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(54) **SYSTEM AND METHOD FOR THERAPY AND DIAGNOSIS COMPRISING IN COMBINATION NON-MECHANICAL AND MECHANICAL DISTRIBUTORS FOR DISTRIBUTION OF RADIATION**

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(57) **ABSTRACT**

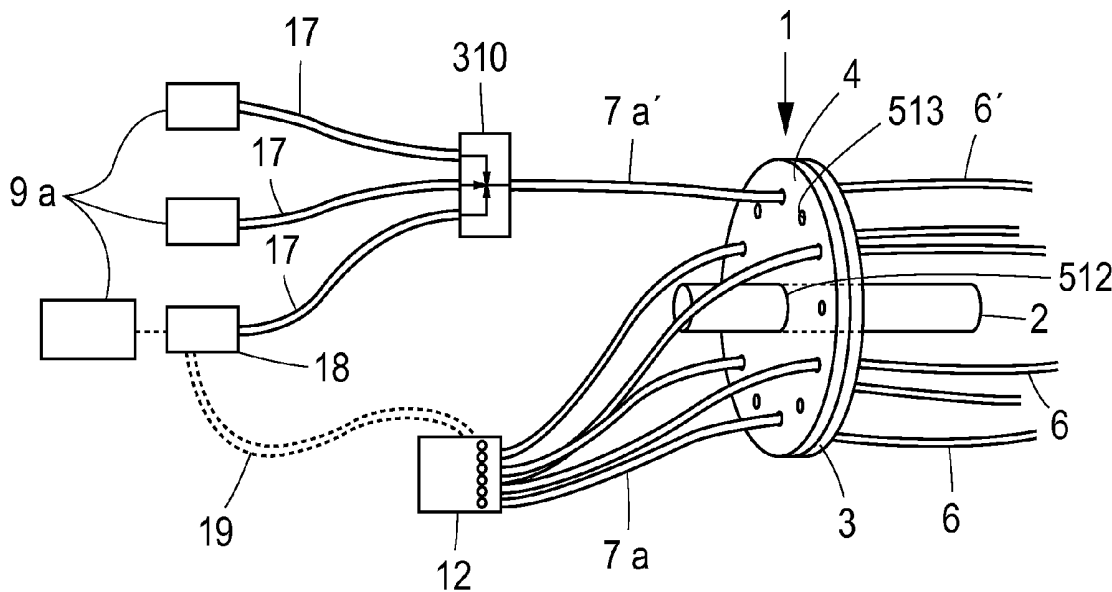
A system and method for therapy and diagnosis of a human or animal. At least one coupling element for coupling of radiation couples radiation from at least a first radiation source to a tumor site and/or from said second radiation source to said site and/or from said site to a detector. The coupling elements are combinations of at least one translatory distributor, at least one rotary distributor, and at least one operation mode selector means for directing either said therapeutic radiation or said diagnostic radiation to said site through said at least one first radiation conductor. The system may be used for interactive interstitial photodynamic tumor therapy. The system and method according to the invention combines the advantages of purely mechanical and purely non-mechanical solutions in a new and synergetic way.

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(60) Provisional application No. 60/470,856, filed on May 16, 2003, provisional application No. 60/470,854,



