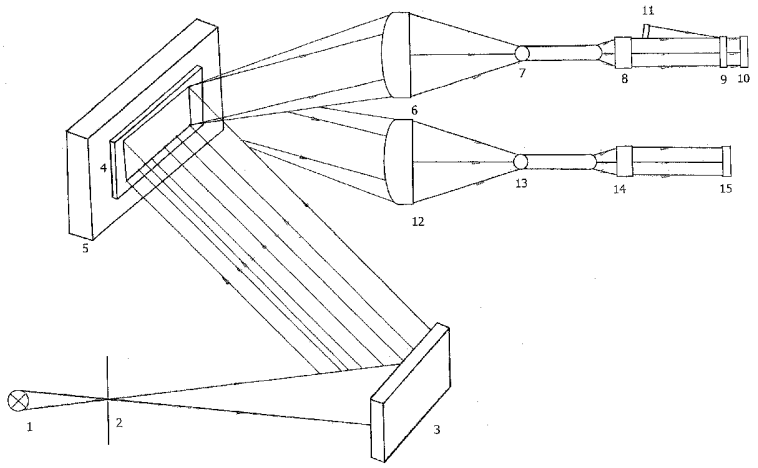
(54) Title: A SYSTEM FOR MEASURING AN OPTICAL SPECTRAL RESPONSE AND/OR IV DATA OF A PHOTOELECTRIC DEVICE UNDER TEST



(57) Abstract: A system for measuring an optical spectral response or property and/or IV data of a device or object under test (9), comprising in optically coupled sequence: a broadband light source (1) for emitting light of a prede- fined spectrum, a slit and/or light guide (2), a wavelength dispersive device (3), a spatial light modulator (5) for re- ceiving the emitted light and controlling an intensity and spectrum of light reflected by said modulator (5), focusing optics (6, 7, 8, 12, 13, 14) for the reflected light directed to - wards a reference detector (15) and towards the device or object under test (9), wherein the spatial light modulator (5) is embodied as a beamsplitter and is combined with a fil- ter (4) for suppression of second and higher order frequen- cies of the primary frequen - cies in the reflected light.

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A system for measuring an optical spectral response and/or IV data of a photoelectric device under test

The invention relates to a system for measuring an optical spectral response or property of a device or object under test, comprising in optically coupled sequence: a broadband light source for emitting a light beam of a predefined spectrum, a slit and/or light guide, a wavelength dispersive device, a spatial light modulator for receiving the emitted light beam and controlling an intensity and spectrum of light reflected by said modulator, focusing optics for the reflected light beam directed towards a calibration device and towards the device or object under test.

Such a system is known from US-B-8,436,630 and applies a light distributing device having at least one input portion to receive the reflected light beam and a distributing structure to distribute the light beam in a known ratio to a first area and a second area where a photovoltaic device under test and the calibration device respectively are located. The light distributing device is embodied as an integrating sphere. The system further includes data acquisition electronics coupled to the device under test and to the calibration device for receiving simultaneously generated output signals therefrom, wherein the data acquisition electronics are coupled to a processor to correct for possible intensity variations in the spectrum of the light and for determining the optical spectral response of the device under test in relation to the calibration device.

The use of the integrating sphere has notable disadvantages, viz. it results in a relatively low light intensity at the device under test which deteriorates its signal-to-noise ratio. A further disadvantage is that it is not possible to measure the reflectance of the device under test. Still another disadvantage is that there is an implicit inaccuracy in that the calibration device and the device under test will receive light with different intensities due to their different positions within the integrating sphere. Still another disadvantage is that the integrating sphere

prevents that measurements are carried out to measure the response of the device under test with different incident angles of the light beam.

It is an object of the invention to provide accurate measurements regarding the spectral response and/or IV data (current - voltage) under different light conditions of a device or object under test. It is also an object of the invention to provide these measurements fast and reliably, and that possible variations due to the positioning of the device under test and due to variations in the incident angle of the reflected light beam can be measured.

According to the invention a system for measuring an optical spectral response or property of a device or object under test is proposed. The property may relate for instance to the device's optical transmittance, reflectance, layer thickness, optical absorption or its IV characteristics. The system comprises in optically coupled sequence:
a broadband light source for emitting light of a predefined spectrum, a slit and/or light guide, a wavelength dispersive device, a spatial light modulator for receiving the emitted light and controlling an intensity and spectrum of light reflected by said modulator, focusing optics for the reflected light directed towards a calibration device and directed towards the device or object under test, wherein the spatial light modulator is embodied as a beamsplitter.

By embodying the spatial light modulator as a beamsplitter it is arranged that the light incident on the calibration device and incident on the device or object under test is received from and entirely determined by the spatial light modulator.

Preferably the beamsplitter is combined with a filter for suppression of second and higher order frequencies of the primary frequencies in the reflected light. By filtering out second or higher order wavelength radiation in the light beam incident on and/or reflected by the spatial light modulator that corresponds to the exciting primary wavelengths, it is possible to provide a measurement of the spectral response of the device or object under test that is accurate for all the wavelengths that are under investigation, without

disturbing contributions from second or higher order reflections. It is possible to apply a filter separate from the spatial light modulator but preferably the filter is integrated with said spatial light modulator.

