

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(12)

Oversættelse af europæisk patentskrift

(10) **DK/EP 2158513 T3**

-
- (51) Int.Cl.: **G 02 B 27/10 (2006.01)** **G 02 B 21/00 (2006.01)** **G 02 B 21/06 (2006.01)**
G 02 B 27/14 (2006.01)
- (45) Oversættelsen bekendtgjort den: **2020-02-03**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-11-06**
- (86) Europæisk ansøgning nr.: **08736652.2**
- (86) Europæisk indleveringsdag: **2008-05-06**
- (87) Den europæiske ansøgnings publiceringsdag: **2010-03-03**
- (86) International ansøgning nr.: **EP2008055538**
- (87) Internationalt publikationsnr.: **WO2008151884**
- (30) Prioritet: **2007-06-15 DE 102007028337**
- (84) Designerede stater: **AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR**
- (73) Patenthaver: **Leica Microsystems CMS GmbH, CPTD, Ernst-Leitz-Strasse 17-37, 35578 Wetzlar, Tyskland**
- (72) Opfinder: **SEYFRIED, Volker, Jahnstrasse 28, 69226 Nussloch, Tyskland**
- (74) Fuldmægtig i Danmark: **RWS Group, Europa House, Chiltern Park, Chiltern Hill, Chalfont St Peter, Bucks SL9 9FG, Storbritannien**
- (54) Benævnelse: **STRÅLESAMLER OG EN LYSKILDE MED EN SÅDAN STRÅLESAMLER**
- (56) Fremdragne publikationer:
EP-A- 1 182 445
WO-A1-00/39545
WO-A1-02/057759
DE-A1- 19 633 185
DE-A1-102004 052 955
DE-A1-102004 054 262
DE-B3-102004 030 208
US-A- 5 880 473
US-A1- 2001 028 031
US-A1- 2004 105 485
US-A1- 2004 238 719
US-A1- 2006 006 067
US-A1- 2006 237 666

Description

The invention relates to an optical arrangement comprising a beam combiner for combining at least two light beams to form a combined light beam in the beam path of the optical arrangement, preferably a microscope.

Beam combiners and light sources of the type mentioned at the outset are known from practice and are used, for example, in the field of confocal microscopy. For this purpose, combining the light beams of two lasers differing in the wavelengths by way of dichroic beam splitters - colored beam splitters - is known according to DE 196 33 185 C2. Three or more laser beams can be combined by sequential arrangement of this structure.

Combining light beams via polarization beam splitters is also known according to EP 0 473 071 B1. Furthermore, effectuating the combination of light beams via optical fibers is known to the applicant. Moreover, performing a spatial spectral splitting of light beams is known from DE 103 37 558 A1, wherein the combining is completed spatially via a structured, microstructured, and/or switchable element and the light beams are brought together again by a dispersive element on a common beam axis.

It is problematic in the case of the known beam combiners that, for example, the use of colored beam splitters results in a power loss of the white light, which is usually generated in a complex manner and is not powerful in any case. Furthermore, for example, polarization beam splitters are not usable in the case of light sources having a photonic crystal fiber, since the emission light is unpolarized.

In addition, most of the known arrangements do not permit a computer-controlled switching of the characteristic. Where this is possible, for example, in the arrangement known from DE 103 37 558 A1, the switching times are excessively long in consideration of present requirements.

Document DE 10 2004 030 208 B3 discloses an incident light microscope having an optical device embodied as an acousto-optic element, which is arranged in an illumination beam path and a
5 detection beam path. The disclosed incident light microscope furthermore comprises a multiline laser for generating illumination light. Illumination light of the multiline laser is divided into a desired part for illuminating a sample and an undesired part by the optical device. The undesired part is
10 guided by the optical device into a beam dump.

Document US 2001/0028031 A1 discloses a device for combining laser light beams of at least two laser light sources. The laser light emitted by the at least two laser light beams has
15 essentially the same wavelength in each case here. The device comprises an acousto-optical deflector for combining laser light beams. The acousto-optical deflector is activated synchronously with the pulse sequence of the laser light beams - in a time multiplex - so that the laser light beams are each deflected to
20 form a combined light beam and are thus combined.

Document EP 1 182 445 A2 discloses an integrated optical interferometer, in which light of a single light source is coupled into a light incidence grating. The light incidence
25 grating is designed to select light of a single wavelength from the coupled-in light and to guide it into a waveguide.