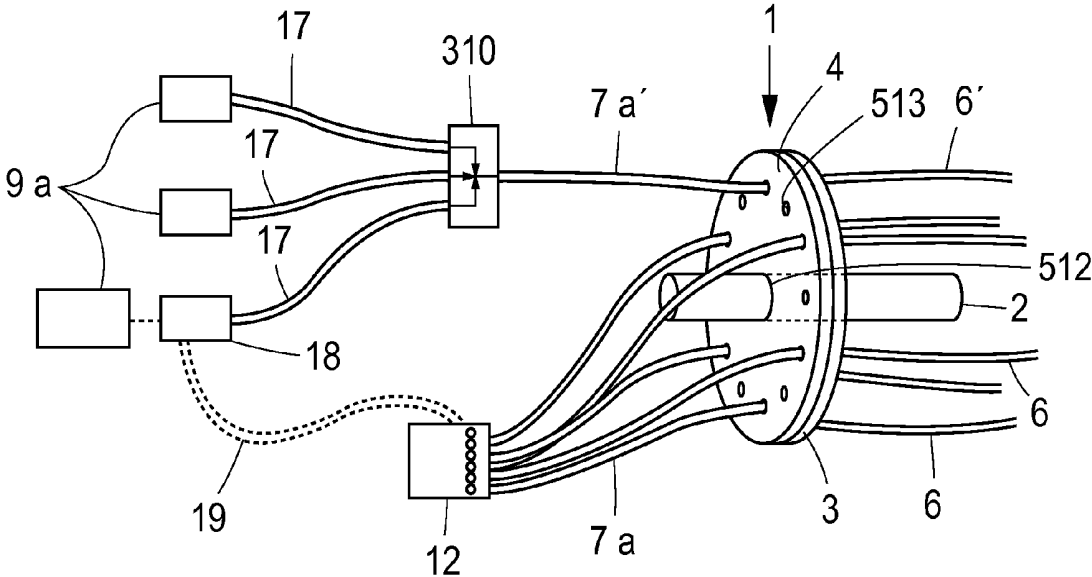


Fig.1

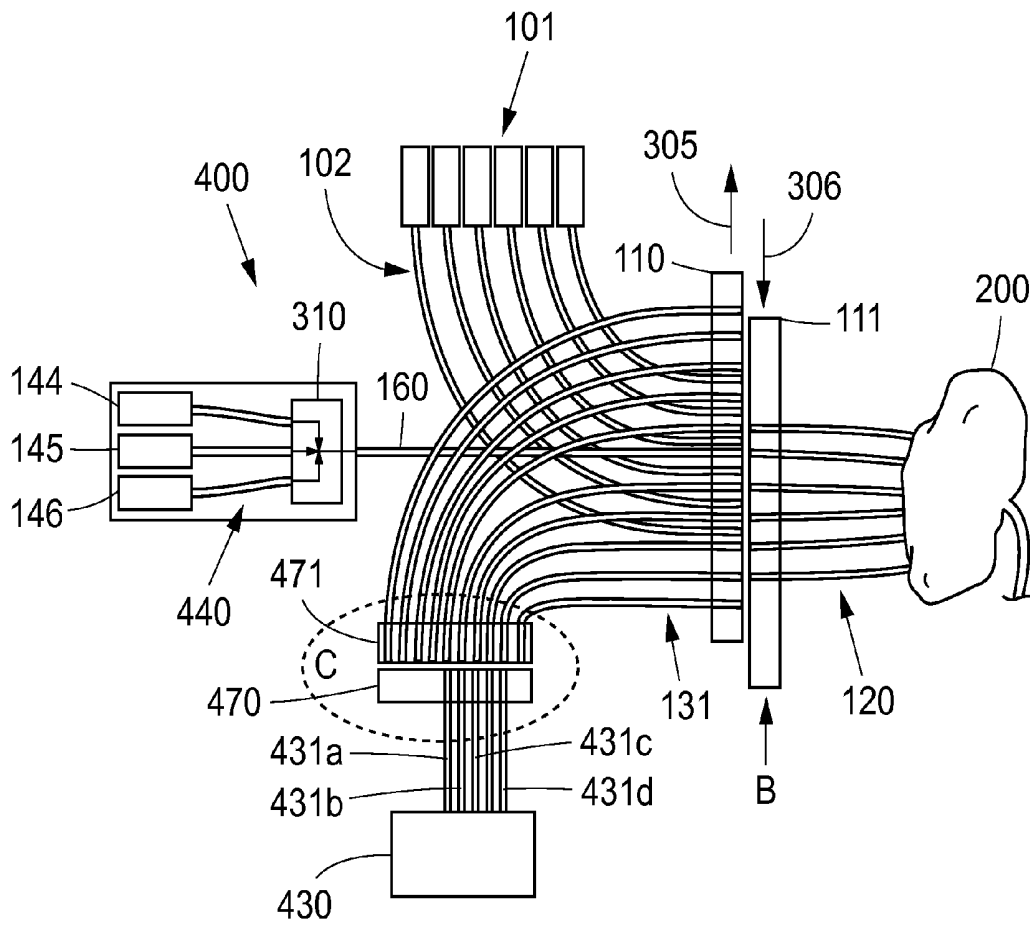


Fig.2

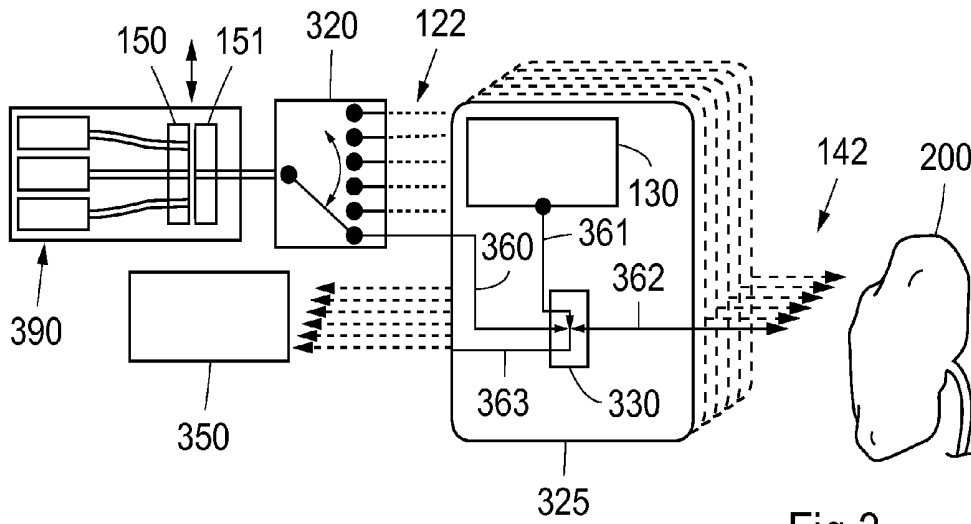


Fig.3

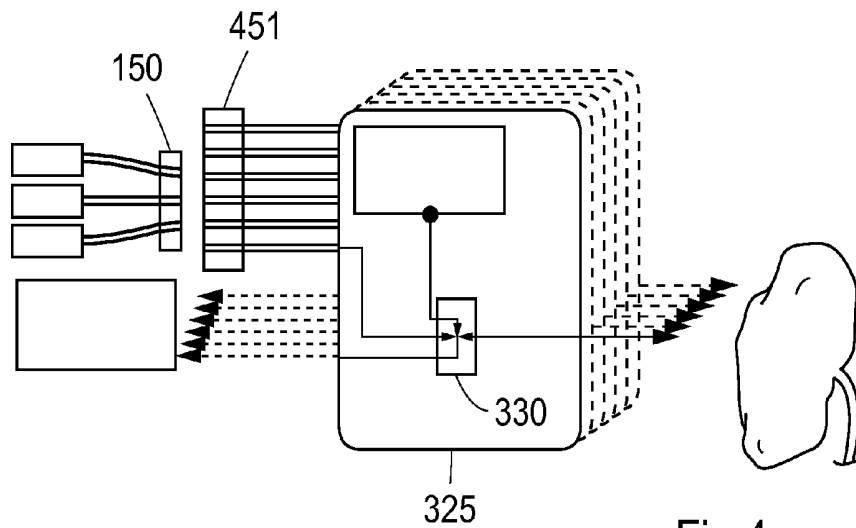


Fig.4

**SYSTEM AND METHOD FOR THERAPY AND
DIAGNOSIS COMPRISING IN
COMBINATION NON-MECHANICAL AND
MECHANICAL DISTRIBUTORS FOR
DISTRIBUTION OF RADIATION**

**CROSS REFERENCE TO RELATED
APPLICATIONS**

[0001] This application is a continuation of U.S. application Ser. No. 10/556,919, filed on Dec. 4, 2006, which is a National Phase filing of PCT/SE04/00758. This application also claims priority to Provisional Applications 60/470,856; 60/470,854; and 60/470,855. The content of U.S. application Ser. No. 10/556,919 is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates generally to a system and a method for therapy and diagnosis in a subject. More particularly, the system and method relate to a system and method for tumor therapy and diagnosis in a human or animal. Even more particularly, the invention relates to a system and method for photodynamic therapy (PDT) and/or photothermal therapy (PTT) and/or photodynamic diagnosis (PDD) of a site on and/or in a body, wherein electromagnetic non-ionizing radiation is conducted to the site for reaction with the radiation, wherein the system comprises at least one operation mode selector element for distribution of radiation from at least one source of radiation to a reaction site, and/or from the reaction site to at least one radiation sensor, respectively, and wherein the reaction site generally is a tumor site with a tumor, such as a malignant tumor.

[0004] 2. Description of the Related Art

[0005] Within the field of medical therapy of tumor diseases, a plurality of treatment modalities has been developed for the treatment of malignant tumor diseases: operation, cytostatic treatment, treatment with ionizing radiation (gamma or particle radiation), isotope therapy and brachytherapy employing radioactive needles are examples of common treatment modalities. In spite of great progress within therapy, the tumor diseases continue to account for much human suffering, and are responsible for a high percentage of deaths in western countries. A relatively new treatment modality, photodynamic therapy, commonly abbreviated PDT, provides an interesting complement or alternative in the treatment field. A tumor-seeking agent, normally referred to as a precursor or sensitizer, is administered to the body intravenously, orally or topically. It generally accumulates in malignant tumors to a higher extent than in the surrounding healthy tissue. The tumor area is then irradiated with non-thermal red light, normally from a laser, leading to excitation of the sensitizer to a more energetic state. Through energy transfer from the activated sensitizer to the oxygen molecules of the tissue, the oxygen is transferred from its normal triplet state to the excited singlet state. Singlet oxygen is known to be particularly toxic to tissue; cells are eradicated and the tissue goes in necrosis. Because of the localization of the sensitizer to tumor cells a unique selectivity is obtained, where surrounding healthy tissue is spared. The clinical experiences, using in particular haematoporphyrin derivative (HPD) and delta aminolevulinic acid (ALA) have shown good results.

[0006] Sensitizers may also exhibit a further useful property; to yield a characteristic fluorescence signal when the substance is excited with visible or ultraviolet radiation. This signal clearly appears in contrast to the endogenous fluorescence of the tissue, which is also called autofluorescence, and is used to localize tumors and for quantifying the size of the uptake of the sensitizer in the tissue.

[0007] The limited penetration in the tissue of the activating radiation is a big drawback of PDT. The result is that only tumors less than about 5 mm in thickness can be treated by surface irradiation. In order to treat thicker and/or deep-lying tumors, interstitial PDT (IPDT) can be utilized. Here, light-conducting optical fibers are brought into the tumor using, e.g., a syringe needle, in the lumen of which a fiber has been placed.

[0008] In order to achieve an efficient treatment, several fibers have been used to ascertain that all tumor cells are subjected to a sufficient dose of radiation so that the toxic singlet state is obtained. It has been shown to be achievable to perform dose calculations of the absorptive and scattering properties of the tissue. E.g., in the Swedish patent SE 503 408 an IPDT system is described, where six fibers are used for treatment as well as for measurement of the light flux which reaches a given fiber in the penetration through the tissue from the other fibers. In this way an improved calculation of the correct light dose can be achieved for all parts of the tumor.

[0009] According to the disclosure of SE 503 408, the light from a single laser is divided into six different parts using a beamsplitter system comprising a large number of mechanical and optical components. The light is then focused into each of the six individual treatment fibers. One fiber is used as a transmitter while the other fibers are used as receivers of radiation penetrating the tissue. For light measurement light detectors are mechanically swung into the beam path which thus is blocked, and the weak light, which originates from the fibers that collected the light which is administered to the tissue, is measured.

[0010] However, such open beam paths result in a strongly lossy beamsplitting and the resulting losses of light drastically impair the light distribution as well as the light measurement. Furthermore, such a system must often be adjusted optically, which is also an important drawback in connection with clinical treatments. The system is also large and heavy and difficult to integrate into a user-friendly apparatus. Moreover, it is difficult to control the power of the light sent into each individual fiber, which makes the measurement results unreliable.

[0011] EP-A1-0523417 discloses a pipeline switch for distribution of radioactive emitters and/or test objects for radiotherapy, i.e. radioactive radiation treatment of a body. The emitters or test objects are conveyed within pipelines on flexible wires movable within the conduit. First pipes for conveying the flexible wires to the switch are on the one hand connected to a moveable switch element and second pipes further conveying the flexible wires to the body connected to a second, stationary switch element. The two switch elements are moveable relative each other and different constellations of pipelines are thus possible. However, when changing from one constellation to another, the flexible wire has to be retracted between each switching process, otherwise the relative movement of the switch element is obstructed. Switching times and treatment times are thus very long. Furthermore, the pipelines are not suitable for conducting radiation them-

selves, they just provide external protection and guidance to the flexible wires conveyed therein. The construction is also bulky and not suited for small optical fibers. Moreover, the arrangement of the disclosure is not suited for diagnosis, only for therapy, and no interactive co-operation is disclosed.

[0012] EP-A2-0280397 discloses a sterilizable endoscope having a central coherent fiber bundle for carrying an image to a viewing means. The fiber bundle is surrounded by light fibers. The proximate end of the endoscope is provided with a coupling means for aligning the optical fiber bundle with the optical system of the viewing means and for providing an interface with light transmitting means to transmit light from a light source along the light fibers to a body cavity to be inspected. The device can be used for detection of cancer cells and treatment thereof by phototherapy. A dye is attached to the tissue being examined and subsequently exposed to an exciting laser light frequency. Cancer cells will emit fluorescent light at a characteristic fluorescence frequency. The fluorescence light is detected and displayed on the video monitor and light with the same frequency as this fluorescent light is then transmitted through the light fibers to the cell for phototherapy treatment. However, only the use of a single wavelength light source is disclosed, it is thus not possible to have multiple diagnostics performed without manually exchanging the light source. Moreover, it is not possible to switch between different constellations of the light fibers, i.e. all fibers always have the same function (light in or light out). The coupling means mentioned in EP-A2-0280397 is only used to adjust the path of light through a two-part endoscope when it is assembled prior to use. In addition, different fibers are used for directing therapeutic light to a cancer location and to direct diagnostic light back through the endoscope. No distribution is performed between different operating modes. This solution offers for instance neither interactive treatment nor tomographic mapping of tumors.