Preferably the filter is a linear variable filter, such as an interference filter, a uniformly colored glass filter or a graduated colored filter, which makes fast measurements possible due to its controllability.

It is remarked that the wavelength dispersing element can be a grating, preferably corrected for flat field aberrations.

Further it is remarked that the spatial light modulator can be a magneto-optic modulator, or preferably a digital mirroring device.

Preferably the system of the invention is provided with a transmission detector in the transmission path behind the device or object under test. The system with the transmission detector can then advantageously be used not only when the device under test is a photovoltaic device but also when the device or object is subject to measurements for determining its transmission, absorption and reflection and their derivatives.

The invention will hereinafter be further elucidated with reference to the drawing schematically showing in a single figure the system of the invention.

In the figure the system for measuring an optical spectral response of a device or object under test 9 is shown. The device under test 9 can be a photovoltaic device, which is the normal case, but it can also be an object of which the transmission, reflection and/or absorption needs to be measured. This will be discussed hereinafter after having discussed the system’s normal use for measuring the spectral response of a photovoltaic device.

The system of the invention comprises in optically coupled sequence:
a broadband light source 1 for emitting light of a predefined spectrum, a slit and/or light guide 2, a wavelength dispersive device 3, a spatial light modulator 5 for receiving the emitted light and controlling an intensity and spectrum of

light reflected by said modulator 5, focusing optics 6, 7, 8, 12, 13, 14 for the reflected light directed towards the device under test 9 and towards a reference detector 15, respectively. The focusing optics 6, 7, 8, 12, 13, 14 can include homogenizing optics 7, 13 and collimating optics 8, 14. To provide the light beams towards the reference detector 15 and towards the device under test 9 the spatial light modulator 5 acts as a beamsplitter that splits the reflected light with a known ratio into preferably approximately equal parts directed to said reference detector 15 and device under test 9 respectively. The light beam directed to the reference detector 15 has its own focusing optics 12, 13, 14, whereas the light beam directed to the device under test 9 has its own focusing optics 6, 7, 8.

In accordance with the invention the spatial light modulator 5 is combined with a filter 4 for suppression of second and higher order frequencies of the primary exciting frequencies in the reflected light. The filter 4 is preferably a linear variable filter, such as an interference filter, a uniformly colored glass filter or a graduated colored filter.

In the shown embodiment the wavelength dispersing element 3 is a grating, preferably corrected for flat field aberrations, and the spatial light modulator 5 is preferably a digital mirroring device.

It is possible to apply a reflection detector 11 to detect reflections by the device under test 9. It is also possible to apply in addition a transmission detector 10. The radiation detected by the reflection detector 11 and the transmission detector 10 should add up to the total amount of radiation received at the position of the device or object under test 9. The embodiment with the transmission detector 10 can also be used when the device under test 9 is not a photovoltaic device but a device or object which is subject to measurements for determining its transmission, absorption and/or reflection.

Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the apparatus of the invention, the invention is not restricted

to this particular embodiment which can be varied in many ways without departing from the gist of the invention and the scope of the appended claims. The discussed exemplary embodiment shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the invention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using this exemplary embodiment.

CLAIMS

1. A system for measuring an optical spectral response or property and/or IV data of a device or object under test (9), comprising in optically coupled sequence:
a broadband light source (1) for emitting light of a predefined spectrum, a slit and/or light guide (2), a wavelength dispersive device (3), a spatial light modulator (5) for receiving the emitted light and controlling an intensity and spectrum of light reflected by said modulator (5), focusing optics (6, 7, 8, 12, 13, 14) for the reflected light directed towards a reference detector (15) and towards the device or object under test (9), **characterized in that** the spatial light modulator (5) is embodied as a beamsplitter.

2. System according to claim 1, **characterized in that** the beamsplitter is combined with a filter (4) for suppression of second and higher order frequencies of the primary frequencies in the reflected light.

3. System according to claim 1 or 2, **characterized in that** the filter (4) is a linear variable filter, such as an interference filter, a uniformly colored glass filter or a graduated colored filter.

4. System according to any one of claims 1 - 3, characterized in that the filter (4) is integrated with the spatial light modulator (5).