Document WO 02/057759 A1 discloses a spectroscopic analysis device comprising a beam combiner, which comprises an acousto-optical deflector (AOD). The frequency of a sound wave which
30 propagates through the AOD is selected in such a way that a first-order diffracted beam having a first wavelength and a zeroth-order diffracted beam having a second wavelength are deflected in such a way that they leave the AOD in parallel.

35

Document DE 10 2004 054 262 A1 discloses a device for the examination and manipulation of microscopic objects. The device comprises a first light source for producing an illumination

light beam, a second light source for producing a manipulation light beam, and an acousto-optical element. The acousto-optical element is arranged in the beam path of the illumination light beam and is designed in such a way that the illumination light beam and the manipulation light beam are deflected in such a way that they leave the acousto-optical element at a small relative beam angle.

Document WO 00/39545 A1 discloses an optical arrangement comprising two laser light sources, the light beams of which are brought together in a collinear manner by an AOTF.

Finally, a more compact and stable structure can only be implemented with difficulty in the known arrangements and the known arrangements are relatively technically complicated, sometimes difficult to adjust, and very inflexible.

The present invention is therefore based on the object of designing and refining an optical arrangement comprising a beam combiner of the type mentioned at the outset in such a way that a flexible beam combination is enabled using simply designed means.

The above object is achieved according to the invention by an optical arrangement comprising a beam combiner having the features of Claim 1. Accordingly, the generic beam combiner is characterized by an AOTF (Acousto-Optical Tunable Filter) in which a mechanical wave or soundwave for deflecting or diffracting light beams is producible in such a way that a first light beam entering the AOTF and at least one second light beam entering the AOTF leave the AOTF in a collinear fashion as a combined light beam.

It has been recognized according to the invention that it is possible for the beam combination to use an AOTF in which a mechanical wave or soundwave is producible for deflecting or diffracting light beams. In this case, a first light beam entering the AOTF and at least one second light beam entering

the AOTF are combined in such a way that they leave the AOTF in collinear fashion as a combined light beam. Using the beam combiner according to the invention, for example, very rapid computer-controlled switching of the characteristic is possible.

5 The switching time is in the order of magnitude of 1 μ s in this case. Furthermore, acousto-optical elements can be integrated very easily into optical arrangements because of the typically modular design thereof.

10 Therefore, a beam combiner in the form of an AOBM (Acousto-Optical Beam Merger) is specified by the beam combiner according to the invention, in which a flexible beam combination is enabled using simply designed means, whereby a more compact and stable structure can be implemented, which is additionally also very
15 easily adjustable.

Specifically, the first light beam is able to radiate through the AOTF in a manner such that the mechanical wave or soundwave does not deflect or diffract the first light beam. Furthermore,
20 it is provided that the mechanical wave or soundwave deflects or diffracts the at least one second light beam such that the first light beam and the second light beam leave the AOTF in collinear fashion as a combined light beam. In this way, more reliable combination of the light beams is enabled.

25 In a further advantageous manner, the beam combiner has a compensation element for compensating spatial splits or chromatic or polarization-dependent aberrations caused by the AOTF.

30 In a particularly simple and advantageous manner, the compensation element is an acousto-optical element. In this case, the compensation element is furthermore advantageously a preferably passive AOTF. Very generally, the compensation
35 element could be a passive crystal complementary to the acousto-optical element, whereby a particularly simple design of the beam combiner is implementable.

The selection of the compensation element is to be adapted to the respective application.

The use of a further acousto-optical element - neglecting the compensation element possibly designed as an acousto-optical element, which is used, for example, for aberration correction, but then does not have to be connected and therefore only acts passively - is avoided. In this way, costs can be significantly reduced and the control can be substantially simplified.

The beam combiner according to the invention may be used particularly advantageously in the field of microscopy, in particular in the field of laser scanning microscopy or confocal microscopy. It is advantageous in many cases here to arrange a controllable beam splitter, preferably as a main beam splitter of a confocal microscope, downstream of the beam combiner according to the invention. An AOBS (Acousto-Optical Beam Splitter) could be used as the beam splitter here.

In such a case, an adapted and/or synchronized control of the components can then particularly advantageously be performed. This includes above all the main beam splitter of the confocal microscope always being connected such that the light intended for use by the beam combiner can pass the main beam splitter in as unobstructed a manner as possible - or with a defined attenuation. For this purpose, for example, for a plurality of connections of the beam combiner according to the invention, in each case the associated optimum setting of the downstream confocal microscope main beam splitter is determined, stored accordingly, and used for the later control, so that an optimum adaptation of the components can be performed in every situation. Of course, in general the calibration can only be performed for individual light wavelengths. However, it is easy to achieve the optimum calibration for all wavelengths in the usable field by interpolation of the values at several support points.