[0013] WO-A1-02074339 discloses a device and method for photodynamic diagnosis of tumor tissue by using fluorescent cobalamins. These fluorescent cobalamins are used as diagnostic and prognostic markers (a) to distinguish cancer cells and tissues from healthy cells and tissues, and (b) to determine if an individual responds positively to chemotherapy using cobalamin-therapeutic bioconjugates. An apparatus is disclosed that includes a camera coupled to the proximal end of a surgical telescopic device. The surgical telescopic device is used for illuminating tissue with non-white light and detecting the emitted fluorescence for diagnostic purposes. The use of a dual light sources including a red (non-white) and a white light source is disclosed. The white light source is used for conventional illumination of the tissue. A switch is mentioned for switching between the alternative light sources. The switch might be voice-actuated, mechanically-operated (foot pedal), optically-operated, or electronically-operated. The switch is not described in more detail, except that a mirror or prism under mechanical or electromechanical control can be used to switch between the two light sources. Alternatively, a light source with two physically separated outputs is disclosed. In this case the light input to the surgical telescopic device has to be moved between the two outputs in order to switch illumination source for the tissue. The device is not suitable for therapy. Therapy has to be performed conventionally by a surgeon removing the cancerous tissue detected by means of fluorescence. Therefore, this device is not suited for interactive diagnosis and therapy. Furthermore, there is no indication for a switch suitable for

switching between different modes of diagnosis or therapy. Furthermore, the disclosed device offers only substantially superficial diagnosis or treatment, interstitial tissue cannot be diagnosed or treated. The device is also limited to existing body cavities and has the drawback that endoscopic probes are bulky and large compared to single optical fibers.

[0014] EP-A2-0195375 discloses a catheter for laser angioplasty. The device is used for detecting atherosclerotic plaque deposits by means of detecting fluorescent light as a reaction on excitation light sent through the catheter comprising optical fibers for this purpose. The same fiber may be used for sending excitation light to the plaque and for receiving fluorescent light from the plaque. When plaque is detected, it may be removed by sending high energy light through selected fibers in the catheter. However, this system is not suited for diagnosis or treatment of tumors. Fibers to be illuminated are selected by purely mechanical arrangements either moving the light source or the fibers in order to align the two towards each other. This device is also bulky compared to single fibers, similar to the above mentioned endoscope, bound to existing body cavities and works substantially superficial. Furthermore it is not selective, i.e. all tissue aimed at is destroyed, independently if it is noxious or healthy.

[0015] Thus, there is a need for a new compact device allowing distributing of radiation in a system for PDD, PDT and PTT for implementing a smart way of performing interactive interstitial treatment. One solution would be to use smart mechanical constructions for switching between different operating modes avoiding e.g. the lossy beamsplitters and allowing e.g. automatic calibration.

[0016] Such a mechanical solution to the above mentioned problems has been proposed in PCT/SE02/02050, wherein a distributor for radiation having two discs rotating relative each other is described. The radiation distributor couples optical fibers between different operating modes by rotational movement of fibers in these discs relative each other. For switching between several light sources to one fiber going to the patient, an assembly with a total of four discs is described. There is a need to further reduce the size of the described solution in order to further minimize the size of the system.

[0017] However, although these purely mechanical constructions are improvements to the above described known IPDT system and although the above described problems are solved, these mechanical solutions have other limitations, related to e.g. mechanical inertia limiting the switching time between the different modes of a therapy and diagnosis system such as an interactive interstitial treatment system. There is also a desire to remove at least a certain number of mechanical switching elements in order to minimize costs for service. However, sometimes it is not economically defendable to replace all mechanical systems.

[0018] Thus, there is a need for a new system and/or compact device allowing distributing of radiation in a system for therapy and diagnosis in a human or animal, wherein the therapy and diagnosis comprises PDD, PDT and PTT, and wherein the system provides an optimal relationship between advantages such as reliable measurements, optimum of flexibility, cost-effectiveness, production efforts, but also that e.g. multiplexing, as described below, is possible.

SUMMARY OF THE INVENTION

[0019] The present invention overcomes the above identified deficiencies in the art and solves at least the above identified problems by providing a system and a method accord-

ing to the appended patent claims, wherein a very practical and efficient implementation of interactive IPDT is achieved in that different radiation measurements for diagnostics and dosimetry can be performed in an integrated and simple way. An important application of the invention is interactive, interstitial photodynamic therapy, and/or interactive photothermal tumor therapy. According to the invention, the size of a system using existing radiation distributors, such as described in PCT/SE02/02050 is further reduced. Furthermore, the invention is improving the prior art by providing alternative solutions to the problems and drawbacks associated with the systems according to the prior art. Moreover, the system according to the invention combines the advantages of purely mechanical and purely non-mechanical solutions in a new and synergetic way. Non-mechanical elements have several advantages. Among others, these advantages comprise: high switching speed between different system operation modes (diagnosis, photodynamic therapy, thermal therapy); compactness and stability of the system; excellent radiation parameters; long life of the system due to no mechanical wear of the components and due to many more switching cycles during a life-cycle of the elements of the system, and low noise offering comfort to the user and patient, etc. In combination with mechanical distributors for radiation, non-mechanical elements for distribution of radiation also provide increased flexibility.

[0020] The term "radiation" used hereinafter in this specification refers to radiation suitable for the field of the invention, i.e. for photodynamic therapy (PDT) and/or photothermal therapy (PTT) and/or photodynamic diagnosis (PDD). More specifically this radiation is "optical" radiation, i.e. non-ionizing electromagnetic radiation within the wavelength-range of infrared (IR), visible or ultraviolet light. This also concerns radiation sources, radiation conductors, radiation sensors, radiation switches etc. within the scope of the embodiments and claims defining the invention, i.e. these sources, conductors or sensors for "radiation" are adapted to generate, conduct, measure, etc. the above-mentioned radiation.

[0021] According to one aspect of the invention, a system for therapy and/or diagnosis of a human or animal comprises at least one first radiation source for emission of a diagnostic radiation, at least one first radiation conductor adapted to conduct radiation to a site at or in said human or animal, at least one second radiation source for emission of a therapeutic radiation through at least one of said radiation conductors to said site, and at least one radiation detector, wherein at least one coupling element for coupling of radiation couples radiation from at least the first radiation source to the site and/or from said second radiation source to said site and/or from said site to said detector. The coupling elements are combinations of at least one translatory distributor comprising at least one translatory element being arranged in such a manner that radiation is coupled in different constellations by translatory movement of said translatory element between pre-determined positions, wherein radiation conductors are attached to said translatory element, and at least one rotary distributor comprising two rotary elements being arranged in such a manner that radiation is coupled in different constellations by rotational movement of said rotary element between pre-determined positions, wherein radiation conductors are attached to said elements, and at least one operation mode

selector means for directing either said therapeutic radiation or said diagnostic radiation to said site through said at least one first radiation conductor.

[0022] As already mentioned, the system combines the advantages of non-mechanical elements with the advantages of mechanical elements in an optimal way. Among others, these advantages of radiation elements comprise: high switching speed between different system operation modes (diagnosis, photodynamic therapy, thermal therapy); compactness and stability of the system; excellent radiation parameters; long life of the system due to no mechanical wear of the components and due to many more switching cycles during a life-cycle of the elements of the system. Examples of the advantages of mechanical elements comprise: easy manufacturing; inexpensive; readily available technology; efficient radiation transmission; low crosstalk. Yet a further advantage is an adaptation to effective consideration of power management and compatibility of the system components. In general, the radiation used for therapy has a much higher effect/power than the diagnostic radiation, with at least a factor 10 in difference. The elements for switching/coupling this radiation have to be adapted to this effect. In general it is more cost-effective to use mechanical solutions for high power applications. Thus, the combination of elements suggested by the present application has a surprising synergetic effect that one does not realize immediately. Yet a further advantage is that according to one embodiment, the system is made more simple by using a therapeutic radiation source also for diagnostic radiation, thus saving a diagnostic radiation source. Finally switching times are provided that offer a convenient and comfortable treatment of a patient.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In order to explain the invention in more detail, a number of embodiments of the invention will be described below with reference to the appended drawings, wherein

[0024] FIG. 1 is a schematic view illustrating an embodiment of the invention having a radiation distributor with two rotationally arranged discs and a radiation element for coupling between diagnostic radiation sources;

[0025] FIG. 2 is a schematic view illustrating another embodiment of the invention having two different translatory radiation distributors and one radiation element coupling three diagnostic radiation sources, wherein radiation guides are arranged interstitially inserted in a tumor;

[0026] FIG. 3 is a schematic view of a further embodiment of the invention comprising radiation combiners, an radiation switch and a translatory radiation distributor; and

[0027] FIG. 4 is a schematic view illustrating yet a further embodiment of the system according to the invention with a radiation distributor coupling diagnostic radiation sources by means of a translatory element.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0028] Different embodiments of the system according to the invention are now described with reference to the drawings. In order to simplify the description of the embodiments, reference numerals for similar elements shown in the drawings are not repeated throughout all the figures.