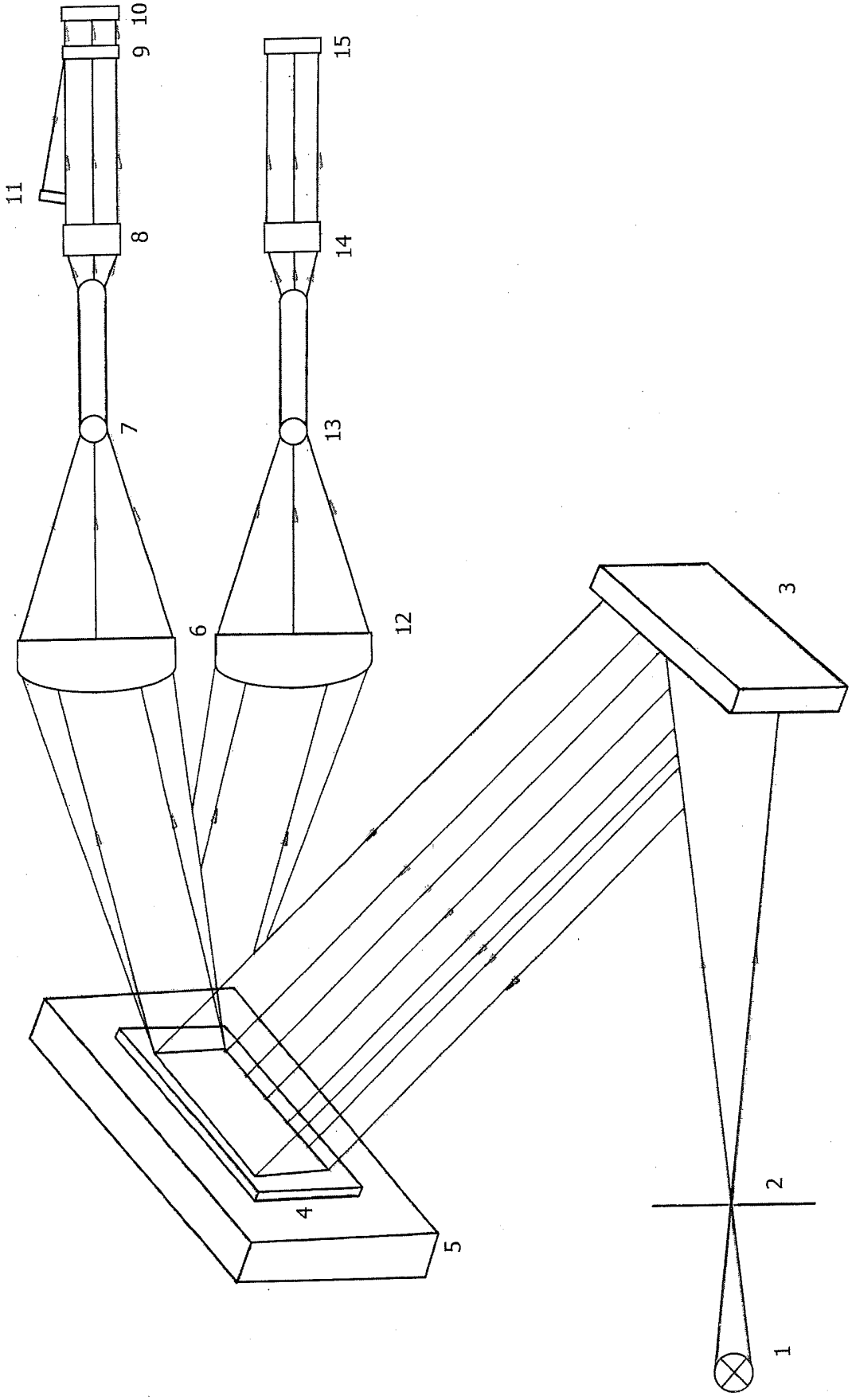
5. System according to any one of claims 1 – 4, **characterized in that** the wavelength dispersing element (3) is a grating, preferably corrected for flat field aberrations.

6. System according to any one of claims 1-5, **characterized in that** the spatial light modulator (5) is a digital mirroring device.

7. System according to any one of the previous claims, **characterized in that** it is provided with a reflection detector (11) in the light path reflected by the device or object under test (9).

8. System according to any one of the previous claims, **characterized in that** it is provided with a transmis-

sion detector (10) in the transmission path behind the device or object under test (9).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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2014/050807

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01J3/18 G01J3/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/084717 A1 (FONG ALEXANDRE Y [US] ET AL) 14 April 2011 (2011-04-14) paragraphs [0020] - [0024]; figure 1	1-8
A	US 5 570 180 A (NAGAI YOSHIROH [JP]) 29 October 1996 (1996-10-29) column 5, lines 15-50; figures 1a-c column 7, lines 31-67; figures 2a-c	2,3
A	ANONYMOUS: "Order-Sorting Filters", INTERNET CITATION, February 2011 (2011-02), pages 1-33, XP002729303, Retrieved from the Internet: URL:http://materion.com/~/media/Files/PDFs/BarPrecisionOptics/OrderSortingFilters [retrieved on 2014-09-04] page 2	2,3

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2015	31/03/2015

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2014/050807

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 420 681 A (WOODRUFF ROBERT A [US]) 30 May 1995 (1995-05-30) column 4, line 64 - column 5, line 2	2,3,5
A	WO 98/46935 A1 (WATERS INVESTMENTS LTD [US]; LEVEILLE MICHAEL J [US]) 22 October 1998 (1998-10-22) page 21, lines 8-15; figure 1B	1
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2014/050807

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