The beam combining technology according to the invention could

also be combined with other beam combining technologies, wherein, for example, further beams can be combined in addition with beams already combined beforehand.

- 5 To further enhance the flexibility of the use of the beam combiner, at least one element varying the light intensity, preferably an AOTF, can be arranged upstream of and/or downstream of the beam combiner.
- 10 With respect to a device which is particularly simple to handle, the beam combiner could be designed as a module or as a mechanical unit. The beam combiner or such a unit could comprise further components such as an AOTF or a temperature stabilization unit, for example, in a further advantageous
- 15 manner.

Using the beam combiner according to the invention it is advantageously possible to combine not only a second, but rather also a third or further light beam with the first light beam.

20 Finally, "stringing together" multiple light beams is possible here.

For example, the first or second light beam could be formed from a multi-wavelength laser, preferably an argon-ion laser, from

25 already combined individual beams, from a white light source, or from a tunable laser.

In a further advantageous manner, the white light source or the tunable laser or a tunable light source could comprise a

30 microstructured element, a so-called "tapered" fiber, a specially doped fiber, preferably having anomalous dispersion, or an element inducing - preferably comparable - optical nonlinearities, wherein light of a laser is coupled therein, from which new wavelengths are produced by nonlinear processes.

35 In this case, the microstructured element could preferably comprise a photonic crystal fiber (PCF), a photonic crystal, or a photonic bandgap material. A simple adaptation to individual requirements is thus enabled by the selection of the design of

the microstructured element.

If at least one of the wavelengths of one of the light sources is tunable or selectable, a radiofrequency at the acousto-optical element could advantageously be adaptable to a modified wavelength. In this adaptation, the temperature of the acousto-optical element and/or its surroundings could furthermore advantageously be taken into consideration, such that an optimum adaptation of the radiofrequency is enabled.

To already block out undesired light beforehand, at least one optical filter could be arranged upstream of the beam combiner. In the case of a white light laser, above all this is longer-wavelength light than the actually desired useful light, which could be blocked out, for example, by a band edge filter to minimize the light load of the acousto-optical components.

In a further advantageous manner, the beam combiner could comprise a beam dump, in which the light not intended for use is collected. Such a design is important in particular at strong light powers, since otherwise undesired effects such as damage to components or laser safety problems could occur.

To implement a particularly compact arrangement, the beam combiner could be arranged in a housing of one of the light sources or laser light sources producing the light beams. In this case, the light beam of the other light source or laser light source could preferably be guided by means of a glass fiber into the housing of the one light source or laser light source to the beam combiner, such that the combined light of both light sources or laser light sources could leave the housing jointly through a second glass fiber.

To avoid repetitions, reference is made to the above statements on the advantages of the beam combiner according to the invention with respect to the advantages of such a light source.

Using the beam combiner according to the invention, the

combination of multiple light beams to form one common beam is enabled, wherein in particular continuously tunable laser beams, for example, from white light sources, can be combined.

5 There are now various options for advantageously designing and refining the teaching of the present invention. For this purpose, reference is made, on the one hand, to the appended patent claims and, on the other hand, to the following explanation of an exemplary embodiment of the invention on the
10 basis of the drawing. Generally preferred designs and refinements of the teaching are also explained in conjunction with the explanation of the preferred exemplary embodiment of the invention on the basis of the drawing. In the figures of the drawing

15

Figure 1 shows a schematic illustration of an exemplary embodiment of a beam combiner according to the invention and

Figure 2 shows a schematic illustration of a typical use of the
20 beam combiner according to the invention in a confocal microscope.

Figure 1 shows a schematic illustration of an exemplary embodiment of a beam combiner according to the invention for
25 combining at least two light beams 1 and 2 to form a combined light beam 3. With regard to flexible beam combining using simply designed means, the beam combiner comprises an acousto-optical element 4 in which a mechanical wave or soundwave for deflecting or diffracting light beams is producible such that a first light
30 beam 1 entering the acousto-optical element 4 and a second light beam 2 entering the acousto-optical element 4 leave the acousto-optical element 4 in collinear fashion as a combined light beam 3.

35 Specifically, the first light beam 1 is able to radiate through the acousto-optical element 4 in such a manner that the mechanical wave or soundwave - at least partially - does not deflect or diffract the first light beam 1. The mechanical wave

or soundwave influences the second light beam 2, however, such that the first light beam 1 and the second light beam 2 leave the acousto-optical element 4 in collinear fashion as a combined light beam 3.