[0029] FIG. 1 is a schematic view illustrating an embodiment of the invention, wherein a rotary radiation distributor 1 comprises two flat and in proximity lying discs 3,4 made of,

e.g., 1 cm thick material such as steel, aluminum/titanium/magnesium, a composite material etc. When composite material is used, this may reduce the thickness to some mm, depending on different parameters, such as the way of fastening the radiation conductors to the distributor. When a contact element, such as conventional optical fiber couplings are used for fixing the radiation conductors to the distributor, these couplings ensure the mechanical stability and define the size of the distributor elements. In case the radiation conductors are optical fibers directly attached to the distributor elements, the elements are more compact. This reasoning is valid for similar elements. In the case of a micromechanical realization even smaller dimensions are obtained. The lighter the material is, the faster rotation of the discs between fixed positions is possible, while it is important that the discs at the same time are rigid and preferably durable. The same applies to the material of the other mechanical distributors described in this application. The two discs 3,4 are hereby arranged on an axis 2, wherein one of the discs is a fixed disc 4 and the other one is a turnable disc 3, wherein the terms "fixed" and "turnable" are merely for the purpose of simplifying and not for limiting the present description. The two discs 3,4 are rotatable relative each other. In use the discs 3 and 4 are arranged in close proximity against each other, as shown in FIG. 1.

[0030] Evenly distributed holes 513 lying on a circle are arranged in both discs (not shown in the Figs.) for fixation of radiation conductors 6, 6', 7a, 7a'. Preferably the diameter of the holes is 0.1-0.7 mm in case the radiation conductors are optical fibers directly attached to the disc. In order to attain a high precision, allowing the radiation conductors to be arranged exactly face to face, the holes of the two discs can be drilled together, e.g. with a centering tube. Alternatively, high precision cutter or drilling machines may be used for producing the discs or any other mechanical elements mentioned in this description. Then the common axis 2 is utilized arranged through centrally located holes 512 of the discs 3,4. It is thus possible to achieve a very high precision when making the series of holes.

[0031] By employing discs drilled together, radiation conductors can be fixed in said discs, wherein an extra, thinner disc then can be turned slightly, preferably spring-loaded, so that all radiation conductors are simultaneously pinched in their positions without the need for any glue or other fixation means. Alternatively, the diameter of the holes is made larger than the diameter of the radiation conductors, wherein the holes can be dressed with an appropriate piece of tubing, or the ends of the radiation conductors can be supplied with a fitted hose. Alternatively, the ends of the radiation conductors can be flared or flanged into the holes or the holes may be equipped with appropriate SMA connector or other type of connectors for receiving radiation conductors. The same principle applies to the holes and fixation of radiation conductors in the translatory radiation distributors as described with reference to the following embodiments.

[0032] Preferably the radiation conductors are optical fibers, wherein different types of hoses or flexible tubes containing a radiation-conducting material are included. The radiation conductors should have such a length and be arranged in such a way that the discs can be turned a full turn (± 180 degrees) without problems. The direction of movement may be reversed to avoid the radiation conductors forming a spiral. The same principle applies to the translatory elements disclosed in this description, wherein the radiation conductors connected to the translatory elements should have

such a length that the function of the translatory elements or the radiation conductors is not negatively influenced. Moreover, the length of the radiation conductors should be sufficiently long, that the positioning of the distal ends of the patient radiation conductors are not negatively influenced.

[0033] According to this embodiment of the invention, a plurality of first radiation conductors 6 in a system for PDD, PDT and PTT are arranged in turnable disc 3 for conduction of radiation to and from a reaction site 200 (shown e.g. in FIG. 2). By a reaction site we in the present context mean a site where photodynamically active compounds will react in a tumor when subject to therapy, e.g., by being forwarded through the lumen of injection needles which are placed in the tumor, these radiation conductors 6 are then fixed in the reaction site 200. Then the radiation conductors are moved forward to arrive outside the distal end of the needle. The same radiation conductor 6 is used continuously during the treatment for integrated diagnostics and dosimetry as well as to avoid that the patient be subjected to multiple pricks.

[0034] The holes 513 in the fixed disc as well as in the turnable disc are arranged on a circular line, wherein the circle radius on one disc equals the circle radius on the other disc. The holes on one disc are equally distributed along the circle line with an angular separation of $v1=(360/n1)$ degrees, where $n1$ equals the number of holes, and the holes of the other disc are equally distributed along the circle line with an angular separation $v2$ equaling $(360/n2)$ degrees. The first ends of the first radiation conductors 6 are fixed in the holes of the turnable disc 3, and first ends of the second radiation conductors 7a are fixed in the holes of the fixed disc 4. In order to make the holes, and thereby the radiation conductors in both discs connectable to each other in different constellations by turning of the turnable disc 3, $n2$ is selected to be a multiple of $n1$, in such a way that $n2$ is obtained as an integer larger or equal to 1. Suitably the number of holes in the fixed disc is chosen from two to more than six, e.g. two, three, four, five, six, seven, eight, nine or ten.

[0035] According to the currently described embodiment, six holes are arranged in the turnable disc 3 and twelve holes are arranged in the fixed disc 4. With six first radiation conductors 6 the angular separation of the holes will accordingly become 60 degrees in the turnable disc 3 and with twelve holes arranged in the fixed disc 4 the angular separation will become 30 degrees for the second radiation conductors 7a.

[0036] The coupling of diagnostic radiation from diagnostic radiation sources 9a to a single radiation conductor 7a' is accomplished by means of a radiation combiner 310. For switching to a diagnostic operation mode, the therapeutic radiation sources (not shown in FIG. 1) are switched off and subsequently one of the three diagnostic radiation sources 9a is activated. Thus, diagnostic radiation is conducted to combiner 310 via radiation conductors 17, where the radiation from the active diagnostic radiation source is coupled to the output of the combiner leading via the radiation conductor 7a' to disc 4, where it is coupled to one radiation conductors 6 going to a tumor site 200 in a patient.

[0037] In order to facilitate the comprehension of the invention the following description of a preferred embodiment of the distributor of the system according to FIG. 1 comprises a rotary radiation distributor, which relates to six first radiation conductors 6 arranged in the turnable disc 3 for conduction of radiation to and from the reaction site 200.

[0038] Thus, the turnable or rotatable disc 3, as well as the fixed disc 4, have six holes 513 for corresponding second

radiation conductors, and, for disc 4, in addition, six further holes for second radiation conductors being connected to therapeutic radiation sources (not shown in FIG. 1). All these radiation conductors can release radiation to the reaction site 200 and receive radiation from said site. Thus, several measurements can be recorded and read out simultaneously.

[0039] By turning the turnable disc 3 the first and the second radiation conductors become connectable to each other in different constellations. An exact positioning of the opposing radiation conductors in the distributor 1 is facilitated by arranging means for stopping the turnable disc 3 in predetermined angular positions, for instance, grooves may be arranged in the axis 2 for catching a spring-loaded ball arranged in the turnable disc 3 (not shown in the Figs.) or an angular detector on the rotatable disc can be used. Alternatively electronic regulation using stepper motors or servomotors may be used for this purpose, also in combination with then "seventh hole" method described below.

[0040] In order to allow a fast and efficient switching between a diagnostic operation mode and a therapeutic operation mode, every second of the second radiation conductors of the distributor 1 according to the invention, are divided into a first and into a second series. Both series of holes are arranged on the same circle, but displaced by 30 degrees with regard to each other. A specific radiation conductor in the first series of every other second radiation conductor is arranged for emitting radiation from at least one radiation source. The other, non specific radiation conductors in the first series of second radiation conductors are arranged for conduction of radiation to at least one radiation sensor 12. The second series of every other second radiation conductor is for therapeutical purposes arranged to emit radiation to the reaction site 200 from at least one radiation source.

[0041] The radiation conductors are preferably optical fibers, which in the distributor 1 shown in FIG. 1 are connected to the fixed disc 3 as well as the turnable disc 4. Out of the fibers, which are connected to the turnable disc 4, six fibers can be used for diagnostic purposes and six can be used of therapeutical purposes. However, in the diagnostic operation mode, radiation from one to more than three modalities 9a can be employed.

[0042] With reference to FIG. 1 only radiation conductors which are coupled for diagnosis to a fixed disc are for clarifying purposes shown; the other radiation conductors are not shown although they are coupled to said disc.

[0043] By turning the turnable disc 3 by 30 degrees the fibers 6 which are optically coupled to the tissue of the patient can be employed for therapy as well as diagnostics and measurements. One radiation conductor 7a' out of every second radiation conductor fixed on disc 4 is in the diagnostic operation mode connected to different radiation sources for diagnostics, while the other five radiation conductors 7a receive signals, which are related to the interaction of these radiation sources with the tissue. Radiation conductors (not shown in FIG. 1, whereas the holes 513 are shown) are connected to therapeutic radiation sources, e.g. lasers, whereas radiation conductors 7a are connected to radiation detectors. Radiation conductors 17 are coupled to diagnostic radiation sources 9a.

[0044] Since intensity as well as spectral resolution is of interest, the distal ends of these five radiation conductors 7a are arranged in a slit-like arrangement so that they overlap the entrance slit and/or constitute the entrance slit of the radiation sensor 12, which may be a compact spectrometer or other type of detector and is supplied with a two-dimensional detec-

tor array or one to several one dimensional detector arrays. The recording range of the spectrometer is preferably within the range of approximately 400 to 900 nm. Each of the radiation conductors 7a can of course be connected to an individual radiation detector 12 in the form of a spectrometer or another type of detector, e.g. a compact integrated spectrometer.