5

In the exemplary embodiment shown here, the acousto-optical element 4 is an AOTF.

The beam combiner has a compensation element 5 for compensating spatial splits or chromatic or polarization-dependent aberrations caused by the acousto-optical element 4, which are produced by the refraction or double refraction, respectively, in the crystal of the AOTF. The compensation element 5 is designed as a passive AOTF or as a prism.

10
15

Furthermore, the beam combiner also has diverse mirrors and fiber couplers for coupling the light sources 6 and 7.

The light source 6 is a continuously tunable laser. The light source 7 can be an argon-ion laser.

Figure 2 shows a schematic illustration of the use of the beam combiner from Figure 1 in a confocal microscope 9 having a controllable beam splitter 8. The beam splitter 8 is used as the main beam splitter of the confocal microscope 9.

Upon the use of the beam combiner, an adapted and/or synchronized control of the components is implemented. This includes the beam splitter 8 or main beam splitter, respectively, of the confocal microscope 9 always being connected in such a way that light intended for use by the beam combiner can pass the main beam splitter 8 in a manner as unobstructed as possible. For this purpose, in the case of a plurality of connections of the beam combiner according to the invention, in each case the respective associated optimum setting of the downstream beam splitter 8 is determined, stored accordingly, and used for the later control, so that an optimum adaptation of the components can be performed in every situation. The beam combiner is arranged in a housing

20
25
30
35

10 of the light source 6. The light beam 1 of the other light source 7 is guided in the housing 10 to the beam combiner. The light beam 1 is a light beam which consists of combined individual beams.

5

Reference is made to the general part of the description and to the appended patent claims with respect to further advantageous embodiments of the teaching according to the invention to avoid repetitions.

10

Finally, it is to be noted that the above-described exemplary embodiment serves solely to explain the claimed teaching, but does not restrict this teaching to the exemplary embodiment.

List of reference numerals

	1	first light beam
	2	second light beam
5	3	combined light beam
	4	acousto-optical element
	5	compensation element
	6	light source
	7	light source
10	8	beam splitter
	9	confocal microscope
	10	housing

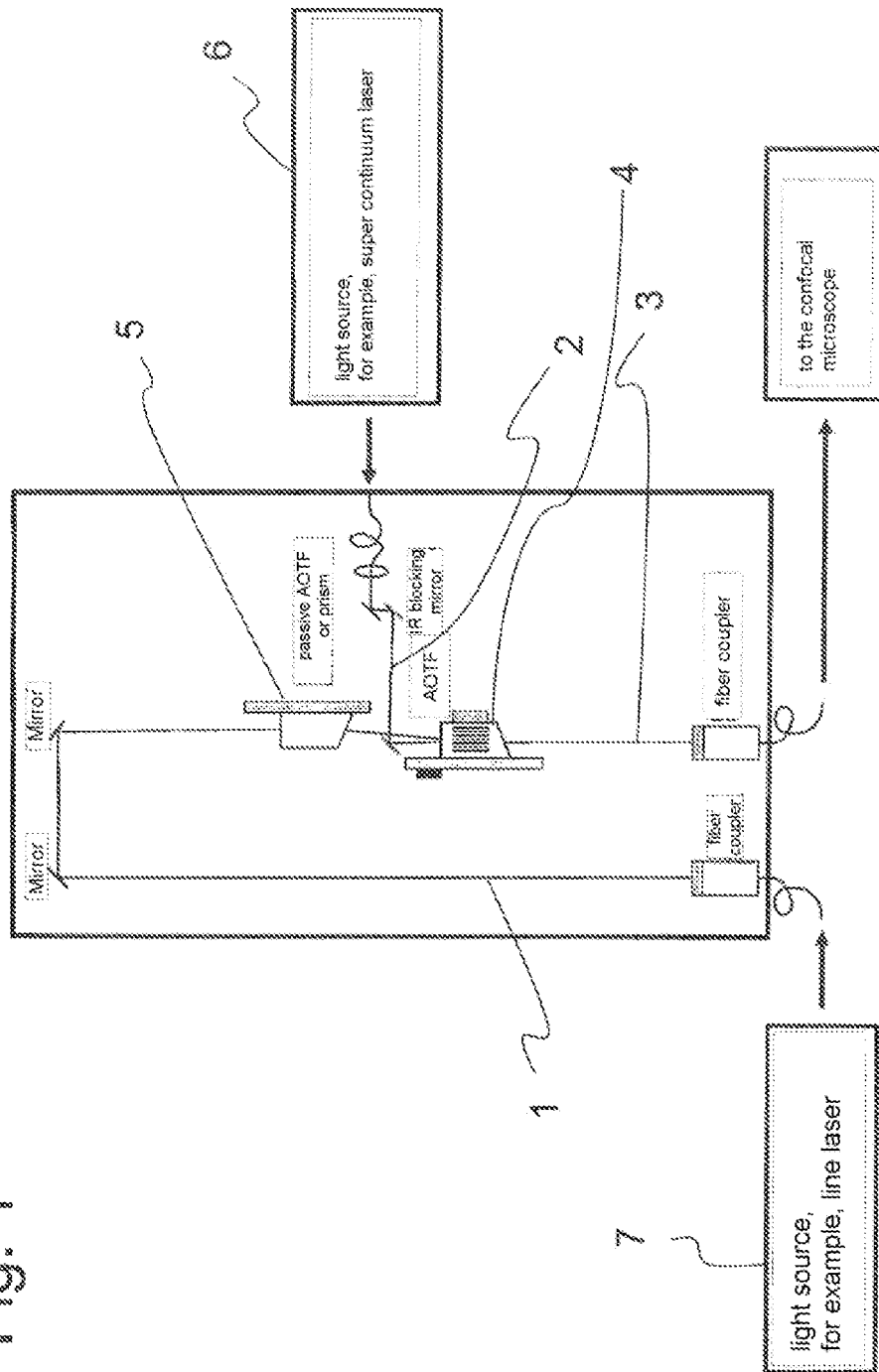
Patentkrav

1. Optisk arrangement med
en strålesamler til samling af i det mindste to lysstråler (1,
5 2) til en samlet lysstråle (3), nemlig i det mindste en første
lysstråle (1) og en anden lysstråle (2), i det optiske
arrangements strålegang,
en til strålesamleren koblet første lyskilde (7) til generering
af den første lysstråle (1) og
10 en til strålesamleren koblet anden lyskilde (6) til generering
af den anden lysstråle (2),
hvor den første lyskilde (7) til generering af den første
lysstråle (1) er en enkeltbølgelængde- eller
flerbølgelængde-laser,
15 hvor den første lysstråle (1) eller den anden lysstråle (2) har
lys med forskellige bølgelængder eller lys med forskellige
spektrale andele, og
hvor strålesamleren har en første AOTF (Acousto Optical Tunable
Filter) (4), i hvilken der kan genereres en mekanisk bølge eller
20 lydbølge til afbøjning eller bøjning af lysstråler, således at
den i strålesamlerens første AOTF (4) indtrædende første
lysstråle (1) og i det mindste den i den første AOTF (4) i
strålesamleren indtrædende anden lysstråle (2) forlader den
første AOTF (4) som samlet lysstråle (3) kollineært med
25 hinanden,
kendetegnet ved, at den anden lyskilde (6) til generering af den
anden lysstråle (1) er en kontinuerligt justerbar laser, at
strålesamleren har et kompositionselement (5) til komposition
for af den første AOTF (4) fremkaldte rumlige opspaltninger
30 eller kromatiske eller polarisationsafhængige aberrationer,
at kompositionselementet (5) er et akustooptisk element i form
af en anden AOTF, og
at den første AOTF (4) kan gennemstråles sådan af den første
lysstråle (1), at den mekaniske bølge eller lydbølge ikke
35 afbøjer eller bøjer den første lysstråle (1), og at den mekaniske
bølge eller lydbølge afbøjer eller bøjer den anden lysstråle (2)
sådan, at den første lysstråle (1) og den anden lysstråle (2)
forlader den første AOTF (4) kollineært med hinanden som samlet

lysstråle (3).

2. Optisk arrangement ifølge krav 1, kendetegnet ved, at der efter strålesamleren er koblet en aktiverbar stråledeler (8) eller en aktiverbar stråledeler som hovedstråledeler til et konfokalmikroskop (9).
3. Optisk arrangement ifølge krav 1 eller 2, kendetegnet ved, at der før og/eller efter strålesamleren er anbragt i det mindste et element, der varierer lysintensiteten, eller en AOTF.
4. Optisk arrangement ifølge et af kravene 1 til 3, kendetegnet ved, at strålesamleren har en temperaturstabilisering.
5. Optisk arrangement ifølge et af kravene 1 til 4, kendetegnet ved, at strålesamleren er anbragt i et hus (10) til en af de lyskilder (6) eller laserlyskilder, der genererer lysstrålerne (2).
6. Optisk arrangement ifølge et af kravene 1 til 5, kendetegnet ved, at det optiske arrangement er et mikroskop.

Fig. 1



29