[0045] The assembly 1 is shown with the two discs 3,4 on a common axle 2 and the combiner 310 for coupling different diagnostic radiation sources. In this way a compact and robust construction is obtained for switching between the diagnostic radiation sources.

[0046] Preferably one of the radiation sources 9a is a laser of the same wavelength as the ones utilised for the laser irradiation for photodynamic tumor therapy, but could be of lower output power.

[0047] Certain of the radiation sources 9a are utilised in order to study how radiation (light) of the corresponding wavelength is penetrating through the tissue of the tumor. When radiation from a radiation source is transmitted through the particular radiation conductor via combiner 310 and the discs 4, 3 into the tissue, one radiation conductor 6' of the first radiation conductors 6, which is the one opposing the radiation conductor 7a', will function as a transmitter in the tumor, and the other five radiation conductors 6 in the tumor will act as receivers and collect the diffuse flux of radiation reaching them. The radiation collected is again conducted via the discs 3, 4 and via radiation conductors 7a to the radiation sensor 12 and five different radiation intensities can be recorded on the detector/detectors/detector array.

[0048] When the turnable disc 3 is turned by 60 degrees, the next radiation conductor 6 to the patient will get the role as transmitter, and the five others become the receivers for a new radiation distribution. After four further turns of the turnable disc 3, each by 60 degrees to the following radiation conductor 6 in the patient, radiation flux data for all remaining combinations of transmitters/receivers have been recorded. Thus, in total 6x5=30 measurement values are obtained and can be used as input data for a tomographic modeling of the radiation dose build up in the different parts of the tumor during the course of the treatment. Furthermore, by switching through the three radiation sources 9a, by means of switching the appropriate radiation source on or off, these 30 measurement values are multiplied by the number of radiation sources, resulting in 90 tomographic measurement values.

[0049] In addition to a specific wavelength, radiation from a white light source and/or broadband light emitting diodes and/or line light sources can be coupled into the particular active radiation conductor in radiation distributor 1. On passage through the tissue to the receiving radiation conductor 6 in the patient, the well-defined spectral distribution of the radiation source will be modified by the tissue absorption. Then, oxygenated blood yields a different signature than non oxygenated blood, allowing a tomographic determination of the oxygen distribution utilizing the thirty different spectral distributions which are read out, five spectra at a time in the six possible different constellations on rotation of the turnable disc 3 during a diagnostic investigation. Such a determination of the oxygenation in the tumor is important, since the PDT process requires access to oxygen in the tissue.

[0050] Finally, a light source for red, blue/violet or ultraviolet light, e.g. a laser, can be coupled to the particular active radiation conductor in radiation distributor 1. Then fluorescence is induced in the tissue, and a sensitizer administered to

the tissue displays a characteristic red fluorescence distribution in the red/near-infrared spectral region. The strength of the corresponding signal allows an approximate quantification of the sensitizer level in the tissue.

[0051] Since the short wavelength light (ultraviolet or blue/violet light) has a very low penetration into the tissue, the induced fluorescence will only be measured locally at the tip of the radiation conductor. For this task there is in this case for the corresponding radiation source **9a** at the distal end of the particular radiation conductor **17** a beamsplitter **18**, connected via the radiation conductor **17** and which is preferably a dichroic beamsplitter, transmitting the exciting radiation but reflecting the red-shifted fluorescence radiation. This reflected radiation is focused into the distal end of a conveying radiation conductor **19**, the other end of which is connected to the radiation sensor **12**, which records the fluorescence radiation distribution. A suitable self-contained fluorosensor is described in Rev. Sci. Instr. 71, 3004 (2000). Such a system with dichroic beamsplitters may also in a similar way be implemented by means of the other distributor system as shown in FIGS. 2 to 4.

[0052] By rotating the turnable disc **3**, the fluorescence that is a specific function of the concentration of the sensitizer, can be measured sequentially at the tips of the six radiation conductors **6**. Since the sensitizer is bleached by the strong red treatment radiation, being particularly strong just around the tip of the radiation conductor **6** conducting radiation to the patient, it is essential to make this measurement before the start of the treatment.

[0053] If the tips of the radiation conductors **6** in addition are treated with a material, the fluorescence properties of which are temperature dependent, sharp fluorescence lines are obtained upon excitation, and the intensity of the lines and their relative strength depend on the temperature of the tip of the radiation conductor **6**, being employed for treatment. Examples of such materials are salts of the transition metals or the rare earth metals. Thus also the temperature can be measured at the six positions of the six radiation conductors, one at a time. The measured temperatures can be utilised to find out if blood coagulation with an associated radiation attenuation has occurred at the tip of the radiation conductor **6**, and for studies regarding the utilization of possible synergy effects between PDT and thermal interaction. Since the lines obtained are sharp, they can be lifted off the more broad-banded fluorescence distribution from the tissue.

[0054] The concentration of the sensitizer can for certain substances be measured in an alternative way. Then the red radiation used for the radiation propagation studies is used to induce near-infrared fluorescence. This fluorescence penetrates through the tissue to the tips of the receiving radiation conductors **6**, **120**, **142**, and are displayed simultaneously as spectra obtained in the radiation sensor **12**. A tomographic calculation of the concentration distribution can be performed based on in total thirty measurement values.

[0055] After diagnostic measurements and calculations have been performed, the fibers **6** optically coupled to the tissue of the patients can be utilised for therapy by rotation of the turnable disc **3** by 30 degrees. Therapeutic radiation sources are thus coupled to the patient fibers **6**. The therapeutic radiation sources are preferably laser sources with a wavelength, which is adapted to the absorption band of the sensitizer. At the photodynamic tumor treatment a dye laser or a diode laser is preferably used, with a wavelength which is selected with regard to the sensitizer employed. For Photo-

Erin® the wavelength is 630 nm, for delta aminolevulinic acid (ALA) it is 635 nm and for phthalocyanines it is around 670 nm. The individual lasers are regulated during the treatment to a desirable individual output power. If desired, they may have built-in or external monitoring detectors.

[0056] The therapeutic treatment can be interrupted and new diagnostic data can be processed in an interactive method until an optimal treatment has been reached. This method can include synergy between PDT and hyperthermia, where an increased temperature is reached at increased fluxes of laser radiation. The whole process is controlled using a computer, which does not only perform all the calculations but also is utilised for regulation.

[0057] This present embodiment has the advantages of being cheap, all diagnostic radiation sources may be switched on at the same time or multiplexed, there is little risk of "blooming" (detector in permanent saturation) of the radiation detector **12**, there is no moving element or mechanical part for switching between the detector radiation sources, optical fibers with large diameters may be used, and the system has low radiation losses, i.e., it has a sound "photonomics". FIG. 2 is a schematic view illustrating another embodiment **400** of the invention having two different translatory radiation distributors B, C and one radiation element **310** coupling three diagnostic radiation sources, wherein radiation guides **120** are arranged interstitially inserted in a tumor **200**.

[0058] The coupling of diagnostic radiation from diagnostic radiation sources **144-146** to a single radiation conductor **160** is accomplished by means of an radiation combiner **310**. For switching to a diagnostic operation mode, the therapeutic radiation sources **101** are switched off and subsequently one of the three diagnostic radiation sources **144-146** is activated. Thus, diagnostic radiation is conducted to combiner **310**, where the radiation from the active diagnostic radiation source is coupled to the output of the combiner leading via the radiation conductor **160** to a transversal radiation distributor **110, 111**, where it is coupled to one of radiation conductors **120** going to a tumor site **200** in a patient.

[0059] A first translatory distributor B for radiation comprises two, in close proximity to each other lying, longitudinal translatory elements **110, 111** made of, e.g., 1 cm thick steel, however lower thicknesses are possible, as mentioned above. The longitudinal translatory elements are hereby arranged in such a manner that they may move translatory relative to each other in such a manner that a plurality of radiation conductors **160** or **102, 131** respectively, such as optical fibers, being attached to holes in the first translatory element **110** are coupled to a second plurality of fibers **120, 431a-431e** respectively, being attached to holes in the second translatory element **111, 470** by appropriately positioning the two elements relative to each other. The system **400** shown in FIG. 2 comprises two such radiation distributors B and C comprising the translatory elements **110, 111, 470, 471**. These elements are shown as longitudinal elements in FIG. 2. However, they may have another geometrical configuration. Furthermore, at least one of the elements may be integrated into a housing etc. The elements may be sledges, for coupling either treatment radiation or diagnostic radiation to a patient.

[0060] In the diagnostic position radiation is coupled to at least one radiation detector **430**. The diagnostic part of system **400** comprises three diagnostic radiation sources **144-146**, which are coupled to a single output radiation conductor **160** by means of an radiation combiner, in such a manner that an

active diagnostic radiation source is coupled to radiation conductor **160** and further to the site in the patient to be treated via translatory radiation distributor B. This diagnostic operation mode will be described in more detail below. Furthermore a plurality of diagnostic radiation sources may be used simultaneously. In this case several diagnostic radiation sources may be modulated, so that the diagnostic radiation may be detected simultaneously by means of e.g. a lock-in method or by multiplexing the signals, wherein the therapeutic radiation preferably, but not necessarily, is shut off in diagnostic operation mode.

[0061] Main radiation distributor B comprises two translatory elements **110**, **111**. The two translatory elements **110**, **111** are displaceable with relation to the other translatory element, as indicated by the arrows **305**, **306**. The displacement is controlled in such a manner that a plurality of radiation conductors **120** lead radiation to and from a tumor site **200** in a patient. Main radiation distributor B switches between the diagnostic operation modes and the therapeutic operation mode. The radiation conductors **120** leading to and from the patient are fixed to the translatory element **111**. The translatory element **110** of the main radiation distributor B comprises a $(3N-1)$ to N radiation distributor, wherein N is the number of radiation conductors **120** to/from the patient fixed in translatory element **111** and $(3N-1)$ is the number of radiation conductors fixed in translatory element **110** of which N are radiation distributors **102** coupled to radiation sources **101** and $2(N-1)$ are radiation distributors **131** coupled to radiation detector **430**, and one, **160**, is coupled to the diagnostic radiation sources **144-146** via combiner **310**.

[0062] In the therapeutic operation mode, B is adjusted translatory in such a manner that treatment radiation originating from the radiation sources **101** is coupled to radiation conductors **102**. These radiation conductors, preferably light guides or optical fibers, are coupled to translatory displacement element **110**. Element **110** is aligned with translatory displacement element **111** in such a manner that the radiation from radiation sources **101** is coupled to radiation conductors **120** and further to the treatment site **200** in the patient.

[0063] In diagnostic operation mode the at least one active diagnostic radiation source **144-146** is coupled to fiber **160** by means of combiner **310**. Main radiation distributor B is in diagnostic operation mode adjusted such that one of the N patient fibers **120** is coupled to a diagnostic radiation conducting radiation conductor **160**, as illustrated in FIG. 2. This is accomplished by transversally sliding the translator elements **110**, **111** relative each other, as indicated by arrows **305**, **306**. The radiation, which is being transmitted back from the site in the patient through the remaining $(N-1)$ fibers from the plurality of fibers **120**, is also called diagnostic radiation. This diagnostic radiation is coupled to $(N-1)$ radiation conductors from a plurality of radiation conductors **131** leading to the radiation detector **430**. Subsequently, the radiation distributor B is adjusted in such a way that another of the N patient fibers **120** is coupled to diagnostic radiation emitting fiber **160**. This is accomplished by once again sliding the translator elements **110**, **111** transversally relative each other, as indicated by arrows **305**, **306**. In this way another set of $(N-1)$ fibers is coupled to $(N-1)$ radiation conductors from a plurality of radiation conductors **131** leading to the radiation detector **430**. This is repeated N times, until all N coupling combinations of fiber **160** to the N patient fibers, is accomplished. In case a plurality of n diagnostic radiation sources is present in the system, the N measurements are carried out

with each of the n radiation sources, which results in $(N*n)$ diagnostic measurements, each measurement delivering $(N-1)$ measurement values. Alternatively to the sequence described above, the n radiation sources are applied subsequently, before switching to the next input fiber to the patient. The detector may be a single detector or a plurality of detectors or an array detector.

[0064] A further translatory radiation distributor C having elements **470**, **471** is used for minimizing the number of radiation conductors leading to detector **430**. Distributor C comprises two translatory elements **470**, **471**. The two translatory elements **470**, **471** are displaceable with relation to the other translatory element respectively. A plurality of $(N-1)$ radiation conductors **431a-431e**, corresponding to the $(N-1)$ radiation conductors conducting diagnostic radiation from the patient, are fixed to the translatory element **470** and lead to the detector **430**. $2*(N-1)$ radiation conductors **131** lead from the translatory element **110** to the translatory element **471**. Radiation distributor C is adjusted in such a manner that only the active $(N-1)$ radiation conductors of the plurality of conductors **131** are coupled to the detector **430** through radiation conductors **431**. Alternatively, the translatory element **471** may be integrated with the translatory element **110** and the translatory element **470** may be integrated with the translatory element **111** (not shown in the Figs.). In this way, the one and same translator may be used for therapy and diagnostic measurements.

[0065] $N=6$ and $n=3$ in the exemplary embodiment given above. However, other numbers of N and n are equally possible.

[0066] For calibration purposes of at least the mechanical part of a system according to embodiments of the present invention comprising at least one mechanical radiation distributor, a 7th hole may be present in translator **111** or similar elements. Preferably this hole is located exactly between two fibers **120** on translator **111**, with reference to the linear translator shown in FIG. 2. Concerning the disc **4** shown in FIG. 1, the 7th hole is preferably located anywhere in between holes on the disc **4** to which the radiation conductors **7a** are attached. The 7th hole is used to exactly define the position of an input fiber in a hole on the opposite element of a radiation distributor. The 7th hole is either directly equipped with a radiation sensor or connected to a radiation sensor for detecting radiation transmitted from a radiation conductor facing the 7th hole from the opposite side. In this way the positioning of the elements of a radiation distributor may be calibrated. For instance the position of the 7th hole may be used to zero the position of stepping motors driving these elements. The additional hole may equally be used to calibrate the position of translatory element C or any other translatory or rotary element of the embodiments of the system according to the invention in the same way.

[0067] This embodiment has the advantages of avoiding torsion of the radiation conductors, there occurs no "blooming" of the detectors, and it allows a compact and flat implementation including a very compact layout of a device for performing the method according to the invention. Furthermore, there is no moving element or mechanical part for switching between the detector radiation sources, optical fibers with large diameters may be used, and the system has low radiation losses, i.e. it has a sound "photon economy".

[0068] FIG. 3 is a schematic view of a further embodiment of the invention. The system shown in FIG. 3 comprises radiation combiners, a radiation switch and a translatory

radiation distributor. More particularly, a system is shown comprising a translatory 3×1 element **150**, **151** and a radiation 1×6 switch **320** as well as a radiation combiner **330** as an operation mode selector in six modules **325**. For interstitial treatment six therapeutic radiation sources **130**, preferably laser radiation modules, are coupled to the six radiation combiners **330**. Each radiation combiner **330** works in such a manner that the therapeutic radiation in therapy operation mode is coupled through the corresponding radiation conductor **142** to the treatment site **200**. For switching to the diagnostic operation mode, the therapeutic radiation source is switched off and subsequently one of the three diagnostic radiation sources in box **390** is activated. Thus, diagnostic radiation is conducted to the translatory 3×1 element **150**, where the radiation from the active diagnostic radiation source is coupled to the output of the translatory 3×1 element **151**, leading to the radiation switch **320**. The radiation switch **320** couples the input radiation to an output radiation conductor **122** leading to the corresponding radiation combiner **330** comprised in one of modules **325**. From combiner **330**, the diagnostic radiation is sent to the treatment site via a radiation conductor **142** connected to combiner **330**, as shown in FIG. 3. Thus the diagnostic radiation is spread in the treatment site and partly to the remaining five radiation conductors **142** for diagnostic measurements and partly reflected back. The diagnostic radiation from the patient is via combiner **330** sent to radiation detector **350**. Thus five ($=N-1$) measurement values are obtained. Subsequently the radiation switch **320** switches the incoming diagnostic radiation from the radiation source indicated at **310** to the next combiner **330** comprised in the next module **325**. Thus five further measurement values are obtained. This measurement procedure is repeated until all six modules **325** have been activated, resulting in six times five ($=30$) measurement values. These thirty measurement values obtained may be used as input data for a tomographic modeling of the radiation dose build up in the different parts of the tumor during the course of the treatment. This measurement procedure may be repeated with the remaining diagnostic radiation sources, yielding three times thirty ($n \cdot N \cdot (N-1)$) or ninety tomographic measurement values. Also the diagnostic radiation reflected at site **200** from the illuminating radiation connector may be used for diagnostic purposes. This embodiment allows fast treatment cycles due to fast switching times. Furthermore the diagnostic radiation does not need to be switched off during e.g. therapy, as e.g. the radiation switch may disconnect the radiation beam path, or the translatory elements **150**, **151** may be adjusted so that no coupling from an diagnostic input radiation conductor to corresponding output radiation conductor occurs. During the diagnostic operation mode collecting the ninety tomographic measurement values, all the diagnostic radiation sources may also be switched on, as there is no coupling between the different diagnostic radiation sources indicated at **310**. Furthermore, this embodiment avoids torsion of the radiation conductors going to the site in the patient as well as other mechanical movement that may be induced by mechanical movement of the radiation conductors going to the site in the patient.

[0069] The combiner **330** may be a fiber combiner commercially available from, e.g., Polymicro Technologies.

[0070] As a basis for the radiation switch **320** one may use a commercially available radiation fiber switch from Piezo-system Jena Inc. The working principle of the combiner **330** is described below in more detail. The combiner **330** may also

be based upon a commercially available fiber combiner from Polymicro Technologies. The combiner is connected to two source radiation conductors **360** and **361** one detection radiation conductor **363**, and one patient radiation conductor **362**, wherein radiation is mainly transmitted along these radiation conductors in the directions as indicated by arrows on the corresponding radiation conductors shown in FIGS. 3 and 4. The source radiation conductors **360** and **361**, and the detection radiation conductor **363** are fused together to the patient radiation conductor **362** along a certain length being shorter than the total radiation length of the combiner **330**. Thus radiation is transmitted via the source radiation conductors to the patient radiation conductor, while radiation from the patient radiation conductor is transmitted in the opposite direction to the detection radiation conductor. In the embodiment according to FIG. 3, one source radiation conductor is connected to the therapeutic radiation source **130**, and the second source fiber is connected to the diagnostic radiation source **110** and the detection radiation conductor is connected to the radiation detector **350**. The combiner **330** can be made to transmit the main part of the diagnostic radiation emerging from the tissue site **200** via the patient radiation conductor **362** to the detection fiber **363**, assuring an efficient use of the occasionally faint diagnostic radiation. The combiner **330** does not transmit radiation directly from the source fibers **360**, **361** connected to the diagnostic and therapeutic radiation sources respectively to the detection fiber **363** and thus to the radiation detector **350**.

[0071] FIG. 4 is a schematic view illustrating yet a further embodiment of the system according to the invention with a radiation distributor coupling diagnostic radiation sources by means of a translatory 3×6 element. Similar to the system shown in FIG. 3, the system shown in FIG. 4 comprises radiation combiners and a translatory radiation distributor, but the radiation switch is skipped. More particularly, a system is shown comprising a translatory 3×6 element **150**, **451** as well as a radiation combiner **330** as an operation mode selector in six modules **325**. For interstitial treatment six therapeutic radiation sources **130**, preferably laser radiation modules, are coupled to the six radiation combiners **330**. Each radiation combiner **330** works in such a manner that the therapeutic radiation in therapy operation mode is coupled through the corresponding radiation conductor **142** to the treatment site **200**. For switching to the diagnostic operation mode, the therapeutic radiation source is switched off and subsequently one of the three diagnostic radiation sources **110** is activated. Thus, diagnostic radiation is conducted to the translatory 3×6 element **150**, where the radiation from the active diagnostic radiation source is coupled to the output section **451** of the translatory 3×6 element. Element **451** is directly connected to radiation conductors **122** leading to the corresponding radiation combiner **330** comprised in one of modules **325**. From combiner **330**, the diagnostic radiation is sent to the treatment site via a radiation conductor **142** connected to combiner **330**, as shown in FIG. 3. Thus the diagnostic radiation is spread in the treatment site and partly to the remaining radiation conductors **142** for diagnostic measurement and partly reflected back. The diagnostic radiation from the patient is via combiner **330** sent to radiation detector **350**. Thus five ($=N-1$) measurement values are obtained. Subsequently another diagnostic radiation source may be activated from the radiation source **310** to the next combiner **330** comprised in the next module **325**. Thus five further measurement values are obtained. This measurement procedure is repeated

until all six modules **325** have been activated, resulting in six times five (=30) measurement values. These thirty measurement values obtained may be used as input data for a tomographic modeling of the radiation dose build up in the different parts of the tumor during the course of the treatment. This measurement procedure may be repeated with the remaining diagnostic radiation sources, yielding three times thirty ($N \cdot (n-1)$) or ninety tomographic measurement values. Also the diagnostic radiation reflected at site **200** from the illuminating radiation connector may be used for diagnostic purposes.

[0072] Furthermore the diagnostic radiation sources **310** may be modulated, so that the diagnostic radiation may be detected simultaneously by means of, e.g., a lock-in technique or by multiplexing the signals, wherein the therapeutic radiation is preferably shut off in diagnostic operation mode.

[0073] Diagnostic measurements may be made simultaneously according to the present embodiment by multiplexing the diagnostic radiation sources. As shown in FIG. 4, three diagnostic radiation sources are coupled simultaneously to radiation conductors **122**, except in the end positions of the translatable elements relative each other. Element **150** has to be moved nine times in the present embodiment for obtaining the mentioned ninety measurement values.

[0074] Alternatively, the radiation conductors in part **150** are attached to part **150** with a different interval space between the radiation conductors than the interval space of radiation conductors **122** in element **451**. In this case, element **150** has to be moved eighteen times. However, this has the advantage that the diagnostic radiation sources do not need to be switched off between the measurements, as two of the three radiation conductors in element **150** are alternately disconnected from radiation conductors **122** (by translatable displacement) and only one radiation conductor **122** conducts radiation to the corresponding module **325**.

[0075] This embodiment allows a very compact construction, it is very cheap to implement and there is only one moving part and no torsion in the radiation guides.

[0076] For calibration purposes of the system according to the invention, the overall performance of the system is recorded prior to the treatment by direct measurements on a calibrated tissue phantom made of, e.g., a sterile intralipid-water solution and/or a sterile solid phantom made of, e.g., Delrin®. The performance of the therapeutic radiation sources may either be monitored by internal and/or external power meters.

[0077] The radiation switches described may work according to different principles. One is the switching by direct radiation conductor movement actuated by piezoelectric movement of the radiation conductor in relation to output radiation conductor. Another is the switching by microradiation beam deflection, which may be based on micromechanical components, such as micropisms or mirrors or by acousto-optical means, deflecting an optical beam to different output/input fibers. The switching and beam deflection is based on optical principles without mechanical movement of components such as prisms or mirrors. Examples of non-mechanical switching principles are for instance beam deflection by an acousto-optical means based on sound generated Bragg deflection, or acousto magnetic means, or by an electrically controlled variation of the refractive index of a material through which the beam travels, thereby deflecting an optical beam to different output/input fibers. Examples for materials having a variable refractive index suitable for electro-optical switches are e.g. LiNbO_3 , LiTaO_3 , GaAs, HgS,

CdS, KDP, ADP or SiO_2 . The Agiltron™ company provides commercially available optical switches of this type, namely the CrystalLatch™ Solid-State Fiber Optic Switch family or the NanoSpeed™ Optical Switch Series.

[0078] The therapeutic radiation sources are preferably laser sources with a wavelength, which is adapted to the absorption band of the sensitizer. At the photodynamic tumor treatment a dye laser or a diode laser is preferably used, with a wavelength which is selected with regard to the sensitizer employed. For PhotoErin® the wavelength is 630 nm, for delta-aminolevulinic acid (ALA) it is 635 nm and for phthalocyanines it is around 670 nm. The individual lasers are regulated during the treatment to a desirable individual output power. If desired, they may have built-in or external monitoring detectors.

[0079] The therapeutic treatment can be interrupted and new diagnostic data can be processed in an interactive method until an optimal treatment has been reached. This method can include synergy between PDT and hyperthermia, where an increased temperature is reached at increased fluxes of laser radiation. The whole process is controlled using a computer, which does not only perform all the calculations but also is utilised for regulation.

[0080] The radiation distributors described are preferably driven by stepper motors/servomotors in order to move between the different constellations.

[0081] Naturally, diagnosis and therapy may also be performed at the same time, if so desired. With an appropriate number of radiation conductors going to the tumor, for instance the above mentioned six radiation conductors for therapeutic irradiation plus four radiation conductors for simultaneously diagnosing the effect of the therapeutic light, it is possible to directly regulate therapy in real-time. This is of particular interest when performing therapy on sensitive organs that are not to be damaged by the therapeutic optical radiation. Of course it is a goal to only destroy tumor tissue. In the given example, the six radiation conductors illuminate the tumor tissue into which the distal ends of the six radiation conductors are placed. The four diagnostic radiation conductors are also placed into the tumor tissue at appropriate locations and pick up both the excitation radiation from the therapeutic radiation conductors scattered in the tumor tissue and the fluorescent radiation resulting in the tumor tissue. This picked-up radiation may be analyzed in a spectrometer and be used for regulating the therapeutic radiation source. These, for example, four extra radiation conductors can be placed in-between the six radiation conductors for therapeutic irradiation. When the six radiation conductors are connected to the radiation sources by means of the above-described arrangements, the four extra radiation conductors are suitably automatically connected to the radiation detector, e.g. because of the arrangement of the translatable slides or rotating discs.

[0082] The present invention has been described above with reference to specific embodiments. However, other embodiments than the preferred above are equally possible within the scope of the appended claims, e.g. different shapes of the translatable elements, different radiation coupler elements than those described above or other elements described in this description than those described above, performing the above method by hardware or software, fluorescence or temperature measurements described in one embodiment, etc. Moreover, the translatable elements may be further minimized by using micromechanical technologies for constructing the

elements. Thus, one realization of the elements may be provided by a Micro-Electro-Mechanical System (MEMS) produced by microfabrication technology. The elements described may work according to different principles. One is the switching by direct fiber movement actuated by piezoelectric movement of the fiber in relation to output fibers. Another is the switching by microoptical beam deflection, which may be based on micromechanical components, such as microprisms or mirrors deflecting an optical beam to different output/input fibers. Piezosystem Jena Inc or Pyramid Optics Inc. provide suitable components based on the latter micromechanical principles.

[0083] Furthermore, the term “comprises/comprising” when used in this specification does not exclude other elements or steps, the terms “a” and “an” do not exclude a plurality and a single processor or other units may fulfill the functions of several of the units or circuits recited in the claims.

What is claimed is:

1. A system for interactive interstitial photodynamic or photothermal tumor therapy or tumor diagnosis of a human, comprising; at least a first and a second light source for emission of light within the wavelength-range of infrared (IR), visible or ultraviolet light; at least one light detector, for detection of light; and a plurality of first optical fibers adapted to conduct light to or from a tumor site of said human, whereby one therapeutic light source is coupled to each of said optical fibers for transmission of said therapeutic light to said tumor site through each of said optical fibers, during which the diagnostic light sources are inactivated, wherein distal ends of the optical fibers are configured for positioning at different interstitial locations of the tumor site in order to enable an effective interactive diagnosis and therapy of the tumor, wherein at least two coupling elements for coupling of diagnostic light from at least the first light source to the tumor site and therapeutic light from said second light source to said tumor site and light from said tumor site to said detector, the coupling elements in combination being:

- a) at least one longitudinal translatory distributor comprising at least one translatory element being arranged to couple said therapeutic or diagnostic light in different constellations for different operating modes of said system by longitudinal translatory movement of said longitudinal translatory element between pre-determined positions, wherein optical fibers are attached to said translatory element, and at least one non-mechanical operation mode selector means for optically directing either said therapeutic light or said diagnostic light to said site through said at least one first optical fiber; or
- b) at least one rotary distributor comprising two rotary elements being arranged to couple light in different constellations for different operating modes of said system by rotational movement of said rotary element between pre-determined positions, wherein optical fibers are attached to said rotary elements, and at least one non-mechanical operation mode selector means for optically directing either said therapeutic light or said diagnostic light to said site through said at least one first optical fiber;

wherein the longitudinal translatory element or the rotary distributor is configured for aligning the optical fibers for transmitting or receiving said light to or from optical fibers of an opposing corresponding coupling element.

2. The system according to claim 1, wherein said rotary distributor comprises two discs, one of which is the opposing coupling element, arranged in close proximity to each other, wherein said discs are turnable relatively to each other around a common axis, each disc having holes arranged on a circular line, wherein the circle radius on one disc equals the circle radius on the other disc and where the holes in one disc are equally distributed on a circle line with an angular separation of $v_1=(360/n_1)$ degrees, n_1 being the number of holes, and the holes in the other disc are equally distributed on the circle line with an angular separation of $v_2=(360/n_2)$ degrees, wherein $n_2=m \times n_1$, and wherein m is a multiple, which yields n_2 as an integer >1 , and wherein the first ends of the first optical fibers are fixed in the holes of the first disc and first ends of other optical fibers are fixed in the holes of the second disc, whereby the first and the second optical fibers by rotation of the turnable disc are connectable to each other in said different constellations for said aligning of the optical fibers for transmitting or receiving said light to or from optical fibers of an opposing corresponding coupling element.

3. The system according to claim 1, wherein said translatory distributor is a translatory element having a plurality of first optical fibers arranged for conducting light to and from tumor site, said opposing coupling element being a second translatory element, a plurality of second optical fibers arranged for delivering radiation from at least one light source and/or conduction of light to at least one light sensor, and wherein said distributor is a distributor for distribution of light from at least one light source to the tumor site and/or from the site to at least one light sensor, wherein the distributor comprises at least one translatory element being arranged in such a manner that light is coupled in said different constellations by translatory movement of said element between pre-determined positions relative to the second translatory element for said aligning of the optical fibers for transmitting or receiving said light to or from optical fibers of an opposing corresponding coupling element.

4. The system according to claim 3, wherein each of said translatory elements has holes arranged for receiving said optical fibers and that corresponding holes on the two elements are equidistantly arranged on a straight line for said aligning of optical fibers.

5. The system according to claim 3, wherein first ends of the first optical fibers are fixed in the holes of a translatory displacement element and first ends of second optical fibers are fixed in the holes in the second translatory element, wherein the first and second optical fibers are connectable to each other in different constellations through said translatory movement between pre-determined positions of the first translatory displacement element and the other translatory element relative each other.

6. The system according to claim 1, wherein light mode selector means is at least one non-mechanical light switch and/or at least one light combiner.

7. The system according to claim 1, wherein said plurality of first optical fiber having a distal end, wherein said distal end is brought to said treatment site, wherein at least one first optical fiber is in use employed as a transmitter and/or a receiver for conduction of light from said at least one light source to and/or from the site for diagnosis and/or therapy.

8. The system according to claim 1, wherein said diagnostic light sources being coupled to one of said mode selector means for transmission to said site, and the remaining mode

selector means transmitting said diagnostic light to said at least one light detector, wherein said therapeutic light sources are inactivated.

9. The system according to claim 8, wherein said diagnostic light source is coupled to said mode selector means by means of a $n \times N$ translatable light distributor, wherein n is the number of diagnostic light sources and N is the number of mode selector means.

10. The system according to claim 9, wherein said diagnostic light source is coupled to said mode selector means by means of a translatable light distributor having n light inputs and one light output, wherein n is the number of diagnostic light sources and N is the number of mode selector means, and a light distributor coupling said light output to one of said mode selector means.

11. The system according to claim 9, wherein said mode selector means is a light combiner.

12. The system according to claim 3, wherein a first longitudinally translatable light distributor element coupling said optical fibers to/from said site to a first optical fiber connected to said diagnostic light sources, wherein said diagnostic light sources are connected to said first optical fiber via a light element, and to a second longitudinally translatable light distributor element coupling $2 \times (n-1)$ optical fibers to $(n-1)$ optical fibers connected to at least one light detector, wherein n is the number of optical fibers coupled to said site, and to N optical fibers coupled to said therapeutic light sources.

13. The system according to claim 12, wherein a diagnostic operation mode in which one diagnostic light source is coupled to said n first optical fibers to said site and said $(n-1)$ first optical fibers are coupled to said light detectors by, longitudinally translatable positioning said first and second translatable light distributor elements, and by a therapeutic operation mode in which the N therapeutic light sources are coupled to corresponding N first optical fibers.

14. The system according to claim 13, wherein said light element coupling said diagnostic light source is a light combiner.

15. The system according to claim 1, wherein said translatable displacement element is an optical sledge.

16. The system according to claim 2, wherein $n1$ is the number of holes in the first disc of the distributor, $n1=6$ and $m=2$, yielding $n2=12$ holes in the second disc of the distributor.

17. The system according to claim 1, wherein a rotary light distributor element coupling said optical fibers to/from said site to a first optical fiber connected to said diagnostic light sources, wherein said diagnostic light sources are connected to said first optical fibers via a non-mechanical light distributor element, and to said at least one light detector from the remaining first optical fibers.

18. The system according to claim 1, wherein the first optical fibers distal ends are treated by a material with temperature sensitive fluorescence emission.

19. The system according to claim 1, wherein said therapeutic light sources are light sources for coherent light of a single fixed wave-length and/or light emitting diodes.

20. The system according to claim 18, wherein said system is adapted to record fluorescence from said site through the same optical fiber as the one transmitting light to the site.

21. The system according to claim 20, wherein for interactive photodynamic therapy one or several of the optical fibers which are treated with the material with a temperature sensitive fluorescence emission are configured to measure the temperature at the site, that the light is sent to the site is adapted to heat the treatment site, and that the intensity of the light is controllable by the measured temperature in order to regulate the temperature of the site at the individual optical fibers.

22. The system according to claim 1, wherein the operation modes are:

interactive interstitial photo-dynamic tumor therapy, photothermal tumor therapy using hyperthermia, and tumor diagnostics, whereby these operation modes in use are alternated during the same occasion of treatment of said tumor site.

23. A method for interactive interstitial photodynamic tumor therapy and/or photothermal tumor therapy and tumor diagnosis, wherein at least one light sensor and optical fiber is connected to a tumor site and the optical fiber is used as a transmitter and/or a receiver for conduction of light to and/or from a tumor site for diagnosis and therapy of a tumor at the tumor site, wherein the switching between tumor therapy and tumor diagnostics is achieved in an automated way by switching between diagnostic light and therapeutic light by means of at least one coupling element according to claim 1, and in that the results from the diagnostics are controlling the therapy process by regulating a therapeutical light intensity depending on the results of the diagnostics until an optimal treatment of the tumor site has been achieved.

24. The method according to claim 23, wherein alternately utilizing interactive interstitial photodynamic tumor therapy, photothermal tumor therapy using hyperthermia, and tumor diagnostics during the same occasion of treatment of said tumor site.

25. Use of non-mechanical switches for distribution of light and/or light combiners for distribution of light in combination with mechanical light distributor elements for a system for interactive tumor therapy and diagnosis of a human or animal.

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专利名称(译)	用于治疗 and 诊断的系统和方法包括用于辐射分布的非机械和机械分配器的组合		
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摘要(译)			

用于治疗或诊断人或动物的系统和方法。用于耦合辐射的至少一个耦合元件将来自至少第一辐射源的辐射耦合到肿瘤部位和/或从所述第二辐射源耦合到所述部位和/或从所述部位耦合到检测器。耦合元件是至少一个平移分配器，至少一个旋转分配器和至少一个操作模式选择器装置的组合，用于通过所述至少一个第一辐射导体将所述治疗辐射或所述诊断辐射引导到所述部位。该系统可用于交互式间质光动力肿瘤治疗。根据本发明的系统和方法以新的和协同的方式结合了纯机械和纯非机械解决方案的优点。

